

CROATIAN METALLURGICAL SOCIETY (CMS)  
HRVATSKO METALURŠKO DRUŠTVO (HMD)

16<sup>th</sup> INTERNATIONAL / 16. MEĐUNARODNI

SYMPOSIUM OF CROATIAN METALLURGICAL SOCIETY  
SIMPOZIJ HRVATSKOG METALURŠKOG DRUŠTVA

# S H M D '2023

MATERIALS AND METALLURGY / MATERIJALI I METALURGIJA  
BOOK OF ABSTRACTS / ZBORNİK SAŽETAKA

*Obljetnice Hrvatskog metalurškog društva*  
*Anniversaries of Croatian Metallurgical society*

1952.-2022. HRVATSKO METALURŠKO DRUŠTVO / CROATIAN METALLURGICAL SOCIETY / 70 god./y

1962.-2022. ČASOPIS METALURGIJA / METALURGIJA JOURNAL / 60 god./y



ZAGREB, CROATIA, April 20 – 21, 2023  
ZAGREB, HRVATSKA, 20. – 21. travanj 2023.

## THE AIM OF SYMPOSIUM

The aim of this Symposium is to point out all the possibilities of the materials and achievements in metallurgy.

## TOPICS OF THE SYMPOSIUM WERE:

### Materials

- New Materials
- Refractory Materials
- The Development
- Applications
- Physical Metallurgy

### Metallurgy

- Process Metallurgy and Foundry
- Plastic Processing of Metals and Alloys
- Technologies
- Energetics
- Ecology in Metallurgy
- Quality Assurance and Quality Management

16<sup>th</sup> International Symposium of Croatian Metallurgical Society „Materials and Metallurgy“ was held as a part of Anniversaries:

**1952.–2022. HRVATSKO METALURŠKO DRUŠTVO / CROATIAN METALLURGICAL SOCIETY**

**1962.–2022. ČASOPIS METALURGIJA / METALURGIJA JOURNAL**

„Countries Participating at the 16<sup>th</sup> International Symposium of Croatian Metallurgical Society“ – total 50 „Organizer“, „Co-organizer“, „Co-operation with organizations“, same as 15<sup>th</sup> symposium, Please see Metalurgija 62 (2023) 1, 8-10

## ACCEPTED ABSTRACTS

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## PATRONS (same as for 15 th Symposium)

- World Steel Association (WSA)
- International Society of Steel Institutes (ISSI)
- European Steel Federation (ESF)
- European Steel Institute Confederation (ESIC)
- University of Slavonski Brod, Faculty of Mechanical Engineering, Croatia
- University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

## NAPOMENA:

- Mnogi autori / koautori nisu se pridržavali zadanog oblika i dužine sažetaka referata. Znanstveni odbor je izveo usaglašavanje, te isprika ako postoje nedostaci. Moguće je i možebitni izostanak nekog sažetka. Sve Reklamacije se usvajaju do 30. travnja 2023. god., posebice tisak, Metalurgija 62 (2023) 3.

## NOTE:

- Many authors / co-authors have not observed the given form and length of abstracts of their reports. Scientific board has made adjustments, so we apologize if there are any faults. An abstract might be failing. All Protests will be accept till April 30, 2023, and after separately publish, Metalurgija 62 (2023) 3.

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*Dear Participants, Authors, Co-authors et al.,*

*Thirty years (1993-2023) have passed since foundation of International Symposiums of Croatian Metallurgical Society „Materials and Metallurgy“. First Symposium (September 15-17, 1993) was postponed due to war operations in Sisak, and subsequently held in Zagreb, February, 16-18, 1994. Till now total 16, Countries participating were about 50, over 70 different Institutions, total 6 459 Abstracts of over 10 000 Authors and Co-authors.*

*Dear al., my thanks to You, because without You this Symposiums would have never come about.*

*Special thanks and compliments are to many Members of Committees Scientifics, Organizing, Honour Boards, Reviewers, Chairman of Sections etc.*

*I just hapen to be first amoving equals.*

*Leader of all Symposiums*

*Akad. I. Mamuzić, Prof.h.c.,dr.h.c.*

### Countries Participating at the 16<sup>th</sup> International Symposium of Croatian Metallurgical Society “Materials and Metallurgy”

<b>1</b> Argentina	<b>18</b> Greece	<b>35</b> Portugal
<b>2</b> Austria	<b>19</b> Hungary	<b>36</b> Romania
<b>3</b> Belgium	<b>20</b> India	<b>37</b> Russia
<b>4</b> Belarus	<b>21</b> Indonesia	<b>38</b> Saudi Arabia
<b>5</b> Benelux	<b>22</b> Iran	<b>39</b> Serbia
<b>6</b> Bosnia and Herzegovina	<b>23</b> Italy	<b>40</b> Singapore
<b>7</b> Brazil	<b>24</b> Japan	<b>41</b> Slovakia
<b>8</b> Bulgaria	<b>25</b> Kazahstan	<b>42</b> Slovenia
<b>9</b> Chile	<b>26</b> Korea	<b>43</b> South Africa
<b>10</b> China	<b>27</b> Lithuania	<b>44</b> Spain
<b>11</b> Croatia	<b>28</b> Macedonia	<b>45</b> Sweden
<b>12</b> Czech Republic	<b>29</b> Malaysia	<b>46</b> Thailand
<b>13</b> England	<b>30</b> Mexico	<b>47</b> Turkey
<b>14</b> Egypt	<b>31</b> Montenegro	<b>48</b> Ukraine
<b>15</b> Finland	<b>32</b> Netherlands	<b>49</b> USA
<b>16</b> France	<b>33</b> Philippine	<b>50</b> Vietnam
<b>17</b> Germany	<b>34</b> Poland	

### All 16 Symposiums have been held:

- 1<sup>st</sup> Zagreb: 1994, February, 16-18 (88 lectures)
- 2<sup>nd</sup> Split: 1996, June, 20-22 (150 lectures)
- 3<sup>rd</sup> Šibenik: 1998, June, 25-27 (192 lectures)
- 4<sup>th</sup> Opatija: 2000, June, 25-29 (333 lectures)
- 5<sup>th</sup> Šibenik: 2002, June, 23-27 (375 lectures)
- 6<sup>th</sup> Šibenik: 2004, June, 20-24 (368 lectures)
- 7<sup>th</sup> Šibenik: 2006, June, 18-22 (475 lectures)
- 8<sup>th</sup> Šibenik: 2008, June, 22-26 (615 lectures)
- 9<sup>th</sup> Šibenik: 2010, June, 20-24 (541 lectures)
- 10<sup>th</sup> Šibenik: 2012, June, 17-21 (641 lectures)
- 11<sup>th</sup> Šibenik: 2014, June, 22-26 (689 lectures)
- 12<sup>th</sup> Šibenik: 2016, June, 19-23 (546 lectures)
- 13<sup>th</sup> Šibenik: 2018, June, 24-29 (561 lectures)
- 14<sup>th</sup> Šibenik: 2020, June, 21-26 (435 lectures)
- 15<sup>th</sup> Zagreb: 2022, March, 22-23 (527 lectures)
- 16<sup>th</sup> Zagreb: 2023, April, 21-22 (259 lectures)

# Anniversaries of Croatian Metallurgy

## 1. I. Mamuzić

### Anniversaries of Croatian Metallurgy

The goal of this work is to give a short collective overview on occasion of Anniversaries of Croatian Metallurgy:

- The Foundation and Development of Croatian Metallurgical Society (CMS) 1952-2022, with achievements and activities.
- The Development of metallurgy in the world whose beginnings date 7 000 years also 6 000 y metallurgy on the territory of today Croatia: Vučedol, Celtic and Roman, after with the arrival of Croatia to this territory. History of metallurgy, achievements and the destructions (1990-2012).
- Sixty years of the Foundation and Development of University studies of metallurgy in Sisak / Metallurgy Faculty 1960-2022. By results and difficulties during 60 years, gave citations Author's works about MF.
- Sixty years of the publishing of the Metalurgija Journal ( 1962-2022 ), with print: 199 issues (238 Numbers), published 2721 Scientific (and Technical) papers, 287 contributions, total 3008 works, from 3558 Authors and Co-authors.
- Separately published from 16 Symposiums „ Materials and metallurgy“ of Croatian Metallurgical Society 16 Editor Books.

## 2. I. Mamuzić

### Seventy years of the foundation of Croatian Metallurgical Society ( CMS ) 1952-2022

The goal of this article is to give an overview of the foundation and development of Croatian Metallurgical Society (CMS ) from the Society of Engineers and Technicians of Steelworks Sisak 1952 with monitoring of goals and tasks of CMS, main activities of the Society are also set out: publishing of the magazine Metalurgija, International Symposiums „ Materials and Metallurgy“, and productive cooperation with an array of institutions in Croatia and abroad, (over 70 institutions from 50 th countries).

The overview includes also several futile press notices to the public made by the member of the Society of their own initiative in order to sustain and revitalize the Croatian metallurgy.

## 3. I. Mamuzić

### 6000 years of the metallurgy on the territory of Croatia

This work deals with the development of metallurgy in the world whose beginnings date 7 000 years B.C. On the territory of today's Croatia metallurgy has been present for 6 000 years. Three civilizations have left evidence the Celtic, the Roman and civilization of Vučedol.

After the arrival of the Cratis to this territory, metallurgy developed more intensively in the region of Sisak and Banovina as well as Samobor and Gorski Kotar. Bells and guns were cast in Dubrovnik and Zagreb. The industrial production started in 1853 (Foundry in Rijeka), production of ferroalloys, Šibenik 1900 y, also Dugi Rat 1906 y, and in 1937 the production of aluminium and Al-alloys in Lozovac (continued by 1905) as with the construction of the blast in Caprag in 1939 furnace.

The period after 1945 until 1990, Croatia had several metallurgical companies and acceptable production coke, steel, ferro-alloys, electrodes, casting, reinforced concrete steel, seamless and welded tubes, strips, billets, aluminium etc. Total production in Croatia in 1990 was – 3 000 000 tons of various metallurgical products (without casting).

Per year in 1990 until 2012 plants of over 2 600 000 t of metallurgical products per year were torn down or put out of operations.

Total metallurgical production in Croatia in was 2011 y 248 910 tons i.e. level 8,3 % (comparison with production in 1990 y), what is significant of the destruction of Croatia metallurgy for 22 years.

## 4. I. Mamuzić

### Sixty years of the publishing of Metalurgija Journal, 1962-2022

The goal of the work is to give whole the description history, organizations of Journal activities and achievements of Journal from 1962 since 2022y, with this including List of Boards and Co-workers, were publishing total papers 3 008 i.e. 2 721 Scientific and Technical and 287 Contributions, total 3 558 Authors and Co-authors from over 40 Countries.

On the occasion of this Anniversary, separately with thanks for Privates, Institutions etc. For dedicated effort have managed to overcome many technical, organizational and financial problems encountered over past Years.

## 5. I. Mamuzić

### Sixty years of University Studies of Metallurgy in Croatia 1960-2020

The goal of this work is to give history, organizations of University Studies in Croatia.

The Dep. of Metallurgy in Sisak of the Faculty of Technology Zagreb was founded in 1960 with Ironwork Sisak, Petrol refinery Sisak and Assembly of the Municipality Sisak as Founders. During 60 y (1960-2020) were several organizations transformed, important 1977-1978 y when is Metallurgical Dep./Engineering including in Institute for metallurgy Sisak, name Metallurgical Faculty. With transform 1990-1991 y Metallurgical Faculty have separate from Institut for metallurgy Sisak and come into existence as autonomous the organization at University of Zagreb.

Till now, have published many works about history, activities in teaching, scientific and professional works and achievements.

## 6. I. Mamuzić

### 16 International Symposiums „Materials and Metallurgy“ of Croatian Metallurgical Society (CMS)

First symposium (September, 15-17, 1993) was postponed due to war operations in Croatia in the time, and subsequently held in Zagreb (February 16-18, 1994).

In total CMS was held 16 Symposiums with different but always 4 sections: „A“ Materials, „B“ Process Metallurgy, „C“ Plastic processing, „D“ Metallurgy and related topics.

In organization and of participated in all Symposiums were till 50 countries and over 70 institutions. Till now were total 6 459 abstracts of over 10 000 Authors, Co-authors.

The goal of this report is to give an overview of 16 symposiums for all 4 sections with reports of subject matter.

## 7. I. Mamuzić

### Metalurgija Journal 2022 y List of published papers

Sixty years ( 1962-2022 ) have passed since the foundation and the first publishing of the Metalurgija Journal. On the occasion of this Anniversary have published Bibliograph 1962-2022. Last the Article was No 3008 60 ( 2021 ) 3-4,463-464. The goal of this report is to give List of published papers for 2022 y: 4 ( one by one ) issues, 4 Numbers: 148 scientific and technical and 11 contributions – total 159 papers. Now, last published the paper in 2022 y is 3171, Metalurgija 61 ( 2022 ) 3-4,888 ( total pages in 2022 y, 896 ).

## 8. I. Mamuzić

### Metalurgija Journal 2022 y – List of Authors and Co-authors

On the occasion of sixty years ( 1962-2022 ) of published Metalurgija Journal in Bibliograph have published all Authors, Co-authors ( scientist, expert in the field of metallurgy and other relevant branches, from 40 countries, i.e. 5 continent ) with name / surname and Numbers ( 1-3008 ) of papers when are published – total 3558 Authors, Co-authors.

The goal of this report is to give thin dates for Authors, Co-authors, with survey in 2022 y : 395 Authors, Co-authors of 159 papers.

# Materials – Section „A“

## 1. J. Wang, J. Li, Y. W. Wang

**Prepare method of the new structure PbTiO<sub>3</sub> nanowires.** When the self-made with Teflon lined with stainless steel reaction kettle is used to produce PbTiO<sub>3</sub> nanowires with the adoption of hydrothermal reaction. The crystal structure of nanowire was analyzed by X-ray diffraction (XRD) and electron backscatter diffraction (EBSD). The results indicate, PbTiO<sub>3</sub> nanowires with new structure can be made when Pb / Ti equals 2,2.

## 2. G. Z. Ouyang, W. Y. Zhang

**A surface defect detection method of steel plate based on yolov3.** This paper proposes a single-stage surface defect detection method of steel plate based on yolov3, which can classify defects, determine the location of defects, and greatly improve the detection speed. It is of great significance to realize the automation of cold rolling production line. The experiment shows that the detection speed of this model reaches 62 fps and the accuracy reaches 73 %, which has a good prospect in industry.

## 3. Y. Y. Zhang, Y. X. Chen

**Rapid optimization of laser quenching process based on BP neural network.** The rapid optimization of laser quenching process parameters were studied. First of all, the experiment is carried out by orthogonal method, which achieves the purpose of finding the influence law of process parameters with a small number of samples. Then, the neural network modeling is used, the process parameters and the experimental results are functionally fitted, and the model is continuously revised by reducing the feedback error, and finally the prediction model with the smallest error is obtained. Finally, the genetic algorithm is used to quickly search for optimization, and based on the prediction model, population selection, crossover, mutation and iteration are used to obtain the optimal fitness and corresponding variable value.

## 4. T. Šolić, M. Samardžić, D. Marić, I. Samardžić

**Analysis of interconnection between physical and protective properties of two-component epoxy primer.** This paper presents the research into protective properties of two-component epoxy primer obtained by measurements of the notch corrosion and by testing of the gloss as a physical property. In order to obtain different values of measured response, the first experiment was done by applying the primer in various amounts of the dry film thickness, while the second experiment was based on combining various contents of anti-corrosion pigment. Analysis of the obtained research results proved the interconnection between the two observed properties. It was confirmed that the obtained results were inversely proportional for both experiments. Protective properties of coating could be assessed by measuring the gloss value, which is simpler and faster than measuring the notch corrosion.

## 5. T. Šolić, D. Marić, A. Bašić, I. Samardžić

**Influence of surface roughness on the rate of corrosion penetration into the steel.** This research analyses the influence of surface roughness on the rate of corrosion penetration into the steel. The test specimens were mechanically treated with fine abrasive jet to make their surface slightly rougher than it was in the initial state. The test specimens were then kept in conditions of atmospheric corrosion for 90 days to be tested afterwards by weighing, i.e. by the mass loss method. The analysis showed that a slight increase in surface roughness facilitated faster development of corrosion mechanisms, thus drastically increasing the rate of corrosion penetration into the material. Changes in surface roughness can be also caused by abrasion or erosion damage, so it is important to choose adequate surface protection technologies for prevention of unwanted wear of the steel.

## 6. A. Z. Issagulov, Sv. S. Kvon, V. Yu. Kulikov, D. R. Aubakirov, Ye. P. Chsherbakova

**Studying the chrome-nickel cast iron structure and properties after modification on industrial samples.** The paper presents the results of studying the structure and properties of chrome-nickel cast iron samples obtained under production conditions. Cast iron with a given ratio of silicon and chromium smelted in an industrial arc furnace was treated with titanium carbide followed by modification with a complex modifier containing (Scanning electron microscope). As a result of the composition adjustment and appropriate processing, a mixed structure was formed represented by an austenite-ledgeburite matrix, iron, chromium and titanium carbides and a small amount of free graphite, both lamellar and spherical. This structure is characterized by higher wear resistance and impact resistance compared to Nihard-2 but at the same time it shows lower hardness.

