Kontinuirnost obvladovanja kaljivosti jekla

Continuity of Steel Hardenability Control

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Kaljivost je ena od pomembnih lastnosti jekla, zato ima vidno mesto v sistemu zagotavljanja kakovosti jekla. Predstavljena celovitost obvladovanja zagotovljene kakovosti jekla od konvencionalnega modela do sodobnega temelji na sistemu »POKA-YOKE« (11), to je na preprečevanju in odpravljanju vzrokov neprave kaljivosti v procesu izdelave jekla v elektro peči ali po postopku ponovčne metalurgije (VAD).

Predstavljena je računalniška podpora zagotavljanju kaljivosti jekla od izdelave matematičnega modela napovedi kaljivosti do integracije in uporabe napovedi v računalniško krmiljenem procesu izdelave jekla v elektrojeklarni. Podani so tudi večletni rezultati in izkušnje.

Samostojni računalniški programski paketi napovedi kaljivosti jekla so namenjeni raziskovalcem, tehnologom toplotne obdelave, kontroli kakovosti in uporabnikom jekla.

1. Cilji

Namen raziskovanja, modeliranja, uporabe računalnika je izboljšati celovito obvladovanje kakovosti jekla na področju kaljivosti. Na kaljivost ima močan vpliv kemična sestava jekla, vendar nam standardni in kupčevi predpisi kemične sestave vedno ne zagotavljajo obvladovanja zagotovljene kaljivosti. Zanesljivost sistema zagotavljanja kakovosti kaljivosti jekla se ugotavlja periodično s širino distribucije Jominy krivulje in deležem šarž zunaj zagotovljene kaljivosti.

Ta delež je sicer majhen, vendar želimo, da je še manjši. Dolgoročni cilj je »ZERO DEFECT«.

2. RAČUNALNIŠKA PODPORA ZAGOTAVLJANJU KAKOVOSTI KALJIVOSTI (1)

Obdelava podatkov Jominy preizkusov je v železarni Ravne že od leta 1975 del kompleksnega informacijskega sistema avtomatske obdelave podatkov tehnične kontrole in raziskav (AOP-TKR). Celoten sistem obravnava podatke:

— fazne kontrole v obratu,
— kemijskega laboratorija,
— laboratorijske kalilnice,
— mehanskega laboratorija in
— podatke o neuspeli proizvodnji.

Podatki o Jominy preizkusu spadajo v skupino podatkov laboratorijske kalilnice in jih lahko obravnavamo samostojno ali v povezavi z drugimi vrstami podatkov in meritev.

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Hardenability is one of the most important steel properties taking up an essential position in the quality steel quaranteeing system. The presented quality steel guarrantee from the conventional to the modern model is based on "POKA-YOKE" system (11), which means preventing and abolishing causes of irregular hardenability in steel making process in an electric furnace or in the VAD process.

The paper presents the computer aided control of steel hardenability assurance starting with a mathematical model of hardenability prediction through integration and the application of the mentioned supposition in computer controlled steel making process in electric steel works. It presents the results and experiences obtained in many years.

The computer program packages on steel hardenability prediction are made for researchers, heat treatment technologists, and steel consumers quality control.

1. SCOPES

The improvement of steel quality with special emphasis on hardenability is by research, modelling, and computer application. Steel hardenability is strongly affected by chemical composition of steel yet the standard and purchaser's specifications of chemical composition assure control of guranteed hardenability now and then only. The reliability of hardenability quality assurance system is examined periodically by Jominy curve distribution and a number of heats without guaranteed hardenability.

This share is small, yet in this case the end effect is expected to be "ZERO DEFECT"

2. COMPUTER AIDED HARDENABILITY CONTROL ASSURANCE (1)

Since 1975 the Jominy test data processing has presented a part of the complex information system of the automatic data processing system of the quality control and research department (AOP-TKR). The whole system is engaged in processing the following data of:

— shop floor quality control,
— chemical laboratory,
— heat treatment sample preparation,
— unsuccessful products data.

Jominy experiment data belong to the heat treatment sample preparation data group and could be processed independently or together with other data and measurements.

The current data processing of the reference field could be ranged in the following two classes:

— data entry to the data bank,
— regular data processing to check the quality level.

Tekočo avtomatsko obdelavo podatkov obravnavanega področja lahko razdelimo v dve skupini:

— polnjenje banke podatkov in

— redne obdelave podatkov za preverjanje nivoja kakovosti.

