*Digitalni računalniki v proizvodnji jekla**

Digital Computers Applied to Steelmaking

UDK: 669.669.168.1.B1,65.011.51
ASM/SLA: U4k, X14, D5, A5f, 1—5h, 18—74

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Računalniška tehnologija je danes razvita veliko bolj, kot bi to lahko sklepali po uporabi računalnika v proizvodnji jekla. Poskušali smo analizirati današnjo uporabo aparaturne računalniške opreme in računalniških sistemov v proizvodnji jekla. Za primer smo vzeli vodenje elektropeči in peči z uporabo kisika (LD, BOF, AOD in Q — BOP). Rezultati krmilnih sistemov v teh procesih kažejo, da je računalnik postal sestavni del proizvodnega procesa v jeklarni.

The presently available computer technology far exceeds its level of application to steelmaking processes. An analysis is given of the application of computer hardware and operating systems to steelmaking environments. Control of electric furnace and oxygen (LD, BOF, AOD and Q-BOP) steelmaking processes are used as examples. Results given of control systems applied to these processes show that the computer has become an integral part of steelmaking.

UVOD

Prvotno smo uporabljali računalnike v primerih, ko je bila periferna in osrednja računalniška oprema ter programska oprema neprimerna za razpoložljivi tehnološki nivo procesa. Danes pa lahko mirno trdimo, da se je računalniška tehnologija razvila do take mere, da ni več izrabljena v zadostni meri. S skrbno analizo in uvedbo te računalniške tehnologije v krmilni sistem lahko proizvajalec jekla prihrani precej stroškov. V tem sestavku bomo spregovorili o načrtovanju in razvijanju krmilnih sistemov za kisik in proizvodnjo jekla v električnih pečeh.

JEKLARSKO OKOLJE

Zaradi vročine, vlažnosti, prahu in drugih problemov, s katerimi se srečujemo med proizvodnim procesom, je okolje v jeklarni zelo neprimerno za elektronske instrumente.

V preteklosti smo elektronske instrumente, npr. digitalne računalnike, skušali izolirati znotraj jeklarne, vendar je taka oprema uspešno delovala le zelo kratek čas. Danes želimo računalniško opremo namestiti v prostoru, ki je ločen od jeklarne, ter prenašati signale iz jeklarne v računalnik s koaksialnim kablom.

Na sliki 1 vidimo shematiziran razpored prostorov, ko smo računalniško opremo namestili

* Referat na jeklarskem dnevu XXIV. strokovnega posvetovanja 6. oktobra 1978 v Portorožu.

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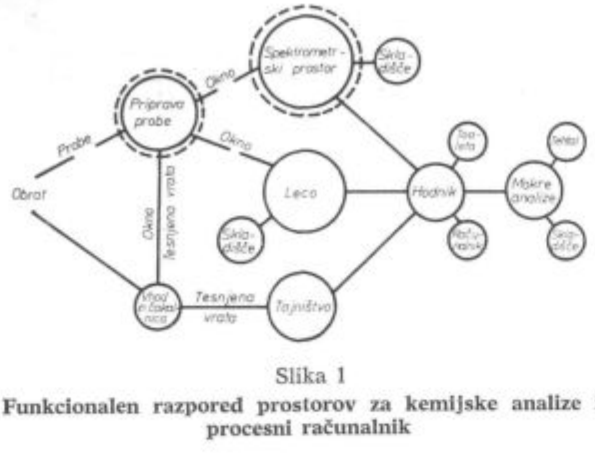
INTRODUCTION

In the early days of process control in steelmaking areas, applications were attempted where the environment, computer hardware, and/or operating software for the computer exceeded the available technology. Now it can be safely said that computer technology exceeds the applications to which it is being placed in the steel industry. With careful analysis and implementation of this computer technology, the process control system can be the most cost effective tool the steelmaker can make available to his operation. This paper will go into the planning and the evolution of process control systems for oxygen and electric furnace steelmaking.

STEELMAKING ENVIRONMENT

Due to the hot, humid, conductive dust and other environmental problems that are encountered, the steelmaking facility is very destructive to the operation of electronic instrumentation. Past attempts of isolating electronic instrumentation, i. e., digital computers within the steelmaking environment, have usually led to a minimum time of successful operation of the equipment. The present trend is to place the computer equipment separate from the meltshop and telemeter the signals from the meltshop area to the computer by coax cables.

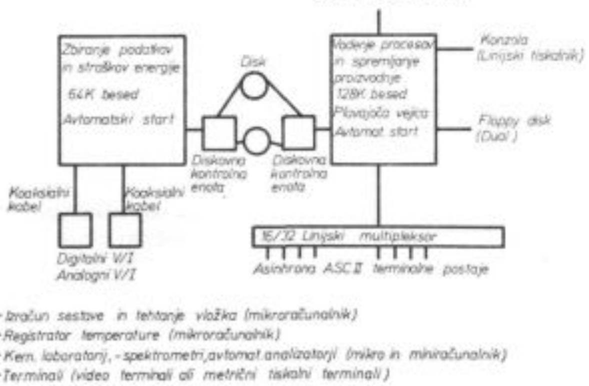
Figure 1 shows such an installation where the computer equipment has been placed in the same building, next to the meltshop, within the area that is also used for analytical analysis. This installation is contained within the meltshop but is



Slika 1
Funkcionalen razpored prostorov za kemijske analize in procesni računalnik

v stavbo poleg jeklarne, in v prostoru, ki ga uporabljamo tudi za kemijske analize. Računalnik se tako nahaja v sami jeklarni, vendar je izoliran od neposrednega okolja s tem, da ima osebje poseben vhod in izhod. Na ta način preprečimo, da bi jeklarniška atmosfera vstopila v zaščiteno atmosfero. Prostor za analiziranje je ločen od stebrov in opornikov jeklarne, tako da se v opremo za analiziranje in/ali računalniško opremo ne prenašajo tresljaji z žerjava itd. Preko ločenega klimatizacijskega sistema prihaja v prostor zunanji zrak, ki vsebuje minimalno količino prahu. Oprema je pred tokovnimi nihanji zavarovana z neprekinjeno oskrbo in stabilizirano energijo.

Kakor vidimo, lahko jeklarniško osebje vstopi v prostor z računalnikom le tako, da zapusti jeklarno in vstopi skozi vrata v zunanji steni jeklarne. Razen tega ima osebje dostop le do vhodnih pisarn in prostora za pripravo vzorcev in ima torej otežen dostop do prostora z opremo za kemične analize in računalnik. Vse to do skrajnosti zmanjšuje možnosti za prenašanje jeklarniške atmosfere v ta prostor. Poleg tega s takšno namestitvijo zagotovimo tudi dovolj prostora za osebje, ki dela z računalnikom ali upravlja aparature za kemijske analize.



Slika 2
Hierarhični sistem vodenja proizvodnje jekla

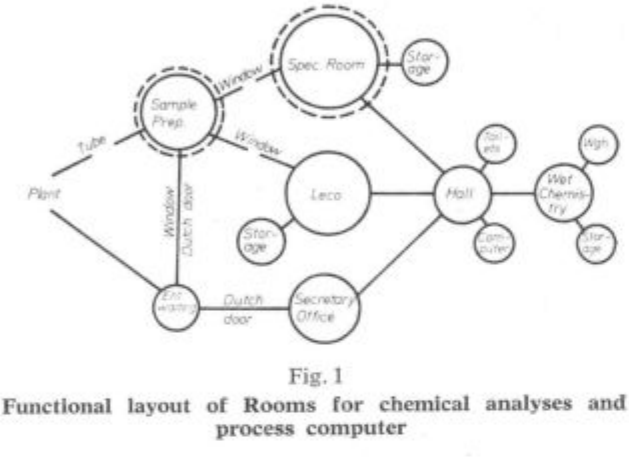


Fig. 1
Functional layout of Rooms for chemical analyses and process computer

isolated from the meltshop environment with personnel entry and exit external to the meltshop to assure that the meltshop environment does not enter the protected environment. The analytical facility is isolated from the columns and supports of the meltshop so that no vibration from cranes, etc., is transmitted to the analytical equipment and/or the computer facilities. A separate air conditioning system draws make-up air from outside of the meltshop, assuring that a minimum level of particles is in the incoming make-up air. The facility is isolated from variations in current in electrical power via an uninterruptible power supply. As can be seen, ability of meltshop personnel to enter this facility is only possible by going outside the meltshop facility and entering the door that is contained in the outer wall of the meltshop facility. Then the personnel are limited to entry ways, offices, and sample preparation facilities. It is extremely hard for operating personnel to get access to either the analytical and/or computer facilities. This minimizes any carrying of meltshop environment into the facilities. It also assures that the facility can and will be kept clean for the type of personnel that will be required to maintain both the analytical and computer facility.

