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POSSIBILITIES AND PERSPECTIVES FOR DEVELOPMENT OF METALLURGY IN THE REPUBLIC OF MACEDONIA

MOŽNOSTI IN PERSPEKTIVE ZA RAZVOJ METALURGIJE V REPUBLIKI MAKEDONIJI

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Installed metallurgical capacities in the Republic of Macedonia exceed the local market and a significant share of products is exported. These exports represent a very significant share of foreign currency inflow. The production of steel is based on scrop import. Ferroalloys industry shows improving performances because of transformation of ownership and restructuring. The increasing of production capacities is expected and especially it is planned to build facilities for exploitation of all lead in zinc concentrates produced in Macedonia.

Key words: Macedonia, metallurgical industry, production of steel, ferroalloys, lead, zinc, cadmium, silver

Instalirane metalurške kapacitete v Republiki Makedoniji presegajo absorbcijo domačega trga in precejšnja količina proizvodov se izvaža. Ta izvoz predstavlja pomemben deleže dotoka deviz. Proizvodnja jekla bazira na uvozu starega železa. Proizvodnja ferolegur kaže naraščujoče dosežke zaradi olastninjenja in restrukturiranja. Pričakuje se povečanje kapacitet, predvsem pa se načrtuje povečanje exploatacije koncentratov svinca in cinka.

Ključne besede: Makedonija, metalurška industrija, proizvodnja jekla, ferozlitine, svinec, cinka, kadmij, srebro

1 INTRODUCTION

The capacities of ferrous and non ferrous metallurgy are overextended considering the market requirements in the Republic of Macedonia. In accordance with the fifty years period of development of the Republic of Macedonia, within the former Yugoslav Federation, and the natural resources, the strategic development of ferrous metallurgy of the Republic of Macedonia was projected in accordance with the capacities in Slovenia and the previously started construction of the Steel Complex in Zenica, Bosnia and Herzegovina (BH). The strategy of the Yugoslav industrial development was strongly oriented towards the West European market and the regions more closer to Europe were developed as final exporters for western markets. Other regions should have supported the technological and the industrial development of northern regions through raw materials, and have provided food and other less finalized products for local markets.

The production of steel in Macedonia, the primary processing of steel sheets and the production of ferrochrome and ferrosilicon, combined with Slovenian production should have supplied the Yugoslav market with beaded profiles. Profiled steel should have been provided by the Republic of BH while the production of tubes was given to the Steel Complex in Sisak, Republic of Croatia.

In the former SFRY, the planed roles did not change, not even after the year 1970 and in Macedonia, two large extractive metallurgical capacities, one for ferroalloys (FeNi) and the second for lead and zinc, have been built. Processing plants for these raw materials have not been foreseen in Macedonia.

Considering the industrial structure in Macedonia with the processing of steel and other metals was far below the installed capacities for steel constructions and seam tubes, as well as the disproportion between extractive and processing units in steel industry, the Macedonian ferrous industry was forced towards foreign markets. The foreseen supply with semi finished products for the Steel Complex Skopje from the Steel Complex in Smederevo has never been accomplished since, and beside the blast furnaces and the steel plant, rolling mills for profiles almost identical to the assortment of the Steel Complex in Skopje were built in Serbia. The steel processing capacities in Macedonia, were left without raw materials, and faced with the local market competition. The solution was found in the import of semi-finished products, mainly from the former USSR and other foreign markets.

2 FERROUS METALLURGY

At present, in the Republic of Macedonia, the following metallurgic capacities for production and processing of steel and ferroalloys are in operation:

- Electric Steel Processing Plant and Rolling Mill in Skopje "Rudnici i Zelezarnica Skopje"

- Chemical Electric-Metallurgical Complex "Jugohrom", in Jegunovce (in the vicinity of Tetovo)
- Company with mixed ownership for production of ferronickel "Fenimak" in Kavadarci
- Factory for welded tubes "11 Oktomvri" in Kumanovo

