PLASTIC PROCESSING - SECTION "C"

Plastic deformation

1. V. V. Chygyryns'ky, I. Mamuzić*, V. N. Levchenko; *National Metallurgical Academy of Ukraine, Dnepropetrovsk, Ukraine, *Faculty of Metallurgy University of Zagreb, Sisak, Croatia*
Solusion of Some Applied Problem of the Theory of Plasticity. Solution of a flat problem of the theory of plasticity allows calculating the stress and strain fields of different processes of metal forming. The influence of technological parameters of a process on distribution of stresses and strains in zone of the form changing was shown.

2. V. V. Chygyryns'ky, I. Mamuzić*, F. Vodopivec, V. I. Gordienko;** *National Metallurgical Academy of Ukraine, Dnepropetrovsk, Ukraine, *Faculty of Metallurgy University of Zagreb, Sisak, Croatia**Institute of Metals and Technology, Ljubljana, Slovenia*
The Influence of the Temperature Factor on Deformability of the Plastic Medium. Using the solution of a closed problem of the theory of plasticity some analytic expressions were obtained for determination of the strain parameters of zone of deformation in view of the temperature factor.

3. T. Večko-Pirtovšek, G. Kugler*, M. Godec, R. Turk*, M. Terčelj*;** *Metal Ravne d.o.o., Ravne na Koroškem, Slovenia**, *Faculty of Natural Sciences and Engineering University of Ljubljana, Ljubljana, Slovenia**, **Institute of Metals and Technology, Ljubljana, Slovenia*
Hot Plasticity of CRV3 Tool Steel. CRV3 is a high alloyed cold work tool steel with about 1,1 % C, 0,3 % Si, 0,3 % Mn, 11 % Cr, 1,5 % V, 2,3 % W and 1,3 % Mo. As such it has a lot of ledeburitic carbides in microstructure, thus its hot plasticity should be investigated. The temperature range examined was 850 °C to 1200 °C and the strain rates varied from 0,001 s^{-1} to 6 s^{-1}. Special attention was paid to mechanisms, which are responsible for poor plasticity at upper and lower border of temperature range of hot working. Hot deformation behaviors of steel CRV3 have been studied also by using Prasad's processing (efficiency of power dissipation) and instability maps developed on the basis of dynamic materials model. CRV3 exhibits flow instability at lower strain rates and temperatures. Lower strain rates and lower deformation temperatures result in accelerated precipitation of secondary phases on grain boundaries and consequently in increased flow curves. Thus, at lower temperature and strain rates higher flow stresses than those at higher strain rates were obtained.

4. M. Terčelj, I. Peruš*, G. Kugler, P. Fajfar, R. Turk; *Faculty of Natural Sciences and Engineering University of Ljubljana, Ljubljana, Slovenia**, *Faculty of Civil Engineering and Geodesy University of Ljubljana, Ljubljana, Slovenia*
Hot Workabiliy of AISI A2 Tool Steel. The hot deformation behaviour of AISI A2 tool steel was investigated by means of hot compression test carried out on a Gleeble 1500D thermomechanical simulator over a wide range of temperatures (900 - 1200 °C) and with a strain rate of 0,001 - 8 s^{-1} and true strains of 0 - 0,7. For the given set of AISI A2 curves, the activation energy was calculated. The value obtained is compared with literature data which were acquired from the analysis of a hot torsion experiment. A special attention was also paid on influence of heating conditions on hot plasticity. The obtained results exhibit that various heating conditions result in various temperature ranges of safe hot forming. Hot deformation behaviors have been studied also by using Prasad's processing (efficiency of power dissipation) and instability maps were developed on the basis of dynamic materials model.

5. P. Fajfar, R. Turk, G. Kugler, B. Breskvar*, M. Terčelj; *Faculty of Natural Science and Engineering, University of Ljubljana, Ljubljana, Slovenia, *Institute of Metals and Technology, Ljubljana, Slovenia*
Hot Deformation Behaviour of As-Cast and of Deformed ZnCuTi Alloy: Laboratory Hot Compression and Industrial Measurement. The deformation behaviour of as-cast and of as-deformed ZnCuTi alloy in the temperature range 80 - 210 °C and strain rate 0,001 to 10 s^{-1} has been studied to obtain its strength characteristics. The flow curves were described by Hajduk`s expression. This was starting points to check the possibilities of rolling of block with increased dimensions on determined rolling mill. For this purpose also an improved model for rolling force, torque and temperature fall was developed and verified on industrial measurement. The measurement of loads on the mechanical side (torque on the mean shaft) and on the energetic side (electric current, voltage, revolutions of electromotor, etc.) of rolling mill were carried out. Furthermore the temperature of rolling block, block reduction, microstructure of rolled block, etc. has been recorded. The measured and calculated values for flow curves and for loads on rolling mill are in a good accordance. The analyze of loads on rolling mill shown on reserve for increasing of block weight.

6. V. F. Balakin, R. P. Diduk*, E. V. Kuznetsov;** *National Metallurgical Academy of Ukraine, Department of Technological Design, Dnepropetrovsk, Ukraine; *National Mounting University of Ukraine, Department of Technologic of Mounting Mashing Buildin, Dnepropetrovsk, Ukraine; **National Metallurgical Academy of Ukraine, Department of Physic, Dnepropetrovsk, Ukraine*
Investigation of Shear-Relaxation Oscillations Dynamics during Plastic Flow of Metals. In modern presentations the plastic flow of metals has wave nature. Distribution of plastic waves is related to the successive shear-relaxation acts series which is going on in the body being deformed. Until now there are no methods of plastic deformation wave effects quantitative description suitable for the use at practical calculations. In a number of cases it hinders the reception of construction materials deformation conduct reliable estimations. An attempt to fill in this blank is undertaken in the offered article. The got results allowed to ground low-frequency vibrostimulating of plastic deformation and became the subject of the scientific discovery.

7. G. G. Shlomchak, V. P. Balakin, I. Mamuzić*; *National Metallurgical Academy of Ukraine, Dnepropetrovsk, Ukraine, *Faculty of Metallurgy University of Zagreb, Sisak, Croatia*
Autoswaying Mechanism of Process of Plastic Deformation of Metal at Rolling. On the laboratory complex of the National metallurgical academy of Ukraine for the physical design of processes of rolling, the polarization-optical model of process of the hot rolling is developed. On the pictures of interference in the transparent mangles their state is studied and epyury of contact Efforts are got: It is set that the process of deformation of large crystalline metal a coarse- grained dynamically flows in the swaying mode. Autooscillations of the tense state of hearth of deformations steady and differ by permanent frequency.