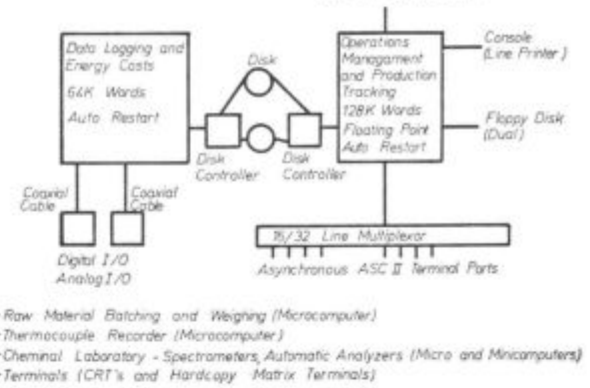


Fig. 2
Hierarchial Steelmaking Control System

Na sliki 2 vidimo hierarhični sistem za spremljanje proizvodnje, OPEN-LOOP TIME SHARING aplikacije, komunikacije med obema podsistemoma, terminali in obdelavo glavnih podatkov jeklarne. Ta sistem ima primaren in sekundaren spomin za rezervne datoteke. Operacijski sistem je »multi-task«, »interrupt level control«, lahko prenaša sporočila med terminali, istočasno dela več enakih ali različnih programov in v uporabi je več eksternih spominskih enot. Takšni sistemi so vedno na razpolago pri dobaviteljih miniračunalnikov.

Ta hierarhični sistem je uporaben za:
- krmiljenje proizvodnih procesov,
- komuniciranje z drugimi računalniki,
- vodenje materialnega poslovanja obrata,
- spremljanje proizvodnje in
- terminiranje proizvodnje.

Podsistemi so primarno bazirani na računalnikih, ki imajo samo spomin in zahtevajo zelo zanesljivo časovno odvisnost zaprtih zank v vodenju procesov. V takšno uporabo je vključena oprema za kemično analizo, tehtanje vložka, vodenje električne energije itd. Kadar je okolje čisto, postavimo računalniško opremo poleg procesa, ki ga vodimo. Če pa je okolje neprimerno, postavimo računalniško opremo v poseben prostor, signale pa preko koaksialnega kabla in multipleksorja povežemo z računalnikom.

V preteklosti so računalniške sisteme postavljali poleg procesa, ki so ga vodili, in to zato, ker je bilo potrebno zmanjšati stroške za kable. Z uvedbo oddaljenih vmesnikov, pri katerih se koaksialni kabel uporablja za prenos multipleksiranih signalov, pa postavitev računalnika ni več odvisna od proizvodnega procesa, ki ga želimo nadzirati. Na sliki 3 vidimo primer (takšnega) od računalnika oddaljenega vmesnika. Oddaljeni kabinet je odporen na industrijsko okolje. V tem primeru vsebuje vmesnik »multislote«, tako da kartice za digitalne in analogne signale sprejema in razporedi signale že v kabinetu. Na ta način lahko jeklarna izkorišča eno osrednjo lokacijo za računalnik in prenos analognih in digitalnih signalov različnih stopenj iz oddaljenega vmesnika, ki je z računalnikom povezana preko koaksialnega kabla.

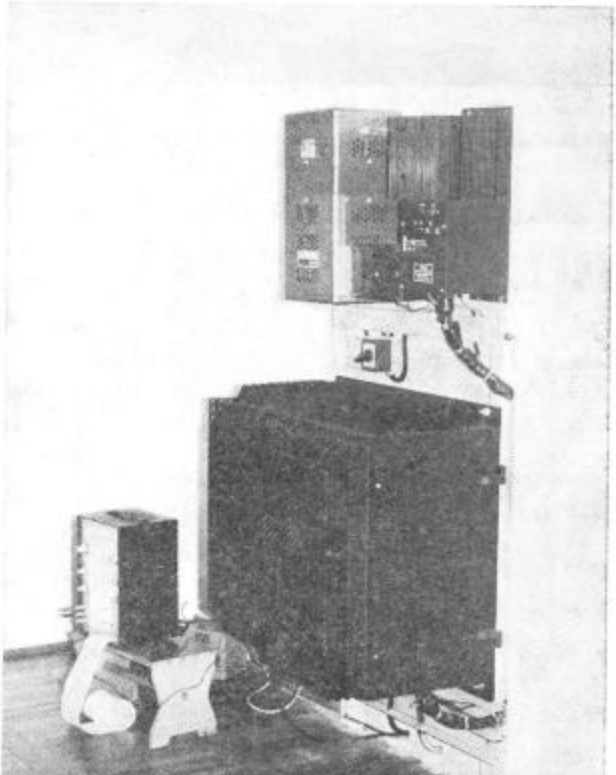
Terminale in konzole za izmenjavo sporočil med glavnim računalnikom in proizvodnim procesom so multipleksirani s standardnim asinhronim multipleksorjem ASC II. Pri razdaljah, ki so večje od približno 100 metrov, uporabljamo modeme, ki modificirajo in povišajo napetost signalov, tako da so med glavnim sistemom in njegovimi oddaljenimi terminali možne velike razdalje.

Video terminal na sliki 4 lahko namestimo kjerkoli v jeklarniškem okolju. Kontrolna enota za video terminal je tudi vključena v terminalski kabinet. Tastatura vsebuje komplet funkcijskih tipk, ki prenašajo asinhrone ASC II znake. Kot standardno dobavno opremo kontrolni enoti video terminala lahko uporabljamo funkcijsko

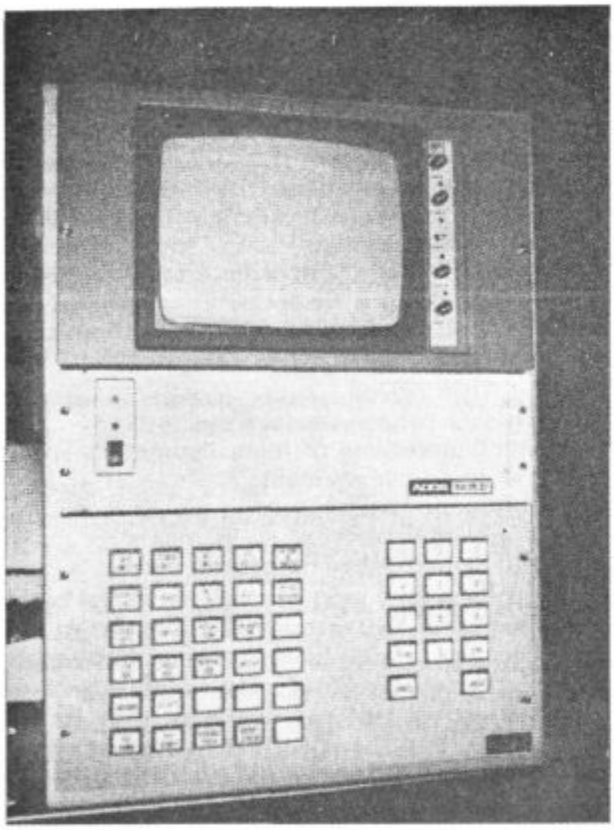
Figure 2 shows the type of hierarchial system that does the production tracking, open-loop time-sharing-type applications, and communications with both the subsystem, terminals, and the main data processing computer for the steel plant. This system has both primary memory and secondary memory for file maintenance. Its operating system is multi-task, interrupt level control, and able to support communication with multi-terminals, running multi-tasks at the same time, and driving multi-storage devices. Such operating systems are currently available from a wide-range of minicomputer suppliers. Applications that would be run on this system are:

- process control models
- communications to other computers
- materials management
- inventory control
- production tracking
- production scheduling

The subsystems are primary memory based only computers that require high reliability on time-dependent, closed loop, process control applications. These types of applications include



Slika 3
Oddaljen industrijski vmesnik
Fig. 3
Remote industrial I/O Interface



Slika 4
Industrijski video terminal NEMA 12 s funkcijskimi tipkami
Fig. 4
Industrial CRT in NEMA 12 Cabinet with functional panel

in/ali običajno tastaturo. Za funkcijsko tastaturo je potreben samo en priključek. Dešifriranje ASC II številk se izvrši »softwaresko« v računalniškem programu. Na ta način spremenimo tipke tako, da enostavno spremenimo primerjalno tabelo tipk in znakov, s čimer se program le mini-

Slika 5
Uporaba terminala z matričnim tiskalnikom v jeklarni
Fig. 5
Terminal with matrix printer in meltshop

running of analytical equipment for chemical analysis, weigh scale batching of materials, energy management control, etc. When the environment of the control function is clean, the computer mainframe would be located next to the equipment being controlled. When the environment is hostile, the equipment would be located within the computer room and the signals multiplexed into the equipment over coax cable.

