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INŠTITUT ZA KOVINSKE MATERIALE IN TEHNOLOGIJE, LJUBLJANA – 50 LET RAZVOJA IN RAZISKOVANJA

INSTITUTE OF METALS AND TECHNOLOGY, LJUBLJANA – 50 YEARS OF DEVELOPMENT AND RESEARCH

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Opisane so bistvene odločitve v zvezi z ustanovitvijo, organiziranostjo in delom Inštituta v obdobju 1950-2000. Povzeta je dinamika razvoja kadrov in pridobivanja raziskovalne opreme, način selekcije raziskovalno-razvojnih projektov in nalog, vsebina in cilji raziskovalno-razvojnega dela ter njihove spremembe, skladno z razvojem matičnega industrijskega okolja in raziskovalne politike. Predstavljeni so nekateri primeri, ko je bilo delo na inštitutu zelo pomembno za nekatera podjetja in za razvoj metalurške vede in stroke. Navedene so zlitine, razvite na Inštitutu, in tiste, ki so se pilotno proizvajale na obstoječi raziskovalni opremi, in vrste ter obseg ekspertnih storitev. Prikazan je številčni pregled o poročilih, raziskovalnih nalogah in projektih ter objavah v državi in tujini po desetletjih ter seznam najbolj pogostih naročnikov raziskovalno-razvojnih projektov.

Ključne besede: Inštitut za kovinske materiale in tehnologije, Ljubljana, Slovenija, organiziranost inštituta, delo in kadri, vsebina in cilji raziskovalno-razvojnega dela, raziskovalna oprema, selekcija raziskovalnih nalog in projektov, raziskovalni in razvojni dosežki, poročila in objave, naročniki raziskovalno-razvojnih projektov

Important decisions relating to the founding, the organisation and the research work in the institute in the period 1950 to 2000 are presented. Research & development (R&D) policy, the acquisition of research equipment, the selection of R&D projects, the content and goals of the R&D projects and their change with regard to the needs of industry and public reseach policy are summarised. Some significant R&D contributions to the metallurgical industry are presented. Different alloys developed for industrial production and pilot manufacturing on research equipment as well as expertise and industrial services are also summarised. This is also a survey of R&D reports and publications in Slovenia and abroad, as well as industrial companies, financers and users of R&D.

Key words: Institute of Metals and Technology, Ljubljana, Slovenija, organisation of the institute, evolution of cadres, topics and aims of research and development, acquisition of R&D equipment, significant results of R&D work, industrial companies financers of R&D projects

1 USTANOVITEV, POMEMBNI MEJNIKI IN KADRI

Inštitut za kovinske materiale in tehnologije, Ljubljana (IMT), prej Metalurški inštitut (MI) je bil ustanovljen pri Tehniški visoki šoli leta 1948 z dekretom Sveta za prosveto in kulturo Ljudske republike Slovenije (LRS). Pobudnik ustanovitve, nestor slovenske metalurgije in dolgoletni direktor prof. Ciril Rekar je v poročilu ob 15-letnici dela zapisal, da je bil MI dejansko ustanovljen 1. maja 1950 s slovesno otvoritvijo eksperimentalnega plavža. Ta je bil zgrajen v okviru raziskovalnega projekta, katerega cilj je bil razviti postopek za izdelavo surovega železa z gorivi, ki so bila na voljo v tedanjem jugoslovanskem prostoru. V projekt je bila vključena tudi skupina kemikov, ki jo je vodil akademik Maks Samec, katere naloga je bila, da iz domačih goriv izdela za uporabo v plavžu primeren koks.

Ustanovitelj Inštituta Izvršni svet Ljudske skupščine LRS (Uradni list št. 30-120/1954) je na osnovi soglasja Sveta za znanost LRS o prenosu upravne pravice na MI in v soglasju z Univerzo z Uredbo št. 01-2276/1-58 dne 14. 8. 1958 (Uradni list št. 28/1958) odločil, da je MI znanstveni zavod in samostojna pravna oseba.

1 FOUNDING, SIGNIFICANT TURNING POINTS AND STAFF

The Institute of Metals and Technology (IMT), Ljubljana, former The Institute of Metallurgy, Ljubljana (MI), was established at the Technical High School in 1948, with a decree from the "Svet za prosveto in kulturo, Ljudske republike Slovenije". The "nestor" of modern metallurgy in Slovenia, and the first director, wrote in a report prepared for the 15th anniversary that the institute was actually founded on 1st May 1950, with the introduction of an experimental blast furnace. This furnace was constructed as part of a project aimed to investigate the production of pig iron using reductants from coals mined in the former Yugoslavia. The project involved a group chemists, with ac. Maks Samec as the head, who were given the task of developing a reductant from domestic coals for use in the blast furnace.

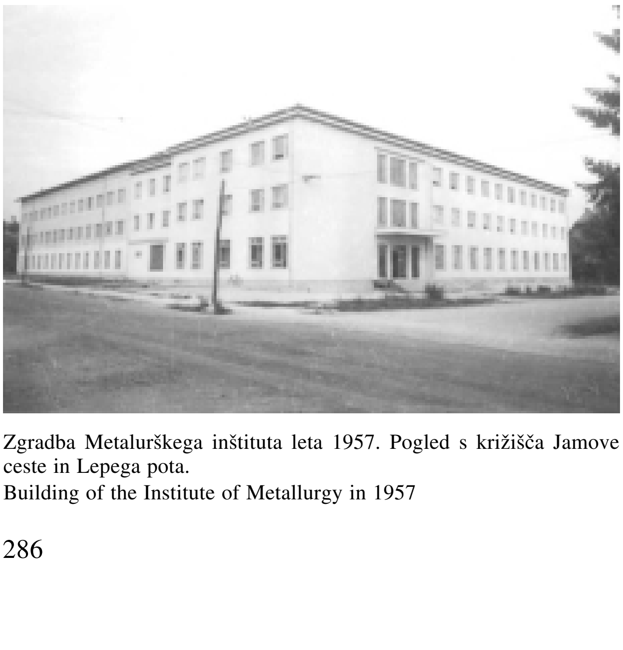
The official founder of the institute, the Executive Council of the People's Assembly of Slovenia (Off. Gazette No. 30-120/1954) established, in agreement with the Science Council of Slovenia and the University of Ljubljana, with the decree No 01-2276/1-58 from 14 August 1958 (Off. Gazette No 28/1958), the institute as

Del zgradbe, v kateri inštitut deluje, so začeli graditi že leta 1947 ob Marmontovi cesti, sedanji Jamovi, poslopje pa je bilo dokončno zgrajeno 1. maja 1950. Gradnja drugega trakta ob Lepem potu je bila končana leta 1958. Privredni Savjet FNRJ je svojo raziskovalno enoto v Polju (oplemenitenje rud, hidrometalurgija, goriva) 1. aprila 1952 predal MI-u in je imela naziv MI-Laboratorij Polje. Kasneje sta bila zgrajena študijska koksarna za lignite v Šoštanju z nazivom MI-Laboratorij Velenje in Laboratorij za morsko korozijo v Mosčeniški Dragi, ki je bil nato prenesen na Bernardin-Portorož. Tu je bil leta 1959 z zveznimi sredstvi postavljen sončni reaktor za taljenje čistih oksidov z visokim tališčem z nazivom MI-Laboratorij Piran.

Od ustanovitve je bilo raziskovalno delo usmerjeno v iskanje in izkoriščanje domačih surovin za izdelavo grodlja in jekla, neželeznih kovin in zlitin ter goriv za celotno jugoslovansko metalurško industrijo. Zato je leta 1958 Izvršni svet LRS za 10 let z Uredbo in pogoji (Ur. l. št. 28/58) prenesel ustanoviteljske pravice na Udruženje jugoslovenskih željezara (UJŽ) iz Beograda, kjer je inštitut pridobil mesto osrednje raziskovalne organizacije metalurške industrije. Z odmiranjem zvezne uprave in naraščanjem republiških pristojnosti se je težišče dela preusmerilo na hitro razvijajočo se slovensko metalurško industrijo, in leta 1971 je bil MI imenovan za osrednjo raziskovalno ustanovo za metalurške raziskave. S podpisom samoupravnega sporazuma o pridružitvi MI v SOZD Slovenske železarne (SŽ, 27. 11. 1973) je inštitut postal samostojna raziskovalna organizacija (SŽ MI) v SOZDU SŽ vse do leta 1991, ko je zaradi ekonomskih razmer izstopil iz SOZDA SŽ in se zaradi spremenjene vsebine dela preimenoval v Inštitut za kovinske materiale in tehnologije (IMT).

Leti 1994 in 1997 sta posebej pomembni zato, ker je bil leta 1994 inštitut podržavljen s sprejemom zakona o zavodih, leta 1997 pa je z uredbo vlade dobil status javnega raziskovalnega zavoda.

Pomemben mejnik v razvoju inštituta je še leto 1992, ko je prevzel izdajanje revije Železarski zbornik in kot



Zgradba Metalurškega inštituta leta 1957. Pogled s križišča Jamove ceste in Lepega pota.
Building of the Institute of Metallurgy in 1957

a scientific institution and an independent corporate body.

The construction of the institute began in 1947 on the corner of the crossroads between Marmont (now Jamova) and Groharjeva streets. The building was completed on 1st May 1950. The construction of the second phase, along Lepi pot street, was finished in 1958. The Council for Economics of the former Yugoslavia transferred its research facility in Polje (ores beneficiation, hydrometallurgy, metallurgical fuels) to the institute on 1st April 1952. The name of this separate facility was MI-Laboratorij Polje. Later, the test coking plant for lignite at Šoštanj, called MI-Laboratorij Velenje, and the laboratory for corrosion testing in marine environments in Mošćenička draga were established. This laboratory was later transferred to Portorož-Bernardin, and known as MI-laboratorij Piran. A reactor heated with sun energy was built in 1959 in this laboratory, and investigations involving the melting of high-temperature oxides were successfully carried out.

In the early years, activities focused on the research and exploitation of domestic raw materials for the development of pig iron and steel, non-ferrous metals and alloys, and solid fuels for the Yugoslavian metallurgical industry. For this reason, the Executive Council of Slovenia, with the decree published in the Off. Gazette No 28/58, transferred the founder rights to the Udruženje Jugoslovenskih Željezara (The Association of Yugoslavian Ironworks) in Belgrade. As part of this association, the institute achieved the position of a central research institution for the metallurgical industry in Yugoslavia. With the diminishing power of the central administration and the increasing influence of the republics, the activities turned gradually towards the rapidly growing Slovenian industry, and in 1971, the institute was designated as a central institution for metallurgical research in Slovenia. With the signing of the self-management agreement with the Association of Slovenian Steelworks (SOZD) on 11th November 1973, the institute was established as an independent research institution with this industrial group. The institute withdrew from this group in 1991 because of the deterioration in the economic situation, and its name was changed to the Inštitut za kovinske materiale in tehnologije (Institute for Metallic Materials and Technology) – IMT.

The years 1994 and 1997 are of particular importance in the history of the IMT. In 1994, the institute was nationalised with the adoption of the law on institutions, and in 1997 it was granted, with a decree from the Government of Slovenia, the status of a public research institution.

The year 1992 was also significant: the institute assumed responsibility for publication of the periodical Železarski Zbornik, and associated as co-editors several industrial companies and research institutions. With the aim of providing a forum for authors from non-metal soizdajatelje vključil več industrijskih podjetij in raziskovalnih ustanov. Da bi pridobila avtorje z drugih področij, se je revija preimenovala v Kovine Zlitine Tehnologije, s povečanjem števila objav iz nemetalurških področij pa v Materiali in Tehnologije.

Leta 1950 je imel Inštitut 22 redno in tri honorarno zaposlene, med njimi 10 z visokošolsko izobrazbo. Do leta 1960 je zaradi povečanja obsega dela število redno zaposlenih zraslo na 100, med njimi 45 z univerzitetno diplomo, število honorarno zaposlenih pa na 27. Zaradi programske preusmeritve in postopnega izboljšanja opremljenosti pa število zaposlenih po letu 1970 (104 zaposleni, 6 dr. znanosti, 3 magistri in 19 z visokošolsko izobrazbo) ni več pomembno naraščalo in leta 1980 je bilo zaposlenih 99 (14 dr. znanosti, 2 magistra in 11 dipl. inž.). V osemdesetih letih je Inštitut zaradi preusmeritve predal Laboratorij Polje Rudarskemu inštitutu, in število zaposlenih je do leta 1990 padlo na 87. Inštitut je zelo hudo finančno krizo doživel v letih 1989 do 1991 (dolgovi MIL-PP, zmanjšanje tržišča za izdelke pilotne proizvodnje), tako da se je število zaposlenih zmanjšalo od 87 na 62. Ob pridobitvi statusa javni raziskovalni zavod leta 1997 je bilo na IMT zaposlenih 64 delavcev, od tega 29 raziskovalcev (11 dr. znanosti in 7 magistrov). Ob 50-letnici dela leta 2000 pa je bilo zaposlenih 62 delavcev, med njimi 34 z univerzitetno diplomo, od teh pa 17 z doktoratom ter 8 magistrov iz metalurških, gradbenih, fizikalnih ali strojniških ved.

V 50 letih so od začetka naprej inštitut vodili: prof. inž. Ciril Rekar (16 let), Alojz Prešern, univ. dipl. inž. (21 let), prof. dr. Jože Rodič, univ. dipl. inž. (4 leta), prof. dr. Franc Vodopivec, univ. dipl. inž. (5 let), prof. dr. Leopold Vehovar, univ. dipl. inž. (4 leta) in od aprila leta 2000 je na tem mestu direktorica doc. dr. Monika Jenko, univ. dipl. inž.

2 FINANCIRANJE RAZISKOVALNEGA DELA IN NABAVE OPREME

Do leta 1954 je inštitut financiralo Ministrstvo za prosveto in kulturo LRS, potem pa se je financiral samostojno s projekti, študijskimi elaborati in drugimi deli. Od leta 1954 do 1960 sta se prihodek in odhodek povečala za več kot petkrat. Raziskovalne projekte so financirali do okoli leta 1965 uporabniki iz vse Jugoslavije. Sredstva iz zveznih skladov in Sklada Borisa Kidriča do leta 1961 niso presegala 8 % prihodka, v letu 1962 je financiranje iz skladov zraslo na 20 % prihodka in se nato za nekaj let ustalilo na 15 do 20 % prihodka inštituta. Vsa leta je inštitut pridobival do 20 % prihodka iz ekspertnih in laboratorijskih storitev za različne naročnike, predvsem industrijska in energetska podjetja. V tej dejavnosti so imeli pomembno vlogo laboratoriji za mehanske preiskave, kemijsko analitiko, metalografijo, po letu 1986 pa tudi laboratorij za vakuumsko toplotno obdelavo. Mnogo večji, kasneje pa enak je bil prihodek iz pilotne proizvodnje na inštitutu

research fields, the title of the journal was first changed to Kovine Zlitine Tehnologije, and then finally to Materiali in Tehnologije (Materials and Technology).