## 7. I. Aimbetova, O. Baigenzhenov\*, E. Aimbetova, G. Issayev, D. Berdi

**Investigation of the technology for obtaining thin coatings of vanadium pentoxide for the production of smart windows.** This article deals with the doping of vanadium pentoxide with tungsten in various quantities and obtaining coatings used in the production of "smart windows" from the resulting melt. The properties of the obtained coatings were determined using X-Ray diffraction (XRD) and scanning electron microscope (SEM). The thermo-optical properties, namely solar reflectance and IR emittance, were investigated and were correlated with the doping tungsten effect in thin vanadium oxide films.

## 8. C. Kolmasiak, M. Łągiewka

**Foundry properties of composites on AlMg10 alloy matrix with SiC and Cgr particles.** This paper presents the results of tests concerning the castability of metal composites based on an aluminium alloy matrix. The castability of composite suspensions containing carbide particles and suspensions containing graphite particles was tested using two tests: spiral and rod tests. It was found that as the volume fraction of particles increases, the castability of composites decreases, with graphite particles having a greater effect on the decrease in castability than silicon carbide particles. The paper also presents the results of research concerning the effect of ceramic particles on the shrinkage of solidifying and cooling composites. The shrinkage test results show a positive effect of ceramic particles introduced into the aluminium alloy, manifested by a decrease in the shrinkage value.

## 9. M. Łągiewka, C. Kolmasiak

**The porosity of TiN bronze castings.** The presented work presents the results of the research on the influence of the method of hydrogen removal from tin bronze on porosity and tensile strength. The dehydrogenation was carried out by three methods. In the first method, hydrogen was removed utilizing a vacuum furnace, in the second method, the melt was blown with compressed air, and in the third method, the melt was refined with the salt called Ecosal CU 440. Recirculating scrap was used to make samples. For comparative purposes, castings were also made of melted ingots of the alloy. The density of the castings was determined and the effect of the dehydrogenation method on porosity and the tensile strength was determined on this basis.

## 10. A. A. Alina, V. Yu. Kulikov, A. E. Omarova, P. V. Kovalev

**X-ray phase analysis XPA of a cold-hardening mixture (CHM) and the effect of the mixture properties on the casting.** The objectives of this type of research are as follows: identifying the phase composition of the samples under study; assessing the effect of the composition on the mechanical properties of the samples. Prior to the study by the XPA, the authors obtained 9 samples of different compositions to select the optimal composition of cold-hardening mixture (CHM). The method of X-ray phase analysis was selected for the phase composition of the CHM samples. After examining the samples using XPA analysis, molds were made from CHM (resin+clay) according to the composition of sample No. 3. To evaluate the quality of the castings, there was measured roughness.

## 11. N. N. K Astuti, E. Surojo, T. Triyono, S. I. Cahyono, N. Muhayat, Triyono

**Microstructure analysis of dissimilar metals weld between S690Q and S355J2+N steel under flame straightening treatment.** Flame straightening process is needed to improve joint alignments due to the distortions induced by welding heat. This research shows that flame straightening can be applied safely on the weld of dissimilar metals such as S690Q and S355J2+N steel. The results indicated an increase in hardness of the flame straightened base metal, heat affected zone (HAZ), and weld metal due to pearlite transformation in these areas. Furthermore, the two metals were welded in accordance to the welding procedure standard (WPS) and then straightened by applying heat. It was then cooled rapidly with an air jet along the root of the weld joint. Lastly, microstructure investigation and hardness test were carried out on the area which was flame straightened.

**12. A. T. Kanaev, A. V. Bogomolov, T. E. Sarsembaeva, I. M. Kossanova**

**Plasma hardening of heavily loaded parts of soil-cutting machines.** The influence of plasma hardening on hardening processes of heavy-duty and, therefore, wear parts of working elements of soil-cutting machines has been studied. It is shown that surface plasma hardening of ploughshare made of structural steel 65Mn in the hardened zone with thickness of 0,8 mm leads to formation of gradient-layered (mixed) structure consisting of finely dispersed mixture decay products of fine-grained austenite with variable microhardness in the range of 760 – 395 HV. It is confirmed that the creation of gradient-layered structure and features of its formation after the surface plasma treatment are explained by ultrahigh heating and cooling rates, unattainable with traditional methods of heat treatment.

**13. Y. X. Sun, Y. J. Zhang, Z. H. Wei, J. T. Zhou**

**A classification and location of surface defects method in hot rolled steel strips based on YOLOV7.** Hot-rolled steel strip is widely used in production life and surface defects inevitably occur during its production process. In order to solve this problem, this paper proposes a method for classifying and locating surface defects in hot-rolled strip steel based on the YOLOV7 target detection model, which takes into account both accuracy and real-time performance. The method is capable of distinguishing seven common surface defects with an average accuracy of 84,3 % and a maximum accuracy of 99,6 % in a single category of defects.

**14. I. Mamuzić, G. Shvachykh, L. Sushko, I. Hulina**

**Maximum parallel forms of difference scheme algorithms in applied problems of metallurgical thermal physics.** The problem of constructing the maximum parallel forms of difference algorithms to solve applied problems of metallurgical thermal physics is investigated. The features of parallelization by piecewise-analytical method of lines and method of permutations are revealed. The proposed approach does not impose any restrictions on grid nodes topology of computational domain. In addition, with regard to parallel computation of arithmetic expressions, it separates the error of initial data from the rounding operations inherent in classical methods. It is shown that the constructed parallel form of the algorithm is maximum, and, therefore, has the minimum possible implementation time when using parallel computing systems.

**15. Akhyar, P. T. Iswanto, R. Syaputra, A. Farhan**

**Experimental investigation on hardness, tensile strength, and microstructure of Al-3,1Cu cast-alloy after T6-tempered.** This research aims to investigate Brinell hardness and tensile strength properties of Al-3,1Cu cast-alloy after T6-tempered treatment and evaluate its microstructural changes. This experiment was first performed by using an electric furnace to melt the metal alloy. The liquid metal was then poured into a rectangular metal mold, and the properties of the cast sample material were improved by using T6 heat treatment. Furthermore, the cast product was processed following acceptable tensile and impact tests standards. The results showed an increase in Brinell hardness and tensile strength after T6-Tempered treatment on the cast product. The observation of the microstructure also showed that the precipitate that grows evenly in  $\alpha$  was finely dotted.

**16. Akhyar, A. Farhan, Azwinur, Syukran, T. A. Fadhilah**

**Impact toughness of ASTM A36 low carbon steel by metal active gas (MAG) welding process using different cooling media.** This study was conducted to examine the immersion effect of cooling media used after the MAG welding process on impact toughness behavior of A36 steel plate. The media used in the experiment include air, water, and ice while CO<sub>2</sub> shielding gas and ER70S-6 filler metal were used in the MAG process. It is also important to note that the speed of the weld material cooling process has the ability to affect the hardness and toughness of the post-welding product. The experimental results showed that the use of cooling media affected the impact properties of the welding joint. The highest toughness value was recorded in the ice cooling media with 4,38 J/mm<sup>2</sup>.

**17. W. C. Pei, W. Q. Wu, Y. Hu, H. C. Ji**

**High temperature constitutive model of Q345B steel.** In order to accurately predict the flow stress of Q345B steel at high temperature, the Q345B steel was subjected to a hot compression test on the Gleeble-1500D thermal simulation test machine at a deformation temperature of 1 173,15~1 373,15 K and a strain rate of 0,01~10 s<sup>-1</sup>. Through the obtained true stress-strain curve, strain factors are introduced into the Arrhenius equation to establish a more accurate strain-coupled constitutive model. The results show that the correlation coefficient of the Arrhenius model considering strain compensation is 0,993, and the average absolute error is 4,59 %, which can accurately predict the flow stress. The experimental data and the calculated prediction curve fit well, which verifies the feasibility of the model.

**18. Y. P. Li, J. M. Zhao, H. C. Ji, J. T. Wu, W. C. Pei**

**Constitutive model of low carbon alloy steel (LCAS) expandable tubular.** The downhole expansion process of the expansion tube is the dynamic deformation process of the expansion tube metal material at different temperatures. In this paper, the dynamic tensile test is used to measure the dynamic tensile stress-strain curve of low-carbon alloy steel in the temperature range of 25 – 300 °C. upon analyzed the dynamic tensile test results, with the strain rate factor Z and McCormick physical model, the paper set up low carbon alloy steel constitutive equation of underground temperature field. The calculation results of the Sellars creep equation are compared with the residual stress value after expansion in the finite element analysis of the solid steel pipe expansion to verify the actual application reliability of the steel for the expansion pipe with high expansion rate.

**19. T. V. Kimstach, S. I. Repiakh, I. Mamuzić, K. I. Uzlov**

**Cu-Al-Sn system low-alloyed alloys properties investigation.** The best of investigated alloys within Sn and Al variation indicated ranges has ultimate tensile strength  $R_m = 220 \dots 300$  MPa, tensile yield strength  $Re_{0,2} = 115 \dots 130$  MPa, specific elongation  $A_5 = 20 \dots 30$  %, impact toughness KCU = 50... 120 J/cm<sup>2</sup> and hardness BH = 770 ... 830 MPa. Cast alloy free linear shrinkage value is 1,31 ... 1,49 %, absolutely difficult linear shrinkage is 0,39 ... 0,43 %. Alloy transition temperature from ductile to elastic state during cooling in casting mold is 255 ... 305 °C. It has been found that for developed alloy with aluminum and tin content increasing,  $A_5$ , KCU and  $R_m$  values decrease.  $Re_{0,2}$  value increases with content of both Al and Sn in bronze increasing.

**20. M. Abishkenov, Z. Ashkeyev, A. Naizabekov, K. Nogaev, L. Uktayeva, S. Kydyrbayeva, G. Issabekova**

**Micromechanical properties of cryo-rolled (CR) aluminum alloy Al0,6Mg0,35Si.** The present study is devoted to the effect of cryorolling (– 150 °C) in mill rolls implementing shear alternating severe plastic deformation (SPD) on the microstructure and mechanical properties of the alloy. Comparison of the processes of cryorolling (CR) and rolling at room temperature (RTR) is given. The study of the microstructure of the samples and the mechanical properties showed that CR ensures the production of ultra-fine grained (UFG) material with an average grain size of 350 ± 500 nm, as well as an increase in hardness by 162,2 % (118 ± 2 HV) and  $R_m$  by 106,34 % (293 ± 5 MPa).

**21. Ye. Makhambetov, A. Abdirashit, Yekuathbaya. Yerzhanov, G. Issengaliyeva, A. Angsapov**

**Research of microstructure and phase composition of a new complex alloy – aluminosilicomanganese (Al-Si-Mn).** The paper presents the results of a physicochemical study of a new complex alloy of aluminosilicomanganese. The phase composition of the alloy was studied by X-ray diffraction (XRD) phase analysis on an Empyrean Malvern Analytical X-ray diffractometer. Radiographs were processed and decoded using the Match! 3 software and the FullProf-2021 database. The HighScorePlus, Match! 3 and FullProf-2021 programs are based on the Rietveld method. The study of the microstructure of the alloy was carried out on a scanning electron microscope (SEM) of the JEOL - JSM7001F type. The chemical composition of the phases was determined using an Oxford INCA X-max 80 energy dispersive spectrometer (EDS) installed on a JEOL JSM-7001F scanning electron microscope.

**22. K. O. Chornoivanenko, I. Mamuzić**

**Spheroidization of eutectic carbides in the high-speed steels under annealing. The two phases will be in equilibrium in high speed steels by heating under isothermal holding conditions.** These are solid solution (austenite) and carbides. This difference in the curvature of the interfacial surface leads to the chemical inhomogeneity of the solid solution. The concentration of carbon and alloying elements at the tip of the plate is greater than at the flat interface. A concentration difference is created. Sufficiently long isothermal holding at high temperatures leads to diffusion transfer of carbon atoms and alloying elements from the tip to the flat boundary. Spheroidization leads to fragmentation of the network of eutectic carbides into separate plates and to their termination into equiaxed rounded crystals, which significantly improves the properties of steel.

- 23. Ye. Makhambetov, A. Abdirashit, Ye. Kuatbay, A. Yerzhanov, A. Mukhambetkaliyev, M. Abishkenov**  
**Thermodynamic diagrammatic analysis (TDA) of the system Al-Si-Mn-Fe.** The article presents the results of thermodynamic diagrammatic analysis of the Al-Si-Mn-Fe metal system as characterizing the final composition of the manganese-containing complex ferroalloy. By the method of thermodynamic diagrammatic analysis, the phase equilibrium of the Al-Si-Mn-Fe metal system was constructed, and the coexisting phases in the alloy were determined. Experimental samples of the aluminosilicomanganese alloy were studied on an Empyrean Malvern Panalytical X-ray diffractometer (XRD), where the presence of phases in the form of an intermetallic compound was determined -  $\text{MnSi}$ ,  $\text{Mn}_{15}\text{Si}_{26}$ ,  $\text{Al}_2\text{Fe}_3\text{Si}_4$ ,  $\text{Al}_3\text{Fe}_2$ , FeSi and structurally free silicon.
- 24. K. I. Uzlov, S. I. Repiakh, A. V. Dziubina, I. Mamuzić**  
**Aluminum bronze BrA9Zn3L per GOST 493 solid state transformations and properties processing.** According to aluminum-ferrous bronze BrA9Zn3L microstructure and reticular characteristics studies results, it has been found that under significant undercooling (cooling rate  $> 1^\circ\text{C}/\text{min}$ ) below eutectoid temperature (at  $\sim 500^\circ\text{C}$ ), martensitic transformation occurs with high-temperature  $\beta$ -phase stabilization and/or its martensitic derivatives:  $\beta_1$ ,  $\beta_1'$ ,  $\beta'$ , etc. formation. Technological or natural impurity  $\text{Zn} > 0,2 \dots 0,3\%$  content leads to impact properties catastrophic decreasing. This is due to in alloy, as eutectoid structure  $\alpha + \gamma_2$  component, rhombohedral chemical compound  $\gamma_2\text{-Cu}_9\text{Al}_4$  of trigonal system formation. That is, such Zn content stimulates in low-temperature region ( $< 565^\circ$ ) diffusion eutectoid transformation with  $\gamma_2$ -phase with its reticular characteristics negative for material of product formation.
- 25. D. Yessengaliyev, N. Ubaidulayeva, R. Orynassar, Zh. Yussupova, M. Abishkenov, S. Kydyrbaeva**  
**Analytical expressions of the Fe-Zr-Si-Al system and phase composition of the complex alloy of ferrum-silicon-zirconium.** The goal there was constructed a diagram of the state of the system Fe-Zr-Al-Si by method of thermodynamic diagram. With the help of modeling, it is possible to track the phase structure a complex alloy of ferrum-silicon-zirconium. As a result of the calculations, it was found that the Fe-Zr-Al-Si metal system consists of 12 elementary tetrahedron. The sum of the relative volumes of elementary tetrahedron of the Fe-Zr-Si-Al, system equals one (1,00000), which confirms the correctness of the tetrahedron. The analytical equation of each tetrahedron is obtained. As a result, the alloy with a content of 25 % Zr is modeled by the  $\text{Si-Fe}_2\text{Al}_5\text{-FeSi}_2\text{-Zr}_6\text{Si}_5$  tetrahedron. The compositions of the alloy with 35 and 50 % Zr are decomposed in the  $\text{Si-Fe}_2\text{Al}_5\text{-FeSi}_2\text{-Zr}_6\text{Si}_5$  and  $\text{Zr}_3\text{Si}_3\text{-Fe-Fe}_2\text{Al}_5\text{-FeSi}$  tetrahedra.
- 26. Y. Proydak, I. Mamuzić, G. Shvachych, I. Hulina**  
**Temperature and gradient mathematical simulations in problems of determining thermal physical characteristics of metals.** The problem is considered to research the materials' thermal and physical properties by inverse methods. The corresponding class of mathematical simulations is derived. The main research purpose is that the simulations processing procedure as those that are controlled by input parameters reduce, on residual principle basis, to an extreme formulation. This approach allows developing effective algorithms for solving quotient problems on simulations of arbitrary accuracy order with adaptation of time modes of a thermal and physical experiment. A package of applied problems had been developed for solving coefficient problems of heat-conductivity by mathematical simulation methods. The package creation had been carried out considering the requirements of object-oriented programming.
- 27. B. Oleksiak**  
**Determination of optimal parameters for the cementation process of cadmium and copper from zinc sulphate solution.** In the presented work, research was carried out to select the optimal parameters for the cementation process of zinc sulphate solution, from impurities in the form of copper and cadmium. This process is one of the stages of the hydrometallurgical method of zinc production, which largely determines the purity of the produced zinc. The tests were carried out in the temperature range of  $20\text{-}60^\circ\text{C}$  and for the pH of the solution in the range of 3,5 - 5,0.
- 28. Ye. Zhumagaliev, G. Yerekeyeva, A. Nurumgaliev, O. Mongolkhan, A. Davletova, G. Sagynbekova**  
**Thermodynamic-diagram analysis of the Fe-Si-Al-Cr system with the construction of phase relations.** The Fe-Cr-Si and Fe-Cr-Al systems are the basic ones in the development of the technology for smelting a new complex alloy - aluminosilicochrome. Aluminosilicochromium can be used as a reducing agent for metallothermic production of low- and medium-carbon ferrochromium grades with subsequent use in the smelting of stainless steel grades. Construction of a diagram of the phase composition of a four-component system Fe-Si-Al-Cr, consisting of 4 three-component systems Fe-Si-Al, Fe-Cr-Si, Fe-Cr-Al, Si-Cr-Al. Three-component Fe-Si-Al system, which will be the base of the Fe-Si-Al-Cr tetrahedron. It is necessary to analyze the thermodynamic properties of compounds for binary and ternary systems.
- 29. S. Baisanov, V. Tolokonnikova, G. Yerekeyeva, G. Narikbayeva, I. Korsukova**  
**Thermodynamic-diagram analysis of the Fe-Si-Al-Mn system with the construction of diagrams of phase relations.** In the practice of complex theoretical studies of multicomponent systems, the so-called thermodynamic-diagram analysis method is known, which greatly simplifies the study of the features of phase transformations in multicomponent systems by dividing them into thermodynamically stable elementary partial subsystems of the same dimension as the main one. Thermodynamic-diagram analysis combines a thermodynamic assessment of the chemical interaction of components in the system under study with a geometric diagram. Such a combination, as studies of the physico-chemical bases of the production of refractories and ferroalloys have shown, turns out to be productive when interpreting chemical interactions in complex systems.
- 30. I. Mamuzić, G. G. Shvachych, P. O. Shcherbyna**  
**Intensification of the regime of spheroidizing annealing of a metal on the basis of the application of a multipurpose computing system.** Research is aimed at the use of a multiprocessor computer system for spheroidizing metal annealing. On the basis of a mathematical model, it becomes possible to control the heating of the metal to its transition to the austenite region and the temperature of phase recrystallization on the entire plane of its section. After solving the inverse problem of thermal conductivity, the mode of non-isothermal holding of the metal is controlled in the annealing temperature range. The use of an installation for an intensive mode of spheroidizing annealing predetermines the uniform distribution of cementite globules in a ferrite matrix, which provides the necessary mechanical properties of the metal, for further cold deformation.
- 31. A. A. Alina, V. Yu. Kulikov, A. E. Omarova, P. V. Kovalev**  
**X-ray phase analysis XPA of a cold-hardening mixture (CHM) and the effect of the mixture properties on the casting.** The objectives of this type of research are as follows: identifying the phase composition of the samples under study; assessing the effect of the composition on the mechanical properties of the samples. Prior to the study by the XPA, the authors obtained 9 samples of different compositions to select the optimal composition of cold-hardening mixture (CHM). The method of X-ray phase analysis was selected for the phase composition of the CHM samples. After examining the samples using XPA analysis, molds were made from CHM (resin+clay) according to the composition of sample No. 3. To evaluate the quality of the castings, there was measured roughness.
- 32. W. P. Zhao, X. P. Guo, L. Sun, J. Y. Li, H. C. Ji, T. Li Issn**  
**Analysis of corrosion behavior of low carbon alloy steel.** In this study, a 72-h neutral salt spray test was conducted on two low-carbon alloy steels and their corrosion kinetic equations were constructed, and tensile tests were conducted on specimens with different corrosion cycles to evaluate the mechanical properties of the two experimental steels. The test results showed that the corrosion resistance of TZ750MS was better than that of H750MS during the whole test cycle; however, the predicted results of the corrosion kinetic equation showed that the corrosion resistance of TZ750MS was lower than that of H750MS after 144 h. The tensile test results showed that the strength of both steels did not change substantially after corrosion, and the tensile stress-strain diagram showed that the specimens would fracture earlier after passing through the plastic deformation zone
- 33. W. Deng, Z. Tian, D. Cang**  
**Experimental study on solidification/stabilization of Cr in stainless steel pickling sludge by high temperature roasting process.** For stainless steel pickling sludge (SSPS) produced in a stainless steel factory in southeast China, Fly ash (FA) and waste glass (WG) were used as solidification/stabilization (S/S) agents to conduct high-temperature roasting experiments on S/S of Cr in SSPS, respectively. The effects of roasting temperature and S/S agent dosage on the S/S of Cr were studied. The results show that both FA and WG can take positive way to S/S. By adding 25 % of FA to SSPS at roasting