2.1 Steel complex 'Skopje'

The Steel Complex in Skopje was built in accordance to the silicate ores reserves on the territory of Macedonia. Due to the lack of cocking coal, and considering the large reserves of lignite in Serbia, electrometallurgy procedure with low combustion electro reduction furnaces and prereduction in rotation furnaces with lignite, was selected. For the beneficiation of the charge up to 42% Fe, a peletisation unit for the magnetic iron ore from the Damjan Mine, in the vicinity of Radovis, was built with magnetic separation, and use of imported ferrous concentrates. The 5 electroreduction low combustion furnaces with the installed power of 195 MW and five 90 m long rotation furnaces, were projected to produce about 600.000 t/years of pig iron. However, due to unsolved technological problems, the production of pig was obtained mainly by reduction of the cold charge in the electric furnaces, which, besides the unfavorable chemical content - high concentration of silicium without manganese - significantly increased the price of pig iron. Within a period of 25 years of production, the projected capacity was not achieved because of back of reducing agents and of electric power. Because of these limiting factors and technological problems in the pre-reduction process, for which numerous pilot and semi-industrial researches have been carried out, the maximum production ever reached was 280.000 t/year[1].

The processing of pig iron with high content of silicon was achieved in two LDAC converters, 130 t each. Because of the small individual capacity of the electric furnaces for homogenization of the chemical content and maintenance of temperature two reservoirs for liquid iron were provided. Pig iron from the electric furnaces with more than 2% Si, was processed in the unit for desiliconition in pig iron ladle. The steel obtained from the converters was cast in slab ingots up to 1981, later a continuous caster for slabs was built.

In order to provide the own steel required by the rolling mill capacity, an electric arc furnace of 100 t was build and additional 200.000 t of pig steel provided. In 1988, the capacity of the electric arc furnace was increased to 350.000 t/year, while in the second phase, by melting of scrap iron steel production was planned to reach 500.000 t/year. However, due to technological problems in the computerized electric arc furnace and difficulties in the supply of appropriate and sorted scrap iron, the new furnace did reach only a yearly production of 250.000 t/year steel.

The basic product are low carbon and carbon manganese structural as well as ship plates and boiler plates. Later also the production of microalloyed steels with niobium, vanadium, titan and zirconium was developed. The converters were also suitable for the production of deep drawing steels.

The Steel Complex 'Skopje' includes the following three rolling mills:

- Hot rolling mill for 3.000 mm heavy plates with the capacity of 500.000 t/year, on a reversible four-high rolling stand, with a vertical duo-stand on line
- Hot rolling mill for 1.600 mm rolled strips with the capacity of 850.000 t/year, with a four-high rolling pre-stand and a final six stands train with four-high rolling stands; and
- Rolling mill for cold rolled strips with two lines: (a) a five stands train with the capacity of 500.000 t/year and (b) a four-high reversible stand of 300.000 t/year.

The cold rolling mill includes also a department zinc coating with the capacity of 100.000 t/year as well as a line for plastification of plates with the capacity of 25.000 t/year.

The rolling mill capacities were built for about 2.000.000 t/year of final products, while the maximal production obtained by the Steel Complex 'Skopje' was 1.250.000 t/year because of the lack of steel of own production. Considering the discrepancies in the primary metallurgical and processing production the Steel Complex was forced to import semi products or to undertake loan arrangements.

The Macedonian market could absorb maximally 100.000 t/year cold roll and plates, while the possibilities for absorption of hot mill strips are greater since the Factory for welded tubes with the capacity of about 600.000 t/year is located at a distance of about 35 km from the Steel Complex. The Steel Complex disposed of the majority of production on the markets of the former Yugoslav republics and to export markets.

After 1991 a significant decrease in production occurred due to the economic and political crisis in the former USSR, the main foreign partner and in the former SFRY. Consequently, in the following 4 years the production of the Steel Complex was significantly decreased and than even discontinued.

The cost of production of pig iron in electroreduction low combustion furnaces and steel in converters was too high and in 1988 it was stopped.

