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Historical Rewiev

This year University of Ljubljana marks its 90th anniversary. Technical fields were joint in the School of Engineering that included the Geologic and Mining Division while the Metallurgy Division was established in 1939 only. Today the Departments of Geology, Mining and Geotechnology, Materials and Metallurgy are part of the Faculty of Natural Sciences and Engineering, University of Ljubljana.

Before War II the members of the Mining Section together with the Association of Yugoslav Mining and Metallurgy Engineers began to publish the summaries of their research and studies in their technical periodical Rudarski zbornik (Mining Proceedings). Three volumes of Rudarski zbornik (1937, 1938 and 1939) were published. The War interrupted the publication and not untill 1952 the first number of the new journal Rudarsko-metalurški zbornik - RMZ (Mining and Metallurgy Quarterly) has been published by the Division of Mining and Metallurgy, University of Ljubljana. Later the journal has been regularly published quarterly by the Departments of Geology, Mining and Geotechnology, Materials and Metallurgy, and the Institute for Mining, Geotechnology and Environment.

On the meeting of the Advisory and the Editorial Board on May 22nd 1998 Rudarsko-metalurški zbornik has been renamed into "RMZ - Materials and Geoenvironment (RMZ -Materiali in Geookolje)" or shortly RMZ - M&G.

RMZ - M&G is managed by an international advisory and editorial board and is exchanged with other world-known periodicals. All the papers are reviewed by the corresponding professionals and experts.

RMZ - M&G is the only scientific and professional periodical in Slovenia, which is published in the same form nearly 60 years. It incorporates the scientific and professional topics in geology, mining, and geotechnology, in materials and in metallurgy.

The wide range of topics inside the geosciences are wellcome to be published in the RMZ -Materials and Geoenvironment. Research results in geology, hydrogeology, mining, geotechnology, materials, metallurgy, natural and antropogenic pollution of environment, biogeochemistry are proposed fields of work which the journal will handle. RMZ - M&G is co-issued and co-financed by the Faculty of Natural Sciences and Engineering Ljubljana, and the Institute for Mining, Geotechnology and Environment Ljubljana. In addition it is financially supported also by the Slovenian Research Agency, Science and Technology of Republic of Slovenia.

Editor in chief

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Laser cladding in the use effects on nitrided and PVD coated steels used for die-casting using various process parameters and techniques

Pojavi pri laserskem navarjanju nitriranih in PVD prevlečenih jekel za orodja za tlačno litje z uporabo različnih parametrov in tehnik

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Abstract: Repair welding of die-casting tools is approach to extend life cycle of expensive dies. Issues addressed in this paper are problems emerging from repair welding of surface treated steels e.g. nitriding, oxidizing, hard coating or duplex-treating. Cladding tests were carried out on various gas nitrided and oxidized or hard coated chrome martempered steel used for die tools. Observed welding defects were extensive hot cracking and copious formation of gas pores. For duplex-treated surfaces a procedure with preceding laser remelting and laser welding is proposed. Minimized negative effects of the base and welded material were found.

Izvleček: Reparaturno varjenje je postopek za podaljšanje trajnostne dobe dragih orodij za tlačno litje. V članku so obravnavani problemi, ki nastajajo pri reparaturnem varjenju površinsko obdelanih jekel: nitriranje, oksidiranje, prevlečenje ali zaporedna površinska obdelava z različnimi procesi (na primer nitrirnanje in nato PVD prevlečenje). Preizkusno varjenje je bilo izvedeno na različnih plinsko nitriranih in oksidiranih ali prevlečenih vzorcih iz kromovega maraging jekla za livarska orodja. Zaznane varilne napake so bile znatne razpoke in številne plinske pore. Za dvojno oplemenitene površine je predlagan nov postopek varjenja s predhodnim pretaljevanjem. Ugotovljeno je bilo zmanjšanje negativnih efektov podlage in varilnega materiala.

Key words: laser cladding, repair welding, die-casting tool steel, nitriding, oxidizing, PVD coating
Ključne besede: lasersko navarjanje, reparaturno varjenje, jekla za orodja za tlačno litje, nitriranje, oksidacija, PVD-prevleke

INTRODUCTION

Parts for automotive industry made from aluminium or plastic are usually casted or moulded. Casting dies are subjected to various complex impact and thermomechanical loads in their working environment. High stresses lead to a plastic deformation of the die during tool's lifetime. Thus, it is required that steels used for casting dies should have some properties such as resistance to high temperatures, thermal deformation, thermal shock during working processes, etc. Depending on a tool application, typical damage and failure mechanisms may differ. A thermal fatigue cracking is the most important life limiting failure mode in the tools for die-casting.[1–4] It is often observed on the tool surface as a network of fine cracks or as individual and clearly pronounced cracks. Formation of thermal fatigue cracks leads to loss of a surface material in form of small fragments. Other common reasons for damage are tension cracks caused by constructional notches, local adherence of a casting alloy and tool i.e. soldering, and steel erosion promoted by the cast molten metal or plastic flow.[5, 6] While moulds for plastic injection moulding are subjected to lower working temperatures their pressure cycles are higher and therefore, mechanical fatigue damage and overload failures might occur. Life time for aluminium casting dies is usually 10^4 cycles.[7] Increasing demand for reduction of manufacturing costs dew to economical reasons requires the exploration of adaptable and reliable solutions for extending the life time of the dies using nitriding, oxidizing, PVD coatings or various duplex treatments. Further extension of the life time of the dies is achieved with die repairing techniques such is surface welding.

Nitrided die casting tools have a lot of advantages i.e. easier separation of a casted part and mould, less frequent cleaning of the die-core system and increase of the service life for up to 50 %.[8] Available reports show that plasma nitriding improves thermal fatigue resistance due to high residual stresses in the diffusion layer and improves its tempering resistance. It is also reported that thermal cracks remain localized in the compound layer.[9] Another surface improvement is oxidation i.e. process that creates a lubricant oxide film to prevent soldering and adhesive wear in high pressure die casting tools, usually performed after nitriding. Further improvements are made using hard coating based on nitrides and carbides of transition metals, e.g. CrN, CrC, TiAlN, TiB_2.[10] Deposition of these coatings is made by physical or chemical vapour deposition (PVD or CVD). These coatings further reduce erosion, soldering, and corrosion but lack in improvement of the thermal fatigue resistance of hot working steels in die-casting conditions. None of the above mentioned surface treatments provides an optimum solution for all failure mechanisms,[11] therefore the best choice is a combination of surface improvements designed specifically for each application.

Repair welding and refurbishing of dies is performed to remove the traces of heat cracking, surface wear, erosion, and stress cracking, thus significantly increasing the tool life cycle.[12, 13] Repair welding of dies is performed by welding with covered electrodes, tungsten inert gas (TIG) welding or laser cladding by wire. Later approach is done by pulsed Nd:YAG laser beam focused at the tool damaged surface while an operator adds a filler wire in the molten pool. Laser repair welding is particularly appreciated due to exact positioning and focalization control of the beam allowing elevated accessibility even in thin and narrow areas that cannot be welded conventionally.[14] Although repair welding is carried out on majority of the tools it is considered critical for improved surfaces due to occurrence of welding defects. Furthermore each surface improvement combination has specific repairing technique, meaning that improvements of repair welding process are necessary.

The primary goal of this study was to investigate problems emerging from laser repair welding of damaged improved die surfaces without prior removal of the damaged parts or surfaces by milling or grinding. Researches were conducted by optical and electron microscopy for metallographic analysis and microhardness measurements for hardness profiles of welded structures.

Experimental procedure

Repair welds investigated in this paper were performed on a high performance AISI H13 (X40CrMoV5-1; Wr.N 1.2344) chromium-molybdenum-va-

Table 1. Parameters of laser repair welding process

Pulse shape (cf. Figure 5)	General			Ramped up			Ramped down		
Code (cf. Figure 5)	Set 1	Set 2	Set 3	Set 1	Set 2	Set 3	Set 1	Set 2	Set 3
Energy per pulse [J]	11.2	12.9	14.9	11.1	13.1	13.2	11.4	12.8	14.4
Pulse power [kW]	1.3	1.6	1.7	1.3	1.6	1.7	1.4	1.5	1.7
Pulse duration [ms]	6.5			6.5			6.5		
Pulse frequency [Hz]	7			7			7		
Spot diameter [mm]	0.6			0.6			0.6		
Travel speed [mm/min]	0.55			0.55			0.55		

nadium hot-work tool steel. Chemical composition in mass fractions of steel samples was 0.35 % C, 0.03 % Si, 0.5 % Mn, 5 % Cr, 2.36 % Mo, 0.55 % V, and balance Fe. Cut samples were hardened and martempered to hardness of 47 *HRC*. After heat treating, samples were gas nitrided and oxidized or hard coated with TiN or CrN coatings. Gas nitriding was performed at 520 ºC for 6 h in a NH_3 atmosphere to a depth of around 80 μm. Oxidation was executed at 500 °C for 4 h in H_2/O_2 atmosphere. The thermionic arc ion plating in a BAI 730 M deposition system was used to obtain CrN or TiN PVD coatings.

Simulation of repair welding was performed using Nd-YAG laser welder and AISI H13 filler wire with 0.5 mm diameter. Effects of the repair welding process parameters were also investigated. Effects of the various laser pulse shapes and different laser welding techniques e.g. frequencies, formation sites, and types of weld defects in continuous seam welds are considered. To resolve a pulse shaping effects, the pulse shapes applied were: general, ramped-up, and ramped-down. Table 1 presents the laser welding and surface remelting process conditions. Continuous seam welds were used as a means of bead on plate welding on specimens to understand the effects of pulse shaping and the formation characteristics of weld defects.

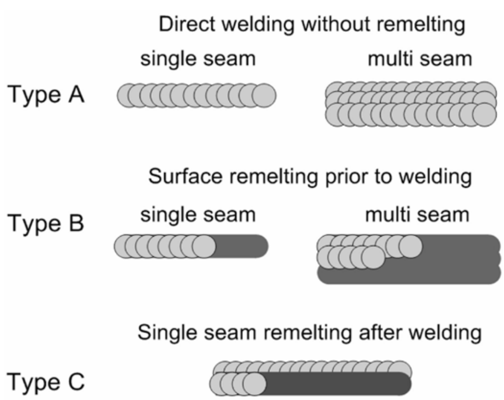

Figure 1. Researched welding techniques

Three types of welding techniques were analyzed in order to improve weldability of improved surfaces. First welding technique designated type A is direct welding without prior surface remelting. Type B involves remelting of whole surface with laser prior to repair welding, where at type C first seam is directly welded and later half of it is remelted and on remelted surface operator deposit next seam. Figure 1 schematically shows all investigated welding techniques.

Cataloguing and characterization of welding defects in the welded layer and the heat affected zone (HAZ) for various welding parameters was carried out by metallographic analysis. Samples for metallographic analysis were prepared with standard grinding and polishing procedures and etched with 2 % Nital solution to reveal welds. Weld morphology and microstructure were evaluated using scanning electron microscope (SEM) and optical microscopy. In addition, microhardness profiles of welds were measured with hardness tester.

Results and discussion

Microstructural analysis of welded nitrided surfaces discloses high concentration of pores. Nature of a laser welding causes abrupt melting and consequent quick solidification. Gases formed during melting therefore stay trapped at the edges of a weld melt pool. High-energy input from laser beam induces dissolution of nitrides in nitrided layer and formation of N_2 gas. Figures 2a and 2b depicts a weld porosities induced by trapped gasses. Sample has been welded with a Type A welding technique and ramped-up pulse with Set 3 process parameters. Analyzed was longitudinal section of the weld (cf. Figure 2b) due to higher probability of discovering weld defects in longitudinal sections compared to cross sections.

Repair welding of a nitrided and CrN coated surfaces is difficult due to formation of cracks at the edges of the HAZ. Their direction of propagation is from pores to apex of the weld due to release of trapped gases. Figure 3a shows weld cracks emerging from pores in the weld. In Figure 3b cracks alongside weld direction in HAZ zone are shown. Depicted repair welded micrograph was obtained from nitrided and CrN coated sample.

Similar defects were present in nitrided and TiN coated welded samples. These types of defectss become apparent only after additional surface treatments and therefore their detection during welding is impossible. Also welding of nitrided and oxidized surfaces causes emergence of pores where dissolute gasses escape from melted weld pool

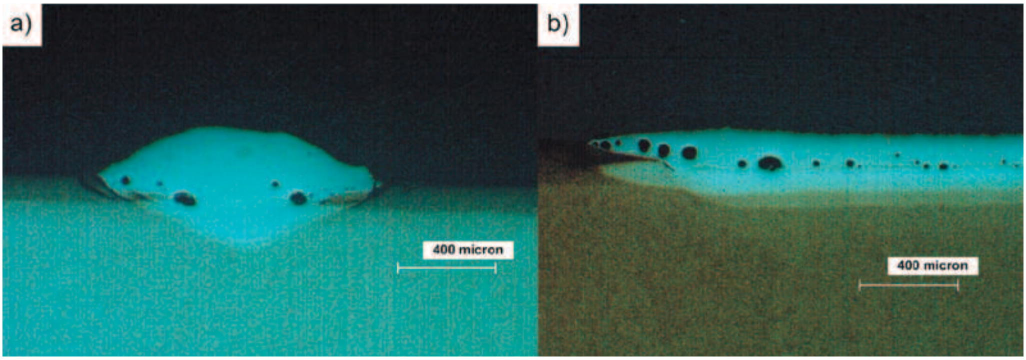

Figure 2. Porosities in weld of nitrided sample; a) cross section, b) longitudinal section

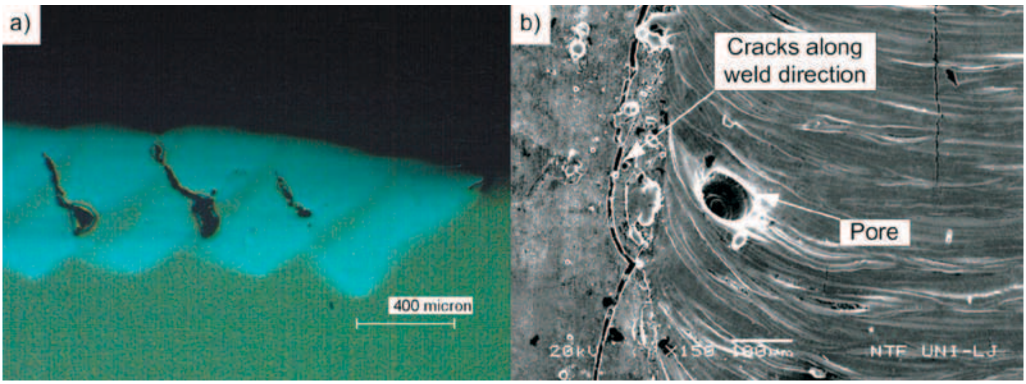

Figure 3. Porosities in weld of nitrided and CrN coated sample; a) micrograph of cracks formed from pores, b) SEM micrograph of cracks along weld direction in HAZ and surface pore

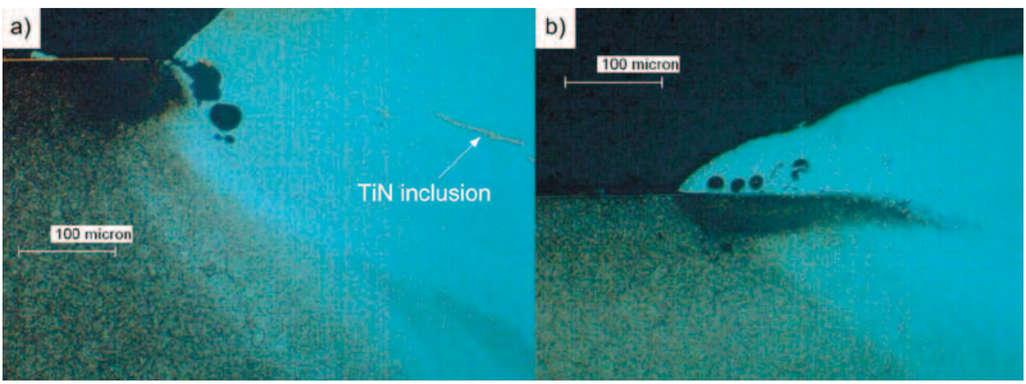

Figure 4. Laser welds on duplex-treated surfaces; a) nitrided and TiN-coated surface, b) nitrided and CrN coated surface

during cooling. Another type of the repair welding defects obtained were cracks along the seam of a weld (cf. Figure 3b). These defects commence due to tensile and compression stress in weld.

Figure 4a depicts traces of TiN coating in the laser weld and porosities at the boundary between the weld and a base material. TiN inclusions from coating in weld could be problematic during grinding and final polishing of weld in die-casting tool. These inclusions have high hardness and can cause increased wear of grinding and polishing tools and consequently loss of shape. Weld micrographs of a nitrided and CrN coated sample did not reveal coating inclusions in the weld. In Figure 4b shows weld of nitrided and CrN coated surface using an inclined beam and type C technique. Repair welding of nitrided and coated samples leads to copious development of gas porosity due to nitrogen release from molten nitrided part of surface or exiting of transitional elements from coatings. Inclusions from coatings in welds also cause problems and are therefore undesired. Therefore, in order to reduce gas porosity investigation of a laser remelting treatment before weld deposition was conducted. The results suggest that using the type C welding technique and close observation of the welding process parameters minimizes the porosity rate. Appearance of pores (cf. Figure 4) at a contact of the weld and the base material is undesired. These pores present danger for peel-off of weld and surface treatment. It revealed that manipulation

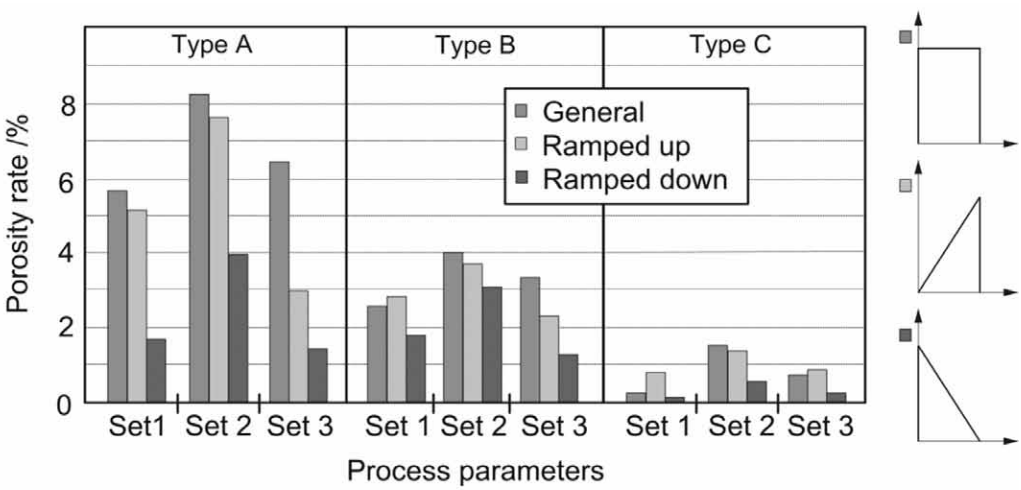

Figure 5. Influence of process parameters, welding technique and pulse shape on porosity rate of weld, with presentation of pulse shapes

of laser beam parameters or inclination of the beam leads to reduction of these type defects. Usage of beam inclination causes a tampon region, which makes excessive cracking of treated surface impossible. It is possible to prevent excess nitrogen evaporation with manipulation of welding parameters. Welding parameters are also important for minimizing the effect of transitional elements (e.g. Cr, Ti) exiting coatings, especially at multi-seam welding.

Unsuitable process parameters, e.g. too high heat input or too low welding velocity are main cause for cracks in HAZ along the seam of the weld due to thermal expansion. With the correct welding process parameters, it is possible to minimize appearance of welding defects. This paper also investigates influence of the process parameters, welding technique and pulse shape on the porosity rate of the weld. Figure 5 shows results of these influences. Depicted in Figure 5 are also pulse shapes marked with colors. Remelting of surface prior to welding causes smaller porosity rate compared to direct welding of surface treated (i.e. nitrided and oxidized or nitrided and PVD coated) surfaces. Type C welding, where each seam is fractionally remelted, has lowest porosity rate. Furthermore, process parameters of the welder and pulse shape are of high importance. As is shown, ramped-down pulse is superior compared to general or ramped-up one. However, it was noticed appearance of low weld fusion penetration or agglutination of weld material. Pulse energy is also very important as pulse energy increase after some critical value leads to declined porosity density in the weld. On the other hand, increase of pulse power causes cracks alongside weld in HAZ and amassment of cracks in surface treated surfaces. One should chose energy per pulse and pulse power specifically for differently treated surfaces.

Figure 6 shows dependences of hardness measured in three depths versus distance from the weld line. Mean hardness value was measured in a horizontal line parallel to the surface for type C welding technique. Depths are designated with letters X for surface layer, Y for middle of the weld and Z for weld apex. Mean hardness in area of weld line are lower for approximately 120 HV_{01} than in area of prior welding remelt line. This is due to tempering effect caused with heat transfer from welding to prior hardened remelt line. Highest measured hardness in remelt line zone was between 720 HV_{01} and 800 HV_{01}. Hardness in weld line was due to tempering effect lower and was between 580 HV_{01} and 650 HV_{01} depending on the depth of the measurement. As expected, it was highest in the apex of the weld due to additional alloying from filler wire.

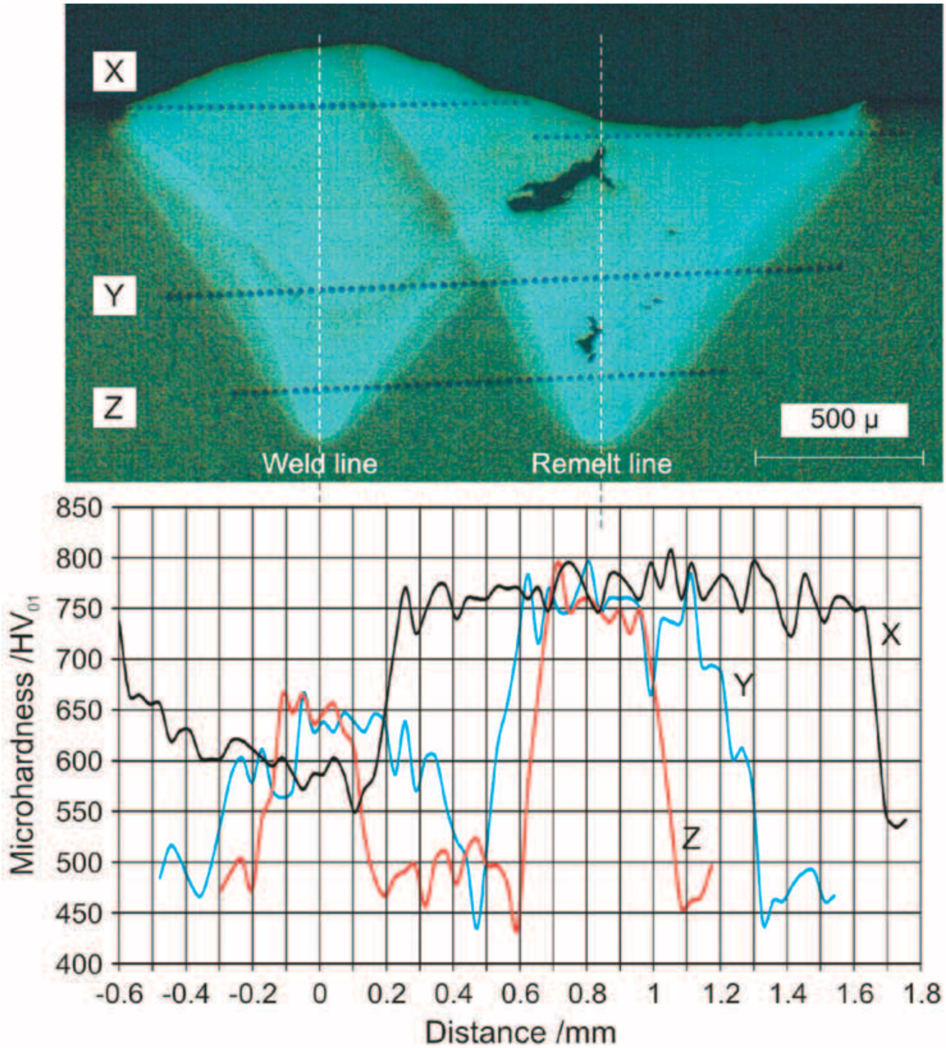

Figure 6. Microhardness profile measured in thee depths of the weld

Measured hardness of base material was approximately 500 HV_{01} and although prior remelting and welding on the remelted zone caused tempering effect, this is not sufficient to reach hardness values corresponding to the base material. Consequently, needed is additional tempering of the welds to obtain uniform hardness profile as is known that increased hardness influences on decreased toughness, which is crucial especially in the lower layers of the tools. Also in Figure 6 can be seen that welding defects due to release of nitrogen gas from nitrides are only in remelt zone. Pores formed as gas trapping were filled with filler wire material. Due to weld deposit, materials in that area was once again remelted and solidified, and as consequence welding porosities were removed. This means special attention is needed to obtain deep enough heat affected zone only to ensure removal of defects and porosities originated from gases in nitrided zone.

Conclusions

From the investigations conducted in this paper following conclusions can be drawn.

- Repair welding of the nitrided samples resulted in the formation of copious gas pores due to nitrogen release during weld metal solidification. Also cracks starting from these voids were detected.
- In PVD coated samples extensive cracking was observed after repair welding tests.
- Special attention should be paid to the first surfacing weld adjacent to the surface. Lower power laser beams and the ramped-up pulse shape should be used in order to reduce the level of surface cracking that may subsequently produce peeling-off of the tool surface at duplex-treated samples. The lowest density of porosity is obtained with the ramped-down shape of a laser pulse and a sufficiently high energy permitting complete remelting of the nitrided layer.
- A combination of welding and preliminary remelting i.e. type B, however, reduces the occurrence of defects, e.g. inclusions and pores, in the surfaced layer, yet this does not provide optimum results since, due to melt spatter, nitride inclusions will persist at the surface and thus pass on to the surfaced layer.
- The occurrence of inclusions, i.e. rests of melted PVD claddings, can be reduced by using “Leading power spike”, which will produce evaporation of the cladding.
- Welds made with type C welding technique i.e. simultaneous remelting of welded seams, in combination with a falling pulse resulted in lowest density of welding defects.

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Characterisation of solid airborne particles in urban snow deposits from Ljubljana by means of SEM/EDS

Opredelitev trdnih zračnih delcev v snežnem depozitu iz urbanega območja Ljubljane s SEM/EDS

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Abstract: The main objective of this study was to identify and characterise solid airborne particles deposited in snow of the Ljubljana urban area over a period of 6 days, according to their morphology and chemical composition and to assess their source and genesis by means of scanning electron microscope coupled with energy dispersive X-ray spectrometer (SEM/EDS). This method enables the characterisation of submicroscopic (crystalline and amorphous) particles, present in very small quantities. Two snow samples were collected and analysed. Spherical particles, irregularly shaped fragments and agglomerates were identified according to their morphology. Geogenic and technogenic sources were assessed by considering their chemical composition and morphology. Geogenic particles are represented mostly by irregular mineral fragments of quartz, zircon and clay minerals. Technogenic particles are mostly spherically shaped carbonaceous particles, originating from combustion of coal or liquid fuel and spherical heavy metal-bearing particles, emanating from high-temperature industrial combustion and steel-melting processes. Irregular technogenic particles emanate mostly from incomplete coal combustion and road traffic emissions. Comparison of treated samples showed no significant differences in particles according to their origin. It can be concluded that the sampling location had no important influence on the distribution of particles by their origin.

Original scientific paper

Izvleček: Cilj predstavljene študije je bil prepoznati in opredeliti trdne zračne delce, ki so bili v šestih dneh odloženi v snegu na urbanem območju Ljubljane. Opredelili smo jih glede na njihovo obliko in kemijsko sestavo ter ocenili njihov izvor in nastanek z metodo vrstičnega elektronskega mikroskopa z energijsko disperzijskim spektrometrom rentgenskih žarkov (SEM/EDS). Ta metoda omogoča opredelitev submikroskopskih (kristalnih in amorfnih) delcev, ki so v vzorcih v zelo majhnih količinah. Odvzeli in analizirali smo dva vzorca snega. Po obliki smo delce razdelili v sferične, odlomke nepravilnih oblik in aglomerate. Glede na kemijsko sestavo in obliko smo ločili delce geogenega in tehnogenega izvora. Geogeni delci so večinoma nepravilni mineralni odlomki kremena, cirkona in glinenih mineralov. Med tehnogenimi delci prevladujejo votli sferični delci, ki vsebujejo večinoma ogljik in so nastali pri izgorevanju premoga ali tekočih goriv, in težke kovine vsebujoči sferični delci, ki so nastali pri visokotemperaturnih procesih industrijskega sežiga in taljenja jekla. Tehnogeni delci nepravilnih oblik nastajajo večinoma pri nepopolnem izgorevanju premoga in prometnih emisijah. Primerjava obravnavanih vzorcev ni pokazala razlik v izvoru trdnih delcev. Sklepamo lahko, da na sestavo trdnih zračnih delcev v vzorcih lokacija vzorčenja ni imela pomembnega vpliva.

Key words: solid airborne particles, snow deposit, Ljubljana urban area, source apportionment, SEM/EDS

Ključne besede: trdni zračni delci, snežni depozit, urbano območje Ljubljane, določitev izvora, SEM/EDS

Introduction

The combination of the scanning electron microscope and energy dispersive spectrometer (SEM/EDS) is a well-established analytical method across different fields of geology. It has also proved to be a very useful method world-wide in environmental geochemistry for the characterisation of particles in different environmental media. Numerous studies of solid aerosol particles and urban snow deposits attested the usefulness of SEM/EDS in terms of particle characterisation and source apportionment (Aragon et al., 2000; Sokol et al., 2002; Kemppainen et al., 2003; Trimbacher & Weiss, 2004; Umbria et al., 2004; Bernabe et al., 2005; Tasić et al., 2006; Choël et al., 2007). This method supplements other analytical methods, used in mineralogical and geochemical studies of environmental media, such as optical microscopy, X-ray diffraction and geochemical methods (ICP-MS, AAS etc.). The SEM/EDS also enables characterisation of particles, which are smaller than the resolution of an optical microscope, whose quantity is too small to be analyzed by conventional geochemical methods and when crystal structure of particles is ill-developed or amorphous and cannot be identified using X-ray diffraction. Thus, the SEM/EDS was a method of choice for identification of solid airborne particles in snow deposit from Ljubljana urban area and for the assessment of their qualitative chemical composition.

