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## Advancement of the scientific-research potential of the Faculty of Metallurgy through the implementation of infrastructure projects

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### Abstract

*Metallurgical production is considered as one of the drivers of the world economy. Metallurgy is a traditional, profitable and export-oriented industry branch in the Republic of Croatia. Excellence can be based on investment in highly sophisticated equipment as a potential for acquiring new and/or innovative knowledge, creativity and recognition on the European research map. The investment potential is based on the infrastructure projects Center for Founding - SIMET (KK.01.1.1.02.0020) of the Faculty of Metallurgy University of Zagreb in partnership with the Sisak-Moslavina County and VIRTULAB – Integrated laboratory for primary and secondary raw materials (KK.01.1.1.02.0022) in which the Faculty of Metallurgy is one of the partners. The projects were funded by the European Fund for Regional Development in the framework of Operational Program Competitiveness and Cohesion (2014-2020). Investment in equipment is not an end in itself! The created research potential forms the basis for investments in the knowledge, skills and competences of employees and students, while opening opportunities for economically targeted activities. Today, self-sustainability must be achieved by delivering excellent research results to stakeholders. Specific scientific research and professional projects as well as targeted education and training for critical and innovative thinking based on sophisticated equipment purchased through infrastructure projects will stimulate innovations in metallurgy. Raising the level of research quality with the motto “From idea to final product” will promote the competitiveness, recognition and general importance of ideas and innovations in metallurgy and metal industry as an important sector of the economic development of the Republic of Croatia.*

**Keywords:** metallurgy, foundry, raw materials, economy, scientific research and high education

### 1. Introduction

The history of metallurgy dates back to 6000 BC, when man's first encounter with copper was recorded. Metallurgy (according to the Greek: μέταλλουργείν: to dig ores) is an economic and scientific activity that deals with the production and application of metals and their alloys. It belongs to the field of technical sciences. It belongs to the field of technical sciences and includes the branches of process, mechanical and physical metallurgy. Process (extractive) metallurgy includes the reduction of metals from ores and their refining, i.e. separation, refining, alloying, casting, and other metal shaping processes in order to obtain semi-finished or finished products. Mechanical (processing) metallurgy deals with the shaping of metal in a plastic or solid state by technological procedures such as rolling, pressing, forging, bending and extrusion of metal. Physical metallurgy deals with determining the physical and chemical repeatability of the metal materials behavior during processing, shaping, testing and application. It includes crystallography, mechanical testing, determination of physical characteristics, metallography and other procedures for metal materials or end products testing to predict their quality, planning production processes and application conditions [1].

Founding is a scientific discipline which deals with the shaping processes of metallic materials in a liquid / molten state. Founding is the primary and most prosperous branch of production due to the exceptional flexibility of production and adaptation to competitive market conditions. It also enables the production of a whole range of

metal materials, essential for everyday life. In addition, the application of modern casting technologies enables high productivity in qualitative and quantitative terms, which makes this industry extremely competitive.

Knowledge becomes an increasingly important resource for economic development. The Republic of Croatia is faced with the challenges of the world economy, according to which it must, among other things, meet certain requirements for the design of the education system. Ensuring the quality of the education system is one of the requirements that the Faculty of Metallurgy has set as a permanent mission. As the population's level of education affects economic progress, it is extremely important for the Republic of Croatia to increase the proportion of people with higher education in strategic field such as metallurgy as a part of technical sciences and STEM (science, technology, engineering and mathematics).

### 2. Infrastructure projects of the Faculty of Metallurgy

The University of Zagreb Faculty of Metallurgy is the only scientific and teaching institution in the Republic of Croatia that, respecting the culture of quality, provides higher education at the undergraduate, graduate, postgraduate and professional levels in the field of metallurgy with outcomes in metallurgical engineering and industrial ecology and also occupational safety, health and environment. The transfer of knowledge and technologies to students, academic society and economic entities in the metallurgi-

cal, metalworking, shipbuilding and foundry industries is done through conferences, seminars, workshops, public forums and lectures, are systematically conducted as part of a lifelong learning and training programme. The Faculty of Metallurgy bases its activities on high academic and ethical values, as well as on contribution and responsibility towards society as a whole [2,3].