In 1950, the staff of MIL consisted of 22 full-time and 3 part-time employees, 10 of whom had a university degree. Over the next 10 years, the number of staff increased to 100, 27 of them with part-time jobs and 45 with a university degree. In 1970, there were 104 employees (6 with PhDs, 3 with MSc degrees and 19 with the degree of diploma engineer), and in 1980 there were 99 employees (14 with PhDs, 2 with MSc degrees and 11 with university diplomas). In the 1980s, the institute transferred the Laboratorij Polje to the Institute of Mining and the number of staff decreased to 87 in 1987. The institute survived a very serious economic crisis in 1990 and 1991, which was due to debts of the MIL-PP, a reduction in the market for pilot-plant production and a decrease in the volume of projects for industrial companies. As a result, the number of staff was reduced from 87 to 62. On the date the status of public research institution was granted, there were 64 employees, 29 of them researchers (11 with PhDs and 7 with MSc degrees). On the 50th anniversary, in 2000, there were 62 employees, 34 researchers from the faculties of metallurgy, physics, civil engineering, mechanical engineering and electrical engineering, 17 of them with PhDs and 8 with MSc degrees.

The directors of the institute were as follows: Prof. Ciril Rekar (16 years); Alojz Prešern, dipl. un. eng. (21 years); Prof. dr. Jože Rodič (4 years); Prof. dr. Franc Vodopivec (5 years); Prof. dr. Leopold Vehovar (4 years); and from the year 2000 Doc. Dr. Monika Jenko.

2 FINANCING OF THE RESEARCH

Until 1954, the work of the institute was financed mostly with grants from the Ministry of Culture of Slovenia. In the years that followed, the institute acquired funds independently with research-and-development (R&D) projects, research reports, expert services, pilot-plant production and from other activities. In the period from 1954 to 1960, the income increased more than fivefold. Until about 1965, the R&D projects were mainly financed by companies from the former Yugoslavia. The money from federal funds and the Slovenian Boris Kidrič fund did not exceed 8 % of the total income. In 1962, the money from public funds increased to 20 % of the total, after which it stabilised at 15 to 20 %. Each year approximately 20 % of the income was earned from expert and laboratory services for different clients, mostly industrial companies and power plants. Most of this activity was performed in the laboratories for mechanical testing, analytical chemistry and metallography, and after 1986, this also included the laboratory for vacuum heat treatment. Initially, more (and later approximately the same level of) income came from the pilot-plant production of alloys with special razvitih zlitin s posebnimi lastnostmi, npr.: različne mehkomagnetne materiale in nikljeve zlitine, pa tudi izdelki iz njih, ter storitve valjanja, kovanja, vlečenja in toplotne obdelave. Dobiček iz storitvenega dela in pilotne proizvodnje se je vlagal v lasten sklad za financiranje raziskovanja.

Pomemben preskok v načrtovanju raziskovanja in financiranja je bil dosežen v začetku sedemdesetih let s tem, da je bila prvič na rednem XXI. posvetovanju strokovnjakov iz podjetij črne in barvne metalurgije ter livarstva v Portorožu javno predstavljena kvantifikacija rezultatov raziskovalnega dela z metalurškega področja v raziskovalnem letu 1974/75 in usklajen spisek predlogov raziskovalnih nalog in projektov s področja metalurgije za leto 1977 (MI s sodelavci iz raziskovalnih oddelkov in Fakulteto za naravoslovje in tehnologijo (FNT) VTO Montanistika). Izhajal je iz predloga srednjeročnega programa slovenske metalurgije do leta 1980 in je bil predložen Raziskovalni skupnosti Slovenije (RSS), Gospodarski zbornici (GZ) in vodstvu Slovenskih železarn (SŽ). V nadaljevanju se je raziskovalne teme usklajevalo v Odboru za raziskave in razvoj SŽ in v Komisiji za razvoj in raziskave Splošnega združenja črne in barvaste metalurgije ter livarstva Slovenije pri GZ in predložilo v financiranje ali sofinanciranje podjetjem in RSS. V program raziskav na Inštitutu in na Metalurškem odseku FNT so bile sprejete tiste teme, ki so jih zastopniki podjetij ocenili kot relevantne. Iz teh tem so se tudi izbirale tiste, ki so bile predložene v sofinanciranje RSS. S tem načinom selekcije tem je bilo doseženo, da sta inštitut in fakulteta ostajala v stalnem ustvarjalnem stiku z raziskovalno in tehnološko problematiko matične industrije in porabnikov proizvodov te industrije, podobno kot raziskovalne institucije v zahodnih razvitih državah.

Po letu 1970 je Inštitut ustvarjal večji del prihodka iz raziskovalnih in razvojnih projektov, ki so jih financirala večinoma podjetja iz Slovenije, delež sofinanciranja RSS je bil okrog 27 %, iz drugih dejavnosti pa okrog 30 %. Način usmerjanja raziskovalnega dela in financiranja se je ohranil do leta 1991, ko se je materialni položaj metalurške in livarske ter druge slovenske industrije skokoma zelo poslabšal. Inštitut se je srečal z resnimi problemi, ker je v enem letu prihodek padel za okoli 40 %. Z angažiranjem vodstva in zaposlenih se je finančno stanje saniralo, tudi za ceno zmanjšanja števila zaposlenih. V devetdesetih letih je IMT pridobival sredstva na javnih razpisih Ministrstva za znanost in tehnologijo (MZT), iz projektnega in kasneje programskega financiranja, iz "ustanoviteljskih obveznosti", iz direktnih pogodb s podjetji iz Slovenije in iz mednarodnih projektov. Tako je bila struktura prihodkov v letu 2000: 63,3 % MZT, 22,5 % industrijska in energetska podjetja, 8,2 % storitve, 2 % tujina in 7 % drugi viri.

properties, developed at the institute, e.g. soft-magnetic materials and other nickel alloys, as well as special products, e.g. sheets, rods, wire, transistor casings, soft-magnetic cores, wire for glass vacuum joints, cast sliding joints, tools from corrosion and wear-resistant alloys, electrodes for the cathodic protection of structures, etc., and also technical services, e.g. sheet rolling, wire drawing, forging and the heat treatment of magnetic materials. The profit from this activity was invested for the support of research.

A very significant step in the planning of research was achieved at the XXI Conference of Experts of Companies from the Ferrous and Non-ferrous Industries, which took place in Portorož. For the first time in Slovenia, a public evaluation and quantification of the results of the R&D work in metallurgy during the years 1974 and 1975 was presented, and a list of potential R&D projects for the year 1977 was discussed and the first selection performed. The basis for the selection of R&D projects was a medium-term plan for the development of metallurgy in Slovenia up to 1980. The selection was then presented to the companies, while the Chamber of Economics was only notified. Thereafter, the R&D projects were discussed by the Research Board of the Slovenian Steelworks and the R&D commission of the Association of Slovenian Foundries, and then finally presented for funding or co-funding to the Slovenian Research Foundation or to various companies. In the research plan for the institute and the Faculty of Metallurgy, the only projects that were included were those assessed as relevant by the delegates from industrial companies. In addition, publicly funded projects had to be approved by industry delegates. Using this method for selecting R&D projects, enabled the institute and the faculty to remain actively and creatively connected with the problems of research and technology in industrial companies and with the users of metal products.

From about 1970 the institute acquired most of its income from R&D projects supported by Slovenian companies, the share of public funding was approximately 27 %, and 30 % of that was for non-research activities. This system for preparing the R&D was used up to 1990, when the transition crisis badly affected the economic situation with regard to industry – as well as the country. The institute was faced with serious problems, and the income decreased by approximately 40 % in one year. With a change in direction and the cooperation of the employees, the financial crisis was overcome. However, this also led to a reduction in the number of people working at the institute. In the 1990s, the institute obtained funding from founder liability and from public calls for R&D projects by the Ministry of Science and Technology (MZT), from other public calls for R&D projects, and from direct contracts with companies in Slovenia and international projects. In 2000, the structure of the income was as follows: 61 %,

3 RAZISKOVALNA OPREMA

Za raziskovalni razvoj Inštituta so važni mejniki-leta, ko je bila kupljena ali izdelana oz. aktivirana večja raziskovalna oprema, ki je imela za posledico skokovit napredek v metodologiji raziskovalnega in analitskega dela. V letu 1956 sta bila na Inštitutu dva trgalna stroja, naprava za merjenje hitrosti lezenja v razponu temperature od 400 °C do 800 °C, naprava za določanje trajne nihajne trdnosti s kombinacijo upogiba in torzije, mala merilna in analitska oprema ter oprema za bogatenje mineralnih surovin. Že od leta 1956 je Inštitut financiral razvoj in gradnjo presevnega elektronskega mikroskopa na Fakulteti za elektrotehniko Univerze v Ljubljani. Mikroskop je bil postavljen leta 1958, vendar ni bil primeren za rutinsko rabo zaradi premalo natančne mehanske izdelave. Inštitut je v okviru sredstev zveznega sklada razvil in zgradil 2 modela klasičnega in nizkošahtnega plavža z dvema slojema pihalic ter peč s sončnim ogrevanjem, v kateri je bilo mogoče doseči temperaturo do 3500 °C. S to pečjo so bili določeni fazni diagrami za nekatere okside z visokim tališčem. V letu 1959 je bil pridobljen metalografski mikroskop in izdelane so bile naprave za brušenje in poliranje, kar je omogočilo začetek dela na področju metalografije. V letu l961 je bila postavljena vakuumska talilna peč, leta 1963 je bil usposobljen za delo rabljeni dilatometer, darilo inštituta MPIE (Max-Planck-Institut für Eisenforschung) iz Nemčije in IRSID (Institut de Recherches de la Sidérurgie) iz Francije. Tega leta je bila postavljena tudi hladna izostatska stiskalnica. Leta 1962 je bil usposobljen za delo duo valjalni stroj, ki ga je pridobila iz reparacij Mariborska livarna in ga odstopila v uporabo Inštitutu. Leta 1972 je bil dopolnjen za vroče valjanje platin z debelino do 55 mm in nato v začetku devetdesetih let odkupljen.

Pomemben skok v raziskovalni metodiki je bil dosežen v letu 1969, ko je bil na Inštitutu postavljen s sredstvi več podjetij, inštitutov, univerze in RSS elektronski mikroanalizator, ki je deloval vse do leta 1998. V sklopu te naprave je bila pridobljena tudi najbolj nujna in sodobna oprema za metalografsko delo in šolski presevni elektronski mikroskop za opazovanje replik. V sedemdesetih letih sta bili izdelani dve napravi za raziskave preoblikovalnosti kovin pri visokih temperaturah s torzijo, ena konvencionalna in ena, ki je omogočala zelo kratke preizkuse z veliko hitrostjo deformacije in ohlajanja. Postavljeni sta bili najprej majhna, nato pa večja naprava za električno pretaljevanje pod žlindro. Na večji napravi se je talilo okrogle ingote s premerom 200 mm, tudi ingote, ki so jih v Železarni Ravne kovali v delovne valje za Sendzimir valjalniška ogrodja za hladno valjanje tankih trakov z veliko stopnjo enkratne deformacije. Izdelan je bil polindustrijski »fluo-solid« reaktor in nabavljena naprava za vpihovanje prašnih delcev v talino. Leta 1978 je bil nabavljen vrstični (scanning) elektronski mikroskop, ki je bil kasneje nadgrajen za elektronsko mikroanalizo in je še v

public funding; 22 %, industrial companies and power plants; 8%, services; 2%, foreign projects; and 7 %, other sources.

3 RESEARCH EQUIPMENT

Modern research instruments are vital for the institute, since such equipment makes it possible to carry out a variety of investigations and analyses. In 1956, the institute's scientific equipment consisted of the following: two tensile-testing machines, a device for creep measurement in the temperature range 400–800 °C, a fatigue-testing machine with a combination of flexion and torsion stressing, various types of apparatus for ore beneficiation studies and small analytical and measuring instruments. In 1956, the institute financed the development and the construction of a transparent electron microscope at the Faculty of Electrical Engineering of the University Ljubljana. The microscope was installed in 1958; however, it was not suited for routine observations because of the poor quality of some of the mechanical parts. With funding from the federal fund, the institute designed and built two classical blast furnaces and one low-stack blast furnace with two layers of tuyères. In addition, a solar-energy furnace was designed and built, which was able to reach a temperature as high as 3500 °C, and was used for investigations of the phase diagrams of oxides with high melting points.

In 1959, a metallographic microscope was acquired; some basic devices for the preparation of specimens for optical microscopy were manufactured; and work on microstructures was begun. In 1961, a vacuum melting furnace with a capacity of 25 kg was installed; in 1963, two dilatometers, gifts of the Max Planck Institut für Eisenforschung, Germany, and of the Institut de Recherches de la Sidérurgie, St. Germain-en-Laye France, were commissioned. This year also saw the purchase of a cold isostatic press. In 1962, a two high rolling stand, war reparation object for the company Mariborska livarna was put into operation at the institute. In 1972, it was reconstructed for the hot rolling of small slabs with thicknesses up to 55 mm. Later, the rolling stand became the property of the institute.

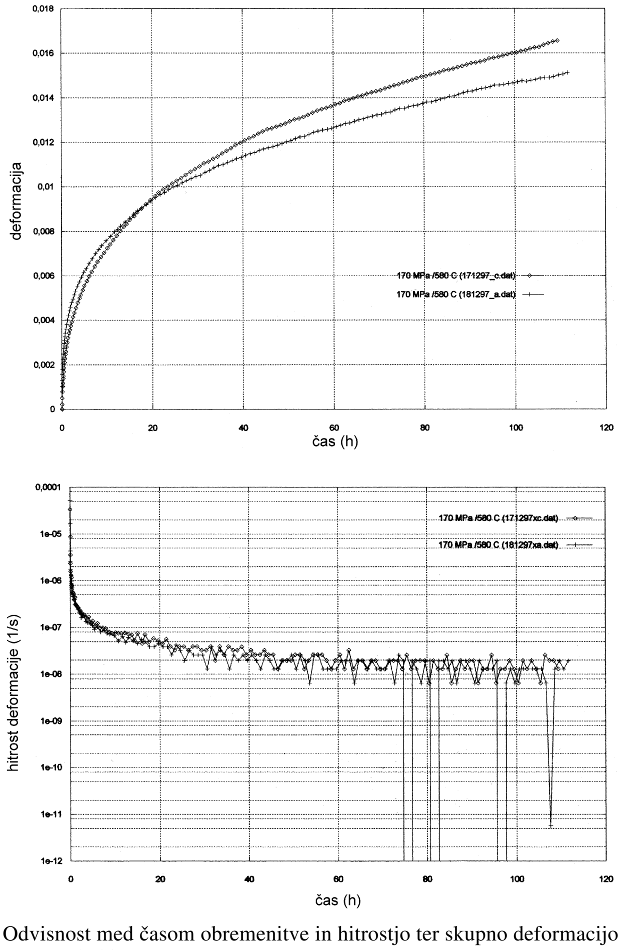
A significant milestone was achieved in 1969, when an electron microprobe analyser was acquired with funds provided from the institute, several other institutes, industrial companies, the University of Ljubljana, and the support of the Research Foundation of Slovenia. The microanalyser was in operation up until 1998. At this time, some indispensable pieces of equipment for modern metallography and a small electron microscope for the observation of replicas were obtained. After 1970, two machines for the testing of hot deformability with rotational stressing – one for conventional testing and one for tests at high rates and high cooling rates – were designed and manufactured. A small and then a large furnace for electric slag-remelting were also