temperature of 1 500 °C, the Cr leaching concentration of S/S products can decrease to 0,63 ppm. As for WG as S/S agent, the Cr leaching concentration of the product can be reduced to 0,45ppm when the dosage is 20 % and the roasting temperature is 1 400 °C,. Considering the dosage and roasting temperature, WG is suggested as a better S/S agent.

**34. T. Šolić, D. Marić, Iva Samardžić, T. Vukušić, I. Samardžić**

**Comparison of adhesion properties of the primers for wide consumption.** This research focused on comparison of adhesion properties of three different primers for wide consumption. Tested primers differed in their price range, and the conducted experiment aimed to determine whether more expensive primers were providing better adhesion between the substrate material and the coating. The primers were applied on specimens in two layers, each being 30 μm thick (total dry film thickness was 60 μm), as well as in one layer being 45 μm thick. After drying, specimens were exposed to indoor and outdoor atmospheric conditions. Adhesion properties were tested by the cross-cut test, and analysis of obtained results proved that the primers' price range cannot be considered as an indicator of the primers' quality with respect to their adhesion properties.

**35. A. Marek**

**The impact of galvanizing on the mechanical properties of rebars.** This article reports on the results of tests on the impact of hot dip galvanizing on the strength of B500SP reinforcing bars. The bars were hot-dip galvanized in baths with different process parameters. Following each hot dip galvanizing, the structure of the coatings obtained was inspected and tensile tests were conducted. Tensile testing results were compared with the properties of non-galvanized reinforcing bars. It was established that, regardless of the parameters set for the hot dip galvanizing process, zinc coatings slightly increase the mechanical properties of B500SP reinforcing bars.

**36. I. Vidaković, G. Heffer, V. Špada, I. Samardžić**

**Comparison of wear resistance of induction-hardened and gas-nitrided samples in the abrasive mass motion.** The experiment was focused on comparison of mass loss exhibited by induction-hardened and gas-nitrided samples made of 42CrMo4 steel. The mass loss was caused by abrasive wear, i.e. by motion of the abrasive particles. Wear testing was performed with different input parameters (sample velocity and impact angle of abrasive particles and the tested surface). This experiment proceeded with metallographic analysis performed by an optical microscope and by imaging of wear path done by SEM microscope, to conclude with the statistical analysis of obtained data. The conducted experiment determined that the gas-nitrided samples lost less mass at all levels of input parameters than the induction-hardened samples.

**37. J.W. Liu, C.Y. Song, Y.L. Gui, S. Wang**

**Cooling rate calculation and microstructure evolution of Sm-Fe alloy powder prepared by high pressure gas atomization.** The Sm<sub>2</sub>Fe<sub>17</sub> alloy powder was prepared by high-pressure gas atomization technology, and its morphology and size distribution were analyzed. The relationship between the micro-structure evolution of the Sm-Fe alloy powder and the cooling rate was calculated. Besides, the relationship between the cooling rate of the high-pressure aerosolized alloy powder and the change of secondary dendrite arm spacing (SDAS) was verified. The cooling rate of the powder was indirectly determined according to the empirical relationship between the dendritic spacing of the rapidly solidified alloy and the cooling rate. After comparison, the results are consistent with the theoretical calculation.

**38. Z. J. Xue, M. B. Han**

**Crack analysis of crankshaft for diesel engine.** The cause of crankshaft fracture crack of a certain vehicle has been analyzed through macroscopic analysis, microstructure analysis, mechanical properties test and dimension inspection. The analysis results show that: the fatigue strength of the crankshaft is reduced due to spheroidization recession, low strength and shallow nitriding layer of the fillets.

**39. Z. Zhang, L. Miao, S. Y. Cui, N. Jiang, H. Xu**

**Effect of CeO<sub>2</sub> addition on hardness of induction heated Ni-WC composite coatings.** Getting Ni-WC composite coatings with different rare earth CeO<sub>2</sub> additions on the substrate of 45 steel by induction heating; testing the surface hardness and cross-section microhardness of the coatings with Rockwell hardness tester and microhardness tester; meanwhile analyzing the microstructure and WC morphology of the coatings by scanning electron microscopy, in order to find the best amount of CeO<sub>2</sub> in the coatings. The results show that the 0,5 / % content of CeO<sub>2</sub> helps to improve the interdiffusion bonding between the coating and the substrate, and to refine the grain size, homogenize the composition and increase the hardness of the coating.

**40. D. Tang, Q. Q. Zhang, F. D. Wang, G. L. Tan, C. J. Xu**

**Analysis of transformation kinetics of 1035 steel at different cooling rates.** In this paper, the enthalpy change of 1035 steel during phase transformation at different cooling rates was measured by differential scanning calorimetry (DSC). The activation energy of the phase transformation process was calculated by the equal conversion method, and the mechanism function of the process was also determined. The results shown that the value of the activation energy of phase transformation process varied with the transformation fraction, and the mechanism functions of transformation process are different in different temperature ranges, which are  $-\ln(1-\alpha)^{1/3}$  for  $\geq 645^\circ\text{C}$   $-\ln(1-\alpha)^{1/2}$  for 660-655°C and  $-\ln(1-\alpha)$  for 650-645°C respectively.

**41. S. Y. Cui, L. Miao, Z. Zhang, N. Jiang, H. Xu, Y. H. Li**

**Effect of CeO<sub>2</sub> addition on wear, corrosion and resistance to thermal fatigue of induction heating Ni-WC coatings.** Ni-WC composite coatings with different rare earth CeO<sub>2</sub> additions were prepared on the substrate of 45 steel by induction heating. The wear resistance, corrosion resistance and resistance to thermal fatigue of the coating were checked with a self-made friction and wear tester, a medium-sized salt spray corrosion tank and a box-type resistance furnace. Meanwhile, the microstructure and WC morphology of each coating were analyzed by scanning electron microscopy to assist in the analysis of performance changes. The results show that the 0,5 / % CeO<sub>2</sub> content helps to refine the grain size and the WC morphology, and that the 0,5 / % CeO<sub>2</sub> content coating has the highest wear resistance, corrosion resistance and resistance to thermal fatigue.

**42. A.B. Zhantlessova, S.K. Zhumazhanov, T.B. Akimzhanov, Y.Zh. Sarsikeyev, B.B. Issabekova, Zh.B. Issabekov, A.D. Mekhtiyev, A.D. Alkina**

**Improving the method of controlling the stress-strain state of steel structures of electromechanical systems.** The article presents the results of improving the method of controlling the stress-strain state of steel structures of mine hoisting machines, which can be attributed to electromechanical systems. The method of controlling the stress-strain state of steel structures of electromechanical systems subjected to fatigue failure is based on the use of mechanical properties of an optical fiber (OF) and the effect of photoelasticity arising from its deformation. The optical fiber is used as a sensor and allows to control the stress-strain state of metal structures in real time.

**43. H.A. Fadly, E. Surojo, N. Muhayat, Triyono**

**Effect of flame straightening treatment on the microstructure of fillet weld S355J2+N steel.** Flame straightening is the most common method applied in welded steel to mitigate distortion. This research showed that flame straightening can be safely applied on fillet T-joint S355J2+N steel. The microstructure and hardness on the back surface of the fillet T-joint were affected by the flame straightening process. The surface experienced a decrease in hardness and changes in the shape and size of the microstructure. In this research, the welding procedure standard (WPS) was applied to the welding test coupon. The straightening process was then applied on the back surface of the fillet T-joint by heating and then cooling rapidly with an air jet. Lastly, microstructure investigation and hardness test were performed on the flame-straightened area.

**44. M. M. Li, H. C. Ji, Q. S. Lin, C. D. Wu, S. Cai**

**Simulation analysis of X80 pipeline steel welding.** In order to improve the quality of welded joints and increase the service life of pipelines, ABAQUS finite element software was used to simulate the temperature field of 18.4 mm thick X80 pipeline steel in multi-layer and multi pass welding. The peak temperature of different passes was compared, and the change trend of temperature field in the welding process was obtained. The results show that the peak temperature of the weld and its adjacent areas is higher, and the peak temperature of the weld center is the highest. Due to the fast welding speed, the heat cannot be transferred to other areas in time, resulting in uneven heating of the entire test panel.

# Process Metallurgy – Section „B“

## 1. B. Dai, M. Yuan, N. Zhang, Y. Ma

**Research on relationship between charging principle and hearth activity of blast furnace (BF).** The relationship between charging principle and hearth activity of blast furnace has been clarified in this research. Discrete element method (DEM) analog simulation illustrates that both central and non-central coke charging result in the stratified structure of coke and ore in BF center. It is suggested to take non-central coke charging to promote central gas flow if the quality of raw materials meets the corresponding requirements. For the BF with poor raw materials, it is reasonable to employ central coke charging to keep the long-term stability of the production.

## 2. D. Grigorova

**Ferrosilicon production method using sintered iron silicate - fayalite.** The study aims experimentally investigate how to obtain a ferrosilicon alloy using iron silicate - fayalite generated after flotation enrichment of slag in pyrometallurgical production of copper. This material contains about 46 % iron and about 27 % silicon dioxide. Due to its dispersed structure, fayalite is first sintered. The article describes mathematical and physical modeling of the agglomeration and ore thermal process for the production of ferrosilicon. The main fraction of the obtained agglomerate (57,60 %) is over 15 mm. In the electric arc furnace, the time for refining the agglomerate tap to tap is 40 - 60 minutes. The obtained alloy yield is 46 %. In the three melts, the silicon content in the alloy averaged 44 %, meeting the ferrosilicon standard.

## 3. S. P. Wang, L. Cao, J. Li

**Experimental study on influencing factors of NO<sub>x</sub> emission in iron ore sintering process.** Through the sintering pot test, the effects of coke breeze ratio, sinter mixture moisture, sinter mixture basicity and material bed depth on NO<sub>x</sub> emission were studied. The results show that reducing the ratio of coke breeze is beneficial to reducing NO<sub>x</sub> emission under the condition of certain sintering time and not affecting the quality of sinter. At the same time, adopting low moisture and deep bed sintering can also achieve the purpose of reducing NO<sub>x</sub> emission. The basicity of sinter mixture has little effect on NO<sub>x</sub> emission.

## 4. C. Z. Zhao, Z. H. Yan

**Study on sintering flue gas desulfurization process selection.** The new flue gas desulfurization system of 108m<sup>2</sup> sintering machine is reformed, combined with the applicable scope of common desulfurization and dust removal process and the basic principles of desulfurization and dust removal process selection, the advanced and reliable rotary spray dryer absorber (SDA) technology is selected for flue gas desulfurization. Taking the process equipment of desulfurization system as the carrier, the process flow of desulfurization and dust removal system is designed.

## 5. J. N. Zhang, Y. H. Yang

**Viscosity and phase translated analysis of converter molten slag.** Slag viscosity effect the physical and chemical process of the converter. In the paper, thermodynamic calculations and interruption experiments are carried out to explore the slag viscosity and phase translated. With the increase of new components Al<sub>2</sub>O<sub>3</sub> and TiO<sub>2</sub>, the viscosity is decreased. According to experiment result, the low-basicity slag is in molten state except for a small amount of SiO<sub>2</sub>, and the SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub> and Fe<sub>2</sub>O<sub>3</sub> are not melted in the high-basicity slag. Thus the reasonable basicity should be controlled at 2,4 ~ 3,2 at 1 500°C.

## 6. B. S. Saurbayeva, Y. N. Ivashchenko, R. A. Ramazanova, B. S. Tantybayeva, S. K. Kabdrakhmanova

**Research of component composition and catalytic reactivity of metallurgical industry slag.** The slags component composition was investigated by X-ray fluorescence analysis. The slag stuff has been modified with alkali (NaOH) and mineral acids (HNO<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub>, HCl and H<sub>3</sub>PO<sub>4</sub>), and their catalytic reactivity in the catalytic decomposition of ethyl alcohol and hydrogen peroxide has been determined for the first time. The revealed catalytic reactivity of the slag staff for the decomposition of ethyl alcohol and hydrogen peroxide indicates the need for a more detailed research and development of an industrial non-ferrous waste treatment technology.

## 7. Z. Y. Wang, H. Q. Xie, M. Zhou, R. Guo

**Thermodynamic analysis on the reduction of iron and chromium in vanadium-extracted waste slag by biomass.** In this paper, the feasibility of carbon thermal reduction of vanadium-extracted waste slag with biomass as reducing agent was studied via thermodynamic analysis. The effects of oxygen absorption ratio, temperature and basicity on the reduction results, especially on the recovery of valuable metals (iron and chromium) were discussed emphatically.

## 8. R. Guo, H. Q. Xie, M. Zhou, Z. Y. Wang

**Energy analysis on the reduction of iron from vanadium-extracted waste slag: comparison of biomass and different coals.** In this paper, lignite, bituminous coal, anthracite, and biomass were used as reducing agents for carbon thermal reduction of vanadium-extracted waste slag. The energy consumption analysis and environmental impact assessment were carried out on the vanadium-extracted waste slag by reducing with different reducing agents via thermodynamic analysis, providing a reference for energy saving and emission reduction work.