Prva skupina obdelav podatkov vsebuje že klasično kontrolo in prenos podatkov v eksterni del računalniškega spomina. Za področje analiz kakovostnega nivoja in vzrokov neprave kaljivosti jekel je primerna vrsta rednih obdelav in cela vrsta matematično-statističnih analiz. Shemo druge skupine obdelav podatkov kaže **slika 1.**

Slika 1

Obdelava podatkov nadzora kakovosti in raziskav v jeklarstvu

Kontrolne karte (predvsem X-Rp) nam služijo za slikovni kronološki prikaz kaljivosti določenega jekla in nas opozarjajo na tiste šarže, ki so zunaj kontrolnih mej. Uporaba kart je primerna za podrobno analizo kakovosti posameznega jekla.

S pomočjo analize porazdelitve lahko objektivno definiramo pasove zagotovljene kaljivosti. To področje je še posebej pomembno.

Matematično-statistično metodo primerjav srednjih vrednosti in standardnih deviacij lahko uporabljamo za primerjanje pomembnosti razlik med kaljivostjo sorodnih jekel in pomembnostjo razlik v kaljivosti jekla, ki smo mu spremenili tehnološki postopek izdelave, torej za primerjavo kakovosti jekla, izdelanega po stari in novi tehnologiji.

Kako lahko uporabimo primerno organizirano banko podatkov za povezovanje podatkov Jominy poizkusov z drugimi vrstami podatkov, nam kaže analiza vpliva kemične sestave na kaljivost jekla s pomočjo analize korelacije in regresije. Regresijske in druge matematično-statistične analize lahko opravljamo na različnih računalnikih z enim od matematično statističnih paketov, ki omogočajo iskanje tudi nelinearnih regresijskih enačb.

Računalniški modeli napovedi kaljivosti so izdelani za osebne računalnike in računalnike DEC. Napoved bazira na modelu regresijskih enačb in na poznani ali pričakovani kemični sestavi jekla.

Redne obdelave podatkov neuspele proizvodnje so razdeljene tako, da je mogoče problematiko obravnavati z naslednjih vidikov:

— izdelek

— jeklo

— peč ali stroj

— vrsta napake

— delavec.

Za področje kaljivosti jekla še posebej spremljamo vrsto napake, to je kaljivost zunaj predpisanega območja jekla. Praviloma se obravnava vsako jeklo posebej in le v raziskovalne namene združujemo in raziskujemo sorodne skupine jekel. Kajti pri oblikovanju in uporabi mo-

The first group of data processing is controlled in the classical way and its data transferred to the external part of the computer memory. To analyse the quality and causer for irregular hardenability of steels a series of regular processings and mathematical-statistical analyses are provided for. ***Figure 1*** *shows the outline of the other data processing group.*

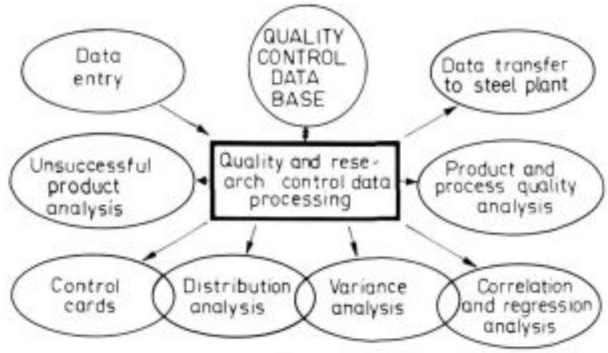


Figure 1

Quality assurance control data processing.

Control cards (above all X-Rp) show pictures and chronological view of a definite steel hardenability and point out the heat outside the specification range. These cards are used for detailed quality analysis of a specific steel.

For an exact determination of the guranteed hardenability bands the distribution analysis is used. This is very important.

The mathematical-statistical comparative method of average value and standard deviations determination could be used to compare the hardenability of steel made by the old technological procedure to the one made by new technological procedure.

A correctly prepared data bank can be used to link the Jominy tests data to other data as is shown by the analysis of chemical composition effects on steel hardenability by means of correlation and regressive analysis.

Regression and other mathematical-statistical analyses could be performed by any computer with one of the mathematical-statistical packages which make the search for non linear regression analysis possible.