Računalniško krmiljena naprava za meritve počasne deformacije pri visoki temperaturi

Computer controlled equipment for creep measurements

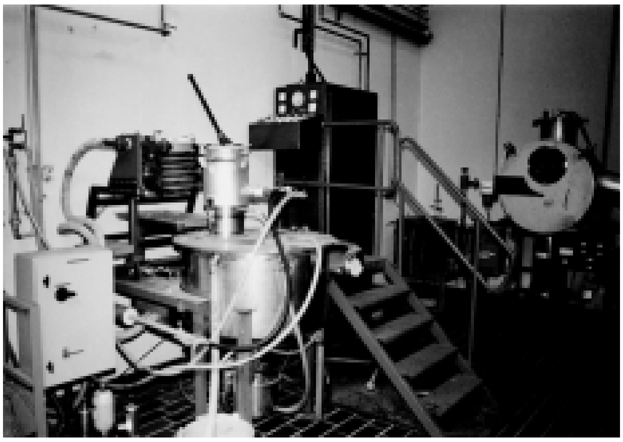
Analizator ogljika in žvepla (ELTRA CS800) ter analizator kisika in dušika (ELTRA ON900) v laboratoriju za analizno kemijo

Carbon and sulphur analyser and oxygen and nitrogen analyser in the laboratory of analytical chemistry



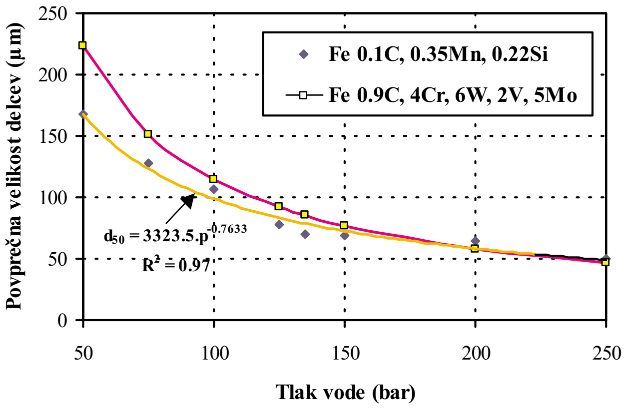
Odvisnost med časom obremenitve in hitrostjo ter skupno deformacijo (D. A. Skobir)

Relationships creep rate and creep deformation versus testing time (D. A. Skobir)



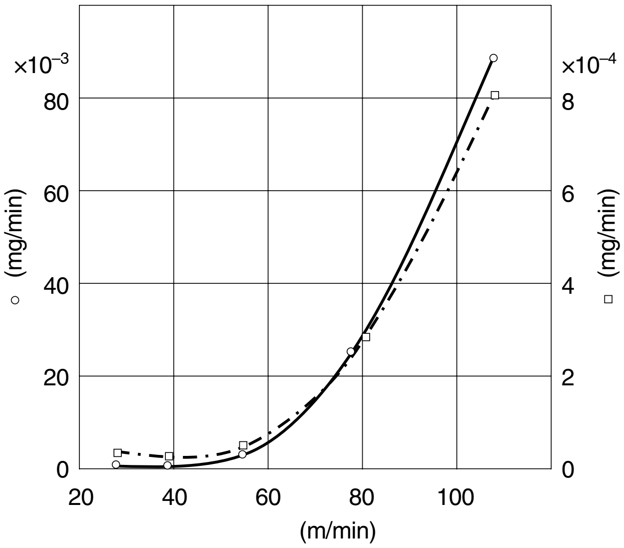
Napravi za vodno atomizacijo in ulivanje tankih trakov ter vpliv pritiska vode na povprečno velikost zrn prahu iz dveh jekel

Devices for water atomisation and casting of thin sheet and influence of water pressure on average size of powder from two steels



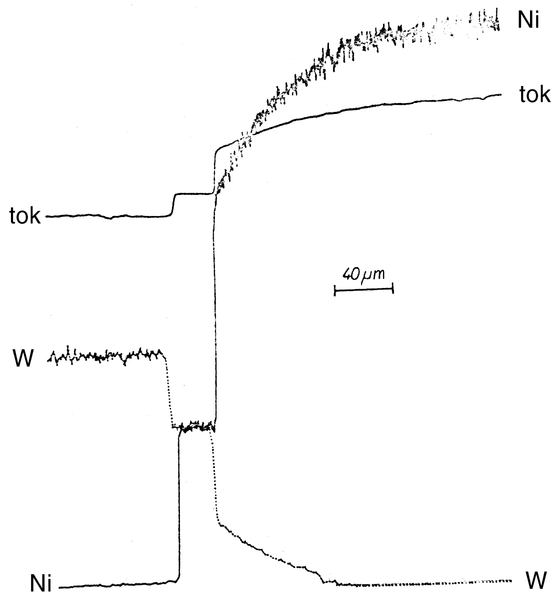
Vpliv pritiska vode na povprečno velikost zrn prahu iz dveh jekel (B. Šuštaršič)

Influence of water pressure on average size of powder from two steels (B. Šuštaršič)



Slika 1: Naraščanje specifične obrabe noža iz hitroreznega jekla pri struženju jekla za obdelavo na avtomatih (F. Vodopivec, D. Senčar, J. Hodnik in H. Golias, 1964)

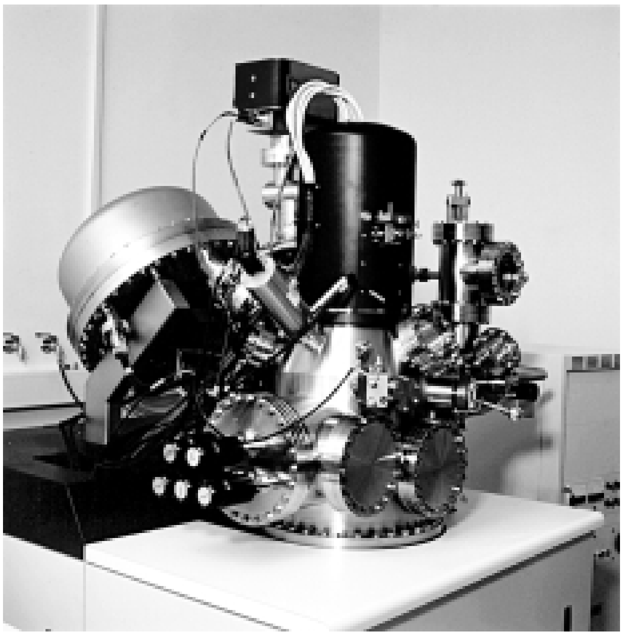
Figure 1: Growth of the specific wear of a high-speed-steel tool by turning a free-machining steel (F. Vodopivec, D. Senčar, J. Hodnik in H. Golias, 1964)



Slika 2: Difuzijska cona v paru Ni-W, ki je bila žarjen 100 ur pri 1200 °C. (L. Kosec, F. Vodopivec, B. Ralić, 1971)

Figure 2: Diffusion layer in a Ni-W couple annealed for 100 h at 1200 °C (L. Kosec, F. Vodopivec, B. Ralić, 1971)

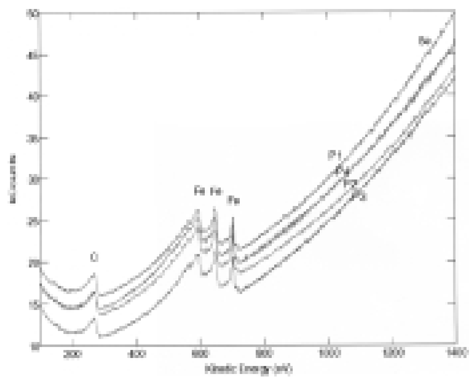
rabi. Omogočal je tudi stereološke analize mikrostruktur. Istega leta je bil postavljen sodoben univerzalni preizkuševalni stroj (500 kN) za mehanska statična in dinamična preizkušanja (frekvenca od 0 Hz do 200 Hz), ki dela še danes, in kasneje hidravlična stiskalnica 2500 kN kot neustrezni nadomestek za plastometer. Leta 1984 je pričel delovati osnovni del procesnega računalnika PDP 11, ki se je v nadaljnjih letih dopolnjeval, vendar z njim niso bili doseženi pričakovani rezultati zaradi hitrega razvoja računalniških tehnologij. Nato so sledili:



Microlab 310-F visokoločljivostni spektrometer Augerjevih elektronov z dodatno opremo

Microlab 310-F high resolution Auger electron spectrometer with additional equipment

(a)

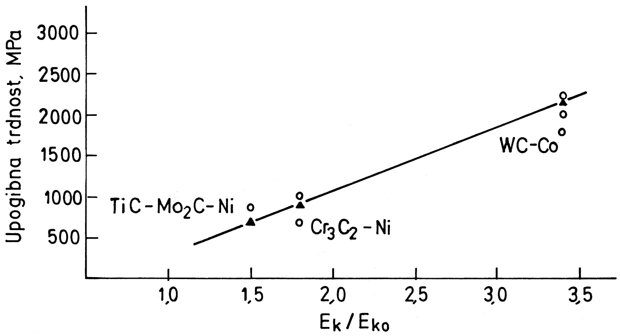


(b)

Rekonstrukcija površine in rast interkristalne faze pri povišani temperaturi pri opazovanju v Microlab 310-F (a) in AES-spekter za 4 točke označene na SEM-posnetku (b) (M. Jenko)

Surface reconstruction and growth of a new phase on a grain boundary at higher temperature observed in Microlab 310-F (a) and AES spectra for 4 points on the SEM-image (b) (M. Jenko)

installed. The larger furnace produced ingots with a diameter up to 200 mm, which were used in the Ravne



Slika 3: Odvisnost med upogibno trdnostjo karbidnih trdin ter razmerjem med elastičnim modulom karbidne in kovinske komponente (S. Jurca, 1971)

Figure 3: Dependence bending strength of hard metals versus the ratio of the elastic modulus of the carbide and the metallic component (S. Jurca, 1971)

visokofrekvenčni aperiodični generator 100 kW, 1986 peč za toplotno obdelavo v vakuumu in dušiku, naprava za neprekinjeno konduktivno ogrevanje žic, leta 1990 naprava za vodno atomizacijo talin in leta 1994 peč za ionsko nitriranje v pulzirajoči plazmi.

Leta 1988 je bila s sredstvi posojila, ki ga je najela Interna banka SŽ, na Inštitutu postavljen sklop naprav (indukcijski vakuumska in talilno vzdrževalna peč s kapaciteto do 350 kg in računalniško voden sistem za trižilno neprekinjeno horizontalno litje), na kateri je bilo razvito litje posebnih zlitin v vrsto različnih drobnih profilov, tudi profilov s trapezastim prerezom 20 mm^2. Ta projekt je povzročil velike finančne težave, ki so bile deloma obvladane z ustanovitvijo samostojnega podjetja MIL-PP, d. o. o., ki je s stečajem prenehalo delovati leta 1994.

Poseben dosežek raziskovalno inženirskega znanja je bilo načrtovanje in izdelava računalniško krmiljene naprave za preizkuse lezenja z natančnostjo merjenja raztezka, boljšo od 1 µm, in regulacijo temperature v razponu ± 0,5 °C. V vsem času dela se je inštitut bogatil z manjšo raziskovalno opremo, npr. z modernimi napravami za instrumentalne kemijske analize, napravami za moderne raziskave in preiskave korozijskih pojavov, aparaturami za toplotno tehnične meritve, optičnimi mikroskopi, zadnji je opremljen s kamero in programom za stereologijo, napravami za merjenje trdote, inštrumentiranim Charpyjevim kladivom, v zadnjem desetletju pa tudi z osebnimi računalniki in računalniško mrežo. Zadnja velika pridobitev leta 1998 je bila najsodobnejša naprava za analizo površin, ki omogoča analize po metodah HRAES, SEM, SAM, XPS, XRD in EELS.

4 MEDNARODNO SODELOVANJE

Kmalu po ustanovitvi je Inštitut vzpostavil sodelovanje s tujimi sorodnimi inštituti. Najbolj poznana sta bila MPIE Düsselldorf, Nemčija, in IRSID St. Germain-en-Laye, Francija. Na obeh inštitutih so se

Steelworks for the forging of working rolls and for the cold rolling of thin sheets with a large per-pass rolling deformation on the Sendzimir rolling stand. A pilot-plant fluo-solid reactor was also constructed, while a device for the injection of powder into a melt was purchased.

In 1978, a scanning electron microscope was acquired, and later supplemented with devices for electron microprobe analysis and stereology. This microscope is still in use. In the same year, a modern tensile-testing machine with a capacity of up to 500 kN was installed. The machine is used for fatigue testing with a frequency up to 200 Hz and it is still in operation. Later, a 2500-ton hydraulic press was acquired as an unsuitable substitute for a plastometer. In 1984, the basic part of a PDP 11 computer was acquired. In the following years it was added to; however, its use did not produce the expected results. Other equipment acquired by the institute included: a high-frequency aperiodic 100-kW generator; in 1986, a furnace for vacuum heat treatment and quenching in high-pressure nitrogen; a device for the continuous heating of wire during drawing; in 1990, a water-atomisation device; and in 1994 a furnace for plasma-ion nitriding.

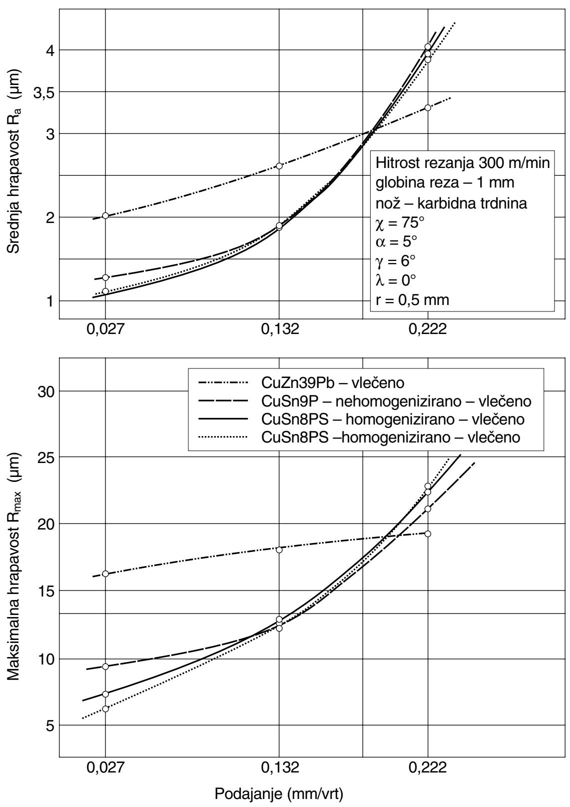
In 1988, the Interna banka SŽ financed the installation of a complex of industrial devices at the institute: a vacuum melting and a holding furnace with capacities of 350 kg and a computer-controlled three strands horizontal continuous-casting machine. Using this installation, the casting of different small-section profiles, as well as profiles with a trapezoidal section down to 20 mm^2, was developed. The realisation of this project placed the institute in debt, because the institute's working capital was also bound up in the project. This situation was partially overcome with the establishment of the independent company MIL-PP, which went bankrupt in 1994, leading to a significant reduction in the number of institute staff.

