NAUČNO-ISTRAŽIVAČKA I RAZVOJNA SARADNJA IZMEĐU FAKULTETA, INSTITUTA I INDUSTRIJE

Raziskovalno in razvojno sodelovanje fakultete, instituta in industrije

Research and development cooperation between faculty, institute and industry

Borut Kosec

University of Ljubljana
Faculty of Natural Sciences and Engineering
Ljubljana, Slovenia

University of Ljubljana is an institution with a very rich tradition.

It was established in 1919 on the foundations of long-established pedagogical tradition.

24 Faculties
3 Academies

approx. 52,000 graduate and post-graduate students
approx. 3,500 teaching and research staff
approx. 900 technical and administrative staff

www.uni-lj.si
WEBOMETRICS (2012)
(www.webometrics.info)

University of Ljubljana

106th position in the World

23th position in Europe
Faculty of Natural Sciences and Engineering

Department of Geology
Department of Mining
Department of Textile and Graphic Engineering
Department of Chemical Engineering
Department of Materials Science and Metallurgy

www.ntf.uni-lj.si
Department of Materials Science and Metallurgy

6 chairs

Engineering materials

Foundry

Metal processing technology

Metallography

Metal forming

Thermal technics
Education programmes at
University of Ljubljana
Faculty of Natural Sciences and Engineering
Department of Materials Science and Metallurgy

B. Sc. education programmes
Metallurgical Technologies
Engineering Materials

M. Sc. education programme
Metallurgy and Materials

Ph.D. education programme
Materials Science

Interdisciplinary Ph.D. university education programme
Environmental Protection
### Projects:

**SLOVENIAN RESEARCH AGENCY (2005 – )**

<table>
<thead>
<tr>
<th>Code</th>
<th>Project Title</th>
<th>Duration</th>
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</thead>
<tbody>
<tr>
<td>L2-3496</td>
<td>Synthesis of Composite Materials and Compounds with high Energy Rate</td>
<td>1.7.2002 - 30.6.2005</td>
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<tr>
<td>L2-6313</td>
<td>Optimisation of the manufacturing technologies of steel semiproducts for the automotive industry</td>
<td>1.7.2004 - 30.6.2007</td>
</tr>
<tr>
<td>L2-6342</td>
<td>Superplasticity of Al-Mg and Al-Zn-Mg-Cu alloys with scandium addition</td>
<td>1.7.2004 - 30.6.2007</td>
</tr>
<tr>
<td>M2-0108</td>
<td>New shape memory metal alloys</td>
<td>1.6.2006 - 31.5.2010</td>
</tr>
</tbody>
</table>
International cooperation (2005 – )

**EUREKA E!2982 COMBUB**

**BI SLO – CZ** (SLO-CZ 05/06-014)

**EUREKA E!3704 RSSMA**
Rapidly Solidified Shape Memory Alloys (1.1.2006 – 30.11.2008)

**EUREKA E!3863 MET-STR**

**TEMPUS IB JEP-41156-2006 (RS) TIMEA**
Training of Institutions in Modern Environmental Approaches and Technologies (1.9.2007 – 31.01.2010)

**BI SLO – PL** (SLO-PL 08/09-023)

**BI SLO – BiH** (BI-BA 08/09-002)

**EUREKA E!4213 NANO-FOIL**
Development of Nano-Foils for Dentistry and Jewellery (1.5.2008 – 1.1.2011)

**BI SLO-CRO** (SLO-HRV 09/10-023)

**BI SLO-PL** (SLO-PL 09/10-002)

**BI SLO – BiH** (BI-BA 10/11-011)

**BI SLO – CG** 201072011-5

**TEMPUS 510985-TEMPUS-1-2010-1-RS-TEMPUS-JPHES** (2 010 - 3366 / 001 - 001) ISIS
Trans-European Cooperation Scheme for Higher Education (15.10.2010 – 14.10.2013)

**BI SLO – CG** (SLO-CG 12/13-014)

**BI SLO – ZDA** (SLO-ZDA 12/13-026)

**BI SLO – CRO** (BI-HR 12/13-038)

**ERA NET**
New metallic materials and characterization methods (1.6.2011 – 30.5.2014)

**EUREKA E!6735 ESPAL**
Energy Savings by application of Electromagnetic Field in production of Al-alloy billets by DC casting method (1.4.2011 – 1.4.2013)
Cooperation with the foreign universities / institutes in the fields of research and education