Also the costs analyses of steel production from local ores led to its stopping. Lately two electric reduction furnaces were restructured and the production of ferromanganese and siliconmanganese was started on the base on imported raw materials. The actual production amounts to 36.000 t/year of ferromanganese and 44.000 t/year siliconmanganese. Other units were preserved and the converter unit was dismantled.

2.2 Production of 'Jugohrom' Jegunovce

The enterprise 'Jugohrom' is the producer of mass ferroalloys as FeSi, FeCr, silicon metal and silicon-chrome primarily for the requirements of the ferrous metallurgy and casting industry of the former SFRY. The products are lately totally exported.

The capacity of 'Jugohrom' was rebuilt for a modern production of ferroalloys, with melting aggregates with medium and large installed power; permanently modernized in terms of technique and technology, providing:

- Increased production compared to the originally projected;
- Alternative production and quick adjustment to the market conditions, necessary for a competitive market oriented production;
- Improvement of operating conditions;
- Environment protection etc.

The production of ferroalloys in 'Jugohrom' in accordance with its assortment can be performed in nine electric furnaces with the total installed capacity of 140.2 MVA, in accordance with the schedule presented in **Table 1**.

The intensive development of processes of ladle processing for acquiring ferroalloys with improved physical-mechanical properties, as well as technological and exploitation characteristics required the application of a broad scale of complex alloys - modifficators for cast iron. Based on these trends of development in metallurgy, in the current phase of modernization, 'Jugohrom' has developed the technology for production of complex alloys-modificators based on ferrosilicon used as inoculant and nodulators.

The production of these alloys is based on FeSi, with addition of Mn, Ba, Ca, Al, Mg, Ce, MM, and C. By applying the direct procedure, a further alloy-up of melted FeSi or its alloys into a melting pot with spilling, sinking and mixing homogenous complex alloys - modificators of a broad assortment like FeSi, FeSiAl, FeSiMn, FeSiBa, FeSiBaMn, FeSiMgCeMM and composite mixtures FeSiC and FeSiBaC are obtained.

The production capacity and assortment depend of the demand on local as well as on export markets.

The metallurgical production in 'Jugohrom' was conditioned by the development of new technologies of steel production and casting of gray and nodular iron, primarily by the ladle processing by modification, alloying and microalloying, providing a high yield of metal and ferro alloys. From this point of view, the long-standing experience of 'Jugohrom' will be directed in future towards:

- quality improvement of the present assortment of ferroalloys and modificators;
- production of special, fine ferroalloys, especially of fine FeSi, by application of new technologies;
- extension of the production of complex alloys - modificators with new more efficient types and assortment of inoculators and nodulators;
- introduction of quality FeSi with low content of Si: FeSi 15 (14-16 Si) for production of resolvable anodes for cathodic protection, FeSi 15 powder for separation of ore minerals in heavy liquids;
- development of auxiliary devices for casting industry and metallurgy;

Development of dust collecting and utilization of waste gases heat and its conversion into electric power, all contributing to the environment protection and improvement of the overall operation of the enterprise.

2.3 Production of ferronickel

The Ferronickel producer 'Feninmak' in Kavadarci is organized as a share holding company and exploits local raw materials of laterite type.

The technological process includes are beneficiation and preparation for metallurgical processing based on differences in density and magnetic properties of minerals in the ore and the distribution of the nickel. The process is performed in the plant for ore pulverizing, pneumatic, dry and wet magnetic separation, as well as for

Table 1: Characteristics of the melting units in 'Jugohrom'

Furnace	Type of the furnace	Install. capacity MVA	Type of electrodes	Production of ferroalloys		
				Basic		Alternative
				Type	Production technical capacities t/year	
I	Electric-arc reduction	6.5	A	Si-metal	3.400	FeSi45/75/90
II	"	10.0	A	"	4.000	"
III	"	6.5	A	"	3.00	FeSi45/75/90 SiCr
IV	"	16.0	A	"	5.200	FeSi45/75/90 Cr
V	Electric-arc rafin.	3.5	G	LC FeCr	4.500	"
VI	Electric-arc slake	4.4	Sö	FeSi 75	13.300	FeSi 45/CaC2
VII	Electric-arc reduction	21.3	Sö	FeSi 75	13.300	FeSi 45/CaC2
VIII	"	48.0	Sö	"	34.000	FeSi 45
IX	"	24.0	Sö	"	14.000	FeSi 45HCFeCr
Total	9	140.2			77.300	

