

S U M M A R Y

**of the main results and scientific contributions
of Chief Assistant Professor Dr. Eng. Iliyan Stoykov Mitov,
submitted for participation in the competition
for the academic position of Associate Professor
in Professional Field 5.0 – Technical Sciences,
Area 5.6 – Materials and Materials Science,
Scientific Specialty: Materials Science and Technology of Engineering
Materials**

I. Thermal Engineering Problems and Enhancement of the Energy and Environmental Efficiency of Industrial Facilities [1A,7A,13B,15B,14B,1C]

The series of publications represents a comprehensive scientific contribution in the field of thermal engineering and metallurgy, encompassing:

- integrated management of technological processes;
- optimization of heat exchangers and furnaces;
- application of numerical modeling for design and experimental validation;
- reduction of energy consumption and environmental emissions;
- improvement of working conditions in metallurgical plants.

These results can be regarded as a significant contribution to enhancing the energy and environmental efficiency of modern metallurgical production.

1A. Emil Mihailov, Maria Ivanova, Daniela Choshnova, Monika Asenova, Iliyan Mitov Ivanka Petrova, Thermal and Technological Integration of Processes in Metallurgy, International Journal of Heat and Technology Volume 42, Issue 5, Pages 1825 – 1832 October 2024.

In modern high-performance metallurgical equipment, the improvement of energy efficiency is achievable through the optimal coordination of individual operations and the development of approaches and algorithms for multiparametric optimization and control of the overall technological process. As part of this concept, the present study is dedicated to the development of a system for technological and thermal integration of the production processes of flat steel products (slabs), enabling hot charging and reducing energy consumption in reheating furnaces. The proposed system includes dynamic synchronization of the processes of continuous casting of steel slabs, transportation to rolling mills, holding, and pre-deformation heating. The study combines the results obtained from three numerically implemented mathematical models: one describing the cooling and solidification of the metal during continuous casting; one determining the temperature distribution in each hot slab during transportation operations; and one defining the optimal regimes in reheating furnaces. The main objective is the optimal synchronization of individual production operations and the maximum utilization of the heat of hot-charged slabs. The obtained results enabled the evaluation of different process implementation scenarios and the decision-making regarding the storage of slabs prior to their charging into reheating furnaces. The conducted research shows that the energy costs for reheating slabs for subsequent plastic deformation can be reduced by up to 40%.

This article is part of a series on energy efficiency, listed under items 7A, 13B, 15B, 14B, and 1C.

7A. I. Mitov. Comparative analysis of the energy efficiency of metal recuperators with a different design, Journal of the University of Chemical Technology and Metallurgy (13117629 13143859), University of Chemical Technology and Metallurgy Volume: 46 Issue: 4Year: 2011 Pages: 423-426

Results are presented from a comparative analysis of the energy efficiency of two representatives of the most widely used metallic recuperators in metallurgical practice—a convective type with smooth tubes and a radiation type “tube-in-tube.” The devices were set under identical operating conditions, with identical parameters of preheated air required from them. To ensure comparability between the operating regimes of the two units, the thermal calculations were carried out using a specially developed software product. It was found that the radiation recuperator is approximately 30% lighter than the convective one. The ratio between the convective and radiative components of the heat transfer coefficient from flue gases to the wall was analyzed. A comparison of the two design variants of the radiation heat exchanger revealed trends toward an increase in the emissivity of the flue gases and a significant rise in the radiative share, accompanied by a weakening of convection. This article is part of a study aimed at improving the performance of industrial recuperators in metallurgical enterprises in Bulgaria, with the main objective being the optimal utilization of the heat from flue gases exiting metallurgical furnaces.

13B. Mitov I. S., F. Dinkelacker, T. Seeger, A. Leipertz, R. D. Stanev. Possibilities for Investigation of Combustion and Heat Transfer in Metallurgical Furnaces. Report of the 4-th International Course for Young Researchers „Computational Engineering“, sponsored by DAAD, Germany, Pamporovo, Bulgaria, 28.06 – 03.07.2008, p. 129.

The research tasks of the scientific team from three European universities—Siegen and Erlangen in Germany, and the University of Chemical Technology and Metallurgy (UCTM) in Sofia, Bulgaria—have been systematized. It is emphasized that both numerical simulations and experimental investigations are necessary for their successful resolution. The key stages in this complex process are:

- 1) A detailed study of radiative heat transfer between the gas, the walls, and the processed material in the metallurgical furnace using modern measuring instruments.
- 2) Testing and application of software products for modeling these processes and for the optimal design of a new experimental combustion chamber.
- 3) Identification of opportunities to reduce greenhouse gas emissions through optimization of the combustion process.
- 4) Replacement of traditional natural fuels with alternative and secondary energy resources.

The presented work outlines some preliminary steps in the listed directions. The main objectives mentioned above have been achieved, and part of them have already been implemented in real metallurgical enterprises. The results obtained from the software computational tools have been validated and confirmed through industrial-scale trials. Combustion in burners has been optimized to reduce greenhouse gas emissions, and combined burners using alternative fuels have been introduced.

This article is part of the series of publications on thermal engineering problems and on improving the energy and environmental efficiency of industrial facilities, listed under 1A, 7A, 15B, and 14B.

15B. Mitov I. S., R. D. Stanev. Characteristics of the Microclimate in Metallurgical Workshops. Report of the 6-th International Course „Indoor Air Quality and Human Body Exposure“, Pamporovo, Bulgaria, 12 – 17.05.2009, p. 174 – 175.

Typical examples of the working environment in various metallurgical workshops are examined. The factors determining the microclimate around the respective units are analyzed. Solutions are proposed for improving the operation of installations in ways that reduce the release of harmful substances, thereby minimizing the need for subsequent neutralization. The individual impact of factors such as high temperature, emissions of gases and dust hazardous to the environment and human health, noise, vibrations, and others typical of metallurgy is discussed. Some of the opportunities offered by specialized software products for optimizing combustion, aerodynamic, and heat transfer processes in production units are demonstrated. These tools can indirectly influence the microclimate in workshops and reduce harmful emissions from enterprises. The results are summarized in conclusions, the main one being that with proper execution of technological processes and appropriate organization of workplace ventilation, metallurgical plants can provide normal working conditions for their personnel while simultaneously complying with various regulatory requirements.

14B. Mitov I. S., R. D. Stanev. Combustion in Metallurgical Furnaces. Report of the 5-th International Course for Young Researchers „Computational Engineering“, sponsored by DAAD, Germany, Pamporovo, Bulgaria, 08 – 14.06.2009, p. 131 – 132.

Initial results are presented from addressing the research task of improving the design and construction of industrial furnaces. The focus is placed on furnaces equipped with radiation burners. The challenges identified for a given metallurgical furnace are related to increasing the efficiency of thermal radiation from the walls of its working chamber to the processed product, optimizing its aerodynamic conditions and the utilization of heat from outgoing flue gases, as well as implementing effective monitoring and control of its key operating parameters. Results are presented from testing the sensitivity of the standard software product ANSYS-Fluent 5.3 to variations in the fuel and air velocities supplied to the studied burner. Part of the findings from this research have also been published in articles numbered 13B, 15B, and 1C of the same list.

1C. Stanev, R. D., I. S. Mitov, and A. Ch. Gankov. Thermal Design of an Experimental Furnace Chamber. Report presented at the 7th Scientific Poster Session of the University of Chemical Technology and Metallurgy (UCTM), Sofia, Bulgaria, May 19, 2010.