Manufacturing activities and education form the basis of the development of every country, and the development strategy must rely precisely on excellent young people who, by acquiring knowledge and a research approach at the Faculty of Metallurgy, enrich the economy with specific knowledge, skills and competences. All of this is reflected in the strategic development directions Metallurgical Engineering and Industrial Ecology, Metal Materials and Occupational Safety, Health and Environment [4]. Excellence is based on investment in highly sophisticated equipment as a potential for new and/or innovative knowledge, creativity and visibility on the European research map. The investment potential is based on the infrastructure projects Center for Founding - SIMET (KK.01.1.1.02.0020) in partnership with Sisak-Moslavina County financed with 5.847.910,69 €. The other infrastructural project VIRTULAB – Integrated laboratory for primary and secondary raw materials (KK.01.1.1.02.0022) of the Faculty of Mining, Geology and Petroleum Engineering as a project leader, with 403.286,60 € for the Faculty of Metallurgy as a one of the partners. Both projects were financed by the European Fund for Regional Development, Operational Program of Competitiveness and Cohesion (2014-2020). Investment in equipment is not an end in itself! *The created research potential forms the basis for investments in the knowledge, skills and competences of employees and students, while opening opportunities for economically targeted activities through the opening of spin-off companies as a way of achieving self-sufficiency. Targeted activities should open up lifelong learning opportunities for interested external stakeholders. These could create start-up companies through scientific research and professional projects as well as targeted education related to research opportunities and critical and innovative thinking training, according to the motto: from the idea to the final product.*

In order to strengthen the competitiveness of economic stakeholders, smart specialization of production is necessary, i.e. sustainable high-quality production, cheap and environmentally friendly products. The global market requires optimization of existing technologies and the rationalization of production costs.

In recent years, a number of small companies have successfully developed (automotive industry parts, hospital chairs, profiled sheet metal, construction sheet metal) that successfully compete on the domestic and also global markets with innovations and high quality products. Given the growing demand for small series goods by global makers, it is assumed that they will establish a supplier network to which Croatian producers can contribute. Small series quantities are adequate to utilize their production capacities, and with qualified labor and new

market possibilities, established businesses will expand, as will the establishment of new ones. By investing in sophisticated equipment and production certification, metal producers show their commitment to growth. The basic features of Croatian industry are consistent product quality and reliability in accordance with EU standards, while on the other hand it is important to invest in the available professional workforce, targeted support from academic and scientific institutions, and excellent production infrastructure with an emphasis on modern technologies and global transportation connections.

Since the Croatian market is too small for a significant increase in production, companies in the observed industry primarily direct their production capacities to countries in the European Union, which also means an increase in the level of productivity of assets and labor force, in order to compete with foreign competition. Competitiveness can be based solely on modern technology, efficient production procedures, but also on a highly qualified workforce. All of this requires investment in infrastructure and educational study programs that should strive to acquire, first of all, practical knowledge and skills with an emphasis on the development and application of modern materials and technologies in order to position the Republic of Croatia as an important production partner on the global market.

Therefore, the Faculty of Metallurgy University of Zagreb, recognized the necessity of influencing a transformative vision development of science, the teaching process and the economy by applying and implementing infrastructure project Center for Founding - SIMET, strategically important for the Faculty of Metallurgy, University of Zagreb as a whole, Sisak-Moslavina County and Republic of Croatia [5].

The problems faced by the Croatian metal industry are related to the unfavorable business environment, insufficiently developed entrepreneurial culture, lack of business investments and capital, and promotion measures of related institutions. In comparison to EU norms, the startup rate is extremely low. The number of small and medium-sized enterprises based on knowledge of metallurgy is insufficient. Furthermore, there is a lack of active cooperation between small and medium-sized enterprises in the field of metallurgy, the academic community and public authorities, as well as limited communication within the research community itself. Due to the lack of an inter- and multidisciplinary approach and the lack of suitable equipment, the cooperation of higher education institutions with small and medium-sized enterprises was limited.

The problem has been recognized precisely in the lack of capacity for the know-how concept of production. At this point, the Faculty of Metallurgy has identified a niche for its smart specialization, in which it will place itself as a provider of project ideas and advances, i.e. knowledge-based economic recovery. Therefore, a partnership between the Faculty of Metallurgy University of Zagreb and the Sisak-Moslavina County was established to create a favorable environment through the Center for Founding

- SIMET, which would raise the level of technology transfer and research and development (R&D) results from of higher education institutions to economic entities.