The computer models of hardenability prediction are made for PCs and DEC. The predictions are based on regression equation model and known or expected chemical composition of steel.

Regular data processing of unsuccessful products is arranged in such a way, that the problems causes can be treated from the following points of view:

— final product,

— steel grade,

— furnace of machine

— error,

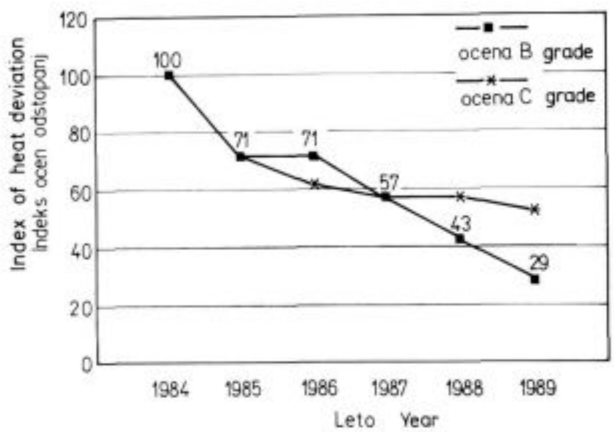
— foreman.

An error in steel hardenability i. e. the hardenability outside the specification range is followed all the way along. Usually each steel is analysed separately. Sometimes analogne steels are researched as a group of steels but for strictly development reasons, as the creation and application of prediction models showed that reliable models for a real heat-steel are based on data of one and the same grade. Detailed description is to be found later in this paper.

Hardenability quality grade analysis contains results of regular Jominy test data processing. Data processing delov napovedi se je pokazalo, da dobimo zanesljivejše modele za konkretno šaržo-jeklo, če je model izdelan samo iz podatkov enega jekla. Vendar več o tem kasneje. Analiza kakovostnega nivoja kaljivosti vsebuje rezultate obdelav podatkov rednih Jominy preizkusov. Prikazane so po oddaljenosti od kaljenega čela in podane tudi v odstotkih odstopanja od predpisa.

Posebno novost predstavlja uvedba ocenjevanja velikosti odstopanja od predpisa (12). Imenuje se ABC metoda in je podobna tisti, ki se uporablja pri ocenjevanju odstopanja kemične sestave. Vsak Jominy preizkus dobi po vnosu podatkov v računalnik oceno zadetja kaljivosti in sicer:

A — vse v mejah garantiranega pasu kaljivosti
B — manjša odstopanja od predpisa. To so odstopanja, ki so manjša od 10 % širine predpisa na posamezni globini. Oceno B dobi meritev za odstopanje na eni ali več globinah.
C — večja odstopanja od predpisa. To so odstopanja, ki so večja od 10 % širine predpisa na posamezni globini.



Slika 2
Spremljanje ocen odstopanj kaljivosti vseh aktualnih vrst jekel
Figure 2
Estimation of hardenability defects of all actual steel grades.

results show hardenability and deviations for all Jominy distances. The estimation of regulation deviation (12) is a special novelty. It is called ABC metod and is similar to the one used in estimation of misfits in chemical analysis. After the data are entered the hardenability of each Jominy testriments is valued as to its accuracy as follows:

A = within guranteed hardenability band.

B = insignificant deviations. These are differencies of less than 10 % of hardenability band with at a specific Jominy distance.

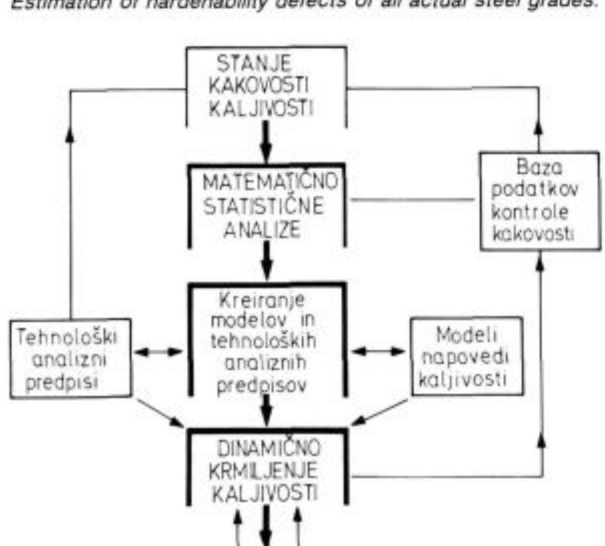
C = major deviations: these differences exceede 10 % of the hardenability band at a specific Jominy distance.