## 9. F. Yang, Zh. Tong, Sh. W. Zou, Zh. Y. Li, Z. J. Shen

**Pelletizing analysis of cylinder pelletizer on MgO-fluxed pellets by discrete element method (DEM).** Discrete Element Method (DEM) was used to analyze palletization process of MgO-fluxed pellets in cylinder pelletizer. The effects of the charge ratio and rotational speed of the cylinder pelletizer on the behavior of MgO-fluxed pellets were investigated by using the simulation. The simulation results show that under the condition of a certain gradient angle of the cylinder pelletizer (The gradient angle is 3°), the suitable parameters of the cylinder pelletizer are that the charge ratio is 3 % and the rotational speed  $N$ /critical rotational speed  $N_c$  is 0,3.

## 10. X. L. Zhang, Y. J. Zhang, L. B. Wu

**Adaptive fault estimation (FE) and fault-tolerant control (FTC) for the molten steel level in a strip casting process.** Firstly, an intermediate estimator and an adaptive state observer are designed to estimate actuator fault and unknown states respectively. Then, based on back-stepping method, a neural fault-tolerant controller and adaptive laws are constructed, which can ensure that the output signal of the systems can track the reference signal under inclined angle and actuator fault. Finally, the effectiveness of the studied control strategy is verified by semi-experimental systems dynamic model.

## 11. A. A. Akberdin, A. S. Kim, A. Sorlov, R. B. Sultangazyev, A. M. Makasheva

**Mathematical models of viscosity diagrams and crystallization temperatures of melts of the CaO – SiO<sub>2</sub> – Al<sub>2</sub>O<sub>3</sub> – B<sub>2</sub>O<sub>3</sub> system.** Mathematical diagrams of viscosity and crystallization temperatures of melts of the CaO – SiO<sub>2</sub> – Al<sub>2</sub>O<sub>3</sub> – B<sub>2</sub>O<sub>3</sub> system were created. To obtain them, experimental studies were carried out using the simplex-lattice method of experiment planning. It was used to study 35 slags containing (wt.%) 9.8-52 CaO, 33.6-70.4 SiO<sub>2</sub>, 16.0-51.52 Al<sub>2</sub>O<sub>3</sub>, 0-20 B<sub>2</sub>O<sub>3</sub>. The experiments were carried out on an electrovibrational viscometer in molybdenum equipment, in a stream of purified argon in the temperature range of 1 473–1 923 K.

## 12. B. Dai, Y. Ma, F. Yu, M. Yuan, J. Chu, Y. Xu

**Research on promoting the formation and clusters of TiN phase in high purity cast iron.** High purity cast iron produced by blast furnaces in China is always unable to meet national standard of high-end castings due to the exceeding of Ti. Based on the thermodynamic analysis, a detitanization method of increasing N in hot cast iron to promote the formation and clusters of TiN is proposed. High-temperature experiment has proved that N-addition can effectively promote the formation and clusters of TiN in hot cast iron, which provides the possibility for subsequent removal of Ti from high purity cast iron to meet the national standard.

## 13. Y. X. Chen, L. Gao

**Quality study on laser welding 304 stainless sheet.** High automation, high speed and high efficiency are the advantages of laser welding metallurgical products. It is a great significance to study the quality of laser welding. In the paper, the input current and pulse width of laser are used as variables to improve the tensile strength of welding samples. Firstly, the effect of current and pulse width on tensile strength is obtained through experiments. Then the fitting formula and curve of experimental data are obtained by orthogonal regression method. Finally, the prediction and optimization of tensile strength are carried out, and the error of the results is less than 12,5 %, indicating that they have a certain guiding role.

## 14. C. Han, J. Yuan, Y. Z. Zhong, X. M. Fang, G. C. Yu, H. C. Ji

**Q345C steel welding process simulation analysis.** In order to meet the requirements for the quality of steel structure welding projects in severe cold areas, reasonable and effective technical research and welding scheme improvement are carried out for welding in low temperature environments. Based on ABAQUS software to simulate different welding conditions, mainly for welding after traditional flame heating and ceramic sheet heating in low temperature environment, the corresponding temperature field is obtained. Compared with the actual welding results, it is concluded that the weldment welded after heating with ceramic sheet is of better quality, fully verify the accuracy of welding simulation, optimize process design, shorten the time required for practical inspection accumulation.

## 15. Y. Z. Zhong, J. Yuan, C. Han, X. M. Fang, G. C. Yu, H. C. Ji

**Q345C weld deformation analysis of butt joints.** Q345C steel is welded under two different pre-welding heating methods of traditional flame heating and ceramic sheet heating. The finite element analysis of the butt joint weldment by ABAQUS software is used to summarize the law of welding deformation and compare the welding quality under different pre-welding heating methods according to the residual stress and deformation trend of the welding joint weld. The results show that the main stress after welding is concentrated in the weld seam and the surrounding area. The residual stress after welding after the heating and welding of the ceramic sheet is significantly less than the residual stress after the traditional flame heating welding, and the welding after the heating of the ceramic sheet can obtain better welding quality.

## 16. Zh. Romazanov, O. Silayeva, M. Tatieva, M. Latypova, A. Petrovskaya

**The feasibility study for the creation of production based on technology of lost-foam casting.** The problems of establishing a new foundry in Kazakhstan utilizing Lost-foam casting technology are discussed in this article. The study's main objectives are to determine the technical and financial viability of arranging such production in the country. Calculations of the manufacturing program were carried out as part of the study, and a financial-economic model of the project was developed. The research shows that establishing such a foundry is feasible, and the project may be recommended for execution.

## 17. A. A. Kamenov, A. V. Bogomolov, P. O. Bykov, A. K. Zhunusov, M. M. Suyundikov

**Determination properties of cast iron used in the installation of anodes.** This paper presents the results of determining the cast iron's properties, which is used in the installation of anodes in the electrolytic production of aluminum. The research methods and applied instruments used for metallographic analysis and chemical composition analysis are described. The results of metallographic analysis of cast iron microstructure “before” and “after” electrolysis are presented. The cast iron's chemical composition was analyzed by using an X-ray fluorescence spectrometer. The results of experimental melting for testing the casting properties of cast iron for fluidity in a spiral sample are presented.

## 18. I. Mamuzić, G. G. Shvachych, P. O. Shcherbina

**Features of application of new computer technologies of metal processing.** Solving applied metallurgical problems using well-known standard approaches is a complex problem, which can be overcome only through the use of modern multiprocessor computer technologies. High performance computing allows you to solve multidimensional problems, as well as tasks that require a large amount of processor time. Speed makes it possible to effectively manage technological processes or even create prerequisites for the development of new promising technological processes. The multiprocessor computing system is connected via an information bidirectional communication interface to the process control unit. The technological process of metal processing acquires such advantages as high productivity, reduction of energy consumption and automated control of technological parameters of metal processing.

## 19. A. Nitsenko, V. Volodin, X. Linnik, N. Burabaeva, F. Tuleutay

**Behavior of copper chalcogenides during vacuum-thermal processing.** In this work, thermodynamic functions of evaporation of copper chalcogenides ( $\text{Cu}_2\text{S}$ ,  $\text{Cu}_2\text{Se}$ , and  $\text{Cu}_2\text{Te}$ ) are determined via previously published data and thermodynamic values obtained by the authors of the work. The obtained results indicate a very low probability of separation of compounds into copper and chalcogen by dissociation under vacuum-thermal processing conditions. Liquid-vapor phase transitions in binary systems  $\text{Cu}_2\text{S} - \text{Cu}_2\text{Se}$ ,  $\text{Cu}_2\text{S} - \text{Cu}_2\text{Te}$ , and  $\text{Cu}_2\text{Se} - \text{Cu}_2\text{Te}$  at low pressures of 15 and 0,7 kPa are constructed based on the vapor pressure of copper chalcogenides. It is shown that the pressure eases over the liquid bath impairs the separation of chalcogens, therefore separation in one stage by thermo-vacuum treatment at a pressure of 0,7 – 15 kPa is not possible.

## 20. M. Mukhametkhan, Ye. Mukhametkhan, G. Zhabalova, L. Kamkina

**Investigation of physico-chemical characteristics of iron-containing technogenic raw materials in the conditions of JSC “AMT”.** The results of experiments conducted to determine the efficiency of the use of man-made waste, including large-scale in volume among the waste of metallurgical production, melted films and sludge of the oxygen converter shop are presented. During the study of the sludge of the converter shop, the chemical, phase, granulometric composition and density of rolling scale and sludge of the oxygen converter shop were revealed.

## 21. A. Biryukova, E. Kuldeyev, T. Dzhienaliyev, G. Abdykirova, S. Temirova

**Preparation of pellets from manganese concentrate for the production of ferromanganese.** The results of studies on the production of pellets for the metallurgical stage based on manganese concentrate with a manganese content of 34 %, obtained from waste manganese-containing sludge, are presented. Kaolin and high-iron diatomite in combination with calcium oxide and coke were tested as binder components of charges. Manganese-containing pellets were produced by composition pelletizing in a Eirich high-speed mixer-granulator. The size of pellets in the form of rounded granules was in the range of 5 - 10 mm. Sintering roasting temperature of pellets was 1 150 - 1 200 °C. Strength of roasted pellets was 1 313 with kaolin as binder, 1 940 with diatomite, and diatomite with lime addition – 2058 N/pellet respectively.

## 22. A. Abdirashit, Ye. Makhambetov, A. Yerzhanov, Zh. Sarkulova, N. Aitkenov, N. Aitbayev

**Large-scale laboratory tests for smelting medium-carbon ferromanganese using jezda manganese ore and SiMn17 silicomanganese fines.** At present, Kazakhstan has established production of ferrosilicomanganese, while refined ferromanganese is not produced. This is primarily due to a lack of high quality feedstock, as well as a lack of theoretical and applied research into new production conditions. To address these issues we conducted large-scale laboratory tests on smelting medium-carbon ferromanganese by one-stage silicothermic method. As a result of these tests, medium-carbon ferromanganese meeting the standard grade with more than 80 % manganese content was produced.

## 23. Zh. D. Zholdubayeva, L. A. Mazhitova, D. K. Issin, G. E. Sirgetaeva, Zh. B. Smagulova

**Studies of changes in the activity of dissolved oxygen in the simulation of ferromanganese filtration.** The article deals with the solution of an urgent problem related to the process of filtration refining of ferroalloys. Based on the data obtained, it was found that combining the filtration process with casting ensures the flow of refined melt directly into the mold cavity and partial or complete elimination of secondary oxidation. To identify the underlying mechanism of filtration refining, the interaction of liquid metal with the filter in its separate pore channel was simulated. The main technological parameters of the process under consideration are calculated and practically confirmed.

- 24. Z. B. Karshyga, A. A. Ultarakova, N. G. Lokhova, A. M. Yessengazyev, E. I. Kuldeyev, K. K. Kassymzhanov**  
**Study of fluoroammonium processing of reduction smelting dusts from ilmenite concentrate.** The article presents the results of studies on the processing of fine waste dusts of electric smelting of ilmenite concentrates. The main silicon impurity was preliminarily removed from the dusts. The process of dust fluorination with titanium fluorides extraction is studied. The influence of temperature and time on sublimation degree of titanium fluorides was studied. The optimum conditions for sublimation of titanium fluorides were determined:  $T = 600 \pm 10$  °C, time - 2 hours. The extraction of titanium in sublimations was up to 99 %. The XRD method showed that phases of heptofluorotitanate, hexafluorosilicate and ammonium hexofluoroferrate are present in the sublimations. The impurity components of iron, manganese, chromium are sublimated at a sufficiently low degree during titanium fluorination.
- 25. N. Akhmadiyeva, S. Gladyshev, L. Imangaliyeva, A. Kassymzhanova**  
**Development of a method of electrodeposition of non-ferrous metals on a rotating cathode covered with gallium.** Electrodeposition of copper and nickel from acidic solutions using a rotating cathode coated with liquid and solid gallium has been studied. Methods of nonferrous metals separation from the gallium coating of the cathode were determined. Electrodeposition on the liquid gallium coating was carried out at a temperature of 50 °C. Separation of metals from gallium was performed by alkaline treatment. On the solid gallium cathode coating, electrodeposition was performed at 25 °C. The metal precipitates were separated from the cathode after it was heated. When using cathode with hard gallium coating the reduction of electric power consumption for copper by 85 % and for nickel by 15 % was obtained.
- 26. A. M. Dolzhanskiy, I. Mamuzić, N. F. Kurbatova**  
**Improvement of quality control in the refrigeration plates manufacture for blast furnace.** Refrigerating plates for external thermal insulation of the blast furnace furnaces are made in the sizes (140...180) x (1 000...2 500) x (500... 1 500) mm by filling with cast iron a coil of steel pipes. This can cause shrinkage shells and indigestion, which worsen or even damage the entire product. In practice, quality control of refrigeration plates was carried out, mostly by tapping (to detect internal voids), visually (to assess the appearance) and so on. In this regard, the analysis of the manufacturing technology with the definition of the process critical control points and the available means of the product quality identifying at these points and their effectiveness was realized. As a result, it is proposed to use certain objective means of control at critical control points, based, in particular, on penetrating radiation.
- 27. Zh. Romazanov, O. Silayeva, M. Tatieva, M. Latypova, A. Petrovskaya**  
**Feasibility study of the creation of a special coke production in Kazakhstan.** The article examines the issues of creating a special coke production in the country. The objectives of the study were to assess the technical and economic feasibility of organizing such production. In the course of the study, the production program, investment estimates and a model of financial and economic payback of the project were calculated. The study confirms the effectiveness of creating a special coke production in Kazakhstan, and the project itself can be recommended for implementation.
- 28. I. Mamuzić, H. Brui, O. Kuchin**  
**Observations of the stability of the boards of pit and deposit under the conditions of the open development of iron ore deposits.** One of the main tasks of mining enterprises is the forecasting and timely prevention of these processes. To accomplish the task, it is necessary to carry out geodetic (mine surveying) observations of the stability of the sides. At the same time, the presence of measurers in the landslide zone should be minimized. The solution of this problem can be solved using conditionally remote survey methods: GNSS, photogrammetric methods using aircraft, reflectorless survey methods with robotic electronic total stations. However, the most important criterion in choosing the method of performing observations is the accuracy of the measurements. The purpose of the presented studies is to analyze the accuracy of the observational technique in accordance with the requirements.
- 29. B. Bul'ko, L. Fogaraš, S. Hubatka, P. Demeter, K. Ondrejko, P. Buček**  
**Verification of non-standard F-curves during steel intermixing in a tundish.** Minimization of intermixing length during continuous casting of steel is a crucial step towards higher productivity and yield of a continuous casting technology. For such a complex mass transfer problem, physical simulation using scaled-down water models might become indispensable tool to quantify the liquid steel parameters in the tundish. In this paper, such an advanced, water-based model of tundish from Železiarne Podbrezová, a. s. is used to model the intermixing process of two consecutive heats with different chemical composition. Obtaining the non-standard F-curves while manipulating the liquid level and the casting speed simultaneously gave us a valuable insight into the process of intermixing and allowed us to make preliminary conclusions on the intermixing optimization problem.
- 30. P. O. Bykov, A. B. Kuandykov, A. K. Zhunusov, L. B. Tolymbekova, M. M. Suyundikov**  
**Complex processing of primary aluminum to remove impurities of non-ferrous metals.** The paper presents researches on the complex processing of primary aluminum produced by electrolysis with flux treatment with boron-containing materials and further filtration refining through granular filters. The research methods and applied instruments used for the analysis of the chemical composition and electron microscopy are described. The results are presented before and after the complex treatment of primary aluminum, showing a significant reduction in non-ferrous metal impurities (vanadium, titanium, etc.) and other undesirable impurities.
- 31. J. Cupek, J. Pieprzyca, J. Walek, M. Saternus, M. Tkadlečková, T. Merder**  
**Optimization of the steel flow in the two-strand tundish using different geometry of impact pad.** One of the primary factors affecting the quality of continuously cast billets is the way the steel flows and mixes in the tundish of Continuous Steel Casting (CSC) machine. This is of particular importance in the case of continuous billets. The article presents the results of model tests of identifying the mechanism of liquid steel flow through a tundish under the influence of the applied arrangement of the working space. Two models of turbulence inhibitors and an impact pad with the surface of a sphere segment were used for the research. The tests were carried out with the use of the physical water model of the CSC device, and the obtained results were verified by numerical methods.
- 32. A. Yu. Proydak, I. Mamuzić**  
**Prospects for the use of Ukrainian phosphorites for ferrophosphorus production.** For the first time, microstructure of representative samples of phosphorite ore was studied using electron microscopic investigation as well as scanning electron microscopy for quantitative measurements. Chemical composition of the phosphate substance that cements minerals of waste ores was defined. It was determined, that ore mineral is a phosphorus-containing mineral that by its element chemical composition corresponds to fluorocarbon-hydroxyl-apatite with the following content (% wt): 45,23 % Ca; 15,67 % P; 27,87 % O; 3,77 % F and 4,05 % Si. On the basis of the results of complex studies of phosphorite ore, and complex studies of minerals with different properties subjected to magnetic separation and flotation, there was developed a scientifically substantiated and experimentally confirmed basic technological scheme for beneficiation of phosphorite ores extracted from Malokamyshvatsk deposit, Kharkiv oblast (Izium district).
- 33. E. Kardas, R. Prusak**  
**The assessment of quality of sinter and its effect on the efficiency of blast furnace process.** The assessment of selected quality parameters of sinter and the effect of the its quality on the efficiency of blast furnace process is presented. The analysis of chemical composition of sinter was conducted. As a main quality parameter sinter richness (Fe content) was selected. Then influence of sinter richness on two parameters of efficiency was calculated. The study was carried out in cooperation with a Blast-Furnace Department of a Polish steelworks and was based on the results coming from this Department. The analysis covers the period of one calendar year.
- 34. T. Matuła, G. Siwiec**  
**Thermogravimetric (TG) studies of the reaction of lead oxide with lead sulphide.** In the paper, results of thermogravimetric study on reaction between lead oxide and lead sulphide, both loose and agglomerated samples. The research results showed that the reaction of lead sulphide with lead oxide is possible at temperatures exceeding 850 °C. Comparing the influence of the reaction temperature on the course of the TG curve and the percentage

weight loss of the samples, it was found that the percentage weight loss of the samples increased with the increase of the temperature. This effect was observed both for samples introduced in loose form, as well as for the agglomerated one.