A particular scientific and engineering success was the design and the construction of a computer-controlled machine for creep testing with a deformation measurement accuracy of better than 1 µm and a temperature regulation inside of ± 0.5 °C. During this time, the institute was constantly acquiring small research devices, e.g. modern devices for analytical chemistry, for investigations of corrosion processes, for heat technology measurements, optical microscopes (equipped for stereology), hardness testers, an instrumented Charpy tester, and a large number of personal computers linked by a computer network. The last major research-equipment purchase was in 1998, when the institute bought apparatus for surface analysis equipped with HRAES, SEM, SAM, XPS, XRD and EELS.

4 INTERNATIONAL COOPERATION

Soon after the start of activities, the first director, Prof. C. Rekar, established contacts with foreign institutes active in the field of metallurgy, and in particular the Max Planck Institut für Eisenforschung usposabljali nekateri raziskovalci z Inštituta in FNT Montanistike. V kasnejših letih se je razvilo še sodelovanje z inštituti v Glivicah na Poljskem, VUHŽ iz Dobre v ČSR, VASKUT iz Budimpešte in Paton iz Kijeva ter s sorodnimi inštituti, ki so nastali po letu 1965 v Jugoslaviji. Leta 1959 je Inštitut v sodelovanju z MPIE in IRSID-om priredil v Portorožu eno od prvih, če ne prvo, mednarodno znanstveno konferenco v Jugoslaviji "Residuals and trace elements in iron and steel (Oligoelementi v železu in jeklu)", na kateri so nastopali predvsem raziskovalci iz tujine in o kateri je bil kasneje v Franciji tiskan zbornik. Na tej konferenci so bili poleg drugega prvič javnosti predstavljeni rezultati analiz dendritskega izcejanja v jeklu z uporabo elektronskega mikroanalizatorja. Konference so se periodično prirejale do leta 1986. Poleg te konference so tuji strokovnjaki sodelovali na vsakoletnih posvetih v okviru Jesenskih posvetovanj in Znanstveno tehnoloških posvetov. Leta 2000 je bilo 53. posvetovanje o metalurgiji in kovinskih materialih, 8. posvetovanje o materialih in 8. konferenca o materialih in tehnologijah.

Pred letom 1990 so bili raziskovalci z Inštituta dve triletni obdobji vključeni v raziskovalni projekt EU Casting and Solidification in v dva bilateralna projekta v sodelovanju z ZDA, počasi se je sodelovanje razširilo

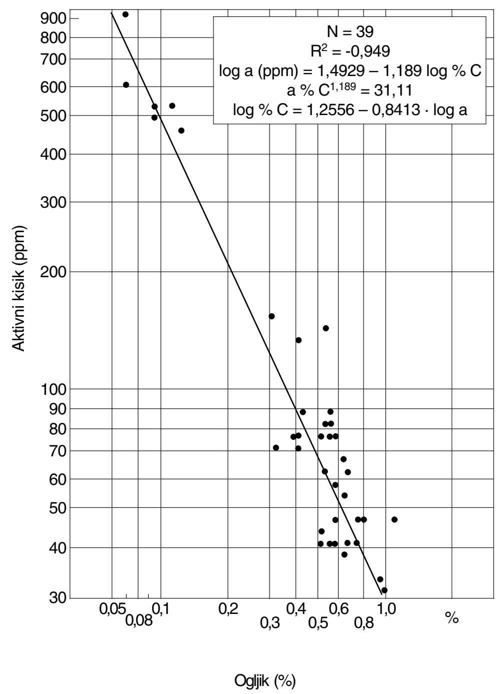


Slika 4: Hrapavost površine R_a in R_{maks} primerjalne medi (100-odstotna obdelovalnost) in ležajnih bronov za obdelavo na avtomatih. Broni so še v proizvodnji (B. Breskvar, 1975)

Figure 4: Roughness of the surface of a comparative brass (100 % of machinability) and of free-machining bearing bronzes. The bronzes are still in production (B. Breskvar, 1975)

(MPI) in Germany and the Institut de Recherches de la Sidérurgie (IRSID) in France. Several researchers from the institute and from the Faculty of Metallurgy were trained at various times in both institutes. Later, cooperations were also started with other institutes, such as the Institute of Metallurgy in Glivice, Poland; VUHŽ in Dobra, Czechoslovakia; VASKUT in Budapest, Hungary; The Paton Institute in Kiev, Ukraine; and still later with institutes founded after 1970 in Yugoslavia. In 1958, in cooperation with the MPI and IRSID, one of the first – if not the first – international scientific conference in Yugoslavia was organised in Portorož, with the title "Residuals and Trace Elements in Iron and Steel". Most of the speakers at the conference were from abroad. Later, a conference book was printed in France. At this conference, for the first time results on the electron-probe analysis of dendritic segregations in steel were presented. Subsequent conferences were periodically organised up until 1986. Foreign speakers were also present at annual, national symposia and conferences. In 2000, the 53rd Symposium on Metallurgy and Metallic Materials was organised jointly with the 8th Conference on Materials and Technology.

Before 1990, the researchers at IMT were for two periods of three years involved in the project "Casting and solidification" in the frame of the HACS and two bilateral Slovenia-USA projects. Gradually, the cooperation with foreign institutions broadened, and in 2000, IMT researchers were involved in a number of international R&D projects: COST 517, EUREKA EU



Slika 5: Odvisnost med vsebnostjo aktivnega kisika in ogljika v jekleni talini (B. Koroušić, 1976)

Figure 5: Correlation between the contents of active oxygen and carbon in the steel melt in an electric-arc furnace (B. Koroušić, 1976)

tako, da so leta 2000 raziskovalci sodelovali pri 10 projektih, in sicer: COST 517, EUREKA EU 2060, BRITE-EURAM HEMBOT, pri treh projektih izmenjalnih analiz, pri dveh slovensko-hrvaških, enem slovensko-ameriškem in enem slovensko-italijanskem projektu.

5 ORGANIZIRANOST IN CILJI RAZISKOVANJA

V petdesetih letih je imel Metalurški inštitut številne oddelke in pododdelke: konstrukcijski oddelek in delavnice, v raziskovalnem sektorju pa kemično skupino, skupino za rude, goriva in nekovine, metalurško skupino, fizikalno in metalografsko skupino, tehnološko skupino ter laboratorij Piran in administracijo.

V šestdesetih in sedemdesetih letih je raziskovalno delo potekalo po raziskovalnih področjih in oddelkih (bogatenje mineralnih surovin, priprava rude in železarstvo, jeklarstvo, livarstvo, kovinarstvo in metalurgija prahov, v ognju odporni materiali, toplotna tehnika in metalurške peči, kemijske analitske in tehnološke raziskave, teorija metalurških procesov, metalografija in tehnologija kovin). Z oženjem programa dela in s hitro rastjo pomena raziskav tehnologije izdelav in predelav, lastnosti železnih in neželeznih kovin in zlitin ter njihovih lastnosti pri uporabi, se je zmanjševal obseg raziskovanja na področju ekstraktivne metalurgije, zato se je število oddelkov zmanjševalo. Po letu 1980 se je delo odvijalo po dejavnostih v štirih kompleksnih skupinah: ekstraktiva (fizikalna kemija metalurških procesov, železarstvo, jeklarstvo, barvne kovine), tehnološka metalurgija (metalografija, mehanske preiskave, toplotna obdelava, tehnologija barvnih kovin, livarstvo, toplotna tehnika in energetika ter pilotna proizvodnja), kemijska analitika (klasična analitika, fizikalno-kemična analitika, analiza plinov, fazna analiza in varstvo okolja) in bogatenje mineralnih surovin (rude barvnih kovin, nekovinske rude, livarski materiali, tehnologije oplemenitenja in sekundarne surovine).

Težišče raziskovalnega dela v prvih dveh desetletjih po ustanovitvi so bili problemi pridobivanja mineralnih surovin, ekstraktivne metalurgije železa, barvnih kovin in ognje-vzdržnih materialov. Največ dela in sredstev je bilo vloženih v projekt razvoja konstrukcije plavža, v katerem bi uporabljali polkoks iz lignita oz. rjavega premoga kot reducent za železovo rudo in v sončni reaktor. Raziskave so obsegale študije in investicijske elaborate za gradnjo jugoslovanskih surovinskih, metalurško ekstraktivnih in predelovalnih obratov, tehnologijo bogatenja rud barvnih kovin; karakterizacijo železovih, nekovinskih rud in livarskih surovin iz jugoslovanskih nahajališč, izdelavo polkoksa, obratovanje in rekonstrukcije ogrevnih peči v železarnah; rekonstrukcije visokih in Siemens-Martinovih peči, zamenjavo ogrevanja z generatorskim plinom z ogrevanjem z mazutom, strjevanje evtektične celice v sivi litini; termodinamiko in kinetiko procesov v žlindrah,

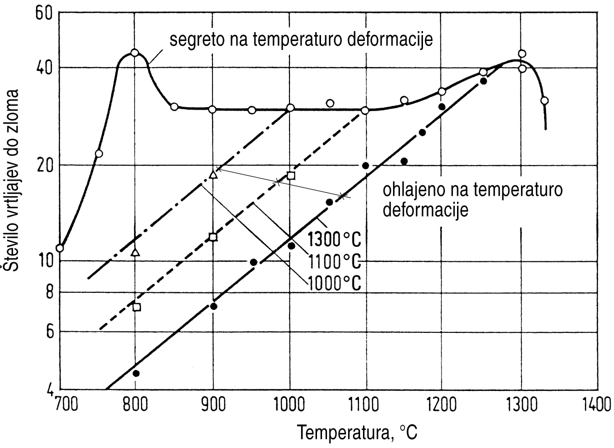
2060, BRITE-EURAM HEMBOT and two projects involving the exchange of results of analyses, in two Slovenia-Croatia projects, one Slovenia-USA project and one Slovenia-Italy project.

5 ORGANISATION AND RESEARCH GOALS

In the 1950s, the institute consisted of a number of units: the research units, a design group, the mechanical and electrical workshops and the administration. The research sector consisted of groups for chemistry, ores and fuels, metallurgical and chemical technology and the Piran laboratory.

In the next two decades the research activity was gradually reorganised to conform better with the economic activity in metallurgy and mining in a number of laboratories and groups, these included: ore benefitiation, iron-ore treatment and pig-iron production, steel technology, casting technology, non-ferrous metals, powder metallurgy, refractory materials, heat technology and metallurgical furnaces, analytical and technological chemical investigations, the theory of metallurgical processes, metallography and non-ferrous metals technology. By the end of the 1970s the research program started to narrow fields related to extractive metallurgy, while the importance of research in topics related to manufacturing, the hot and cold working of steels and non-ferrous alloys as well as their properties started to grow. The number of departments, laboratories and working groups was gradually decreased also. After 1980, the research was performed in four departments: extractive metallurgy (physical chemistry of metallurgical processes, pig iron, steel and non-ferrous alloys), technological metallurgy (metallography, mechanical tests, heat treatment, technology of non-ferrous alloys, heat technology and pilot-plant production), analytical chemistry (conventional and instrumental analyses, analyses of gases in metals, chemical phase analyses, environment analyses) and ore benefitiation (benefitiation processes, non-ferrous ores, castings off auxiliary materials, scrap metals).

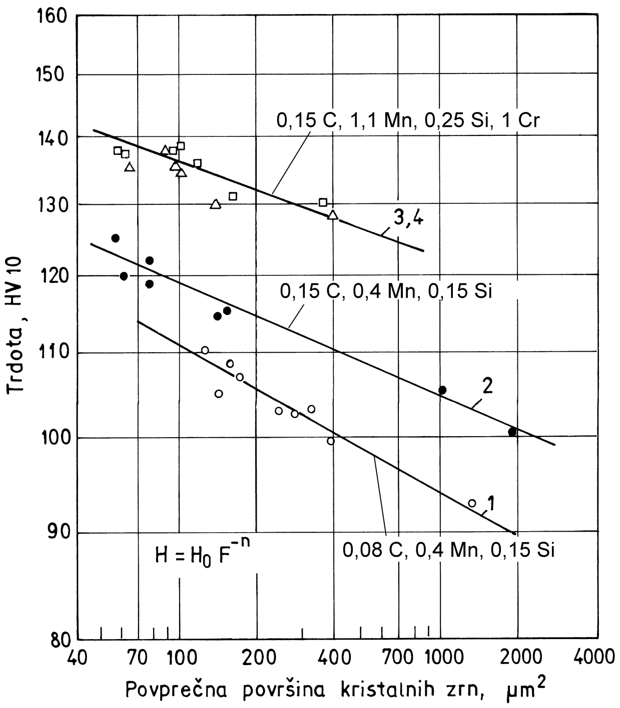
In the first two decades of activity, the accent was on topics relating to the extraction of mineral raw materials, on the extractive metallurgy of iron and non-ferrous metals and the connected development of refractory materials. A lot of funding was invested in a project to design and construct a new type of blast furnace, in which semi-coke from lignite or brown coal would be used as a reducing agent for iron ore and for the solar-energy reactor. The activity included studies and investment-expert reports for the construction of plants for the exploitation of ores and the casting of auxiliary materials, for different metallurgical plants, and research topics, such as the characterisation of ores from deposits in Yugoslavia, the technology of benefitiation of non-ferrous ores, the production of semi-coke, the working and reconstruction of heating furnaces in steel



Slika 6: Preoblikovalnost jekla v odvisnosti od temperature in načina segrevanja oz. ohlajanja na temperaturo začetka deformacije (A. Kveder, M. Taučer, 1974)

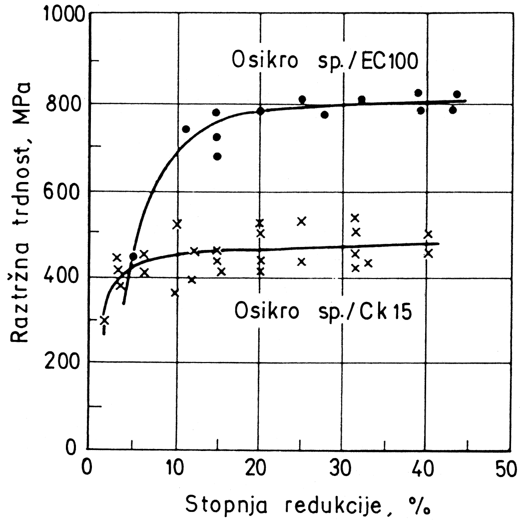
Figure 6: Hot workability of steel in dependence of the test temperature achieved with heating and cooling of specimens to the test temperature (A. Kveder, M. Taučer, 1974)

talinah in v trdnem; cementacijo, toplotne obdelave, obdelovalnost jekla s struženjem, selektivno oksidacijo površine jekla in z njo povezano segregacijo oligoelementov; izdelavo TTT diagramov za različna jekla; razvijanje postopkov za kemijske analize metalurških surovin in izdelkov, skupaj z izolacijo nekovinskih faz, optimizacijo luženja jekel, razvoj zlitin s posebnimi



Slika 7: Odvisnost med trdoto in velikostjo zrn ferita v rekristaliziranih jeklih za masivno preoblikovanje (A. Kveder, A. Razinger, 1976)

Figure 7: Dependence of hardness versus ferrite grain size for cold forging steels (A. Kveder, A. Razinger, 1976)