Hardenability level change tracking in each individual and all steels together during certain periods is made exacter by the ABC method of valuation. The guaranteed hardenability of each steel is subject to several national and customer specifications. In quality, in the course of time they become more uniform. Therefore the ABC classification of the required hardenability has to be done for each order separately and in agreement with the customer. Thus one of the ABC estimation is reached.

*The regular data processing results could be shown as a graph as shown in **Figure 2.***

***Figure 2** shows an extremely satisfying trend of B or C marked heat appearance reduction. To prove this the year 1984 was compared to the following years up to 1989. 1984 was indexed with 100. Results show the heats improved for 2—3 times. It is evident the improvement can only be obtained by continuous striving to improve the insurance of hardenability quality.*

*The model of the development information system of continuous control and improvement of steel hardenability as a whole is shown in **Figure 3**. It consists of four basic operational and program packages connected to each other and logically following each other according to circle principle of introducing the product or process quality improvement.*



Slika 3
Računalniška podpora zagotavljanju kaljivosti jekla

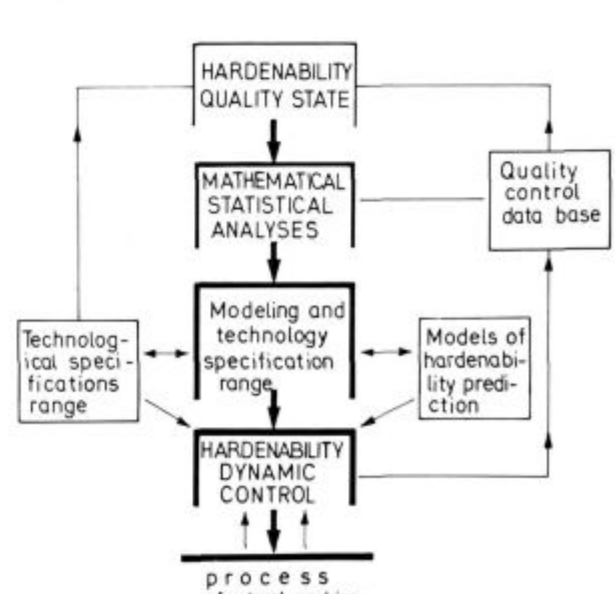


Figure 3
Computer aided steel hardenability assurance.

Ocenjevanje po metodi ABC nam omogoča objektivnejše spremljanje spremembe nivoja zagotavljanja kaljivosti posameznega jekla in vseh jekel skupaj po primernih časovnih obdobjih.

Za posamezno jeklo obstajajo različni državni in kupčevi predpisi zagotovljene kaljivosti. V letih se spreminjajo v smeri zahtevnejše, enakomernejše kakovosti. Zato je v odvisnosti od posameznega naročila in kupčevih zahtev potrebno takoj opredeliti, ali je pri jeklu dosežena zahtevana kaljivost. Torej dobi eno od ocen A, B ali C.

Dobljene rezultate rednih obdelav podatkov prikazujemo tudi na računalniku v grafični obliki, kot to kaže **slika 2.**

Na sliki 2 vidimo izrazito ugoden trend zmanjšanje deleža šarž z oceno B in C. Kot osnovo vzamemo leto 1984 z indeksom 100. Vsako leto se je stanje izboljšalo. Skupaj se je do leta 1989 stanje izboljšalo dvakrat do trikrat! Očitno se takšen rezultat ne doseže z enkratno akcijo, temveč s kontinuirnim prizadevanjem za izboljšanje kakovosti zagotavljanja kaljivosti.

Shema celotnega razvojnega informacijskega sistema kontinuirnega obvladovanja in izboljševanja kaljivosti jekla je prikazana na **sliki 3.** Vsebuje štiri osnovne delovne in tudi programske sklope, ki so med sabo povezani in si logično sledijo po principu kroga uvajanja izboljšave kakovosti izdelka ali postopka.

3. METODE OBVLADOVANJA KALJIVOSTI JEKLA

3.1 Uporaba tehnoloških analiznih predpisov in matematično-statističnih analiz

Računalniški model napovedi kaljivosti temelji na nelinearnih regresijskih enačbah. Med jekli in globinami Jominy preizkusa upoštevamo različne vplive kemičnih elementov. Primer spreminjanja koeficienta determinacije za jeklo C 44732 vidimo na **sliki 4.** Med 20 in 35 mm dobimo razmeroma visok koeficient determinacije, približuje se 0,80, vendar pri 40 in 50 mm zopet pade.