The strategic goals on which the future development of the Faculty of Metallurgy in the area of scientific research is based include expanding the scope and increasing the quality of scientific research to a level that ensures the international recognition and competitiveness of the Faculty in the European research area; raising the quality of university postgraduate studies and the scientific advancement and employee training. The strategic goals of the Faculty of Metallurgy in the area of professional activity envisage professional advancement and competitiveness based on a strong connection of the Faculty of Metallurgy with leading economic entities in the Republic of Croatia, a strong alumni organization and recognizable lifelong learning and training programs; connecting with the economy, public and local community and improvement of professional work. An important segment is the transfer of knowledge and technology to students, the academic community and the economy.

The motivation for the initiation and implementation of projects Center for Founding – SIMET and VIRTULAB – Integrated laboratory of primary and secondary raw materials are defined by the general and specific goals of the project. The general goal of the projects was defined as follows:

- Investing in organizational reform and infrastructure in the research, development and innovation (RDI) sector aims to increase the sector's ability to conduct top-quality research and meet the needs of the economy, all of which contribute to economic strengthening applying research and innovation.
- By strengthening the capacity of investigation, research and innovation (IRI), the competencies of teaching staff and students will be improved. Therefore, the Faculty of Metallurgy and the metallurgical sector in general will be able to identify and activate their IRI potential.

In both infrastructure projects specific goals related to academic institutions are [6]:

1. Improving the accessibility of current instrumentation while introducing contemporary technology to improve the quality of scientific research.
2. Increasing productivity, i.e. the number of scientific research papers and the number of applications for competitive scientific and innovative projects.
3. Improving the quality of teaching while strengthening students' competencies and thus their competitiveness and employability on the labor market.
4. Transfer of knowledge and innovation to the economy.

The SIMET and VIRTULAB were established to connect necessary parties as a target group and enable the transfer of knowledge and skills in the function of research in the

creation of materials and technologies to prospective users:

- scientific, teaching and professional staff and students and also,
- stakeholders from the economy sector.

through the design of innovative materials in response to market requirements and the creation of the final product, designing, characterization and reuse of primary and secondary raw materials, then product development using specific technologies (CAD/CAE technologies), computer-supported design of the product development process and construction, production preparation, but also through lifelong learning intended for students, business experts, etc.

The global market requires optimization of existing technologies and rationalization of production costs. The significance of the Center for Founding – SIMET and also the use of the VIRTULAB equipment will be represented in focused research in material development and technology transfers to partners from the real sector under the motto from idea to final product. The activities will be divided into three categories:

- designing of innovative materials for specific market requirements, i.e. the manufacturer, and the characterization of the synthesized or innovative material based on the specific improved and/or required properties of the final product,
- product development using sophisticated CAD/CAE technologies (CAD - Computer Aided Design, computer-supported design of the product development process and structural preparation of production and CAE - Computer Aided Engineering, casting and solidification process elaboration and prediction of potential errors). When developing products in addition to creating prototypes and tools, attention is paid innovation and optimization of production processes and procedures,
- lifelong learning (L3) – the goal is to bring sophisticated equipment and research and knowledge based on it to students, business experts and all interested stakeholders, allowing for the development of engineering skills, innovation, and inventiveness in solving project tasks, and thus launching globally competent experts in the metal processing industry and employees of metallurgical companies.
- Designing and developing products as well as prototyping, emphasizes innovation and optimization of production processes and procedures with targeted research and development outcomes with carefully selected equipment unique in the Republic of Croatia, whose contribution to the development of materials and technologies is shown in a schematic representation of research methods and techniques connected to the Center for Founding – SIMET as shown in Figure 1.

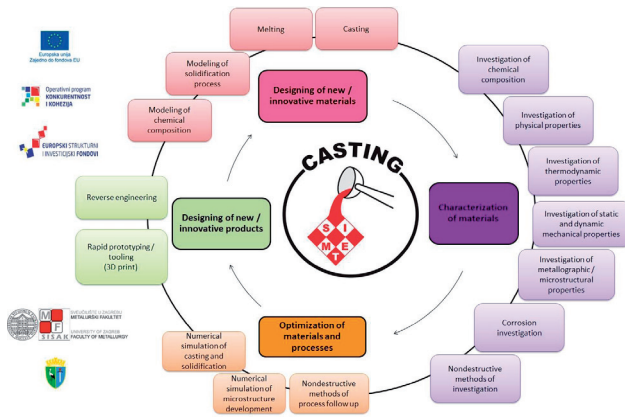


Fig. 1. Schematic representation of R&D outcomes within the infrastructure project Center for Founding – SIMET.