In the past, computer systems have been located next to the process which they serve due to the desire to decrease cabling costs. With the advent of telemetered systems where a coax cable is used to multiplex multi-signals from a multiplexor back to a computer mainframe, the location of the computer became independent of the process. An example of such a multiplex arrangement is given in Figure 3. The remote cabinet is engineered to live within an industrial environment. The cabinet gin this case contains multislots so that boards for signals that are digital and analog can be intermixed within this cabinet. In this way, the steel plant can utilize one central location to bring analog and digital signals of various levels to the remote telemetering device. From the remote telemetering device, the coax cable is run to the computer facilities.

Terminals and consoles for communications between the main computer and the process are multiplexed through the standard, asynchronous, ASCII multiplexor. When the distances are greater than approximately 100 meters, modems are used to modify and boost the signals so that greater distances can be maintained between the main system and its remote terminals. The CRT shown in Figure 4 is suitable to be located any place within a steelmaking environment. The CRT screen is contained with a NEMA 12 CABINET. The controller for the CRT panel is also contained within the cabinet. The panel is actually a set of function keys that transmit asynchronous ASCII characters. In this way, the standard port on the CRT controller can be used for either the panel and/or a normal keyboard. Only one port is required for the CRT with operating panel. All decoding of the ASCII characters is done at the task level within the software of the computer. This makes changing of keys simply changing the keycap in lettering along with a minimum change to software. In this way, as changes are required during the implementation and evolution of the control system, they are easily accommodated through the specialized design control consoles.

With the advent of matrix printers, the ability to put hardcopy printers out in the meltshop environments has increased. Less problems with maintenance of previous mechanically-complex terminals has been experienced. Figure 5 shows such a terminal in operation in a melt-shop environment. These terminals are low-maintenance, high-speed, and of minimum cost.

malno spremeni. Kadar so med uvajanjem in razvijanjem kontrolnih sistemov potrebne spremembe, jih dosežemo s specializirano obliko konzole.

Z uvedbo matričnega tiskalnika se je povečala možnost uporabe tiskalnih terminalov v jeklarni. Pri vzdrževanju nove vrste terminalov je manj težav. Slika 5 prikazuje takšen terminal, ki deluje v topilniškem okolju. Ti terminali so hitri, poceni in enostavni za vzdrževanje.

Razvoj računalniške tehnologije in možnosti, ki smo jih s tem dobili za kontrolo proizvodnih procesov, je spremljalo 25—30 % letno znižanje stroškov. Največ stroškov in dela imamo še vedno z razvojem programske opreme za računalnike.

VODENJE KISIKOVEGA POSTOPKA IZDELAVE JEKLA

Na sliki 6 smo prikazali načrt aparaturne opreme računalnika za celoten sistem konvertorskega postopka. Takšna razporeditev aparaturne opreme je primerna za vse vrste uporabe, ki smo jih navedli v tabeli 1.

Zaradi vmesnikov in terminalov lahko ta sistem zasleduje in sprejema vse primarne informacije o proizvodnji s področja konvertorske izdelave jekla. Te informacije sistem nato posreduje osrednjemu računalniku jeklarne. Skrajšan je čas ponavljajočega se prenosa podatkov kemijskih analiz in proizvodnih podatkov med različnimi deli jeklarne in s tem čas od preboda do preboda šarže. Prvotno je izračun sestave vložka z materialnega in toplotnega stališča usmerjen v to, da se dobi več šarž že v prvi fazi v predpisanem območju.

Zaradi upoštevanja boljših korelacij učinka kemične sestave žlindre na življenjsko dobo opeke za obzidavo so novejši modeli izračuna sestave vložka vključili te korelacije, s čimer smo podvojili in potrojili življenjsko dobo za obzidave. V zadnjem času je postalo že običajno, da ena obzidava zdrži od 500 do čez 2000 šarž.

The advances in computer technology and capabilities available for process control have been accompanied by a compounded 25 percent decrease per year in cost. The majority of cost and effort is increasingly in application software development.

OXYGEN STEELMAKING CONTROL

The hardware configuration for complete oxygen steelmaking control system is given in Figure 6. This hardware configuration will support the applications listed in Table 1. Due to the interfaces and terminals included, all primary production information from the oxygen steelmaking area would both be tracked and captured by this system. The system would then communicate it to the central computer for the steel works. The rapid communications of chemical analysis and operating data between the different parts of the oxygen steelmaking shop results in taking minutes off the tap-to-tap time for the steelmaking facility.

Early charge design calculation models were developed to bring more heats into carbon and temperature specifications at first turn-down from a material and thermal (thermochemical) standpoint. With the inclusion of better correlations of the effect of slag chemistry on refractory lining life, recent charge design models have included these correlations and have resulted in doubling and tripling the refractory life on oxygen vessels. It is not uncommon to take an oxygen vessel lining life from 500 heats to over 2,000 heats per lining. Modern charge designs also include options for superheating of the scrap, desulfurization correlations, blowing trajectories, etc. Results of the charge design model can be utilized to predict the bath weight, chemistry and temperature at the end of oxygen blowing. Utilizing this information, ferroalloys can be calculated and prebatched with the final trim being made when a spectrographic

Slika 6
Sistem vodenja konvertorja

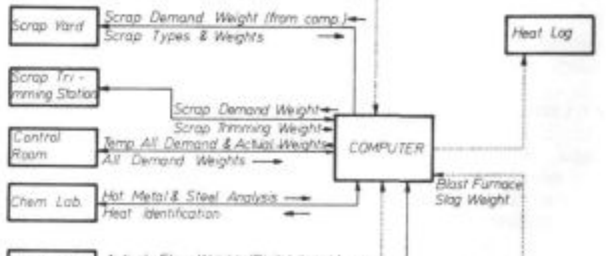


Fig. 6
BOF control system

Tabela 1: Krmilne funkcije in vsebina programov AUTO B. O. P. procesne kontrole

Krmilna in/ali programska funkcija	Opis
*Datoteka prakse	Tehnologija za posamezne vrste jekla.
*Izračun sestave vložka	Izračun primerne mešanice materialov za izdelavo željene teže, temperature in vsebnosti ogljika pri jeklu in željene kemijske sestave žlindre.
*Izračun dodatka ferolegur	Izračun najcenejšega dodatka ferolegur pri korekturi vsebnosti elementov v jekleni talini, za dosego končne kemijske sestave jekla.
Avtomatsko shranjevanje podatkov o šarži	Avtomatsko izpiše informacije o šarži, dobljene med izdelavo šarže.
Inštrumentacija kemijskih analiz	Priključitev inštrumentov, sekvenčna kalkulacija kemijske sestave in primeren prenos iz spektrometrov in inštrumentov dobljenih analiz v proizvodno področje.
Adaptacija vodenja	Adaptacija krmilnih funkcij pri napovedovanju, ki so dobljene na osnovi dejanskih rezultatov.
Prikazovanje in alarmiranje	Prikazovanje ključnih spremenljivk procesa in alarmiranje, ko so vrednosti izven normalnega dopustnega območja.
Podatkovna komunikacija z drugimi računalniki	V AUTO B. O. P. zajeti sistem informacij vodenja proizvodnje in naročil se lahko prenaša na drug računalnik.
Preverjanje mehanskih lastnosti	Preverjanje mehanskih lastnosti za dobljene kemijske sestave in nameravano obliko in dimenzijo proizvoda (natezna trdnost, kontrakcija itd.)
Analiziranje operativnih podatkov	Uporaba podatkov že izdelanih šarž za materialno in stroškovno bilanco (šaržo za šaržo).
Shranjevanje podatkov o dogodkih in zastojih	Shranjevanje podatkov o dogodkih in zastojih, tako kot so si sledili.
Preverjanje operativnih podatkov	Kontrola in dopolnjevanje operativnih podatkov ter operativnih funkcij pred prenosom podatkov na drug računalnik.
Evidenca odlitih ingotov	Evidenca ingotov po mestih skladiščenja v povezavi z materialnim poslovanjem.
Prikazovanje stanja v livni jami	Spremljanje in načrtovanje toplotnih pogojev v livni jami in prilagoditev proizvodnim zahtevam.
Nadzornik terminalov	Ta program obsega in ščiti vse komunikacije med terminali in načunalnikom. Beleži aktivnosti, daje možnost prenosa sporočil med terminali, prikazuje motnje na linijah in varuje operacijski sistem računalnika.