Osrednja značilnost računalniškega modela kaljivosti je v tem, da imamo zaradi izboljšanja točnosti napovedi za vsako jeklo poseben model. V raziskovalne namene pri iskanju splošnih zakonitosti sorodnih jekel združujemo in dobimo grupni model.

Model napovedi trdote na posamezni globini Jominy preizkusa lahko prikažemo grafično z nomogrami vpliva variacij kemičnih elementov na trdoto. Slaba stran nomogramov je v tem, da je potrebno veliko časa za izdelavo. Še večji problem je nepreglednost pri večjem številu kemičnih elementov v enem diagramu.

Sistematične regresijske analize in preverjanje rezultatov v praksi nas vodijo k vse točnejšemu modelu napovedi kaljivosti in vse manjšim odstopanjem od zagotovljene kaljivosti, to je k boljšemu obvladovanju kakovosti jekla.

Napoved kaljivosti jekla na osnovi kemične sestave predstavlja najpomembnejši del napovedi kaljivosti, vendar je v praksi toplotne obdelave treba upoštevati še druge tehnološke dejavnike, kot temperaturo avstenitizacije in popuščanja. Osnovni sistem kaljivosti jekla predstavlja Jominy poizkus in metodologija pasov zagotovljene kaljivosti.

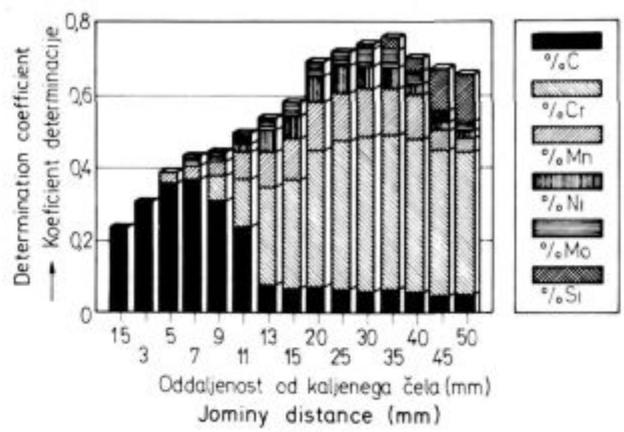
Za izboljšanje doseganja zagotovljene kaljivosti s pomočjo tehnoloških (internih) analiznih predpisov je značilen dvostopenjski postopek:

1. — zoženje porazdelitve kemične sestave in kaljivosti z uporabo procesnega računalnika pri legiranju jekla,
2. — centriranje porazdelitve kaljivosti v sredino pasu.

3. STEEL HARDENABILITY CONTROL METHOD

3.1. Use of Technological Chemical Specification Range and Mathematical-Statistical Analyses.

The computer model of hardenability prediction is based on nonlinear regression equations. The steel grades and Jominy distances are affected by chemical elements. ***Figure 4*** *shows an example of Č.4732 steel determination coefficient change. At the distance between 20 and 35 mm the determination coefficient is relatively high approaching number 0,80; at the distances of 40 and 50 mm it is lower again.*



Slika 4
Vpliv kemičnih elementov na kaljivost jekla C 4732

Figure 4
Effect of chemical elements on Č.4732 steel hardenability.

The most important characteristic of the computer aided hardenability model is that for each grade a specific model is created which is due to improved accuracy of prediction. When looking for general characteristics for research the similar grades are groupped together building a group model. The model of hardenability predicton in each specific Jominy test distance can be presented graphically by nomograms of effects the chemical elements have on hardness. But the nomograms show a weakness which lies in their time consuming preparations. Even more problematic is lack of clearness when one diagram consists of numerous chemical elements.

Systematic regresion analyses and result checks make the hardenability prediction model improve in accuracy and guaranteed hardenability deviations decrease; this means an improved quality control assurance.

The most significant part of hardenability prediction is the hardenability prediction based on chemical composition yet heat treatment has to consider other technological parameters such as the austenitisation and tempering temperatures. The Jominy test and the methodology of guaranteed hardenability bands represent the basic system of grade hardenability.