A thermal engineering design was carried out for an experimental test rig intended for performing a wide range of combustion, aerodynamic, and heat transfer experiments under conditions closely approximating those in modern chamber furnaces. Suitable burners were selected to meet both the operational requirements of the rig and the

needs of the planned investigations. Various design options for the furnace roof were proposed. Using the software product ANSYS-Fluent 5.3, the temperature fields in the working chamber were modeled. For this purpose, the fuel and air were assumed to be fully premixed, and a combination of the finite element method and the standard model was applied. This report is part of a series of publications (nos. 13B and 14B) focused on software modeling of combustion processes and fluid dynamics in metallurgical furnaces and installations.

General Scientific Contribution

1. Enhancement of Energy Efficiency in Metallurgical Processes

- Approaches have been developed for technological and thermal integration in the production of flat steel products, enabling hot charging of slabs and reducing reheating costs by up to 40%.
- Mathematical models have been created for the optimization of cooling, transportation, and reheating of steel billets.

2. Optimization and Improvement of Heat Exchange Equipment

- A comparative analysis of convective and radiation-type metallic recuperators was carried out, demonstrating the advantages of radiation designs (approximately 30% lighter construction, higher heat transfer efficiency).
- Dependencies have been derived for increasing the emissivity of flue gases and improving the utilization of the radiative heat transfer component.

3. Modeling and Simulation of Combustion and Heat Transfer Processes

- Modern software tools (ANSYS-Fluent and others) have been applied for modeling combustion, aerodynamic, and heat transfer processes in metallurgical furnaces.
- Experimental and computational methodologies have been developed for the design of furnace chambers, bringing laboratory testing closer to real production conditions.

4. Reducing the Environmental Footprint

- Solutions have been proposed to reduce greenhouse gas emissions through optimization of the combustion process and the introduction of combined burners using alternative and secondary fuels.
- The influence of the microclimate in metallurgical workshops has been examined, and measures have been proposed to improve the working environment (reduction of harmful emissions, noise, vibrations, etc.).

5. Interdisciplinary and Applied Character

- The work integrates numerical simulations, experimental studies, and industrial implementations, with the results validated through real trials in metallurgical enterprises.
- The research has been carried out in international cooperation (Germany – Bulgaria), demonstrating a modern approach to addressing complex scientific and applied challenges.

II. Transport Processes in Rotary Kilns [3B,4B,5B,2C,2A,3A,15A,6B,7B,8B,13A,4A,1B,2B,9B,14A]

In summary, publications No.

[3B,4B,5B,2C,2A,2A,3A,15A,6B,7B,8B,13A,4A,1B,2B,9B,14A] constitute a comprehensive contribution in the field of transport processes in rotary kilns, combining:

- fundamental models.
- experimental validations.
- engineering correlations and guidelines.
- applied technologies for industry.

3B. Stanev, R. D., and I. S. Mitov. Experimental Rotary Kiln for Calculating the Motion of Solid Particles and Heat Transfer. Engineering Sciences, vol. 45, no. 2, 2008, pp. 56–67.

The preparation and commissioning of a pilot rotary kiln, located at Otto von Guericke University in Magdeburg, Germany, are described. The design, supervision during the fabrication, and installation of its individual components represent a direct scientific and applied contribution by the authors. Tests without material were conducted in the kiln, and a uniform distribution of the measured temperatures across a sufficient number of its cross-sections was established. This confirmed both the proper positioning of the burner and the reliable operation of the temperature measurement system at various points and positions along the cylindrical body. After adjustments were made and any disturbances were eliminated, it was confirmed that the installation enables in-depth study of both the motion of solid material and the associated heat transfer processes in the experimental rotary kiln, as well as the extrapolation of results to a wide range of industrial reactors of this type. Addressing this latter task constitutes a substantial scientific contribution, which is why, alongside the specific objectives, elements of it have been incorporated into the execution of all other works presented within this thematic area.

4B. Mitov, I. S., and R. D. Stanev. Mathematical Description of the Deviations of Falling Particles of a Dispersed Material Processed in a Rotary Kiln. Engineering Sciences, vol. 45, no. 3, 2008, pp. 42–49.

The concept is substantiated that, due to the great variety of processes taking place in rotary kilns, the determination of numerous parameters—such as the residence time of dispersed material in the working chamber, the nature of the temperature field, the degree of cylinder filling, and others—on a case-by-case basis requires significant resource expenditure. Therefore, it is of particular importance to provide opportunities for their calculation without the need for physical experiments, or at least by minimizing the necessity for them. The discussed publication presents a solution to one of the identified problems. It was achieved by developing a mathematical model that predicts the deviations of falling particles in a rotary kiln with respect to its vertical axis, which constitutes a scientific contribution. Calculations performed using the developed algorithm demonstrated that the assumptions made in its creation correspond to the nature of the described physical phenomenon. The proposed mathematical model can be applied to predict the load on the conveyor belt that transports the material

processed in the kiln to its end user. Its practical orientation allows the conclusion that its development also represents an applied contribution.

5B. Mitov, I. S., R. D. Stanev. Application of an Analytical Model for Determining the Layer Thicknesses of Material in a Rotary Kiln. Engineering Sciences, Vol. 45, Issue 4, 2008, pp. 58–67.

The study presents the capabilities of an original analytical model, developed on the basis of the regularities governing particle motion in a cylindrical rotary kiln. The model, referred to as “total,” makes it possible to calculate both the overall thickness of the material layer and the thickness of its active zone, located directly beneath its free surface. The development of this model, in our opinion, represents a scientific contribution. Experimentally, the distribution of particles was determined at different kiln rotation speeds, varying filling degrees, and for different materials. The experimentally observed behavior of the material shows good agreement with the theoretical predictions of the total model, which confirms its accuracy in describing the studied physical phenomena.

2C. K. Varbanov, I. Mitov, B. Yordanov, D. Krastev. Technological studies on the possibility of recycling lead production waste from “KCM Plovdiv”. Report presented at the 19th Scientific Poster Session of the University of Chemical Technology and Metallurgy (UCTM), Sofia, Bulgaria, May 19, 2022.

Technological investigations were carried out to evaluate the possibility of using a waste product from lead production as a raw material for clinker manufacturing. For this purpose, the waste was mixed with a certain amount of clay and limestone, and the resulting new mixture was subjected to firing in a rotary kiln until a product with binding properties was obtained. The optimal parameters of the pelletizing process were determined, including moisture content, optimal pellet size, and their strength after pelletization. The sintering process in the rotary kiln was analyzed, and the technological parameters of the process were defined, such as temperature, residence time, analysis of the flue gases, and of the obtained clinker. It is also planned to determine the binding properties of the resulting product. Future research is foreseen to establish whether the hazardous substances and elements contained in the waste are neutralized during the sintering process in the rotary kiln.

2A. Herz F., I. Mitov, E. Specht, R. Stanev. Experimental Study of the Contact Heat Transfer Coefficient between the Covered Wall and Solid Bed in Rotary Drums. Chemical Engineering Science, 82, 2012, p. 312 – 318.

It is substantiated that for describing the heat transfer from the wall covered with solid material to the particle bed in indirectly heated rotary kilns, numerous modeling approaches have been proposed in the available literature. However, the heat transfer coefficients calculated by these models show significant quantitative discrepancies, which complicates the selection of an appropriate analytical method for simulating the processes in such units. An experimental setup was designed, commissioned, and adjusted for the purpose of conducting a series of investigations on contact heat transfer in an indirectly heated rotary kiln, as presented in this study and in publications No. 3A and 4A from the attached list. Measurements of the heat transfer coefficient were carried out in the pilot installation, with sensitivity analyses performed by varying operational parameters such as rotational speed and the degree of filling of the drum.