Solid airborne particles are present in all environmental media, reaching from snow to stream sediments, as a consequence of transport processes in the Earth's atmosphere and hydrosphere (Neinavaie et al., 2000). Due to erosion processes and the omnipresent geological and pedological substrata, the sources of natural mineral airborne particles are heterogeneous and well dispersed in all environmental compartments (Neinavaie et al., 2000). Compared to anthropogenic (technogenic) point sources, natural (geogenic) sources are less significant and usually represent a natural background. Solid airborne particles can be very reactive and toxic to living organisms, due to their chemical composition and large specific surface area available for interactions. For this reason it is essential to assess their chemical composition, morphology, size and source area.

Materials and methods

Snow is a natural collector and an ideal medium for observation of atmospheric constituents, which have been dry or wet deposited and are mostly well preserved in the snow (Schöner et al., 1993). Solid airborne particles in urban snow deposits are solid particles of different sizes that have been transported and deposited in the snow exclusively by air in the period between the last snowfall and the time of snow sampling. Sources of larger particles are usually located in the vicinity of sampling points; smaller particles, however, can travel between several kilometres and several tens of kilometres in the atmosphere. The average travelling distance of a particle with a diameter of 10 μm, emitted from a source 20 m above the ground, amounts to 10 km. Particles, emitted from a 100 m high source can travel as far as 60 km (Guthmann, 1958; Neinavaie et al., 2000). The content of solid airborne particles in the snow is relatively low, which is why snow samples are often prone to contamination (Telmer et al., 2004).

Two snow samples were taken at two sampling points in the urban area of

Ljubljana. The first sampling point was situated at the sports ground between the Faculty of Economics and the Chamber of Commerce and Industry of Slovenia, 250 m west of Dunajska cesta (Dunajska street) (sample SV-1; *Y* = 5 462 825, *X* = 5 103 317). The second sampling point was placed in the park between Dunajska cesta and the Chamber of Commerce and Industry of Slovenia, 13 m west of Dunajska cesta (Dunajska street) (sample SV-2; *Y* = 5 462 561, *X* = 5 103 235).

Snow samples were collected from a surface of 1 m^2 area and a depth of 1 cm, approximately 6 days after the last snowfall (20^{th} of January 2009). Snow samples were melted at room temperature in covered glass containers and filtered through an analytical white ribbon filter paper. Filter residue was dried at 50 °C, mounted on a carbon tape and sputter-coated with a thin layer of gold. Analysis was carried out in high vacuum mode using a scanning electron microscope JEOL JSM 6490LV, coupled with an energy dispersive spectrometer Oxford INCA Energy at accelerating voltage 20 kV and working distance 10 mm. Particles were observed in BSE (backscattered electron) mode, which allows their identification by relative elemental composition (atomic number). Qualitative chemical composition of particles was measured using EDS point X-ray microanalysis with acquisition time 10 s to 30 s.

All scanning electron microscopy and energy dispersive spectrometry investigations were performed in our laboratory at Geological Survey of Slovenia.

Results and discussion

Solid airborne particles in both samples of snow deposit were successfully identified, characterised according to their morphology and elemental composition and allocated to different source categories using the SEM/EDS method. Spherical particles, irregularly shaped fragments and agglomerates were recognised according to their morphology. Particles were classified as geogenic and technogenic, considering their genesis (Table 1).

Geogenic particles

Particles of geogenic origin are mineral phases, resulting from the weathering of bedrock and erosion of soil and stream sediments (Neinavaie et al., 2000). The size of analysed solid airborne particles of geogenic origin ranges from 12 μm to 320 μm, averaging 86.2 μm (median: 70 μm). Morphologically, geogenic particles are mostly irregularly shaped sharp-edged fragments of mechanically and chemically resistant rock-forming minerals (zircon, quartz, feldspars etc.). Spherically shaped particles (some clay minerals) are also present but in smaller quantities.

Table 1. Allocation of solid airborne particles in urban snow deposits according to their source

Geogenic	Technogenic
zircon fragments (Figure 1) barite (also technogenic) pyrite (also technogenic) amphiboles pyroxenes quartz (Figure 2) K-feldspars plagioclase clay minerals carbonates	***combustion products***: low-temperature domestic combustion: hollow spherical particles (less porous) irregularly shaped soot particles irregularly shaped coal residues (coke) (Figure 2) high-temperature industrial combustion: (spherical) coal and liquid fuel combustion: hollow spherical particles (porous) (Figure 3) Ca-ferrites (Figure 4) (Ca, Al)-silicates steel-melting and processing: (Cr, Ni, Fe)-oxides (Cr, Fe)-oxides (Figure 5) (Ca, Fe)-silicates (Figure 6)
	road traffic: exhaust soot tyre fragments steel fragments

Pyrite and barite both occur as geogenic and technogenic mineral phases. The origin of geogenic pyrite and barite is most probably the weathering of bedrock in the surroundings of Ljubljana. Technogenic pyrite probably derives from inorganic mineral constituents or inclusions in parent raw coal dust or occurs as non-combustible residue in ashes produced in coal combustion (Kopcewicz & Kopcewicz, 2001; Parish & Wright, 1994).

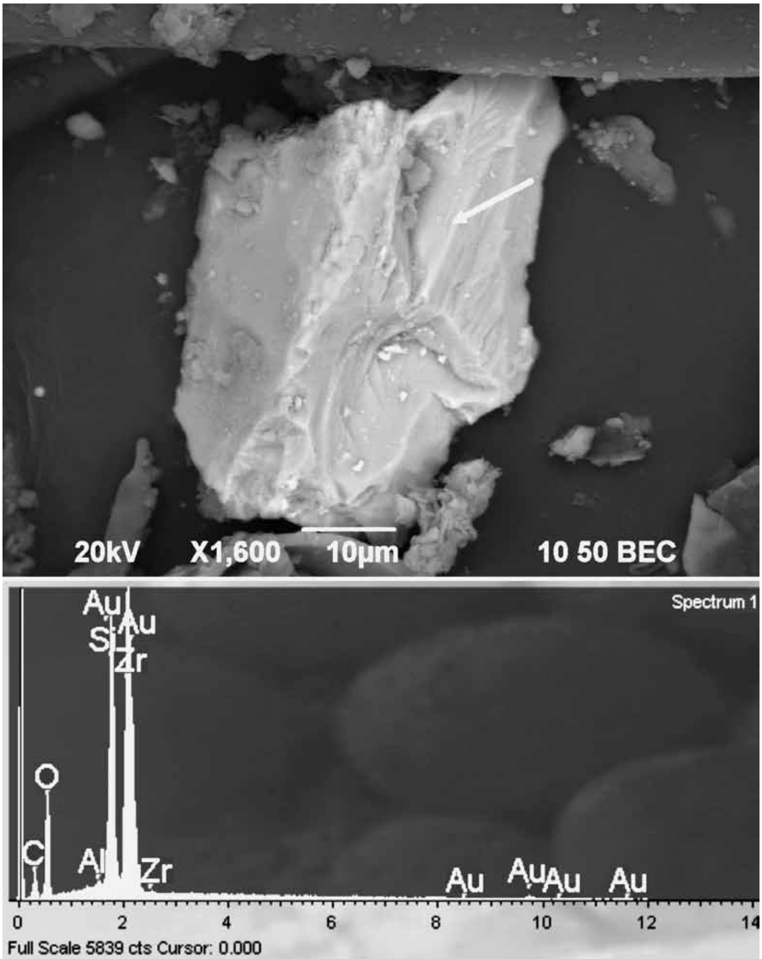

Figure 1. Geogenic zircon fragment

Technogenic barite appears as one of the basic constituents of inorganic colouring pigments (Trimbacher & Neinavaie, 2002) or as a secondary mineral phase, formed by chemical reaction of barium ions with sulphate ions, arising from high-temperature industrial coal combustion. Technogenic barite also occurs in the form of inclusions in irregularly shaped carbonaceous particles of coal residue (coke) (Trimbacher & Neinavaie, 2002).

Technogenic particles

The diameter of technogenic particles ranges from 2.5 μm to 700 μm, averaging 50 μm (median: 37.5 μm). Preva-

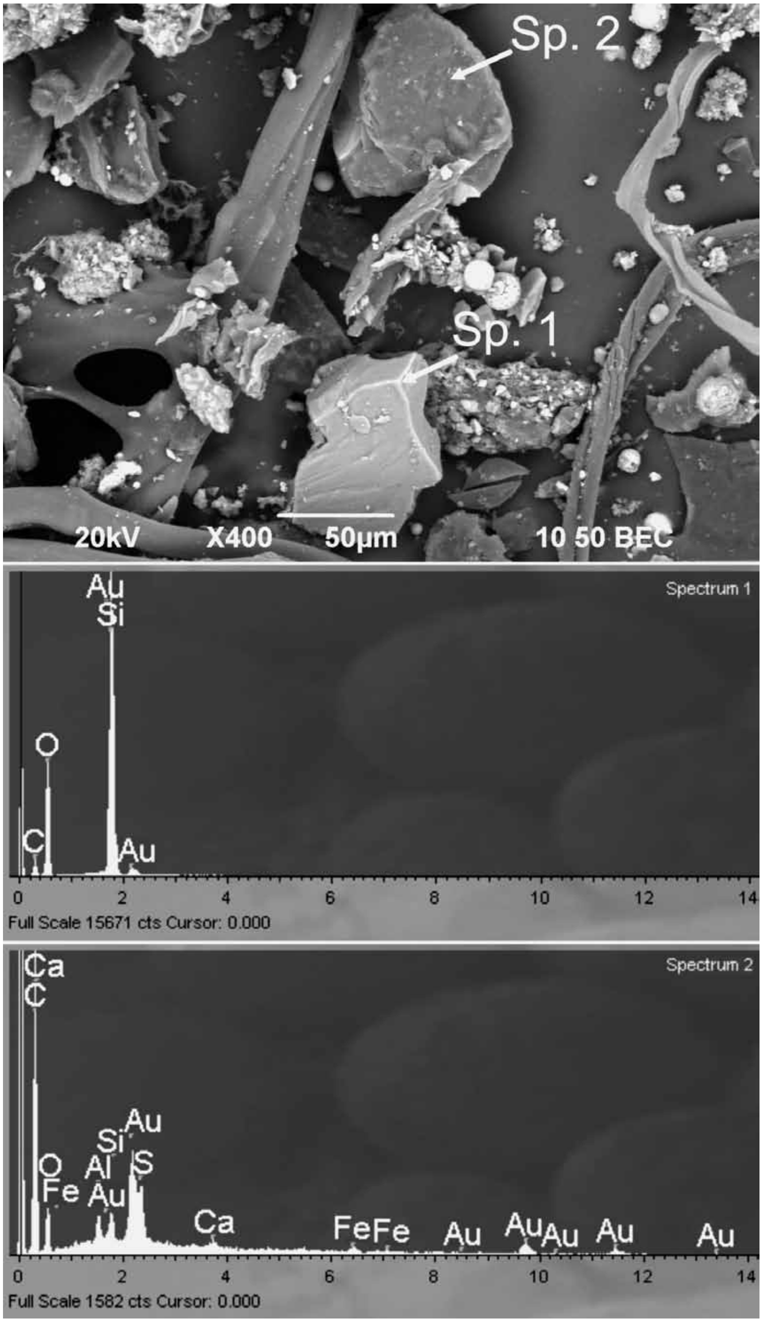

Figure 2. Geogenic quartz fragment (sp. 1 - spectrum 1) and presumably coal residue (coke) (sp. 2 - spectrum 2)

lent particle types in both samples are irregularly shaped carbonaceous technogenic particles and hollow spherical technogenic particles, as anticipated.

Irregularly shaped technogenic carbonaceous particles were interpreted as coke, originating from incomplete coal combustion, and consisting mostly of carbon, sulphur and small contents of silicon, iron, calcium and magnesium. They often contain inclusions of mineral phases such as quartz, barite and pyrite. Hollow particles have been formed during the combustion of coal (Flagan & Seinfeld, 1988) or liquid fuel (fuel oil) (Umbria et al., 2004, Massei et al., 2007). Less porous hollow spherical particles were formed during low-temperature (700–750 °C) incomplete combustion, while more porous and brittle hollow spherical particles were most probably formed during high-temperature complete combustion of coal and liquid fuel. The main constituents of these particles are carbon, sulphur and chlorine while contents of silicon, iron, calcium and magnesium depend on fuel type and manner of combustion.

The hollow spherical shape is a result of expulsion of gaseous or liquid materials from the particle interior, due to an increase in internal pressure or decrease in external pressure (Umbria et al., 2004), which is a consequence of abrupt changes in temperature during combustion processes.

Spherical particles, emanating from high-temperature industrial combustion, are mostly characterised by massive spherical shape resulting from melting processes that occur during their formation (Umbria et al., 2004; Tasić et al., 2006).

Spherical particles, consisting basically of calcium and iron, are Ca-ferrites, which are mineral phases of technogenic origin, formed during high-temperature industrial coal combustion (1400–1500 °C) and can be used as index minerals or indicators for industrial high-temperature processes (Neinavaie et al., 2000). Ca-ferrites are typical of coal-fired heating stations and thermal power plants emissions (Neinavaie et al., 2000; Sokol et al., 2002). Besides calcium and iron Ca-ferrites often contain trace contents of manganese, titanium, copper and zinc. The elemental composition of Ca-ferrites is strongly dependent upon the composition of inorganic mineral constituents in coal and different coal burning methods (Umbria et al., 2004). Considering the relatively wide range in size of analysed particles, it may be concluded that they most probably originate from local thermal power plants.

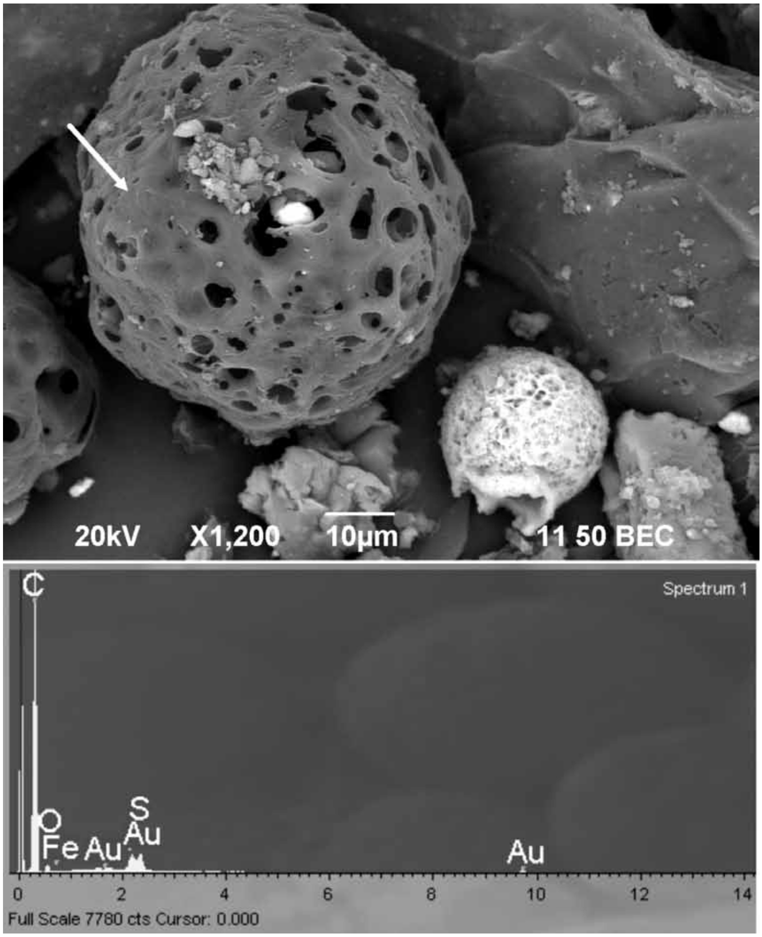

Figure 3. Porous hollow spherical particle (high-temperature coal and liquid fuel combustion)

More unusual and unexpected is the fairly high content of spherical particles, comprising compounds of iron and heavy metals, such as chromium, nickel and vanadium in variable ratios. Spherical iron oxides sometimes occur in the form of the technogenic minerals goethite, hematite and magnetite.

Particle morphology (spherical shape, dendritic and skeletal crystals in glassy matrix) suggests that they were formed during the melting of steel at very high temperatures, followed by rapid cooling (Aragon et al., 2000). According to their chemical composition these particles were most likely formed in

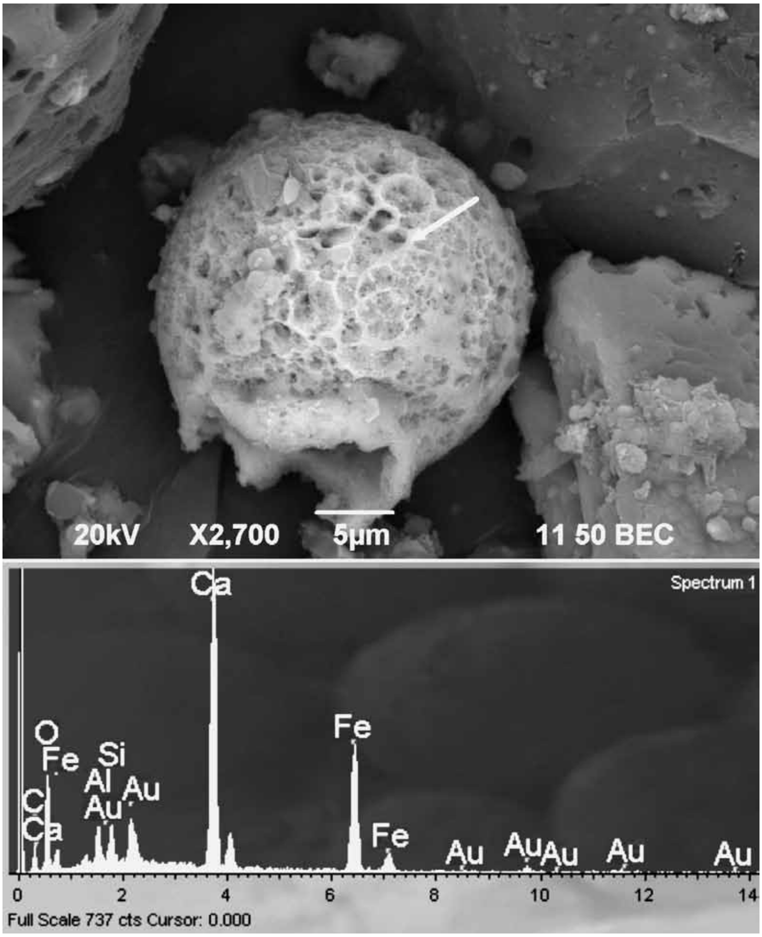

Figure 4. Spherical particle of Ca-ferrite (high-temperature industrial coal combustion)

high-temperature steel production processes or during re-melting and refining of scrap steel, containing the aforementioned heavy metals as alloy components (SEAMES, 2003; ZHANG et al., 2005; CHOËL et al., 2007). Cr-Ni-V-Fe compounds are common components of different steel grades (http://www.litostroj.com/files/Materials.xls; KAKER & GLAVAR, 2005). In some cases, spherically shaped (Cr, Fe)-oxides contain small amounts of manganese and copper, while sharp-edged (Cr, Fe)-oxides (also chromite) often contain titanium, which replaces iron ions in the (Cr, Fe)-oxide crystal lattice. Spherical

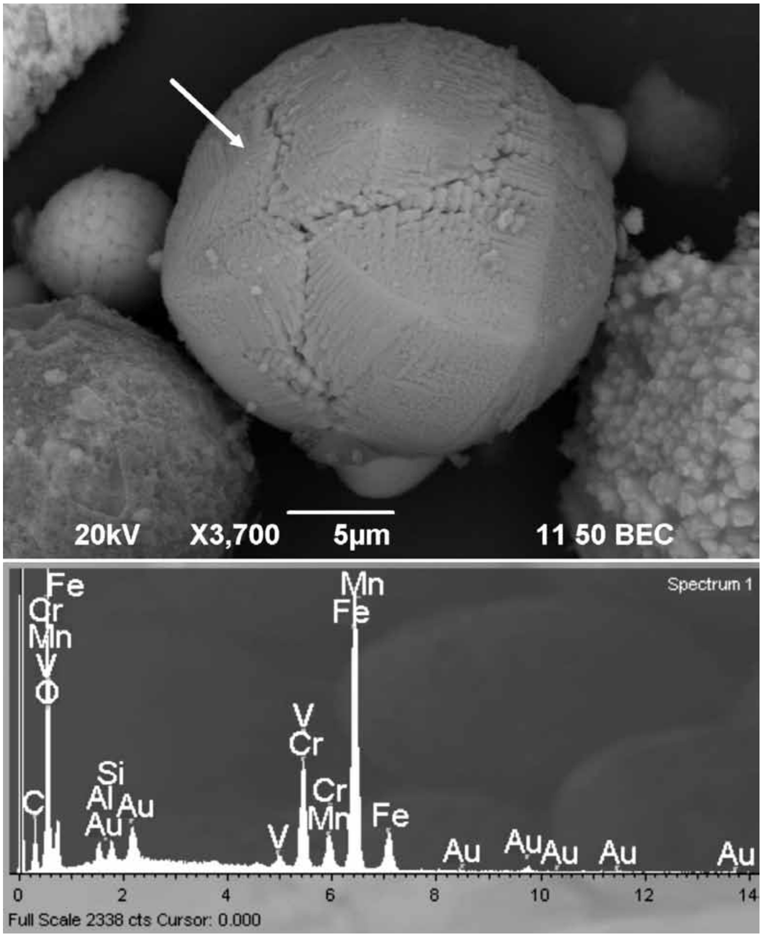

Figure 5. Spherical particle of (Cr, Fe)-oxide with V (high-temperature steel-melting processes)

(Ca, Fe)-silicates are commonly characterised by well-developed euhedral crystals of Fe-oxides (magnetite) in the glassy matrix of (Ca, Fe)-silicates (Figure 6). The euhedral form of Fe-oxide crystals suggests that they were first to crystallise from the melt, followed by (Ca, Fe)-silicates.

There are no steelworks facilities in the surroundings of Ljubljana. Two possible explanations of origin of heavy metal-bearing spherical particles or combination of both are given:

- The heavy metal-bearing spherical particles were formed during the melting and casting of steel in local steel castings production. This explanation is supported by the relatively high content of these particles in both samples and wide range in their size, ranging from 2.5 µm to 98 µm (averaging 35 µm).

- Particles emanate from a more remote source. However, it needs to be considered that a particle of 10 µm in diameter can travel over a distance of 60 km, if emitted from a source located 100 m above the ground level (Guthmann, 1958; Neinavaie et al., 2000). In our case particles have an average diameter of 35 µm (less than 11 % of particles are smaller than 10 µm) and it can be assumed that their source is either closer than 60 km or higher than 100 m.

Characteristics of samples SV-1 and SV-2 and their comparison

Sample SV-1

Irregularly shaped and sharp-edged carbonaceous technogenic particles, interpreted as coke, and geogenic particles, such as quartz, zircon and clay minerals, are the most abundant particle types among analysed particles in sample SV-1.

Heavy metal-bearing spherical technogenic particles, formed during high-temperature industrial combustion, are present in lesser quantities. The size of geogenic particles ranges from 12 µm to 320 µm, averaging 77.8 µm (median: 54.5 µm). The largest particles belong to grains of quartz and the smallest to zircon fragments, which are also the most frequently occurring particles of geogenic origin. The measured size of technogenic particles ranges from 5 µm to 181 µm, averaging 44.8 µm (median: 37 µm). The largest technogenic particles originate from low-temperature combustion processes (hollow spherical particles, coke, soot). The smallest are heavy metal-bearing particles, originating from high-temperature industrial combustion and steel-melting processes ((Cr, Fe)-oxides, (Cr, Ni, Fe)-oxides, Ca-ferrites and Fe-oxides).

Sample SV-2

Analysed particles are represented mostly by irregularly shaped flat carbonaceous particles, interpreted as coke, and geogenic particles (quartz, zircon, clay minerals). Heavy metal-bearing technogenic particles are present in smaller quantities. The size of the geogenic particles ranges from 24 µm to 173 µm, averaging 99 µm (median: 115 µm). Grains of Al-silicates and quartz are the largest and the most abundant among geogenic particles, while zircon fragments are the smallest. The technogenic particles range in size from 2.5 µm to 700 µm, averaging 57 µm (median: 38 µm). The largest technogenic particles arise from low-temperature

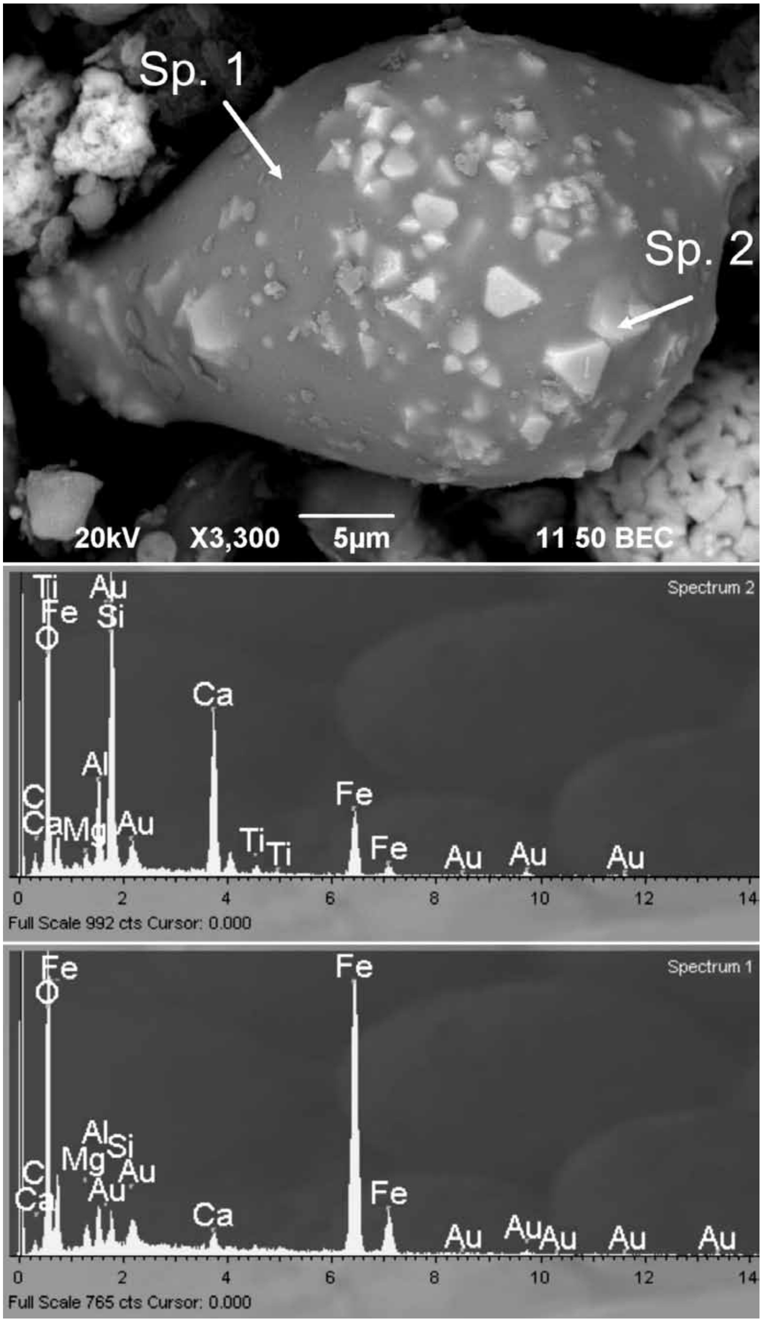

Figure 6. Particle of (Ca, Fe)-silicate with euhedral crystals of Fe-oxide (high-temperature steel-melting processes)

combustion processes (hollow spherical particles, coke, soot). The smallest in diameter are spherical Ca-ferrites, (Ca, Fe)-silicates and heavy metal-bearing (Cr, Ni, Fe)-oxides, Fe-oxides and (Cr, Fe)-oxides that are also the most numerous among heavy metal-bearing particles.

Great differences in the ratio between geogenic and technogenic particles in both samples were expected. Higher contents of technogenic particles, originating from road traffic emissions, should be present in sample SV-2, collected at sampling point close to the main road, compared to sample SV-1. But this was not the case. Comparison of both samples showed no significant differences in content of particles considering their origin. Figure 7 shows that, although absolute average particle size in the sample SV-1 differs from that in the sample SV-2, the trend of average particle size is similar in both samples.

Technogenic particles from high-temperature industrial combustion and melting processes are the smallest particle types in both samples, while the largest belong to the hollow spherical and irregularly shaped carbonaceous technogenic particles, emanating from high-temperature coal and liquid fuel combustion and low-temperature domestic combustion, respectively.

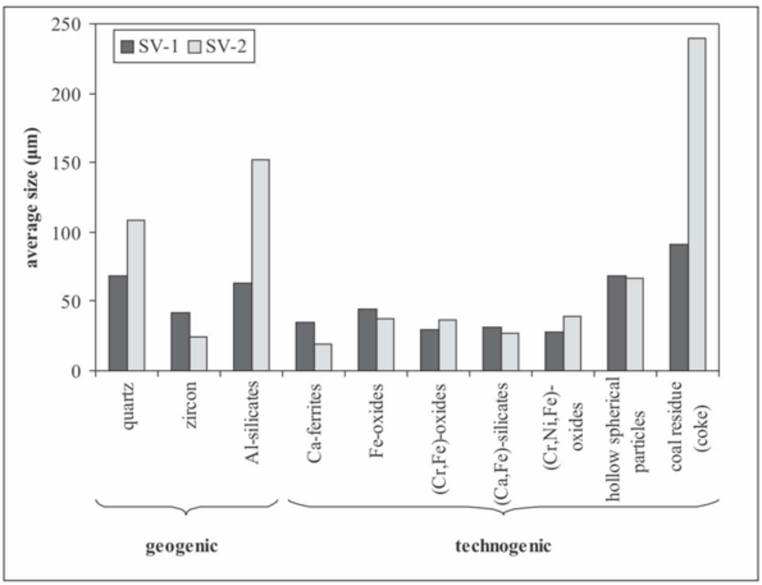

Figure 7. Comparison of average size of geogenic and technogenic particles in samples SV-1 and SV-2

Conclusions

Using the SEM/EDS method, solid airborne particles in snow deposit from the Ljubljana urban area were successfully characterised and classified according to their genesis, morphology and elemental composition. Geogenic particles are mostly sharp-edged, while technogenic particles are spherically and irregularly shaped.

It was established that irregularly shaped technogenic particles, interpreted as coke and originating from incomplete coal combustion and sharp-edged geogenic mineral particles, such as quartz, zircon and clay minerals, are the prevailing solid airborne particles in Ljubljana urban snow deposits. Spherical technogenic particles, resulting from high-temperature combustion processes, are present in smaller quantities. Considering relatively wide size range of analysed technogenic particles, formed during high-temperature industrial combustion and melting processes, it may be concluded that their source is in close vicinity of sampling points.

Comparison of both samples, SV-1 and SV-2, showed no significant differences in particles considering their origin and chemical composition. It can be concluded that sampling location had no important influence on distribution of solid airborne particles by their origin.