**35. T. Selivorstova, V. Selivorstov, I. Mamuzić**

**Analysis of the possibilities of using complex technologies of gas dynamic influence on the melt in the foundry mold.** The analysis of the results of theoretical and experimental works, existing technological developments on the use of blowing processes, vacuuming and the use of gas pressure to improve the quality of cast metal of large castings or ingots, showed the prospects of using the specified effects for processing the melt directly in the foundry mold. As a result of a contextual analysis of the operation of devices for squeezing out melt from the siphon pouring system of large castings and ingots and the implementation of intra-mold blowing, as well as the processes of vacuuming and gas dynamic pressure during the solidification of metal in the mold, specific options for their design and corresponding technological features of operation were determined.

**36. M. Niesler, J. Stecko, D. Gierad, M. Nowak, S. Stelmach**

**Comparison of the chemical composition of char from waste car tires to the coke breeze used in the iron ore sintering process.** The increasing automotive development generates large amount of waste car tires, which cannot be landfilled and the reuse level of raw materials used in vehicles production must achieve at least 95 %. The calorific value of waste tires is very high and they can be considered as energy carriers, for example in the form of char generated during pyrolysis process. The article presents the results of chemical analysis of char samples and parameters which are crucial from the environment and iron ore sintering process point of view. The results show, that char samples with high carbon content, low sulfur, zinc and pyrolysis oil content can be applied in the iron ore sintering process.

**37. Nurumgaliev, Ye. Makhambetov, Ye. Kumatbay, G. Yerekeyeva, A. Abdirashit, Ye. Mynzhassar**

**Study of softening temperatures of manganese ores in central Kazakhstan.** The article presents the results of studying the temperatures of the beginning, end and temperature range of softening, samples of manganese ores in Central Kazakhstan. For the study, samples of manganese ores from the Zhezdzinsky, Karazhal, Keregetas, and Western Kamys deposits were taken. The temperature interval for the softening of ores was determined by the method of isothermal heating on a specially assembled installation.

**38. Z. X. Wang, Z. H. Lin, G. Q. Liu**

**Numerical simulation study on the impact area of six-hole oxygen lance in a 260 t converter.** In the process of converter smelting, the impact area formed when the jet sprayed by the oxygen lance hits the molten pool to a large extent determines the steel quality. In this study, six sets of oxygen lance models with different inclination angles were established based on the a 260 t converter, and the influence of the jet angle and position of the oxygen lance nozzle on the jet impact area was studied by numerical simulation, and the law of the change of the impact area with the lance position under different impact velocity was explained through theoretical analysis. It was found that the effective impact area of the jet with an inclination angle of 15° was the largest, and the stirring of the molten pool was more uniform.

**39. A. K. Tarakanov, I. Mamuzić**

**The interactive system «Blast furnace operator's PC».** The functions of the system are the automated search for optimum baseline operation modes related to given process conditions and principal process engineering calculations. All data needed for simulation and computation is inputted by user at the system's request. The system enables a process engineer to carry out computational simulation and engineering calculations, to use their results for bringing current operation mode closer to an optimum for the conditions at hand, and thereby to exploit the vast potential of process engineering measures for improving blast furnace performance. The operator-computer dialog facilities may be provided with support for another language at customer's request.

**40. K. Yang, C. Hu**

**A prediction method of silicon content in hot metal of blast furnace.** In blast furnace smelting, the silicon content in hot metal can indirectly reflect the blast furnace temperature and measure the quality of hot metal. For more accurate prediction, according to the reduction reaction, the input parameters affecting the silicon content are selected to form a data set. The Weighted Random Forest (WRF) prediction model and the Scaling Coefficient Particle Swarm Optimization (SCPSO) algorithm are proposed. The prediction method based on SCPSO-WRF has higher prediction hit rate and lower mean error than those traditional methods. The results show that the prediction hit rate and mean error of SCPSO-WRF are 89,1 % and 0,0291 respectively. The prediction method has theoretical research and practical application value.

**41. Z. G. Guan, Z. J. He**

**Experimental study on sinter pot test with added light burnt dolomite in sintering production.** Reasonable matching structure of sintering flux has great effect on improving the sinter quality and reducing energy consumption. In this paper, the feasibility of replacing part or all of quick lime in sintering production with limestone, dolomite, light burnt magnesium powder and light burnt dolomite is studied by sinter pot test in the lab. The result shows that when with 5,47 % of light burnt dolomite replacing part of the quick lime, the results such as the weighted average of sinter granularity, the production yield, the utilization coefficient, the tumbler index and the reduction degree meet the actual production requirements.

**42. A. K. Tarakanov, I. Mamuzić**

**The system for automatical control of blast-furnace charging.** The CHARGE system operates a Paul Wurth charging device and appreciably outperforms the original control system both functionally and operationally. The system has a blocked structure and all its subsystems share one information base. Each block is a self-contained automatic subsystem capable of independent operation. The major function of the weighing block is to define charge weight to be dumped at each chute position based on the position count and the operator's instruction. The division relative error is considerably less than under the control of original system, because the original control system has not used the predictions. Imaging subsystem conveniently presents the process of dumping, laying and distributing materials at the furnace top with the help of the original mathematical model.

**43. Y. F. Yao, Z. S. Zhang**

**Numerical simulation study on the influence of current stabilizer on tundish flow field.** The software ProCAST is used to simulate the flow field in the tundish. In the tundish without current regulator, the long nozzle injection impacts the tundish bottom directly, which is easy to cause damage to the refractory. The molten steel flow diffuses far along the bottom, and the disturbance is large near the submerged nozzle. The maximum speed at the bottom can reach 0.8m/s, and the general flow trend is that the injection flow direction is upward from the bottom to both sides, which is not conducive to the upward floating of inclusions. In the tundish with current stabilizer, the velocity of the injection decreases rapidly under the action of the liquid steel contained in the current stabilizer. Due to the attenuation of injection kinetic energy, the scouring effect on the bottom of tundish is obviously smaller and the flow field is more stable.

**44. S. H. Wang, H. K. Sun, S. Tong, C. X. Li, Y. K. Xue, Y. Zhang**

**Effect of iron oxide content on dephosphorization behavior of slag gasification.** The coke reduction gasification dephosphorization experiments were conducted on converter slag with FeO contents of 15 %, 20 %, 30 % and 35 %, respectively. Thermodynamic calculations, Scanning Electron Microscope(SEM) and Energy Dispersive Spectrometer (EDS) showed that the actual reduction Gibbs free energy of  $P_2O_5$  was less than that of FeO for the coke reduction converter slag product of  $P_2$ , and the reactive driving force of  $P_2O_5$  was greater under high FeO conditions. With the increase of FeO content, the gasification dephosphorization rate showed a trend of increasing first and then decreasing. After gasification dephosphorization, the presence of the Fe phase will adsorb more P elements, so the high FeO content is beneficial to increase the  $P_2O_5$  activity, which is conducive to the gasification dephosphorization reaction.

**45. Yefimenko, I. Mamuzić**

**Development of the technology of using fuel of plant origin in the burning of iron ore pellets.** Iron ore requires agglomeration, which consumes a lot of fuel, which is accompanied by harmful emissions. An alternative is to use biomass to partially replace fossil fuels. A technology has been developed for replacing fossil fuels with biofuels during the firing of pellets. When burning sunflower husks, heat is released to replace up to 48,3 % of natural gas. Using biogas instead of natural gas also has its advantages. The possibility of producing carbon-containing pellets from agricultural waste and palm shells is considered. The use of biomass as a reducing agent in iron ore mining has proven to be a suitable method for improving the quality of iron ore as well as reducing CO<sub>2</sub> emissions.

**46. T. Wojtal**

**The influence of temperature on the speed of reduction of tin oxide with argon-hydrogen mixture.** Recently, the usage of hydrogen in the processes of metal extraction has been a very important challenge to metallurgical industry. Replacing conventional reductor, taking into consideration CO<sub>2</sub> emission restrictions will enable maintaining and developing this branch of industry. The results of the research on tin oxide SnO reduction using hydrogen given as a mixture Ar – 5 % vol. H<sub>2</sub> in temperature range 773 – 873 K. are shown in this article. The tests were conducted using thermogravimetric method. It is demonstrated that with the rise of a temperature in the analyzed range the speed of reaction rises as well and the obtained degree of reduction varies from 40 to 99,5 %. Stabilization the weight change in the tested sample thermogravimetric (TG) was reached after from 25 min for 773 K to 15 min for temperature 873 K.

**47. Ye. Kuatbay, A. Nurumgaliyev, T. Zhuniskaliyev, S. Smailov, A. Yerzhanov, G. Bulekova**

**Development of carbon ferrochrome smelting technology using high-ASH coal.** This article presents the results of experimental tests using coal from the Saryadyr deposit as a reducing agent for the smelting of carbonaceous ferrochrome. Large-scale laboratory tests were carried out on the smelting of carbonaceous ferrochrome in an ore-thermal furnace with a capacity of 200 kV · A. X-ray diffraction analysis of the obtained alloy and slag on a diffractometer was carried out. The presence of forsterite 2MgO · SiO<sub>2</sub> and magnesitochromite Cr<sub>2</sub>Fe<sub>0,2</sub>Mg<sub>0,8</sub>O<sub>4</sub> in the slag was revealed, as well as the FeCr compound and the absence of silicide compounds. The optimal percentage of replacing traditional coke with coal up to 30% (by weight) has been found, which can significantly reduce the specific consumption of quartzite in the charge.

**48. V. O. Ruban, O. M. Stoianov, Y. V. Synehin, I. Mamuzić**

**Analysis of the thermal performance of a graphitized hollow electrode.** An analysis of the process of heating a graphitized hollow electrode (GHE) during steel processing at the “ladle-furnace” unit was carried out. Coefficients of the heat transfer by convection have been calculated for the inner and outer GHE surface: 1,60 and 1,80, and 5–17 W/(m<sup>2</sup>·°C), respectively. Values of the electrode temperature gradient in the high-temperature zone were obtained, which, for the first heating period, reached 8,286 °C/m, for the third – to 6,571 °C/m. It was established that during the cooling periods of the electrode, the temperature gradient is significantly reduced and amounts to the inner surface of 379 °C/m; to the outer surface – 3,613 °C/m.

**49. I. Bondarenko, N. Serzhanova, Y. Kuldeev, N. Sadykov, A. Tastanova**

**Beneficiation of chrome slurry tailings at donskoy mining and beneficiation plant (DMBP) JSC to produce hard pellets.** The article is about the problem of beneficiation of finely dispersed chromium slurry tailings of “Donskoy Mining and Beneficiation Plant” JSC by chemical and gravitation methods. Chemical destruction of chromium spinelids by sulphation with a mixture of ammonium sulphate and sulphuric acid enables to transfer a part of magnesium oxide to a water-soluble state and further gravitation beneficiation on concentration tables to obtain a fine-grained rich chromium concentrate. Silica, calcium, and iron oxide additives are used to produce pellets from the fine chrome concentrate, serving as binding agents and enabling the production of hard chrome pellets during roasting. In the future, roasted pellets will be used in the smelting of high-carbon ferrochrome in electric furnaces.

**50. A. A. Mukhanova, A. M. Yessengazyev, M. B. Barmenshinova, N. O. Samenova, G. A. Toilanbay, K. N. Toktagulova**

**Improvement of the technology related gold-containing raw materials with the use of ultramicroheterogeneous floateragent.** The material composition of the gold-containing tailings of the flotation beneficiation of the Zholymbet ore deposit was studied. It was determined that the samples contain 0,9 g/t of gold, 1,22 g/t of silver. The flotation technologies of technogenic gold-containing raw materials with the use of basic and ultramicroheterogeneous flotation reagents were developed. The content of gold in a draft gold concentrate, in comparison with the basic mode, increases by 2,28 g/t - with 19,56 to 21,84 g/t. The extraction of gold in concentrate increased - by 5,52 % - with 66,07 % to 71,59 %. Thus the consumption of collectors is cut for 50 g/t, with 130 to 80 g/t.

**51. V. S. Mameshyn, K. H. Nizhaiev, S. V. Zhuravlova, I. Mamuzić**

**The use of rheoscopic fluid in the study of metallurgical processes.** The document presents the studies results of possibility of using the rheoscopic fluid in the “cold” modeling in steelmaking processes. It is proposed to use a rheoscopic fluid containing 0.4 % of pearl pigment. It has been established that the use of rheoscopic fluid allows to visualize the movement of hydrodynamic flows in “cold” blowing modeling.

**52. Ye. Mukhambetgaliyev**

**Research of electrical resistance and temperature of the beginning of softening of charge mixtures for smelting a complex alloy.** The results of the study of the electrical resistance and the temperature of the beginning of softening of high-ash coals of three working seams of the Saryadyr deposit and mixtures of charge materials are presented. The high electrical resistance of the charge in the ore smelting furnace provides a low proportion of charge conductivity and, thereby, contributes to the release of the bulk of the energy in the reaction zone of the furnace, where the metal is formed. The research results showed that the magnitude of the electrical resistance of the charge during non-isothermal heating to high temperatures largely depends on the chemical and mineralogical composition of the charge, as well as on the processes of phase transformations in the sample.

**53. A. Khabiyeu, O. Baigenzhenov, Zh. Korganbayeva, A. Toishybek, T. Chepushtanova, B. Orynbayev**

**Niobium(v) recovery from leaching solution of titanium wastes: kinetic studies.** This paper deals with the removal of Nb content from chemically leached solutions of titanium wastes using static ion exchange technology. The chemically leached solutions contained 2 g/L of Nb. The investigations involved the optimization of process parameters, such as contact time at different concentrations of niobium at room temperature. Sorption experiments are performed to evaluate the optimum conditions at a concentration of HCl 3,0 M, 1,0 g resin dose for 3,5 h contact time at room temperature. The maximum sorption capacity reaches to 0,089 g/g. Kinetics studies were proposed for the process by pseudo-first-order, pseudo-second-order, and intra-particle diffusion models.

**54. A. Abdirashit, Ye. Makhambetov, T. Tushiyev, A. Nurumgaliyev, S. Smailov**

**Thermodynamics of integrated deoxidation of steel with a new alloy of aluminum-silicium-manganese (Al - Si - Mn).** The article considers the issue of using a complex alloy of aluminosilicomanganese as a deoxidizer. The value of the Wagner parameter of steel interaction - silicon, aluminum, manganese and concentration in the liquid, were associated with their activity in the metal. A certain consumption of the deoxidizer - aluminosilicomanganese per ton of liquid steel to improve the residual oxygen content in the metal. Possible generators of non-metallic inclusions are established.

**55. L. I. Solonenko, S. I. Repiakh, K. I. Uzlov, I. Mamuzić**

**Sand-sodium-silicate mixtures steam-microwave structuring technological peculiarities.** Steam-microwave structured sand-sodium-silicate mixtures highest technological properties have been obtained under conditions if they are initially in free-flowing state, used sand is mainly fractions of 0,16 ... 0,20 mm and, after cladding with sodium silicate solute, sieved through sieve with 0,315 mm mesh. For structuring, water steam should be fed into mixture as water charges. Their location in rigging allows the water steam, released from them, to move in direction from rigging dead-end parts to mixture open surface. Water mass single water charge is 1 ... 3 g of water per 2,5 kg of mixture. When structuring, do not allow interruption of microwave radiation influence on mixture for more than 20 ... 30 seconds before it ends.