*Razpoložljiva s pomočjo odprtega TIME SHARING sistema

Table 1: Control Functions and programs Contained within the Auto B. O. P. Process Control System

Control Function and/or Programs	Description
*Practice File	The process constants which are placed on producing grades of metal.
*Charge Design Calculation	The calculation of a proper blend of materials to produce a specified weight, carbon and temperature, and a proper slag chemistry.
*Alloy Additions Calculation	The calculation of the least-cost alloy additions to be made to bring an analyzed metal bath to the final solidified steel grade specification.
Heat Summary Log	The summation via computer printout of the information generated during the production of the heat.
Instrumented Chemical Analysis	The instrument setup, sequencing, chemical composition calculation, and transmission to appropriate production area of chemical analysis obtained from spectrometers and instrumented analysis.
Adaptive Control	The using of the predicted versus the actual obtained results to adapt the control functions.
Monitor and Alarming	The monitoring of key process variables and the alarming when these variables are out of range.
Data Communication to Other Computers	The communication of the information captured within the AUTO B. O. P. system to other computer systems for production control and accounting purposes.
Physical Properties Verification	The verification that with the steel chemistry obtained and the intended product shape, the physical properties specification will be satisfied (tensile strength, elongation, etc.).
*Operating Data Analysis	The analysis of past heat information to determine material and cost balances on a heat-by-heat basis.
Event and Delay Log	The logging of delays and events as they occur.
Operating Data Verification	The checking and editing before releasing operating data to another computer system and/or function than operations.
Billet and Ingot Inventory	The tracking of billet and ingot inventories along with mapping of storage positions.
Soaking Pit Status and Monitoring	Tracking and mapping of the thermal conditions for the soaking pits and ingots in them. Firing control in pits to match production requirements.
Terminal Manager	This program captures and screens all communications between terminals and the computer. Activity accounting, interterminal messages, line noise monitoring, and system protection are handled by the terminal manager.

*Available through timesharing computer services on world-wide basis.

Moderni izračun sestave vložka vključuje tudi možnosti za predgretje starega železa, korelacije za odžveplanje, pihalne poti itd. S pomočjo teh informacij lahko računamo dodatek ferolegur, ki jih dokončno določimo, ko dobimo rezultate spektrografske analize prvega vzorca. V zadnjem času dobivamo vzorec proti koncu vpihavanja kisika z uporabo drugega kopja, da izključimo prvo fazo dela. Od temperature, vsebnosti ogljika, včasih pa tudi od koncentracije kisika je odvisno, kdaj je treba končati vpihavanje kisika, da bo imelo jeklo pravilno temperaturo in vsebnost ogljika.

Z uporabo drugega kopja smo pri vsaki šarži skrajšali čas od preboda do preboda za tri minute. Večina konvertorskih jeklarn vključuje danes procesne računalnike pri izračunu sestave vložka.

V zadnjem času uporabljamo miniračunalnike za merjenje količine žlindrinih dodatkov, ferolegur, registracijo temperature tako dobro kot za spektrometre. Z miniračunalniki smo zmanjšali obremenitev glavnega sistema ter omogočili posredovanje informacij v glavni sistem z ASC II asinhronsko podporo. Zaradi tega ne potrebujemo več digitalnih in analognih I/O, obenem pa smo zmanjšali tudi potrebo po posebnih upravljavcih.

AVTOMATIZIRANJE ELEKTRIČNE PEČI

V zadnjem času se avtomatizira vse več električnih peči. Običajno avtomatiziramo manjša področja v procesu električnega pridobivanja jekla. Posebno izstopa avtomatizacija kemijskega laboratorija, izračun dodatka ferolegur ali vodenje električne konice. Le redki proizvajalci jekla so skušali integrirati celotni sistem (slika 7). Slika 2 prikazuje načrt aparaturne opreme računalnika za celotno vodenje proizvodnje, s katero bi lahko avtomatizirali vse funkcije iz tabele 2. Osrednji veliki sistem služi za krmiljenje porabe energije, zbiranje in shranjevanje podatkov iz procesa in v kemijskem laboratoriju. V zadnjem letu ali dveh smo ugotovili, da je primerno (zaradi boljše aparaturne in programske opreme računalnikov), da priključimo na osrednji sistem deset do dvajset terminalov za aplikacije, kot je materialno poslovanje. Ta vključuje dodatek ferolegur, optimalno izbiro jekla, sestavo vložka in nabavo surovin. Spremljanje in prikazovanje proizvodnje vključuje terminale in informacije, od tehtanja vložka do javljanja podatkov o litju šarže. Zbiranje, shranjevanje in prikazovanje podatkov lahko služi v centralnem sistemu za dajanje proizvodnih povratnih informacij jeklarne.

Z računalniškim izračunavanjem dodatka ferolegur v procesu električnega pridobivanja jekla se je razsipanje v končni kemični analizi zmanjšalo za polovico, število šarž z enim ali več zgrešenih elementov pa za tretjino (sl. 8).

analysis is obtained from the first turn-down sample. Recent developments have included the use of secondary lance to obtain a sample towards the end of an oxygen blow so as to eliminate the first turn-down step. The temperature, carbon indication, and sometimes oxygen concentration determine when the oxygen blow should be terminated and the steel will be at the proper carbon and temperature level. The use of secondary lance has cut as much as three minutes per heat off the tap-to-tap cycle.

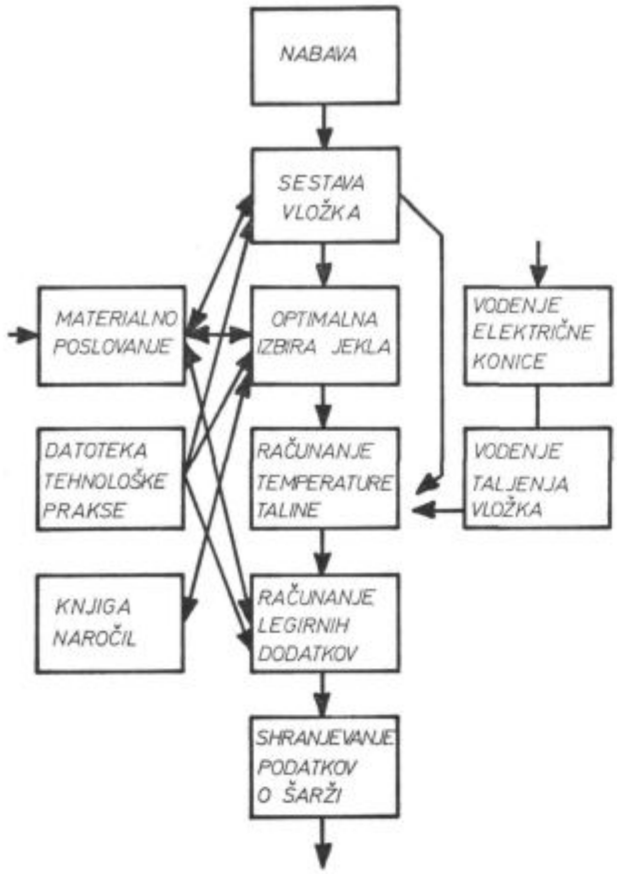
Most oxygen steelmaking jobs now include process control computers for the charge design calculation.

Recently, microcomputers have been applied to scales, flux and ferroalloy weighing systems, thermocouple recorders, as well as spectrometers. These microcomputers have both decreased the process control load on the main system and communicated the date captured to the main system via ASCII asynchronous ports. This eliminates previously used digital and analog I/O along with minimizing the special handlers required.