8. M. Terčelj, G. Kugler, R. Turk, I. Peruš*; *Faculty of Natural Science and Engineering, University of Ljubljana, Ljubljana, Slovenia, *Faculty of Civil Engineering and Geodesy University of Ljubljana, Ljubljana, Slovenia*

Effect of Chemical Composition on Hot Deformability of AISI D2 Tool Steel. In this contribution the mutual effects of carbide forming elements, carbon, sulphur, manganese, etc. were analyzed as a function of hot deformability. About one hundred combinations of chemical composition have been studied. The applied charges had nominally the same composition but in fact they varied within the allowable ranges. Thus quite unintentionally we obtained a wide range of chemical composition within AISI D2 type that enabled to carry out a passive experimental design method. The complex analyze was carried out by CAE neural networks. Analysis of this data has revealed important information for further increase of yield of hot rolling of D2 tool steel. The favorable ratio between manganese and sulphur was obtained, the recommended values for carbide-forming elements were calculated, influences of particular trace elements on deformability were detected, etc.

9. E. A. Pop, V. Hotea, R. Pop*; *North University of Baia Mare, Baia Mare, Romania, *CUPROM S. A. Bucureşti, Romania*

The Influence of Antimony, Arsenic and Lead Content of the Copper Cathodes on the Elongation of the Rolled Copper Wire. To determine the influence of the impurities upon elongation at fraction by traction we used a method of mathematical modeling. This is the analysis of regression through active experiment. The equation of the elongation of the copper wire in relation with the antimony, arsenic and lead in the copper cathodes is: y' = 53,9–2,71Sb–2,06As –2,29Pb+0,6Sb As+0,44Sb Pb+0,31As·Pb–0,13Sb·As·Pb. With the help of a spectrometer we have determined the chemical composition of 27 samples of copper cathodes. Consequently, we have determined the elongation of the copper wire production from these cathodes. This makes the hot deformation impossible. It is important to know the elongation of the wire in relation with the raw material in the process of wire production.

10. M. Golja; *Faculty of Metallurgy University of Zagreb, Sisak, Croatia*

Mechanical and Deformations Properties, Flow Strees and Deformability of High and Low Alloyed Structural Steels. This paper deals with the flow strees and deformability of steels by high temperatures are investigated. In order to analyse the deformation characteristics of steel, torsion tests and tensile test were performed at different temperature in the range from 800 to 1200 °C. The plastic deformation of metals is a process depends on the stress, temperature and material properties with special modeling of hardening and softening to dynamic recrystallisation. The aim of this paper is to present laboratories investigated in dependence the efficiency by hot plastic processing, based on empirical results.

11. I. Peruš, G. Kugler*, M. Terčelj*, P. Fajfar*; *Department of Civil Engineering University of Ljubljana, Ljubljana, Slovenia, *Faculty of Natural Sciences and Engineering University of Ljubljana, Ljubljana, Slovenia*

Flow Stress Prediction of Hot Compressed Tool Steel by CAE NN and Hyperbolic-Sine Equation. Hot compression experiments are carried out on steel workpieces by means of Gleeble 1500 thermo mechanical simulator in wide range of temperatures 800 °C - 1200 °C with strain rates 0,1 s^{-1}, 1,0 s^{-1} and 8,0 s^{-1} and true strains of 0,0 to 0,5. Hot flow curves were estimated by means of the CAE neural networks. The methods of constant smoothness parameter and non-constant (ellipsoidal) smoothness parameter were applied. The use of the latter proved more exact (up to 3,4 %) and simpler if we compare it with the existing data for the flow curve prediction of tool steel by BP NN (up to 7 %), as the proposed method yields better results. The activation energy and other parameters in hyperbolic-sine equation were calculated according to the method proposed by McQueen et al. and according to the method recently proposed by Kugler et al. The latter yields better results at predicting the maximum values of hot flow curves.

12. G. Stepanov, V. Zubov; *Pisarenko Institute for Problem of Strength, National Academy of Sciences of Ukraine, Kiev, Ukraine*

Calculation of Metals Strength with Account of a Micro-inhomogeneity of Plastic Deformation. Tests on elongation, compression and shear of structural metals reveal their strength increase with strain rate. Tests results on impact indentation of a rod with conical head confirm increase of dynamic hardness (defined as specific energy per unit volume of conical cavity formation) with the impact velocity in the range below 10 m/s. But, decrease of dynamic hardness in the range of higher indentation velocity follows from the experiments. Accounting the joint influence of viscosity, increase of temperature during plastic deformation and its localization can explain mentioned drop of dynamic hardness at high indentation velocity. In the presentation the simplified model of metal behavior accounting the effect of plastic strain non-uniformity on micro level (but neglecting strain hardening and viscosity effects) is described.

13. P. Fajfar, M. Bogdan, M. Terčelj, R. Turk; *Faculty of Natural Science and Engineering, University of Ljubljana, Ljubljana, Slovenia*

Influence of Interruption Time on Multi-Stage Flow Lines. The influence of interruption time on multi-stage flow lines for two steel grades was examined. Specimens were taken from the continuous-casting slab in the direction of flow and perpendicular to this direction. In this purpose a series of compression tests at constant temperature of 1050°C and constant strain rate 5 s^{-1} were realized. Time between the first and the second deformation and time after the second deformation before quenching were varied (1, 5, 15 s). Tests were realized using a simulator for thermo-mechanical states Gleeble 1500. In the work the estimation of stability of performing compression tests, the comparison of flow stress curves for the first and the second stage of deformation and estimation of softening is presented.

14. T. Kvačkaj, V. Vrchovinský, I. Pokorný, I. Mamuzić*; *Faculty of Metallurgy Technical University of Košice, Košice, Slovakia, *Faculty of Metallurgy University of Zagreb, Sisak, Croatia*

Nanostructural Formation by Severe Plastic Deformation. The influence of severe plastic deformations on structural, mechanical and plastic properties of ARMCO-Fe in equal-channel angular pressing procedure was investigated. Mathematical simulations of stress and temperature fields were applied, too.

15. M. V. Degtyarev, T. I. Chashchukhina, L. M. Voronova; *Institute of Metal Physics, Ural Division of Russian Academy of Sciences, Yekaterinburg, Russia*

Thermal Stability of Nanomaterials Formed by Severe Plastic Deformation. Austenite steel, copper, iron and structural steels represent three classes of materials in which different relaxation processes occur during high-pressure torsion at room temperature. These processes are pressure induced transformation, dynamic recrystallization and cold hardening, respectively. At high strains all these processes result in the formation different-type structures which consist of structure elements having high-angle boundaries and an average size of 50 - 100 nm. The structure

formed by identical structure elements demonstrates the highest thermal stability. In copper the dynamic recrystallization prohibits formation of homogeneous structure contrary to cold hardening in iron. The pressure induced transformation delays the formation of the same structure.