- 56. B. Kelamanov, S. Smailov, A. Yerzhanov, A. Apendina, R. Adilhanov, S. Kabylkhanov**  
**The possibility of involvement in ferroalloy conversion of nickel ores of Kazakhstan.** The article considers the method of using substandard oxidized nickel ores of the Batamsha deposit and their suitability for sintering. Laboratory studies on the agglomeration of domestic nickel ores with different reducing agents were carried out for the metallurgical evaluation of nickel ores. Agglomeration was carried out according to standard technology, the layer height averaged 24 cm. The agglomeration process proceeded intensively at a discharge of 1 100 -1 200 mm Hg, the sintering temperature of which reached over 1 200 °C. To improve the mechanical properties of the obtained agglomerates, it is necessary to continue research with a change in the composition of charge materials and a metallurgical assessment with the smelting of nickel-containing intermediates.
- 57. Synehin Y. V., Niziaiev K. H., Sukhovetskii S. V., Ostrianiin R. Y., Dei M.O.**  
**Influence of adjusting liquid steel flows in the CCM tundish on the efficiency of refining non-metallic inclusions.** Based on scientific papers, the methods of refining steel from non-metallic inclusions were analyzed. The prospects for the use of flow swirling methods for the removal of non-metallic inclusions have been established. According to the results of experiments on the water model, the increase in the efficiency of removing non-metallic inclusions in the rotary chamber of the tundish was experimentally confirmed.
- 58. V. V. Bochka, M. V. Yaholnyk, A. V. Sova, I. Mamuzić, M. O. Fursov, K. I. Malenko**  
**Sintering of agglomerate during separate preparation of the charge.** The paper presents the results of research into a common and separate method of preparing a charge for sintering agglomerate. The best quality of the agglomerate was ensured by separate lumping of the “concentrate-ore-lime-limestone” composite, the basicity of which was 0.9-1.0 units, and the residual charge with the basicity of 1.6-1.8 units, after which both composites are mixed in parallel. Then their joint granulation takes place. Fuel is supplied at the end of granulation. Sintering of the agglomerate prepared by the proposed method allows to increase the yield of suitable agglomerate by 10.25 % and to reduce the content of the 0-5 mm fraction after the strength test by 11 %.
- 59. A. S. Kim, A. A. Akberdin, R. B. Sultangazyev, A. S. Orlov, G. H. Adamova**  
**Features of the slag regime of smelting boron containing silicochrome.** The article presents the results of a study of the slag mode of melting boron-containing silicochrome. It is shown that the addition of boron-containing fluxes to the silicochromium charge made it possible to reduce the thermal level of the melting process by reducing the melting temperature and viscosity of the final slags.
- 60. M. S. Zhou, E. J. Hou, G. Yang, J. N. Zhang, L. W. Zhai, X. Jin, X.C. Li**  
**Study of the optimal particle size of sintering solid fuels.** Carbon combustion rates can be altered with different particle sizes of solid fuel, which can directly affect the mineralization of iron ore sintering. A quantitative relationship between coke size and iron ore sintering indexes was studied using a mixture regression design method and simplex-lattice design. Also, the effects of optimal coke particle size on the cold intensity and productivity of the sinter were verified by sinter pot tests and analytical studying the sintering mineral structure. Results show that changing and optimizing the proportion of different coke sizes (<1 mm, 1 mm–3 mm, 3 mm–5 mm, >5 mm) can satisfy the need for sintering production to indexes. It has important significance to reduce solid fuel consumption and improve the yield and quality of sinter.
- 61. C. Y. Shi, S. Y. Guo, B. S. Wang, X. X. Yin, P. Sun, Y. K. Wang, L. Zhang, R. Chen, Z. C. Ma**  
**The forecast of slag addition during the LF refining process based on LWOA-TSVR.** LF refining slag addition is an important factor affecting the end steel composition of the refining process. In order to better control the end steel composition and improve the production efficiency, this paper uses an improved whale optimization algorithm to optimize twin support vector machines to establish a LF refining slag addition prediction model. The LWOA-TSVR model is trained and tested by historical data, and the model has a strong generalization capability and high accuracy. Applying the model to the industrial production process, it was verified that the model has high prediction accuracy and can provide guidance for the actual refining production process of LF refining slag addition, which is important for the control of the end steel composition.
- 62. D.R. Magomedov, A.K. Koizhanova, G. Toktar, N.A. Abdyldayev, A.N. Bakrayeva**  
**Determination of optimal pressure parameters for the system of pulp microaeration dispersants in column flotation.** The article presents the results of experiments intended to beneficiate gold-bearing mineral raw materials by column flotation with the use of micro aeration of pulp through a dispersant system. The influence of the pressure level in the pressure system of dispersants within the range from 202,65 to 1013,25 KPa was studied during the experiments. It was found that the parameter of 607,95 KPa enables to achieve the optimal balance of the precious metal mass yield and the content in the concentrate, with a final gold recovery of 87 %.
- 63. R.A. Ramazanova, B.S. Saurbayeva, Y.N. Ivashchenko, B.S. Tantybayeva, M.K. Zhamanbayeva**  
**Research on zinc concentrate dressing at the zhezkent processing plant to obtain conditioned concentrate.** The article investigates dressing of zinc concentrate of Zhezkent processing plant with the purpose of receiving conditioned zinc concentrate and copper product output. The scheme of the zinc concentrate dressing is suggested which includes the following operations: desorption of the initial concentrate by sodium sulfide and activated carbon; preliminary hydraulic classification (washing of thin sludge) complicating the flotation process; comminution of the concentrate in a ball mill up to the size of 96 %, class - 0,044 mm; flotation of copper minerals by reagents: xanthate, Methyl isobutyl ketone blowing agent, and depressors ( $\text{Na}_2\text{S}$ ,  $\text{FeSO}_4$ ,  $\text{ZnSO}_4$ ). The proposed dressing scheme provides obtaining conditioned zinc concentrate of grade KC-3 with Zn 47,0 %, and Cu 1,9 %.
- 64. J. Cupek, M. Tkadlečková, T. Merder, J. Walek, M. Saternus, J. Pieprzyca**  
**CFD analysis of medium flow and removal of inclusions in a two-strand tundish.** Metallurgical cleanliness of steel products is one of the basic criterion for assessing their quality. The flow and mixing method of liquid steel in tundish has a significant impact on the effectiveness of removing impurities. The article presents the results of the Computational Fluid Dynamics (CFD) simulation of the method of medium flow and mixing, as well as the movement and removal of solid particles in the model of two-strand tundish as a result of installed internal arrangement. Two variants including turbulence inhibitor and impact pad with a ball cutting area were modeled for the tests. CFD simulations are a continuation of previous tests with the use of the physical water model of the Continuous Steel Casting (CSC) device.
- 65. Zh. Shoshay, M. A. Sadenova, M. M. Suyundikov, R. V. Sapinov, P. S. Varbanov, D. R. Absolyamova**  
**Investigation of ultrasonic influence on the kinetics of extracting gold from electronic waste.** In this paper the effect of ultrasonic treatment on the apparent activation energy of gold leaching from e-waste in aqueous thiourea solution was studied. The leaching was carried out under conventional conditions and under ultrasonic treatment. The leaching in both cases was carried out at 25 °C, 35 °C, 45 °C and 60 °C. The apparent activation energy using ultrasonic activation decreases. In both cases the process of gold leaching from e-waste proceeds in the diffusion region. Thus, ultrasonic intensification is a means of increasing the efficiency of hydrometallurgical processes of e-waste processing by reducing the activation energy of the process.
- 66. J. Schwietz, B. Panic**  
**Improvement of the process of feeding the slag-foaming material to the electric Arc furnace, using of the sound.** The research described, aimed to determine the value of the sound level (originating exclusively from the operating electric arc) at which the feeding of the slag foaming material to the Electric Arc Furnace (EAF) should start, in correlation with the stabilization of the furnace's active power consumption level. For this purpose, the frequency band generated by the working electric arc was extracted from the entire spectrum of sound emitted by the furnace. Using sound analysis in 1/3 octave bands, the focus was on the band with a center frequency of 100 Hz. It was found that feeding the foaming material should start at a sound level of 103 dB.

# Plastic Processing – Section „C“

1. L. Ding, X. S. Gao, X. X. Lu, B. S. Sun, X. D. Shu

**Influence of pass spacing on the spinning process of nickel-based alloy conical casing.** Using GH4169 superalloy as the material, a Finite Element Model (FEM) was established based on the Simufact platform, and the influence of the pass spacing on the spinning process was explored by using the concave curve and circular arc trajectory. The results show that the stress-strain increases with the increase of the pass spacing. Obtain the optimal pass spacing under specific conditions: blank wall thickness  $t = 2,5$  mm, blank diameter  $d = 250$  mm, feed ratio  $f = 1,2$  mm/rad, mandrel speed  $n = 300$  r/min, pass spacing  $p = 14$  mm.

2. B. Zheng, D. Xu, Y. Q. Wang, L. X. Guo, H. Y. Zhao, D. Y. Ju

**Study on constitutive models of hot deformation for 34CrNi3MoV steel.** Isothermal constant strain rate compression experiments were conducted on 34CrNi3MoV steel using a thermal simulation experimental machine to study its thermal deformation behavior, with deformation temperatures ranging from 800 - 1 200 °C and strain rates ranging from 0,01 - 10 s<sup>-1</sup>, and the corresponding stress-strain curves were obtained for 60 % compression. According to the results, through regression analysis of the 1stOpt software, parameter values of three constitutive models were obtained, and then the precision of prediction was compared by different models of flow stress.

3. G. Shvachych, I. Mamuzić, Y. Proydak, L. Kabak

**Simulation of heat treatment of metal billets by multiprocessor computing system.** Development features and application of multiprocessor computing system with its mathematical support and software for heat treatment modes simulation of metal billets are considered. Modern multiprocessor computing technologies application was suggested for increasing speed and efficiency of computation, which enables to effectively control technological processes. Multiprocessor system with special software is capable to set and control necessary temperature conditions along all the plane of cross-sectional of a billet at heating and self-control of metal, and with possible control of thermal mode of treatment in temperatures interval of annealing. The practical value of results obtained showed that the technological process by appropriate mathematical simulations was improved.

4. T. Q. He, Y. Gao, L. Y. Huang, Z. J. Xue

**Strength analysis of shearer body based on ansys.** Taking a certain type of shearer as the research object, using the large-scale Finite Element Analysis (FEA) software ANSYS, according to the actual situation of load distribution, the stress model of the shearer body is established, the stress and deformation of the shearer body are analyzed, and the deformation curve and equivalent stress nephogram of the shearer body under working state are fitted. The stress and strain distribution of fuselage structure under working conditions are analyzed. The calculation results show that the structural design of the shearer body is more reasonable and has better stiffness and strength under normal working conditions. The calculation results have a certain reference value for the analysis and research of high-power shearer.

5. Q. Y. Lu, X. D. Shu, C. Xie, H. Q. Huang, W. J. Pan

**Simulation and forming mechanism analysis of multi-pass spinning process of deep cylinder parts.** In this paper, the forming mechanism of 3103 aluminum alloy forming deep cylinder part under ten passes spinning is studied. The forming process of each step is simulated by finite element method. The distribution characteristics of equivalent stress field and strain field in forming were analyzed in detail. The influence of feed ratio on spinning force is obtained. By measuring the thickness and circularity of the final forming deep cylinder part, the final forming effect of multi-pass spinning is obtained.

6. F. Lin, X. D. Shu, C. Q. Ye, Y. M. Li, S. Zhang

**Numerical analysis of integrated forming process of diagonal rolling and piercing of flange nuts.** In this paper, Simufact FE software is used to establish a simulation model of three-roll diagonal roll piercing integrated forming flange nut blanks, elaborate its process principle, analyze its forming process through numerical simulation. The law of load change, equivalent plastic strain distribution and wall thickness uniformity during the piercing process and diameter reduction process were investigated, and verify the feasibility of this forming process for manufacturing flange nut blanks.

7. I. Mamuzić, G. Shvachych, L. Kabak, A. Matviichuk

**Mathematical simulation of wall thickness variation of hot rolled pipes.** The periodic components of the wall thickness function of hot rolled pipes are investigated. Using the compiled mathematical simulation, the wall thickness of pipes is interpreted as a function of the angular coordinate that allows identifying periodic components that characterize the structure of wall thickness variation of pipes. The analysis of the corresponding harmonic components and their parameters for a real experiment is carried out. This allowed applying the proposed approach for analyzing the wall thickness distribution along perimeter of hot rolled pipes, which is difficult in hot rolling. Special software has been developed for conducting practical experiments in a real process.

8. S. K. Shi, J. H. Qiao, L. N. Cao, J. Cong, S. Guo, H. C. Ji

**Research on hot extrusion forming of 7075 aluminum alloy wheel profile.** Design the wheel mold according to the cross-sectional view of the light-weight aluminum alloy wheel profile, determine the length of its working belt and use HyperXtrude software to simulate it, verify the rationality of the working belt design, analyze the flow velocity and temperature of the mold outlet, and determine the 7075 aluminum alloy. The alloy wheel profile is most reasonable to be produced on a 10 MN extruder. Finally, the optimized working belt length is used for production. The quality of hot extrusion profile is qualified, which proves the accuracy of the simulation.

9. Sz. Pawlak

**Stability of the rolling process of ribbed bars based on the analysis of strength parameters.** The article presents the results of the strength properties of 12 ÷ 24 mm ribbed bars used for concrete reinforcement. The strength properties and the ribbing geometry of the ribbed bars is a key factor in ensuring the safety of building structures. Therefore, the continuous analysis of the mechanical parameters of ribbed bars and the reasons for their change is essential for any rolling mill. This article aims to present an analysis of the strength properties of ribbed bars made of high ductility steel in 2021 in a selected production plant, and then, based on the obtained results, to perform an analysis aimed at verifying the stability of the rolling process.

10. G. C. Yu, G. Song, C. Han, Y. Z. Zhong, H. C. Ji, J. Yuan

**Study of hot processing map of AISI 1035 steel under high temperature.** In this study, AISI 1035 steel was selected as the research object, and a single-pass thermal compression simulation experiment was carried out. Based on the true stress-strain curve obtained from the experiment, the dynamic DMM thermal processing map theory was used to draw the material under different thermal deformation conditions. and the rheological instability map based on the Prasad instability criterion, and the thermal processing map is used to predict the suitable processing interval and rheological instability interval for the thermal deformation process of the material under different process conditions. So as to provide theoretical support for the optimization of the material processing technology.

11. I. Mamuzić, G. Shvachych, S. Shvachych, O. Khylyko

**The application features of mathematical apparatus of harmonic analysis to determine the accuracy of rolled pipes.** The degree of influence of the tube rolling unit mills on formation of wall thickness variation is investigated. For this purpose, a mathematical simulation of pipe wall thickness was compiled as the sum of a number of harmonic components. Using the mathematical apparatus of the Fourier transforms, the amplitudes of harmonic components that describe various types of wall thickness variation are distinguished. The proposed computerized approach for rolling process control is focused on mathematical simulations processing of control of wall thickness variation of sleeves, of rough and finished pipes to increase their accuracy.

**12. Sh. Xu, X. D. Shu, Zh. L. Shen, L. J. Zhu, J. Zhao**

**Plastic properties and microstructure evolution of 20CrMoA steel during warm deformation.** The plastic properties and microstructure evolution of 20CrMoA steel was analyzed at 600-750 °C and strain rate of 0,01-10 s<sup>-1</sup>. The result reveals that the deformation behavior is hardening followed by softening at low strain rates (0,01 s<sup>-1</sup> and 0,1 s<sup>-1</sup>), but hardening is dominant in the whole deformation process at high strain rates (1 s<sup>-1</sup> and 10 s<sup>-1</sup>) and low temperature (600 °C and 650 °C). The strain rate sensitivity exponent increases with the increasing deformation temperature except for 650 °C and high strain rate. The spheroidization mechanism of cementite is the mechanical fracture and the dissolution of cementite particles. At 700 °C, spheroidized particles are finer and their distribution is more uniform than that at 750 °C.

**13. X. S. Gao, X. D. Shu, X. Chen, L. Ding, B. S. Sun**

**Effect of process parameters on microstructure of 42CrMo steel ball hot skew rolling.** Microstructure grain refinement is an effective way to improve the quality of 42CrMo steel ball. A three-dimensional thermal-mechanical-microstructure coupled Finite element model (FEM) of steel ball skew rolling is established in the finite element simulation software. Simufact software was used to simulate the effects of process parameters on the microstructure of steel balls, and the effects of roll Angle, roll temperature and roll speed on the average grain size of rolled pieces were analyzed by single factor variable method. The research results provide some reference for the improvement of 42CrMo steel ball quality.

**14. I. Mamuzić, Y. Proydak, G. Shlomchak, G. Shvachych**

**Experimental research of contact stresses during rolling.** The research provides a methodology and results of experimental research of contact stresses in the non-stationary process of strip rolling, in a special laboratory mill with rolls made of optical glass grades, lead strips were rolled, and the contact stresses in their development were determined. The research aims at developing a method for the experimental determination of contact stresses during rolling with a linearly increasing back tension of the strip. The development is studied from the free stationary rolling process up to the strip slipping start in the rolls and the regularities establishment in the change of the friction ratio. It is shown that among the methods for studying the mechanics of a deformable solid, the most rigorously substantiated theoretically is the polarization-optical method of direct measurement of stresses.

**15. Y. Y. Shao, Z. W. Jia, Q. Guo**

**Effect of hot rolling reduction on microstructures and textures of grain oriented silicon steel.** The effect of hot rolling reduction on microstructures and textures of grain oriented silicon steel was studied by optical microscopy (OM), zeiss ultra 55 Scanning electron microscope (SEM) and Electron backscatter diffraction (EBSD) technique respectively. The results indicate that the effect of hot rolling reduction on grain size of hot rolled and normalized sheets in surface layer is great, while the effect on grain size of primary recrystallized grain is little. The shear zone thickens with the finishing reduction decreases, moreover strong {111}<112> and {110}<001> textures can be obtained in hot rolled sheets. Combined with the previous research conclusions, it can be found that the rolling process of oriented silicon steel is contributed to the formation of texture, while the recrystallization process reduces the sharpness of the texture.