Finding, repurposing or reusing of raw materials is the driving force and link between the scientific community and the economy. The organization of VIRTULAB indicates the multiple analytical possibilities focusing on the life cycle of primary and secondary raw materials using areas of expertise of the involved laboratories and Faculties [6]. VIRTULAB has research capabilities that meet the needs of prospective research of primary and secondary raw materials, exploitations, refining, production processes, recycling, and finally finding substitute raw materials.

### 3. The impact of infrastructure projects on the development of scientific-research field of metallurgy

Nowadays, modern metallurgy is a specific discipline that deals with the design, development and characterization of everyday materials that surround us in our homes and workplaces, as well as materials with special requirements for specific purposes such as those for the automotive or space industries. At the same time, the right choice of production processes is also essential. The recovery of metal and disposal of waste materials from production is covered by industrial ecology in correlation with the management of materials and technologies.

Metallurgical production is considered one of the most important factors influencing the development of the world economy. It is profitable in the world, but a number of problems have been identified in the Republic of Croatia, such as a poor business environment, a lack of investment and poor communication between small and medium-sized entrepreneurs in the metal industry, scientific institutions, universities and local and regional authorities. The implementation of SIMET and VIRTULAB made it possible to change these conditions. In terms of theoretical knowledge, the metallurgical profession is highly dependent on the economy in mutual exchange of knowledge and experience. The already mentioned important segment of knowledge transfer, but also an important part of technology, will be reflected in the organization of many activities. Some of them have already been recog-

nized, some are being targeted, and some will serve not only academic stakeholders, but also socially responsible businesses, such as Scientific and professional seminars, International Foundrymen Conference, Career Day, but also participation with innovations at international fairs / exhibitions innovation [5].

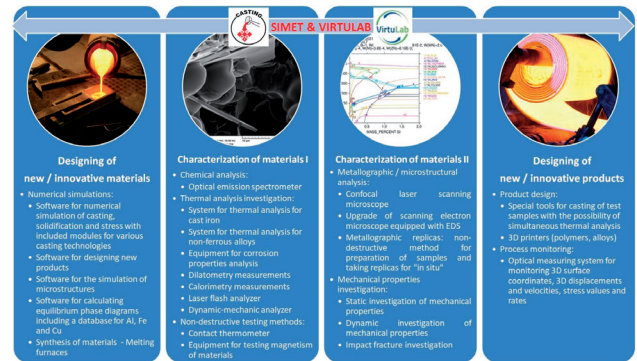


Fig. 2. Schematic representation of investigation methods and techniques within the infrastructure project Center for Founding – SIMET and VIRTULAB – Integrated laboratory of primary and secondary raw materials.

Within the framework of the Center for Founding – SIMET and VIRTULAB – Integrated laboratory of primary and secondary raw materials, the planned research and development activities, together with other activities related to the introduction of innovations in companies, are necessary for the positioning, recognition of the excellence of the Faculty of Metallurgy, recognition and visibility of the University of Zagreb, the recognition of Sisak and Sisak-Moslavina County as a center of attractive scientific excellence, knowledge and competence and therefore a niche for the development of the economy of the Republic of Croatia.

### 4. Conclusion

The metal industry in Croatia has a future, but it is necessary to concentrate on the trinity of the competitiveness of the metal industry using modern technology, an efficient production process and a highly qualified labor, to which the Center for Founding – SIMET and VIRTULAB – Integrated laboratory of primary and secondary raw materials directly contribute. For the development of the scientific, teaching and professional activities of the Faculty of Metallurgy University of Zagreb, as well as the development of the metal industry in the Republic of Croatia, a representative triangle of influential factors such as business sector, scientific research capacities and public policy plays a key role in the Triple Helix mode.

Through the implementation of the Center for Founding-SIMET and VIRTULAB – Integrated laboratory of primary and secondary raw materials projects, the Faculty of Metallurgy will strengthen its recognition as a place of continuous improvement of knowledge and its acquisition as well as competences in metallurgy and related

STEM fields. With increasing opportunities for scientific and professional development and networking, the Faculty of Metallurgy will achieve the status of an integrative and competitive scientific and educational institution within the framework of European higher education and research. This strengthens its position as a socially responsible institution by raising the level of education, the expertise of outcome engineers in the technical field, and the development of economic branches related to metallurgy, materials, environmental protection, and occupational safety, health, and environment while adhering to academic ethical principles.

## 5. Acknowledgment

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