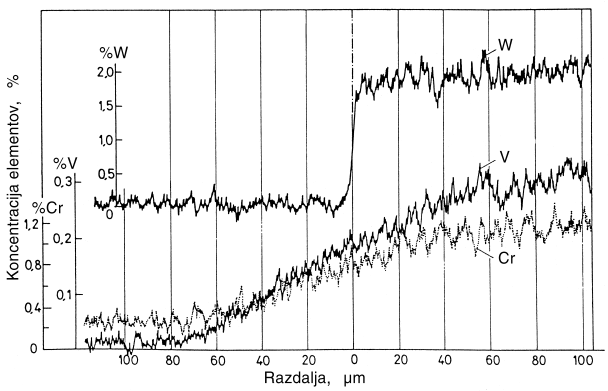


Slika 8: Vpliv stopnje predelave z vročim valjanjem na trdnost valjalniško platiranega spoja med orodnim in dvema konstrukcijskima jekloma (D. Kmetič. J. Gnamuš, F. Vodopivec, 1987)

Figure 8: Effect of hot-rolling deformation on the strength of the plated joining of two tool steels and a structural steel (D. Kmetič. J. Gnamuš, F. Vodopivec, 1987)

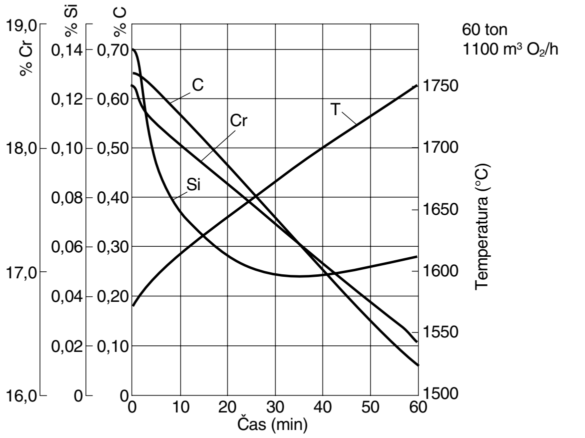
works, the reconstruction of Siemens-Martin furnaces, the replacement of the generator gas with mineral fuel, the eutectic cell solidification in grey irons, the thermodynamics and kinetics of processes in slags, melts and in solid metals, case hardening, the machinability of steels, heat treatment, the selective oxidation of steels containing residuals, the preparation of TTT diagrams for a variety of steels, the methodology of analytical chemistry, phase separation and determination, the de-scaling and pickling of steels, the development of alloys with particular properties for defence projects, the manufacturing of alloys from powder, etc.

Starting from 1970, the volume of research in topics related to extractive metallurgy gradually decreased, while the volume of research related to the technological processes of melting, the hot and cold working of metals



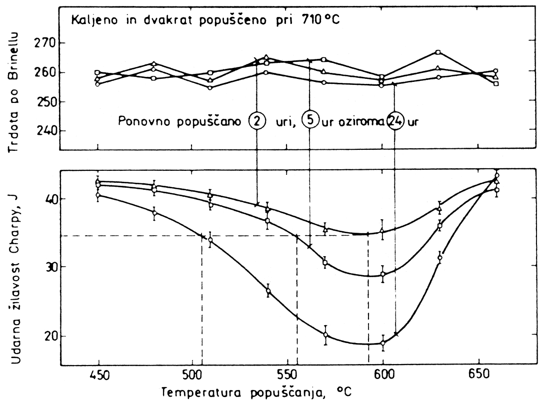
Slika 9: Porazdelitev legirnih elementov v difuzijskem pasu valjalniško platiranega konstrukcijskega in orodnega jekla (D. Kmetič, J. Gnamuš, F. Vodopivec, 1987)

Figure 9: Distribution of alloying elements in the diffusion layer of a hot-rolling joint between a tool and a structural steel (D. Kmetič, J. Gnamuš, F. Vodopivec, 1987)



Slika 10: Računalniška simulacija oksidacije različnih elementov v jekleni talini v VOD-peči pri vpihovanju O_2 1100 m^3/h (N. Smajić, 1985)

Figure 10: Computer simulation of the oxidation of different elements in the steel melt in the VOD furnace during the blowing of O_2 at 1100 m^3/h (N. Smajić, 1985)



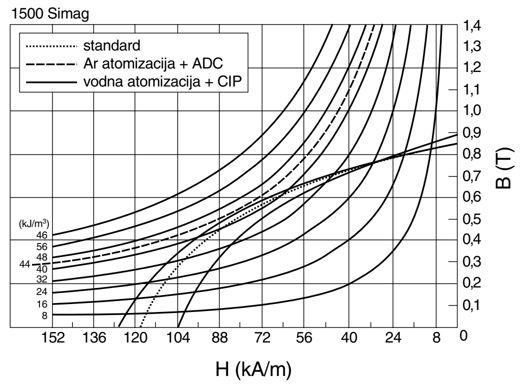
Slika 12: Zmanjšanje Charpyjeve žilavosti krom molibdenovega jekla zaradi segregacije fosforja po kristalnih mejah martenzitnih zrn (B. Ule, F. Vodopivec, M. Pristavec, F. Grešovnik, 1990)

Figure 12: Decrease of Charpy toughness of a chromium-molybdenum steel because of the segregation of phosphorus on martensite grain boundaries (B. Ule, F. Vodopivec, M. Pristavec, F. Grešovnik, 1990)

fizikalnimi lastnostmi za namensko proizvodnjo, izdelavo zlitin po postopkih metalurgije prahu in drugo.

Že pred letom 1975 se je začel zmanjševati obseg raziskovanja na področju ekstraktivne metalurgije, rasti pa je začel obseg raziskovanja tehnoloških procesov in lastnosti kovin, metalurgije prahov, procesne metalurgije, razvoja zlitin s posebnimi lastnostmi, jeklarskih procesov in tehnologije, metodologije raziskovanja, tehnologije barvnih kovin. Kakovost raziskovalnega dela in širina tematike sta se povečevali zaradi boljših kadrov in opremljenosti ter sodobne metode dela. V raziskovalne projekte je bilo pritegnjeno vsako leto več desetin inženirjev raznih strok iz podjetij, ki so bila naročniki RR-projektov, zato je bilo bogato in ustvarjalno sodelovanje med Inštitutom in industrijo ter matično fakulteto.

Po letu 1980 se je vse raziskovalno delo na Inštitutu združilo v naslednja tematska področja:

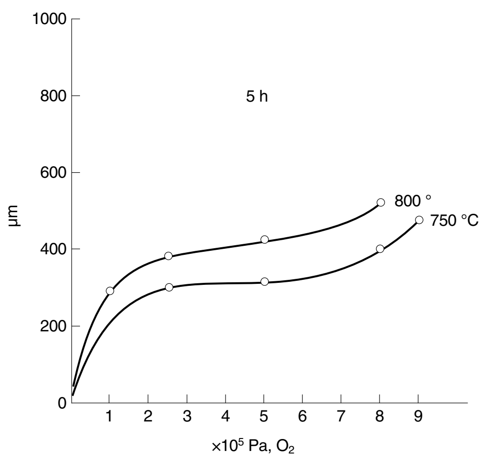


Slika 11: Razmagnetilna krivulja za liti AlNiCo magnet in za magneta, izdelana s sintranjem vodno in v argonu atomiziranega prahu (B. Šuštaršič, Z Lengar, S. Tašner, V. Holc, S. Beseničar, 1992)

Figure 11: Demagnetisation curve for the cast AlNiCo magnet and two magnets manufactured with the sintering of argon and water-atomised powders (B. Šuštaršič, Z Lengar, S. Tašner, V. Holc, S. Beseničar, 1992)

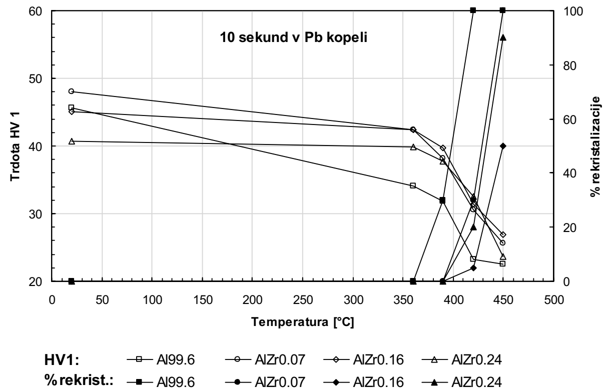
and alloys increased, as did the development of alloys and improvements to their properties. Specific topics were as follows: the processing metallurgy for steels and non-ferrous metals, powder metallurgy technology and products, the development of alloys for special purposes and research methodology. The quality and the relevance of the investigative work increased gradually due to the improving competence of the research staff, better research equipment and the improving working methodology. In R&D projects, every year a number of collaborators with different university degrees from industrial companies were involved, and in this way, the institute and the faculty were also closely involved in the solution of practical problems of technology and of properties of products.

A better assessment of the work performed can be obtained from a survey of the topics of the applied and



Slika 13: Globina notranje oksidacije zlitine Ag10,5Cd pri dveh temperaturah v odvisnosti od tlaka kisika (B. Breskvar, D. Gnidovec, 1984)

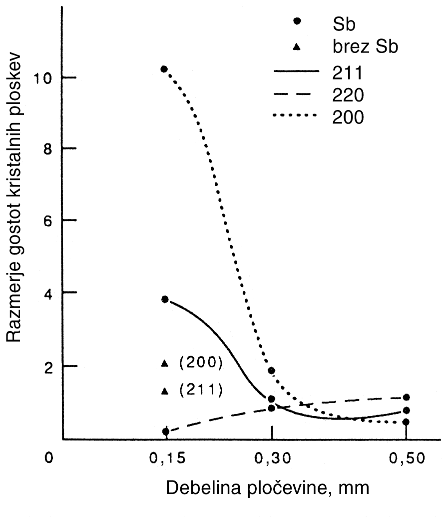
Figure 13: Thickness of the layer of internal oxidation for the alloy Ag10.5Cd for two temperatures in dependence of the oxygen pressure (B. Breskvar, D. Gnidovec, 1984)



Slika 14: Delež rekristalizacije in spremembe trdote po kratkotrajnih žarjenjih pri različnih temperaturah in pri aluminijevih zlitinah za bimetalne trakove za enostranske izparilnike. Trakovi so bili predhodno izvaljani s 60-odstotno enkratno redukcijo pri temperaturi 460 °C. (B. Breskvar, I. K. Banič, J. Marinič, 1995)

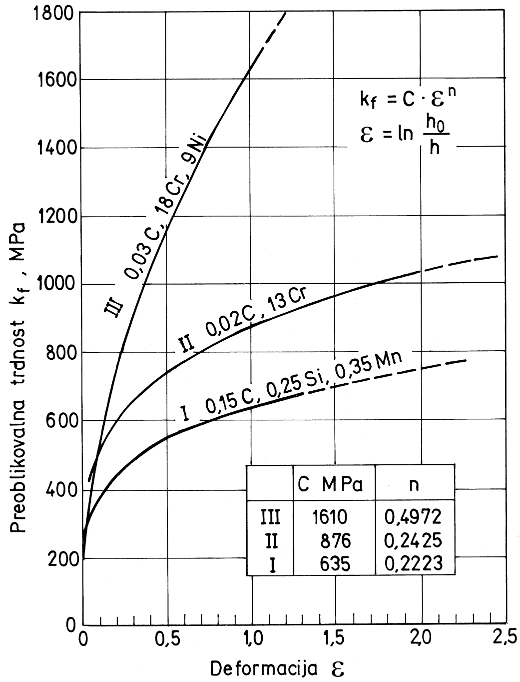
Figure 14: Share of recrystallisation and hardness change after short annealing for aluminium alloys for bimetal strips for one-sided-blown evaporators (B. Breskvar, I. K. Banič, J. Marinič, 1995)

– Jeklarska teorija in tehnologija. Raziskovalci so bili aktivni nosilci ali sodelavci pri projektih uvajanja mazutnih gorilnikov za Siemens-Martinove peči, kar je bistveno izboljšalo produktivnost in ekologijo jeklarske proizvodnje. Temu je sledila dezoksidacija z aluminijem, uporaba sintetičnih žlinder, električno pretaljevanje pod žlindro; uporaba kompleksnih dezoksidantov, najprej z dodajanjem v kosih, nato z vpihovanjem prahov in končno z injekcijo žice, polnjene s CaSi, v jekleno talino, uvajanje neprekinjenega litja, uvajanje ponovčne metalurgije in uvajanje vakuumskega žilavenja. Zaradi stalnih inovacij je proizvodnja jekla preživela in je danes tehnološko na nivoju tehnologije razvitih industrijskih držav, na takem nivoju pa nista proizvodna in predelovalna oprema.



Slika 15: Relativna gostota polov v mehkomagnetni pločevini različne debeline iz silicijevega jekla z dodatki antimona in brez njih (F. Vodopivec, M. Jenko, F. Marinšek, F. Grešovnik, 1992)

Figure 15: Relative density of poles in soft magnetic sheet of different thickness for a steel with and without antimony (F. Vodopivec, M. Jenko, F. Marinšek, F. Grešovnik, 1992)

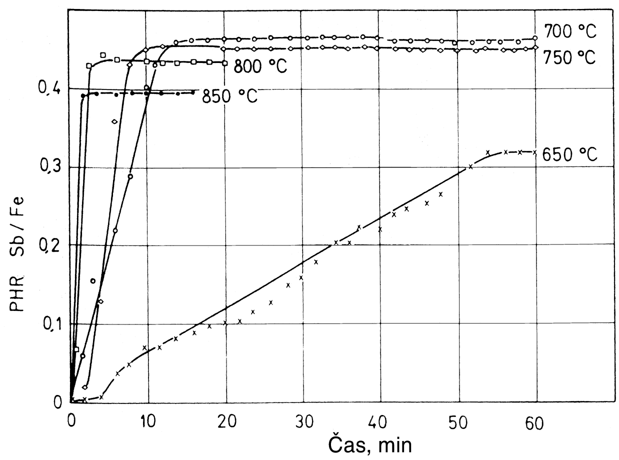


Slika 16: Deformacijska utrditev za mehko konstrukcijsko jeklo ter za superferitno in avstenitno nerjavno jeklo (B. Arzenšek, F. Perko, J. Mrak, N. Vojnovič, D. Lazar, F. Legat, D. Kmetič, J. Žvokelj, 1990)

Figure 16: Strain hardening for a soft steel and a superferritic and an austenitic stainless steel (B. Arzenšek, F. Perko, J. Mrak, N. Vojnovič, D. Lazar, F. Legat, D. Kmetič, J. Žvokelj, 1990)

related basic research, where the activity increased after 1980:

– Processing of steel. The institute research staff was actively involved in projects, such as: the introduction of oil burners to the Siemens-Martin furnaces, which improved the economics of production and the environmental acceptability; aluminium de-oxidation; the use of synthetic slags and of complex deoxidisers,



Slika 17: Kinetika nastajanja ravnotežne površinske segregacije antimona v silicijem jeklu za mehkomagnetne pločevine (M. Jenko, F. Vodopivec, B. Praček, 1993)

Figure 17: Kinetics of the equilibrium surface segregation of antimony on a silicon steel for soft magnetic sheets (M. Jenko, F. Vodopivec, B. Praček, 1993)

– Metalurgija barvnih kovin. Raziskovalci Inštituta so vodili ali sodelovali pri razvoju ekstraktivnih postopkov priprave surovin, kasneje tudi sekundarnih surovin barvnih kovin ter pri razvoju materialov in tehnologij, npr.: disperzijsko in izločevalno utrjene bakrove zlitine za elektrode, baker in bakrove zlitine za obdelavo na avtomatih, svinčeve zlitine za akumulatorje, mikrocink za tiskarsko tehniko, superplastične cinkove zlitine, neprekinjeno litje in predelava Properzi, aluminijeve gnetne in livarske predzlitine in zlitine, izboljšanje tehnologije obdelave talin aluminijevih zlitin, dentalne zlitine, trožilno (do ϕ 7 mm) neprekinjeno litje srebrovih lotov in večslojni električni kontakti. Z večletnim projektom Orao pa je bila vpeljana proizvodnja vseh oblik duralov za letalsko industrijo, prav tako pa izdelava primarnih referenčnih etalonov za livarske zlitine. S področja aluminijevih zlitin velja posebej omeniti razvoj platiranega traka za enostransko izbočene hladilne plošče in razvoj industrijske naprave za rafinacijo aluminija s čistostjo nad 99,7 %. Mnogo razvitih postopkov je postalo standardna tehnologija v podjetjih, številni razviti proizvodi pa so bili sprejeti v program industrijske proizvodnje.