Abbrev.: A-amorphi, G-graphite, Sö-Söderberg pelletisation of nickel concentrate. It has been foreseen that the magnetic fraction in the ore should be about 30%, representing the ferrous concentrate, with a lower content of nickel and the difference with higher nickel content.

Besides preparation and pelletisation, the technological process includes roasting of the pellets, their pre-reduction in rotation furnaces by addition of lignite and melting of the pre-reduced material into 16% FeNi, which is further refined up to 45% FeNi into oxidind converters. Two pyrometallurgical lines with separate rotating and rectangular electric furnaces with six Södeberg electrodes set in line are in operation. The projected total capacity of the plant was 21.000 t/year nickel in FeNi by average ore content of 1.03% Ni. So far only one technological line was used[2].

Changes in mining technology and unprecise previous geological investigations lead to a very small magnetic fraction with higher percentage of nickel during exploitation and affected the production costs. Consequently, magnetic concentration is being avoided and the overall ore supply is ground and pelletized.

Nickel is a stock exchange product which price in the last 10 years changed significantly. In 1984 and 1985 it was very low and the production of FeNi was interrupted only one and a half year following the start of production. As a result of changes in nickel prices on world market and after investments of several companies the production of one technological line re-started at the end of 1991. During recent years the production increased permanently, however the projected values, will not be obtained due to the decrease average content of nickel in the ore. **Table 2** indicates the trend of production in the restart period.

Table 2: Production of Ni as FeNi in 'Fenimak'

Year	1992	1993	1994	1995
Produced in t	4.220	4.493	3.981	4.960

Due to the second decrease of the nickel price in the period of 1993 to 1995, the society in the period of 1993/94 operated with loss and profit was obtained later because of the light increase of nickel price.

If the present trend of increase of nickel price will continue, the production could increase to 5.500 t/year with only one technological line and be profitable. Following the re-start, rigorous economic measures have been undertaken related with the restructuring of the production, to the decrease of the number of employees, to the improvement of the technology within given conditions related to the supply of raw materials and direct marketing. 'Fenimak' is forced to import lignite from SR Yugoslavia. The enterprise undertakes serious and detailed investigations of the mineralogy of the mine deposit, as well as for possible alternatives for economic beneficiation of the nickel ore. The production could increase only if the nickel content in the charge of furnaces is increased. This can be obtained through the supply of rich raw materials and requires additional working capital. Domestic investments are almost impossible because of the present economic situation, since Macedonia is exhausted by the political and economic changes imposed by the disintegration process and the war on the territory of the former SFRY as well as the economic and transport blockades of some neighbours of the Republic of Macedonia. New investments in the present production of 'Fenimak' and its increase with the re-start of the second technological line will be welcome and of benefit for the investors since the enterprise employs qualified managerial staff and disposes of modern technological devices with capacity non exploited.

Ferro-nickel is sold on foreign markets and only a very small quantity was sold on the local market, because of the crisis in steel metallurgy during the last years.

3 CAPACITIES OF NONFERROUS METALLURGY IN MACEDONIA

Moderate quantities of nonferrous metals are produced in the MHK 'Zletovo'. Smelter 'Zletovo' is using Imperial smelting process for exstraction of zinc, lead, cadmium and silver.

3.1 Lead and zinc

Lead and zinc ores have been exploited for centuries in the Kratovo-Zletovo ore deposit. Traces such as tools, slag, pots etc. indicate that lead has been smelted in the region during the Roman period.

'Zletovo' Metallurgical and Chemical Company in Titov Veles is the only producer of lead and zinc in the Republic of Macedonia. It is based mainly on the ore deposits and capacities of the three surrounding lead and zinc mines: Zletovo, Sasa and Toranica.