16. S. V. Dobatkin ,*, A. A. Kuznetsov*, G. A. Salishchev, Ya. Yu. Beigelzimer***, D. V. Orlov***;** *Baikov Institute of Metallurgy and Materials Science, Russian Academy of Sciences, Moscow, Russia, *Moscow State Steel and Alloys Institute (Technological University), Moscow, Russia, **Institute for Metals Superplasticity Problems, Russian Academy of Sciences, Ufa, Russia, ***Physics and Technology Institute of the National Academy of Sciences of Ukraine, Donetsk, Ukraine*

Submicrocrystalline Structure of Oxygen-Free Copper after Different Methods of Severe Plastic Deformation. The structure and properties of oxygen-free copper were studied after different types of severe plastic deformation (SPD): equal-channel angular pressing (ECAP), multiaxial deformation (MD), twist extrusion (TE), and accumulative roll bonding (ARB) as a function of the degree of deformation (to a true strain of 30-50) and temperature of subsequent heating. Electronmicroscopic examination revealed the similar and different features of the processes of structure formation upon severe plastic deformation by different methods and to compare the quantitative characteristics of the obtained submicrocrystalline structures. The mechanical properties of copper after different SPD treatments were analyzed. The thermal stability of the strengthening increases in accordance with the following row of the treatments: ARB - ECAP - MD - TE.

17. Yu. F. Ivanov, E. V. Naidenkin, S. V. Shagalina*, Y. T. Zhu, Yu. R. Kolobov, S. V. Dobatkin*;** *Institute of Strength Physics and Materials Science of RAS, Sibirean Branch, Tomsk, Russia, A. A. Baikov Institute of Metallurgy and Materials Science of RAS, Moscow, Russia, **Los Alamos National Laboratory, USA*

Structure and Phase Transformations in 0,1%C-Mn-V-Ti Steel During High Pressure Torsion. The electronmicroscopic (TEM) analysis of the 0,1 % C-Mn-V-Ti steel taken in the initial hot-forged and quenched states after severe plastic deformation (SPD) by torsion under 6 GPa pressure was studied. The samples had been deformed up to 5 revolutions which corresponds to logarithmic strain e = 6,3. The TEM examination of the 0,1 % C-Mn-V-Ti steel deformed after quenching revealed a cellular-like oriented fragmented structure with isolated equiaxed grains of ~ 65 nm in size inside the oriented structure. Upon SPD of this steel initially taken in the hot-forged condition, equiaxed coarse cellular structure areas are observed in addition to the oriented fragments. The average size of the grains formed in the oriented fragments - 95 nm, is larger than that observed in the quenched and deformed state. This work was supported by Grant ISTC № 2114.

18. S. V. Dobatkin, *, V. V. Zakharov, G. I. Raab***, T. D. Rostova**, E. N. Bastarache*, A. G. Kishchenko*;** *A. A. Baikov Institute of Metallurgy and Materials Science of RAS, Moscow, Russia**; ***Moscow State Steel and Alloys Institute (Technological University), Moscow, Russia, **All-Russia Institute of Light Alloys, Moscow, Russia, ***Ufa State Aviation Technical University, Ufa, Russia*

Warm and Hot Equal Channel Angular Pressing of Al-Mg-Sc-Zr Alloys. The structure and properties of the 01515 (Al-3,1 % Mg-0,31 % Sc -0,08 % Zr) and 01570 (Al-5,9 % Mg-0,3 % Sc-0,08 % Zr) aluminum alloys were studied after equal-channel angular (ECA) pressing under the conditions of warm and hot deformation. ECA pressing was performed at temperatures of 200 and 400 °C. The grain sizes of the 01570 and 01515 alloys after ECA pressing at 200 °C were 380 and 550 nm, respectively. At 400 °C, the structure of about 6 μm in average grain size is formed in the 01515 alloy. The maximum strengthening effect is observed after aging of the deformed alloys at 300 °C. The work was supported by the Russian Foundation for Basic Research, project no. 03-32673.

19. S. V. Shagalina, E. G. Koroleva*, G. I. Raab, M. V. Bobylev*, S. V. Dobatkin ,*;** *Baikov Institute of Metallurgy and Materials Science, Russian Academy of Sciences, Moscow, Russia, *Moscow State Steel and Alloys Institute (Technological University), Moscow, Russia, **Ufa State Aviation Technical University, Ufa, Russia*

Formation of Submicrocrystalline State of 0,14 % C and 0,1 % C- 0,003 % B Low-Carbon Steels During ECA Pressing. The structure and properties of 0,14 % C and 0,1% C - B low-carbon steels taken in two initial states, bainitic and ferritic-pearlitic, were studied after cold equal-channel angular (ECA) pressing. ECA pressing leads to the formation of only partially submicrocrystalline structure with a grain size of 150 - 300 nm, depending on the steel alloying and initial state. The finest structure with the elements of 190 nm in size is obtained in the 0,1 % C - B steel. The strength of the 0,1 % C - B steel after cold ECA pressing (UTS =1235 MPa) meets the specifications of fasteners of the R120 strength grade. The strength of the deformed 0.14% C steel is close to the R80 strength grade.

20. J. Kliber, H. Staňková*, O. Žáček, B. Mašek*;** *VŠB-TU Ostrava, Ostrava, Czech Republic, *TU Liberec, Liberec, Czech Republic, **Vitkovice Research and Development, Vitkovice, Czech Republic*

Comparison of Various Methods for Structure Analysis and Strength Properties of TRIP Steel. The development of modern multi-phase steels requires the continual improvement of their structures evaluation. Effective and economic determination of the volume fraction of individual phases were find. The innovative technologies must be designed in accordance with technological parameters in order to be able to reach required deformation, resulting shapes and appropriate mechanical properties. The article describes experience with various analytic methods and processes of specimen preparation. This material was obtained during incremental and as hot rolled thermomechanical TRIP steel treatment with intensive deformation. Among others method the microstructure was assigned through X-ray diffraction (retained austenite) and with assistance of software for image analysis from SEM. Gleeble 1500 was used for other plastometrical simulation and mathematical description of full stress-strain curve was evaluated.

21. T. Kvačkaj, I. Mamuzić*, P. Škodroňová, M. Fujda, I. Pokorný; *Faculty of Metallurgy Technical University of Košice, Košice, Slovakia *Faculty of Metallurgy University of Zagreb, Sisak, Croatia*

Influence of Reheating and Cooling Conditions on Structural Changing of Trip Steel. Paper deal with experimental searching of reheating temperature and time on changing of austenite grain size in steels grade C-Mn-Si a C-Mn-Si-Nb. Mathematical description of austenitic grain size on reheating parameters was base on experimental results. Influence of various cooling rate s on structural changing was searched. The CCT diagrams for observe chemical composition were made.