Technische Universitaet Leoben, Leoben, A
Technische Universitaet Wien, Wien, A
Technische Universitaet Clausthal, Clausthal, D
Universitat Politecnica de Catalunya, Barcelona, E
Technical University of Brno, Faculty of Mechanical Engineering, Brno, CZ
Silesian University of Technology, Gliwice, PL
Technical University Krakow, Krakow, PL
University of Osaka, Osaka, J
University of California, Berkely, USA
Univerzitet u Novom Sadu, Fakultet Tehničkih Nauka, Novi Sad, SR
Univerzitet u Beogradu, Beograd, SR
Univerzitet u Zenici, Zenica, BiH
Univerzitet u Banja Luci, Mašinski fakultet, Banja Luka, BiH
Sveučilište u Zagrebu, Metalurški fakultet, Sisak, CRO
Sveučilište u Osijeku, Strojarski fakultet, Slavonski Brod, CRO
Univerzitet Crne Gore, Podgorica, CG
Universita di Trieste, Trst, I

Metalurški institut Kemal Kapetanović, Zenica, BiH
VTI Vojno tehnički institut, Beograd, SRB
Cooperation with industrial partners

Acroni d.o.o., Jesenice
Metal Ravne d.o.o., Ravne
Štore Steel d.d., Štore
Iskra Avtoelektrika d.d., Šempeter
Impol d.d., Slovenska Bistrica
Cimos d.d., Koper
Talum d.d., Kidričevo
ETI Elektroelement d.d., Izlake
Kolektor d.d., Idrija
Rotomatika d.d., Sp. Idrija
Inductio d.o.o., Ljubljana
MLM d.d., Maribor
Metaling d.o.o., Ljubljana
Terming d.o.o., Ljubljana
BACO d.o.o., Trzin
KOVA d.o.o., Celje
Klima d.d., Godovič
Bosio d.o.o., Štore
Ydria Motors d.o.o., Cerknica
Akrapovič d.o.o., Ivančna Gorica
Kovinarstvo d.o.o., Vitanje
Zlatarna Celje d.d, Celje

ECO Klima GmbH, Wien
Treibacher Auremet GmbH, Treibach
Tomeks a.d., Prijedor / Ljubija
SaMax d.o.o, Banja Luka
Bosio Zenica d.o.o., Zenica
TEM Inženjering d.o.o., Banja Luka
U.S. Steel, Košice
Zlatna Aurora d.o.o., Sisak
EXOR d.d., Buzin

ACS Slovenian Automotive Cluster
Slovenian Plastechnics Cluster
Slovenian Steelmaking Platform
Center of Excellence: Advanced Metallic Materials
SICOS – Court Experts
Industrial projects (2005 – )

Ecologically sound materials for fusible elements of low voltage fuses
ETI d.d. - UL Faculty of Natural Sciences and Engineering

Development, Know-How and Technologies for Production of Foils Made by Continuously Cast Strip on the Base of AA8079 Aluminium Alloy
UL Faculty of Natural Sciences and Engineering - Impol d.d.

Development of wear resistant structural steel
ACRONI d.o.o. – UL Faculty of Natural Sciences and Engineering

Temperature calibration of furnace for heat treatment of Al alloys castings for the automotive industry
Cimos d.d. - UL Faculty of Natural Sciences and Engineering

Heat treatment of steel semi-products for the automotive industry
Iskra Avtoelektrika d.d. - UL Faculty of Natural Sciences and Engineering

Optimisation of the inductive heating and quenching of planetary shafts
Iskra Avtoelektrika d.d. – UL Faculty of Natural Sciences and Engineering – TERMING d.o.o.