Acknowledgements

Presented study was carried out in the frame of the research programme Groundwaters and geochemistry at Geological Survey of Slovenia. The authors would like to thank to the Slovenian Research Agency (ARRS) for financial support and especially to Dr. Hassan Neinavaie from Geological Survey of Austria (GBA) for useful suggestions and help with interpretation and identification of particles in snow deposits.

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Aspects of structures and depositional environment of sand bodies within tomboy field, offshore western Niger Delta, Nigeria

Značilnosti struktur in okolja odlaganja peščenega materiala v območju Tomboyja, priobalna delta Zahodnega Nigra, Nigerija

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Abstract: Sand bodies deposited across normal growth faults and associated rollover anticlines are critical reservoirs for the accumulation of oil and gas. This paper addresses aspects of structures and depositional environments of some sand bodies within the Tomboy field, offshore western Niger Delta. Structural interpretation was undertaken to identify and assign faults found in the 3-D seismic volume. Time and depth structure maps in combination with well logs were used to produce for five horizons, namely: H1 to H5 and identify the depositional environments respectively.

Two major growth faults (F4 and F7 which are normal, listric concave in nature), three antithetic (F1, F3 and F6) and two synthetic faults (F2 and F5) were identified. Structural closures identified as rollover anticlines, and displayed on the time/depth structure maps; suggest probable hydrocarbon accumulation at the downthrown side of the fault F4. Point bars, distributary channel and mouth bars, barrier island and tidal channels are the depositional environments. This study shows that the Tomboy field is made up of sand bodies deposited in different environments across normal, growth faults and associated rollover anticlinal structures.

Izvleček: Peščen material, odložen ob sinsedimentnih normalnih prelomih in z njimi povezanimi naleglimi antiklinalami, so pomembna nahajališča nafte in plina. Članek se ukvarja z značilnostmi struk-

Original scientific paper

tur in okolja odlaganja peščenega materiala v območju Tomboyja v priobalni delti Zahodnega Nigra. S strukturno interpretacijo smo ugotovili prelome iz 3-D seizmičnih podatkov. Na podlagi strukturnih kart v časovni in prostorski domeni ter z elektrokarotažami smo izdvojili pet stratigrafskih horizontov in ugotovili njihova sedimentacijska okolja.
Določili smo dva večja sinsedimentna preloma (F4 in F7, ki sta normalna in listrično konkavna), tri antitetične (F1, F3 in F6) in dva sintetična preloma (F2 in F5). Strukturne pasti v naleglih antiklinalah, ki smo jih identificirali na strukturnih kartah, nakazujejo možnost akumulacije ogljikovodikov v spuščenem krilu preloma F4. Sedimentacijska okolja so meandrske sipine, razvodni kanali ter sipine v ustju, pregradni otoki in plimski kanali. Študija je pokazala, da polje Tomboy sestavljajo peščenjaki, ki so se odložili v različnih sedimentacijskih okoljih ob sinsedimentnih normalnih prelomih in z njimi povezanimi strukturami naleglih antiklinal.

Key words: structures, depositional environment, Niger Delta
Ključne besede: strukture, sedimentacijska okolja, delta reke Niger

Introduction

The Niger Delta Basin to date is the most prolific and economic sedimentary Basin in Nigeria. It is an excellent petroleum province, ranked by the U. S. Geological Survey World Energy Assessment as the twelfth richest in petroleum resources, with 2.2 % of the world's discovered oil and 1.4 % of the world's discovered gas (Klett et al., 1997; Petroconsultants, Inc. 1996). By virtue of the size and volume of petroleum accumulation discovered in this basin, various exploration strategies have been devised to recover the enormous oil and gas deposits. These comprise onshore exploration of oil and gas as well as on continental shelf, and in deep offshore.

Sand bodies were deposited across normal, growth faults and associated rollover anticlines and represent important reservoirs for the accumulation of oil and gas, especially in the Niger Delta. It has been documented in the Niger Delta that growth faults and rollover anticline structures serve as traps for petroleum accumulation (Merki, 1972; Orife & Avbovbo, 1982).

In this study, GeoGraphix software combined with well logs and 3-D seismic volume were used to show how structural deformation and depositional

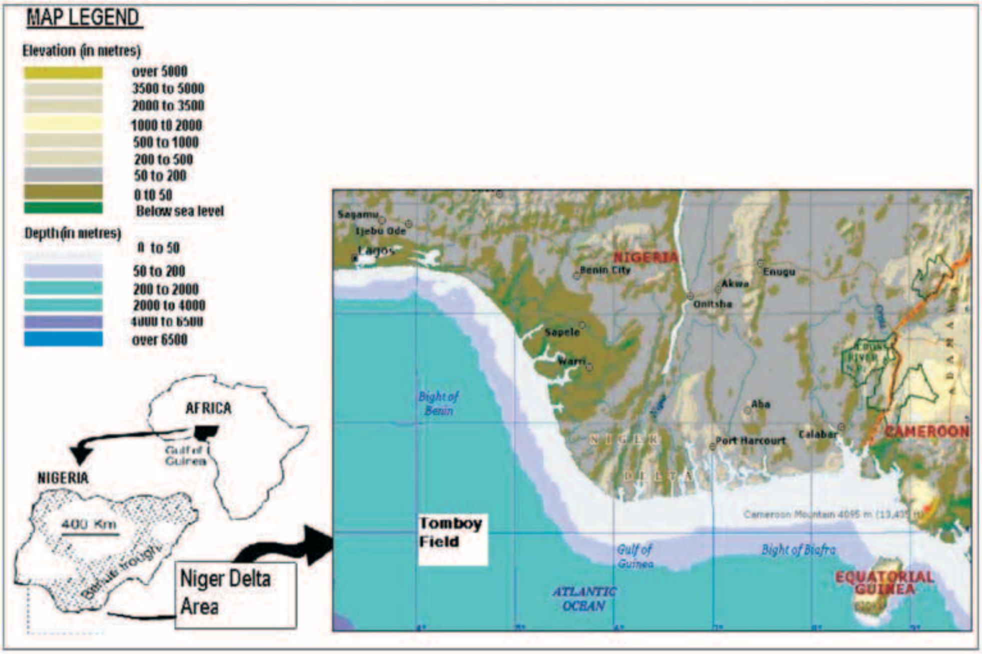

Figure 1. Location map of the study area (Modified from Owoyemi, 2004 and Microsoft Encarta, 2006)

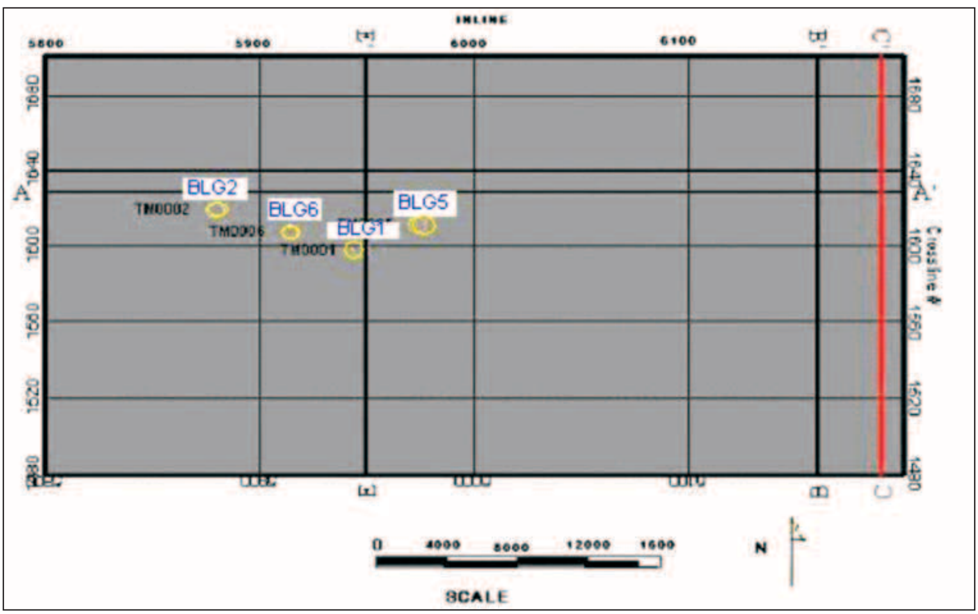

Figure 2. Seismic Survey Base Map of the Tomboy Field showing the location of the four studied wells and seismic section

environment can influence the accumulation of oil and gas. These can assist in well placements and narrow down areas for detailed exploration and production.

Study area and regional geology setting

The area of study, Tomboy Field, is located within the western margin of offshore Niger Delta (Figure 1) and belongs to Chevron Texaco Limited concession. The seismic base map of the area originates from latitude 4.0 °N and longitude 4.5 °E, covering an area of 55 km^2 (Figure 2). The in-lines and cross-lines are in the ranges of 5800 to 6200 and 1480 to 1700 respectively and with a spacing of 25 m between lines.

The four wells, namely BLG1, BLG2, BLG5 and BLG6, utilized for this study were drilled to the depths of 13,019.00 ft (3,945.15 m), 12,996.0 ft (3,938.18 m), 11,541.50 ft (3,497.42 m) and 11,674.50 ft (3,537.72 m) respectively. These four wells have composite well logs which include gamma ray; resistivity, sonic, and neutron/density logs. The 3-Dimensional seismic volume is in SEG-Y format, whereas the well log data are in LAS format.

The Tomboy field is located within the geological setting of the Niger Delta where clastic wedges are deposited along the failed arm of a triple junction system. Originally, the Delta was formed during the breakup of the South American and African plates during the late Jurassic (Burke, 1972; Whiteman, 1982). The two rift arms that followed the southwestern and southeastern coast of Nigeria and Cameroon developed into the passive continental margin of West Africa, whereas the third failed arm formed the Benue Trough which is located under the Gulf of Guinea, offshore Nigeria. After an early history of rift filling in the late Mesozoic, the clastic wedge steadily prograded into the Gulf of Guinea during the Tertiary as drainage expanded into the African Craton with consequent subsidence of the passive margin.

These upward-coarsening strata, offlapping this continental margin, have been divided into three diachronous lithostratigraphic units, namely the Akata, Agbada, and Benin Formations (Figure 3; Short & Stauble, 1967; Doust & Omatsola, 1990). The Akata Formation is the oldest of the units and composed mainly of marine shales which range in age from Eocene to Recent. The Agbada Formation overlies the Akata Formation and comprises mainly alternating deltaic sandstones with shale. It age ranges form Eocene to Recent. The Benin Formation is the youngest in the lithostratigraphic succession, and comprises sandstone, grits, claystone and streaks of lignite. Its age ranges from Oligocene to Recent.

The Niger Delta is subtly disturbed at the surface but the subsurface is affected by large scale synsedimentary features such as growth faults, rollover anticlines and diapirs (Doust & Omatsola, 1990; Stacher, 1995). The structural style, both on regional and on the field scale, can be explained on the basis of influence of the ratio of sedimentation to subsidence rates. The different types of structures are namely, simple non-faulted anticline rollover structures, faulted rollover anticline with multiple growth faults, or anticline faults and complicated collapse crest structures (Evamy et al., 1978). Others are sub-parallel growth fault (k-block structures) and structural closures along the back of major growth faults (Figure 4).

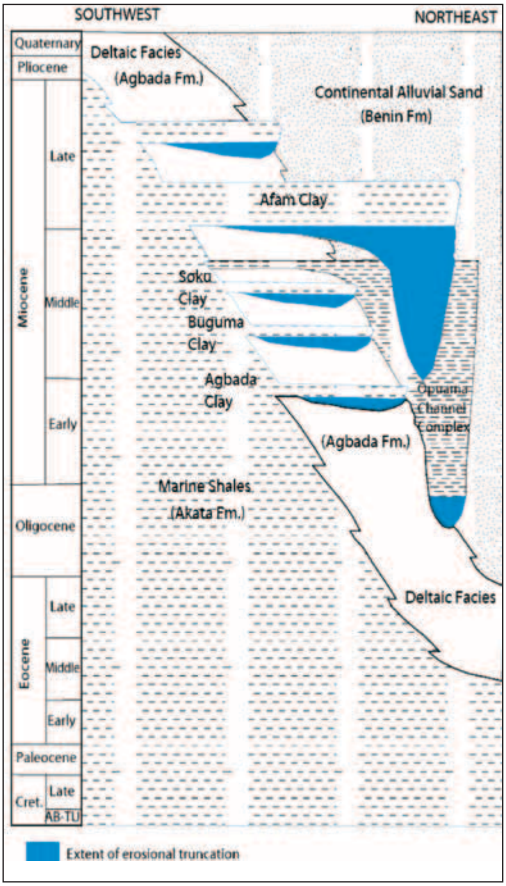

Figure 3. Stratigraphic column showing the three formations of the Niger Delta (After Shannon and Naylor (1989) and Doust and Omatsola 1990)

Continental-margin collapse structures exert control on depositional and stratigraphic patterns within the Niger Delta

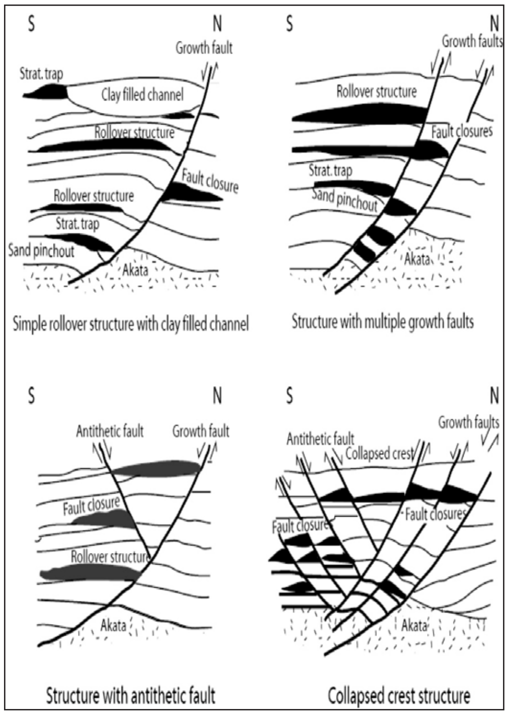

Figure 4. Examples of Niger Delta oil field structures and associated trap types (After Doust and Omatsola, 1990 and Stacher, 1995)

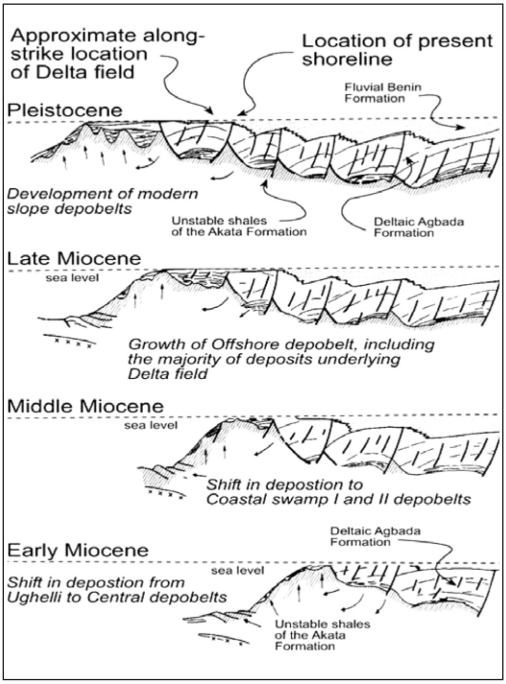

Figure 5. Schematic diagram showing the development of successive growth-fault-bounded depobelts during progradation of the unstable Niger Delta clastic wedge (After Knox and Omatsola, 1989)

clastic wedge (Figure 4). At the largest scale, these structures extend laterally along depositional strike across nearly the entire Niger Delta (hundreds of kilometers), defining "mega structures" of Evamy et al. (1978) and associated "depobelts" that are tens of kilometers wide perpendicular to the shoreline (Knox & Omatsola, 1989; Doust & Omatsola, 1990). Six regional depobelts were deposited during the 25 Ma - from Early Miocene to present (Figures 5 and 6). Depobelts tend to become finer-grained laterally away from areas of most rapid delta progradation and basinward away from areas of most rapid growth fault development (Doust & Omatsola, 1990). Smaller-scale faults and associated structural deformation accommodating collapse of depobelts tend to be more complex near the progradational axis of the delta than at its margins. This pattern of deposition continues still today, with extensional development of the growth faults on the modern shelf and slope, and compressional uplift near the toe of the slope (Armentrout et al., 2000; Hooper et al., 2002).

Materials and methods

GeoGraphix software was combined with well logs and seismic data using laid down procedures as shown in Figure 7. The top and base of the Agbada Formation were determined using the reflection characteristics of the 3-D seismic volume, stratigraphic indicators and the nature of the gamma ray curves that characterize this interval. The lithologies penetrated by the studied wells were determined by setting the cut-off point at 65 API on the gamma ray logs. Major and minor faults were identified, traced and assigned using the GeoGraphix software. The faults which were picked at an interval of 10 on the in-lines section were subsequently reflected on the cross-lines sections.

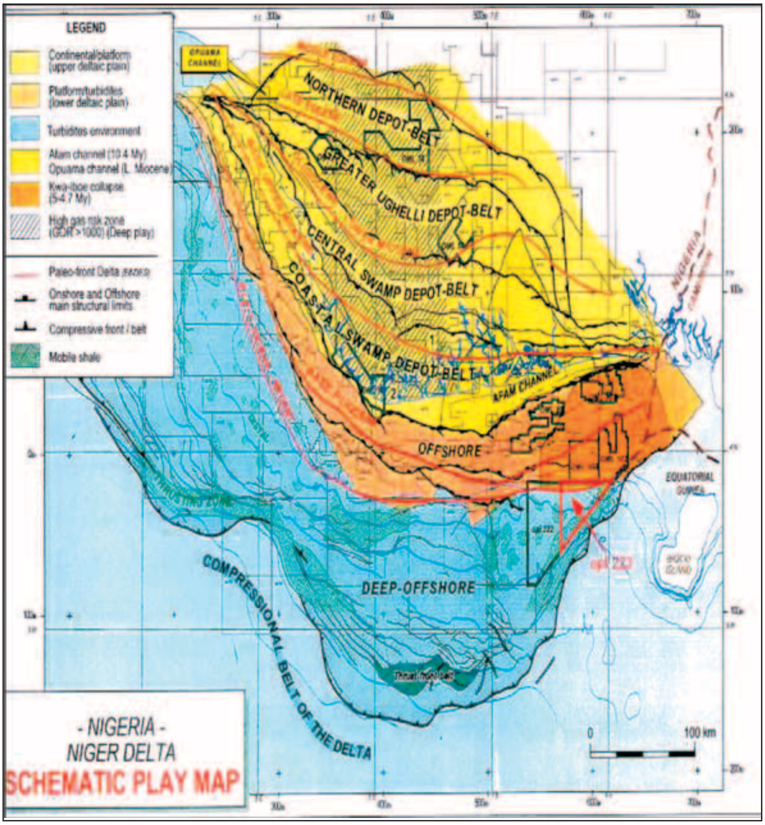

Figure 6. Map of Niger Delta showing the depobelts (After Weber, 1971)

Five horizons were defined on the top of sand bodies from the gamma ray and resistivity log sections (Figure 8). These horizons were later correlated in the 3-D seismic volume in order to produce time and depth structure map of the horizons. After correlation, time and depth structure maps were produced using the GeoAtlas module of the GeoGrapix software. The time-depth relationship was determined by plotting the checkshot data available for the well BLG1 using Microsoft Excel. Interpretation of depositional environments is based on the combination of the gamma ray log with resistivity log signatures which were corroborated by Schlumberger (1985) and Busch (1975) charts (Figures 9 and 10).

Results and discussions

Seismic Record and lithologic identification of the field

Reflection characteristics between 0 s and about 1.35 s two-way travel time observed from the seismic record show

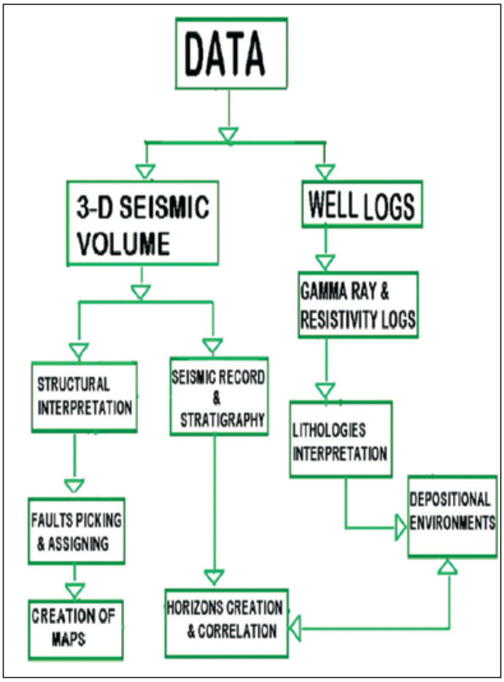

Figure 7. Work flowchart of study

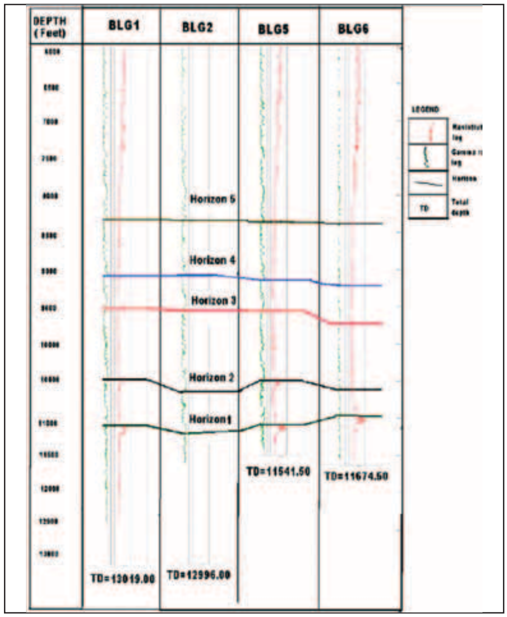

Figure 8. Cross section of the four wells showing horizons delineated on the top of sand bodies

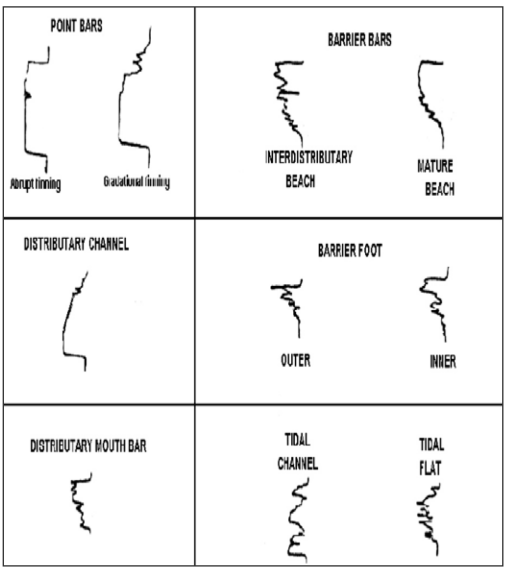

Figure 9. Recognition of depositional environments using gamma ray logs from deltaic reservoirs (After: Schlumberger, 1985)

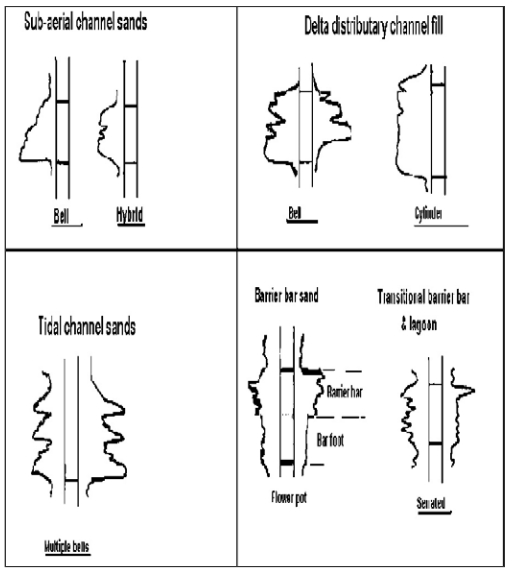

Figure 10. Assortment of gamma ray and resistivity log shapes suggestive of depositional environment (After: Busch, 1975)

a characteristics low amplitude, parallel, and discontinuous reflection patterns of the field (Figure 11). Based on regional studies and the uniformly blocky, low-value gamma-ray patterns observed within this interval, this portion can be inferred as the Benin Formation (Weber, 1971; Orife & Avbovbo, 1982; Doust & Omatsola 1990; Diedjomahor et al., 2002; Larue & Legare, 2004; Obiora, 2006). The reflection interval between 1.35 s to 2.8 s two-way travel time, consist of parallel and high amplitude reflections that is diagnostic of Agbada Formation (Figure 11). Below the 2.8 s two way travel time, are chaotic, low amplitude reflections interpreted as the Akata Formation.

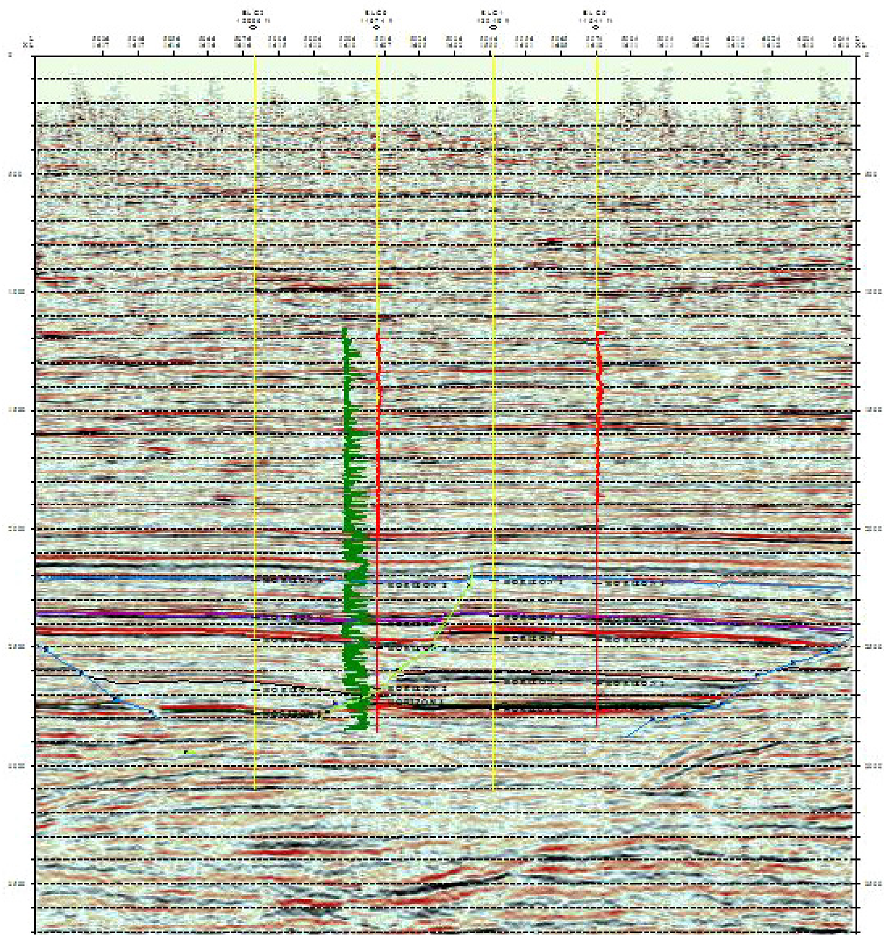

Figure 11. Seismic section showing the four wells and their respective gamma ray and resistivity logs, stratigraphy, faults, horizons and seismic reflection characteristics of the study area.

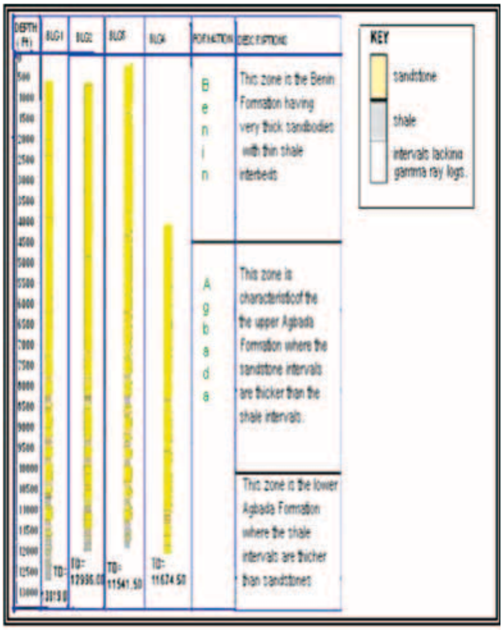

Figure 12. Lithology logs of the Tomboy Field

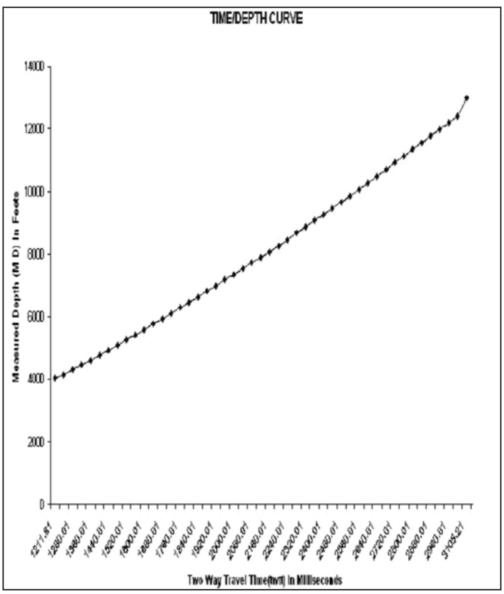

Figure 13. Plot of depth against two ways travel time (TWT) in milliseconds

The four wells located within the field, penetrated two different lithological zones. The first zone lies between the depth intervals 0ft to 5076 ft (1538.18 m), and comprised mainly thick sand bodies with few very thin shale interbeds (Figure 12.). The second zone extends from the depth of 5076 ft (1538.18 m) to about 12900 ft (3909.09 m) and can be regrouped into upper and lower parts. The upper part shows a characteristic where the sandstone intervals are thicker than the shale, whereas in the lower part, a reversed situation is the case. This zone is equivalent to the zone of 1.35 s to 2.80 s two ways travel time, observed from the seismic record and can be assigned to the Agbada Formation (DOUST & OMATSOLA, 1990; OWOYEMI, 2004).

Time and depth structural maps

Time and depth structural contour maps were produced for the five horizons defined on top of sand bodies , namely, H1 to H5 (Figure 8). Both types of structural contour maps show similar structural relationship. This linear relationship was also corroborated by the linear curve observed from the plot of depth against time using the check shot data of the well BLG1 (Figure 13).