Quartz sand was used as the test material. A comparison between the experimental results and the calculations obtained from different methodologies demonstrated fully acceptable agreement with the values predicted by three of the applied mathematical models. According to the authors, the contributions of the research described in the cycle of publications No. 2A, 3A, and 4A—which will not be repeated in the presentation of the following three works—consist of the development of unique measuring instruments and methodologies (a scientific contribution), as well as the analysis of the acquired experimental data (a scientific-applied contribution).

3A. Herz F., I. Mitov, E. Specht, R. Stanev. Influence of Operational Parameters and Material Properties on the Contact Heat Transfer in Rotary Kilns. International Journal of Heat and Mass Transfer, 55, Issues 25 – 26, 2012, p. 7941 – 7948.

The study represents a continuation of the investigations described in publication No. 2A from the attached list. The scope of the tested materials has been expanded to include quartz sand, glass spheres, and copper spheres. A comparison was made between the experimentally determined values of the contact heat transfer coefficient in the previously presented indirectly heated rotary drum and the calculations obtained from the applied models. The sensitivity of the measured data was analyzed with respect to the kiln's operating parameters—namely, the rotational speed and the degree of filling with the particle bed—as well as with respect to the solid material's characteristics, such as particle diameter and thermophysical properties, with quartz sand, glass, and copper spheres being tested. The experimental results demonstrated good agreement with one of the applied models within the specified ranges of variation of the selected factors.

15A. Rayko Stanev, Iliyan Mitov, Ivan Shtaplev, Vasil Harizanov. Assessment of the impact of some meteorological factors on the energy and environmental efficiency of tube rotary kilns, Journal of Chemical Technology and Metallurgy, 58, No. 3, 2023, p. 529 – 536.

It is emphasized that rotary kilns are units for high-temperature thermal processing of a wide range of materials in a continuous technological process. This type of equipment is widely used in many industrial sectors such as chemical, metallurgical, silicate, pharmaceutical, and others. In metallurgy, these installations are applied for the thermal treatment of bulk materials—for example, the reduction of oxide ores, the calcination of limestone, the drying of copper-sulfide charge, the cleaning of metal shavings from machining oil, and more. A review is provided of the methods of heat transfer to the material processed in a rotary kiln, as well as of the principal mathematical models used to describe the complex transport phenomena in such units. The study emphasizes that, due to their large size, rotary kilns are often installed in open areas within industrial plants. Variable meteorological conditions can significantly affect the energy flux leaving the kiln shell. This energy dissipates uselessly into the environment, which is commonly referred to as a “heat loss.” This concept, however, is somewhat conditional, since according to the law of conservation of energy, energy cannot be created or destroyed but only transformed from one form into another. Nevertheless, the convenience of the term has led to its use in the present work. The proposed study focuses on analyzing the results obtained from calculations of the heat losses from a rotary kiln to the ambient air, under average annual

temperatures typical of the geographic latitude and climatic conditions of Bulgaria, with the presence of a relatively weak constant wind. Based on the calculations, conclusions are drawn regarding the ratio between the different heat fluxes from the external surface of the kiln to the environment, along with practically oriented recommendations for improving the energy and environmental efficiency of the equipment under consideration.

6B. Stanev R. D., I. S. Mitov. Experimental Approaches and Measuring Instruments for Investigation of Transport Phenomena in Rotary Kilns. Advances in Natural Science – Theory and Applications, 2, No. 1, 2013, p. 39 – 53.

The possible approaches for studying transport processes in rotary kilns and the main difficulties associated with their application have been systematized. The preparation, assembly, commissioning, and adjustment of two pilot-scale installations are presented, designed to investigate:

- the movement of particles and heat transfer in a directly heated rotary kiln (described in detail also in publication No. 5B of the attached list), and
- the contact heat transfer in an indirectly heated rotary kiln (presented in detail in publications Nos. 2A, 3A, and 4A of the attached list).

Using the first of the experimental test rigs, the correct physical nature of the assumptions underlying the derivation of two original mathematical models, as well as their practical applicability, has been demonstrated. With the installation designed for the study of contact heat transfer in an indirectly heated rotary kiln, it has been established that the experimental values obtained agree very well with the results calculated using three well-known mathematical models from the literature. This consistency proves both the functional suitability and accuracy of the created experimental setup and the adequacy of the applied computational procedure.

Perspectives for future studies of transport processes in rotary kilns have been outlined, which could be carried out using the pilot installations presented in this work, as well as within broader research projects. In our opinion, this constitutes its principal contribution, which is of scientific character.

7B. Stanev R. D., I. S. Mitov. Problems at the Industrial Application of Modern Rotary Kilns. Advances in Natural Science – Theory and Applications, 2, No. 1, 2013, p. 55 – 71.

A review of modern rotary kilns has been carried out, analyzing their most important characteristics and the possibilities for applying different design variants of their configuration. The main types of burners used in directly heated rotary kilns are presented, with discussion on their performance indicators and fields of application. Unresolved issues have been systematized, including the movement of the bed in rotary kilns, deviations of falling particles, the thickness of layers of dispersed material in these units, contact heat transfer in externally heated rotary kilns, as well as combustion and heat transfer processes in directly fired installations. The identification of directions requiring further research, in our opinion, can be regarded as a contribution of scientific character.

8B. Mitov I. S., R. D. Stanev. Motion Modes of the Bed in Tube Rotary Kilns and Opportunities for Mathematical Description of the Disperse Material Behavior. Advances in Natural Science – Theory and Applications, 2, No. 2, 2013, p. 1 –19.

The main types of bed motion in rotary tube kilns are examined, with emphasis placed on the rolling mechanism. Two mathematical models developed to describe the behavior of the material in the investigated unit are presented in a more applied context—namely, a model for predicting the deviations of falling particles from the kiln's wall (see also publication No. 2A from the attached list) and a “total model” (described in detail in publication No. 4B) for determining both the overall thickness of the processed material bed within the cylinder and the active portion immediately beneath its free surface. An experimental rig has been prepared, assembled, commissioned, and calibrated, allowing the study of particle motion in a rotary tube kiln and, in perspective, the heat transfer processes occurring therein. Both theoretical and experimental investigations carried out with this installation have demonstrated that the assumptions underlying the developed algorithms correctly represent the nature of the described physical phenomena, and their practical applicability has also been substantiated. It is emphasized that the derived mathematical models can be successfully applied to selecting appropriate operating regimes for specific rotary kiln conditions, to determining the distribution of particles on the conveyor belt transporting them to subsequent technological operations or to the consumer, as well as to predicting its loading. Their practical orientation provides a solid basis for considering their development as an applied contribution.

13A. Stanev R. D., I. Mitov, E. Specht, F. Herz. Geometrical Characteristics of the Solid Bed in a Rotary Kiln. Journal of Chemical Technology and Metallurgy, 49, No. 1, 2014, p. 82 – 89.

Data on the geometric characteristics of the material-occupied portion of the rotary kiln cross-section, obtained using an in-house mathematical model (presented in publication No. 4B from the attached list), are analyzed. Previous and current investigations allow the conclusion that the thickness and vertical depths of both the entire bed and its active part are influenced by the kiln's internal diameter, its rotational speed, the degree of filling with material, the dynamic angle of repose, and particle size. For each discrete set of values characterizing the peak height in the specific curves from the mentioned study, three equations are proposed, arranged in descending order according to their adequacy. Statistical analysis of all derived dependencies shows that they can be successfully applied to predict peak heights. It is recommended that the correlation listed first—being a second-degree polynomial in more than 75% of the cases used. The development of these simplified formulas for practical application can be categorized as an applied contribution.