22. V. P. Lamachevsky, I. V. Makovetsky; *Pisarenko Institute for problems of Strength, National Academy of Science of Ukraine, Kiev, Ukraine*

Pig-iron Deforming and Strength at Complex Conditions under Stress. At deforming in these materials in microvolumes hot spots of

destruction are formed due to local high internal stress which brings to loosening of structure as a result. Experimental data on peculiarities of deformation, structure damage and forge pig-iron strength collected while testing tube samples under axial force and internal pressure have been analyzed in this report. It has been shown that the material structure degradation depends on its different condition under stress. The appropriate criteria for ultimate yielding conditions description and materials destruction have been established.

23. E. V. Vorob'ev, T. V. Anpilogova; *Pisarenko Institute for Problems of Strength, National Academy of Science of Ukraine, Kiev, Ukraine*
Triggering Mechanism and Manifestation of Low-Temperature Jump-Like Deformation of Metals. The effect of low-temperature discontinuous yielding of metals realized at temperatures below 30 K is studied. A model is proposed according to which the triggering and synchronizing mechanism for a discontinuous yielding of metallic materials is the initial jump in temperature and stress due to a break through the barriers by the most powerful dislocation concentration. Dynamic and thermally-activated dislocation motion corresponds to the appearance of uniform and localized strains. Based on the analysis of tensile and strain hardening curves at a temperature of 4 K for a specimen of 03Х20Н16АГ6 steel, an assessment of these components of low-temperature jump-like deformation was performed. The amount of the uniform specimen elongation in the total elongation can reach, in this case, 30 %.

24. E. V. Vorob'ev, V. A. Strizhalo; *Pisarenko Institute for Problems of Strength, National Academy of Science of Ukraine, Kiev, Ukraine*
Temperature- and Force-Based Criterion for the Stability Loss of Elastoplastic Deformation of Metals under Conditions of Deep Cooling. A system of phenomenological criteria defining the conditions of realization of the low-temperature discontinuous yielding effect was formulated and the relationships between them were established. On their basis, a combined temperature- and force-based criterion for the stability loss of elastoplastic deformation of metals was obtained, which makes it possible to calculate both maximum critical temperature T_{max} and critical stress σ_c for a given temperature level T_c. To this end, use is made of two material characteristics, heat capacity and discontinuous yield stress experimentally determined at some temperature T_{c_0}. The applicability of the combined criterion is demonstrated using АМг6 aluminum alloy and 03Х20Н16АГ6 austenitic steel as an example. For these materials, in the temperature-stress coordinates instability areas were obtained, which are limited by the true values of ultimate strength at the corresponding values of $T_{c_{max}}$ and the curves of $\sigma_c = \sigma(T_c)$.

25. M. Besterci, O. Velgosová*, F. Lofaj, L. Kováč; *Institute of Materials Research Slovak Academy of Sciences, Košice, Slovakia, *Faculty of Metallurgy Technical University of Košice, Slovakia*
Superplastic Deformation of Al-Al_4C_3 Composites. Deformation of the Al-Al_4C_3 composites with different volume fraction of Al_4C_3 phase was investigated at different temperatures (293 - 723 K) and different strain rates ($2{,}5\cdot10^{-5}$ s^{-1} - $1{,}0\cdot10^{-1}$ s^{-1}). At temperatures 673 - 723 K and at the highest strain rate of $1{,}0\cdot10^{-1}$ s^{-1}, a significant ductility increase was observed. TEM analysis suggests the onset of superplasticity may be the result of dynamic grain polygonization, grain slip and rotation, partial recrystallization and dislocation creep in the tested system, which is known as strain induced dynamic recovery. Increase of the volume fraction of secondary phase in the studied composite resulted in a shift from slip on grain boundaries controlled mechanism to the grain rotation controlled deformation mechanism.

26. V. G. Barylo; *Pisarenko Institute for Problems of Strength, National Academy of Science of Ukraine, Kiev, Ukraine*
Stable and Unstable Deformation of the Defect-Containing Components. The method of calculating the limiting state of solids built on known elasticity relations is proposed to describe stable and unstable deformation of the defect-containing material. The basis for the method is evaluating the rigidity distribution over the body volume. The limiting state of the body is associated with the total negative rigidity of the body and loading system. An increase in damaged area sizes that are much smaller than component sizes is shown to result in stability and carrying capacity losses of the whole component at a certain rigidity of this area. Rigidity calculations for the bodies in the form of a sphere, cylinder or plate with inclusions as well as a crack-containing plate are cited.

27. P. Fajfar, M. Kočar, G. Kugler, R. Turk; *Faculty of Natural Science and Engineering, University of Ljubljana, Ljubljana, Slovenia*
Similarity of Contour of an Inhomogeneous Necking for Hot Tensile Test. Presumptions that for hot tensile test a rule for the formation a contour of an inhomogeneous necking regarding temperature, strain rate and strain is verified. Several tensile specimens were tested at different thermo-mechanical parameters. Contours of necking regions were measured with a microscope. Evaluation of similarity was done according to the correlations: temperature-elongation, temperature-neck, strain rate- elongation, strain rate-neck, force-elongation and according to a strain hardening rate and a softening rate.

28. M. Terčelj, G. Kugler, R. Turk, P. Fajfar, T. Rodič; *Faculty of Natural Science and Engineering, University of Ljubljana, Ljubljana, Slovenia*
Newly Designed Plane-Strain Spike Forming Test Rig for Determination of Friction Coefficient in Metal Forming. In this contribution an improved test rig (plane-strain forming test) with corresponding developed mathematical tools for friction calculation will be presented. The main advantage of presented test in comparison to other test is inverse identification of friction coefficient from measurements of external processing parameters such as forming force, torque and displacement on free surfaces of the deformed workpiece that increased the accuracy of calculated friction coefficient. The tests are designed to be used in conjunction with inverse identification and reconstruction techniques. The inverse approach is based on the least squares method. The governing equations were discretised by finite element method.

29. D. Ćubela; *Faculty of Metallurgy and Material Science University of Zenica, Zenica, Bosnia and Herzegovina*
The Research of Technological Parameters Influence on the Process of Nitinol Fabrication and Plastic Deformation. Titanium and nickel alloy, with 48 - 55 at. % Ni (rest Ti), named Nitinol has property of thermal and mechanical memory and its properties and application depends strongly on a fabrication processes. Nitinol was produced in semi-industrial conditions. Testing results of the quality of the obtained alloy are related to technological parameters of the production and processing. The aim of this work is to give an answer to the question which technological parameters are most influential and possible for the quality control what kind of corrections regarding literature instructions are needed for successful production of Nitinol for given conditions.