To improve the guaranteed hardenability attainment by technological chemical specification range the following two-step process is to be performed:

1. *Narrowing of chemical elements distribution and hardenability by process computer during alloying.*
2. *Move of hardenability distribution to the band center. When prediction model is reliable the first step could be omitted and the process started at step 2. In doing so the process is statistically controlled.*

Pri zanesljivih modelih napovedi lahko pristopimo takoj k drugi stopnji, to je centriranje porazdelitve kaljivosti. Pri tem dosežemo, da je proces statistično nadzorovan.

3.2 Računalniški model napovedi kaljivosti

Programski paket napovedi kaljivosti za kontrolo kakovosti (HARD-QC) je potreben za zanesljivejše doseganje zagotovljene kaljivosti, raziskave, tehnologom toplotne obdelave, konstrukterjem in uporabnikom jekla. Sestavljen je iz dveh programov.

Prvi je namenjen vnosu, spreminjanju in izpisovanju modela napovedi kaljivosti posameznega jekla.

Drugi program vsebuje vrsto funkcij in ima obširen osnovni menu, kot to kaže **slika 5.**

MENU

1-Napoved Jominy krivulje trdot
2-Napoved trdot po preseku kaljene palice
3-Napoved kritičnih trdot in premerov
4-Napoved trdote in prevojne točke J-krivulje
5-Napoved Ms točke in premenske točke Ac3
6-Risanje pričakovanega območja kaljivosti za analizni predpis
7-Risanje pričakovane Jominy krivulje kaljivosti
8-Risanje pričakovane 'U' krivulje kaljivosti
9-Izpis predpisane kaljivosti in teh. analiznega predpisa
K-Konec (ali pritisk na tipko RETURN)

Slika 5
Primer osrednega menuja programa HARD-QC za napoved kaljivosti

Povezovanje trdote, izmerjene na Jominy preizkušancu (J-krivulja), in trdote, dosežene pri kaljenju v praksi po preseku različnih izdelkov (U-krivulja), dosežemo na osnovi enakih hitrosti ohlajevanja. J-krivulje se lahko pretvorijo v U-krivulje, grafično s pomočjo nomogramov ali neposredno s pomočjo računalnika, kot je to rešeno s programskim paketom HARD-QC.

3.3 Krmiljenje kaljivosti v procesu izdelave jekla

Pristop k neposrednemu krmiljenju kaljivosti v procesu izdelave jekla v elektro jeklarni temelji na preprečevanju in odpravljanju vzrokov neprave kaljivosti pri izvoru. To je eden od osnovnih principov tudi znane japonske metode POKA YOKE (11).

Brez dvoma ima kemična sestava odločilen, ne pa edini vpliv na kaljivost. Zato je pravi čas in mesto reguliranja kaljivosti jekla v procesu izdelave jekla, ko je še mogoče spreminjati kemično sestavo šarže.

Sedaj že konvencionalni postopki uporabe računalnika v fazi legiranja se dopolnijo z modelom krmiljenja kaljivosti. Takšni modeli imajo predvsem nalogo:

— preveriti, ali je kemična sestava taline takšna, da je mogoče doseči načrtovano kaljivost, in če ni,

— izvrši korekturo permanentnih ciljev kemične sestave jekla v nove dinamično postavljene cilje.

Nujnost korekture načrtovane sestave pride v poštev yedno, kadar odstopajo vplivni oligoelementi in če ima eden ali več vplivnih legirnih elementov previsoko vsebnost že pred končnim legiranjem.

Dinamična sprememba načrtovane kemične sestave je večstopenjska. Najprej izračunamo novi cilj za cenejše legirne elemente, in če to še ni dovolj, poiščemo nove

3.2. Computer Model of Hardenability Prediction

The program package of hardenability prediction for quality control (HARD-QC) is necessary for reaching of more reliable guaranteed hardenability. Such program packages are necessary for researches, for hot working; technicians, mechanical engineers and steel consumers. They consist of two programs.

The first one is used for entering, changing and printing of the hardenability prediction model for each individual steel grade. The second program contains numerous functions and an extensive basic menue as shown in ***Figure 5.***

MENUE

1- Jominy hardness curve prediction
2- Hardness along quenched rod cross section prediction
3- Critical hardnesses and diameters prediction
4- Hardness and turning point of J-curve prediction
5- Ms point and Ac3 transition point prediction
6- Drawing of expected hardenability area for analysis specification
7- Drawing of expected Jominy curve of hardenability
8- Drawing of expected "U" curve of hardenability
9- Print of hardenability and techn. specification
K- End (push button RETURN)

Figure 5
Sample of main menue of HARD-QC program for hardenability prediction.