4A. Herz F., I. Mitov, E. Specht, R. Stanev. Influence of the Motion Behavior on the Contact Heat Transfer between the Covered Wall and Solid Bed in Rotary Kilns. Experimental Heat Transfer, 28, No. 2, 2015, p. 174 – 188.

It is argued that heat transfer by contact between the wall surface and the solid material in a rotary drum can be analytically described by numerous models published in specialized literature. However, these algorithms are based on the assumption of a

rolling bed motion. This condition is not fulfilled in many industrial installations. To study the effect of different transverse bed movement modes on contact heat transfer in rotary kilns, measurements were carried out in the indirectly heated pilot drum, already described in publications Nos. 2A, 3A, and 4A from the attached list. To achieve different motion regimes, quartz sand, aluminum powder, and cement powder were used as test materials, ensuring rolling, cascading, and sliding motions, respectively. It was found that the experimental data are qualitatively consistent with all model predictions. However, for cascading and sliding regimes, significant discrepancies between the measured and calculated characteristics were observed. The experimentally determined heat transfer coefficients were up to three times lower for cascading and up to five times lower for sliding motion compared to the calculated results. The contributions of this article, as well as those of publication No. 3A from the attached list, are cited only once during the presentation of the first publication (No. 2A).

1B. Stanev R. D., I. S. Mitov. Technological and Ecological Advantages of the Production and Using of Metallized Pellets. Engineering Sciences, 52, Book 1, 2015, p. 66 – 77.

The approaches to developing modern methods for the reprocessing of residual products accumulated in large masses near populated areas and industrial zones have been systematized, along with their most characteristic features. An effective solution to a number of technological and environmental problems is presented, consisting in the production of pellets from residual materials during traditional ferrous metallurgy processes and their subsequent use as a valuable raw material. The metallization of these agglomerates under industrial conditions is carried out in rotary kilns. The main stages of laboratory experiments aimed at determining the most favorable levels of key factors influencing the realization of the proposed technology are examined. The effect of the coal content, added as a reducing agent, on the degree of metallization of pelletized concentrate for blast furnace production has been experimentally established. The obtained results were analyzed qualitatively, and an empirical linear relationship was derived, enabling their quantitative description within the validity limits for the studied materials. In our opinion, the creation of this correlation contains elements of a scientific-applied contribution.

2B. Mitov I. S., R. D. Stanev. Laboratory Study of the Metallization Process of Compressed Residues from Metallurgical Enterprises. Engineering Sciences, 52, Book 2, 2015, p. 45 – 54.

The paper presents and discusses the results of an experimental study on the influence of several key factors on the metallization of briquettes obtained by pressing residual materials from traditional ferrous metallurgy processes. The industrial realization of this process takes place in rotary kilns, which complicates and increases the cost of conducting experiments in such facilities. It was established that increasing the particle size of the reducing agent slows down the process, with the trend becoming more pronounced for particles with an equivalent diameter greater than 0.003 m. It was found that increasing the relative coal content leads to a higher degree of metallization for all tested samples and sizes, with the quantitative effect being more significant for smaller briquettes. Experimental results further demonstrated that replacing air cooling of

briquettes with water cooling has an inhibiting effect on the reduction of iron oxides only at lower concentrations of the cooling agent. A hypothesis was proposed that the reduced metallization degree of the samples when sodium silicate is added as a mechanical strength enhancer is due to the increase in density and decrease in porosity, which hinders the penetration of the reducing agent into the material. Specific conditions and optimal levels of influencing factors were recommended for the practical implementation of metallization of the studied cubic briquettes. The presented results can be categorized as both scientific-applied and applied contributions.

9B. Stanev R. D., I. S. Mitov. Influence of the Reducing Agent Characteristics on the Metallization of Briquettes from Residual Ferrous Oxides. *Advances in Natural Science – Theory and Applications*, 3, No. 2, 2014, p. 1 – 9.

It is emphasized that the primary focus in the utilization of residues from traditional processes in modern metallurgical plants lies in improving methods for the reduction of oxides in raw materials using coal. This process increases the iron content in the resulting semi-products while also achieving a significant environmental effect. The mechanism of metallization of agglomerates made from iron-containing materials is examined, with particular emphasis on the leading role of intensive heat transfer to the surface of the body and subsequently to its internal parts. Based on this, the main challenges for the effective operation of rotary kilns used for the reduction of oxides in the raw materials with coal have been identified. A methodology for laboratory investigation of the metallization of briquettes obtained from iron scale is presented. Its application is demonstrated for assessing the influence of two key factors determining the process in cubic briquettes, namely the relative coal content and the size of the agglomerates. Experimental results confirmed that as the size of the test bodies increases, the degree of metallization decreases under otherwise equal conditions. The same parameter shows a markedly slower growth when the share of the reducing agent in the samples increases beyond a certain value, while below a specific lower limit, it drops to unacceptably low levels. These results can assist in determining the optimal operating regimes of industrial facilities for the production of iron-bearing agglomerates and represent contributions of both scientific-applied and applied character.

14A. Stanev R. D., I. S. Mitov. From Energy-Technological to Energy-Economical Combining. *Journal of the University of Chemical Technology and Metallurgy*, 46, No. 2, 2011, p. 175 – 180.

A critical review has been carried out of the most widespread schemes for utilizing the sensible heat of exhaust gases from furnace units. The existing practice of energy-technological integration has been analyzed, and the problems associated with its implementation have been identified. A new approach is proposed, giving priority to the economic evaluation of all elements and processes within the different system configurations, followed by the search for ways to technically implement the most cost-effective option. Several potential directions are outlined for identifying competitive alternatives to the existing schemes, which could prove advantageous when adopting energy-economic integration as the leading principle. The presented analyses can be regarded as a scientific-applied contribution.

Scientific Contributions (Publications No. 3B, 4B, 5B, 2C, 2A, 3A, 15A, 6B, 7B, 8B, 13A, 4A, 1B, 2B, 9B, 14A)

1. Experimental Infrastructure and Measurement Approaches

Within the research activities, two unique pilot-scale rotary kiln test rigs were designed, constructed, and commissioned (pub. No. 3B, 2A, 3A, 6B, 4A):

- The first is a directly heated rotary tube kiln for studying the motion of dispersed particles and heat transfer.
- The second is an indirectly heated rotary drum enabling determination of the wall–bed contact heat transfer coefficient.

Original methodologies and measurement tools were developed, allowing experimental determination of thermal parameters under controlled variations in rotation speed, fill degree, and physico-mechanical characteristics of the material (quartz sand, glass and copper spheres, etc.). The metrological reliability of the test rigs was confirmed through uniform temperature fields and reproducible data. These results represent both scientific and applied contributions, as they provide an experimental basis for validating mathematical models and for subsequent industrial applications.

2. Mathematical Models and Geometrical Correlations

Two original mathematical models were developed (pub. No. 4B, 5B, 8B):

- a model describing the deviations of falling particles in rotary kilns;
- the so-called “total model” for determining the overall and active layer thickness.

Experimental studies (pub. No. 3B, 5B, 8B) demonstrated good agreement between theory and practice, confirming the physical correctness of the models.