30. F. Trebuňa, F. Šimčák, M. Buršák*, J. Bocko, P. Senko, P. Šarga; *Faculty of Engineering Technical University of Košice, Košice, Slovakia, *Faculty of Metallurgy Technical University of Košice, Košice, Slovakia*

Quantification of Residual Stresses in Hot Rolled Sheets by the Hale Drilling Method. The paper deals with the problems of quantification of residual stresses in hot rolled sheets produced under various regimes. On the base of stress distribution along width and thickness of the belt is pointed out on possibilities of belt deformation from the plane as a result of action of torsional moment as an integral internal quantity in cross-sect1on. For the non-uniformly distributed stresses along the thickness of the sheet the new method for residual stresses determination was developed where the stress non-uniformities along the length of the hale are considered. This method was applied in the paper.

31. T. Večko-Pirtovšek, R. Turk*, G. Borchardt, M. Terčelj*;** *Metal Ravne d.o.o., Ravne na Koroškem, Slovenia*, **Faculty of Natural Science and Engineering, University of Ljubljana, Ljubljana, Slovenia*, ***TU Clausthal, Germany*
Interfacial Reactions during Cladding of Steel by Hot Rolling. Cladding of commercial steels (tool steel OCR12VM - AISI D2 - DIN X155CrVMo12-1 and construction steel EC100 - DIN 20MnCr5) was studied by laboratory hot rolling experiments under the same thermomechanical conditions at which commercial rolling of compound strips is performed, i. e. at a temperature of 1150 °C with a degree of deformation of 0,5 and a slow cooling rate. The relations between the thermomechanical conditions during hot rolling and the mechanical properties of the compound strip are discussed in terms of the properties of the interfacial layer. The experiments demonstrate that cladding of the two steels is achieved. The moderate tensile strength of the compound material is due to a pure ferrite layer in the contact zone.

32. G. G. Shlomchak, I. Mamuzić*, M. A. Mironenko; *National Metallurgical Academy of Ukraine, Dnepropetrovsk, Ukraine*, **Faculty of Metallurgy University of Zagreb, Sisak, Croatia*
Peculiarities of Rheologically Complex Metals Flow while Rolling it with Superreductions. It was established that while rolling a rheologically complex metal under conditions of the moderate ($\varepsilon \approx 0{,}2$ - 0,3) single degrees of deformation in consequence of exceptionally high unevenness of deformation in the section of zone of deformation being near the contact with rolls are forming nuclei of the maximum intensity of the rate of deformation, H_{max}. During the time of passage through these nuclei metal is softening and the surface layers of metal are flowing with the rate greater than the depth ones to the excit from zone of deformation. In the case of rolling rheologically complex metal under conditions of the extra great single deformations ($\varepsilon \geq 1$) the nuclei H_{max} close up forming the common zone of metal softening. In the end this decreases energy expense for deformation.

33. I. G. Brodova, I. G. Shirinkina, I. P. Lennikova; *Institute of Metal Physics of Ural Division Russian Academy of Sciences, Yekaterinburg, Russia*
Deformation Dissolution of Transition-Metals Aluminides upon Torsion under Pressure. Metallographic, X-ray diffraction and electron microscopy were used for study the effect of a crystal structure on a kinetic and a mechanism of deformation dissolution of metastable and stable aluminides in Al alloys with transition metals. It was established that metastable aluminides with the cubic lattice $L1_2$ are deformed along with the Al matrix as a continuum medium. For example, the crystals having monoclinic lattices are broken into isolated small fragments with a size of 10 - 20 nm. The interphase boundary between the structure constituents is retained and the deformation is localized in crystal microvolumes.

34. L. V. Kravchuk, R. I. Kuriat, K. P. Buyskikh, Ye. A. Zadvornyy, S. G. Kiselevskaya; *Pisarenko Institute for Problems of Strength, National Academy of Sciences of Ukraine, Kiev, Ukraine*
Study of Damage Kinetics in Superalloys under Thermal Cyclic Loading in Gas Flow. The authors have studied the character and mechanisms of damage in Ni-based superalloys of various crystalline structures, both uncoated and with protective coatings including multilayer ones, under high-temperature thermal cyclic loading in a gas flow. The intensity of irreversible changes in the material surface layers has been found to be governed by the corrosiveness of the high-temperature gas flow, time variation of temperature, and the level of acting thermal stresses.

Plate and shape rolling

35. J. A. Dinnik, M. I. Babenko, J. N. Nikolaenko, K. G. Kolesnychenko; *National Metallurgical Academy of Ukraine, Dnepropetrovsk, Ukraine*
Process Control of the Continuous of Multithread Rolling. Multithread rolling in the draft and intermediate groups of continuous finely sorted and wire mills results in additional violation of stability of process because of change of amount of the simultaneously rolled bars. The optimum terms of joint work of multithreads and of single thread groups of continuous of high qualities and wire figures are certain. Algorithms of management of the speed mode of multithreads groups by running in size inflexibilities of mechanical descriptions of drive engines of cages are developed.

36. V. V. Chygyryns'ky, I. Mamuzić*, G. I. Bergeman; *National Metallurgical Academy of Ukraine, Dnepropetrovsk, Ukraine, *Faculty of Metallurgy University of Zagreb, Sisak, Croatia*
Investigation of Schedules of the Thermomecanical Treatmen for the Complex Form Rolled Products under Conditions of the Heavy Shape Mill. The experimental investigations of the thermo mechanical metal treatment upon mechanical properties of the rolled product we carried out in conditions of the rolled mill 550 of Petrovsky metallurgical plant (Dnepropetrovs'k). Different schemes of the thermo mechanical treatment was test in industrial conditions on the shape SVP -22 (mine support).

37. D. Ćurčija, I. Mamuzić; *Faculty of Metallurgy University of Zagreb, Sisak, Croatia*
Optimisation Process of Strip Cold Rolling Solutions of differential equations for smooth surfaces and transversal strip roughness with inertial lubrication forces were analyzed. Ten factors impacting the height of lubrication film at material input deformation zone were systemized through: rheologic lubrication properties, kinematics of technological processes and geometric characteristics of rolling processes. Linear optimization is based on the process of cloning, where two methods are proposed (rotary and step-like) and it contains three variants of adjustment of technological factors. The cloning process disposes of a possibility of the control of differential equations. The cloning is carried out with the Osnup tool that proposes a static and a dynamic method of transmission of similarity criterion over a singular point.