The hardness estimated on a Jominy sample (J curve) and the one reached on the cross-sections during quenching (U curve) can be compared to each other when they are cooled by the same means. J curves can be turned into U curves graphically by nomograms or directly by computer e. g. by program package HARD-QC.

3.3. Hardenability Control in Steel Making Process

Application of direct hardenability control in the steel manufacture process in an electric steel plant is based on prevention and abolishment of incorrect hardenability at the source. This is one of the basic principles of the well known Japanese method called POKA JOKE (11).

Chemical composition affects hardenability in an essential yet not the only way. Thus the steel hardenability has to be regulated during the steel making process while melt is still able to change in chemical composition.

To the computer proceedings controlling the alloying phase (which have already become conventional) the hardenability control model is added. The task of such models is the following:

— to check the chemical composition in capability of producing the aimed hardenability and if not;

— to supplement the permanent chemical composition of steel with dynamic one. Correction of aimed composition is necessary when an appearance of deviation in the effective accompanying elements is present or the contents of one or more of these alloying elements are too high in the preliminary sample.

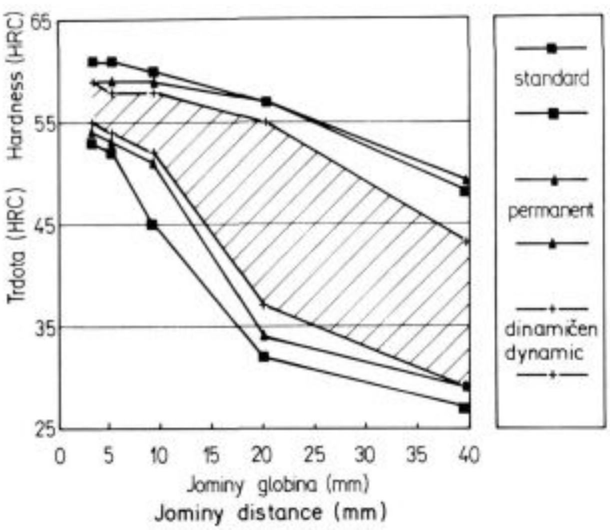
The change in dynamics of the aimed chemical composition consists of various steps. A new aim for the cheaper alloying elements is calculated first. If this proves insufficient, aims for more expensive alloying ele-

cilje še za dražje legirne elemente. Skratka, prednost ima takšna sprememba ciljev, da so stroški legiranja v okviru možnosti čimnižji. Pri tem seveda ne smejo poslabšati druge lastnosti jekla.

4. REZULTATI IN ZAKLJUČKI

Že na sliki 2 vidimo ugoden trend izboljšanja kakovosti kaljivosti jekla. Zanesljivost doseganja zagotovljene kaljivosti je iz leta v leto boljša (12). To dokazujejo tudi tri naslednje slike.

Slika 6 prikazuje primerjavo med uporabo permanentnega in dinamičnega modela kaljivosti. Vrisano je območje 95 % statistične zanesljivosti. Kljub temu, da je delež šarž zunaj zagotovljene kaljivosti razmeroma nizek, želimo, da je še nižji. Dolgoročni končni cilj je že omenjeni »ZERO DEFECT«. Na **sliki 7** vidimo kontinuirano izboljševanje stanja deleža šarž zunaj zagotovljene kaljivosti. Stanje v letu 1984 smo postavili kot indeks

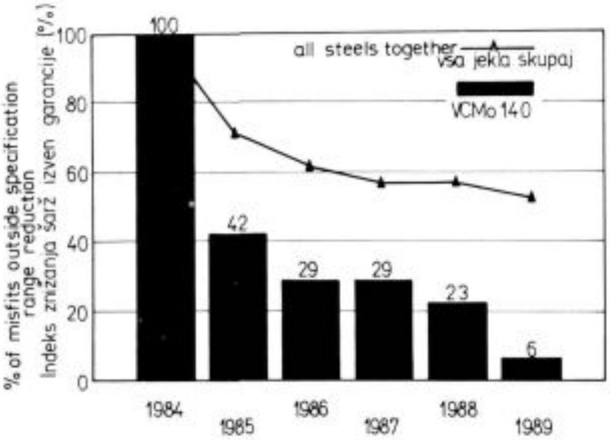


Slika 6

Primerjava rezultatov uporabe permanentnega in dinamičnega modela napovedi kaljivosti jekla

Figure 6

Results of permanent model on steel hardenability prediction compared with a dynamic one.