The Imperial Smelting process route was the most convenient for treating lead and zinc concentrates simultaneously. Moreover, it offered an opportunity to produce bulk concentrates, thus increasing the overall metal recovery. Therefore, an agreement was signed, the site preparation began, and the first quantities of slab zinc and lead bullion were produced in November 1972.

'Zletovo' Smelter was designed for a maximum production of 65,000 tpa of slab zinc and 35,000 tpa of lead bullion. **Figure 1** shows the annual production rates in the period from 1973 to 1995. Numerous prerequisites are required to reach the designed capacity of the ISF.

The break of the continuous growth of metal production from 1986 to 1991 was due to series of problems arising from the disintegration of former Yugoslavia, international sanctions against the Federal Republic of Yugoslavia, and Greek embargo against the Republic of Macedonia. These events created enormous difficulties in transporting both raw materials and products and led to higher production costs.

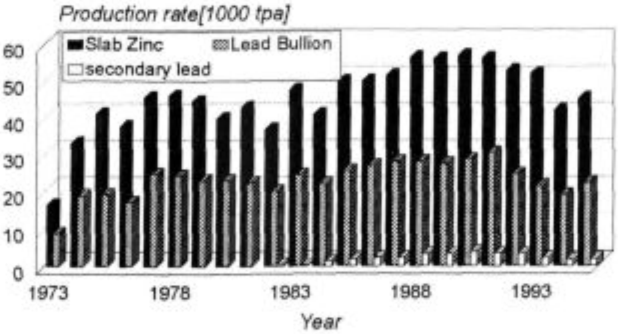

Figure 1: Annual production of slab zinc, lead bullion and secondary lead from plant start-up to 1995
Slika 1: Letna proizvodnja slabov cinka, primarnega in sekundarnega cinka od zagona podjetja do 1995.

Most of the refined lead produced at 'Zletovo' smelter is consumed within the country, mainly in the lead batteries plant having a capacity of 24000 tpa. However, due to the same reasons as above, especially the disintegration of SFR Yugoslavia, the market the battery plant was designed for, the production rate has been reduced down to 30%.

Lead and zinc production rates are increased since the Dayton and New York agreements were signed last year, but a period of several years is necessary for a full recovery.

3.2 Cadmium

Most of the cadmium fed onto the sinter machine is eliminated during the sintering process. The degree of elimination depends mainly on sulfur and cadmium contents of the raw mix, but the usual level is as high as 65 to 80%. With the construction of the cadmium plant based on the Ion Exchange Process the recovery of cadmium is accomplished with high efficiency (over 92% as shown in **figure 2**).

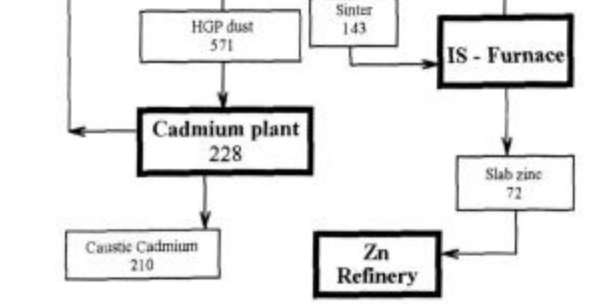

Figure 2: Overall cadmium balance
Slika 2: Celovita bilanca kadmija.

Cadmium is leached from the hot gas dust precipitator by means of weak sulfuric acid. Depending on the chemical compounds in which cadmium is present in the dust, leaching efficiencies from 30 to 60% are obtained. The resulting leach liquor is countercurrently washed in a system of three decanters, filtered through a pair of sand filters and subjected to ion exchange on IR 120 cation exchange resin. Stripping is performed by means of 10% brine solution. Cadmium sponge produced by cementation on zinc rods in suitable trammel tanks is melted in a caustic furnace and combined with the zinc refinery to a cadmium alloy for further refining.