Optimisation of mechanical properties of Inconel 718 with heat treatment
Rotomatika d.d. – UL Faculty of Natural Sciences and Engineering

Deformation of superplastic Al alloys
Impol d.d. - UL Faculty of Natural Sciences and Engineering

Foundry total waste management
KOVA d.o.o. - UL Faculty of Natural Sciences and Engineering

Development of new dental alloys
UM Faculty of Mechanical Engineering - Zlatarna Celje d.o.o.- UL Faculty of Natural Sciences and Engineering

Continuous tinning of Cu ribbons
Kolektor d.d. - UL Faculty of Natural Sciences and Engineering
Field(s) of research

Department of Materials Science and Metallurgy

Synthesis and characterisation of materials (metalls, ceramics, polymers and composites).

Failure and Fracture analysis. Expert work.

Microscopy. OM. SEM.

Modelling (experimental, mathematical, numerical).

(Micro)hardness measurements, measurements of carbon and sulphur content.

DTA and STA materials analysis.

Thermal and thermochemical treatment of metallic materials.
Field(s) of research

Department of Materials Science and Metallurgy

Foundry. Die casting.

Steelmaking. Continuous casting.

Engineering measurements.


Production of high-speed solidified materials (amorphous materials, Al and Cu based alloys, composites, shape memory alloys).
Melt spinner

E!2982 COMBUB  

E!3704 RSSMA  

Rapidly solidified shape memory alloys

Cu-Al-Ni
Cu-Al-Ni-B
Cu-Al-Zn-Ni
In Department for materials and metallurgy, Faculty of Natural science and engineering, University of Ljubljana, we have testing hardenability of various steels that are needed in Slovenian and foreign industry. Existent system consisted of electrical furnace in which testing samples are heated on an austenitization temperature and quenching bath that with a jet of water cools down the head surface of a testing sample. For cooperative needs for industry the upgrade of a current system was made including a system that enables continuous measurements of temperature of a testing sample during a whole experiment.
Device for measurement microstructural changes

Measuring system

User interface
Aluminium alloys for superplastic forming

The equipment for the investigation of the superplastic properties.

The highest elongation to failure was achieved at optimum forming conditions 2000 %. The superplastic forming with suitable elongations over 400 % was also achieved at lower forming temperatures and higher strain rates. That is very important for the industrial production of superplastic sheets.

The samples of the Al-Mg-Mn-Sc alloy before and after the tensile tests at various temperatures and at constant initial strain rate.
Modernization of the Continuous Casting Technology for Steel Semi-Products

FEذاBRURY 2011

Anton Košir, MSc Thessys
Fusible elements of low voltage fuses

Development of ecologically sound materials for fusible elements of low voltage fuses.

SnCd_{20} \rightarrow ETI-Sn-Bi-Sb

<table>
<thead>
<tr>
<th>Composition</th>
<th>SnBi_{5}Cu_{1}Sb_{0}</th>
<th>SnBi_{5}Cu_{1}Sb_{0.5}</th>
<th>SnBi_{5}Cu_{1}Sb_{1.0}</th>
<th>SnBi_{5}Cu_{1}Sb_{1.5}</th>
<th>SnBi_{5}Cu_{1}Sb_{2.0}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breaking time (s)</td>
<td>100</td>
<td>200</td>
<td>300</td>
<td>400</td>
<td>500</td>
</tr>
<tr>
<td>Melting point (°C)</td>
<td>650</td>
<td>550</td>
<td>450</td>
<td>350</td>
<td>250</td>
</tr>
</tbody>
</table>
Synthesis of Composite Materials and Compounds with high Energy Rate

Metallic materials, whose properties are very different and whose dimensions are relatively large, can be efficiently welded together into a functional whole only through explosive welding. The explosive represents a source of large energy concentration, which is released in short time intervals and serves as an efficient tool for welding of materials whose mechanical, technological and physically chemical properties are very different and which, due to these factors and their large geometric dimensions cannot be welded together by any other currently recognized engineering procedure.