ELECTRIC FURNACE AUTOMATION

Increasingly, electric furnace shops are being automated. The normal approach, though, is to automate small areas within the electric furnace steelmaking operation. Typically selected for automation are chemical labs, alloy additions, or power demand requirements. Few have tried to integrate the complete system (Figure 7). Figure 2 shows a complete process control hardware configuration which would automate all the functions given in Table 2 of this report. The large central system would be used for energy management, process data logging, and chemical laboratory control. Within the last year to two years, it has become reasonable (because of hardware and operating software improvements) to hang ten to twenty terminals on the central system to do materials management type applications. Materials management includes alloy additions, optimum heat assignment, charge design, and purchasing models for raw materials. The tracking and production monitoring includes terminals starting at the receipt of raw materials through the laying down of the first cast. product. With the data logging and production monitoring information being fed back through the main central system, it is available to be transmitted then to the management information system of the steel plant.

In going to a computerized alloy additions calculation in electric furnace steelmaking, it has been found that the scatter in final analysis is cut to onehalf of its previous level and the number of heats with one or more elements out of specification are cut to one-third the previous level (Figure 8). Cost savings from computerized alloy additions result from:



Slika 7

Blok diagram za vodenje elektro peči

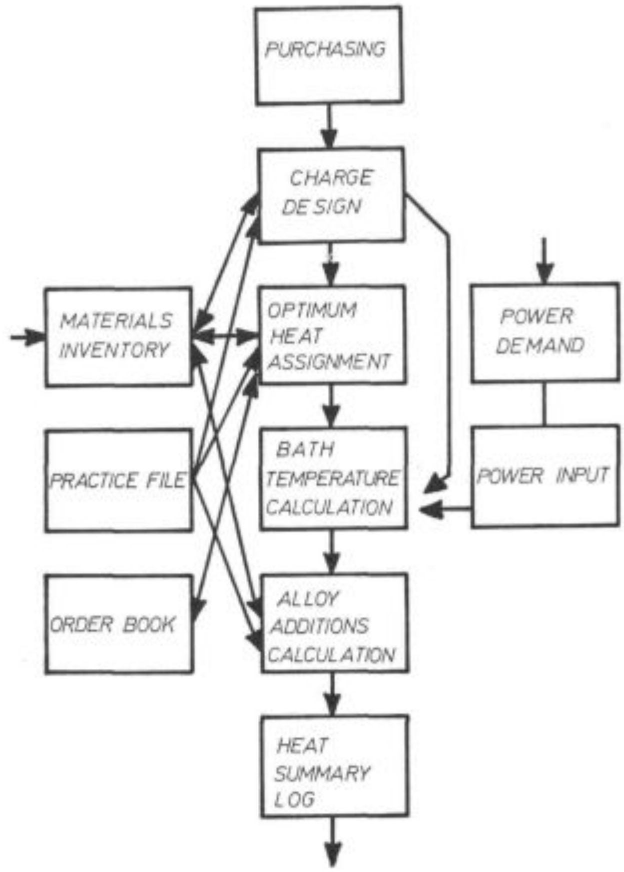


Fig. 7

Electric furnace control function flow diagram

Tabela 2: Krmilne funkcije in vsebina programov AUTO MET Process control system

Krmilna in/ali programska funkcija	Opis
*Model naročanja	Določitev optimalnih naročil za vložek, zaloge in pričakovanega nivoja proizvodnje.
*Knjiga naročil in preskrbe	Naročila za izdelavo in omejitve pri zaporedju izdelave jekel.
*Datoteka prakse	Omejitve kemijske sestave in dodatkov materialov za posamezne vrste jekla.
*Zaloge materialov	Zaloge materialov z opisom kemijskih in fizičnih značilnosti.
Spremljanje in rokovanje z materialom	Beleženje porabe materiala za preverjanje proizvodnje in spremljanje materialov v integralnem proizvodnem ciklusu.
*Izračun sestave vložka	Računanje najcenejše sestave vložka za izdelavo želene teže in kemijske sestave taline po raztalitvi vložka.
*Optimalna izbira naročila	Na osnovi knjige naročil, dadoteke prakse in razpoložljivih materialov določiti najprimernejše naročilo.
*Izračun dodatka ferolegur	Računanje najcenejšega dodatka ferolegur za izdelavo želene in predpisane končne kemijske sestave.

Table 2: Control Functions and Programs Contained within the Auto met Process Control System

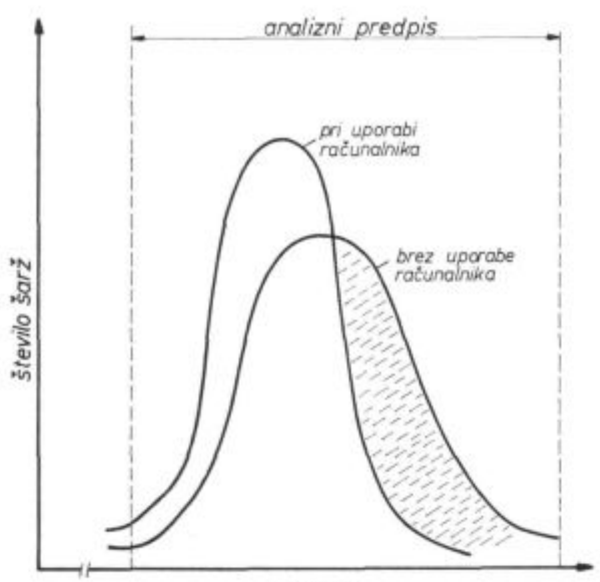
Control Function and/or Programs	Description
*Purchasing Model	Determining the optimum purchases based on raw materials market, inventory and anticipated production levels.
*Order Book and Providing	The orders to be produced and the restrictions upon the sequence in which they can be produced.
*Practice File	The chemistry and material constraints that are placed on producing grades of metal.
*Materials Inventory	The inventory of materials with their chemical and physical characteristics.
Material Handling and Tracking	The accounting of materials as they are committed to production and the tracking of materials as they are integrated into the production cycle.
Charge Design Calculation	The calculation of a least-cost blend of materials to produce a specified weight and chemistry after melting.
*Optimum Heat Assignment	The determination of the least-cost order to be fulfilled based upon the orderbook, practice file, and materials available.

Krmilna in/ali programska funkcija	Opis
Automatsko zbiranje in izpisovanje podatkov o šarži	Računalnik izpiše informacije o šarži, dobljene med izdelavo šarže.
Inštrumentacija kemijskih analiz	Priključitev inštrumentov, sekvenčna kalkulacija kemijske sestave in primeren prenos iz spektometrov in inštrumentov dobljene analize v proizvodno področje.
Računanje mehanskih lastnosti	Računanje in določitev ciljane kemijske sestave za izračun dodatka ferolegur na osnovi kemijske analize predprobe in želenih mehanskih lastnosti jekla.
*AOD kontrola	Postavitev vpihavanja in računanje dodatka materialov tekom AOD procesa.
Adaptacija vodenja	Adaptacija krmilnih funkcij pri napovedovanju, ki so dobljene na osnovi dejanskih rezultatov.
Automatsko raztapljanje vložka	Računanje potrebne energije in krmiljenje automatskega raztapljanja vložka.
Računanje temperature taline	Računanje in prikaz temperature taline hitrega ogrevanja in faze rafinacije.
Krmiljenje električne konične obtežbe	Krmiljenje porabe električne energije in to tako, da ne pride do prekoračitve dopustne porabe energije.
Prikazovanje in alarmiranje	Prikazovanje ključnih spremenljivk procesa in alarmiranje, ko so vrednosti izven normalnega dopustnega območja.
Podatkovna komunikacija z drugimi računalniki	V AUTO MET zajeti sistem informacij vodenja proizvodnje in naročil se lahko prenaša na drug računalnik.
Preverjanje mehanskih lastnosti	Preverjanje mehanskih lastnosti za dobljeno kemijsko sestavo in nameravano obliko ter dimenzijo izdelka (natezna trdnost, kontrakcija, žilavost itd.).
*Analiziranje operativnih podatkov	Uporaba podatkov že izdelanih šarž za materialno in stroškovno bilanco (šarža za šaržo).
Shranjevanje podatkov o dogodkih in zastojih	Kronološko shranjevanje dogodkov in zastojev.
Preverjanje operativnih podatkov	Kontrola in dopolnjevanje operativnih podatkov ter operativnih funkcij pred prenosom podatkov na drug računalnik.
Evidenca odlitih ingotov	Evidenca ingotov po mestih skladiščenja v povezavi z materialnim poslovanjem.
Prikazovanje stanja v livni jami	Spremljanje in načrtovanje toplotnih pogojev v livni jami za ingote. Vodenje ogrevanja v jami in prilagoditev proizvodnim zahtevam.
Nadzornik terminalov	Ta program obsega in ščiti vse komunikacije med terminali in računalnikom. Beleži aktivnosti, daje možnosti prenosa sporočil med terminali, prikazuje motnje na linijah in varuje operacijski sistem računalnika.