– Na področju preoblikovanja se je raziskovala plastičnost jekel s torzijo in z valjanjem, evolucija mikrostrukture konstrukcijskih jekel med vročim valjanjem, identifikacija nastanka površinskih napak na vroče valjanih profilih, valjarniško platiranje orodnih na konstrukcijska jekla in tehnologija zaključnega valjanja jekel, legiranih s silicijem in z aluminijem za mehkomagnetne pločevine. Na inštitutu se je opravilo tudi pionirsko delo pri razvoju danes splošno uporabljanega termomehanskega kovanja delov za motorna vozila v utopih in pri razvoju mikrolegiranega jekla za ta postopek kovanja.

– Na področju toplotne obdelave jekla je bilo v letih 1965-1970 zelo intenzivno raziskovanje kaljivosti jekel za cementacijo ter povezave mikrostrukture in trdote z vsebnostjo ogljika. Po letu 1970 so se raziskave toplotne obdelave izvajale predvsem v podjetjih na industrijskih napravah v okviru projektov, ki so jih financirala podjetja. Na inštitutu so bili narejeni diagrami za premeno avstenita pri izotermnem in pri kontinuirnem ohlajanju za zelo številna jekla. Raziskovanje na področju toplotne obdelava in trdega spajkanja je močno zaživelo po letu 1985, ko je inštitut iz programa nabave raziskovalne opreme tedanje RSS in s sponzorstvom iz industrije nabavil sodobno peč za vakuumsko toplotno obdelavo, ki je omogočila, da se je razširila tudi storitvena dejavnost, predvsem za več deset podjetij, ki izdelujejo in izvažajo industrijska orodja, npr. orodja za hladno oblikovanje kovin, orodja za tlačno litje aluminijevih zlitin itd. Dejavnost je pridobila na obsegu in vsebini po letu 1994, ko je bila nabavljena naprava za nitriranje v plazmi. To je omogočilo, da se je inštitut vključil v nekatere bilateralne in multilateralne projekte držav EU.

first in the form of lump additions, then the injection of powder, and finally with the injection of filled wire; the introduction of continuous casting, ladle metallurgy and the vacuum treatment of steel melt. The constant introduction of innovations in steel processing kept the steel companies at a similar level of technology to their competition in more developed countries; however, the companies lagged behind when it came to investments in modern production equipment.

– The metallurgical processing of non-ferrous alloys with researchers from IMT involved the preparation of raw materials, the development of extraction processes, also for the use of metal scrap; the development of different copper alloys, e.g. alloys for dispersion and precipitation hardening, free machining alloys; lead alloys for batteries; micro-zinc for printing plates; continuous casting and working processes; the development of aluminium casting and working alloys, and the processing of their melts; the development and pilot-plant production of dental alloys, multilayer electrical contacts and primary reference alloys for the analytical chemistry of cast aluminium alloys and the development of the continuous casting of wire from silver alloys. In addition, the production of different aluminium alloys for aircraft was introduced in the frame of defence projects. A significant success was the original technology developed for the manufacturing of one-sided convex aluminium sheets and the design, construction and the start of an original device for the refining of an aluminium melt to a purity greater then 99.7 %. A number of the processes were (or still are) a standard technology, in use in different companies, whereas a number of products were for a time (or still are) in production.

– In the field of hot working, the evolution of microstructure was investigated with hot torsion and rolling tests; the integrity of the surface of rolled products was improved; the process of hot-rolling plating of tool steels was developed; the hot-rolling technology of soft magnetic steels alloyed with silicon and aluminium was improved and a pioneering work in the introduction of controlled forging for automotive-parts manufacturing was successfully achieved.

– In the field of heat treatment, the hardenability of case-hardening steels was investigated in the years 1965-1970, and the relation to the content of carbon, cooling rate, microstructure and hardness was established. After the 1970s, the investigations relating to heat treatment were performed mostly on industrial equipment in different companies. In the institute, TTT diagrams for continuous and isothermal cooling were established. The research in heat treatment and brazing increased a great deal after 1985, when a vacuum furnace for cooling in high-pressure nitrogen and vacuum brazing was acquired. The furnace was also used for heat-treatment services for industry, especially for a few tens of companies, manufacturers of tools for export, e.g. tools for the cold-forming of metals, for the pressure

– Prvi uspeh na področju metalurgije prahov (PM) je bil razvoj bakrove zlitine za elektrode za točkasto varjenje, disperzijsko utrjene s kromovim oksidom. Zlitina je bila pri uporabi mnogo boljša kot do tedaj uporabljane elektrode. Sledil je razvoj različnih karbidnih trdnin, kontaktnih materialov AgNi, AgC, WAg in elektrodnega materiala za erozijo (W-Cu). Nato se je PM-dejavnost zmanjšala, ker se je nosilni raziskovalec prezaposlil v industrijskem podjetju in tam razvil PM v izvozno proizvodnjo. Njegovo delo se je nekaj časa nadaljevalo v okviru oddelka za tehnologijo barvnih kovin in zlitin. Iz tega obdobja velja omeniti razvoj in proizvodnjo drobnih mikrofiltrov zahtevnih oblik z garantirano prepustnostjo in padcem tlaka za utekočinjenje plinov v miniaturnih napravah, razvoj večplastnih pirometaluških PM-kontaktnih materialov AgCdO/AgCd/Ag/Ag-lot ter novega kontaktnega materiala PM AgZnO/Ag/Ag-lot, prodani in industrijsko uvedeni pa sta bili licenci za srebrov prah in kontakte WAg. Nato je delo znova zaživelo v okviru samostojne dejavnosti po letu 1990, ko je bila na inštitutu postavljena naprava za vodno atomizacijo kovinskih materialov in kasneje naprava za hitro strjevanje, ki sta skupaj omogočili raziskave in razvoj železnih ter neželeznih zlitin, izdelanih po postopkih metalurgije prahov. Med pomembnejšimi uspehi s področja PM velja posebej omeniti izdelavo AlNiCo-magnetov iz vodno atomiziranega prahu, ki je danes v Sloveniji industrijska tehnologija.

– Na področju metrologije smo bili prvi v Jugoslaviji od Zveznega zavoda za mere in plemenite kovine pooblaščeni za kemične analize, silo in trdoto ter za umerjanje strojev in naprav za mehanska preizkušanja, od Zveznega zavoda za standardizacijo pa je inštitut imel tudi posebno pooblastilo za atestiranje verig za ladijska sidra.

– Na področju racionalne rabe energije so se raziskave izvajale na industrijskih agregatih. Na osnovi rezultatov so bile izvršene rekonstrukcije ogrevnih peči, izboljšalo se je njihovo delovanje, znižala se je poraba energije za ogrevanje, povečala se je produktivnost agregatov, v zadnjih letih je bilo uvedeno računalniško krmiljenje naprav.

– Razvite so bile tehnologije in izdelava naslednjih zlitin s posebnimi lastnostmi, npr.: različno mehkomagnetni materiali vrst permaloy, kovar, invar, koercit, nikelj in druge nikljeve zlitine pa tudi izdelki iz njih, npr.: razni trakovi, palice in žice, ohišja za tranzistorje, mehkomagnetna jedra, miniaturni transformatorji, magnetni oklopi, žica za vtaljevanje v steklo in keramiko, ulitki (drsna tesnila) in orodja iz korozijsko in obrabno obstojnih zlitin (akrit, stellit), elektrode za katodno protikorozijsko zaščito konstrukcij itd., pa tudi storitve valjanja, kovanja, vlečenja in toplotne obdelave, psevdozlitine vrste AgCdO, AgZnO, WAg, WCu in AgNi za električne kontakte, električni kontakti, dentalne zlitine na osnovi kobalta in niklja, dvostransko platirani trakovi Sn/Pb/Sn za elektromedicino, zlitine ogljika, casting of aluminium alloys, and for the drop forging of steel parts. This activity increased again in 1994 with the acquisition of a furnace for plasma nitriding. In these areas, the institute was involved in international bilateral and multilateral projects with institutions and companies from the EU.

– The first success in the field of powder metallurgy was the development of a copper alloy, dispersion hardened with chromium oxide, which during use behaved much better than the other alloys used at that time. There was also the development of specific hard alloys; contact alloys AgNi, AgC, AgW; and of the alloy CuW for spark erosion electrodes. Later, activity in the field of powder metallurgy diminished because the leading researcher left for a company, where he introduced the industrial manufacturing of PM parts. His work at the institute was continued at a reduced level, by the group for non-ferrous metallurgy. A particular success was the development and the pilot-plant production of microfilters of different forms, with determined permeability and with controlled loss of pressure of diameter down to 3 mm for miniature air-liquefying devices; multilayer contact alloys AgCdO/AgCd/Ag/ Ag solder, a new contact alloy AgZnO/Ag/Ag solder. Two licenses were sold for the manufacturing of the electrical contact alloy and for Ag powder. After 1990, when a water-atomisation installation, and after, a spin-melt device were acquired, the research in powder metallurgy continued again as an independent unity. A significant success was the development of AlNiCo magnets from water-atomised powder, which is now in production.

– The institute was the first institution to receive from the Federal Institute for Measures and Precious Metals in the former Yugoslavia the authorisation for arbitration chemical analysis and the calibration of devices for determining force and hardness. The federal institute for standardisation authorised the institute for the official testing of chains for ships' anchors.

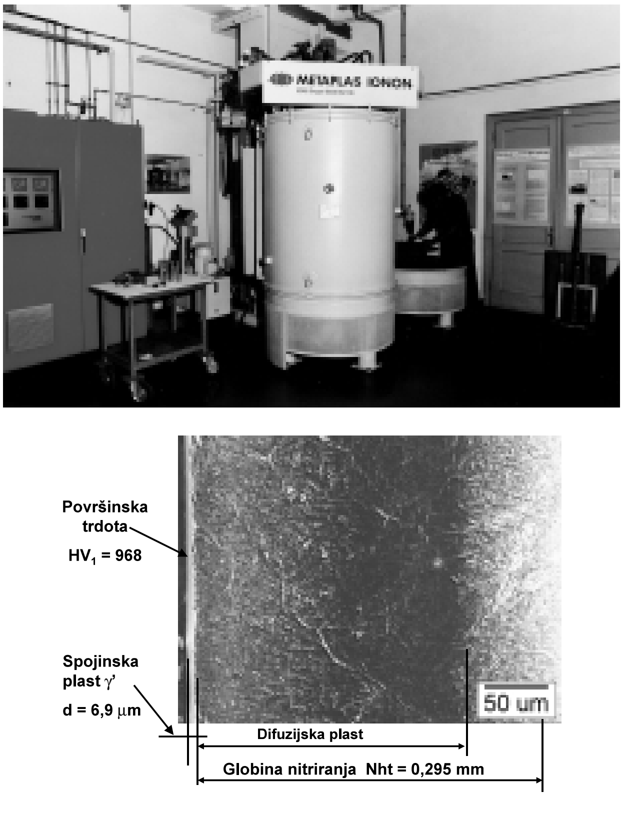
– In the field of the use of energy technology, work was performed on industrial installations. Several reconstructions were carried out on heating furnaces, their operation was improved, their productivity was increased, their consumption of energy diminished, and in recent years their operation became computer controlled.

– Special alloys were developed, and for a considerable time manufactured as pilot-plant production, e.g. different soft-magnetic materials of the types permalloy, kovar and invar in sheets, rod and wire, or products such as transistor casings, soft-magnetic cores, miniature transformers and magnetic yokes; wire for glass solders; castings for slip seals; tools from corrosion- and erosion-resisting hard alloys; high-silicon-alloy electrodes for the electrolytic protection of steel structures; silver and copper pseudoalloys for different purposes; electrical contacts; dental alloys based on cobalt, kobalta, kroma, in molibdena za vložke orodij, ki so obremenjena s korozijo in abrazijo, posebne visoko silicirane železove zlitine za korozijsko zaščito podzemnih jeklenih cevovodov, disperzijsko in izločevalno utrjene bakrove zlitine za elektrode za točkovno varjenje, bakrove zlitine za obdelavo na avtomatih, bakrove zlitine za spajke, koluti iz zlitine bakra, kobalta in berilija za varjenje nerjavnih pločevin, različne cinkove zlitine, npr. mikrocink, ZnCuTi, tiskarske zlitine, mehke in trde spajke, superplastična pločevina in žice iz zlitine ZnAl 22, zlitine za rafinacijo in modifikacijo aluminijevih gnetnih in livarskih zlitin in še druge zlitine. Materiali so se izdelovali na opremi, ki je bila namenjena predvsem za raziskovanje.