Additionally, empirical correlations (pub. No. 13A) were derived for the peak height in the transverse cross-section of the bed as a function of kiln diameter, rotation speed, fill degree, dynamic angle of repose, and particle size. These correlations are suitable for rapid engineering calculations and represent an applied contribution.

3. Wall–Bed Contact Heat Transfer

A systematic experimental analysis of wall–bed contact heat transfer in indirectly heated rotary kilns was conducted (pub. No. 2A, 3A, 4A). It was shown that existing analytical models often provide widely differing results and fail to capture real flow regimes.

- For rolling motion, good agreement between models and experiments was confirmed.
- For cascading and slipping motions, typical in industrial kilns, experimentally measured heat transfer coefficients were found to be 3–5 times lower than model predictions.

These findings constitute an original scientific contribution, as they challenge the reliability of classical models and provide a basis for recalibrating them under real operating regimes.

4. Energy–Environmental Efficiency and Influence of External Factors

Publication No. 15A analyzed the influence of meteorological conditions on heat losses from outdoor-installed rotary kilns. Calculations for average annual conditions in Bulgaria (with prevailing winds) identified the ratios between heat fluxes from the kiln's outer surface. Practical recommendations for reducing losses and improving energy and environmental efficiency were formulated.

In pub. No. 14A, a new approach was proposed for transitioning from energy–technological to energy–economic integration, where the choice of waste heat recovery schemes is based on value analysis of alternatives. This represents an applied scientific contribution with direct industrial relevance.

5. Utilization of Residual Materials and Metallization

Publications No. 1B, 2B, and 9B investigated pelletizing and metallization of iron-bearing residues. The following were established:

- the influence of reductant (coal) particle size and relative content;
- the effects of different cooling modes (air, water);
- the negative impact of additives such as water glass on the degree of metallization.

Empirical correlations and optimal conditions for laboratory and industrial implementation were derived, representing an applied contribution to the circular economy and reducing the ecological footprint of metallurgical industries. Publication No. 2C complements these results with studies on waste from lead production, highlighting new recycling perspectives using rotary kilns.

6. Overviews and Priorities for Future Research

Review publications (No. 6B, 7B, 8B) systematized:

- available experimental and mathematical approaches;
- key problems in bed motion, contact heat transfer, and energy recovery;
- promising directions for future research, including combined experimental–numerical methodologies.

These overviews provide a scientific contribution by outlining pathways for solving complex tasks in thermal engineering and transport processes.

Practical Significance

- More accurate engineering tools for the design, reconstruction, and optimization of rotary kilns.
- Reduced energy consumption and emissions through improved modelling of contact heat transfer and control of external losses.

- Development of waste utilization technologies aligned with circular economy principles and environmental standards.

III. Utilization of Waste from Metallurgical Processes [5A, 6A, 8A, 10B]

General Scientific Contribution

- New technological schemes have been developed for the utilization of waste from barite, iron concentrates, and copper oxides.
- A complete cycle has been achieved, from laboratory research to industrial implementation – including the construction of plants for bleached barite, for direct reduction of iron-bearing pellets, and a flotation factory.
- Innovative methods (magnetizing roasting, ETRS) have been introduced, enhancing classical technologies.
- It has been proven that metallurgical waste can be transformed into valuable raw materials for production, delivering both economic and environmental benefits.

5A. Iliyan Mitov, Ani Stoilova, Rositsa Gavrilova, Boyan Yordanov. Production of barium sulfate with considerably improved whiteness through calcination of barite recovered from waste material. Journal of the University of Chemical Technology and Metallurgy, Volume: 60, Issue: 4, 2025, Pages: 679-684

The study presents the calcination of barite obtained from waste stored in a tailings pond located in Bulgaria, with the aim of producing BaSO₄ with improved whiteness. The calcination was carried out in a rotary kiln at 1150 °C in the presence of air. Samples from three batches of barite with different particle sizes—40 µm, 20 µm, and 6 µm—were processed, and both the color and whiteness values of the product were measured. The residence time of the material in the kiln, specifically within the heated zone, was also determined. The results show that the whiteness of the barite extracted from the tailings can be improved by 4–20 units through heating. The article is part of research dedicated to the processing of metallurgical waste in Bulgaria, with the main objectives being the development of economically viable technological schemes for waste containing valuable components and the extraction of useful elements. This work is directly related to articles No. 5A, 6A, 8A, and 10B from the same list. The findings from these studies were applied in the construction of a plant for bleached barite at the former tailings site of the “Kremikovtsi” Metallurgical Combine in the Botunets district of Sofia.

6A. Mitov, I., Yordanov, B., Gavrilova, R., Karadjova, V. Technological possibilities for the utilization of iron-containing waste from metallurgical industries, Journal of Chemical Technology and Metallurgy, 2025, 60 (3), pp. 497–502.

The study presents the possibilities for processing iron-containing waste from metallurgical production. The raw material for the experiments was obtained from the tailings pond of a metallurgical plant in Bulgaria, with the aim of producing a product suitable for use as feedstock in blast furnace production. The tests were carried out in a rotary kiln at 1150 °C, 1100 °C, and 1050 °C in the presence of a reducing agent.

The raw materials for the direct reduction process included three different types of iron ore and coal. During the experiments, the main technological parameters of the reduction process were determined, such as temperature, process duration, furnace pressure, and the composition of the off-gases. The article is part of the series dedicated to the processing of metallurgical waste, with the specific focus here on the recycling of iron-containing waste. The results of these studies were applied in the construction of a plant for the direct reduction of iron-containing pellets in a rotary kiln in the town of Lom.

8A. Mitov, I.; Stoilova, A.; Yordanov, B. and Krastev, D. Technological research on converting iron ore tailings into a marketable product. J. S. Afr. Inst. Min. Metall. [online]. 2021, vol.121, n.5, pp.181-186. ISSN 2411-9717. <http://dx.doi.org/10.17159/2411-9717/1273/2021>.

We present three technological scenarios for extracting the iron components from waste stored in the tailings pond of the “Kremikovtsi” metallurgical plant in Bulgaria, converting them into commercial iron-containing pellets. In the first approach, the iron concentrate was recovered through a two-stage flotation process, followed by desliming and magnetic separation. In the second proposed process, the iron concentrate underwent four consecutive stages of magnetic separation combined with selective magnetic flocculation. The third method involved the less commonly applied technique of so-called magnetizing roasting, followed by selective magnetic flocculation, desliming, and magnetic separation. The iron concentrate was pelletized in a laboratory pelletizer. Each technology was evaluated in terms of the mass recovery of iron, lead, and zinc to determine the most effective method. The results of the research were applied in the construction of a flotation plant for the production of two products—barite and iron concentrate—at the former tailings pond of the “Kremikovtsi” metallurgical complex in the Botunets district of Sofia.

10B. B. Yordanov, D. Krastev, R. Petkov, I. Mitov, E. Koleva D Reduction Of Copper Oxide With Powder Carbon at Electrothermal Rotary bed Conditions Journal (ISSN): 49 th International October Conference on Mining And Metallurgy, Bor Lake, Serbia, October 18-21, 2017. (978-86-6305-066-2) (978-86-6305-066-2 978-86-6305-066-2) Publisher: University of Belgrade, Technical Faculty in Bor in 664 pages Year: 2017

This study investigates the possibility of reducing copper oxide (Cu_2O), obtained as waste from the hot rolling of copper slabs. The reduction process was carried out at 600–800 °C for 60 minutes under isothermal holding in a furnace operating on the principle of an Electro-Thermal Rotating Layer (ETRL). The required heat for the process and the reducing atmosphere were generated directly in the furnace working space by industrial-frequency electric current passing through the reaction mixture composed of dispersed copper scale waste and graphite powder. Cooling was achieved by passing an inert gas such as argon or nitrogen through the reaction mixture after switching off the power supply, down to 80–100 °C, followed by possible cooling in air. X-ray and sieve analyses were performed on the obtained reduced powder. At 800 °C and 60 minutes of isothermal holding, for fractions of 0.4–0.63 mm and 0.63–0.8 mm, the reduction was found to be fully completed, yielding small globular copper particles of the required technical purity.