*Razpoložljivo s pomočjo odprtega TIME SHARING sistema

Control Function and/or Programs	Description
*Alloy Additions Calculation	The calculation of the least-cost alloy additions to be made to bring an analyzed metal bath to the final solidified steel grade specification.
Heat Summary Log	The summation via computer printout of the information generated during the production of the heat.
Instrumented Chemical Analysis	The instrument setup, sequencing, chemical composition calculation, and transmission to appropriate production area of chemical analysis obtained from spectrometers and instrumented analysis.
Physical Properties Calculation	The calculation of the aim points for alloy chemistry based upon the preliminary analysis of a molten bath.
*AOD Control	The setup of blowing cycle and calculation of materials addition during the AOD process.
Adaptive Control	The using of the predicted versus the actual obtained results to adapt the control functions.
Power Input Calculation and Control	The calculation of the required power cycle and its control.
Bath Temperature Calculation	The calculation and display of bath temperature during the super heat and refining cycle.
Power Demand Control	The control of energy usage so that it does not exceed a predetermined demand limit.
Monitor and Alarming	The monitoring of key process variables and the alarming when these variables are out of range.
Data Communication to Other Computers	The communication of the information captured within the AUTO MET system to other computer systems for production control and accounting purposes.
Physical Properties Verification	The verification that with the steel chemistry obtained and the intended product shape, the physical properties specification will be satisfied (tensile strength, elongation, etc.).
*Operating Data Analysis	The analysis of past heat information to determine material and cost balances on a heat-by-heat basis.
Event and Delay Log	The logging of delays and events as they occur.
Operating Data Verification	The checking and editing before releasing operating data to another computer system and/or other function than operations.
Billet and Ingot Inventory	The tracking of billet and ingot inventories along with mapping of storage positions.
Soaking Pit Status and Monitoring	Tracking and mapping of the thermal conditions for the soaking pits and ingots in them. Firing control in pits to match production requirements.
Terminal Manager	This program captures and screens all communications between terminals and the computer. Activity accounting, interterminal messages, line noise monitoring, and system protection are handled by the terminal manager.

*Available through timesharing computer services on world-wide basis.



Slika 8
Koncentracija legirnih elementov

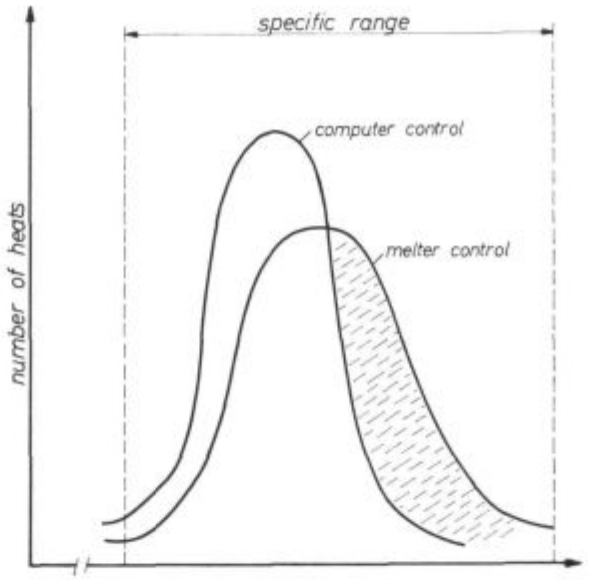


Fig. 8
Element concentration

Pri računalniškem določanju legirnih dodatkov prihranimo stroške, ker:

— dodajamo manjše količine legirnih elementov,

— pridobivamo elemente iz cenejših virov in

— izdelamo manj šarž slabše kvalitete, oz. izmečka.

Pri dodajanju legirnih elementov v ponev računamo, da bo efekt ohladitve pri dodatku ferolegur upoštevan pri temperaturi. Zaradi natančnejšega računalniškega določevanja končne kemične sestave in ker imamo na razpolago sredstva za izračunavanje enačb, ki so odvisne od kemične sestave, se vse več jeklarn z električnimi pečmi odloča za izračunavanje fizikalnih lastnosti materiala, da lažje določajo zaželeno končno kemično sestavo, ki zagotavlja zahtevane fizikalne lastnosti. Pri konstrukcijskih jeklih lahko na ta način izboljšamo natezno trdnost, pri jeklih za globoko vlečenje vlečne lastnosti, zadnje čase pa se tega poslužujemo tudi pri jeklih za cementiranje.

V jeklarnah z električnimi pečmi uporabljajo sorodne enačbe, kot se uporabljajo za izračun dodatka ferolegur, da bi pri tem raziskali korelacije fizikalnih lastnosti glede na kemično sestavo in zaželeni izdelek. Računalnik omogoča integriranje teh enačb istočasno z izračunavanjem količine dodatka ferolegur. S specifikacijo želenih legirnih elementov dobimo želene fizikalne lastnosti, obenem pa izbiramo tudi najcenejše dodatke.

Optimalna izbira jekla temelji na kemični analizi po raztalitvi vložka in je povezana s knjigo naročil ter daje najboljše naročilo pri danih omejitvah jeklarne.

Ugotovimo lahko, da kemične sestave ni mogoče vnaprej natančno določiti iz izračuna sestave vložka. Zaradi ogljika in variiranja ostalih

— adding less pounds of the alloying elements

— obtaining the elements from cheaper sources

— less missed and/or downgraded heats

When adding alloys in the ladle, the chilling effect of the ferroalloys is also calculated to come up with a temperature to tap the heat from the furnace. With the narrowing and positioning of the final chemistry more exactly under computerized control and the availability of a device that can calculate equations dependent on chemistry, more and more electric furnace meltshops are including calculations on physical properties of materials so as to modify their final aim chemistry to obtain specific physical properties. We have seen this happen in structural steels to obtain tensile strengths, in deep drawing steels to obtain drawability indices, and now in case hardening steels.

Electric furnace meltshops are now using the same equations that the alloy development group used to develop the correlations of physical properties vs. chemistry and product desired. The calculating power of the computer allows these equations to be integrated at the same time that the calculation for the amount of each additions is being calculated. By modifying the aim points of the added elements, specified desired physical properties are obtained along with the cheapest cost additions.

Optimum heat assignment is taking the meltdown chemistry and integrating the orderbook to determine the best order to be filled with the meltdown chemistry and the constraints of the meltshop. This approach is realizing that the meltshop chemistry is not totally predictable from the charge design calculation. The variations in residual elements and carbon will cause the prespecified grade to be more expensive to make than elementov je izdelava predvidene vrste jekla dražja kot morda izdelava druge vrste jekla ali naročila iz načrtovane proizvodnje. Optimalna izbira jekla ima naslednje prednosti:

— Idealna startna osnova za dodajanje ferolegur. Iz datoteke naročenih vrst jekla in preliminarne kemične sestave se optimalno izbere najcenejša rešitev. Z optimalno izbiro jekla določamo najcenejšo vrsto jekla, ko zasledujemo kemične analize od taljenja do končnega proizvoda.

— Skrajšamo čas za pihanje kisika ali rude. Z optimalno izbiro jekla računamo stroške za vpihovanje kisika ali rude in ti stroški so upoštevani v zmanjšanju stroškov od taljenja do legirnih elementov.

— V izračunavanju količine legirnih elementov se upoštevajo oligo elementi. V nekaterih primerih so oligo elementi zaželeni elementi v kemični sestavi končnega proizvoda. Nekatere od teh elementov npr. nikelj, krom in mangan, lahko dobimo v kemijski sestavi po taljenju vložka. V optimalni izbiri jekla se to upošteva pri določevanju najcenejše rešitve za legirne dodatke.