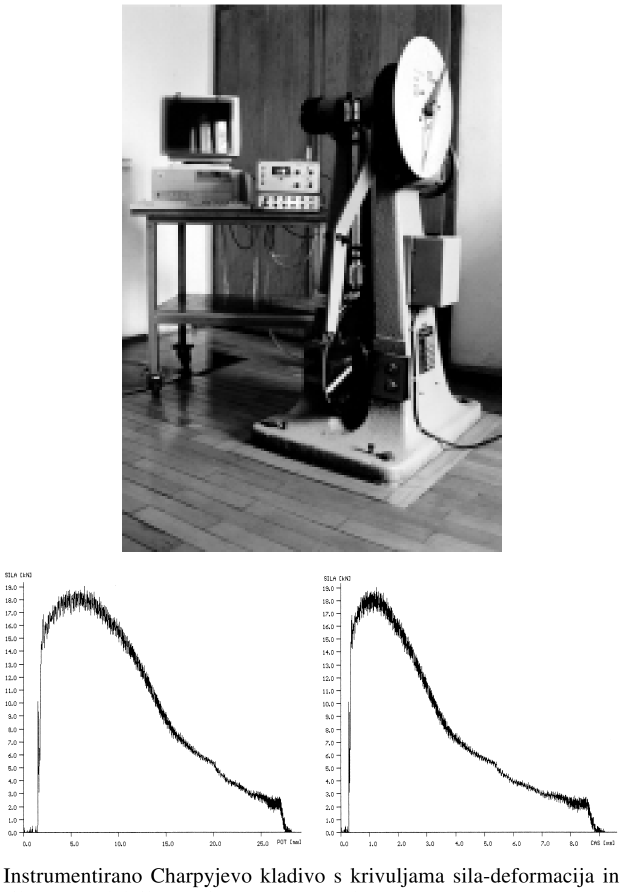
– Mnogo truda in inventivnosti je bilo vloženo v osvajanje novih raziskovalnih in kontrolnih metod in tudi v razvoj in konstrukcijo lastnih naprav. Posebej velja omeniti analitski laboratorij, ki se je izkazal npr. s tem, da je pri 0,02 % Al in 0,01 % N v jeklu določil, koliko aluminija je vezano v oksidni oz. nitridni obliki in koliko ga je raztopljenega v feritu. Zgodaj so bile osvojene različne metode za stereološko ovrednotenje mikrostrukture, z uporabo elektronskega mikroanalizatorja pa je postala dosegljiva analiza izcej in mikrotujkov do velikosti 1 µm. Veliko dela je bilo vloženega tudi v razvoj metodike mehanskih preiskav, in

chromium and nickel; two-sided plated sheets for use in medicine; carbon-cobalt-chromium alloys for tools resistant to corrosion and erosion; dispersion-hardened copper alloys for electrodes for spot welding; copper solder alloys and Cu-Co-Be alloys for welding discs; different zinc alloys, e.g. micro-zinc for printing and Zn-Cu-Ti alloys with increased creep resistance; alloys for brazing and soldering; super-plastic ZnAl 12 alloy and primary alloys for the modification of aluminium alloys. The pilot-plant production was carried out on equipment intended primarily for research.

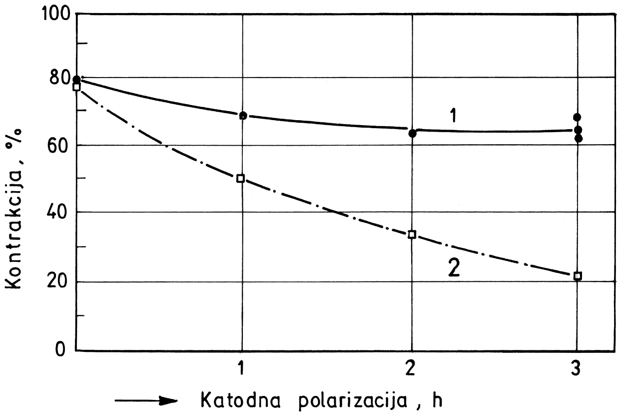
– Considerable efforts were oriented to the development and the implementation of new investigation and control methods and in the design and the construction of scientific equipment, e.g. the laboratory of analytical chemistry was able to determine by 0.02 % Al, 0.01 % N_2 and 0.0005 O_2 % in steel, the share of aluminium in solid solution and bound to nitride and oxide. At a very early stage, sterology was used for quantitative metallography, while the electron probe analyser opened the way for the analysis of constituents of microstructure down to a size of 1 µm. The results made it possible to improve the technology in ferrous and non-ferrous metallurgy as well as fundamental research. The mechanical testing methods were improved constantly



Naprava za ionsko nitriranje in mikrostruktura nitrirane plasti ob površini nitriranega jekla (V. Leskovšek)
Device for ion nitriding and microstructure of the nitrided layer of the surface of the steel (V. Leskovšek)

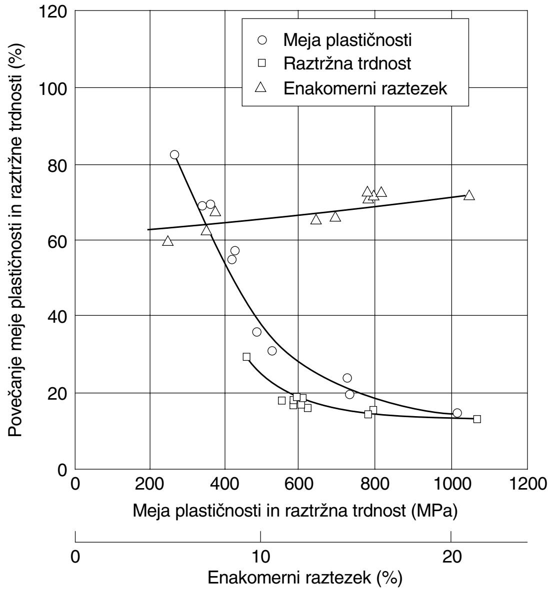


Instrumentirano Charpyjevo kladivo s krivuljama sila-deformacija in sila-čas za duktilen prelom (B. Arzenšek)
Instrumented Charpy device and relatonshios load versus deflection and time (B. Arzenšek)



Slika 18: Vpliv trajanja katodne polarizacije na kontrakcijo dveh konstrukcijskih jekel. Jeklo 1- mikrostruktura iz toplotno obdelanih ferita in perlita in mejo plastičnosti 490 MPa, jeklo 2- mikrostruktura iz poligonalnega ferita in perlita in mejo plastičnosti 350 MPa (L. Vehovar, 1995)

Figure 18: Influence of the length of cathodic polarisation for two structural steels on the reduction of area. Steel 1: microstructure of heat-treated ferrite and pearlite and yield stress of 490 MPa. Steel 2: microstructure of polygonal ferrite and pearlite and yield stress of 350 MPa (L. Vehovar, 1995)



Slika 19: Sprememba meje plastičnosti, trdnosti in enakomernega raztezka konstrukcijskih jekel po deformacijskem staranju v odvisnosti od meje plastičnosti v nestaranem stanju (F. Vodopivec, J. Vojvodič-Tuma, M. Lovrečič, 1999)

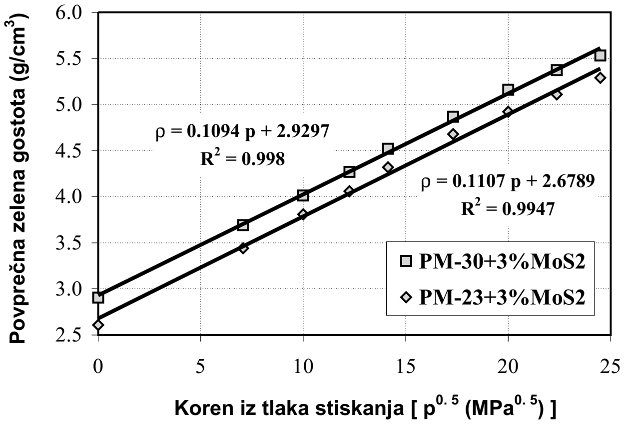
Figure 19: Change of yield stress, tensile strength and unform elongation after strain ageing of structural steels in dependence of the yield stress of the non-aged steels (F. Vodopivec, J. Vojvodič-Tuma, M. Lovrečič, 1999)

v zvezi s tem velja posebej omeniti načrtovanje in konstrukcijo naprave za določanje deformacije z lezenjem. Razviti so bili tudi postopki za toplotno obdelavo v vakuumu in ionsko nitriranje.

Zelo pomembna je bila in je še storitvena dejavnost za zunanje naročnike, npr. laboratorijske meritve, analize, preiskave ter ekspertna mnenja za mednarodne arbitraže o velikih havarijah na energetskih in industrijskih napravah. Na Inštitutu so bile pripravljene tudi ekspertize o havarijah, pri katerih je škoda presegala milijon EUR-ov, ki so bile uveljavljene proti dobaviteljem iz zahodnih držav. Veliko je bilo storitev iz laboratorijev kemijsko-analitskega, mehanskega (ta laboratorij ima uradno pooblastilo za umerjanje

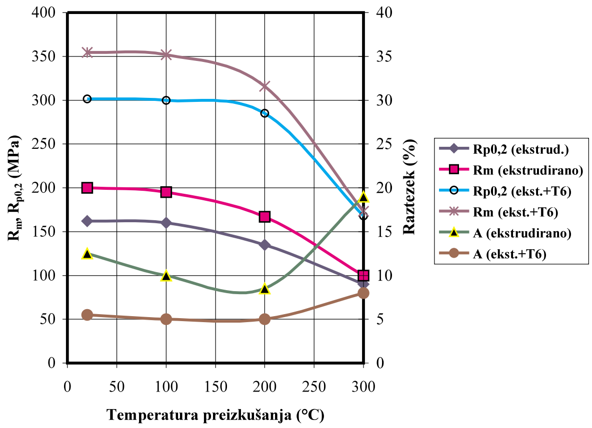
and in this field, the design and the construction of an original computer-controlled machine for creep testing with excellent performance should be mentioned. Specific processes for vacuum thermal treatments and ion nitriding were developed also.

The servicing of external clients continues to be an import area, with different laboratory measurements and analyses. These have included expert reports for international arbitrations on damages to industrial and



Slika 20: Skrček surovca iz praha vodno atomiziranega hitroreznega jekla z dodatkom molibden disulfida v odvisnosti od temperature (B. Šuštaršič, 2000)

Figure 20: Shrinking of a green specimen of water-atomised powder of a high-speed steel with the addition of molybdenum sulfide versus the sintering temperature (B. Šuštaršič, 2000)



Slika 21: Odvisnost med temperaturo preizkušanja in mehanskimi lastnostmi ekstrudiranega kompozita Al/SiC z volumskim deležem 20 % SiC (B. Šuštaršič, M. Doberšek, B. Breskvar, M. Torkar, V. Kevorkijan, A. Smolej, V. Nardin. S. Dai, 1992)

Figure 21: Dependence between the testing temperature and the tensile properties of an extruded composite Al/SiC with 20 vol. % of SiC (B. Šuštaršič, M. Doberšek, B. Breskvar, M. Torkar, V. Kevorkijan, A. Smolej, V. Nardin. S. Dai, 1992)

preizkuševalnih naprav) in metalografskega laboratorija ter iz oddelka za toplotno in površinsko obdelavo. V laboratoriju za metalografijo je bilo opravljeno veliko dela pri elektronskem mikroanalizatorju in vrstičnem elektronskem mikroskopu. Poseben dokaz zaupanja v kakovost in odgovornost dela je pooblastilo Inštituta, da vsako leto opravlja nekatera nadzorna dela pri remontih v NEK (Krško) in dejstvo, da je inštitut pripravil tisti dela varnostnega poročila po 20-letnem obratovanju, ki obravnava stanje zlitine, iz katere je izdelan primarni cevovod. Laboratorijske storitve in pilotna proizvodnja so ohranjale operaterski kader pri raziskovalnih napravah v dobri kondiciji, kar je bilo bistveno za napredek metodike raziskovanja in za zanesljivost ter racionalnost laboratorijskega dela.

6 OBJAVLJANJE IN SODELOVANJE NA ZNANSTVENIH IN STROKOVNIH KONFERENCAH TER POSVETOVANJIH

O vsakem raziskovalnem projektu in nalogi je bilo pripravljeno vsako leto podrobno delovno poročilo, vsako leto tudi letno poročilo in ob okroglih obletnicah večletna poročila, v katerih so bili povzeti najbolj pomembni dosežki iz preteklega obdobja in predstavljeni statistični podatki, pomembni za dejavnost Inštituta. V **razpredelnici 1** so navedeni podatki o številu poročil o raziskovalnih in razvojnih nalogah in projektih ter o objavah v Sloveniji, v Jugoslaviji in v drugih državah po desetletjih za obdobje 1950-2000.

Institut je prvo mednarodno konferenco organiziral s sodelovanjem sorodnih inštitutov iz Nemčije in Francije že leta 1959. Konference v sodelovanju z obema inštitutoma so bile organizirane periodično do leta 1986. Od leta 1968 naprej so bila vsako leto organizirana posvetovanja, na katerih se je poročalo o rezultatih uporabe raziskovalnih projektov v industrijskih podjetjih, predstavljena pa so bila tudi znanstvena dela v obliki govornih in kasneje posterskih prispevkov. Vsakoletne konference, ki se pod nazivom Konferenca o materialih in tehnologijah organizirajo še sedaj in na njih se predstavlja med 80 in 100 deli v govorni in posterski obliki.

energy installations up to 1 million ECU. Most services were performed in the laboratories for analytical chemistry, mechanical testing, metallography and vacuum heat treatment. The fact that the institute staff is involved every year in control operations for the NE power plant Krško and that it was called upon to prepare part of the safety report related to the state of the primary circuit is good evidence of the quality of the routine work of different laboratories. The laboratory services and the pilot-plant production kept the operators in good condition, which was, and still is, essential for good laboratory work.

6 PUBLISHING AND PARTICIPATION IN NATIONAL AND INTERNATIONAL CONFERENCES

Annual reports were prepared for all projects and programs, a report summarising all the activity in the past year and periodical reports on the activity for a few years were prepared, and statistical data on the activity included. In **Table 1** is the data on the number of reports on R&D projects and on the number of publications in Slovenia, Yugoslavia and abroad per decade in the period 1950 to 2000.

The first international conference, probably the first of its type in Yugoslavia, was organised with the cooperation of institutes from Germany and France, in 1959. Periodically, conferences with the cooperation of both institutes were organised up to 1986. Starting from 1968, a national conference was organised every year, where besides the standard communications and lectures, a survey was also given on the implementation of R&D results in industry. An annual conference with the title "Conference on Materials and Technology" is still organised every year, and 80 to 1000 communications are presented in the form of oral lectures and posters.

The publication in periodicals began after 1960, for results available to the public in Slovenian and Yugoslavian journals, such as: Rudarsko-metalurški Zbornik, Železarski Zbornik (the name was later changed to Kovine Zlitine Technologije and finally to Materiali in Tehnologije), Rudarstvo, Geologija in Metalurgija, Metalurgija and Livarski Vestnik. Articles

Preglednica 1: Število poročil o raziskovalnih nalogah in objavah po desetletjih v obdobju 1950-2000. Pripravila N. Ličanin.
Table 1: Number of reports on research projects and of publications per decade for the period 1950 to 2000. Data from Ms. N. Ličanin

Obdobje/ Period	Članki v revijah/Articles in journals			Predavanja v/Comm. at confer.			Naloge, projekti/ R&D projects, reports
	Sloven./ Slov.	Jugosl./ Yugosl.	tuje/ Foreign	Sloveniji/ Slov.	Jugosl./ Yugosl.	tujini/ Foreign	
1950-1960	45	26	4	4	2	20	185
1961-1970	140	21	36	65	28	37	717
1971-1980	181	30	73	169	77	41	715
1981-1990	135	11	32	227	44	79	658
1991-2000	164	21	103	192	17	142	245
Skupaj/Total	665	109	248	657	168	301	2.520

Raziskovalci z Inštituta so bili vsako leto obvezani pripraviti izčrpna poročila o izvršenih raziskovalnih in razvojnih projektih in nalogah. Že kmalu po letu 1962 so se začela objavljati dela, za katera je naročnik dal pristanek, da smejo v javnost, in sicer v slovenskih in jugoslovanskih revijah, npr. Rudarsko-Metalurški Zbornik, Železarski Zbornik (kasneje preimenovan v Kovine Zlitine Tehnologije, sedaj Materiali in Tehnologije) Rudarstvo, Geologija i Metalurgija, Metalurgija in Livarski vestnik. Objavljali pa so tudi v revijah, ki so se tiskale v Nemčiji, Franciji, Angliji, Kanadi, Nizozemski, Avstriji, Italiji, in Japonski, npr. Memoires Scientifiques de la Revue de Métallurgie, Archiv für das Eisenhüttenwesen-Steel Research, Metals Tehnology, Metals Science, Materials Science and Technology, Journal of Magnetism and Magnetic Materials, Journal de Physique, Journal of Materials Processing Technology, Vacuum, Journal of ISI of Japan in drugih. Raziskovalci so sodelovali tudi na številnih znanstvenih konferencah v praktično vseh državah Evrope, v ZDA, Aziji in v Avstraliji. Podatki v razpredelnici kažejo, da se je po desetletju 1950-1960 število poročil o raziskovalnih nalogah in projektih ustalilo, število objav pa v vsem obdobju stalno raste, skladno z izboljšanjem kakovosti in izvirnosti raziskovalno-razvojnega dela in zahtevami okolja za večjo odprtost. Če upoštevamo, da je bilo povprečno število raziskovalcev v vsem obdobju okoli 30, je število objav različne vrste zelo veliko. K temu je treba prišteti še vsako leto nekaj deset ekspertiz različne zahtevnosti in obsega, pogosto tudi arbitraž in ocen velikih havarij na industrijskih objektih.