**16. J. T. Wang, X. D. Shu, C. Q. Ye, Y. X. Xia, S. Zhang, S. X. Li**

**Research on metal reflow law of three roll skew rolling (TRSR) hollow axle.** In the process of TRSR hollow axle, there is metal reflow on the surface of the rolled piece, which greatly reduces the forming accuracy of the rolled piece. To solve this problem, it is necessary to study the metal reflow law of axle body. First, the flow law of metal on the surface of rolled piece is obtained by point tracking method. Moreover, the effects of process parameters on the metal reflow degree of axle body are carried out, and the influence law of process parameters on the metal reflow degree of axle body is obtained. Finally, by comparing the results of the experiment and the simulation, the reliability of the simulation is proved.

**17. X. G. Chen, X. D. Shu, J. N. Shi**

**Study on the variation law of temperature field in three-roll skew rolling of variable diameter specimen.** This paper takes the simplified high-speed train hollow axle variable diameter section sample as the research object, uses Simufact. Forming simulation software for simulation, analyze the rolling piece inner variable diameter section, equal diameter section, outer variable diameter section three stages in the forming process of temperature field distribution characteristics and variation, and discusses the causes of temperature field variation.

**18. F. B. Lian, S. W. Wang, H. Song, M. X. Gao, J. Yang, Y. Zhang, L. H. Fu**

**Research on logarithmic spiral roll profile in hot rolling.** Presented is a new logarithmic spiral roll profile for 2-high hot rolling, and successfully establishing the logarithmic spiral roll profile equation. The inherent benefits over traditional sine curve roll profile include control of rolling force and optimization of strip profile. Comparison of rolling force and strip profile produced by logarithmic spiral rollers with that produced using traditional sine curve rollers through three-dimensional finite element simulation also verifies the new roll profile is more prominent in reducing rolling force and optimizing strip profile than traditional sine curve roll profile.

**19. M. I. Medvedev, O. S. Bobukh, I. Mamuzić, O. M. Kuzmina, A. A. Samsonenko**

**Improvement of forging titanium alloys technology at the «Dnepropress Steel» Co.Ltd.** The paper presents an improvement in the process of forging titanium alloys in order to prevent significant unevenness of the structure due to changes in the technological parameters of the existing production in the conditions of LLC “Dnepropetrovsk Steel” affects the resulting structure and mechanical properties of the semi-product, which in turn possible to obtain a satisfactory macro- and microstructure of the pipe billet, which characteristics ensured the defect-free pressing of the front pipes with a size of Ø 78 × 14 mm on a horizontal hydraulic press and subsequent cold rolling of pipes measuring Ø 19,05 × 1,6 mm with mechanical properties that meet the requirements of the regulatory documentation ASTM B 338-91a “Standard Specification for Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers”.

**20. X.G. Chen, X.D. Shu, Q.J. Lian**

**Effect of feed rate on forming quality of cross wedge rolling of gear shaft teeth.** In order to improve the forming quality of cross wedge rolling of gear shaft teeth, this paper adopts the single factor research method and uses DEFORM - 3D software to carry out the finite element simulation of the rolling process with different feed rate dies. The results show that the total feed rate of 2,75 mm is the most appropriate, and the tooth top defect of rolled piece gear can be repaired under this condition. The feed rate in the first stage is more important than that in the other stages, and the suitable range of it is 1,0 mm - 1,2 mm.

**21. Z. L. Zhao, H. C. Ji, J. M. Zhao, B. X. Liu, W. C. Pei**

**Johnson-Cook model for TC4 titanium alloy based on compression experiment.** To obtain the exact mechanical properties of TC4 titanium alloy, the compression experiments on TC4 titanium alloy at different strain rates (10<sup>-2</sup>, 10<sup>-3</sup>, 10<sup>-4</sup> s<sup>-1</sup>) were performed at room-temperature on the MTS-810 electrohydraulic servo material testing machine. The data of TC4 titanium alloy compression experiments at different rates were obtained. And furthermore Johnson-Cook constitutive model is established. Due to different conditions, the equation is simplified, the constitutive parameters are obtained by step-by-step estimation method, and the Johnson-Cook (JC) constitutive model of TC4 titanium alloy at room temperature is established. The prediction results of the model were compared with the experimental data, the prediction curve is in good agreement, which verifies the feasibility of the model.

**22. D. V. Konovodov, I. Mamuzić**

**Manufacturing multilayer strips by single-pass rolling.** In presented work, the process of plastic deformation of strips from magnesium and aluminum alloys is considered. Three-layer strips consisting of an inner magnesium layer and outer aluminum layers were obtained by the plastic deformation method. Plastic deformation was carried out by the method of joint rolling of strips in one pass. A study of the mechanical properties of three-layer strips of magnesium and aluminum alloys, in particular the bond strength, has been carried out. The chemical composition and structure of the connection zone between the layers of aluminum and magnesium have been investigated. The results of the work can be used in the development of technology for manufacturing bimetallic strips from non-ferrous metals by plastic deformation methods.

# Metallurgy and Related Topics – Section „D“

## 1. V. Selivorstov, O. Shakirov, I. Mamuzić

**Analysis of the technological efficiency of temperature stabilization of shell ceramic molds before pouring.** The analysis of the data characterizing the effect of the molding method on the cooling of ceramic molds after tempering showed that the longest stability of the mold temperature is observed with the methods of molding ceramic molds into a granular support filler and a thermostat. Moreover, by changing the thickness or material of the heat-insulating layer of the thermostat, it is possible to adjust the duration of thermostating of the ceramic mold within wide limits, and thereby control the processes of casting formation and its quality. It has been established that during molding in a thermostat, the sufficient duration of calcination of ceramic shells at 950...980 °C is about 1 hour.

## 2. O.S. Maksakova, A. M. Dolzhanskiy, I. Mamuzić

**Prospects for the fruit and vegetable products standardization development (D) Fruit and vegetable products are a source of biologically active and mineral substances, enzymes, carbohydrates, and organic acids that are important for life in the human body.** In total, 121 standards have been adopted by the International standardization organization (ISO) for this area of the economy. A comparison of these information sources revealed that the European Committee for Standardization (CEN) has not adopted any ISO standard in the field under consideration; Ukraine adopted 96 international standards as national standards (79 % of the number of ISO standards). Additional analysis revealed that CEN has accepted 40 standards for vegetables, fruits and their processing products, all of which relate to test methods rather than product quality characteristics. Ukraine has adopted 32 European standards (80%) of them.

## 3. O. K. Abdirashev, S. Zh. Oralbayev, Y. D. Shambulov, G. A. Smailova, A. Bukayeva, D. Yergaliyev, A. Tulegulov, A. Zhauyt

**Theoretical background of the restoring of the crankshaft necks by ferromagnetic materials welding.** When developing the technological process of cast iron crankshaft restoring, it is necessary to obtain a martensitic structure in the pad weld in order to ensure the wear resistance needed. To form the martensitic structure the cooling rate after padding must be at least 80 - 90 °C / s. The helical surface welding does not lead to such a result, so in our research we use the welding according to the width of the shaft neck. We also examined the heat release from the pad weld and its cooling rate. For its implementation, the necessary calculations were made according to a compiled program in the QBASIC language. On the basis of these provisions, the theoretic background is proposed for the possibility of the wide-ringed welding of crankshaft necks, which ensures a minimal change in the structure and geometry of the crankshafts.

## 4. G. Shvachych, I. Mamuzić, B. Moroz, L. Sushko

**Deceleration problem research in multiprocessional computing systems.** The research is aimed at determining the deceleration factor associated with the increase in computing of a multiprocessor system. It should be noted that the research of these problems is important and relevant. This is due not only to fundamental limitation of maximum possible performance of ordinary serial computers, but also to the almost constant existence of computational problems that can not be solved with insufficient capabilities of existing computer facilities. The aim of the research is the further approach development associated with methodology definition for evaluation of the multiprocessor modular computing system effectiveness and this value impact of the computational deceleration.

## 5. I. Mamuzić, S. Shvachych, M. Sazonova, S. Zinchenko

**Research of the problem of modeling the environment's internal aerodynamics.** The paper shows that at the present stage of scientific research, the numerical experiment is one of the most important areas in studying the internal aerodynamics of the environment. It is noted that machine experiment is sometimes the only possible way to obtain information about the process under study. Given further progress in the research methodology of parallel numerical methods and parallel computing systems can be expected in the near future to further and significant increase in numerical computations of environmental aerodynamics problems on more complete mathematical models of atmospheric dynamics.

## 6. M. S. Zharlikov, R. A. Aubakirova, G. K. Daumova, E. N. Ivashchenko, B. S. Saubayeva, Sh. K. Sanyazova

**Improving the assay-gravimetric method for determining the content of noble metals.** The study considers the current state and problems of analytical control as the most important component of all stages of technology and production of noble metals. Based on the analysis carried out, a universal method for measuring the mass fraction of gold and silver in ores, products of their enrichment and metallurgical processing by the assay-gravimetric method was improved, and the optimal parameters for determining gold and silver were determined.

## 7. G. Shvachych, I. Mamuzić, B. Moroz, M. Spilnyk

**Distributed modelling of visualization of vectors of solutions for applied tasks' of metallurgy on the basis of schemes with increased order of accuracy.** The problem is considered to the distributed modeling of visualization of vectors of solution for applied tasks solutions of metallurgy on the basis of schemes with increased order of accuracy. Higher acceleration of computations compared with the finite-difference approach is illustrated by the use of analytical solutions that allow simultaneous and parallel computation for all temporary layers. It is shown that the most perspective approach to mathematical modeling of applied tasks of metallurgy should be considered the one based on numerical and analytical decisions.

## 8. I. Mamuzić, G. Shvachych, D. Kozenkov, O. Zaporozhchenko

**Maximum parallel structures for solving a single class of applied problems.** Research reveals the features of constructing the most parallel forms of mathematical models of a tridiagonal structure. Two methods of discretization of differential problems are considered by the example of solving the equation of mathematical physics. The paper proposes finite-difference and numerical-analytical methods application along with the splitting method as a methodological basis for constructing numerical methods for solving applied problems. The splitting method provides an economical and robust implementation of scalar sweep numerical models.

## 9. G. Abdykirova, R. Abdulvaliyev, N. Akhmediyeva, L. Imangaliyeva

**Study on the kaolin clay beneficiation ability.** The material composition of kaolin raw materials with the content of  $Al_2O_3 - 17,21$ ;  $SiO_2 - 66,27$ ;  $Fe_2O_3 - 0,51$ ;  $TiO_2 0,574$  was studied. The main valuable minerals are kaolinite, halloysite, muscovite, quartz, rare marks of tourmaline, ilmenite. Particle size analysis of kaolin raw materials shows that the largest mass is represented by the size class (- 0,05+0 mm) - 43,08 %. 79,74 % of alumina with its content of 32,0 % is in the size class (- 0,05+0 mm), and it can be used as a raw material for further processing into alumina or as a universal filler for production of paper, rubber, cable, plastic and perfumery products.

## 10. I. Mamuzić, G. G. Shvachych, P. O. Shcherbina

**Improving the security of systems based on graphic encryption keys.** The idea of constructing graphic encryption keys based on models of intersecting layers of multidimensional neural networks is considered. Stereometric figures are used as elements of the system. The figure planes are considered as neural network layers. The method allows us to consider the shape of a key as a "graphical object" built on the basis of neural network solutions. Depending on the teaching methods and the shape of the graphic object, the reliability of the generated key is significantly increased.

## 11. I. Mamuzić, G. Shvachych, D. Moroz, T. Karpova

**Numerical and analytical visualization concept of applied problems' solutions.** The maximum parallel forms of the algorithm are of special interest because they determine the least time of visualization algorithm implementation. The developed approach illustrates a standard for comparison with other practical methods. In this regard, this paper further develops the idea of improving schemes of increased accuracy based on the numerical-analytical approach to the computation of a wide range of studied problems. Its importance in this paper is demonstrated by the solution example of the initial-boundary Dirichlet problem.

**12. M. Chalada**

**Sustainable supply chain on the example of the steel sector in Poland.** A sustainable supply chain provides products and services that meet customer expectations, and at the same time has the lowest possible impact on the environment in accordance with the principle of corporate social responsibility. There are still no system solutions in the steel sector in Poland. The aim of the study is to present the essence of the concept of a sustainable supply chain in relation to the life cycle product.

**13. I. Mamuzić, S. Semenov, S. Yenhalychev**

**Mathematical model of the task scheduler in a distributed computing system.** A study of distributed data processing systems, as well as algorithms for their functioning, was carried out. Restrictions associated with the heterogeneity of processing objects, fuzziness of input and output data about them are revealed. The expediency of taking into account these limitations in the entity description model is substantiated. An improved GERT-network of scheduling distribution tasks for a single n-th set of data types. Based on the Gert-network, a mathematical model of a task scheduler in a distributed computing system has been developed, taking into account the possibilities of analyzing and adapting heterogeneous entities. Accounting for these factors made it possible to increase the accuracy of modeling up to 1.5 times.

**14. G. Shlomchak, I. Mamuzić, G. Shvachych, M. Mironenko, P. Shcherbina**

**Analysis of the recession in the global steel market.** The global steel production market is in recession in 2022. This decline is due to a number of global factors. These are the consequences of the recent COVID-19 pandemic, which significantly affected both the markets of the leading consumer states and the states producing metallurgical products: China and the United States. Among the twenty-two steel-producing countries, only two, India and Saudi Arabia, are seeing growth in 2022. The largest decline in production of more than 60% in Ukraine due to a full-scale military conflict with Russia. Overcoming the negative trends of the current year in 2023 looks illusory, since it is not clear which components can become a growth driver for this year.

**15. Sz. Pawlak, T. Malysa**

**Factory production control (FPC) and its requirements for the metallurgical industry.** The article the requirements of the Factory Production Control (FPC) dedicated to construction products (including metal, i.e. ribbed bars, steel pipes, shapes, sheets and metal constructions) introduced to the single market of the European Union, was presented. Meeting the requirements of legal regulations with regard to these products is an important issue for metallurgical companies placing their products on the EU market. These enterprises are required to effectively implement and supervise the FPC system, supervised by a party independent of the manufacturer (third party). The aim of the article is to present the requirements of the FPC and refer them to the requirements of industry standards for metal products – shapes.

**16. S. Semenov, I. Mamuzić, V. Lymarenko**

**A method of countering the multi-lateration verification of the ADS-B signal of an unmanned aerial vehicle.** A study of widespread cyberattacks on unmanned aerial vehicles was conducted. Identified components that can be discredited by an attack on ADS-B controllers. A method of countering the multi-lateration verification of the ADS-B signal of an unmanned aerial vehicle has been developed. The method is based on the hypothesis about the difference in the strength of the ADS-B false signal. This provides an opportunity to use probabilistic methods for the supervisor to estimate the wrong signal and then report it to the ground station.

**17. G. Shlomchak, I. Mamuzić, G. Shvachych, M. Mironenko, R. Korol, P. Shcherbina**

**Features of the development of the metallurgical industry in Ukraine.** Ukrainian metallurgy became unprofitable in 2022 due to rising electricity prices, logistics problems during the war, and falling global prices for metal products. The fall in prices for iron ore raw materials and metal products since the beginning of 2022 corresponded to approximately 35% and 30%. In the pipe-rolling segment, the rate of decline in production over the seven months of 2022 is only a quarter of last year's output. The rapid overcoming of the consequences of the Russian occupation is possible if several important factors coincide, namely: international economic and military-technical support; reparation payments from the aggressor country; continuation of the movement along the path of reforms in post-war Ukraine.

**18. T. Karkoszka**

**Industrial safety in metallurgical company.** Steel mills, due to the used chemical substances of combustible, toxic and explosive properties as well as because of the many other threats to the environment, human and property – must ensure the industrial safety. Therefore, it should cover actions minimizing the occurrence probability and limiting the importance of threats and their effects. In the study, one has presented the scheme of solutions within the range of safe realisation of the processes and loss prevention, concerning both: technical aspects of used technological and measurement control devices as well as the organisational aspects of processes realisation. For the chosen threats one has proposed actions for prevention, protection and limitation realised as technological and organisational layers of protection, which can be applied in the regular conditions as well as during dangerous event.

**19. I. Pobochii, I. Mamuzić, G. Shvachych, V. Kozenkova**

**On the problem of modeling the blockchain technologies and the real options.** The conducted research highlights the main problems of modeling blockchain technologies and real options, both machine and mathematical. For instance, servicing and solving data security problems of such technologies requires powerful computing equipment and high-performance ones. On the other hand, it is noted that the problem of real options pricing can be solved only based on a modern, complex mathematical apparatus. It is shown that the most promising approach to increasing the speed and productivity of computing facilities is parallel computing. It is noted that distributed (parallel) computer modeling can be implemented using the entire spectrum of modern computing technology: supercomputers, cluster computing systems, and local and global networks.