38. D. Ćurčija, I. Mamuzić; *Faculty of Metallurgy University of Zagreb, Sisak, Croatia*
Optimising of Lubrication Layer on the Transversal Strip Roughness. Solutions of differential equations for smooth surfaces and transversal

strip roughness with influence of inertial lubrication forces are analyzed. Ten factors influencing the height of lubricating film at input cross section of metal deformation zone are systemized according to rheological properties of lubricants, kinematics of technological process and geometric characteristics of rolling process. At dressing processes, inertial forces of lubricants have a weak influence on the height of lubrication film at input cross-section of deformation zone. Above the nominal height of lubrication layer the roughness of strip surface also determines the form of lubrication layer in a congruent way, while under the nominal height there is an inversion - concave planes of lubricating layer are transferred into convex ones. A correction of logarithm is presented for the processes of rotary cloning of the solutions of differential equations.

39. D. Čurčija, I. Mamuzić; *Faculty of Metallurgy Sisak University of Zagreb, Sisak, Croatia*
The form of Lubricant layer at Strip Dressing Process. Geometric form of strip lubricant layer in front of rolls at dressing process is analyzed. The influence of it height on the height of lubricant layer on input cross section of deformation zone of metals where there is a strong influence just in small areas of angles of engagement. By the use of Monte Carlo method, differential equation is solved and it gave extreme geometric properties of lubricant layer input cross section of deformation zone. This geometry is possible and achievable at dressing process with high quality lubricants when an economy of lubricant in technological process is to be achieved.

40. R. Fabík, T. Kubina, J. Kliber; *VŠB-TU Ostrava, Ostrava, Czech Republic*
Influence of Undercooled Surface of CCSP on Core Distribution of Longitudinal and Transversal Stresses During Hot Rolling. Investigation of causes of cracking in the interior of thick rolled products. First part of the study concerns research into possible causes of cracking with respect to termal conditions of rolling and microstructural features of steel. Examination of microstructure revealed casting cracks on prior austenite grain boundaries, which might initiate formation of the critical cracks. Second part of paper contains FormFEM and Forge2005 program simulation-aided feasibility study of enhancing the amount of reduction in the bloom centre by means of bloom surface undercooling. Comparison of common rolling process and the newly-designed process is provided. Primary attention has been paid to the magnitude (and sign) of the longitudinal and tansversal stresses in the bloom cross-section and to penetration of strain into the bloom centre.

41. D. Golja, J. Prgin*, A. Prelošćan, M. Golja; *Faculty of Metallrgy University of Zagreb, Sisak, Croatia, *TLM - Šibenik, Croatia*
Parameters of Plastic Deformation of Aluminium by Hot Rolling. This paper shows the review of plastic processing of aluminium and aluminium alloys and describes the parameters of processing by hot rolling. For the aluminium alloys 1100, 5052, 5182 the parameters of each pass by hot rolling on reversible quatro rolling mill have been described.

42. (F. Vode, A. Jaklič, B. Brezovec, R. Robič*, A. Košir*, F .Perko*; *Institute of Metals and Technology, Ljubljana, Slovenia***, ****Acroni d.o.o. jesenice, Slovenia*
Calculation of the Deformational Energy During Slab-Width Rolling. This paper focuses on an automatic calculation of the deformational energy consumed for slab-width rolling. For the calculation of the deformational energy consumed during slab-width rolling a mathematical model of an unloaded edger was built. The edger roller was treated as a stiff, rotary-driven body. The model calculates the consumed power for the accelerations of the unloaded edger using the velocity as an input signal. The existing measurement of electrical power and the model-estimated power of the unloaded edger make it possible to estimate the power consumed for the slab-width rolling only. The integration of the power over every pass through the edger yields the deformational energy.

43. M. Terčelj, J. Bračič, G. Kugler, P. Fajfar, R. Turk; *Faculty of Natural Science and Engineering, University of Ljubljana, Ljubljana, Slovenia*
Determination of Response of an AC Electromotor on Various Course of Load during Metal Forming. An AC electromotor is very frequent used electromotor on metal forming machines, i.e. rolling mills, press machines, forging machine, etc. The loads during metal forming process could change from relatively low to very high values during forging on one side and it can keep relatively constant values during rolling on other side. Ability to calculate the revolutions of electromotor is basic for further increase of productivity on hot metal forming machines and optimization of the process. In this work a new approach for calculation of electromotor revolutions during forming process will be presented and verified on measured (experimental) data obtained on rolling mill and forging machine. Good accordance's between measured and predicted values of revolutions were obtained.

44. P. Fajfar, R. Robič*, M. Terčelj; *Faculty of Natural Science and Engineering, University of Ljubljana, Ljubljana, Slovenia***, ****Acroni, d.o.o., Jesenice, Slovenija*
Pinion Damage Due to Asymmetrical Distribution of Rolling Torque on Upper and Lower Driving Shaft. Toothed wheel of the rolling mill pinion are often damaged due to excessive load. Distribution of the total rolling torque on a lower and upper driving shaft was measured. Generally rolling torques on the lower driving shaft are greater than those on the upper. In some cases upper rolling torques for a moment exceed the value of the lower or even take over the whole torque. Maximal differences between upper and lower rolling torque appear in the first three passes. After that the differences decrease towards the last passes.

Extrusion

45. G. Kugler, R. Turk, T. Večko-Pirtovšek*, M. Terčelj; *Faculty of Natural Science and Engineering University of Ljubljana, Ljubljana, Slovenia, *METAL Ravne, Ravne, Slovenia*
Wear Beahaviour of Nitrided Microstructures of AlSi H13 Dies for Hot Extrusion of Aluminium. This study was based on the analysis of microstructure on dies with intentionally prepared deep and narrow gaps which were nitrided by various manufacturers of equipment for gas and ionic nitriding. The manufacturers chose their own nitriding parameters in order to achieve an optimal wear resistant microstructure. The microstructures obtained showed differences with regard to the presence or absence of a compound layer (white layer), its thickness and its ε/γ' phase ratio (XRD), nitriding depth and microhardness profile. The wear testing results show differences in behaviour of the nitrided samples. The differences in the actual structures, microstructures, hardness, etc. explain the high level of scattering in die life in actual industrial applications.