7 NAROČNIKI RAZISKOVALNIH NALOG OZIROMA PROJEKTOV

Že kmalu po ustanovitvi, ko so se zmanjšala sredstva iz zveznih skladov, je Inštitut poiskal naročnike projektov v številnih podjetjih iz matične in drugih industrij. Večina teh podjetij je na Inštitutu financirala po več projektov za svoje potrebe. Obseg financiranja se je po letu 1990 precej zmanjšal zaradi tranzicijske krize, vendar sodelovanje ni bilo nikdar popolnoma prekinjeno. V prvih 20 letih so naročila za RR-projekte prihajala iz vse Jugoslavije in iz agencij zvezne vlade, ki so v Beogradu odgovarjale za razvoj različnih področij, predvsem oceno možnosti industrijske eksploatacije mineralnih rud in goriv. Po letu 1970 se je ta dejavnost močno zmanjšala in težišče se je usmerilo na tehnološke inovacije, razvoj novih zlitin, zmanjšanje porabe energije in zmanjšanje obremenitve okolja. Podjetja navajamo brez podatkov o tem, koliko projektov je bilo zanje izvršenih in koliko sredstev je s projekti inštitut pridobil. V začetku velika podpora zveznih skladov se je zmanjšala, ko se je Inštitut usmeril predvsem na slovensko okolje, nikdar pa ni prenehalo sodelovanje z industrijskimi podjetji iz vse bivše Jugoslavije. Naročniki raziskovalnih nalog in projektov so bili npr.:

with authors from IMT were printed in Germany, France, England, Canada, Holland, Austria, Italy and Japan, in journals such as: Memoires Scientifiques de la Revue de Métallurgie, Archiv für das Eisenhüttenwese-Steel Research, Metals Technology, Metals Science, Materials Science and Technology, Journal of Technology, Journal of Magnetism and Magnetic Materials, Journal de Physique, Journal of Materials Processing Technology, Vacuum, Journal of ISI of Japan and others. Researchers participated with communications in a number of scientific conferences in virtually every European country, in the USA, Australia and some Asia countries.

The data in the table indicate that the number of reports stabilised after the decade 1950-1960, while the number of publications increased steadily with the increasing originality and quality of the R&D results, and the increasing openness. When taking account of the fact that for the whole period there was a constant staff of approximately 30 researchers, the number of publications of all types is relatively high. Additionally, every year a few tens of expert reports of varying importance were prepared, there were also frequent evaluations of the causes of severe damage to industrial equipment and installations.

7 FINANCERS OF R&D PROJECTS

The support from federal funds diminished soon after the initial years of activity, and the institute was forced to find money for R&D projects from industrial and mining companies. A number of companies financed at least a few R&D or other projects. The volume of industrial financing dropped strongly in 1990 because of the transition's economic crisis; however, it never stopped completely.

In the first 20 years of activity the contracts for projects were concluded with companies from all over Yugoslavia, and from the federal agencies responsible for the development of different industrial branches. Very frequently, the topics of the projects were the evaluation of the feasibility of exploiting ores and solid mineral fuels. After 1970, this activity decreased very significantly, and the accent was given to technological innovations, to the development of new alloys, to the rationalisation of energy use and to the reduction of environmental pollution. The companies are mentioned as R&D partners of the institute without data on the number of projects and the volume of financing involved for their realisation. Although the support of federal funds virtually stopped after the institute turned to Slovenian industry and funds, the cooperation with companies from the whole of Yugoslavia was not interrupted until the break up of Yugoslavia.

Starting from 1950, the financers of R&D projects were: The Federal Direction for Ores, The Federal Fund for Science and the Assotiation of Yugoslavian Iron and

Laboratorijska peč in merilni sistem za visokotemperaturno umerjanje termoelementov (do 1300 °C) in simulacijski model ogrevanja za vsako gredico v realnem času (Allino peč – Metal Ravne), razvit na IMT
Laboratory furnace and measuring system for the calibration of termoelements up to 1300 °C and simulation model for the heating of single billets in real time (Allino furnace – Metal Ravne), developed in IMT

Savezna direkcija za mineralne surovine, Beograd; Savezni fond za naučni rad, Beograd; Sklad Borisa Kidriča, Ljubljana; UJŽ, Beograd; Železarna Jesenice; Železarna Ravne; Železarna Štore; Železarna Skopje; TOVIL, Ljubljana; Žična, Celje; Tvornica FENI, Kavadarci, Makedonija; Institut Mihajlo Pupin, Beograd; RMK, Zenica; EI Niš; Rudnici i topionica, Zletovo; Valjaonica bakra Slobodan Penezič Krcun, Sevojno; Impol, Slovenska Bistrica; TGA-Talum, Kidričevo; Mariborska livarna; Cinkarna Celje; Rudniki in topilnica, Mežica; Aurodent, Ljubljana; LTH, Škofja Loka; Inštitut Zoran Rant, Škofja Loka; Livarna Komen; Zlatarna Celje; Termit, Domžale; Exoterm, Kranj; Iskra Kondenzatorji, Semič; Tovarna polprevodnikov, Trbovlje; Iskra Stikala, Kranj; Vazduhoplovni institut, Žarkovo, Beograd; TLM, Šibenik; TUP, Dubrovnik; KAT, Titograd; Iskra Releji, Ljubljana; Merkur, Kranj; Belt, Črnomelj; Livarna, Ivančna Gorica; Kovaška industrija Zreče; VTI, Beograd; Institut za brodogradnjo, Zagreb; Croacija, Zagreb; Iskra Zmaj, Ljubljana; Iskra Števci, Kranj; Metalna, Maribor; TAM, Maribor; Tovarna dušika in ferozlitin, Ruše; Veriga, Lesce; Plamen, Kropa; Strojna tovarna, Maribor; Kovinarska, Krško; Tomos, Koper; Energoprojekt, Beograd; Energoinvest, Sarajevo; Termoelektrarna Šoštanj; Termoelektrarna in toplarna Ljubljana; Kovinarstvo, Krško; Nuklearna elektrarna Krško; SŽ Acroni, Jesenice; SŽ Metal, Ravne; Litostroj, Ljubljana; Tovarna magnetov, Ljubljana; Feriti, Ljubljana; Kolektor, Idrija; Unior, Zreče in drugi.

8 SKLEP

Zgoščen pregled odkriva v 50 letih dela na Inštitutu zelo uspešna, manj uspešna in celo kritična obdobja. Bila so odsev dogajanja v industrijskem okolju, s katerim je bil Inštitut povezan, in raziskav, ki so bile usmerjene v napredek tehnologije in razvoj novih postopkov ter proizvodov. Pretežna navezanost na industrijo, ki je še

Steelworks, Belgrade; The Boris Kidrič Fund, Ljubljana; Iron Works, Jesenice, Ravne and Štore, Slovenia; Tovil and Žična, Slovenia; Institute Mihajlo Pupin, Belgrade; RMK Zenica, Bosnia; Rudnici in topionica Zletovo, Macedonia; Valjonica bakra Sevojno, Serbia; Impol, TGA-Talun, Mariborska livarna, Cinkarna Celje, Slovenia; Rudniki in topilnica Mežica, Aurodent and LTH, Slovenia; Inšitut Zoran Rant, Livarna Komen and Zlatarna Celje, Slovenia; Termit Domžale, Eksoterm and Iskra kondenzatorji, Slovenia; Tovarna polprevodnikov Trbovlje and ISKRA Stikala, Slovenia; Vazduhoplovni institut, Serbia; TLM and TUP, Croatia; KAT, Montenegro; Iskra releji, Merkur, Belt, Livarna Ivančna Gorica and Kovaška industria Žreče, Slovenia; VTI, Serbia; Institut za brodogradnju and Croatia, Croatia; Iskra Zmaj, Iskra števci and Metalna, Slovenia, TAM, Tovarna dušika in ferozlitin, Veriga, and Plamen, Slovenia, Strojna tovarna Maribor, Slovenia, Kovinarska Krško and, Tomos, Slovenia, Energoprojekt, Serbia; Energoinvest, Bosnia; Termoelektrarna Šoštanj, Termoelektrarna in toplarna Ljubljana, and Kovinarstvo Krško, Slovenia, Nuklearna Elektrarna Krško, Slovenia; SŽ Acroni, SŽ Metal, SŽ Jeklo and Litostroj, Slovenia; Tovarna magnetov Ljubljana, Feriti, Kolektor and Unior, Slovenia and other companie from all Yugoslavia.

8 CONCLUSION

This survey shows that in 50 years of activity the institute has met very successful, less successful and even critical periods, depending on the economic situation in industry and the research policy in the federal and republican agencies charged with subsidizing the scientific research and development. In Slovenia, the strong relations with industry, which are also found in research institutions of similar orientation in developed countries, are not secure in the long term, mostly due to the absence of a stable financing system that is similar to that in developed countries. In addition, the Slovenian danes temelj delovanja v sorodnih inštitutih v razvitih državah, se je dolgoročno pokazala kot nezanesljiva, ker ni bilo sistemske ureditve in financiranja po zgledu razvitih držav in ker raziskovalna politika vlade po letu 1990 ni dovolj podpirala aplikativnega in razvojnega raziskovanja za potrebe slovenske industrije. Če se bo pisala bolj natančna kronika dela inštituta bo mogoče našteti številne konkretne primere, ko je Inštitut dal pobudo ali pa vsaj odigral pomembno vlogo pri razvoju tehnologij in proizvodov v podjetjih matične industrije. Tudi Inštitutu gre zasluga, da je v zadnjem času ta industrija gospodarsko uspešna, saj se je izpostavil v njeno obrambo v času, ko se je zdelo, iz danes nejasnih razlogov, da želijo nekateri politiki ustaviti metalurško industrijo v Sloveniji. Z RR-projekti, s storitvami, pilotno proizvodnjo je Inštitut sodeloval in še sodeluje s številnimi industrijskimi podjetji in je gotovo med institucijami, ki so se z delom pokazale kot zelo koristne za industrijo in državo.

Orientacija na industrijsko okolje in ekonomska navezanost nanj pa nista omogočali, da bi bil inštitut zelo veliko prisoten v temeljnih raziskavah, ki bi sodelavcem dale veliko možnosti za objavljanje rezultatov dela v tujih strokovnih in znanstvenih revijah. Objava tehnološko pomembnih dognanj je bila tudi odvisna od pristanka naročnikov dela, javna sredstva pa so se porabljala za temeljna raziskovalna dela, ki so izhajala iz problemov v tehnologijah in pri proizvodih, ki jih ni bilo mogoče zanesljivo pojasniti z že objavljenim splošnim teoretičnim znanjem. Vendar je bila tudi v tistem času publicistična dejavnost dokaj razvita, Inštitut pa je bil celo soizdajatelj revije Železarski zbornik. Zato je bila mogoča v novem času (ki je v metodiki ocenjevanja kakovosti raziskovanja, ki se financira iz javnih sredstev, dal prednost objavam in citatom ter podcenil pomen relevantnosti raziskovanja pri vedah, ki so bile v Sloveniji dolgoletno navezane na industrijsko okolje), še pravočasna in zadostna preusmeritev in s tem preprečitev tistega, kar se je zgodilo drugim, v preteklosti podobno orientiranim inštitutom. V 50 letih dela pa je bilo toliko uspehov in dosežkov, da so na delo Inštituta lahko ponosni njegovi ustanovitelji, uporabniki ter vsi bivši in še danes zaposleni.

government's research policy after 1990 did not sufficiently support R&D projects with topics of interest to Slovenian industry.

In a more detailed article, a number of cases will be mentioned where the institute did play a significant role in the projects of advanced technology and products in different companies, or at least proposed significant and useful suggestions for changes and improvements. Even the economic success of the metallurgical industry in past years can be partially ascribed to the institute because of its warnings to the public in times of economic crisis that had political roots, when some politicians pleaded openly for a Slovenia without conventional industries. With R&D projects, technical expert work and pilot-plant production, the institute took part in the R&D of a number of industrial companies, and it continues to play a similar role now. The research orientation and the great economic dependence on projects financed by industrial companies did not give the researchers many opportunities for basic research on topics of current scientific interest abroad, which would have given them more opportunity to publish articles in foreign scientific journals. The publishing of findings that could be related to advances in technology was possible only after the consent of the contractor. Public support for basic research was mostly aimed at R&D on topics related to industrial technology and development, and the findings used to prepare better R&D projects for industrial clients. In spite of these impediments, the publishing activity was above average when compared to R&D institutions of similar orientation. The institute was, for a number of years, co-editor of the journal Železarski Zbornik. For this reason, in the period of public research policy, when in the evaluation of research a preference was given to publications that were not industrially relevant, also in technical sciences, the reorientation was possible and with it the prevention of very serious deleterious consequences.

Everything achieved in the 50 years of R&D and related work entitles the founders as well as the past and present staff to be proud of the activity of the institute and its role in the growth of industry in Slovenia and in the former Yugoslavia.

POJASNILO

Pregledu dela je priloženo dvoje vrst slik, ki niso neposredno povezane z razlago v tekstu. Oštevilčene slike prikazujejo izbrane raziskovalno-razvojne izsledke od leta 1964 naprej. Izbrane so bile s ciljem, da se predstavi vsebinski obseg dela in posredno tudi uporabljene raziskovalne in analitske metode. Neoštevilčene slike prikazujejo pomembnejšo raziskovalno opremo v uporabi na inštitutu leta 2000 in primere rezultatov analiz in preizkusov.

Diagrami so predstavljeni tako, kot so bili objavljeni.

EXPLANATION

Two kinds of figures without direct relation to the tekst are included in the survey. The numbered figures present results of R&D work from 1964 and were selected with the aim to show the range of topics of R&D research and to show indirectly also the used experimental and analytical methods. The non-numbered figures show some of the more important research equipment in use in the institute in the year 2000 and examples of tests and analyses.

Diagrams are presented in the original form.