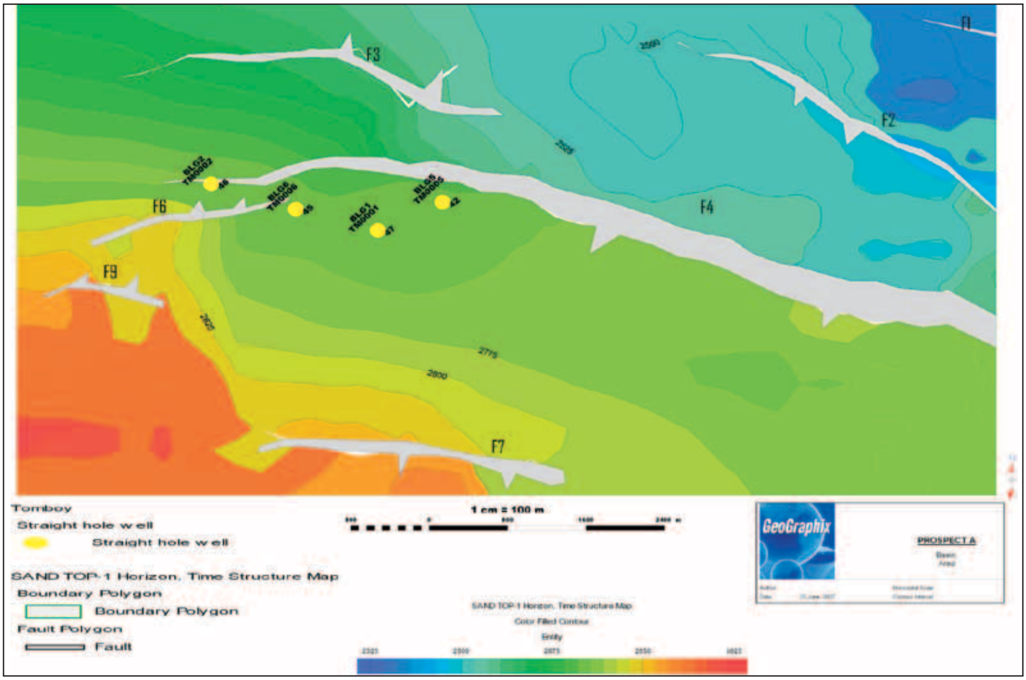

Figure 14. Time Structure Map of Horizon 1

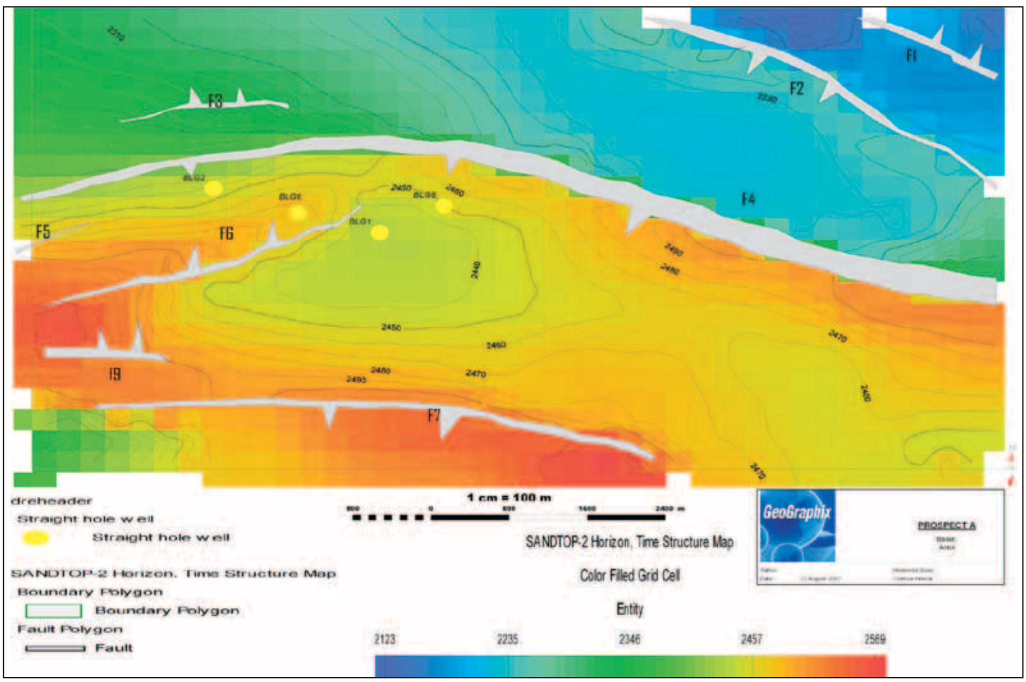

Figure 15. Time Structure Map of Horizon 2

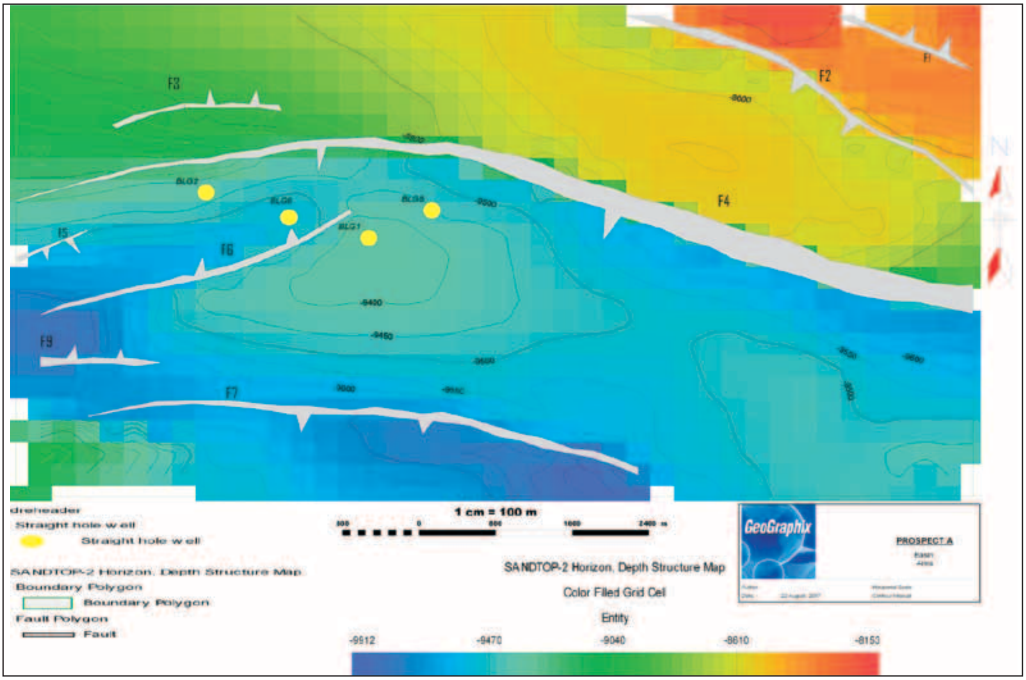

Figure 16. Depth structure map of Horizon 2

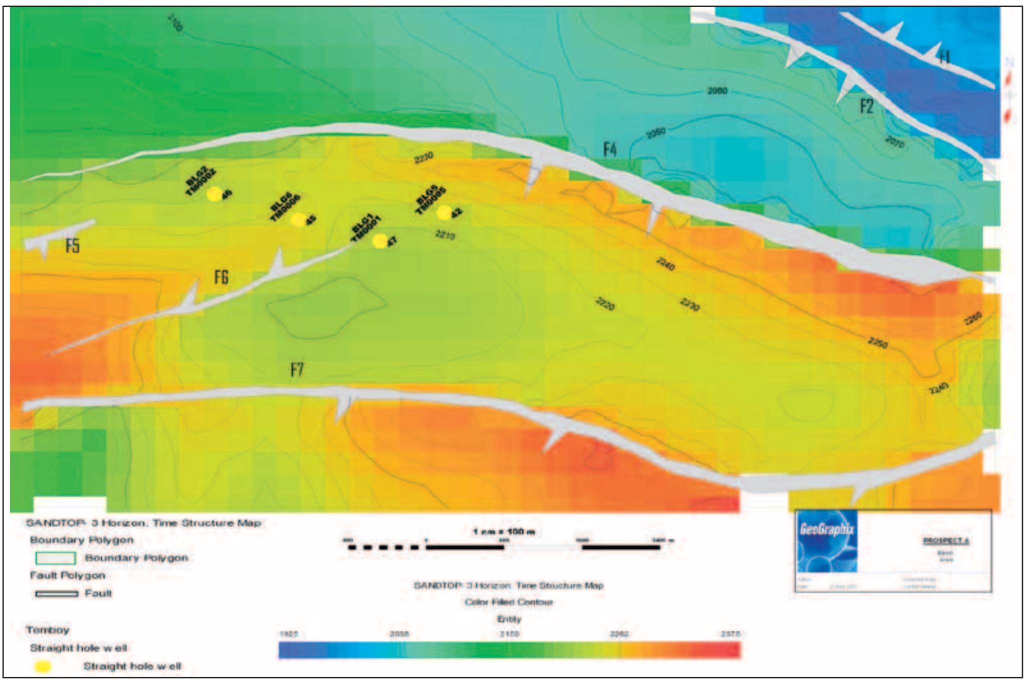

Figure 17. Time Structure Map of Horizon 3

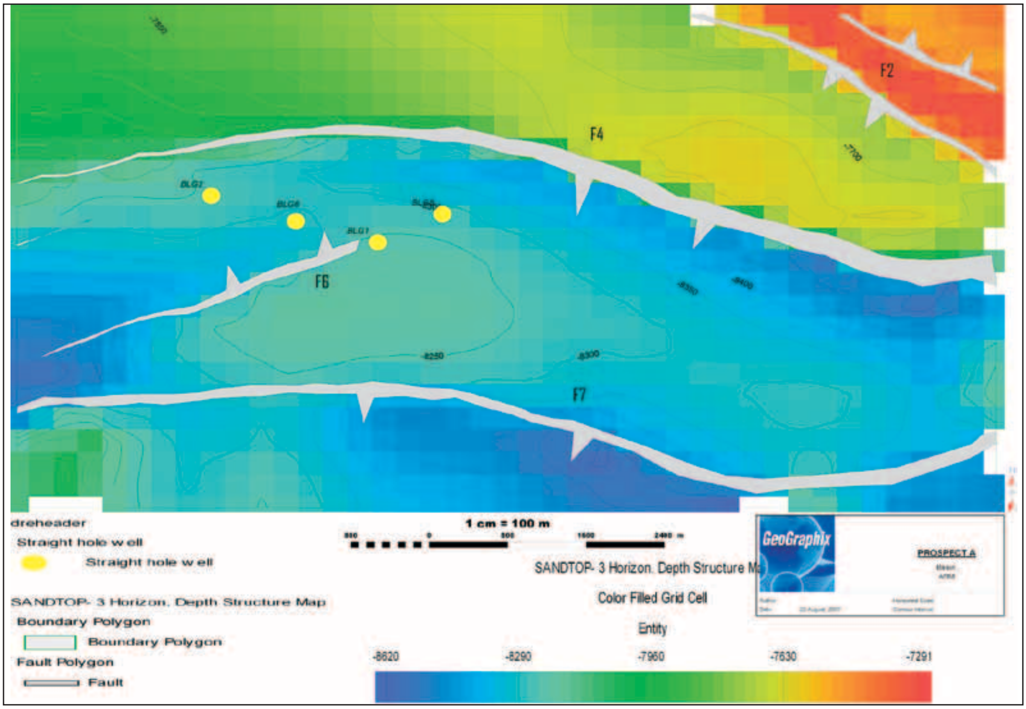

Figure 18. Depth Structure Map of Horizon 3

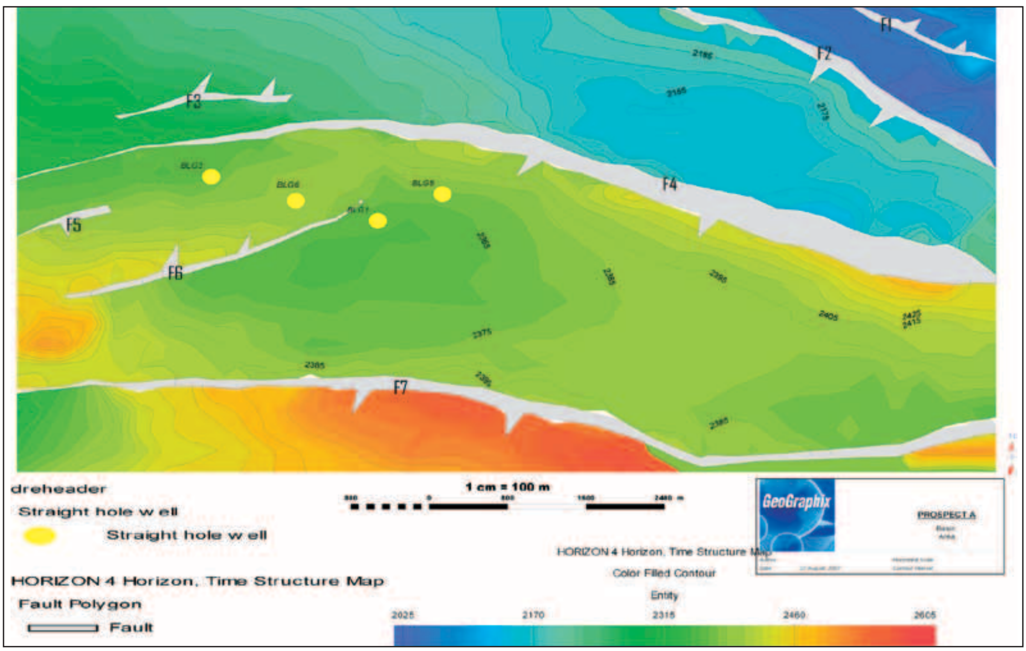

Figure 19. Time Structure Map of Horizon 4

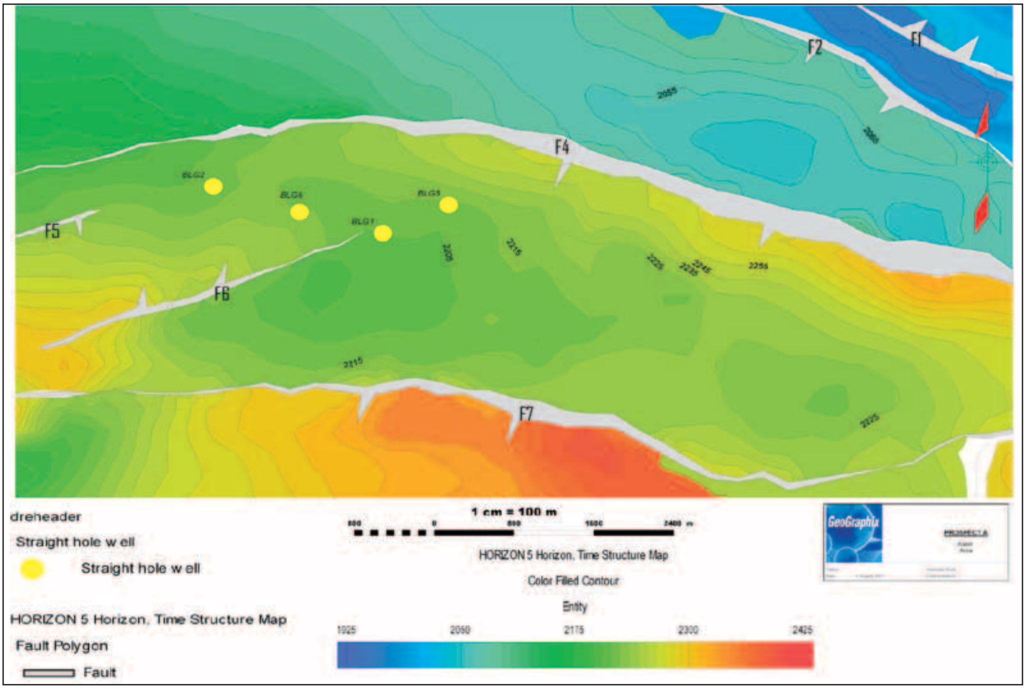

Figure 20. Time Structure Map of Horizon 5

The time and depth structure contour maps show system of differently oriented growth faults F1 to F7 (Figures 14–20). Faults F4 and F7 are the major growth faults, dipping towards southwest and are quite extensive. The fault F4 lies centrally within the mapped area and extends up to 85 % of the entire breadth of the mapped area. A rollover anticline formed as a result of deformation of the sediments deposited on the downthrown block of the fault F4. The fault F7, is also extensive and shows sub-parallel relationship with the fault F4. This sub-parallel relationship is sustained in all the structural contour maps. The fault F4 is observed to be closer to the shoreline and can be interpreted as the active fault, while the F7 is inactive fault, but must have been active in the past and located in offshore direction of the F4. Antithetic faults are F1, F3 and F6, and synthetic faults are F2 and F5, and occur at different positions, at the edge of the mapped area (Figures 14–20).

Sealing Potential and Play Prospect of the Study Area

Evidence of growth faulting and "rollover" anticline associated with the Tomboy Field can be deduced from the time and depth structural contour maps (Figures 14 to 20). The trapping potential of the field can be attributed to faults or anticlines, acting either as fault assisted or anticline closures respectively (Orife & Avbovbo, 1982; Sales, 1997). Anticlinal and fault assisted closures are regarded as good hydrocarbon prospect areas in the Niger Delta (Weber & Daukoru, 1975). Trapping of hydrocarbons in an anticline is simply by means of closure which may be dependent or independent on faults. The rollover anticlines are formed on the downthrown block of the fault F4, which indicate structural closure in these areas (Figures 14–20).

The sealing capability of the faults is dependent on the amount of throws and shale/clay smeared along the fault planes (Busch, 1975; Weber & Daukoru, 1975). According to Weber & Daukoru (1975), faults can be sealing if either the throws are less than 492 ft (150 m), or the amount shale/clay smeared along the fault planes is greater than 25 %. The average throws of the major faults F4 and F7 calculated are 570.8 ft (173 m) and 511.0 ft (154.85 m) respectively (Tables 1 and 2). Judging by the amount of throws, the faults F4 and F7 are not sealing. However, they are probably sealing, considering the amount of shale/clay smeared along the fault plane. Generally, in the Niger Delta, as reported by Weber & Daukoru (1975), the soft and over- pressured Akata Shale, in most cases rises up to fill the fault zone, thus enhancing their sealing capabilities.

Table 1. Table showing throws of fault F4

HORIZONS	Downthrow Depth/feet	Upthrow Depth/feet	Throw of Fault
Horizon 1	1029.7	9787.5	505.8
Horizon 2	9833.9	9251.3	582.6
Horizon 3	9185.9	8650.0	535.9
Horizon 4	9099.1	8423.6	675.5
Horizon 5	8442.1	7887.7	554.4

Average: 570.8

Table 2. Table showing throws of fault F7

HORIZONS	Downthrow Depth/feet	Upthrow Depth/feet	Throw of Fault
Horizon 1	10767.0	11072.9	305.7
Horizon 2	10216.2	10672.9	456.7
Horizon 3	9367.07	100035.07	668.0
Horizon 4	9034.96	9327.47	592.5
Horizon 5	8302.8	8834.93	531.1

Average: 511.0

It can be deduced from this study that the wells were located to target the rollover anticline formed on the downthrown side of the fault F4 (Figures 14–20). The oil and gas reserves recoverable deduced from the time and depth structure maps vary widely (Weber & Daukoru, 1975). The height of oil above the spill- point and the geographic extent of oil pool are directly related to the type of closure in which the hydrocarbons are trapped. Individual prospects of the closures, as illustrated in the Figures 14 to 20, can be ascribed as good prospect (Weber, 1971).

Depositional environment

In the absence of biostratigraphic and other well data, a combination of gamma ray and resistivity curve signatures were used to deduce the depositional environments based on their characteristic patterns from mainly the well BLG 1.

Various depositional environments including point bars, distributary channel, distributary mouth bar, barrier bar, regressive sand, tidal flat, barrier foot and tidal channel fill were identified within the subsurface of the Tomboy Field (Figures 21a–21e). These are based on log characteristics and details as discussed in Adesina (2007).

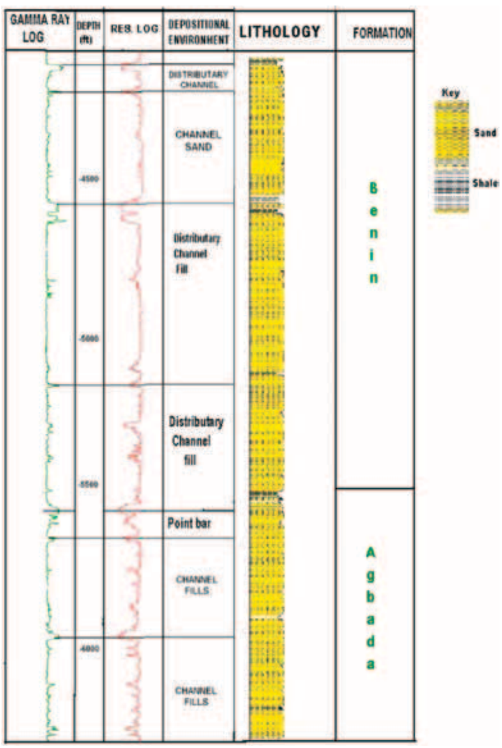

Figure 21a. Gamma ray and Resistivity Logs showing depositional environments from depth interval between 4000 ft (1363.63 m) to 6500 ft (1969.69 m) within well BLG1.

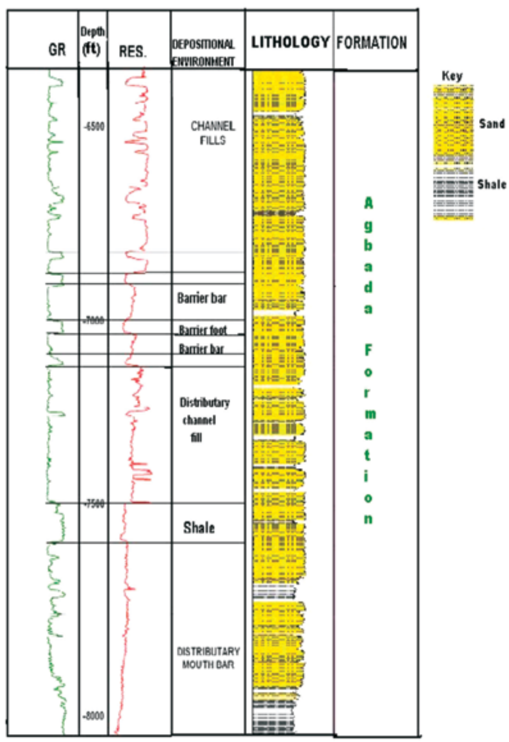

Figure 21b. Gamma ray and Resistivity Logs showing depositional environments from depth interval between 6500 ft (1969.69 m) to 8000 ft (2424.24 m) within well BLG1

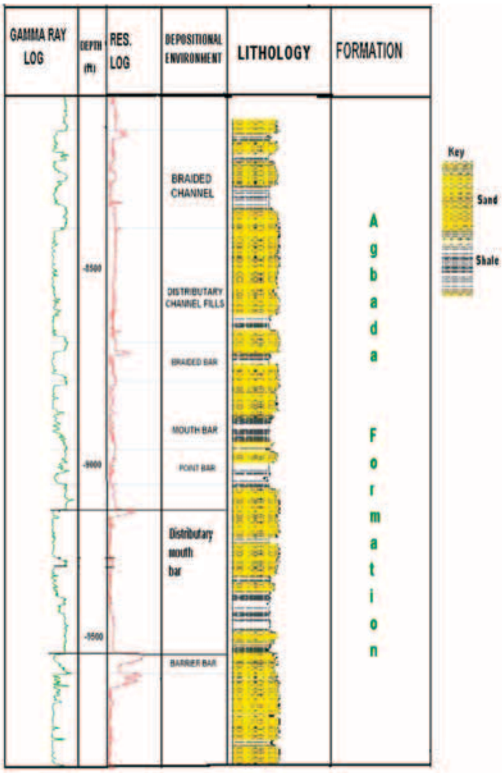

Figure 21c. Gamma ray and Resistivity Logs showing depositional environments from depth interval between 8000 ft (2424.24 m) to 10000 ft (3030.30 m) within well BLG1

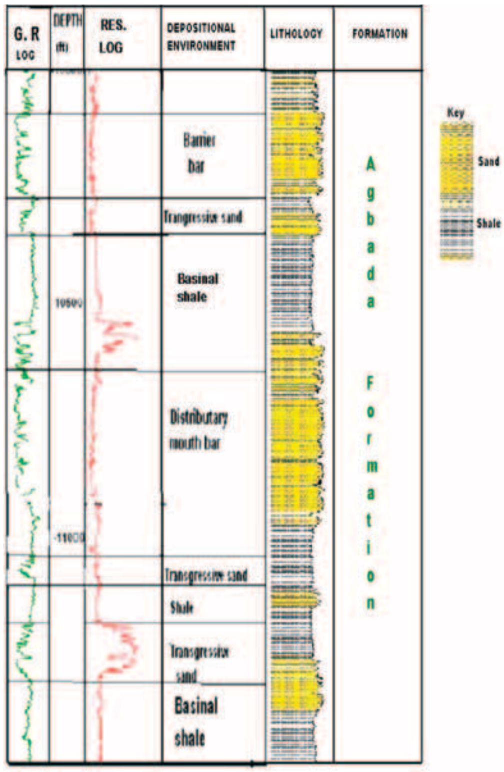

Figure 21d. Gamma ray and Resistivity Logs showing depositional environments from depth interval between 10000 ft (3030.3 m) to 11500 ft (3484.84 m) within well BLG1.

Conclusions

Seismic and well log data have been used to illustrate structural characteristics of identified sand bodies within the subsurface of the Tomboy field. This was made possible by creating time and depth structural contour maps of five horizons using the GeoGraphix interpretational tool. The time and depth structure maps show subsurface structural geometry and possible hydrocarbon trapping potential. Two major growth faults, namely F4 and F7, were observed to extend throughout the entire mapped area. The F4 is the active growth fault located near the shoreline, while F7 is an older inactive fault located offshore which must have been active in the past. The rollover anticline exists at the down-thrown block of the fault F4, which is suggestive of probable hydrocarbon accumulation potential of the sand bodies. The depositional environments identified were barrier bar, channel fill, tidal flat, tidal channel, point bar, distributary mouth bar and tidal ridge. These can serve as reservoirs for the accumulation of oil and gas.

It can be deduced from this study that the four wells located in the Tomboy field were drilled to target the rollover anticline formed on the downthrown block of the fault F4. This study, however, can provide additional information for precise well placement in further exploration and production of oil and gas.

Within the limits of the available data, it is recommended that further studies should include integration of velocity (check shot) and biostratigraphic data of all the wells. This will provide more reliable data for interpretation of the depositional environments.

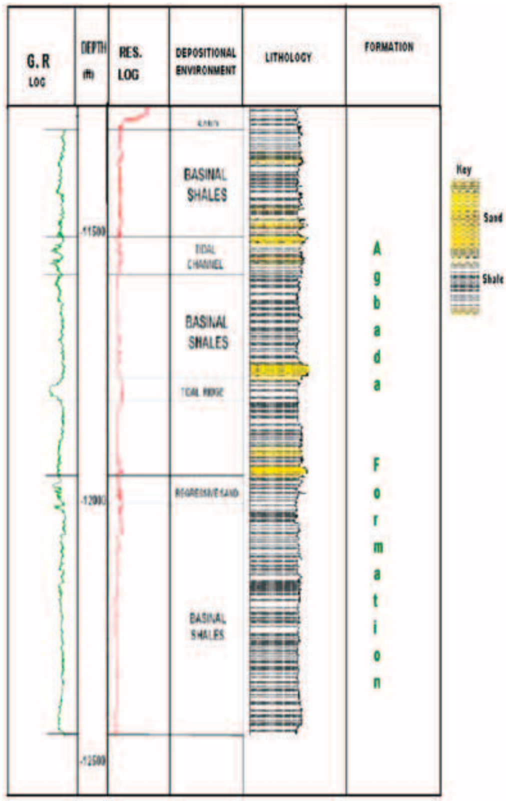

Figure 21e. Gamma ray and Resistivity Logs showing depositional environments from depth interval between 11500 ft (3484.84 m) to 12500 ft (3787.87 m) within well BLG1.

Ackowledgements

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Mineral Policy in the Era of Sustainable Development: historical context and future content

Rudarska politika v času trajnostnega razvoja: zgodovinski kontekst in vsebine prihodnosti

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Abstract: The goal of public policies is to connect desired ends with practical means toward their achievement. How the desired ends are determined, and whose goals and objectives they incorporate, depends upon the culture and political system of the country in question. With few exceptions, policies change over time to reflect changed perspectives and understanding of the world around us. This is true regardless of the policy area in question. Thus, how societies view and manage their mineral resources has evolved in response to public attitudes, societal needs, economic circumstances, cultural perspectives, political orientations, technological advancements, and geological knowledge.

In this paper we examine how the scope of concern has changed for mineral policy. We then review the overarching issues that have in recent years been considered essential components of mineral policies. We point out how neoclassical microeconomics has influenced recent policy design. We then use a market flow diagram to illustrate how policies can be focused at specific market issues. We next discuss mineral resources in the context of sustainable development. We identify issues that become relevant when the frame of reference is enlarged beyond ensuring supply and capturing economic rent. We show that policy based solely on neoclassical economics may not be able to effectively incorporate these issues.

Original scientific paper

Izvleček: Cilj politik je povezati želena stanja s praktičnimi uporabnimi sredstvi z namenom doseganja teh stanj. Kako so določena želena stanja, kakšni so cilji, kako so vključeni v politiko, je odvisno od političnega sistema in stanja v državi. Z manjšimi izjemami se politike spreminjajo glede na spremenjene cilje in poglede na svet. Slednje drži za vse vrste politik. Pogled družbe na mineralne surovine in način, kako z njimi ravna, se spreminjata glede na javnost, potrebe družbe, gospodarske okoliščine, značilnosti nacije, splošne politične usmeritve, stanje tehnološkega razvoja in poznavanje geoloških razmer.

Raziskali smo, kako se je menjalo področje prevladujočega interesa rudarske politike. Pregledali smo splošna vprašanja, ki so v preteklih letih tvorila temeljne elemente rudarskih politik, pri čemer smo posebej poudarili vpliv neoklasične mikroekonomije na oblikovanje sodobnih rudarskih politik. Na diagramu prikazujemo, kako se rudarske politike osredinjajo na specifična vprašanja trga. Poleg tega obravnavamo mineralne surovine v kontekstu načel trajnostnega razvoja, pri čemer identificiramo relevantna vprašanja, kot je okvir politike, širši od zagotavljanja oskrbe z mineralnimi surovinami in zajetja ekonomske rente. S tem dokazujemo, da rudarska politika, temelječa samo na neoklasični ekonomiki, ne vključuje vseh odprtih vprašanj.