**20. G. G. Shvachych, I. Mamuzić, P. O. Shcherbina**

**Investigation of the influence of the capacity of the local i/o interface on the performance of a modular multiprocessor system.** The problem of increasing the overall performance of a multiprocessor computing system is considered. The ways of increasing the efficiency of multiprocessor systems based on the use of InfiniBand technology and the PCIe interface have been studied. The influence of the Socket Direct bridge connection on the performance estimates of a multiprocessor system is analyzed. The proposed approach makes it possible to increase the speed of data exchange between the nodes of a multiprocessor system both directly on the computing platform and at the network interface level for various types of tasks. The effectiveness of the proposed approach is illustrated on the basis of solving problems of metallurgical thermal physics.

**21. A. M. Dolzhanskiy, O. A. Bondarenko, I. Mamuzić**

**Method of control factors levels determining by maximizing of object quality complex indicator.** The purpose of the study is to determine the optimal (rational) levels of technical and/or technological and/or organizational factors used for the stochastic object controlling by maximizing its complex quality indicator, all other things being equal, meeting the requirements of stakeholders for product properties and/or process, and/or systems. According to the corresponding developed algorithm, the process of generalized quality maximizing in the manufacture of steel headquarters is considered. Simultaneously, the significant factors number, the coefficients of individual quality indicators weight and the corresponding values of the object description incompleteness indicator were taken into account. The obtained data are consistent with the rolled theory and production practice.

**22. M. Lisińska, B. Gajda, M. Saternus, S. Brozová, T. Wojtal, M. Rzelewska-Piekut**

**The effect of organic acids as leaching agents for hydrometallurgical recovery of metals from PCBs.** The hydrometallurgical treatment, compared to other recycling processes, is of great interest due to its higher efficiency and better economy. In hydrometallurgy, popular agents used in the leaching processes of e-waste include inorganic acids, ammonia, chlorides, thiourea, thiosulphates. Organic acids are also becoming more and more popular. The article presents an overview of possible paths of the metal recovery from e-waste with the use of various organic acids. The results of own research on the leaching of printed circuit boards with the use of organic acids including citric acid, oxalic acid, acetic acid, formic acid, malic acid, lactic acid are also presented.

**23. P. O. Shcherbyna, I. Mamuzić, G. G. Shvachych**

**Performance analysis of the interface of a pair pcie system based on channel aggregation.** The influence of changing the structural association of elements of the network interface of a multiprocessor computing system to improve its performance by aggregating channels of the PCIe interface adapted to the solution of the studied class of problems has been studied. The approach made it possible to increase the efficiency of parallelization and significantly reduce the computation time. These results were achieved by reducing the time of edge data exchange between the PCIe interface of the paired aggregation system module and the high-speed network adapter. The developed multiprocessor system is used to create new technological processes. It is used in the installation for the intensification of spheroidizing annealing of long steel products.

**24. I. Laktionov, I. Mamuzić, G. Shvachych, T. Karpova**

**On the problem of innovative blockchain technology application.** The carried out studies aimed at eliminating the identified knowledge gap between the potential areas of blockchain technology application and the required configuration of the entity's resources. It is demonstrated that the innovative blockchain technology is still in its infancy, and some researchers still have it with a certain degree of mistrust. Nevertheless, among the features of its application and its inherent features, one can identify a serious potential that eliminates the available level of mistrust. It is shown that the technology allows an enterprise to use blockchain as an effective resource for solving production problems. Additionally, it is emphasized that the major processes of choosing a blockchain as technology should be aimed at comprehending that it is best suited for solving the specific problem.

**25. A. K. Koizhanova, D. R. Magomedov, E. A. Tastanov, B. K. Kenzhaliyev, G. V. Sedelnikova, A. N. Berkinbayeva**

**Intensification of copper leaching from heaps using biological oxidation.** The article presents the results of experiments intended to leach copper from ore heaps of complex mineral composition biochemically. The processing of such heaps is complicated due to the presence of oxidized copper minerals among significant fragments of sulfide minerals and iron-calcium silicates. This factor does not allow to perform standard sulfuric acid leaching effectively without the use of additional oxidation catalysts, or to apply beneficiation methods for that kind of raw materials. Use of *A. Ferrooxidans* bacteria adapted to the composition of the copper dump, as a bio-catalytic agent, significantly accelerates the leaching process and increases the copper recovery degree into the productive solution.

**26. A. Shyrin, I. Mamuzić, G. Shvachych, M.M. Khylo**

**Research of some features of the distributed data registry technology.** The paper highlights the most intensively developing digital economy component, i.e., distributed ledger technology (blockchain). The paper shows that blockchain technology, as a decentralized data registry, is the most discussed and relevant topic in the development of the digital economy. There analyzed the strengths of the technology: cost reduction, high level of security, and transaction transparency. Those qualities draw the focus of various sectors of the economy. The proposed approach to the issue research allowed noting that the digital economy has several subtleties associated with insufficient knowledge, its flexibility, and various problems of technical implementation.

**27. G. G. Shvachych, I. Mamuzić, P. O. Shcherbyna**

**New technological developments based on the application of multiprocessor systems.** Research is aimed at improving existing and creating fundamentally new technological processes. In metallurgy, the heat treatment of metal requires expenses, which are explained by a significant number of full-scale experiments carried out in laboratory, pilot-industrial conditions, at production facilities. By using multiprocessor computing systems, it is possible to reduce the number of experimental studies and the time for their implementation. Consequently, the use of modern multiprocessor computer technologies makes it possible to effectively control technological processes. The technological process of metal processing acquires such advantages as high productivity, significantly reduced energy consumption and allows you to control technological parameters in the required modes of metal processing.

**28. K. Łakomy, T. Lis**

**Copper production and trade in Poland during the COVID-19 epidemic.** The SARS-CoV-2 virus outbreak has created turmoil in domestic economies around the world. The changes are visible in all industrial branches of the economy, including the market of metallic raw materials. The article reviews and analyzes the size of changes in the production and sales of copper and copper products in Poland in 2020, comparing the data in the previous years. The aim of the article is to assess the possible impact of the epidemic and related economic changes on the copper market in Poland.

**29. A. M. Dolzhanskiy, N. A. Bibik, I. Mamuzić**

**Assembly quality of hydraulic drive parts of mechanisms providing.** Some of the main parts of the plane chassis hydraulic drive are the hydraulic cylinder and the rod. In particular, in the manufacture of hydraulic cylinders for the chassis of the aircraft An 140 use seamless cold-drawn pipes made of steel St52. The rod is made of a calibrated steel bar of appropriate diameter with a chrome coating. The analysis of the chassis assembly technology of the An 140 aircraft allowed to determine the control points at which the quality of manufacturing and assembly of hydraulic drive parts is ensured, and to assess the adequacy of the technical control means used. On this basis, the Program of internal audit of the relevant technological processes of manufacture and use of components has been developed.

**30. I. Mamuzić, M. I. Khylo, A. Shyrin, D. Moroz**

**Research of the main principles of real options development.** The paper highlights the fundamental features of the option technologies development as one of the most essential components of the digital economy. It is shown that a real option allows making flexible decisions in conditions of uncertainty. Therefore, the analysis of real options as the most flexible and practical financial instrument of the digital economy was carried out. Furthermore, the conducted research reveals the essence of the main provisions of tactics and strategies in solving the problem of options pricing. Meanwhile, a new authors' classification of options contracts is presented, which allows determining their application, usage, and development. At the same time, the problem analysis of evaluation of the options contracts' price demonstrated the relevance of the new mathematical methods development for their reliable and accurate assessment.

**31. J. Furman, T. Małysa**

**Autonomous maintenance (AM) in the aspect of improvement work safety in the steel sector in Poland.** Autonomous maintenance is one of the important solutions used in industrial companies where part of the tasks related to the operation of machines is transferred to operators. In the steel sector in Poland, accidents related to the operation of technological machines are still reported. Given the above, this article lists the activities of machine operators in terms of methods and tools that allow for a reduction of the number of accidents at work. It aims to show the significance of the adoption of technical and organizational solutions directed at improving the safety of operators within AM in the steel sector in Poland.

**32. L. I. Solonenko, S. I. Repiakh, I. Mamuzić, K. I. Uzlov**

**Environmentally friendly molds and cores - waste-free raw materials for silicate-block and sodium silicate solute production.** Sand mixtures with sodium silicate solute structuring method of steam-microwave solidification (SMS-process) makes it possible for 2..20 minutes to produce sand-sodium-silicate casting molds and cores with compressive strength up to 4.5 MPa and gas-generating capacity of 3 ... 7 cm<sup>3</sup>/g. Mixtures consist exclusively of quartz sand and sodium silicate solute. Molding has been carried out by filling of rigging with dry sand-sodium-silicate mixture and sealing it with vibration. Mixture from castings has been removed as result of shock-vibration or water-jet action on them. Such mixture waste cannot be regenerated, but can be used as raw material for silicate-block, sodium silicate solute production or as part of concrete products, as road surfacing, etc.

**33. O. S. Maksakova, A. M. Dolzhanskiy, I. Mamuzić**

**Prospects for the textile industry standardization development.** It is possible to develop the Ukrainian market of textile products by modernizing the means of production using the modern technologies and with the use of the higher level of modern regulatory documentation. The conducted analysis showed that in general, of 234 standards that had been developed by the International standardization organization, in particular, by the ISO/TC 38 «Textiles» the European Committee for Standardization has adopted about 60 % of ISO standards; about 52,5 % of them have been adopted by Ukraine, while 14 national regulations are harmonized with European standards that correspond to international ones. This determines the expedient vectors of further work in the specified field of activity.

**34. O. A. Bondsrenko, D. V. Tverdokhle, I. Mamuzić**

**Algorithm for the general quality improving of communication between local authorities and the public using qualimetric assessment.** The main conditions of the public communication services development are the dynamic activities improvement, evaluation of their processes, as well as feedback existing goals implementation in full. It is proposed to assess the interaction of local public authorities in the following sequence: making a decision to conduct an assessment; engagement of experts and/or establishment of an internal evaluation team; process planning taking into account qualimetric approaches; determination of process quality indicators and corresponding weighting factors; a comprehensive assessment of the process quality conducting, taking into account feedback data and results analyzing; development of recommendations for improving activities; the report preparation.

**35. Z. J. Chen, J. Zhao, M. A. Liu**

**Metallurgical production fault detection method based on RESLSTM-CNN model.** Timely detection of abnormal working conditions and accurate diagnosis of abnormal working conditions are of great research significance to ensure the safe and stable operation of metallurgical production processes and to avoid losses caused by faults. In this paper, it propose a residual long and short-term memory network and convolutional neural network (RESLSTM-CNN) model for fault detection in metallurgical production processes bearing fault detection with an accuracy of 98,92 %.

**36. J. B. Zheng, X. D. Shu, S. Zhang, Q. Y. Lu**

**Effect of process parameters on forming quality of Mg Alloy(MZ21)-Al Alloy(7075) composite pipe.** This paper mainly studies the effect of process parameters on the deformation mechanism of MZ21 magnesium alloy and 7075 aluminum alloy bimetal composite pipe in spinning process. The two parameters of spinning, the rotary wheel feed ratio and the double tube wall thinning rate were selected to study, and the influence rule of each process parameter on the forming quality of composite tube was simulated by Simufact software. Under different thinning rates of the total wall thickness, the coordinated deformation and the rebound law of the wall thickness of the composite pipe are obtained. The results provide a certain reference for the preparation of magnesium aluminum composite pipe and the selection of reasonable spinning parameters.

**37. W. C. Pei, J. H. Qiao, B. X. Liu, H. C. Ji**

**Constitutive model of 7075 aluminum at high temperature.** In order to obtain the accurate mechanical properties of 7075 aluminum alloy, the Gleeble-1500D thermal simulation test machine was used to perform compression test on 7075 aluminum alloy. The deformation temperature range is 490 °C-560 °C, and the strain rate is 0,001 s<sup>-1</sup>-1 s<sup>-1</sup>. At present, for the high temperature thermal compression process, the Arrhenius constitutive model with strain compensation is usually used. The results show that the correlation coefficient of the Arrhenius constitutive model of 7075 aluminum alloy with strain compensation is 0,9894, and the average relative error is 5,6 %, realizing the fitting of flow stress and prediction, verified the feasibility of the model.

**38. Y. X. Xia, X. D. Shu, S. Zhang, J. T. Wang, C. Q. Ye**

**Research on integrated forming process of three-roll reducing and thickening of necking section for thin-walled tube of aluminum alloy 2A12.** Aircraft joystick pipe is the key part of aircraft hard control system. In this paper, a hollow necking rod pipe made of aluminum alloy 2A12 is taken as the research object. The tapered roller with extrusion cone on one side of the roller surface is designed. Simufact.Forming14.0 was used to analyze. It was found that the radial rolling force at the end of the thickening section in the second pass increased sharply. At this time, the retaining part inhibited the axial extension of the metal and realized the accumulation in the thickness direction. The thickening rate and effect were favorable at 120 rpm, which provide a theoretical basis to realize integrated forming of aeronautical thin-walled aluminum alloy tube.

**39. M. Yu. Kuzmenko, O. P. Egorov, I. Mamuzić**

**Automation of processes of coordinated control rolled products cutting on continuous section rolling mills.** In presented work is dealing with the actual scientific problem of development of universal methods, models and control systems of cutting in conditions of a large-scale rod production. It considers rolling parameter regularities and possibilities of the existing equipment. General regularities which provide efficient cutting of long product at various stages of rod production are established. A method for an active regulation of rolled products tension in the last inter-stand gap of a roughing train was firstly presented. A functional structure and an algorithm of the automated cutting control system and the method of rolled product cutting on a light section mill were established.

**40. G. Shvachych, I. Mamuzich, B. Moroz, M. Aleksiev, I. Hulina, M. Myronenko**

**Mathematical modeling of pipes production forecast based on polynomial regression analysis (PRA).** The paper analyzes some indicators of the production activity of Ukraine's metallurgical plants, which are under the auspices of Ukrtruboprom association for May-August 2022. Mathematical modeling of pipe production process forecast based on polynomial regression analysis was performed. The presented mathematical models provide adequate results for predicted indicators of economic activity of enterprises selected for analysis. The Russian military operations' negative impact on the hostilities' conduct in Ukraine is shown.

**41. K. Piotrowska, M. Madej, J. Kowalczyk, K. Radoń-Kobus**

**The influence of environmental conditions on the tribological properties of the Ti13Nb13Zr alloy.** The paper presents the results of tribological tests of the Ti13Nb13Zr titanium alloy - carried out in the conditions of lubrication with liquids simulating body fluids. Artificial saliva solutions were used for the tests. Two pH values were used - 7,0 characteristic of a healthy organism and 4,9 - typical for the presence of inflammation. The counter-sample in the tested friction nodes were Al<sub>2</sub>O<sub>3</sub> balls with a diameter of 6 mm loaded with a normal force of 1 N. The tests obtained showed a strong influence of environmental conditions on the tribological properties of the Ti13Nb13Zr titanium alloy. This applies to both the value of the coefficient of friction and linear wear. In the case of tests carried out under lubrication conditions with an artificial saliva solution at pH 7,0, they were 0,47 and 31,1 μm, respectively; in the case of a fluid at pH 4,9, they were 25% and 45% higher (0,62 and 65,6 μm).

**42. M. Madej, K. Radoń-Kobus, K. Milewski, S. Drabik, K. Piotrowska, J. Kowalczyk**

**Tribological properties of diamond-like-carbon coating doped with tungsten.** This paper presents the tribological properties of diamond-like coatings (DLC) doped with tungsten. The hardness of the DLC coating was determined using a micro-hardness tester. Using a scratch test, on a scratch tester, the adhesion of the coating to the substrate was studied. Friction tests were carried out on a tribometer in rotational motion in a 100Cr6 steel ball-disk association with a-C:H:W tungsten doped hydrogenated DLC coating. Tests were carried out with loads of 10N, 25N and 50N under technically dry friction conditions. Using a scanning microscope, the surface morphology was observed, and with a confocal microscope, the geometric structure of the surface was observed before and after the friction tests. The wetting angle of the samples was examined on an optical tensiometer for distilled water and diiodomethane. The results indicated that DLC coatings of the a-C:H:W type obtained by the PVD technique can be used in unlubricated high-load tribological systems.

**43. J. Matusiak, J. Wycislik-Sosnierz**

**Fume emission during the arc and laser welding of cast stainless austenitic steel.** The article present results of research fume emission in relation to various arc welding methods, and laser welding technic. Research-related test involved manifold elements and a turbine housing made of cast stainless steel. Laser welding process were shielded by argon. The analysis of test results aimed to identify the effect of arc/laser welding methods on the total emission of welding fume.

**44. J. Kowalczyk, M. Madej, K. Piotrowska, K. Radoń-Kobus**

**Influence of surface roughness on selected properties of the TiAlN coating.** The SW7M steel samples with different surface roughness were used for the tests. After grinding had a roughness parameter of Ra = 0.03 μm, and after polishing Ra = 0.01 μm. A TiAlN coating was applied to the substrate prepared in this way, which was supposed to improve the following properties: tribological, strength [1-4], anti-corrosion [1-6]. Using a scanning microscope equipped with an EDS microanalyzer, the surface morphology was observed and the chemical composition of the coating was examined. Using a confocal microscope with an interferometric mode, the geometrical structure of the samples was analyzed. The optical strain gauge was used to measure the contact angle. Tribological tests were carried out in conditions of technically dry friction. The polished sample with the coating was characterized by a more stable course of the friction coefficient, lower wear and a smaller wetting angle.