— Premija na stroške vložka. Proizvajalci jekla imajo premijo na izkoriščanje nizke vsebnosti oligo elementov. Kadar slučajno dobimo šarže z nizko vsebnostjo oligo elementov v cenenem vložku, se takšna sestava vložka še vedno pogosto uporablja za poceni jeklo. Maksimalna izbira jekla upošteva stroške za izdelavo premiranega vložka in jih vključuje v izračunavanje legirnih dodatkov, da se okoristi z vrstami jekla, ki vsebujejo v predpisu malo oligo elementov, in jih upošteva pri določevanju premirane vrste jekla.

— Razvija stabilnejše proizvodne procese.

Na sliki 9 vidimo primer za izračun optimalne izbire jekla. Računalnik izbere tri najboljše vrste jekla glede na kemično sestavo pri taljenju. Jeklarju je omogočena izbira ene od teh vrst ali pa kakšne druge vrste. Glede na čas vpihovanja kisika in glede na to, kakšna bo kemična analiza ob koncu vpihovanja kisika, izračunava računalnik tudi predvidene potrebne legirne dodatke, tako da jih topilec lahko pripravi za končni dodatek ferolegur.

Z upoštevanjem izračuna sestave vložka zagotovimo uspešno izkoriščanje neoksidacijskih metalov iz vložka, obenem pa tudi dober in cenejši končni izdelek. Z razvojem modelov izračuna sestave vložka in na osnovi izkušenj z izdelanimi šaržami je mogoče bolje napovedati potrebe po nabavi surovin na trgu.

Proizvajalec dobi tudi zagotovilo, da so njegove surovine najcenejša kombinacija surovin, ki se dobijo na tržišču, da uporablja izračun sestave vložka predvsem na osnovi najcenejših mate-

some other grade and/or order on the production schedule. The application of optimum heat assignment has resulted in the following segments:

— Ideal start-of-additions chemistry. Within the grade files of the optimum heat assignment, the preliminary chemistry which gives the lowest cost for the alloy additions stated. The optimum heat assignment functions determine the least-cost grade to be made from the meltdown chemistry to the final specified chemistry.

— Minimize oxygen blowing and/or oreing time. The optimum heat assignment calculates the cost of oxygen blowing or oreing and this cost is considered in the minimizing of the cost from going from the meltdown to alloy additions.

— Takes advantage of residual elements in calculating the amount of alloy additions that has to be made. In some cases, the residual elements are actually specified as aim point elements in the final chemistry. Some of these elements such as nickel, chrome, and manganese can be recovered from the meltdown chemistry. The optimum heat assignment considers this in determining the least-cost alloy additions solution.

— Premium charge materials cost. Steelmakers have premium charges to obtain low residual heats. When low residual heats are obtained by accident from a low-cost charge, many times the residual chemistry is still applied to a low-cost steel grade. The optimum heat assignment considers the cost of making up the premium charges and adds this into the alloy additions calculation to take advantage of meltdown chemistries that are low in residuals and applying them to premium grades of steel.

— Develops consistent standard practices.

Figure 9 contains an example of an optimum heat assignment calculation. Based on the meltdown chemistry, the computer selects the three best grades to be made. The melter is still free to choose any of these three or another grade. Based on the oxygen blowing time, and where the prelim chemistry will be at the end of the oxygen blow, the computer also calculates the alloy additions required so that melters can batch these in preparation for the final prelim analysis.

The applying of charge design calculations to blending of raw materials assures both that the highest recovery of elements from these raw materials will result in the most useful and cost-effective form in the ultimate steel. By utilizing the constraints developed for the charge design calculation on a heat-by-heat basis and determining what should be purchased from the marketplace, the user also assures that his raw materials usage reflects the cheapest combination that exists in the marketplace, to use the charge design to design charges based on the least-cost

ALI SI AŽURIRAL KNJIGO NAROČIL?
3-NOV-76
SO LITE ŠARŽE DELANE SEDAJ? N
ŠARŽA? 12345
VNESI TEŽO ŠARŽE 384000
VNESI ANALIZO PRVE PROBE:
1 C? .92
2 MN? .33
3 CR? .08
4 P? .02
5 S? .03
6 NI? .05
7 CU? .22
OPTIMALNA JEKLA IN NAROČILA SO:

IZBIRA	NAROČILO	JEKLO	TIP	ZADNJI DATUM ZA POLNJENJE
1	3 30BHQ	FN30B223	2 7/8"	11/05/06
2	3 10RIQ	NR10R201	3 IN	11/05/06
3	3 06RIQ	NR06R201	3 IN	11/05/06

KATERO STE IZBRALI?

Slika 9.1
Optimalna izbira jekla

ČAS VPIHAVANJA KISIKA = 33.68
POROČILO ZA ŠARŽO 12345 KVALITETA FN30BB223
Z ZVEZDO OZNAČENI ELEMENTI SO IZVEN CILJA VENDAR ŠE V PREDPISU

MATERIAL	DODATI	ŽE DODANO	ENOT
AL	274.		
GR79	805.		
CR-X	2200.		44.
FEMN	239.		
SIMN	4896.		

SKUPAJ DODATI 8415.
CELOTNA TEŽA KOVINE BO .352436.
CENA LEGIRNIH DODATKOV JE 3011.47
CENA/TONO = 22.13 PLAN. CENA = 19.70
TEMPERATURA IZPUSTA NAJ BO 2943. F

DODANO ELEM.	PREDPR.	KONČNA	CILJ	PREDPIS	IZPLEN
*C = 184.41	0.3000	0.3396	0.3200	0.2900/0.3400	88.1400
MN = 3517.47	0.1551	1.0500	1.0500	0.9500/1.1500	90.0000
S = 4.58	0.0300	0.0307	—0.0400	0.0000/0.0400	100.0000
SI = 1002.45	0.0100	0.2800	0.2800	0.2300/0.3300	95.0000
CR = 1112.12	0.0463	0.3609	—0.4000	0.3600/0.4000	100.0000
CU = 14.73	0.2200	0.2194	—0.3500	0.0000/0.3500	100.0000
FE =		97.7194	IZRAVNAVA		

Slika 9.2
Optimalna izbira jekla (stran 2)

RUN CORD
DID YOU UPDATE THE ORDER BOOK?
OSEL V1.0 3-NOV-76
ARE CASTING HEATS TO BE MADE NOW? N
ENTER HEAT NO 12345
ENTER WEIGHT CHARGED? 384000
ENTER MELTDOWN ANALYSIS
1 C? .92
2 MN? .33
3 CR? .08
4 P? .02
5 S? .03
6 NI? .05
7 CU? .22
OPT V1.0 3-NOV-76
OPTIMUM GRADES AND ORDERS TO FILL ARE

CHOOSE	ORDER	GRADE	TYPE	LAST DATE TO FILL
1	3 30BHQ	FN30B223	2 7/8"	11/05/06
2	3 10RIQ	NR10R201	3 IN	11/05/06
3	3 06RIQ	NR06R201	3 IN	11/05/06

WHICH ONE DO YOU CHOOSE? 1

Figure 9.1
Optimum heat assignment

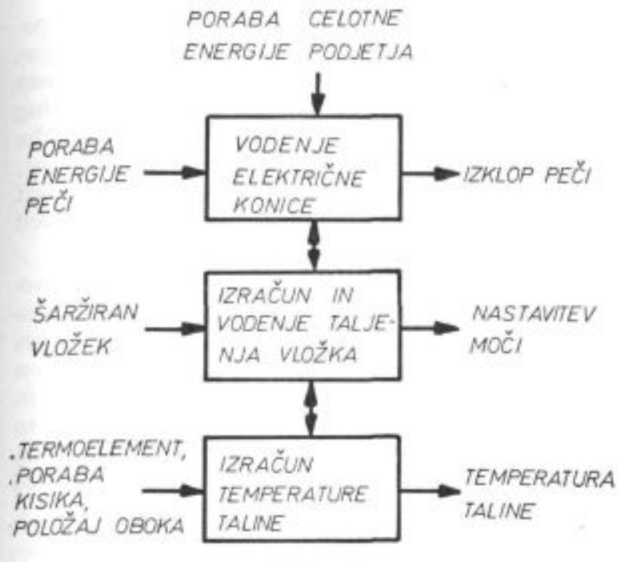
OXYGEN BLOW TIME = 33.68 MIN
REPORT FOR HEAT 12345 GRADE FN30BB223
ASTERISKED ELEMENTS HAVE BEEN MOVED OFF AIM BUT IN SPEC

MATERIAL	POUNDS TO ADD	ALREADY ADDED	UNITS
AL	274.		
GR79	805.		
CR-X	2200.		44.
FEMN	239.		
SIMN	4896.		