Slika 7

Indeks znižanja deleža šarž zunaj mej zagotovljene kaljivosti

Figure 7

Reduction index of heats outside of guranteed hardenability.

ments are calculated. From there result reductions in alloying costs, while the steel properties must be correct.

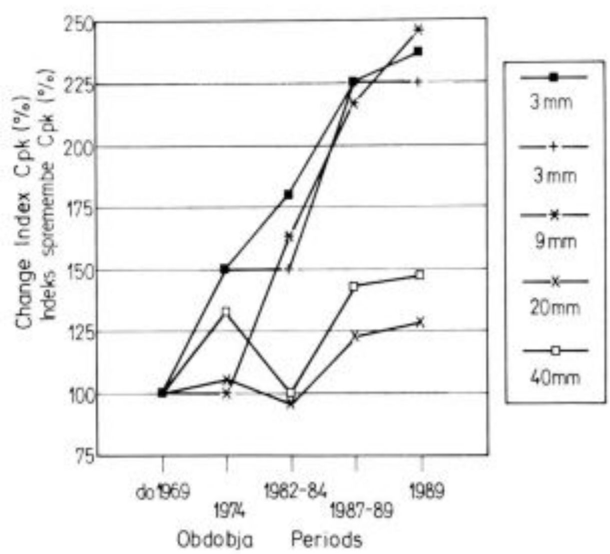
4. RESULTS AND CONSLUSIONS

Figure 2 is the first to show the trend of steel grade hardenability quality towards improvement. From year to year the attainment of guaranteed hardenability quality is improved (12).

This is proven by the following three Figures.

Figure 6 *shows the application of the permanent hardenability model compared to the dynamic one, and a range of 95 % statistic probability. The share of changes outside the guaranteed hardenability is low though, the final effect striven for is "ZERO DEFECT" as mentioned.* ***Figure 7*** *shows a continuous reduction of melts outside the guaranteed hardenability range. The year 1984 was attached the index 100. Within a few years it diminished to 50. Some steels such as e.g. Č.4732 lowered their index to 6.* ***Figure 8*** *shows the improvement on Cpk process capability. If the year 1969 is alloted the index 100 the improvement of Cpk is clearly seen in the following years with better results at shorter distances.*

Thus it can be concluded that good results are obtained by continuous striving for hardenability quality. In the alloying process aided by a standard process computer even better results are attained by the application of the dynamic model. Useful for quality assurance of real hardenability of steel are the technological chemical specifications ranges obtained by specific proceedings. Computer aid is necessary in quality control assurance, mathematical statistical analyses, preparation of a hardenability prediction model and directly in the steel making process.



Slika 8

Indeks izboljšanja koeficienta sposobnosti procesa Cp pri jeklu Č 4732

Figure 8

Improvement index of CP process ability coefficient in Č.4732 steel.

100. Stanje se je izboljšalo na indeks 50. Pri posameznih jeklih, npr. C 4732, se je indeks znižal s 100 na 6! Tudi koeficient sposobnosti procesa Cpk se izboljšuje **(slika 8).**

Če postavimo stanje leta 1969 na indeks 100, vidimo, da je izboljšanje Cpk v naslednjih letih prepričljivo. Vendar so boljši rezultati doseženi pri manjših globinah.

Zaključimo lahko, da dajejo dobre rezultate kontinuirana prizadevanja za boljšo kakovost kaljivosti. Še posebej dobre rezultate daje uporaba dinamičnega modela napovedi kaljivosti v procesu legiranja ob standardni uporabi procesnega računalnika. Še posebej v okviru zagotavljanja prave kaljivosti jekla je v praksi koristna uporaba tehnoloških analiznih predpisov, do katerih pridemo po določenem postopku. Uporaba računalnika je potrebna pri spremljanju kakovostnega nivoja, matematično-statističnih analizah, pripravi modela napovedi kaljivosti in še posebej neposredno v procesu izdelave jekla.

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