The contributions of this work in the field of metallurgical waste utilization include:

1. Demonstration of the feasibility of complete reduction of Cu_2O , obtained as a byproduct from hot rolling of copper slabs, into high-purity copper.
2. Application of the Electro-Thermal Rotating Layer (ETRL) as an innovative approach, simultaneously providing the necessary temperature and reducing atmosphere through industrial electric current directly passing through the reaction mixture.
3. Optimization of technological parameters – proven full reduction of particle fractions 0.4–0.63 mm and 0.63–0.8 mm at 800 °C and 60 minutes of isothermal holding.
4. Achievement of a product with defined morphology – production of small globular copper particles meeting technical purity requirements, suitable for further technological applications.
5. Methodological contribution – implementation of X-ray and sieve analyses for result verification, providing a reliable basis for evaluating the efficiency of the reduction process.

Scientific Contribution (publications No. 5A, 6A, 8A, 10B)

1. Development of technologies for barite waste processing
 - The process of calcination of barite extracted from a tailings pond has been studied with the aim of obtaining BaSO_4 with improved whiteness (pub. No. 5A).
 - Optimal conditions (temperature, residence time, particle size) have been determined, under which whiteness increases by 4–20 units.
 - The obtained results were applied in the construction of an industrial plant for bleached barite at the former tailings pond of “Kremikovtzi” metallurgical complex (Botunets district, Sofia).
 - Contribution: transfer of laboratory results into an industrial technology, leading to a new market product with added value.
2. Utilization of iron-containing waste
 - The technological possibilities for direct reduction of iron-containing metallurgical waste have been examined (pub. No. 6A).
 - Experiments in a rotary kiln at different temperatures (1050–1150 °C) in the presence of a reducing agent (coal) demonstrated the conditions for effective process implementation.
 - The main parameters of the reduction process were established (temperature, time, furnace pressure, composition of outlet gases).
 - The results were applied in the construction of a plant for direct reduction of iron-containing pellets in the town of Lom.
3. Contribution: demonstration of the industrial applicability of the method for transforming waste into raw material for blast furnace production.

New approaches for iron recovery from tailings

- Three technological scenarios for extracting iron components from the “Kremikovtzi” tailings pond have been presented (pub. No. 8A):
 - 1) two-stage flotation + desliming + magnetic separation;

- 2) multiple magnetic separations combined with selective magnetic flocculation;
- 3) magnetizing roasting followed by flocculation and separation.
- The concentrate was pelletized and evaluated in terms of mass yield of Fe, Pb, and Zn.
- The results were applied in the construction of a flotation plant for barite and iron concentrate (Botunets district, Sofia).

Contribution: systematization and experimental comparison of competing technologies; selection of the most efficient method for industrial application.

- 4. Reduction of copper oxides by electrothermal rotating layer (ETRL)
 - The reduction of Cu_2O , obtained as waste from hot rolling of copper slabs, was studied under electrothermal rotating layer (ETRL) conditions (pub. No. 26).
 - Heat and reducing atmosphere were simultaneously supplied by passing industrial current through the reaction mixture (Cu_2O + graphite).
 - It was proven that at 800 °C and 60 minutes holding time, reduction was fully completed for particle fractions of 0.4–0.8 mm.
 - Globular copper particles of technical purity were obtained, confirmed by X-ray and sieve analyses.

Contribution:

- 1) Demonstration of an innovative method (ETRL) for reduction of copper waste.
- 2) Optimization of technological parameters (temperature, time, particle size).
- 3) Creation of a high added-value product with potential for application in metallurgy and other industries.

IV. Wear Resistance, Heat Treatment, and Metallography of Metals and Alloys [9A,11B,12A,11A,12B,16A,17A,10A]

9A. Yordanov, B., Mitov, I. Abrasive wear resistance of steel m390p after heat treatment, Journal of Chemical Technology and Metallurgy, 2025, 60 (2), pp. 319–325.

In the present work, the abrasive wear resistance of M390P steel with a composition of 1.9% C, 0.7% Si, 0.3% Mn, 20.0% Cr, 1.0% Mo, 4% V, and 0.6% W after heat treatment was investigated. The test rig used for the laboratory trials of abrasive wear resistance is a device designed to simulate frictional conditions similar to those encountered during service operation.

The heat treatment consisting of quenching from 1070 °C in oil and tempering at 450 °C provides a maximum hardness of 59 HRC and is suitable for components operating under cutting and grinding conditions with high impact loading. Quenching from 1150 °C followed by double tempering at 550 °C achieves a hardness of 61 HRC. This heat treatment improves resistance to abrasive wear in cutting tools.

Quenching at 1070 °C and tempering at 450 °C resulted in a wear rate of $V = 3.6 \cdot 10^{-5} \text{ g} \cdot \text{m}^{-1}$ and abrasive wear resistance $E = 27,778 \text{ m} \cdot \text{g}^{-1}$. The best parameter values were $V = 1.82 \cdot 10^{-5} \text{ g} \cdot \text{m}^{-1}$ and $E = 54,745 \text{ m} \cdot \text{g}^{-1}$ after high-temperature quenching at 1150 °C and subsequent double tempering at 550 °C.

Scientific contributions:

1. For the first time, the abrasive wear resistance of powder metallurgy steel M390P (1.9% C, 20% Cr, 4% V, etc.) has been studied after different heat treatments in order to establish optimal regimes for service under intensive friction conditions.
2. It was proven that quenching from 1070 °C and tempering at 450 °C provides a maximum hardness of 59 HRC and is suitable for applications under high impact loads, though with lower abrasive wear resistance.
3. It was established that high-temperature quenching at 1150 °C followed by double tempering at 550 °C leads to higher hardness (61 HRC) and significantly improved abrasive wear resistance.
4. A quantitative correlation between the heat treatment regime, hardness, and abrasive wear parameters was derived, showing that in this case higher hardness correlates with better wear resistance.

11B. Rositsa Gavrilova, Todor Todorow, Boyan Yordanov, Iliyan Mitov, Study of defects on details of air weapons and causes of their appearance, International Scientific Journal "Security & Future", Web Issn 2535-082x; Print Issn 2535-0668, Year 2024, Volume 8, Issue 1, p. 31-33.

The Vortex gas piston technology has been developed and manufactured for application in most air rifles, using ordinary air instead of other gases. The manufacturer ***** offers six different types of Vortex pistons, covering the majority of Break Barrel and Underlever lines. Despite the demand for high-quality materials and optimized design, operational impacts inevitably affect the weapon, and defects frequently arise due to various reasons—either material and manufacturing imperfections or those resulting from friction between parts, operating pressure, and errors in maintenance and use. Each of these factors, as well as their combinations, can cause defects, which this study investigates based on the examined details of an original and a failed piston and barrel showing visible damage.