46. P. Cvahte, P. Fajfar*, G. Kugler*, R. Turk*, M. Terčelj*; *Impol d.o.o, Slovenska Bistrica, Slovenia*, **Faculty of Natural Science and Engineering, University of Ljubljana, Ljubljana, Slovenia*

Experimental Technique for Tracing of Cooling Efficiency on Die Bearing Surface During Hot Extrusion of Aluminum. The paper will present an improved method of temperature measurement on the bearing surface and at different distances (cca 0,2 - 1,5 mm) from the bearing surface of an industrial die on 55 MN press machine. Higher extrusion speeds resulted in higher measured temperatures that could be reduced by nitrogen cooling of the die. The reduction of temperature is higher as it was considered so far. The applied method of temperature measurements is good either from the point of economic effect of industrial technologies, i.e. for increased productivity and for looking for technological solutions to cool industrial dies locally (close to the die bearing surface) more intensively that was done at extruding of square profiles. In this case the extrusion speed and obtained mechanical properties of extruded profiles were considerably increased in comparison to the previous methods.

Wire drawing

47. D. Ćurčija, I. Mamuzić; *Faculty of Metallurgy University of Zagreb, Sisak, Croatia*

Mathematical Modelling of Metal Drawing Process. Analysis of theoretic aspect of the influence of inertial lubricant forces on the process of cold metal drawing was performed mathematically. The influence of die structure properties, rheologic lubricant properties as well as kinematics influence of drawing speed and suggested lubricant removing device assembled in the die clearance was taken into consideration. Primary part of the analysis was performed over pressure gradients in which analytical solutions of differential equations were incorporated.

48. D. Ćurčija, I. Mamuzić, F. Vodopivec*; *Faculty of Metallurgy University of Zagreb, Sisak, Croatia, *Institute of Metals and Technology, Ljubljana, Slovenia*

Theoretical Calculation of the Lubrication Layer Thickness by Metal Drawing. The calculation of the lubricant layer thickness using a fluid mechanics approach is shown for the case of cold drawing of metals. Examples of calculation for a solid lubricant layer and a different geometry of the die entering angle are shown. The calculation of the effect of inertial force by great drawing speed on lubricant layer thickness is treated, also.

49. M. Anatoliy, A. M. Dolzhanskiy, D. U. Klyuev, N. M. Ocheretna; *National Metallurgical Academy of Ukraine, Dnepropetrovsk, Ukraine*

Thickness Forming of Technological Lubricant Film at Wire-drawing in Rotating Die. Experimentally, using the gravimetric method, and theoretically the dependence of dry soapy lubricant thickness and regime of friction in the deformation zone on steel wire-drawing speed terms in the rotating die was defined. It was shown, at the satisfactory coincidence of theoretical and experimental data, that the maximum of lubricant film thicknesses and proper minimum of friction parameters was observed at speed of die rotation 0,2 - 0,5 from speed of drawing. These results allow optimizing the wire-drawing process using rotating dies.

50. M. Anatoliy, A. M. Dolzhanskiy, N. M. Ocheretna, D. U. Klyuev; *National Metallurgical Academy of Ukraine, Dnepropetrovsk, Ukraine*

Wire twisting on the Wire-drawing Mills Drums Working with Metal Accumulation. The theoretical determination of wire twisting corner during of its removing up from drums of magazine type at wire-drawing mills, working without sliding, was executed in the process of the continuous wire-drawing. It was shown that the relative twisting corner (on a base length) is straight proportional to the height level removing from its initial position of the coil level, inversely proportional to the radius of a drum and diminishes at the increasing of the base length. These findings allow taking into account additional deformation of metal twisting at the projection of rational wire deformation routes.

51. I. M. Lomov, A. M. Dolzhanskiy, O. B. Lomova, E. O. Petlyovaniy; *National Metallurgical Academy of Ukraine, Dnepropetrovsk, Ukraine*

Steel Rod Twisting and Ovalization in Roller Scale-breaker in a Flow with Wire-drawing. The scale-breaker influence on twisting and ovalization of steel low carbon rod in a flow with wire-drawing is experimentally investigated. It was shown that the rod passage, even through one pair of scale-breaker rollers, located in one plane, was accompanied by metal twisting deformation of 90 - 120° and was occurrence by its ovalization up to 5 %; the ovalization decreased at reduction of a rod diameter. The received results can be useful for rational modes project at the wire-drawing.

Tubes production

52. I. V. Orynyak, V. M. Vasylyuk*, A. V. Bohdan; *Pisarenko Institute for Problems of Strength National Academy of Sciences of Ukraine, Kiev, Ukraine; *JSC "Ukrnafta" Kiev, Ukraine*

Numerical Modelling of the Process of Pulling the Pipeline of Smaller Diameter through the Bigger One. The internal inspection by the intelligent pig had revealed the poor technical condition of the 2 km long transit oil pipeline section (D = 1020 mm) under the river Psel due to the large number of deep corrosion defects. It was decides to insert in it the new pipeline section of the smaller diameter (D = 720 mm) for the oil transportation while keeping the bigger one as a casing. But the experience of pulling the smaller pipeline through another one was absolutely absent at that time. The situation was complicated by the relatively curved profile of the casing. The main destination of the software developed was to predict the integrated pulling force and the distribution of the contact forces between the supporting rings of the smaller pipeline and casing.

53. R. Križanić; *Tube Rolling Mill Sisak, Sisak, Croatia*

Tube Critical Deformation at Pilger Rolling Stand. The realized deformation and steel critical deformation is determined by working conditions. If the realized deformation is equivalent to the critical one or greater than it, cracks appear on the surface. The goal of the work is to determine the realized deformation at tube manufacture from our steel according to API SCT Norm, dimensions 174,80×8,05 mm and 244,48×11,99 mm

on pilger rolling stand, cause surface craks in the firm Valjaonica cijevi Sisak d.o.o. (Tube Rolling Mill Sisak) Based on the research results, it was determined that tube deformation take place under critical boundary, i.e. pilger rolling stand deformation size does not cause surface craks (the cause should be sought in charge quality and other working phases).

54. D. Tkalčić; *Tube Rolling Mill Sisak, Sisak, Croatia*
Tube Surface Preparation for Cold Deformation in Reactive Oil. The goal of the work is the possible fabricating of surface high requirements cylinder tubes (Degree of surface roughness R_z max 0,6 microns). Surface preparation means in plant conditions in reactive oil is related to: - possible drawing of two passes with a relatively high reduction degree, - possible immersion preparation, - tube behavior at cold drawing and achieved surface quality.

55. D. Ćurčija, I. Mamuzić, F. Vodopivec*; *Faculty of Metallurgy University of Zagreb, Sisak, Croatia, *Institute of Metals and Technology, Ljubljana, Slovenia*
Lubrication Flow at Seamless Tube Rolling. An approximate analytical solution of lubricant layer calculation was derived at continuous rolling of seamless tubes for micro and nano technology on long floating mandrel. In the area of nano technology geometrical characteristics of the process overpowers the rheological and kinematical one. The solutions were derived for tools and tubes smooth surfaces and offer a possibility of optimizing quality lubricant for micro technological processes. In nano calculations of lublicant layer the height of the layer is supposed to be artificial irrational value so that it would not to come to the breaking of chains in mathematical calculation. Mathematical analysis proved justification of introducing new geometrical characteristics of mandrel in technology.