Despite the high stage efficiencies, the magnitude of losses is high and disturbing. As shown in **figure 2**, cadmium recirculating load is very high relative to the new input and this feature must contribute considerably to the losses.

Cadmium production rate in a zinc and lead smelter depends primarily on the quantities of new cadmium fed with the raw materials. Since significant quantities of zinc concentrates have been purchased from various producers around the world, it is obvious that the Zn/Cd ratio is rather a varying parameter. However, there are two objectives that a zinc smelter must achieve:

- High cadmium elimination to provide good zinc quality
- High cadmium recovery to avoid environmental problems

The annual production of cadmium from the 'Zletovo' Smelter from its start up to 1994 is shown in **figure 3**.

3.3 Silver

Unlike cadmium, most of the silver fed with concentrates reports in the lead bullion. Desilvering of the later is performed by adding metallic zinc and removing the resulting solid intermetallic compounds (mainly Ag_2Zn_5) together with a substantial amount of mechanically entrained lead as a silver crust. Further treatment of the crust includes evaporating of zinc, oxidizing of lead and electrolytic refining of silver.

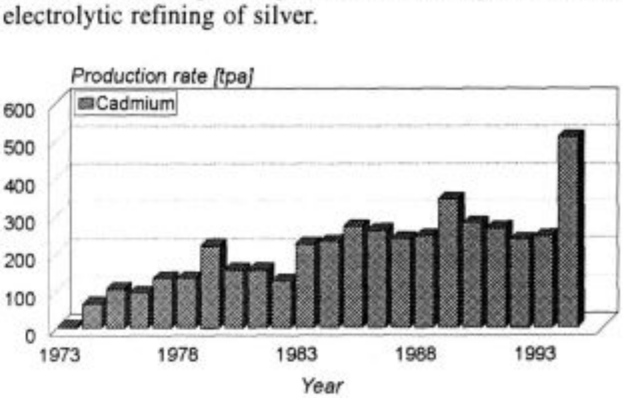

Figure 3: Annual cadmium production from plant start-up to 1995
Slika 3: Letna proizvodnja kadmijev od zagona podjetja do leta 1995.

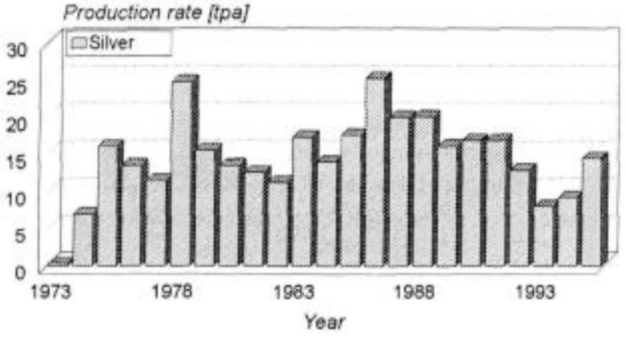

Figure 4: Annual silver production from plant start-up to 1995
Slika 4: Letna proizvodnja srebra od zagona podjetja do 1995.

The electrolytic silver refinery was introduced in 1982. Its total capacity amounts 30 tpa electrolytic silver, but the highest production achieved so far was 24.35 t in 1986.

4 CONCLUSIONS

- The installed metallurgical capacities of iron, its alloys and nonferrous metals in the Republic of Macedonia encompasses the requirements of the local market and is directed towards the foreign market;
- The participation of steel, ferro alloys and nonferrous metals alloys in the national foreign currency inflow is very significant;
- due to the discrepancies between the primary steel production and the installed melting capacities, as well as the limited possibilities for supply of raw materials, the metallurgy in Macedonia is forced to import steel in a slabs and scrap;
- considering the 30 years of experience in the steel industry and in the production of ferro alloys, following the carried out transformation of ownership and completion of the restructuring processes, more profitable operating and its further development may be expected;
- increasing the production capacities regarding various metals could also be expected, but it is intended to provide facilities for treating all the lead and zinc concentrates produced in the Republic of Macedonia. With respect to this, installing a new lead smelter plant has been considered.

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