Scientific contributions:

1. A systematic analysis of defects in Vortex gas pistons and associated barrels of air rifles was performed, with causes categorized into groups: material and manufacturing imperfections, inter-part friction, operating pressure, and maintenance/exploitation errors.
2. A comparative study was conducted between original and damaged pistons and barrels, enabling the identification of characteristic signs and failure mechanisms (wear, plastic deformation, cracks, surface damage).
3. The role of combined operational impacts (mechanical friction + pressure + maintenance) was demonstrated as frequent catalysts of failures, showing that individual factors often act jointly, accelerating the deterioration of component life cycles.
4. Diagnostic and inspection criteria were proposed for incoming quality control and operational inspection (visual checks, geometry/hardness control, monitoring of lubrication and pressure), improving the early detection of defects and reducing the risk of fatal failures during use.
5. The results have direct applicability for improving design, material selection, and manufacturing procedures (e.g., optimization of heat treatment, surface

property control, and tolerances), as well as for developing maintenance guidelines and user instructions aimed at extending service life.

12A. Dimitar Krastev, Boyan Yordanov, Ilyan Mitov, Metallographic investigation of damaged tinplate aerosol cans, Journal of Chemical Technology and Metallurgy, 58, Issue 1, 2023, 222-227

This work presents an investigation of certain defects observed in damaged tin cans, resulting from a specific combination of the steel sheet's properties, its metallurgical production, and the mechanical operations during the can manufacturing process. The characteristics of the microstructure, strength, and ductility of different types of sheet steel have a significant impact on the quality and performance of the produced cans. Many operations in the can production process must be carried out with high precision to prevent future defects during storage and use. The studies revealed that the sheet coils employed in can manufacturing possess a heterogeneous structure which, due to variations in the double-seaming process together with machine adjustment issues, can cause the formation of cracks and delaminations. These defects reduce the effective cross-sectional area and are the primary cause of structural failures. In these areas, the presence of aggressive food components may additionally trigger corrosion processes.

Scientific contributions:

1. An analysis of defects in damaged cans was carried out, linking them simultaneously to the metallurgical characteristics of the steel sheet and to the technological features of the manufacturing process.
2. It was established that the heterogeneous structure of the sheet material, combined with variations in the double-seaming process and machine settings, leads to crack formation and delamination.
3. It was demonstrated that these defects not only reduce the effective load-bearing cross-section of the material but also create preconditions for accelerated corrosion due to contact with aggressive food components.
4. Critical factors were identified whose control is essential for improving can quality—structural uniformity of the steel sheet, precise machine adjustment during double seaming, and prevention of technological deviations.

11A. Yordanov, B., Krastev, D., Mitov, I., Heat Treatment Influence On The Abrasive Wear Resistance Of Hypoeutectic Chromium Cast Iron, Journal of Chemical Technology and Metallurgy, 2022, 57(6), pp. 1267–1274

This study investigates the variation in hardness and wear resistance of a specially designed machine simulating abrasive wear conditions, depending on the type of heat treatment applied to a hypereutectic chromium white cast iron with the following composition: C – 2.19%, Mn – 0.46%, Si – 0.51%, Cr – 11.6%, P – 0.031%, S – 0.046%, Ni – 0.23%, Mo – 0.077%, V – 0.052%, and Al – 0.006%. A maximum hardness of HRC 67 was achieved after quenching at 980 °C in oil and tempering at 200 °C. This treatment is suitable for components operating under conditions of friction and grinding without high impact and dynamic loads. The wear rate after quenching at 980 °C in oil and subsequent low-temperature tempering at 200 °C was $V = 2.42 \cdot 10^{-5} \text{ g} \cdot \text{m}^{-1}$, and the abrasive wear resistance was $E = 41,284$. In the as-cast state, these values were $V = 1.33 \cdot 10^{-5} \text{ g} \cdot \text{m}^{-1}$ and $E = 75,157$, decreasing to $V = 0.30 \cdot 10^{-4} \text{ g} \cdot \text{m}^{-1}$ and $E = 3,331$ after annealing at 870 °C with 180 minutes holding time.

Scientific contributions:

1. The dependence between heat treatment and properties (hardness and abrasive wear resistance) of hypereutectic chromium white cast iron with a complex alloying system (Cr, Ni, Mo, V) was investigated.
2. It was established that quenching at 980 °C in oil and tempering at 200 °C ensures maximum hardness (67 HRC) and wear parameters suitable for components operating under friction and grinding without high dynamic loads.
3. Quantitative values for wear rate and abrasive wear resistance were determined for different heat treatment regimes, demonstrating that annealing at 870 °C with 180 minutes holding time leads to a sharp deterioration of wear resistance.
4. It was shown that a compromise exists between hardness and wear resistance depending on the heat treatment regime, enabling the targeted selection of optimal treatment for specific operating conditions.

12B. Rositsa Gavrilova, Boyan Yordanov, Krastev, D., Mitov, I. Research on loading-transport machine parts in order to determine the causes of defects, Scientific Technical Union Of Mechanical Engineering Industry-4.0 Trans Motauto World Vol.7 (2022), Issue 1, pg(s) 15-18

Possible defects in the piston–cooling jacket system are examined, arising from various causes. This system operates under severe conditions: thermal loads, fluctuating gas pressure, and mechanical friction, which require high strength, good wear resistance under limited lubrication, and overall high resistance to abrasion, corrosion, and other wear mechanisms. The operation of the cylinder–piston assembly with insufficient or poor-quality lubrication is the most common cause of overheating or engine seizure. The jamming of one or more pistons leads to major engine repairs or even scrapping. Damaged fuel injectors, inaccurate injection, or improper ignition timing can also result in melting or cracking of the mechanism. Therefore, it is crucial to identify the exact causes of defects in the system and seek preventive measures.

Scientific contributions:

1. A systematic analysis of possible defects in the piston–cooling jacket system has been performed, identifying the main contributing factors (thermal loads, fluctuating gas pressure, mechanical friction, poor lubrication quality, damaged fuel injectors, etc.).
2. For the first time, a correlation has been established between lubrication quality, combustion regimes, and the operational reliability of the cylinder–piston assembly, enabling more accurate diagnostics and failure prediction.
3. It has been scientifically substantiated that resistance to abrasion, corrosion, and combined wear processes is a critical criterion in the selection of materials and technologies aimed at improving the system's performance.

16A. Boyan Yordanov, Iliyan Mitov, Abrasive wear resistance of high chromium cast iron after heat treatment, Heat Treatment and Surface Engineering, under review ...

This study investigates the abrasive wear resistance after heat treatment of high-chromium cast iron with the following composition: 3.76% C, 0.87% Si, 0.85% Mn, 17.36% Cr, 2.01% Mo, and 0.53% Ni. Quenching from 970 °C in oil followed by tempering at 200 °C provides a hardness of 67 HRC. Quenching from 1100 °C followed by tempering at 600 °C results in a hardness of 63 HRC. Quenching from 970 °C in oil and tempering at 500 °C produces a wear rate of $V = 1.223 \cdot 10^{-5} \text{ g m}^{-1}$ and an abrasive wear resistance of $E = 81,744 \text{ m g}^{-1}$. For as-cast samples, the respective values are $V = 1.406 \cdot 10^{-5} \text{ g m}^{-1}$ and $E = 71,090 \text{ m g}^{-1}$. Quenching from 1100 °C and tempering at 600 °C reduces the wear rate to $V = 9.467 \cdot 10^{-6} \text{ g m}^{-1}$ and increases wear resistance to $E = 105,634 \text{ m g}^{-1}$, representing the best results achieved.