Key words: mineral policy, sustainable development, neoclassical economics, ecological economics

Ključne besede: rudarska politika, trajnostni razvoj, neoklasična ekonomika, ekološka ekonomika

Introduction

The purpose of public policy is to direct or control actions by government bodies or the public so as to achieve desired ends or objectives. Policies can range from the very specific, i.e., a detailed course of action or program of activities, to the general, i.e., an overall plan embracing identified goals, or even to the conceptual, i.e., a general expression of societal purpose.

Which goals are pursued depends upon the values and interests of the people involved in policy creation. Originally, rulers made policies. However, power may devolve over time from absolute rulers to elites to (more or less) democratic governments to the public. And when a country moves along this continuum, the range of issues worthy of consideration in policy broadens to incorporate the needs and interests of the people rather than only those of the ruling classes.

The authors described this gradual evolution in a prior paper (Shields & Šolar, 2006). Recent history was divided into eras, each of which saw major changes in thinking about the nature of the relationship between the government, the economy, workers, the environment and society at large. This expansion of the scope of concern is closely linked to general societal development. The concept of a progression is demonstrated by the changing thinking about mineral supply over the past 100+ years (Figure 1) (Shields & Šolar, 2006):

- Pre-industrial era – concern about access to deposits;
- Industrial evolution – concern about capitalists, industry, and economic markets;
- Late industrial era – concern about workers;
- Post industrial era - concern about environment;
- End of the millennium – concern about social impacts and preferences; and
- Twenty first century – concern about intra- and intergenerational equity.

The focus of the first two eras was ensuring the availability of mineral resources. The third era dealt with the rights and protection of workers. The fourth era can be seen as an extension of the third in that it involves protection of the environment. The rise of environmental consciousness was contemporaneous with the rise of economic liberalism in the latter half of the 1900's. People began to understand more clearly that human societies exist within and are ultimately depen-

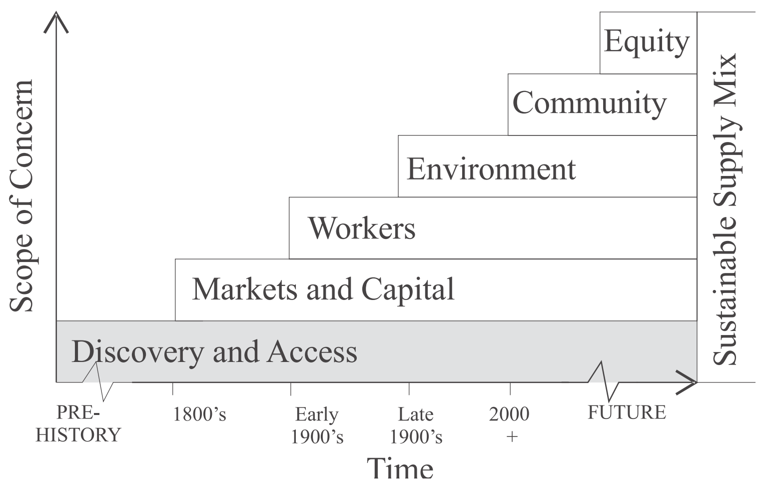

Figure 1. Expansion of Issues of Concern (Shields & Šolar, 2006)

dent upon the services provided by the earth's physical, chemical and biological systems, just as production is dependent upon labor. Inevitably, human actions change environmental systems. The current spatial extent of anthropogenic impacts, combined with their increasing intensity, has endangered and degraded the structure and functioning of some environmental systems.

During the latter part of the 20th century concern increased about social problems as well, for example widespread poverty, lack of access to fresh water, and the needs and rights of indigenous. The broader public became more aware of the fact that the environmental, economic, and social issues societies face display attributes of high uncertainty, urgency, complexity, and connectivity. The sustainable development (SD) paradigm was embraced as a potentially effective way to frame and analyze such problems. First, it is based on a comprehensive and inclusive, i.e., post-modern, view of systems as open, dynamic, and integrated. The interconnectedness of social, economic and environmental systems is explicitly recognized. Second, the overarching goals of sustainability, i.e., economic prosperity, environmental health and intra- and intergenerational equity are widely accepted. The importance of economic development is recognized, but is balanced with an understanding that natural systems must to be protected and the needs of current and future generations fulfilled (Shields et al., 2002; Elliott, 2005).

As will be discussed later in this paper, the principles of sustainability extend to mineral production and management. Thus, the right-hand column of Figure 1 places the original concern about access to mineral resources into a comprehensive sustainability context, a sustainable supply mix (SSM) as it were. Minerals can be supplied from different mines in different regions and countries, using different methods, each with their own set of social, environmental, and economic impacts and benefits. Products containing minerals can be reused and recycled, but again doing so has economic and environmental implications. Achieving a SSM necessitates that these tradeoffs be explicitly recognized and used in decision making. Each of these variables must be weighted so as to reflect societal objectives and the needs, preferences and values of multiple stakeholders. SSM is achieved by selecting that mix of sources that taken together maximize benefits and minimize costs of mineral supply for present and future generations, i.e., that are intra- and inter-generationally equitable. If there is to be a shift to a SSM, mineral policies will need to be reconsidered and in some cases revised or extended.

Mineral policy

The fact that new ideas are discussed, e.g. that concerns about the environment, communities, and future generations are being raised, does not automatically or immediately translate into new or changed policy. Rather, policies change gradually. The procedure by which desired ends are translated in laws, rules and regulations that direct or guide action is called the policy process. In its most simplified form, the cycle comprises 6 stages: 1) identification of objectives and interests, 2) definition of policy, 3) codification of policy in laws and acts, 4) establishment of a regulatory framework, 5) monitoring, and 6) review and adaptation (Šolar & Shields, 2000).

Classical policy models typically assume that policy is created in an orderly, sequential fashion. An issue is defined, alternative solutions are proposed, analyzed, tested, and refined, and eventually a solution is codified in law and then implemented by the government. We acknowledge that this is not a strictly accurate description of the world around us and that policy making is actually a complex and messy business. As Bismark famously noted, one should observe neither the making of sausage nor of legislation. But the cycle does illustrate the reason why there is a time lag between public discourse and revised public policy, which is that each stage of the process requires information, discussion and agreement. The lags are exacerbated in circumstances where the issues at hand are complex and multidisciplinary, and even more so where discourse is limited or suppressed, or where those in power do not see policy revision as in their interest.

Resource policy in general, and mineral policy specifically, is complex for reasons beyond the fact that the scope of concern has expanded over the past 100 years. It is complex because it concerns the allocation of scarce resources, the distribution and full extent for which can never be known with certainty. It necessitates the coordination of both governmental and market processes to be effective. And it is further complicated by the fact that each mineral commodity has its own economic, military, social, environmental, technical, and other considerations.

Nonetheless, there is broad consensus that national mineral policies should cover sovereignty, economics, legislative framework, and regulatory agencies (Otto, 1997). They should clearly define the range of acceptable mineral activity and types of minerals that can be exploited. The goal of policies should be to create an enabling economic environment that aligns the country's investments with its underlying comparative advantage, so as to improve the use of scarce capital and human resources.

This economic environment includes legal, institutional and fiscal reforms, in particular setting tax regimes that allow the nation to capture economic rent generated by mineral extraction. National minerals policies also need to provide the regulatory certainty necessary to foster investments in mineral development, including the allocation of rights to subsurface resources (CARPENTER, 2005). In addition, mineral policies should endeavor to ensure that mineral supply will be adequate to support the economy and the defense of the nation in question, now and in the future.

The Ascendance of Neoclassical Economics

The preceding view of the role of national mineral policies is informed by a neoclassical economic perspective. Four key propositions of neoclassical economic theory are (OTTO & CORDES, 2002):

- Rational pursuit of self-interest by individuals and firms in competitive markets leads to equilibrium outcomes that efficiently allocate scarce resources and maximize economic output.
- Economic growth is a natural and harmonious process made possible by operation of free and competitive markets.
- Pace of growth is greatly enhanced by unrestricted international trade and factor flows (labor, natural resources, and financial and physical capital) consistent with prevailing measures of comparative advantage.
- Governmental interference with market processes reduces or impedes growth and leads to increased social, political and economic unbalance;.

Implicitly, the role of government is to establish the social, political and legal conditions necessary for markets to operate effectively and efficiently, i.e., facilitating production of minerals with a minimization of waste. If a pure neoclassical perspective is taken, government's role does not extend beyond this charge. In economic theory, however, well-functioning, competitive markets have numerous characteristics, the following of which are particularly relevant for minerals:

- Many buyers and sellers, none of whom have capacity to affect market price;
- Neither buyers nor sellers are able to collude or form organizations that can affect market price;
- No positive or negative externalities; and
- Low cost entry and exit from the market.

Few if any markets, mineral or otherwise, can satisfy all these requirements, and individuals and firms do not have the ideal rationality of the economic agents populating neoclassical models. As a result, what could be termed 'purist' neoclassical economics has been expanded to incorporate the concept of market failure, which occurs when one or more of the aforementioned conditions (or those not listed) is not met. Under such real-world conditions, government's role can legitimately be expanded to include combating persistent unemployment, inflation, external account imbalances (Otto & Cordes, 2002), as well as other issues such as environmental oversight and encouraging efficient consumption. One effect of the recent economic crisis has been to highlight the potential for catastrophic disruption of poorly- or un-regulated markets, and a recognition of the need for policies that acknowledge the interconnectedness of socio-economic and bio-physical systems.

Mineral policy and economics in the 1950's, 1960's and 1970's did not reflect a neoclassical perspective. Rather they were marked by governmental interventions in areas such as administrative procedures, taxation, land and resource use restrictions, nationalization, joint ventures, state owned companies, etc. Some governments tried to maximize their incomes through higher taxes on mineral extraction, or by limiting the repatriation of profits earned by foreign mining firms (MMSD, 2002). These measures were in some cases followed by other even more restricting measures (export / import control, national staff employment, mandatory joint ventures with national companies, or even outright appropriation) (Otto & Cordes, 2002).

By the 1980's, it was clear that such policies were not leading to desired outcomes. Bureaucratic, inefficient, or corrupt governments, with unrealistic expectations and plans for commodity power, nationalization, or economic development agreements were seen by many as solely a burden to the mineral industry. They clearly disrupted market functioning and made it difficult for willing buyers and sellers to complete transactions efficiently. For these reasons there was a collapse of confidence in the beneficial effects of active governmental intervention and participation in mineral economic activities and economic liberalization became the prevailing policy in mining sector. Legal, institutional and fiscal reforms took place and in the reform time, neoclassical economic theory prevailed. The way forward was privatization of state companies for revenue and efficiency reasons, and the attraction of foreign investors. Legislation was changed, liberalized, and made more sensitive to investors and markets. During the 1990's over 100 countries restructured their mining legislation.

An Economic View of Market Flows

It is widely recognized that well-functioning, competitive, and efficient mineral markets are in the interests of both mineral producing and consuming nations. Market disruptions or market failures can lead to loss of profit for producers and shortages for consumers. Figure 2 illustrates potential reactions to a market disruption that has caused resource scarcity. We will first describe the flow through the market and then consider where within the flow policies might facilitate the efficient functioning of the market and correct market failures. We will also comment on the policy opportunities during periods when resource supply exceeds demand, leading to surpluses, as has recently been the case.

We begin with a market in equilibrium, which then faces a market, government, or production induced supply disruption. The latter, for example, could stem from a) natural settings (depletion), b) lack of proven reserves caused by insufficient exploration, c) environmental factors (natural disasters), or d) social factors (civil unrest). The inevitable consequence of scarcity in a market economy is increased price. Industry and producers, markets and consumers, and governments all respond to both the scarcity itself and the resultant price change. The most common industry and producer responses are: 1) lowering the cut-off grade, 2) increasing exploration, 3) reopening old and developing new mines that were previously sub-economic or infeasible, 4) diversifying sources of supply, and 5) enhancing delivery, transportation, and distribution systems. Market and consumer responses include: 1) substitution (in consumption or in manufacturing), 2) dematerialization (by increasing material efficiency or conservation), and 3) increasing usage of secondary materials by recycling, reusing, remanufacturing.

Industry and producer responses lead to upward pressure on supply, whereas market and consumer responses lead to downward pressure on demand, which will lead to another market equilibrium. The new equilibrium is in most cases not the same as the previous one, but rather fits the new circumstances that emerged after the market disruption.

From a pure neoclassical perspective, the market will re-stabilize without government intervention, albeit with dislocations and possibly severe consequences for firms, workers, and the economy as a whole.

An alternative view is that effective governmental policies can be used to enhance underlying supply- and demand-side pressures so as to more quickly re-establish an equilibrium and minimize dislocations, Governmental initiatives, incentives, and policies impact market equilibria directly or indirectly. In the case of scarcity, they

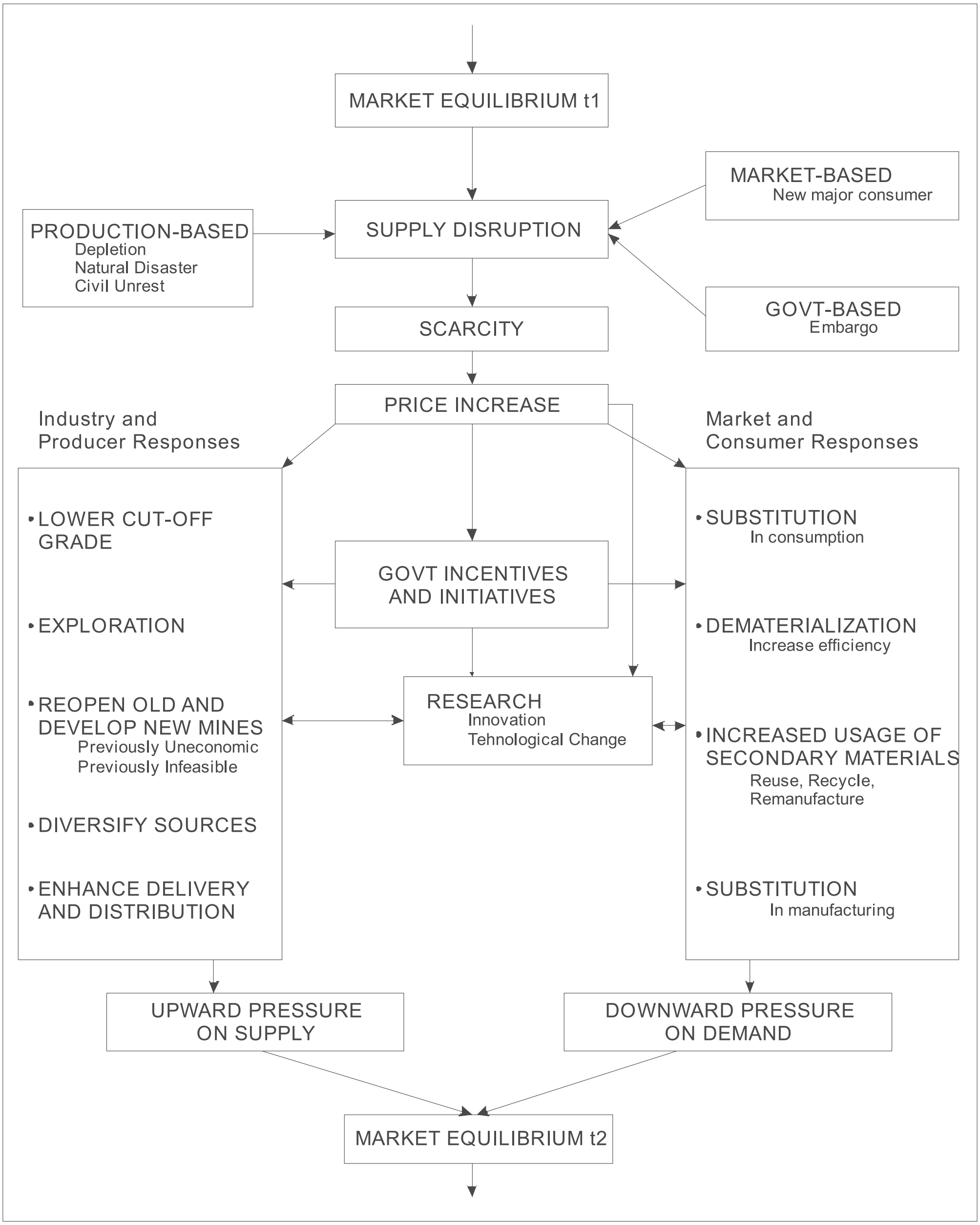

Figure 2. Mineral Market Flow

can be used to enhance the economic viability of the minerals sector through changes in taxation; increase secondary supply by promoting reuse, recycling and remanufacturing support research into substitution among resources; and to increase primary supply by encouraging exploration for and development of new deposits, facilitating trade, and funding studies of enhanced exploration and advanced extraction methods. On the demand side, government can affect consumption choices and levels through taxes or incentives, or the promotion of dematerialization.

In the case of surpluses, affected firms could be offered tax deferments, laid-off workers offered education grants or unemployment benefits, and consumers offered tax incentives to purchase resource intensive durable goods such as appliances or cars. Governments could also invest in infrastructure projects that require mineral resource inputs, which could place a floor under declining demand. For example, recent stabilization and increases in copper prices are seen by the authors as a response to national investment policies. While such policies reflect a more comprehensive neoclassical perspective, they do not in and of themselves reflect a sustainable development perspective. In the next section we discuss how sustainability principles apply to minerals and then address two core aspects of neoclassical economics that are problematic vis à vis sustainability.

Sustainability and minerals

It is inappropriate to speak of mineral resources as being sustainable in the same way as are ecosystems or biological resources. Furthermore, mining does negatively impact the environment, either temporarily or permanently. Together, these facts have led many people to express the simplistic view that mining is either inconsistent with sustainability (once extracted the resource is 'gone'), anathema (primarily a source of pollutants and environmental degradation), or of secondary importance (merely a source of virgin materials for which recycled materials or renewable resources can and should be substituted) (Cowell et al., 1999; Shields et al., 2006). But in reality, sustainable development involves managing resources in a way that is conducive to long term wealth creation and the maintenance of capital (natural, social, human, economic and physical). This perspective extends naturally to mineral resources, which are themselves a form of endowed, natural capital and are an important source of wealth creation. As a result, the discussion about minerals in sustainability now speaks of replacing depleted mineral capital with other forms of capital. The need for environmental protection, fair and just distribution of risks and benefits, and assurance that the contribution of a mine will be net positive over the life of the project, from exploration through post closure, are also considered to be core aspects of minerals sustainability.

Given the importance of neoclassical economic theories in mineral policy, it is essential to understand how those theories deal with sustainability. A traditional economic perspective leads policy makers to focus on efficiency and cost minimizing. More specifically, the neoclassical approach to sustainable development is to treat resources and other forms of capital as substitutes and to assume that technological innovation will ensure that the needs of future generations are provided for. In other words, natural resources are viewed in the same way as we would view any other capital resource – one in which the markets can operate to generate wealth and aid societal economic advancement. By extension, markets are seen as the most appropriate tool for dealing with what is in fact an ethical question: what kind of world do we want to live in and leave for future generations (Boulding, 1966).

Conversely, ecological economists see some natural capital resources as goods that are not easily monetized and which are valued beyond what the marketplace dictates (Williams & McNeill, 2005). According to this paradigm, natural and created capitals are complements, not substitutes (Costanza & Daly, 1992). Recent literature has identified the shortcomings of traditional neoclassical theories of resource economics, including monetary valuation, substitution of natural by economic capital, traditional cost-benefit analysis and normative policy theory (see Rammel & Van den Bergh, 2005, for one review of this literature). In the subsections below we address two economic concepts that distinguish the neoclassical approach to extractive resource exploitation from the ecological economic approach: intergenerational equity and capital substitutability.

Intergenerational Equity

While providing for the future is of concern to both the neoclassical economists and the ecological economists, neoclassical economists prefer an approach in which efficient markets in the present stimulate the economic growth necessary to bring about the technological progress and innovation required to enrich generations in the future. Policies are evaluated in terms of the present value (PV) of their benefits and costs, i.e., their dynamic efficiency. PV analysis starts from the idea that people would rather have money now than in the future, either because purchasing power is expected to be lower in the future due to inflation, or because present money could be invested to generate income for the future. The present and future values of a sum of money are made comparable by discounting to present levels the future value. The 'discount rate', or rate of time preference, reflects a person's (or firm's or a society's) preference for money now versus money in the future.

Benefits minus costs = Σ_i (net revenue) /$(1 + r)^i$
Where: i is the number of years into the future
r is the discount rate.

Any discount rate greater than zero places lower value (importance) on future costs and benefits than those accruing in the present time period. The longer the time horizon, the less value is placed on far future revenues and the less important environmental and social costs are deemed to be. Hence a larger discount rate indicates a preference for the present generation over future generations. Larger discount rates also infer shorter time horizons – the time for which economic benefits will be gained. A zero discount rate indicates a preference that future generations be treated the same as the present generation. As a generalization, neoclassical economists believe a discount rate above zero is appropriate because investments now will make future generations better off and thus better able to deal with future costs, as will technological advancements, which are funded with current revenue streams. Ecological economists believe that a higher discount rate produces an inequity between the generations and is therefore inherently unfair.

One of the challenges of mineral policy relate to the private versus social. The former reflects the preferences of the individual or the firm, while the latter necessarily takes a longer term societal view with the goal of bettering society over time. From a neoclassical perspective, the optimal mineral extraction rate is best determined by maximizing the net present value (the PV of revenues minus costs) of the deposit over the expected life of the mine. The discount rate used should reflect what the firm could have earned with their money in the next best alternative investment available to them (HOTELLING, 1931). Mineral policy should create a situation in which firms are able to optimize extraction based on the private rate of time preference, because doing so will benefit society by providing minerals and also creating wealth.

Although there will undoubtedly be fewer natural resources available to future generations (exhaustible resources will be depleted to some degree), there will also be better technology producing larger amounts of other capital (STIGLITZ, 1979; SOLOW, 1986; and HARTWICK, 1977). Utilizing this approach, a neoclassical economist would say that it is acceptable to exhaust a mine in order to benefit society today as long as the rents created from the mining are invested in the creation of new man-made capital that greater economic benefits than the mine itself produces (Harris, 2003).

The core difficulty with the approach is the reality of market failure. Firms do not incorporate intangible losses (costs) into their financial calculations. Environmental impacts are addressed as expenditures to follow regulations about emissions, to reduce water use and GHG (greenhouse gas) emissions, reclamation etc, but not loss of habitat or displacement of species. Community impacts are included as expenditures to local governments, provision of facilities such as medical clinics. But impacts that cannot be monetized cannot be addressed in a PV calculation. As a result ecological economists reject the neoclassical approach as biased toward business interests, and lacking in fairness to future generations because it uses a discount rate. (The topic of optimal extraction and discount rates for minerals continues to be debated; see for example Eisenhauer, 2005; Krautkramer, 2005.) This fundamental disagreement between neoclassical economists and ecological economists leads us to the issue of capital substitutability.

Capital Substitutability

In 1932, J. R. Hicks introduced substitutability into the resource economic discussion. His concept, along with the previously mentioned work, became the basis for the neoclassical approach to resource substitutability. Under this paradigm, as the price of a resource rises, the demand for the resource decreases, and substitutes (some man-made, some natural) become economically feasible. As such, non-renewable resources will never be completely exhausted; they will simply be replaced by other goods as the resource price becomes prohibitive. This neoclassical position on substitution is known as weak substitutability.

An implication of weak sustainability as expressed by neoclassical economics is that consumption need not be diminished even as the stocks of natural capital decline, as long as the profits generated from the resources are invested in technologies which further the growth of economies. In short, it is the total amount of capital available that matters, regardless of whether it is man-made capital or natural capital. In fact, some neoclassical economists have expressed the belief that natural capital (resources) may not be necessary at all. Such a thought was presented by Solow (1994), who argued that "If it is very easy to substitute factors for natural resources, there is in principle no 'problem.' The world can, in effect get along without natural resources, so exhaustion is just an event, not a catastrophe." Another, related view is that the fixed-stock paradigm of resources is fundamentally flawed and should be replaced by an opportunity-cost paradigm (TILTON & LAGOS). This perspective incorporates the view that technological change can ameliorate depletion, but goes further to suggest that the real issue is what societies are willing to pay to get minerals.

The alternative view is strong sustainability, which is much more restrictive with respect to the ability and feasibility of substituting man-made capital for natural capital. Under strong sustainability, certain types of capital are seen as complements rather than the replacements for each other, and as such the exhaustion of any resource presupposes limits on society in general. In the same manner as it is no longer the ability to catch fish that limits the ability to feed the populace, but rather the availability of fish that serves as the limit, the ability to produce more energy and mineral resources is not limited by the extraction technologies, but rather by the resources themselves (GORDON et al, 2007; WILLIAMS & MCNEILL, 2005; DALY, 1994). This position does not imply that nonrenewable resources should be left in the ground and not be developed, but rather that there needs to be adhered to a set of minimum conditions which leaves the future with necessary resources. COSTANZA & DALY (1992) suggest such minimum conditions for the development of both renewable and nonrenewable resources. For renewables, the suggested approach is to limit the consumption to sustainable yield levels, while non-renewable extraction profits (resource scarcity rent) should be invested in the development of renewable natural capital. It has also been suggested by other authors that in some circumstances or locations mining is not acceptable, even if profits can be reinvested, if other irreplaceable natural or social capital will be lost.

SUSTAINABILITY AND POLICY

The requirements for progress towards sustainability are (GIBSON et al., 2005): 1) socio-ecological integrity, 2) livelihood sufficiency and opportunity, 3) intra-generational equity, 4) inter-generational equity, 5) resource maintenance and efficiency, 6) socio-ecological civility and democratic governance, 7) precaution and adaptation, and 8) immediate and long term integration. All of these topics are relevant to the minerals sector, and each can be addressed through policy. However, in most countries current mineral policies, which for the most part are based in pure neoclassical economics and narrowly focused, either do not deal with these issues or address them partially or tangentially. An important characteristic of these policies is their stand-alone nature; they lack direct connection with or reference to other closely related policies such as those for environmental protection. .

Existing mineral policies reflect the issues and interests of the prior eras when they were put in place. The public policies of the 19th and 20th centuries embodied societal interest in settlement, industrial development, and economic expansion. Core policy issues related to the resource endowment, its size and longevity, its management, and the distribution of economic rent among workers, equity holders, the state and others (Tilton, 2000). Even in circumstances where sustainability is considered, proposed policy options tend to focus on topics such as intergenerational rent distribution and ensuring the appropriate economic climate for innovation (*ibid)* or setting aside 'reserved' mineral deposits for future development (Otto & Cordes, 2002).

The purpose of sustainability policy is to codify the principles and goals of sustainability in a manner consistent with the social structure and desires of the nation in question with the objective ensuring a sustainable future. One key goal would be social betterment, and another is intergeneration equity. In addition, sustainability-based policies need to respond to complex, interconnected, and broad scale issues. To ask whether a policy or economic alternative is 'sustainable' only makes sense within the context of the economy and environment (Woodward & Bishop, 1995).

With respect to minerals, sustainable policies need to: 1) facilitate the transformation of natural mineral capital into built physical, economic, environmental or social capital of equal or greater value; 2) ensure that environmental and social impacts of mining are minimized and their costs incorporated into production functions; and 3) require transparency and information sharing; 4) reconsider the allocation of rights and the availability of resources across generations; 5) address benefit/risk tradeoffs from the perspective of multiple stakeholders, and create contingency plans that will ameliorate the effects of mineral market booms and busts (Shields & Šolar, 2004). It is also essential that a sustainable mineral policy be correlated and consistent with other governmental policies (Shields et al., 2002). A sustainable mineral policy utilizes the strengths of neoclassical economics with respect to reaching a market equilibrium, but goes beyond that theoretical construct to incorporate the issues that are foundational to sustainability.

CONCLUSIONS

The foregoing discussion suggests that a pure neoclassical approach to sustainability has serious limitations. Assumptions about substitution are unrealistic and concern for future generations is truncated by positive interest rates. Further, unquestioning faith in the efficacy of markets and free trade present their own problems, as the recent recession has clearly demonstrated. Market failure is a recognized phenomenon; not all externalities are captured or priced. As a result, mineral prices do not reflect the full cost of commodity production. And trade, while potentially beneficial to a society as a whole, may actually harm certain groups within that society. This type of outcome is not consistent with sustainability principles. Finally, markets are essentially amoral, whereas sustainability is an ethical construct. Markets are not concerned with and cannot be depended upon to reach what societies consider fair or equitable resource allocations within or between generations.

Current mining policies address land ownership, access, taxation, trade and employment, etc., but not capital transformation, social impact reduction, or fairness. Other issues relevant to sustainability, such as environmental protection and worker safety, may be handled in separate legislation, but are seldom part of the policy set of mineral producing countries. The issues current mineral policies address are important and cannot be ignored; however, the scope of mineral policy will need to be broadened to incorporate such topics as the social costs of development and production, equity, and transparency. On the other hand governmental initiatives are beneficial to sustainability outcomes.

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The error estimation in the prediction of ultimate drift of RC columns for performance-based earthquake engineering

Ocena napake pri napovedovanju mejnega zamika AB-stebrov v potresnem inženirstvu

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Abstract: The error in the prediction of the ultimate drift of the reinforced concrete columns is determined by using the CAE method. The results based on the Kolmogorov-Smirnov test indicated that the error of the predicted ultimate drift in columns is mainly normally or log-normally distributed. For the other cases the typical characteristics of the columns were indicated. Their influence will be reduced with extension of the database. Based on the results of the study it was assumed that in the most cases the ultimate drift determined by the CAE method has the coefficient of variation about 0.4. The extensive parametric study performed for the reinforced concrete frame has shown that the influence of different uncertainties, including the uncertainty in prediction of the ultimate drift in columns, is not significant in the range of seismic intensities, which do not cause significant damage in the structure. On the other hand, the uncertainties becomes very important in the range close to the collapse of the structure, since the dispersion in the seismic response parameters is significantly increased and in some cases also the capacity of the structure is decreased if the uncertainties are considered in the analysis.

Izvleček: V okviru opisane študije smo poskušali ugotoviti tipično vrednost napake in njeno porazdelitev pri napovedi kapacitete armiranobetonskih stebrov s CAE-metodo. Pri uporabi testa Kolmogorov-Smirnov smo ugotovili, da se napake napovedi pretežno porazdeljujejo normalno in/ali log-normalno. Za druge primere, ko to ni tako, smo ugotovili, da imajo stebri tipične lastnosti, katerih vpliv se bo zmanjšal s povečevanjem baze podatkov. Glede na dobljene rezultate smo predpostavili, da lahko v veliki večini primerov s precejšnjo zanesljivostjo pri napovedi mejnega zamika s CAE-metodo pri predpostavki log-normalne porazdelitve upoštevamo koeficient variacije, ki je 0,4. Obširna neelastična parametrična študija štirietažne stavbe je pokazala, da lahko vpliv nezanesljivosti na odziv v nekaterih primerih zanemarimo. Po drugi strani pa je določitev kapacitete armiranobetonskih elementov s čim večjo zanesljivostjo zelo pomembna, saj lahko pri matematičnih modelih z visokimi vrednostmi nezanesljivosti pri določitvi začetnih togosti in mejnih rotacij stebrov in prečk opazimo povečanje raztrosa pri potresnem odzivu ter tudi zmanjšanje kapacitete konstrukcije.