Within the framework of this program, we analyzed in detail welded plates of low-carbon steel – corrosion resistant austenite steel, low-carbon steel – tantalum, low-carbon steel – titanium, aluminum – titanium, aluminum – molybdenum, copper – tungsten and the triple layer: low-carbon steel – titanium - aluminum and low-carbon steel – titanium – zirconium, which were fabricated through explosive welding.
DEVELOPMENT OF NEW GENERATION OF ARMOUR PROTECTION STEEL

PROTAC

ACRONI d.o.o. – Protac d.o.o. - UL Faculty of Natural Sciences and Engineering - RCJ d.o.o. - VTI – Institute K. Kapetanovic - ……………………..
Ecological free-cutting aluminium alloys

Al-Cu-Mg-Pb-Bi → Al-Cu-Mg-Sn-Bi

Al-Mg-Si-Pb-Bi → Al-Mg-Si-Sn-Bi

Al-Cu-Pb-Bi → Al-Cu-Sn-Bi

<table>
<thead>
<tr>
<th>Podajanje f (mm/vrt)</th>
<th>Rezalna hitrost $v_c$ (m/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>160</td>
</tr>
</tbody>
</table>

Microradiographic image of tin phases in Al-matrix
Optimisation of production technologies of steel semi-products for the automotive industry

ISKRA Avtoelektirka d.d. – UL Faculty of Natural Sciences and Engineering – UL Faculty of Mechanical Engineering
RECONSTRUCTION AND OPTIMIZATION LINE FOR HEAVY PLATES HEAT TREATMENT

DECEMBER 2012

Franc Zupan, MSc Thessys
Inductive hardening of planetary shafts
Inductive hardening of planetary shafts

Thermographic camera
ThermaCAM PM675 FLIR System
Failure Analysis of Dies for Aluminium Alloys Die-Casting through thermographic measurements, and analysis by the non-destructive metallographic examination methods.
Temperature measurements of furnaces and charges during heat treatment processes
Industrial project
Foundry waste management

ISO 14001

PRODUCTION AND ENVIRONMENT

PRODUCTION SYSTEM

INPUT
Energy
Raw material
Knowledge

Tech. process
Working process
WASTE
Secondary raw material

PRODUCT

Material and energy balance of foundry

KOVA d.o.o.

manpower
Investment and equipment

Products
waste energy
waste material
waste suitable for recycling

Material and energy balance of foundry

KOVA d.o.o.

manpower
Investment and equipment

Products
waste energy
waste material
waste suitable for recycling

Material and energy balance of foundry
Failure Analysis

ANALYSIS OF DIE-CASTING DIE FAILURES

A DAMAGE OF THE SINGLE-SEAT CHAIRLIFT´S BASKET

FATIGUE CRACKING OF AN AIRCRAFT WHEEL
Cracks in heat exchanger (left) and microstructure in heat resistance steel after loading at high temperatures for a long time (right).

Fracture of a motor car spring as a consequence of fatigue corrosion due to cyclic loadings and a corrosion caused by a media in winter time conditions.

Fracture of a cement mill.

Wear of a cutting edge of a knife. Knives for cutting wood have a blunt cutting edge because of insufficient mechanical properties that are a consequence of an unsuitable heat treatment.
Failure Analysis - Publication

Fatigue cracking of an aircraft wheel

Analysis of existing the failure

Failure of sand pipes for hot air supply

Efficiency and Quality of Induction Heaters and Transformers of Planet Shaft

An analysis of problems on the surface of hot plate for an electric oven

Failure of the gear from the drive of a screw mill

Download the full text from the Engineering Failure Analysis website.
Idea I

System for thermal shocks simulation

![Diagram of thermal shock simulation system with temperature and time graph](image)
Idea II

Industrial project: Product Life Cycle Analysis

The 6R Concept

3Rs (REDUCE, REUSE, and RECYCLE) + three other Rs (RECOVER, REDESIGN, and REMANUFACTURE) = 6R concept
Thank you!
Julija leta 1919 so se dolgoletne želje po potrditvi slovenskega jezika oziroma narodnostne zavesti uresničile z ustanovitvijo Univerze v Ljubljani. Začel se je študij na petih fakultetah: pravni, filozofski, tehniški, teološki in medicinski.

Študij metalurgije se je začel leta 1935, ko je bil v sklopu rudarskega oddelka na tedanji tehniški fakulteti ustanovljen kabinet za fužinarstvo. V okviru tehniške fakultete se je leta 1939 pričel izvajati samostojni študij metalurgije v okviru odseka za metalurgijo.

V Fakulteti za naravoslovje in tehnologijo, ki je nastala leta 1960, je bil odsek za metalurgijo organizacijsko povezan v Oddelku za montanistiko skupaj z odsekom za geologijo in rudarstvo.