Scientific contributions:

1. It has been demonstrated that quenching from 970 °C in oil and tempering at 200 °C provides maximum hardness (67 HRC), while quenching from 1100 °C and tempering at 600 °C yields lower hardness (63 HRC) but significantly better abrasive wear resistance.
2. A quantitative relationship has been established between hardness and wear parameters (wear rate V and resistance E), showing that lower hardness does not always correlate with poorer abrasive wear behavior.
3. It has been shown that heat treatment enables optimization of the balance between hardness and wear resistance in high-chromium cast irons, with the best performance achieved at 1100 °C quenching and 600 °C tempering.

17A. B. Yordanov, I. Mitov, T. Todorov, R. Gavrilova, Study of wear resistance of metal alloy as a result of various heat treatment modes Journal of the University of Chemical Technology and Metallurgy, under review ...

The subject of this study is an alloy containing approximately 1.05% C, 1.55% Cr, 0.40% Mn, 0.35% Si, and about 0.02% P and S. The chemical composition of the selected alloy is close to steel grade EN:1.3505 (100Cr6) or AISI:52100. Various heat treatment regimes were applied to standard metallographic specimens with a circular cross-section of $\varnothing 10 \text{ mm}$ and a length of 50 mm. The aim was to trace their influence on the alloy's microstructure and, based on the observed changes, to predict its behavior under abrasive wear conditions.

The investigations were carried out using a Neophot 2 metallographic microscope, a Hanemann microhardness tester, and combined Brinell-Rockwell hardness testing devices. Heat treatments were performed under standard conditions, with parameters selected to achieve maximum hardness during quenching and low-temperature tempering, on the one hand, and satisfactory machinability after normalizing, on the other. The goal of the study was to achieve a smooth surface in subsequent machining of parts made from the selected alloy. With the expansion of the tasks and scope of experiments, it became possible to determine the regimes that increase the abrasive wear of this material.

Scientific contributions:

1. Optimal regimes of quenching and low-temperature tempering were identified, resulting in maximum hardness and improved resistance to abrasive wear.
2. The influence of normalizing on the machinability of the alloy was established, which is practically significant for achieving a smooth surface in subsequent machining.
3. Based on metallographic and mechanical testing, a relationship was derived between microstructure (carbide distribution, martensitic structure, retained austenite) and the alloy's behavior under abrasive wear.
4. Heat treatment regimes were determined under which the abrasive wear of the steel increases, which is important for predicting its performance under different service conditions.

10A. Yordanka Trifonova, Ani Stoilova, Deyan Dimov, Georgi Mateev, Vladislava Ivanova, Iliyan Mitov and Olya Surleva. Photo-Induced Birefringence in Layered Composite Materials Based on Ge–Te–In and Azo Polymer Prepared Through Different Methods, Materials 2025, 18, 3837. <https://doi.org/10.3390/ma18163837>

Chalcogenides in bulk state from the system $(\text{GeTe}_4)_{1-x}\text{In}_x$, where $x = 0, 5$, and 10 mol%, were synthesized using a two-step melt-quenching technique. New layered composite materials based on these chalcogenides and the azopolymer [1-4-(3-carboxy-4-hydroxyphenylazo)benzenesulfonamido]-1,2-ethanediol, sodium salt] were obtained by spin-coating, electrospray deposition, and by vacuum thermal evaporation of the chalcogenide followed by spin-coating of the azopolymer. Using the latter technology, a material consisting of a bilayer (one chalcogenide and one azopolymer film) and a multilayer stack of three chalcogenide and three azopolymer films was fabricated.

SEM analysis revealed that in the materials initially prepared as bilayer and multilayer structures, diffusion occurs at the chalcogenide/polymer interface, leading to the formation of a homogeneous composite medium. In all fabricated thin-film materials, birefringence was induced at 444 nm. The highest value of maximum induced birefringence was measured for the stacked multilayer structure ($\Delta n_{\text{max}} = 0.118$). For the bilayer structure and the electrospray-deposited composite material, the maximum induced birefringence reached values of $\Delta n_{\text{max}} = 0.101$ and $\Delta n_{\text{max}} = 0.095$, respectively. The sample prepared by spin-coating of the chalcogenide dispersion exhibited the lowest value of maximum induced birefringence ($\Delta n_{\text{max}} = 0.066$), compared to the pure polymer film ($\Delta n_{\text{max}} = 0.083$).

For the first time, new layered composite materials based on $(\text{GeTe}_4)_{1-x}\text{In}_x$ chalcogenides and [1-4-(3-carboxy-4-hydroxyphenylazo)benzenesulfonamido]-1,2-ethanediol, sodium salt] have been synthesized and studied. By combining different technological approaches (spin-coating, electrospray deposition, and vacuum thermal evaporation), it was demonstrated that diffusion processes occur at the chalcogenide/polymer interface, leading to the formation of a homogeneous composite medium. Induced birefringence at 444 nm was observed in all fabricated thin-film materials, with a record-high maximum value for the multilayer stack. It was shown that the preparation method has a significant impact on the magnitude of photoinduced birefringence, opening perspectives for controlled design of optical elements with functional anisotropy.

General Scientific Contribution (publications №9A, 11B, 12A, 11A, 12B, 16A, 17A, 10A)

Advancement of knowledge on abrasive wear resistance of steels and cast irons.

For the first time, the abrasive wear behavior of powder metallurgy steel M390P (paper 9A) and various high-chromium cast irons (papers 11A and 16A) was investigated under diverse heat treatment regimes. Quantitative relationships were established between temperature, quenching/tempering regimes, hardness, and wear resistance parameters (V and E), showing that higher hardness does not always guarantee improved wear resistance (papers 9A, 11A, 16A). Optimal heat treatment regimes were identified, providing a balanced combination of hardness and wear resistance for specific service conditions (papers 9A, 11A, 16A, 17A).

Scientifically justified selection of heat treatments for different material classes.

Regimes were determined for EN 1.3505 (AISI 52100) steels (paper 17A), powder high-chromium steels (paper 27), and chromium cast irons (papers 11A and 16A), enabling optimization of hardness, wear resistance, and machinability. The influence of normalization on surface machinability and its practical significance for manufacturing high-quality parts was demonstrated (paper 17A).

Metallographic studies and defect diagnostics.

Approaches were developed for analyzing defects in tinplate for cans (paper 12A), in pistons and barrels of air rifles (paper 11B), and in cylinder–piston groups of engines (paper 12B). It was proven that there is a direct link between metallurgical homogeneity, technological production parameters, and service reliability (papers 11B, 12A, 12B). The main failure mechanisms—cracking, delamination, plastic deformation, and corrosion damage—were systematized (papers 11B, 12A, 12B).

Industrial applicability of results.

Practical guidelines were proposed for controlling production parameters (heat treatments, machine adjustments, lubrication, and maintenance) to extend the service life of parts and equipment (papers 9A, 11B, 12A, 11A, 12B, 17A). Criteria for early diagnostics and incoming material inspection were developed (papers 11B, 12A, 12B). Scientific contribution in the field of new composite materials.

For the first time, new layered composite materials based on Ge–Te–In chalcogenides and azopolymers were synthesized and studied (paper 10A). Photoinduced birefringence at 444 nm was demonstrated, and the effect of fabrication method on the magnitude of the effect was established (paper 10A). A record-high induced birefringence ($\Delta n_{\max} = 0.118$) was achieved for multilayer composite stacks, opening perspectives for applications in optical elements with functional anisotropy (paper 10A).

A - Articles in journals with impact factor, 17

B- Articles in journals without impact factor, 15

C- Conference proceedings, 2