Key words: CAE method, error distribution, drift, RC columns, performance-based earthquake engineering (PBEE)

Ključne besede: CAE-metoda, porazdelitev napake, zamik, AB-stebri, potresno inženirstvo

Introduction

The performance of structures in recent catastrophic earthquakes points to the need for improved seismic design approaches capable of achieving explicit determination of seismic risk. The methodology, which successfully treats this problem, is the widely used PEER Center methodology for PBEE (Deierlein, 2004). It is rigorous probabilistic and permits consistent characterization of the inherent uncertainties throughout the process. The seismic risk assessment problem is decomposed into the four basic elements of hazard analysis, structural analysis, damage analysis and loss estimation. Since the PBEE seeks also to improve quantification of deformation capacity of structural members, the research presented here deals with the prediction of the ultimate drift of reinforced concrete columns failed in flexure, which is expressed in terms of mean or median values and also in terms of dispersion measure, which enables quantification of an error in prediction of the ultimate drift. So far, semi-empirical and empirical approaches are used for determination of the deformation capacity of structural members more or less efficiently. The empirical formulas developed by Fardis and co-workers

(Panagiotakos & Fardis, 2001) have been implemented in Eurocode 8, Part 3 (CEN, 2005). A good overview of the deformation capacity of RC members is provided in FIB (2003). However, capacity of structural elements (i.e. columns and beams of the frame structures) may be predicted also by new approaches, i.e. by using the CAE (Conditional Average Estimator) method. This method, which is based on a special type of multi-dimensional non-parametric regression and represents a kind of probabilistic neural network, was developed by Grabec and Sachse in early nineties and was presented in (Grabec and Sachse, 1997). For successful application of the method, an appropriate database of experimental results is needed. Only recently a more comprehensive databases for RC members become available, such as the databases compiled at the University of Washington (PEER, 2008) and by Fardis and co-workers (Panagiotakos and Fardis, 2001, updated by Fardis and Biskinis, 2003). CAE method has been recently proposed as an alternative approach to the classical approaches in this field by prediction of the ultimate drift. Members of our research group have extended the CAE method and prepared the sound basis for its use in earthquake engineering (Peruš et al., 2006). Note that CAE can be successfully used also in other fields of engineering (Pirtovšek-Večko et al., 2007, 2008).

In this paper the CAE method is presented briefly and corresponding error estimation is addressed. Some examples on the error estimates of the ultimate drift of RC columns are shown and then general recommendations about the use of error estimates in PBEE are given. Practical example of real building demonstrates the proposed estimates.

CAE method for prediction of ultimate drift and error estimation

Detailed description of the CAE method from the engineering point of view is given in Peruš et al. (2006). The basic equations for determining the ultimate drift of RC columns are:

$$\hat{\delta} = \sum_{n=1}^{N} \delta_n \, A_n \tag{1}$$

where

$$A_n = \frac{a_n}{\sum_{i=1}^{N} a_i} \tag{2}$$

and

$$a_n = \frac{1}{\left(2\pi\right)^{D/2} w_n^D} \exp\left[-\sum_{l=1}^{D} \frac{\left(b_l - b_{nl}\right)^2}{2w_n^2} \right] \tag{3}$$

In above equations $\hat{\delta}$ is the estimate of the ultimate drift, δ_n is the same output variable corresponding to the n-th model vector in the database, N is the number of model vectors in the database, b_{nl} is the l-th input variable of the n-th model vector in the database, and b_l is the l-th input variable corresponding to the prediction vector. Note that the each model vector corresponds to the results of one experiment from the database. D is the number of input variables, and defines the dimension of the sample space. The Gaussian function is used for smooth interpolation between the points of the model vectors. In this context the width w_n is called the "smoothing" parameter that corresponds to n-th model vector from the database. In our case the same width w_n of the Gaussian function is used for all of the input variables. Therefore it is important that the input parameters in the equation for a_n are normalized, generally in the range from 0 to 1.

An intermediate result in the computational process is parameter $\hat{\rho}$, defined as

$$\hat{\rho} = \frac{1}{N}\sum_{n=1}^{N} a_n \tag{4}$$

It represents a measure of how the influence of all the model vectors in the database is spread over the sample space and it strongly depends on the smoothing parameter w. It helps to detect the possible less accurate predictions (indicated by small values of $\hat{\rho}$) due to the data distribution in the database and due to local extrapolation outside the data range.

When the expression for ultimate drift $\hat{\delta}$ is compared with the expression for the first order moment of the random variable X, which corresponds to the mean value m_x

$$E[X] = \sum_{i=1}^{N} x_i \; p_x(x_i) = m_x \tag{5}$$

similarity between the two expressions becomes evident. $p_x(x_i)$ is the probability of the random variable $X = x_i$ and corresponds to the weights A_n which depend on the similarity between the input variables of the prediction vector, and on the corresponding input variables pertinent to the model vectors stored in the database. Also, there is evident similarity when the central second order moment of the probability distribution of random variable X, called variance, given by the expression

$$\mu_x = Var[X] = \sum_{i=1}^{N} (x_i - m_x)^2 \; p_x(x_i) \tag{6}$$

is compared with the prediction of so-called "local standard deviation" in the CAE method:

$$\hat{E}_\sigma^2 = \sum_{n=1}^{N} \left(\delta_n - \hat{\delta}\right)^2 A_n \quad (7)$$

Such interpretation of the CAE equations allows us to estimate the corresponding probability distribution and the median value. Note, that the probability density function is composed of weights A_n for ascending order of the corresponding values δ_n.

The briefly presented CAE method was applied for the prediction of the ultimate drift of the RC columns. The experimental database used in this study is based mainly on the PEER database prepared by the University of Washington. The prediction of the ultimate drift is limited only to the columns which failed in flexure since the limited num-

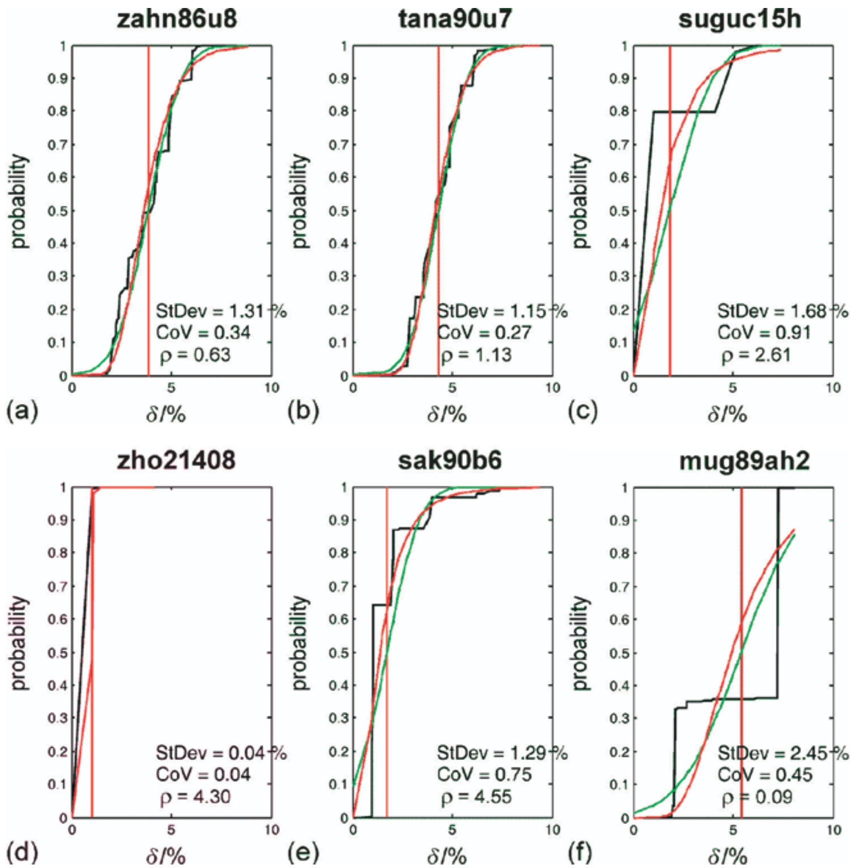

Figure 1. Examples of empirical cumulative probability distributions (black line) in predictions of ultimate drift for randomly chosen RC columns from the PEER database and reference normal (red line) and log-normal (green line) distributions. Vertical red line indicates mean value

ber of column specimens (so-called model vectors with components b_i) in the PEER database failed in shear and therefore the existing database is not yet appropriate for prediction of ultimate drift of columns failed in shear.

By knowing the empirical probability distribution of the sample (RC column), the application of Kolmogorov-Smirnov test (K-S test) can give us the information on the type of known probability distribution. The K–S test is a form of minimum distance estimation used as a nonparametric test of equality of one-dimensional probability distributions. Kolmogorov-Smirnov statistic quantifies a distance between the empirical distribution function of the sample and the cumulative distribution function of the reference distribution (i.e normal and log-normal in our study). Samples are standardised and compared with a standard normal and log-normal distribution, what is equivalent to setting the mean and variance of the reference distribution equal to the sample estimate.

Empirical cumulative probability distributions predicted by CAE method and reference normal and log-normal distributions are shown in Figure 1 for selected columns from the PEER database. The null hypothesis ($H0$) for each RC column from the PEER database was the assumption that the ultimate drift is distributed normally or log-normally with expected values of $\hat{\delta}$ respectively). The rejected level is at α = 0.01. It turns out that for about 52 % of RC columns from and $\hat{E}_{\sigma}^{2}$ (m_x and μ_x, the PEER database (156 specimens) the null hypothesis can not be rejected (i.e. columns in Figures 1a and 1b). On the other hand, the rest of RC columns for which the null hypothesis is rejected (predicted ultimate drift is NOT distributed normally or log-normally), typically belongs to similar columns with very different drifts (Figure 1c), to columns with large similarity with one column in the database (Figure 1d) or to columns with large similarity with two or more columns in the database (Figure 1e) or to columns with small values of $\hat{\rho}$ (Figure 1f). In all these cases relatively large weights A_n are attributed to them and consequently K-S statistics gets relatively high values which reject the null hypothesis. Note, that the existing PEER database is the largest and the most detailed database on RC columns for the time being. It is also known that sample RC columns are not distributed randomly and that the size of the database is still small for more reliable analysis. Authors believe that the extended database would solve this problem. Nevertheless, from the engineering point of view, the obtained results indicate that the distribution of ultimate drift, which is predicted by the CAE method, roughly corresponds to the normal or log-normal probability distribution.

The average "local coefficient of variation" (*CoV*), which is the ratio between the "local standard deviation" and predicted mean value, amounts from zero up to 0.9 in some very rare cases, with an average value of 0.35 and standard deviation of 0.16. Through error and trial procedures it was decided to use a value of 0.4 for *CoV* in case of assumed log-normal distribution. Furthermore, this value may be considered as a good approximation of *CoV* in PBEE, especially when it is compared to value of 0.6, obtained by Fardis & Biskins (2003). Note that use of average *CoV* for prediction of ultimate drifts of RC columns of a building represents a simplification, which can significantly reduce the number of time history analyses (simulations) needed for sufficiently accurate prediction of seismic response parameters, and it does not significantly affects the results, since similar types of columns are usually used in a building.

Application

The aim of the presented example is to demonstrate the influence of some uncertain input variables of the structural model, especially the ultimate drift (rotation) in columns, on the seismic response parameters. For that reason, the relationship between the seismic intensity measure (peak ground acceleration) and the seismic response parameters (maximum story dirft) was determined for a four storey reinforced concrete frame by using the extended incremental dynamic analysis (extended IDA) (Dolšek, 2009).

The four-storey reinforced concrete frame had been designed to reproduce the design practice in southern European countries about forty to fifty years ago and pseudo-dynamically tested in full scale at ELSA Laboratory (Figure 2) (Carvalho & Coelho, 2001). However, the frame can also be typical of buildings built more recently, but without the application of capacity design principles (especially the strong column - weak beam concept), and without up-to-date detailing. The elevation and typical reinforcement in the columns of the four storey frame are presented in Figure 3. The design base shear coefficient amounted to 0.08. In the design, concrete of quality C16/20 and smooth steel bars of class Fe B22k (according to Italian standards) were adopted (Carvalho & Coelho, 2001). Later the strength of material was measured since the pseudo-dynamic tests were performed for the structure. The mean strength of the concrete amounted to 16 MPa, that is less than adopted in the design (f_{cm} for C16/20 is 24 MPa), and the mean yield strength of the steel amounted to 343.4 MPa.

Beam and column flexural behaviour was modelled by one-component lumped plasticity elements, composed of an elastic beam and two inelastic rotational hinges (defined by the moment-rotation relationship). The element based on the assumption of an inflexion point at the midpoint of the element was employed in nonlinear static and dynamic analyses.

The schematic moment-rotation relationship of the inelastic rotational hinge is shown in Figure 4a. The yield (Y) and the maximum (M) moment in the columns were calculated taking into account the axial forces due to the vertical loading on the frame. The effective beam width of 75 cm and 125 cm were determined according to the Eurocode 2 (CEN, 2004) procedure for the short and long beams, respectively. The characteristic rotations, which describe the moment-rotation envelope of a plastic hinge, were determined according to the procedure described by Fajfar et al. (2006). The ultimate rotation Θ_u in

Figure 2. The four-storey reinforced concrete frame building which was tested at ELSA Laboratory

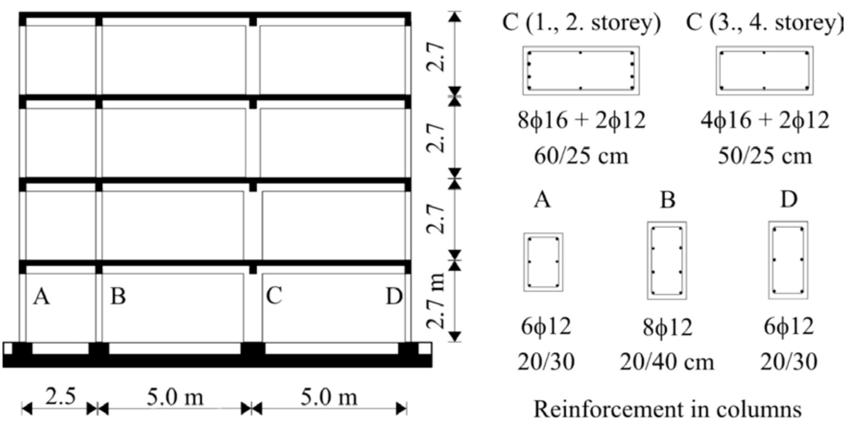

Figure 3. View and typical reinforcement of the columns of the reinforced concrete frame

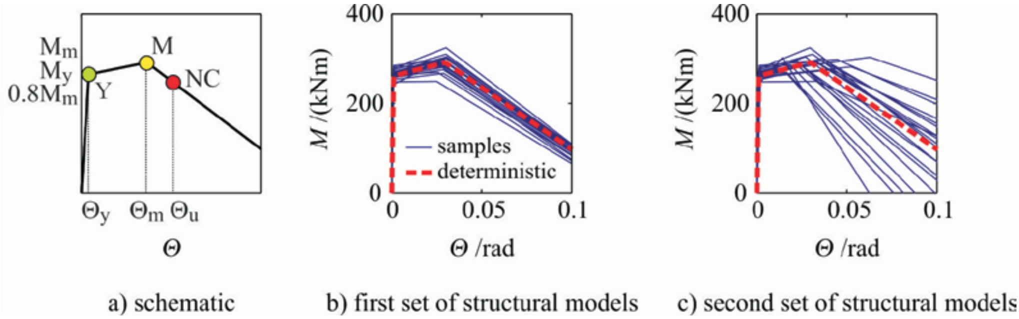

Figure 4. The moment-rotation relationship of column plastic hinge: a) schematic representation, b) column C at second storey for first set of structural models and c) column C at second storey for second set of structural models

the columns at the near collapse (NC) limit state (see Figure 4a), which corresponds to a 20 % reduction in the maximum moment, was estimated by means of the CAE method (Peruš et al., 2006). For the beams, the EC8-3 (CEN, 2005) formulas were used, the parameter γ_{el} being assumed to be equal to 1.0. Due to the absence of seismic detailing, the ultimate rotations were multiplied by a factor of 0.85 (CEN, 2005).

The extended IDA analysis was performed for two sets of structural models, which reflected different sources of uncertainty. Each set consisted of 20 structural models, which were determined based on the Latin Hypercube Sampling method employed in the extended IDA (Dolšek, 2009). In the first set of structural models the following sources of uncertainties were considered in the analysis: mass, strength of the concrete and that of the reinforcing steel, effective slab width and damping, whereas in the second set of structural models also the model for determining the initial stiffness and ultimate rotation in the plastic hinges of the beams and columns was adopted uncertain. All the input random variables considered for the determination of the set of structural models were assumed to be uncorrelated. The statistical characteristics of the input random variables are presented in Table 1.

The initial stiffness and ultimate rotation in the plastic hinges of the beams and columns was considered deterministic in the first set of structural models, while in the second set all input random variables were considered for determination of the set of structural models. In addition to two sets of structural models, which reflect epistemic uncertainties, the deterministic structural model was also used for determination of the relationship between the peak ground acceleration and the maximum storey drift. In order to demonstrate the difference between the structural models used in analysis, the moment-rotation relationship of plastic hinge in the column C at second storey is presented for the two set of structural models (Figure 4b and 4c) and compared to the moment-rotation relationship of deterministic model. It can be observed that the dispersion in the moment-rotation relationship is significantly increased in the case of the second set of structural models, since in this case the initial stiffness and ultimate rotation of beams and columns are considered as random variables which have high coefficient of variation.

Table 1. The statistical characteristic of the input random variables

Name		Mean or Median*	CoV	Distribution
Mass 1st storey	m_1	46 t	0.1	normal
Mass 2nd storey	m_2	46 t	0.1	normal
Mass 3rd storey	m_3	46 t	0.1	normal
Mass 4th storey	m_4	40 t	0.1	normal
Concrete strength	f_{cm}	16 MPa	0.2	normal
Steel strength	f_y	343.6 MPa	0.05	log-normal
Effective slab width	b_{eff}	75 cm or 125 cm	0.2	normal
Damping	ξ	2 %	0.4	normal
Initial stiffness of the columns	$\Theta_{y,c}$	1·computed	0.36	log-normal
Initial stiffness of the beams	$\Theta_{y,b}$	1·computed	0.36	log-normal
Ultimate rotation of the columns	$\Theta_{u,c}$	1·computed	0.4	log-normal
Ultimate rotation of the beams	$\Theta_{u,b}$	1·computed	0.6	log-normal

*mean is shown for normal distribution and median for log-normal distribution

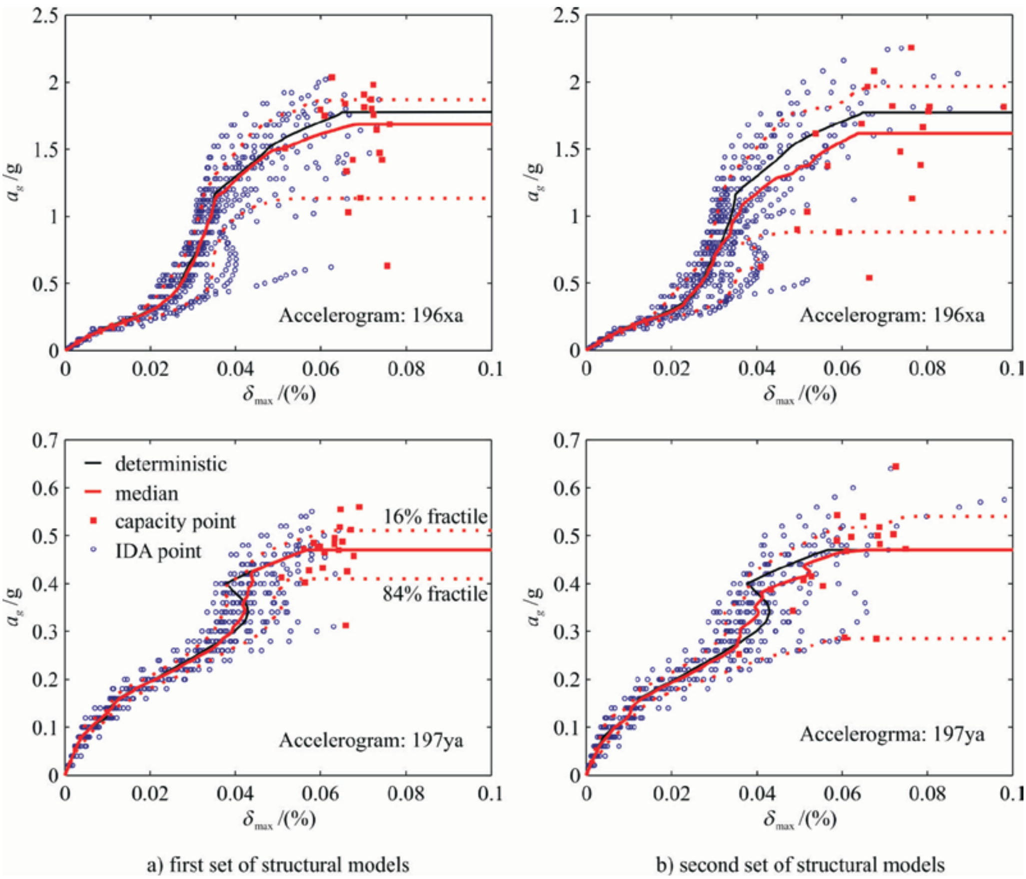

Figure 5. Maximum drift as a function of peak ground acceleration. Results are presented for two ground motion records and for a) first and b) second set of structural model

Two ground motion records were selected from the European strong motion database (Ambraseys, 2000) aiming to demonstrate the influence of the uncertainties on the seismic response parameters. Both ground motion records were recorded on stiff soil during the Montenegro earthquake in 1979. IDA analysis was performed for each ground motion record. The peak ground acceleration, corresponding to instability, was determined with tolerance of 0.005 g. Selected results of IDA analysis are presented in Figure 5. In addition to so called IDA and capacity points, which, respectively, represents the maximum storey drift of one nonlinear dynamic analysis for a given ground motion record and the peak ground acceleration, which corresponds to the global

Table 2. Peak ground acceleration capacity of deterministic model, median peak ground acceleration capacity and its dispersion for probabilistic model with and without the probabilistic ultimate rotation in columns (for two ground motion records)

Ground motion record	Deterministic model	Probabilistic model			
		First set of struct. models		Second set of struct. models	
	$a_{g,C}/g$	$a_{g,C}/g$	$\beta_{g,C}$	$a_{g,C}/g$	$\beta_{g,C}$
196x	1.775	1.715	0.197	1.637	0.403
197y	0.473	0.474	0.100	0.477	0.255

dynamic instability of the structure, the IDA curves of the deterministic model and the summarized IDA curves (median ± σ) of the first and second set of structural models are also presented.

The results in Figure 5 indicate that the influence of uncertainties on the seismic response parameters can be neglected if the peak ground acceleration is much less than the peak ground acceleration which causes the global dynamic instability of the structure. For this range of peak ground acceleration the summarized IDA curves based on the first and second set of structural models are practically the same in comparison to the IDA curve which is determined for the deterministic model. However, uncertainties can reduce the peak ground acceleration, which corresponds to global dynamic instability of the structure, what can be observed for the ground motion record 196xa. In this case the median capacity in terms of peak ground acceleration is reduced for about 3 % and 8 % if compared to that of the deterministic model. For the other ground motion record the capacity is practically the same for both sets of structural models and also for the deterministic model (Table 2).

In addition, the significant increase in the dispersion of the seismic response parameters can be observed for the second set of structural models since high uncertainties were used in determination of the initial stiffness and ultimate rotation of columns and beams. The dispersion in peak ground acceleration, which corresponds to global dynamic instability, is increased for about 100 % in the case of second set of structural model if compared to dispersion calculated from the first set of structural models, and it is also significantly dependent on selected ground motion records (Table 2).

Conclusions

The PBEE seeks to improve quantification of deformation capacity of structural members. Therefore, the research presented here deals with the prediction of ultimate drift with special consideration on dispersion measure. The CAE method was applied for this purpose to the RC columns which fails in flexure. It was found that empirical probability distribution of ultimate drift of RC columns roughly corresponds to normal and/or log-normal distribution. Moreover, an average value of 0.4 for CoV in the case of assumed log-normal distribution is proposed to be used in PBEE. It should be noted that the use of average *CoV* for prediction of ultimate drifts of RC columns of a building represents a simplification. Namely, it does not significantly affect the results, since similar types of columns are usually used in a building. However, uncertainty in prediction of ultimate drift with the CAE method is reduced if compared with procedure proposed by Fardis & Biskins (2003). The reduced uncertainty can significantly reduce the number of time history analyses (simulations) needed for sufficiently accurate prediction of seismic response parameters.

The influence of uncertainties on the seismic response parameters was demonstrated with an example of four storey RC frame building. The results indicate that the influence of uncertainties on the median value of seismic response parameters can be neglected if the peak ground acceleration is much less than the peak ground acceleration which causes the global dynamic instability of the structure. On the other hand, the increase in the dispersion of the seismic response parameters can be observed for the structural models with high uncertainties in determination of the initial stiffness and ultimate rotation of columns and beams. Therefore, it is important to determine the deformation capacity (i.e. ultimate drift) of RC structural members with predictive models which gives the lowest uncertainties and consequently more accurate prediction of seismic risk. Using the CAE method, as demonstrated in this study, represents a step toward this goal.

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Extra machinability modeling

Modeliranje povečane obdelovalnosti

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Abstract: The steels with extra machinability are made according to special technological process. It depends on several parameters, particularly on the steel chemical composition, whether the steel will meet the criterion of extra machinability. By special test it is established whether the steel has extra machinability or not. In our researches the prediction of machinability of steels, depending on input parameters, was performed by logistic regression and genetic programming. The research shows that genetic programming model performs better. The best model developed during the simulated evolution was practically verified.

Izvleček: Jekla s povečano obdelovalnostjo so izdelana s posebnim tehnološkim postopkom. Povečana obdelovalnost jekla je odvisna od mnogih parametrov, predvsem pa od kemične sestave. Obdelovalnost jekla se določa na podlagi posebnega preizkusa. V naši raziskavi smo za napovedovanje obdelovalnosti jekla uporabili logistično regresijo in genetsko programiranje. Rezultati kažejo, da se bolje obnese metoda genetskega programiranja. Rezultati modela so bili preizkušeni v praksi.

Key words: steel, extra machinability, modeling, logistic regression, genetic programming

Ključne besede: jeklo, povečana obdelovalnost, modeliranje, logistična regresija, genetsko programiranje

Original scientific paper

Introduction

In general, tool steels are divided into ordinary steels and steels with extra machinability. These two groups differ in the technology of steel manufacture, which influences the steel properties during machining processes (e. g. turning, milling). In case of steel with extra machinability it is possible to reach much higher resistance of cutting tools even with higher cutting speeds, therefore the price of such steels is 10 % higher on the average than the price of the ordinary steel.[1]

The steels with improved machinability retain all good qualities of ordinary steels their advantage being that they allow machining at 25–50 % higher cutting speeds, 4–6 times lower tool wear and 30 % reduction of machining cost.[1]

In case of steel with extra machinability the molten metal is treated with calcium, which improves their machining properties. Instead of aluminium oxides the steel with extra machinability contains calcium aluminates of 2–20 μm size which are of regular forms and uniformly scattered. In this steel the calcium aluminates have sulphide surface. The heat in the cutting zone softens the sulphide surface and ensures the cutting tool to have lubrication effect. As a result, the tool wear in lower and higher machining speeds are allowed.[1]

The test of the steel machinability is preformed according to the technological standard ISO 3685.[2] The test process is demanding and time-consuming. As long as the data on machinability are not known, the steel cannot be included in the further technological process. If the steel does not reach the degree of extra machinability it is considered to be ordinary steel. The steel machinability is influenced particularly by the chemical composition. As there are several chemical elements in the steel its machinability is hard anticipate and predict. In addition, also other technological parameters change, which additionally make the steel machinability prediction difficult.

In the paper prediction of steel machinability by logistic regression and genetic programming was used. The both methods were also compared. Prediction of machinability of steel helps to avoid time-consuming and expensive testing of steel machinability and to contribute to improvement of the material flow in the production process.

Test of tool resistance

Appropriateness of steel with extra machinability is verified by parameter v_{15}

which is prescribed for each grade of steel.

The parameter v_{15} is the speed of cutting of the tool which is worn out within 15 min. The tool wear is prescribed. The test of tool resistance is preformed on a CNC lathe.

That test is carried out for each batch. The batch is the quantity of steel cast as a whole in the steelworks. The mass of one batch is 52 000 kg. Each batch is identified by its identification number. The steel sample for finding out the machinability must have the diameter of at least 60 mm and the minimum length of 500 mm. After machining (turning) without cooling, within time t (approximately fifteen minutes) and with selected speeds, the wear of the cutting insert is measured under a microscope (Figure 1). The tip of the insert (V_{BB}) may be worn out for not more then 0.30 mm and the entire insert edge ($V_{BB\ max.}$) for not more than 0.60 mm. Afterwards, the parameter v_{15} is calculated by Taylor's equation:[3]

$$v \cdot t^n = C \tag{1}$$

where v is cutting speed, t is cutting time, n is constant depending on tool material (insert). Constant n for ceramic inserts is 0.25.

With cutting speed v = 330 m/min and time t = 22.6 min, within which tool wear takes place, v_{15} amounts to:

$$v \cdot t^n = v_{15} \cdot 15^n \tag{2}$$

$$v \cdot t^{0.25} = v_{15} \cdot 15^{0.25}$$

$$v_{15} = v \cdot \frac{t^{0.25}}{15^{0.25}}$$

$$v_{15} = 330 \cdot \frac{22.6^{0.25}}{15^{0.25}} = 365.6\ m/\min$$

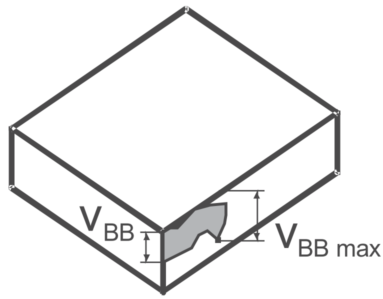

Figure 1. Side wear of the insert

Experimental background

The data were collected in the period of 13 months in the factory Štore Steel Ltd. from Slovenia. The most influencing parameters are the sample diameters and the chemical elements (calcium, oxygen and sulphur) necessary for production of steel with extra machinability. 146 batches were made. Out of them 125 were adequate. If the batch is adequate this means when parameter v_{15} in the individual batch exceeds the prescribed value v_{15} for that batch.