TOTAL POUNDS TO ADD 8415.
TOTAL METAL WEIGHT WILL BE 352436.
ALLOY ADDITIONS COST IS 3011.47
COST/TON = 22.13 PAR COST = 19.70
TAP TEMPERATURE SHOULD BE 2943. F

LBS ADDED	PREL	FINAL	AIM	SPEC-RANGE	RECOVERY
*C = 184.41	0.3000	0.3396	0.3200	0.2900/0.3400	88.1400
MN = 3517.47	0.1551	1.0500	1.0500	0.9500/1.1500	90.0000
S = 4.58	0.0300	0.0307	—0.0400	0.0000/0.0400	100.0000
SI = 1002.45	0.0100	0.2800	0.2800	0.2300/0.3300	95.0000
CR = 1112.12	0.0463	0.3609	—0.4000	0.3600/0.4000	100.0000
CU = 14.73	0.2200	0.2194	—0.3500	0.0000/0.3500	100.0000
FE =		97.7194	BALANCE		

Figure 9.2
Optimum heat assignment (Page 2)



Slika 10
Blok diagram za vodenje porabe energije

rialov, ki so trenutno na zalogi, da uporablja metodo zasledovanja za kontrolo, če se zares uporabljata najcenejši izračun sestave vložka in naročanja materiala, če pa ne, skuša ugotoviti vzrok.

Vodno hlajene plošče na električnih pečeh so omogočile, da lahko računalnik vodi peč s kontrolo vložene energije od šaržiranja do taljenja in dogrevanja. Slika 10 pojasnjuje, kako deluje sistem krmiljenja energije pri električnem pridobivanju jekla. Glede na karakteristike šaržiranega vložka je vodenje raztapljanja vložka po vnaprej postavljenih trajektorijah vhodne moči. Povišanje temperature hladilne vode opozori, kdaj je treba skrajšati oblok, da se uredi maksimalno črpanje toplote za ogrevanje tekoče ko-

Tabela 3: Odstotki možnih prihrankov pri računalniškem vodenju materialnega poslovanja v jeklarni

Področje stroškov	Odstotek v skupnih stroških	Odstotek prihrankov na področje stroškov (načrtovano)	Odstotek prihrankov na skupne stroške (načrtovano)
Staro železo	58.1	8	4.648
Ferolegure	3.6	15	0.54
Kisik	0.7	30	0.21
Žlindra	1.7	20	0.34
Investicije	1.6	10	0.19
Delavci	1.9	10	0.19
Obstojnost obz.	1.6	10	0.16
Skupaj			6.248

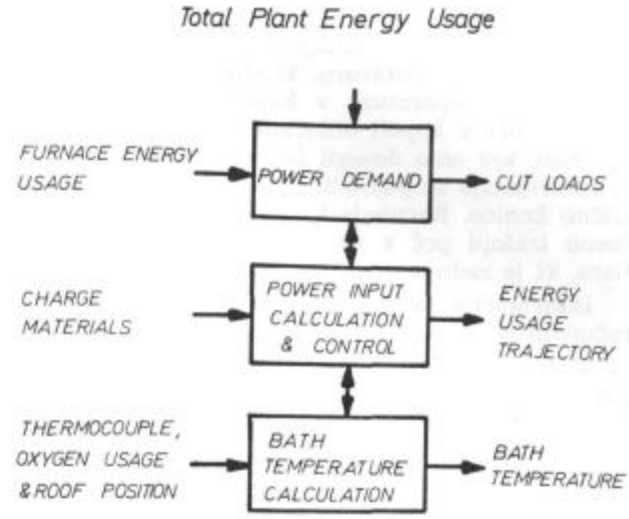


Fig. 10
Energy management flow diagram

inventory that presently exists, to use the tracking function to check whether the least-cost charge design and the least-cost purchasing designs are actually being utilized in production and, if not, who is at fault.

The recent availability of watercooled panels on electric furnaces has made its possible to have the computer reliably drive the furnace through power input control from charging through meltdown and superheat. Figure 10 is a functional representation of how the energy management system works in electric furnace steelmaking. Based on scrap charge characteristics, the power input systems drives the furnace through a set trajectory of power input. The raise in cooling water temperature signals when the arc should be shortened to pump maximum heat to the liquid bath for superheating. A thermocouple reading using the microprocessor to translate millivolts

Table 3: Percent Savings Possible by Computerized Materials Management

Cost Center	Percent of Total Cost	Percent Savings Cost Center (projected)	Percent Savings to Total Cost (projected)
Scrap	58.1	8	4.648
Ferroalloys	3.6	15	0.54
Oxygen	0.7	30	0.21
Flux	1.7	20	0.34
Investment	1.6	10	0.16
Labor	1.9	10	0.19
Refractories	1.6	10	0.16
Total			6.248

peli. Termoelement s čitalcem, ki s pomočjo mikroprocesorja spreminja milivolte v temperaturo, podaja temperaturo, ki služi kot osnova za računanje temperature v kopeli. Z računanjem temperature v kopeli določamo, kdaj prenehamo ogrevati, ker smo dosegli temperaturo izpusta in ta informacija se posreduje do dela, ki vodi električno konico. Računalnik pri vodenju konice začasno izklopi peč z najmanjšo prioriteto, to je tisto, ki je zadnja pričela raztapljanje.

Informacija se posreduje nazaj v osrednji računalniški sistem.

V tabeli 3 je prikazan pregled izboljšav, ki jih je dosegel proizvajalec jekla z računalniško kontrolo procesov pri pridobivanju jekla v električnih pečeh. Zaradi vseh omenjenih prihrankov so se mu investicije obrestovale v nekaj dneh. Vendar pa je za uvedbo vseh kontrol v topilnici z električno pečjo bilo potrebnih 18—24 mesecev.

ZAKLJUČEK

Digitalni računalnik je postal zelo pomemben v proizvodnji jekla. Računalniška tehnologija je že v obliki računalniške aparature in programske opreme premostila omejitve v proizvodnji jekla. Naloga proizvajalcev jekla je, da upoštevajo razvoj računalniške tehnologije in jo razumno ter ekonomično uvedejo v proizvodni proces.

to temperature is used to give a datum temperature to base the bath temperature calculation on. The bath temperature calculation determines when the furnace will be cut for being at tapping temperature and this information is given to the power demand function. The power demand function cuts the furnace of lowest priority at the last instant to shed. The information is communicated back to the main computer system.

Table 3 contains a summation of the improvements that a carbon steelmaker has been able to show under computerized process control in his electric furnace steelmaking operation. Based on these savings, his return on investment was in a matter of days. The time required, though, to implement all of the control functions within his electric furnace shop was between 18 and 24 months.

CONCLUSION

The digital computer has become a very powerful tool in steelmaking. Computer technology in terms of hardware and operating software have far outstripped the applications that have been developed for steelmaking processes. The challenge to the steelmaking community is to take the computer technology and apply it judiciously and economically to the steelmaking process to assist as another tool in steelmaking.

ZUSAMMENFASSUNG

Die Rechentechnologie ist heutzutage viel weiter entwickelt als das aus der Anwendung der Rechner in der Stahlerzeugung erschlossen werden kann. Es ist ein Versuch gemacht worden die Anwendung der Rechnereinrichtungen und der Rechnersysteme in der Stahlerzeugung zu analysieren. Als Beispiel dient uns die rechnergesteuerte Führung des Lichtbogenofens und der Sauerstoffkonvertern (LD, BOF, AoD und Q-BOP).

Die Ergebnisse der Kontrollsysteme dieser Prozesse zeigen, dass der Rechner ein Bestandteil des Erzeugungsprozesses im Stahlwerk geworden ist.

ЗАКЛЮЧЕНИЕ

Вычислительная технология развита в настоящее время гораздо больше, чем это можно заключить на основании применения вычислительной машины в производстве стали.

Сделана попытка проанализировать современное применение оборудование вычислительных приборов, и примененных вычислительных систем при производстве стали.

Как пример взято управление ходом электропечи и агрегатов для производства стали с применением кислорода (LD, BOF, AOD и Q — BOP).

Результаты контрольных систем этих процессов показали, что счетная машина получила роль составной части производственного процесса в сталеплавильном цехе.