The prescribed value of parameter v_{15} depends on the grade of steel. Consequently, during that period the success of production of steels was 21/146 = 85.61 %. The number of each steel grade specimens and the average chemical composition and prescribed v_{15} for steel grade is presented in Table 1.

Table 1. The number of each steel grade specimens and average chemical composition and prescribed v_{15}

Steel grade	Number of specimens	w(Ca)/%	w(O)/%	w(S)/%	v_{15}/(m/min)
16MnCrS5	2	0.0305	0.034	0.0275	410
C45	139	0.0293	0.0462	0.0270	360
C50	2	0.0235	0.0145	0.021	360
C15	1	0.029	0.019	0.028	450
St70.2	2	0.03	0.0375	0.029	360

The experimental data and extra machinability suitability are presented in Table 2. If the batch of steel is adequate then it is marked with logical variable 1 and with 0, if it is not.

Table 2. The experimental data

#	Batch number	Steel grade	Sample diameter	w(Ca)/%	w(O)/%	w(S)/%	v_{15}	Prescribed v_{15}	Extra machin-ability
1	36968	C45	19.0	0.024	0.019	0.031	327	360	0
2	37101	16MnCrS5	60.0	0.026	0.044	0.027	453	410	1
3	37236	C50	70.0	0.026	0.005	0.022	308	360	0
4	37237	C50	70.0	0.021	0.024	0.02	346	360	0
…	…	…	…	…	…	…	…	…	…
143	37322	C45	70.0	0.027	0.018	0.025	261	250	1
144	37358	C45	70.0	0.033	0.042	0.028	452	450	1
145	37359	C45	70.0	0.029	0.044	0.022	459	450	1
146	37360	C45	68.0	0.033	0.046	0.025	438	410	1

Extra machinability modeling

Evaluation of models were determined by Bayesian analysis (true positive *TP*, true negative *TN*, false positive *FP*, false negative *FN*) applying sensitivity *SENS* = *TP*/(*TP*+*FN*), specificity *SPEC* = *TN*/(*FP*+*TN*), positive predictive value *PP V*= *TP*/(*TP*+*FP*) and negative predictive value *NPV* = *TN*/(*FN*+*TN*).

The higher are values of mentioned parameters the better model fits to experimental data.

The parameters in the mathematical models for extra machinability are denoted as:

- φ - sample diameter
- w(Ca)/% - mass fraction of calcium
- w(O)/% - mass fraction of oxygen
- w(S)/% - mass fraction of sulphur

Logistic regression modeling

The most important results of logistic regression are presented in Table 3.

According to the logistic regression results the logistic mathematical model for extra machinability is:

$$\lg\left(\frac{p}{1-p}\right) = 0.058\cdot\varphi + 123.607\cdot w(Ca) + 101.616\cdot w(O) + 326.759\cdot w(S) - 18.537 \quad (3)$$

where p is the probability of steel not being extra machinability steel. If the probability p was lower then 0.5, then the extra machinability was denoted as 1 otherwise as 0.

The logistic regression model sensibility is 0.976, specificity 0.524, positive predictive value 0.924, negative predictive value 0.786 and test efficiency 0.911.

Genetic programming modeling

Genetic programming is probably the most general evolutionary optimization method.[4–6] The organisms that undergo adaptation are in fact math-

Table 3. Logistic regression results

Parameter	B	S. E.	Wald	df	Sig.	Exp(B)
φ	0.058	0.032	3.278	1	0.070	1.060
w(Ca)/%	123.607	67.251	3.378	1	0.066	4.805
w(O)/%	101.616	27.171	13.986	1	0.000	1.353
w(S)/%	326.759	131.147	6.208	1	0.013	8.123
Constant	–18.537	5.089	13.268	1	0.000	0.000

ematical expressions (models) for extra machinability prediction consisting of the available function genes (i.e., basic arithmetical functions) and terminal genes (i.e., independent input parameters, and random floating-point constants). In our case the models consist of: function genes of addition (+), subtraction (-), multiplication (*) and division (/), terminal genes of sample diameter (φ) and chemical composition of steel (Ca, O and S).

Random computer programs of various forms and lengths are generated by means of selected genes at the beginning of simulated evolution. Afterwards, the varying of computer programs during several iterations, known as generations, by means of genetic operations is performed. After completion of varying of computer programs a new generation is obtained that is evaluated and compared with the experimental data, too.

The result values of models for extra machinability prediction above zero predicted that the steel is extra machinability steel (value 1), otherwise not (value 0).

The process of changing and evaluating of organisms is repeated until the termination criterion of the process is fulfilled. This was the prescribed maximum number of generations.

For the process of simulated evolutions the following evolutionary parameters were selected: size of population of organisms 500, the greatest number of generation 100, reproduction probability 0.4, crossover probability 0.6,

$$2w(O)-\frac{0.89395\cdot w(O)}{\frac{1.70735}{w(O)}+w(O)+\frac{2.32712}{w(S)}}+w(S)-\frac{0.89395\left(w(O)-\frac{0.89395w(O)}{\frac{-1.70735}{w(O)}+\frac{1.16356}{w(S)}}+w(S)\right)}{w(O)+\frac{w(O)(w(Ca)+\varphi+w(S))-\frac{0.48069\left(-\frac{1.70735}{w(O)}+w(O)+\frac{2.32712}{w(O)+w(S)}\right)}{-2.32712+w(O)}}{w(O)-w(S)}}-\frac{0.89395(w(O)+w(S))}{w(O)(w(Ca)+\varphi+3w(S))+\frac{2.32712}{-\varphi+w(O)-w(S)-\frac{2.32712}{-\varphi+w(O)-w(S)-\frac{1.11863\left(-\frac{1.70735}{w(O)}+w(O)+\frac{2.32712}{w(O)+w(S)}\right)}{w(O)(2.32712+w(S))}}}} \quad (4)$$

the greatest permissible depth in creation of population 6, the greatest permissible depth after the operation of crossover of two organisms 10 and the smallest permissible depth of organisms in generating new organisms 2. Genetic operations of reproduction and crossover were used. For selection of organisms the tournament method with tournament size 7 was used.

We have developed 100 independent civilizations of mathematical models for prediction of extra machinability. Only one out of 100 is presented in eq. 4 (page 343)

With sensibility of 1, specificity 0.810, positive predictive value 0.969, negative predictive value 1 and test efficiency 0.973.

Conclusions

Due to their specific properties if compared with ordinary steels, the steels with extra machinability will represent a growing share on the market. Their advantage over the remaining steels, in particular, is that they can be machined at higher machining speeds and that they assure smaller cutting tool wear.

In researches two approaches were used for predicting the steel machinability – logistic regression and genetic programming. Evaluation of models was determined by Bayesian analysis.

The logistic regression model was obtained with sensibility 0.976, specificity 0.524, positive predictive value 0.924, negative predictive value 0.786 and test efficiency 0.911.

The best genetic programming model (out of 100) performed better with sensibility of 1, specificity 0.810, positive predictive value 0.969, negative predictive value 1 and test efficiency 0.973. Out of 146 values the best model wrongly predicts 4 values; it means that its reliability is 97.26 %. In case of all 4 wrong predictions the model predicts that the steel has appropriate machinability, while in fact it does not have it.

Research has shown that by using the genetic programming method for prediction of appropriateness of the steel machinability it is possible to establish efficient planning and optimizing of production, to reduce the costs of researches and the handling changes and, finally, to increase satisfaction of the buyers due to shorter delivery times.

The future researches will be focused on testing the mathematical model and optimizing the chemical composition. The prognosis is optimistic.

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Environmental labelling of products with type I labels

Ekološko označevanje proizvodov z oznakami tipa I

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Abstract: Environmental labelling is the important issue in the actual global framework for more than 20 years. Thanks to the development of a national environmental labelling program of Republic of Serbia this issue is becoming very interesting in our country.

In this paper is given a review of national and regional environmental labelling programs, as well as a review of the development of the environmental (eco) labelling. Paper is based on the basic principles of SRPS ISO 14024:2003 standard, with representation of current situation in this area in the Republic of Serbia.

Izvleček: Ekološko označevanje je pomembna tema aktualnega globalnega povezovanja že več kot dvajset let. Po zaslugi razvoja lastnega nacionalnega programa ekološkega označevanja v Republiki Srbiji je ta tema postala izredno zanimiva tudi v naši državi.

V prispevku je podan prikaz nacionalnih in regionalnih programov ekološkega označevanja, kot tudi pregled prikaza razvoja ekološkega (eko) označevanja.

Prispevek temelji na osnovnih principih standarda SRPS ISO 14024:2003 s predstavitvijo aktualnega stanja na tem področju v Republiki Srbiji.

Key words: Environmental labelling, Eco label, Type I, ISO 14024

Ključne besede: ekološko označevanje, eko-oznaka, tip I, ISO 14024

Original scientific paper

INTRODUCTION

Environmental (eco) labelling is a voluntary method of environmental performance certification and labelling practiced around the world. As primary reasons for eco labels introduction, may be isolated next three: [1]

- promotion of development, manufacturing, advertising and using products that causes less influence on the environment,
- stimulation of manufacturing which has maximum savings of physical resources using materials liable to recycle, and
- to offer customers total and secure information about impact of a product/service on the environment.

As an answer on appearance, great number of labels and declarations within this area of life cycle considerations, ISO has identified three broad types of voluntary labels.[2, 3]

Type I - a voluntary, multiple-criteria based, third party program that awards a license that authorizes the use of environmental labels on products indicating overall environmental preferences ability of a product within a particular product category based on life cycle considerations.

Type II - informative environmental self-declaration claims.

Type III - voluntary programs that provide quantified environmental data of a product, under pre-set categories of parameters set by a qualified third party and based on life cycle assessment, and verified by that or another qualified third party.

Further in this paper detailed analysis of program for eco labelling fitting under the Type I is presented.

TYPE I ECO LABELLING

Standard ISO 14024 was declared in 1999, and it defines Type I eco labels. This international standard is referring to programs of environmental labelling that award eco label to those products which satisfied complex previously defined conditions. In that way label identifies products certified as suitable for the environment, and because of that, usually this type is so called „stamps of approval". Type I label is only given to those products that are in their category classified in range from 15–20 % ecologically the most acceptable. Label points out that product ecologically seen more acceptable than products of same category, and purpose is to stimulate buying products that are ecologically acceptable. Type I environmental labelling programs are voluntary. They can be led by public or private agencies and can be national, regional and international.[4]

The aim of Type I eco labelling program is contribution of reducing harmful factors on environment by using products for which is declared are more appropriate for environment. Type I eco labelling program overcomes six basic steps: [1, 6]

- consultations with interested parties,
- product category determination,
- creating, testing and exchanging criteria for environmental products,
- identifications of characteristics of product functions,
- development and implementation of suitable criteria, standards and guiding, and
- certification and licensing.

General characteristic of symbols that are used with this type of eco labels is that should associate on environment, in combination with symbols which are characteristic for some country/region. Thus, to show at the same time something that country/region is recognizable for (sometimes what is characteristic is bird, flower, leaf …) and to take care for environment (e.g. green or blue colour).[7]

Preview of the current Type I eco labelling program

In this chapter is given summary of all national environmental labelling programs, and short presentation of program for eco labelling of European Union, which is regional-international.[3]

National programs for Type I eco labelling

Programs for Type I environmental labelling start to grow previously on national levels, and country (its institutions) mostly was the main initiator and organizer of development and usage of this kind of program. According to this, regional eco labelling system, with easier way of orientation to customers in buying and choosing services, and because of market coverage begun to develop. [3, 8] Table 1 gives us a summary of appearing program of eco labelling.

Table 1. Chronology and summary of programs for Type I eco labelling

Label	Program	Country	Starting year
	Blue Angel	Germany	1977
	TCO Development	Sweden	1980
	Environmental Choice program	Canada	1988
	BRA MILJOVAL	Sweden	1988

	White Swan	Nordic Countries	1989
	Eco Mark	Japan	1989
	Green Seal	USA	1989
	Good Environmental Choice	Australia	1989
	Environmental Choice	New Zeland	1989
	NF Environnement	France	1991
	Milieukeur	Netherlands	1991
	Eco Mark	India	1991
	Eco Mark	South Korea	1992
	Green Mark Program	Taiwan	1992
	Green Label	Singapore	1992
	Medio Ambiente	Spain	1993
	El Distintiu	Catalonia	1993
	Umweltzeichen	Austria	1993
	Prijatelj okoliša	Croatia	1993
	Environmental Friendly Product	Czech Republic	1994

	Kornyezetbarat Termek	Hungary	1994
	Green Label Program	Israel	1994
	Green Label Thailand	Thailand	1994
	Water Lily	Lithuania	1996
	Ecologically suitable product	Slovakia	1998
	Ekologiczny	Poland	2000
	Green Label Eco Label	Hong Kong	2000
	Environment 2000	Zimbabwe	2000
	Vitality Leaf	Russia	2001
	The Program for Development of Ecological Marking in Ukraine	Ukraine	2002
	Green Choice Philippines	Philippines	2002
	Qualidade Ambiental	Brazil	2003
	Ecolabel Indonezia	Indonesia	2006
	Eko oznaka	Bosnia and Herzegovina	2009

Regional programs of Type I eco labelling

Ministry of council of Denmark, Finland, Iceland, Norway and Sweden, in November 1989 made a decision about adopting a common programme for ecological valuation and marking by the name “Nordic Swan Label”. Use of this programme is in jurisdiction of *„Nordic Eco-labelling Board“*. Program covers 69 groups of products. Label is valid for three years, after which revision of criteria is needed.[9]

Figure 1. Label of programme for ecological valuation and marking of Denmark, Finland, Iceland, Norway and Sweden „Nordic Swan Label”

Figure 2. Typical products with label “Nordic Swan Label”

European Union eco labelling program has come to an agreement by Ministry of environment in December 1991, defined by Council Regulation No. 880/92 in March 1992, and became legal in October 1992. Based on the Council Regulation No. 1980/2000 document, the procedure has been revised in September 2000. This was published in The Official Journal of EU on September 21st, 2000 and took the effect three days later.[10]

Figure 3. EU eco label

The groups of products are developed as a result of the suggestions given by all interested parties, among which are the following:[9]

- competent national bodies,
- ecological groups/movements,
- consumers associations, and
- trade unions and tradesmen.

European Commission is responsible for constituting and revising of the criteria for each group of products by giving mandate to a board made of competent bodies and consultation forum that involves all the relevant interested parties – non-governmental organizations like European Bureau for the Environmental Protection, trade and consumers associations.[11] Each EU member state has its competent body for administrating of the procedure on the national level. Competent bodies that have to be independent and neutral receive requests for obtaining of an eco label and decide whether the products are satisfactory comparing to a number of criteria.

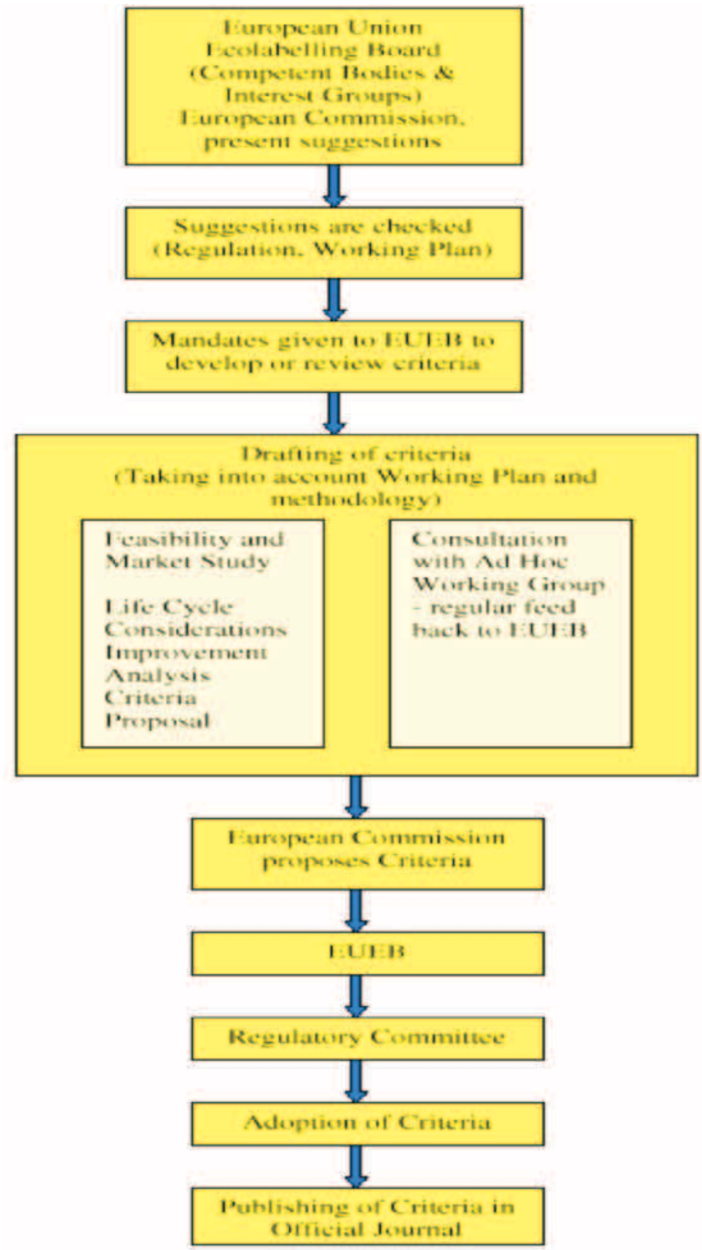

Figure 4. Criteria determination procedure scheme[11]

The manufacturers whose products fulfil their criteria should get registration package that contains clear, step by step directions for obtaining the EU eco label from competent body. Once the application is filled out, it needs to be handed over to the national competent body who, by attaching their argumentation and recommendation, submits it to the European Commission-European Union Eco labelling Board who brings decision by voting. The procedure for getting EU eco label is graphically presented in Figure 5.

The **"Global Eco labelling Network"-(GEN)** is a non-profit association, founded in 1994 to improve and develop the eco-labelling of products and services world-wide. The EU Eco label Scheme is a full member of GEN.[12] The mission of the GEN is to:[12]

- serve its members, other eco labelling programs, other stakeholders, and the public by improving, promoting and developing the eco labelling of products, the credibility of eco labelling programs worldwide, and the availability of information regarding eco labelling standards from around the world,
- faster co-operation, information exchange and harmonization among its members, associates, and other eco labelling programs with regard to eco labelling,
- facilitate access to information regarding eco labelling standards from around the world,
- participate in certain international organizations in order to promote eco-labelling generally, and
- encourage the demand for, and supply of, more environmentally responsible goods and services.

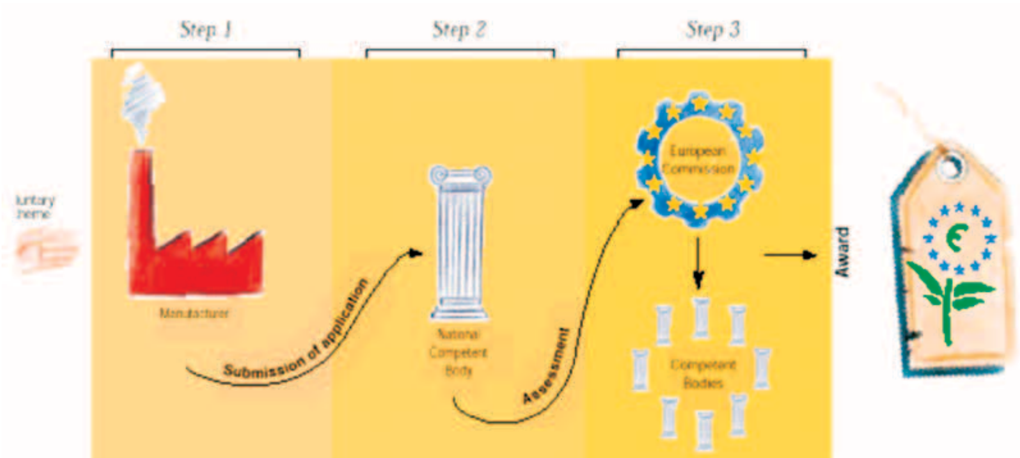

Figure 5. Procedure for getting EU eco label[11]

Figure 6. Logo of GEN[12]

Figure 7: Two versions of eco label of Republic of Serbia[14]

Eco labelling in Serbia

First efforts related to this topic in R. Serbia were done by bringing up the Environmental Law, of which paragraphs no. 53 and 54 determine, respectively award and subtraction of eco label. Label is determined for products intended for universal consumption, process and service, except food, drinks and pharmaceutical products, but licence for using provides Ministry of Environment. This label would be part of Award of Licence for Eco label Application Regulation.[13]

In march 2009 was presented and officially published "Rules on closer conditions and procedure for obtaining rights to the use of eco label, elements, layout and use of eco label for products, processes and services",[14] which met the prerequisites for the beginning of the implementation.

Conclusions

Presented view, which indicates that the countries with national Type I environmental programs, suggests that the current informal tools for the management of environmental protection - is growing. Also, in the paper, through the two regional eco labelling programs, especially for eco labelling of the European Union, clearly points out the advantages of these programs, especially in terms of market globalization.

It is noted in the review that some Member States of the European Union (United Kingdom, Italy, Slovenia, etc.) did not develop their own programs, but have decided for the implementation of the EU as their national. This fact is interesting from the aspect of Republic of Serbia, which established the National Eco labelling Program last year. Although it is, at first glance, in conflict with the approach of above mentioned countries, the fact that "Rules on closer conditions and procedure for obtaining rights to the use of eco label, elements, layout and use of eco label for products, processes and services" made with great respect to the criteria for categorization and evaluation of products from the EU, indicates that Republic of Serbia elected a similar approach. This will ensure not only compliance with the EU program in the future, but also quality and credibility of our program, in terms of easier access of domestic Serbian products to the EU market.

Acknowledgement

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Heat Treatment of Cold Formed Steel Forgings

Toplotna obdelava hladno preoblikovanih jeklenih odkovkov

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Abstract: For economical production of cold formed steel forgings for the automotive industry it is important that they have a long working life. Their corresponding mechanical and thermal properties are achieved by a heat treatment process.

In the Slovenian company ISKRA Avtoelektrika they manufacture, with the processes of cold forming, a great number of a different steel forgings for the Slovenian and European automotive industry. During their exploitation they are exposed to the high mechanical and temperature loads.

A practical example is presented an optimisation of the heat treatment procedure for typical steel forging (pinion) from the ISKRA Avtoelektrika production program.

The practical result of the used heat treatment are (the cold formed) steel pinions with the surface hardness of approximately $HRc = 65$, and the case hardened depth of the surface layer with the hardness higher than 551 $HV1$ approximately 0.7 mm.

On the basis of the results of corresponding economical studies, supported by technical investigations and analysis, second device (of the same producer, type and capacity) for the heat treatment was installed.

Izvleček: Za ekonomično proizvodnjo hladno preoblikovanih jeklenih odkovkov za avtomobilsko industrijo je pomembno, da imajo le-ti dolgo obratovalno dobo. Njihove visoke mehanske in toplotne lastnosti se dosežejo s postopki toplotne obdelave.

V podjetju ISKRA Avtoelektrika, d. d., izdelujejo s hladnim preoblikovanjem veliko število različnih jeklenih odkovkov za slovensko in evropsko avtomobilsko industrijo. Odkovki so med svojo eksploatacijo izpostavljeni velikim mehanskim in toplotnim obremenitvam.

Kot primer je predstavljena optimizacija procesa toplotne obdelave tipičnega jeklenega odkovka (pastorka) iz proizvodnega programa ISKRE Avtoelektrike.

Praktičen rezultat izvedene toplotne obdelave so (v hladnem preoblikovani) jekleni pastorki s trdoto površine približno *HRc* = 65 in površinsko utrjeno plastjo s trdoto *HV*1 višjo od 551 do globine 0,7 mm.

Na podlagi rezultatov izdelanih ekonomskih študij, podprtih s tehničnimi raziskavami in analizami, so v podjetju instalirali drugo napravo za toplotno obdelavo istega proizvajalca, tipa in enake kapacitete.

Key words: Heat Treatment, Steel Forgings, Pinion, Temperature Measurements, Automotive Industry

Ključne besede: toplotna obdelava, jekleni odkovki, pastorek, meritve temperatur, avtomobilska industrija

INTRODUCTION

In the Slovenian company ISKRA Avtoelektrika they manufacture, with the processes of cold forming, a great number of a different steel forgings (Figure 1) for Slovenian and European automotive industry. The cold formed steel forgings[1] are, during their exploitation, exposed to the both: high mechanical and temperature loads.[2–4]

In the frame of this investigation work, the efficiency and quality of the heat treatment (case hardening)[5–10] of the one of the most typical cold formed steel forgings from ISKRA Avtoelektrika production program – pinion no. 16.920.633 has been analysed. The material of the pinion is 16MnCr5 grade steel (Table 1), produced in Slovenian steelwork Metal Ravne, with well known mechanical and thermal properties.[11]

Table 1. Chemical composition of 16MnCr grade steel in mass fraction, *w*/%

	w/%									
	Element	C	Si	Mn	Cr	Cu	Al	Ni	P	S
Standard [11]		0.14–0.19	<0.40	1.00–1.30	0.80–1.10				<0.035	<0.035
Testing	Analysis 1	0.162	0.241	1.192	1.014	0.049	0.033	0.147	0.013	0.026
Charge	Analysis 2	0.164	0.247	1.167	1.028	0.044	0.035	0.146	0.014	0.027

Figure 1. Cold formed steel forgings from ISKRA Avtoelektrika production program. Testing forging – pinion no. 16.920.633 (below, the second from the left).

Figure 2. Device for heat treatment in ISKRA Avtoelektrika.

A device for heat treatment installed in ISKRA Avtoelektrika (Figure 2) is produced by the company CODERE from Switzerland. It consists of four main parts[12]:

- gas furnace (with pure and high controlled atmosphere),
- primary temperature measuring system (measuring the atmosphere temperature in the furnace),
- manipulating system, and
- hardening vessel (with mineral oil).

Experimental Work

For the purpose of temperature measurements[13] of the testing charge a secondary temperature measuring system (Figure 2) consisting from three basic elements[14] has been designed:

- even coated Ni-NiCr thermocouples,
- data acquisition module ADAM – 4018, and
- personal computer (with Microsoft Excel program) which recorded the results of the measurements.

Figure 3. Positions of the samples in the testing charge.

In the frame of our investigation work five testing forgings were bored. Ends (tips) of thermocouples were inserted therein and fixed with wire. Then, in the filling of the basket with the forgings, the five testing forgings were put on precisely defined, pre-selected places in the basket (A, B, C, D and E). Their positions are shown in Figure 3.

The basket holding the forgings has the form of a cylinder, of dimensions: diameter 780 mm and length 680 mm. The basket can hold approximately 700 forgings, which results in the whole charge mass of some 220 kg, and together with basket approximately 325 kg.

The heat treatment in the case given is case hardening which consists of carburizing and hardening. The prescribed time schedule of the heat treatment process is divided in three phases:

- heating,
- superheating, and
- cooling down (hardening) phase.

The first phase is an even heating of the charge up to the temperature 920 °C (the prescribed time of heating ranges from 2 h to 3 h). The time set for superheating of the charge in the furnace at 920 °C is 3.5 h to 5 h. The cooling down phase (hardening) of the whole charge follows in the mineral oil (OLMAKAL Rapid 90) with the initial temperature 80 °C approximately 10 min.

For the recording of the temperature measurements results a 3 s time interval was selected. The ambient temperature cca 1.5 m from the furnace was measured in the same time intervals on the sixth measuring channel. Complete results of the temperature measurements performed in the heat treatment of the testing charge of the cold formed steel pinions, and detail of the cooling down phase are shown in Figure 4.

The efficiency and quality of the heat treatment was analysed with the use of:

- chemical analysis (Table 1),
- hardness measurements,
- measurements of carbon and sulphur content in the case hardened surface layer, and
- metallographic examination methods.

Surface hardness of the testing samples was measured with the Rockwell (*HRc*) method. All measured values were higher than *HRc* 62 (between *HRc* 62.5 and 67.1).

In the Table 2 are presented the results of the hardness measurements (*HV*1) through the case hardened surface layer (average values of 10 measurements), and in the Table 3 a carbon and in the Table 4 sulphur content in the case hardened surface layer at different distances from the surface (0.1 mm to 1.0 mm).

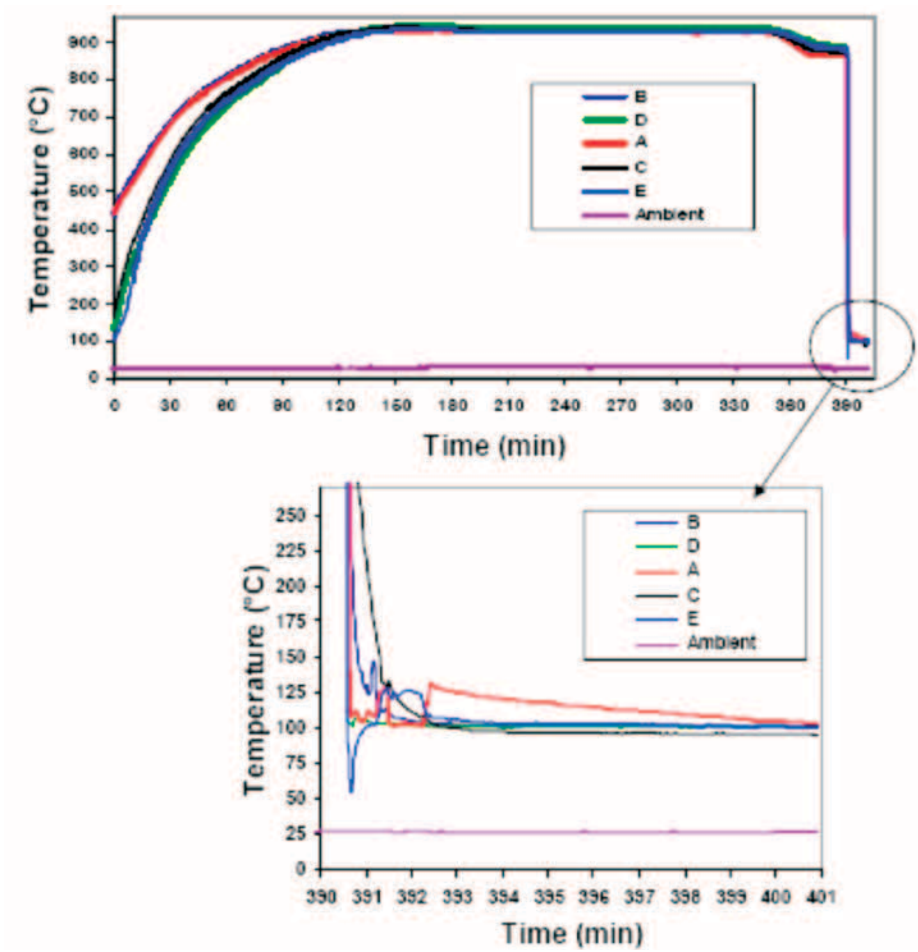

Figure 4. Temperature measurements – testing charge.

Table 2. Hardness through the case hardened surface layer.

Sample	Hardness (*HV*1)									
	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm	0.6 mm	0.7 mm	0.8 mm	0.9 mm	1.0 mm
A	854	839	838	800	751	684	615	564	524	491
B	846	847	840	824	749	698	630	578	531	498
C	843	805	784	744	658	647	585	548	523	503
D	824	778	740	696	656	602	565	528	509	497
E	861	860	854	827	786	734	669	613	573	534

Table 3. Carbon content in the case hardened surface layer of the samples A, C and E.

Sample	*w*/%									
	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm	0.6 mm	0.7 mm	0.8 mm	0.9 mm	1.0 mm
A	0.891	0.771	0.745	0.787	0.776	0.744	0.728	0.743	0.724	0.710
C	0.742	0.689	0.658	0.653	0.631	0.569	0.507	0.503	0.448	0.395
E	0.814	0.696	0.683	0.673	0.678	0.599	0.620	0.618	0.630	0.613

Table 4. Sulphur content in the case hardened surface layer of the samples A, C and E.

Sample	*w*/%									
	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm	0.6 mm	0.7 mm	0.8 mm	0.9 mm	1.0 mm
A	0.072	0.032	0.031	0.032	0.030	0.031	0.031	0.030	0.029	0.026
C	0.052	0.035	0.033	0.028	0.028	0.028	0.028	0.029	0.028	0.028
E	0.057	0.029	0.029	0.028	0.027	0.022	0.021	0.028	0.028	0.027

In the frame of our experimental work also non-destructive metallographic examination by optical microscopy (OM) and scanning electron microscopy (SEM) was applied. In the Figure 5 is the microstructure (martensitic) of the surface layer of the tooth, and the crack through the surface layer at the tooth of the sample D. The crack length is approximately 650 μm.

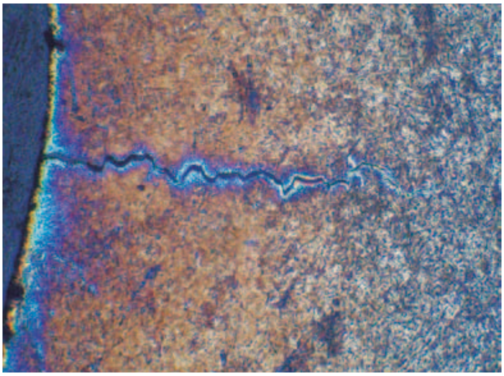

Figure 5. Sample D – tooth. Surface layer, crack through the surface layer; magn. 500-times; OM.

Figure 6. System for heat treatment after installation of the second device.

Conclusions

A gas furnaces and devices play important role in the heat treatments of various metal parts for the automotive industry. Their thermo technical characteristics have a great influence on the both: product quality and costs.

In our case the efficiency and quality of the heat treatment procedure were analysed with the use of: chemical analysis, micro hardness measurements, measurements of the carbon and sulphur content in the surface layer, and metallographic examination methods.

The practical result of the before described heat treatment are cold formed steel pinions with the surface hardness of approximately *HRc* 65, and the case hardened depth of the surface layer (with hardness higher then *HV*1 551) approximately 0.7 mm.

On the basis of the results of economical studies, supported by engineering work, the installation of the second device (Figure 6) - of the same producer, type and capacity - for the heat treatment was done.

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Optimiranje delovanja glavnih ventilatorjev v času mirovanja jame

Optimisation of mine ventilators operation in conditions of stagnation the pit

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Izvleček: Optimiranje zračenja je postopek, ki obsega predvsem analizo opravljenih meritev v primerjavi z doslej izvedenimi. Pomembno je poznati vse delovne parametre delovanja ventilatorjev in izdatnost plinov v kritičnem območju – v odkopnem polju jame. Nujna je izvedba simulacije zračenja z zmanjševanjem delovanja ventilatorjev do take mere, da začne koncentracija ekshaliranih plinov v odkopnem polju jame naraščati. Ob tem določimo optimalni način razredčenja nevarnih plinov pred začetkom delovnega procesa odkopavanja premoga.

Glavna naloga optimizacije je, da ugotovimo najugodnejši način zmanjševanja delovanja glavnih ventilatorjev v Pesju in v Šoštanju. S tem bi se v dela prostih dneh zmanjšala poraba električne energije za zračenje, hkrati pa bi bilo zagotovljeno ustrezno prezračevanje jamskih prostorov in razplinitev pred zagonom proizvodnje.

Abstract: Optimal ventilation is a procedure which includes the analysis of mesurements done in comparison with the known ones. It is important to know all ventilator operational parameters measured in the most critical sectors in the mine, with stationary as well as manual meters. It is necessary to simulate the ventilator reduced operation up to the point when the concentration of mine gases starts to

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increase, and then determine the optimal way of degassing for safety working process.
The main task of the optimalization is to determine the best way of reduced ventilator operation in the Pesje and Šoštanj Pits in order to reduce electricity consumption during the days off and then higher ventilation load to degas the face before the work on it begins.

Ključne besede: rudarstvo, jamsko pridobivanje, zračenje, optimiranje
Key words: mining, underground lignite exploitation, ventilation, optimisation

UVOD

Prezračevanje v jamah velenjskega premogovnika obratuje nenehno in s stalnimi kapacitetami. Zračilni sistem poganjata dva ventilatorja, in sicer ventilator v Šoštanju s 15 000 m^3 zraka v minuti in ventilator v Pesju z 8 000 m^3 zraka v minuti. Zračenje, vezano na ventilator v zračilni postaji Pesje, deluje po sistemu diagonalnega zračenja, zračenje dela jame, ki je vezan na ventilator v Šoštanju, pa deluje v enem delu po sistemu diagonalnega, v drugem pa po sistemu centralnega zračenja. Zaradi potrebe po razplinjenju odprtega dela premogovnega sloja, to je zaradi zmanjševanja koncentracije nevarnih plinov, deluje sistem tudi v dela prostih dneh, kar povzroča veliko porabo energije. Ob delovnih dnevih se jama prav tako zrači s polno kapaciteto, saj so ekshalacije nevarnih plinov zelo velike zaradi velikega napredka odkopov, posebej v zadnjem času zaradi tako imenovane »turbo«-proizvodnje. To je pridobivanje premoga iz odkopov s povečano odkopno dolžino, ki lahko dosega tudi več kot 200 m, z velikim napredkom in zelo visoko dnevno proizvodnjo.

Premogovnik Velenje v teku delovnega leta večkrat prekine svoje obratovanje za več dni, predvsem iz ekonomskih razlogov. V tem času se zmanjšajo vse aktivnosti na minimum, torej tudi delovanje ventilatorjev. Ker v času mirovanja jame in zmanjšane stopnje prezračevanja vseeno naraščata koncentraciji metana (CH_4) in ogljikovega dioksida (CO_2), je treba z optimiranjem delovanja glavnih ventilatorjev zagotoviti varno mirovanje jamskih prostorov in varen ponovni zagon proizvodnje v okviru dovoljenih koncentracij jamskih plinov.

Tehnično se v jamah Premogovnika Velenje zmanjšanje delovanja glavnih ventilatorjev izvede s spreminjanjem naklona lopatic ventilatorjev. Po podatkih je možen premik lopatic ventilatorja, ki obratuje v zračilni postaji Pesje v območju od –20° do +2° naklona. Ventilator v zračilni postaji Šoštanj lahko reguliramo v območju od –8° do +10° naklona lopatic, ne da bi se pri tem obratovalna točka ventilatorja kritično spremenila. Tako se zmanjša depresija, ki jo ustvarja ventilator, in s tem pretok zraka skozi jamske prostore ter posledično poraba pogonske (električne) energije.

Namen optimiranja

Osnovna ideja optimiranja je določiti krivuljo zračenja, s katero bo mogoče organizirati pravočasno (z minimalno časovno zamudo) vklapljanje in izklapljanje glavnih jamskih ventilatorjev s spreminjanjem naklona njihovih lopatic in s tem kapacitete zračenja tako, da bo zračenje energijsko ekonomično in še vedno dovolj varno. Ta zahteva se nanaša predvsem na razredčenje izhajajočih plinov (CO_2 in CH_4) iz premogovega sloja. Glavni namen optimiranja ni ugotavljanje porabe energije ventilatorjev, temveč ugotavljanje učinka zračenja ob doslej uveljavljenem postopku zmanjševanja dotoka zraka v jamske prostore ob dela prostih dneh. Poudarek je na določitvi najzgodnejšega ali najpoznejšega termina zmanjšanja oz. povečanja kapacitete ventilatorja glede na izkazane plinske razmere v zračilnem območju, ne da bi se s tem poslabšale varnostne razmere. Takšna optimizacija lahko omogoči velik prihranek pogonske energije ventilatorjev, ki so sicer zelo velik energijski porabnik.

Glavna usmeritev optimiranja je v zmanjšanju dobavljanja količine zraka v jamski sistem, predvsem ob dela prostih dneh, in s tem tudi ustvarjanja prihranka pri porabi pogonske energije. Ob tem se z meritvami določijo kritična mesta zračenja, največje in najmanjše potrebne količine zraka glede na ekshalacijo plinov, predpisano hitrost in količino zraka. Izvede se simulacija zračenja pri nižji stopnji obratovanja ventilatorja z upoštevanjem vseh potrebnih varnostih parametrov in določi krivulja zračenja za krajše obdobje neobratovanja jame (vikend) in za daljše obdobje (kolektivni dopust, daljši prazniki). Preveri se tudi poraba električne energije in posebej jalova energija ter njena možna izraba.

Postopek optimiranja in meritve

Za izvedbo optimiranja izberemo postopek konkretnih meritev med ustavljanjem obratovanja, mirovanja in ponovnega povečanega zagona ventilatorjev pri zračenju jame po krajši in daljši prekinitvi. Za izvedbo optimiranja ventilatorja, to je prilagajanja novim razmeram, je treba izvesti naslednje meritve:

- meritve glavnih zračilnih parametrov (depresija, pretok, hitrost, količina zraka);
- meritve plinov in hitrost naraščanja zaplinjenja;
- merjenje padca barometrskega tlaka (Δp) in ugotavljanje njegovega vpliva;
- merjenje pretoka (q) in merjenje depresije (h);
- padec tlaka na etažah;
- padec tlaka na etažah pri spremembi naklona lopatic ventilatorja za $\alpha = 1^\circ$ vsak dan;
- merjenje obratovalne točke ventilatorja in določitev krivulje zračenja.

Navedeni parametri so bistvenega pomena za prilagajanje delovanja ventilatorjev.

Operativni del raziskovalne skupine je v jami izvedel meritve v predvidenem času – letni kolektivni dopust in zimski kolektivni dopust ter ob vikendih. Za izvedbo meritev so bili uporabljeni obstoječi stacionarni merilniki, anemometer in aneroidni barometer.

Izvedene so bile štiri meritve, dve ob vikendih in dve ob kolektivnem dopustu avgusta in decembra, in sicer v južnem krilu jame Preloge in v jami Pesje ter dodatno še na lokaciji odkopa v severnem krilu jame Preloge.

Podatki o ventilatorjih

Jama velenjskega premogovnika se zrači z dvema glavnima ventilatorjema. Prvi, tipa Turmag GVhv 34–1800, z nazivno močjo 1800 kW deluje v zračilni postaji Šoštanj in je bil vgrajen leta 1980. Ob njem je enak rezervni ventilator. Drugi ventilator tipa TLT-GAF 34-13, 3-1 z nazivno močjo 800 kW deluje v zračilni postaji Pesje in je letnik 1996. Rezervni ventilator je tipa Turmag GLH-28-660 z močjo 600 kW. Sistem zračenja je naravnan tako, da njuno delovanje medsebojno nima vpliva. Ločena sta v vstopnem zračilnem območju s kratkim stikom.

Območje izvedenih meritev torej napajata dva ventilatorja, in sicer eden za jamo Preloge - sever in jug, iz zračilne postaje Šoštanj in eden za jamo Pesje iz zračilne postaje Pesje.

V zračilni postaji Šoštanj obratuje glavni jamski ventilator z naslednjimi karakteristikami:

Obdelava podatkov delovanja ventilatorjev

Splošna obdelava podatkov temelji na analitičnem primerjanju in linearnem statističnem vrednotenju dobljenih rezultatov. Najpomembnejši so trije glavni parametri zračenja (ventilatorja) in sicer:

- količina zraka $Q/(m^3/s)$
- padec tlaka Δp/Pa
- moč motorja P/kW

Delovanje ventilatorja v zračilni postaji Šoštanj

Količina zraka, ugotovljena iz izvedenih meritev, ki jo daje glavni ventilator v zračilni postaji Šoštanj, je med 190 m³/s

Tabela 1. Podatki za glavni ventilator v postaji Šoštanj

PODATKI ZA GLAVNI JAMSKI VENTILATOR TIPA TURMAG GVhv 34-1800 v zračilni postaji Šoštanj		
parameter	nižja vrednost	višja vrednost
nazivna moč/kW	500	1800
depresija/Pa	1800	4600
napetost/kV	6,0	6,3
tok/A	110	160
cos Ø	0,61	0,92
naklon lopatic/°	–8	+10
pretok/(m³/s)	160	360

V zračilni postaji Pesje obratuje glavni jamski ventilator z naslednjimi karakteristikami:

Tabela 2. Podatki za glavni ventilator v postaji Šoštanj

PODATKI ZA GLAVNI JAMSKI VENTILATOR TIPA TURMAG GAF 24/13, 3-1 v zračilni postaji Pesje		
parameter	nižja vrednost	višja vrednost
nazivna moč/kW	350	800
depresija/Pa	750	3800
napetost/kV	5,9	6,1
tok/A	45	65
cos Ø	0,70	0,80
naklon lopatic/°	–20	+4
pretok/(m³/s)	50	200

Vrednosti za posamezne parametre so zaokrožene.

in 340 m^3/s in kaže padec ob spremembi režima delovanja med mirovanjem jame ter večjo obremenitev ob ponovnem povečanju.

Ekvivalenten količini zraka je padec tlaka, ki pada do najnižje točke delovanja in se ob ponovnem povečanju moči spet dvigne.

Ustrezno količini dovajanega zraka v jamo in padcu tlaka se spreminja moč motorja ventilatorja, ki ima krivuljo enake oblike kot pri količini zraka in padcu tlaka.

Delovanje ventilatorja v zračilni postaji Pesje

Rezultati delovanja ventilatorja v zračilni postaji Pesje so podobni tistim v zračilni postaji Šoštanj.

Rezultati obratovanja so ekvivalentno izraženi tudi s količino zraka.

Podobno kot pri ventilatorju v šoštanjski zračilni postaji se tudi pri ventilatorju v Pesju izraža režim obratovanja z močjo motorja, vendar v manjši meri oziroma z manjšim odmikom.

Za prikaz merjenih parametrov so vzeti samo najpomembnejši, to so količina zraka, depresija oziroma padec tlaka in moč motorja ventilatorjev.

MERITVE SPREMINJANJA KONCENTRACIJE PLINOV

Za nadaljnjo obdelavo sta uporabljena samo ključna parametra jamskega zraka, to sta koncentraciji metana in ogljikovega dioksida v jami Pesje, Preloge - jug in Preloge - sever na merjenih lokacijah.

Na odkopih se izvajajo meritve koncentracije plinov s stacionarnimi kontinuirnimi merilniki metana in CO_2. Meritve koncentracije CH_4 in CO_2 kažejo podobno spreminjanje vrednosti koncentracij plinov na vseh treh etažah in so v soodvisnosti z merjenimi parametri delovanja glavnih ventilatorjev.

Pridobljeni podatki so bili numerično obdelani, na njihovi podlagi pa so bili izdelani ustrezni sklepi. Iz množice meritev so bili uporabljeni samo reprezentativni podatki, ki kažejo shematsko sliko dogajanja pri prezračevanju delovišč med mirovanjem jame.

Spreminjanje koncentracije metana

Spreminjanje koncentracije metana (CH_4) poteka v območju od 1,45 % do 1,8 % v izstopnem zračnem toku z delovišč na začetku procesa, nato se ustali za določeno obdobje na višini okrog 0,65 % do 0,8 %. Po preteku 14 dni mirovanja jame začne koncentracija strmo naraščati in se dvigne na kritično mejo, ko je treba povečati delovanje ventilatorjev. Ta kritični del obsega kratko časovno obdobje in se hitro normalizira. V krajšem časovnem obdobju mirovanja jame, to je preko vikenda, koncentracija metana ne pade pod 1 %, naraščanje pa ne nastopi, saj se zaradi varnostnih ukrepov poženejo ventilatorji pred pričetkom ponovnega obratovanja jame, ki se začne, zaradi kratkega mirovanja, še pred nastankom visoke koncetracije plinov.

Spreminjanje koncentracije ogljikovega dioksida

Spreminjanje koncentracije ogljikovega dioksida (CO_2) je manj intenzivno kot metana. Z vrednosti, ki na začetku dosega od 0,6 % do 0,8 %, se zmanjša na 0,3 % do 0,5 % ter obstane pri teh vrednostih okrog 10 dni. Naraščati začne nekoliko prej kot metan, a ostaja še v dovoljenih mejah koncentracije. Ob izvajanju meritev se vrednost CO_2 ni nikoli približala kritični meji.

Spreminjanje koncentracije ogljikovega monoksida

Spreminjanje koncentracije ogljikovega monoksida (CO) je tesno vezano na količino dotekajočega zraka v jamske prostore in sledi spreminjanju koncentracije metana in ogljikovega dioksida. Pri večji količini zraka se je tudi koncentracija ogljikovega monoksida povečevala in obratno, a nikoli ni dosegla posebej visokih vrednosti. Na merilnih mestih so bile koncentracije med 0 ppm in 10 ppm, le enkrat samkrat je bila izmerjena vrednost 33 ppm.

Spreminjanje koncentracije kisika v zraku

Vsebnost kisika (O_2) v zraku je pokazala dokaj konstantne in normalne vrednosti, ki so bile v volumenskih deležih od 20,3 % do 20,9 %.

Izraba moči ventilatorjev

Ventilator v zračilni postaji Šoštanj

Glavni ventilator v zračilni postaji Šoštanj v normalnih razmerah obratuje s 75 % svoje moči, kar je pri 1375 kW. To je tudi začetna obremenitev ob spreminjanju naklona lopatic in s tem zmanjševanja dotoka zraka v jamo ter s tem razbremenjevanja ventilatorja. Ta lahko pade celo na 48 % svoje vrednosti, kar je 880 kW. Pri povprečni obremenitvi okrog 1150 kW ventilator obratuje 10 dni pri daljšem časovnem obdobju mirovanja jame in dva dneva pri krajšem obdobju mirovanja, kar pomeni 225 kW h prihranka ali do 75 600 kW h prihranka v času daljšega (štirinajstdnevnega) mirovanja jame.

Ventilator v zračilni postaji Pesje

Glavni ventilator v zračilni postaji Pesje deluje v normalnih razmerah z 58 % moči ali pri 470 kW obremenitve. Zmanjšanje moči med daljšim mirovanjem jame je sicer le 18 % od delujoče obremenitve in pade na 48 % nazivne moči ventilatorja. Pri povprečni obremenitvi okrog 390 kW obratuje pribl. 10 dni, s čimer je prihranek energije 80 kW h ali 19 200 kW h v celotnem obdobju. V primeru, da jama miruje dalj časa, pa je prihranek še večji.

KRIVULJA PREZRAČEVANJA JAME V DELA PROSTIH DNEH

Spodnji diagram prikazuje shematsko krivuljo prezračevanja jame v dela prostih dneh – prirejeno za 14-dnevno obdobje mirovanja jame. Krivulja obsega območje in spreminjanja vrednosti metana in ogljikovega dioksida ter ekvivalentno zmanjševanje in povečevanje moči – obratovanja glavnih ventilatorjev v zračilnih postajah Šoštanj in Pesje.

Krivulja je razdeljena na štiri bistvene dele:

- upadni del, kjer zmanjšujemo obratovanje ventilatorja;
- uravnoteženi del, ki lahko traja precej časa, glede na razmere v jami;
- naraščajoči del, kjer se vrednosti dvigajo, in
- stanje normalizacije, kjer se vzpostavi normalno obratovanje ventilatorjev ob ponovnem začetku obratovanja jame.

Na diagramu so prikazane najvišje in najnižje začetne in končne vrednosti koncentracij metana, ogljikovega dioksida ter območje spreminjanja vrednosti, hkrati pa sta predstavljeni krivulji obratovalne moči ventilatorjev.

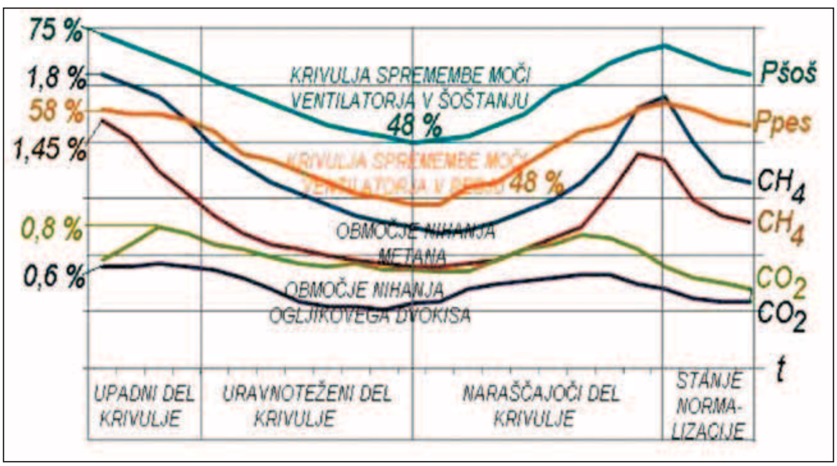

Diagram 1. Krivulja prezračevanja jame v dela prostih dneh

Ocena optimizacije ventilatorjev

Optimiranje obratovanja glavnih ventilatorjev, ki prezračujejo jamo Premogovnika Velenje je v času mirovanja jamskih delovišč privedeno do zelo visoke stopnje, kar je posledica velike skrbi in zavzetosti tako predhodnih kot sedanjih strokovnjakov za zračenje na tem zahtevnem področju. Šoštanjski ventilator ob 2977 Pa depresije in količini 216 m^3/s zraka v času zmanjšane aktivnosti že pade v najnižji režim možnega ekonomskega obratovanja. Ventilator v Pesju je ob obratovanju v enakih razmerah pri depresiji 935 Pa in 181 m^3/s že močno zunaj ekonomskega obratovanja, primerjalno – moč : depresija : količina zraka : cos *Φ*.

Podatki kažejo, da ta dva režima obratovanja ventilatorjev ustrezata plinskim razmeram v jami in sta v skladu z varnostnimi predpisi. Seveda pa je treba upoštevati, da so bili z meritvami zajeti le trije odkopi, druge, oddaljenejše jamske komunikacije pa ne.

Povzetek

Iz prikazanega prilagajanja obratovalnega režima ventilatorjev med mirovanjem jame ni več možno pričakovati velikih prihrankov, določene omejene, sicer finančno zahtevne možnosti pa so naslednje:

- opraviti je treba simulacijo hitrega prilagajanja spremembam koncentracije plinov v jami s primerjanjem že dobljenih podatkov kot najenostavnejši način optimizacije;
- uvesti popolne nadzorne meritve (monitoring) nad delovanjem ventilatorjev in spreminjati njihov režim obratovanja praktično nenehno glede na razmere zaplinjenosti v jami; le s hitrimi spremembami obratovalnega režima ventilatorjev je možno še povečati prihranke pri porabi pogonske energije za 8–9 %;
- izpopolniti avtomatizacijo delovanja ventilatorjev in prilagajanja krivulji zračenja, kar zagotavlja od človeka neodvisno optimiranje;
- začeti prilagajati kvaliteto izdelave, preseka, dolžine in povezav jamskih zračilnih vodnikov – prostorov (prog);
- preveriti izrabo jalove energije, saj se njen faktor (cos *Φ*) precej poslabša ob nižanju moči ventilatorja;
- izvesti polioptimizacijo celotnega ventilacijskega sistema, ki naj zajema stabilnost zračilnega toka, porabo energije, efektivnosti prezračevanja (faktorja izkoristka zračilnega sistema) in inženirsko strojniške zasnove ventilatorjev (difuzor, paralelno delovanje, mehanske poškodbe, korozijo in erozijo, vibracije in aerodinamične komponente).

Podatki za optimizacijo so bili pridobljeni s štirimi meritvami. Meritve so pokazale, da dosedanji način zračenja z zmanjševanjem delovanja glavnih ventilatorjev takoj po prenehanju dela, z zmanjšanim obratovanjem v času prostih dni in s povečanjem delovanja ventilatorjev tik pred nastopom dela po večdnevni prekinitvi za razplinjenje ekshaliranih plinov ustreza zahtevam po varnem delu – razplinjenju.

Optimizacija se lahko izvaja, če so urejeni: avtomatsko merjenje koncentracije plinov v jami ali njenih oddelkih, avtomatska regulacija ventilatorjev in avtomatska regulacija ključnih regulacijskih objektov (vrata in dušilke). Ko se začne večati količina metana v kritičnem tokovnem krogu proti 1,4 %, je treba izvesti regulacijo, da na kritični odsek usmerimo večjo količino zraka. Tehnična opremljenost je pogoj za optimiranje. Ta zahteva daljinsko upravljanje ventilatorjev oziroma daljinsko spreminjanje naklona lopatic ventilatorjev. S tem dosežemo spremembo obratovalne točke ventilatorja in depresije ter spremembo režima obratovanja ventilatorja.

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Folk, R. L. (1959): Practical petrographic classification of limestones. *Amer. Ass. Petrol. Geol. Bull.;* Vol. 43, No. 1, pp. 1–38, Tulsa.

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[1] Trček, B. (2001): *Solute transport monitoring in the unsaturated zone of the karst aquifer by natural tracers.* Ph. D. Thesis. Ljubljana: University of Ljubljana 2001; 125 p.

[2] Higashitani, K., Iseri, H., Okuhara, K., Hatade, S. (1995): Magnetic Effects on Zeta Potential and Diffusivity of Nonmagnetic Particles. *Journal of Colloid and Interface Science, 172*, pp. 383–388.

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Naslov članka (Times New Roman, 14, Na sredino)

The title of the manuscript should be written in bold letters (Times New Roman, 14, Center)

Ime Priimek[1], …, Ime Priimek[X] (Times New Roman, 12, Na sredino)

[X]Univerza…, Fakulteta…, Naslov…, Država… (Times New Roman, 11, Na sredino)

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Izvleček (Times New Roman, Navadno, 11): Kratek izvleček namena članka ter ključnih rezultatov in ugotovitev. Razen prve j bo tekst zamaknjen z levega roba za 10 mm. Dolžina naj ne presega petnajst (15) vrstic (10 je priporočeno).

Abstract (Times New Roman, Normal, 11): The abstract should be concise and should present the aim of the work, essential results and conclusion. It should be typed in font size 11, single-spaced. Except for the first line, the text should be indented from the left margin by 10 mm. The length should not exceed fifteen (15) lines (10 are recommended).

Ključne besede: seznam največ 5 ključnih besed (3–5) za pomoč pri indeksiranju ali iskanju. Uporabite enako obliko kot za izvleček.
Key words: a list of up to 5 key words (3 to 5) that will be useful for indexing or searching. Use the same styling as for abstract.

Uvod (Times New Roman, Krepko, 12)

Dve vrstici pod ključnimi besedami se začne Uvod. Uporabite pisavo Times New Roman, velikost črk 12, z obojestransko poravnavo. Naslovi slik in tabel (vključno z besedilom v slikah) morajo biti v slovenskem jeziku.

Slika (Tabela) X. Pripadajoče besedilo k sliki (tabeli)

Obstajata dve sprejemljivi metodi navajanja referenc:

1. z navedbo prvega avtorja in letnice objave reference v oklepaju na ustreznem mestu v tekstu in z ureditvijo seznama referenc po abecednem zaporedju prvih avtorjev; npr.:
   "Detailed information about geohistorical development of this zone can be found in: Antonijević (1957), Grubić (1962), ..."
   "… the method was described previously (Hoefs, 1996)"

ali

2. z zaporednimi arabskimi številkami v oglatih oklepajih na ustreznem mestu v tekstu in z ureditvijo seznama referenc v številčnem zaporedju navajanja; npr.;
   "... while the portal was made in Zope[3] environment."

Materiali in metode (Times New Roman, Krepko, 12)

Ta del opisuje razpoložljive podatke, metode in način dela ter omogoča zadostno količino informacij, da lahko z opisanimi metodami delo ponovimo.

Rezultati in razprava (Times New Roman, Krepko, 12)

Tabele, sheme in slike je treba vnesti (z ukazom Insert, ne Paste) v tekst na ustreznem mestu. Večje sheme in tabele je po treba ločiti na manjše dele, da ne presegajo ene strani.

Sklepi (Times New Roman, Krepko, 12)

Povzetek rezultatov in sklepi.

Zahvale (Times New Roman, Krepko, 12, Na sredino - opcija)

Izvedbo tega dela je omogočilo ………

Viri (Times New Roman, Krepko, 12)

Glede na uporabljeno metodo citiranja referenc v tekstu upoštevajte eno od naslednjih oblik:

PRVA MOŽNOST (priporočena) - v abecednem zaporedju

Casati, P., Jadoul, F., Nicora, A., Marinelli, M., Fantini-Sestini, N. & Fois, E. (1981): Geologia della Valle del'Anisici e dei gruppi M. Popera – Tre Cime di Lavaredo (Dolomiti Orientali). *Riv. Ital. Paleont.*; Vol. 87, No. 3, pp. 391–400, Milano.

Folk, R. L. (1959): Practical petrographic classification of limestones. *Amer. Ass. Petrol. Geol. Bull.;* Vol. 43, No. 1, pp. 1–38, Tulsa.

DRUGA MOŽNOST - v numeričnem zaporedju

[1] Trček, B. (2001): *Solute transport monitoring in the unsaturated zone of the karst aquifer by natural tracers.* Ph. D. Thesis. Ljubljana: University of Ljubljana 2001; 125 p.

[2] Higashitani, K., Iseri, H., Okuhara, K., Hatade, S. (1995): Magnetic Effects on Zeta Potential and Diffusivity of Nonmagnetic Particles. *Journal of Colloid and Interface Science, 172*, pp. 383–388.

Citiranje spletne strani:

CASREACT-Chemical reactions database [online]. Chemical Abstracts Service, 2000, obnovljeno 2. 2. 2000 [citirano 3. 2. 2000]. Dostopno na svetovnem spletu: http://www.cas.org/CASFILES/casreact.html.

Znanstveni, pregledni in strokovni članki ter predhodne objave se objavijo v angleškem jeziku. Izjemoma se strokovni članek objavi v slovenskem jeziku.

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