56. A. M. Gałkin, A. Rząsowska-Przała, A. Górniak; *Faculty of Materials Processing Technology and Applied Physics Czestochowa University of Technology, Czestochowa, Poland*
The New Method of Producing Small Diameter Pipes and Bars of Hard Deformation Steel in the Skew Roll. In the Moscow Institute of Steel and Allays a new method of obtaining small and medium diameter bars and pipes out of steel, non - ferrous metals and their allays has been worked. In enables the hot production of pipes and bars which dimensions are as follows 14 - 30 mm. The method of skewing thick sided, small diameter pipes and bars in the skew roll reveals a range of important advantages. The aim of the present study is to characterize the method of the slant rolling and compare this method with different ways of receiving bars and pipes. The article presents a method of calculating the price of a new mini roll, which is optimal both for the producer and a prospective customer.

Sheet metal forming

57. Z. Keran, M Škunca, M. Math; *Faculty of Mechanical Engineering and Naval Architecture University of Zagreb, Zagreb, Croatia*
Finite Element Approach to Analysis of Axisymmetric Reverse Drawing Process. The intention of this research is to make analyze of deep drawing Cr-Ni stainless steel process. The research is related to forces that appear in machine tool during the process and also to material stress and its behavior. The results are taken from two sources and their comparison is made. The first source of results are experiments made on hydraulic press, and the other source are results obtained by creation of finite element model (FEM) and process simulation on MSC Marc Mentat program package. The measurements are made in cases of different reduction coefficient and different tool material. Comparison that is given is related to punch and pressure plate forces, and the state of material stress for each reduction coefficient is observed too. Datasheets and force diagrams present the results, and material stress can be seen on figures that are result of the simulation.

58. M. Gavas; *Technical Education Faculty Dumlupinar University, Simav-Kutahya, Turkey*
Increasing the Deep Drawability of Al-1050 Aluminum Sheet using Multi-Point Blank Holder. Aluminum alloys have been widely used in the fields of automobile and aerospace industries. Due to their bad cold-formability in deep drawing, a lot of forming methods have been implemented to increase the drawing height and the limiting drawing rate (LDR). The conventional deep drawing process is limited to a certain limit drawing ratio beyond which failure will ensue. The purpose of this experimental study is to examine the possibilities of increasing this limitation using the multi-point blank holder. The results from the experiments showed that the multi-point blank holder is effective way to promote deep drawability of Al-1050 sheet.

59. M. Jurković, I. Karabegović*, M. Mahmić*; *Faculty of Engineering University of Rijeka, Rijeka, Croatia, *Faculty of Technical Engineering University of Bihać, Bihać, Bosnia and Herzegovina*
An Analyse and Modelling of Spinning Process without Thickness Reduction. It is gotten through spinning process the different axial-symmetric parts by acting spinning roller on blank of sheet metal, which is shaped through a chuck. In the paper is shown an analyze of stressed and strained state, forming force of spinning modelling process. On the ground of experimental results it is made mathematics modelling of spinning forming force. The obtained mathematical model describes enough accurate and reliable (P = 0,98) the spinning forming forces.

60. M. Jurković, I. Karabegović*, H. Rošić*; *Faculty of Engineering University of Rijeka, Rijeka, Croatia, *Faculty of Technical Engineering University of Bihać, Bihać, Bosnia and Herzegovina*
The Theoretical Fundamentals and Experimental Analyze of Flow Formingg Process. The rotating pressing out has wide application at the cylindrical part producing. In the paper is made the theoretical analyze of stress strain state at the forming zone as well as the forces (F_A, F_T, F_R.) component analyse. At the experimental process analyze is shown three component sensor tool for measuring of pressing out force components and special origin tools with building sensors for measuring of contact normally stress (p_n and tangent stresses (τ_x, τ_y).

Reheating process

61. L. Lazić, P. Jelić, V. Brovkin*, V. Veljača;** *Faculty of Metallurgy University of Zagreb, Sisak, Croatia, *National Metallurgical Academy of Ukraine, Dnepropetrovsk, Ukraine, ** Tube Rolling Mill, Sisak, Croatia*

Optimisation of Charge Heating Conditions in Rotary-Hearth Furnace. Considering that the furnace heating efficiency is generally below the designed heating capacity it is necessary to determine furnace outputs, charge formats, steel quality and final heating temperature. By using the model for simulation and by varying the temperature and flue gas composition, optimal heating conditions of rotary-hearth furnace will be determined for individual charge formats and steel quality with respect to specific fuel consumption and sca1e formation. Results will be compared to those obtained by experimental measurements for various temperature regimes.

62. M. Kundak, J .Črnko; *Faculty of Metallurgy University of Zagreb, Sisak, Croatia*
The Quality of a Steel Charge Heating and the Load of the Annular Bootom of a Rotating Hearth Furnace. Providing a correct thermal regime the consumption of heat is reduced as well as the loss of steel because of its surface oxidation. Using the data about the steel charge and the furnace working space geometry and particular requests in connection with the temperature of the charge and the decrease of the rotating hearth furnace heating capacity, the temperature of gases combustion and the inside walls surface along the working space of the furnace are defined by a calculating method. Calculated parameters are used as the initial parameters for the charge heating in working conditions. The steel oxidizing loss as well as the influence of the oxidizing loss on the total heat consumption in the furnace are defined by a calculating method and by direct measuring too. Having the insight of the steel oxidizing loss is a presumption for a more complete heating control as to ensure high quality products of a seamless pipes rolling mill.

63. L. Lazić, M. Kundak, P. Jelić, M. Herout*; *Faculty of Metallurgy University of Zagreb, Sisak, Croatia, * Tube Rolling Mill, Sisak, Croatia*
Analysis of Heating Rate and Temperature Stresses in a Charge. In many cases, due to the complicated conditions of heat exchange in the furnace chamber and the shape of the heated metal, heating conditions cannot be determined by means of traditional analytical calculations but must be found out experimentally. For that reason, a mathematical model of the heating process for a steel charge having an octagonal cross-section will be constructed on the basis of finite element analysis. Transient heat conduction analysis and thermal stress analysis will be performed in order to determine the allowable heating rate with regard to temperature distribution within the structure and the distribution of induced stresses and deformations. The latter are due to the heat transferred from the combustion gases and furnace lining by radiation as well as to the forced convection of combustion gases to the charge. The model will be verified with the help of experimental results obtained by temperature measurements of die main parameters of heating conditions.

Modernization

64. V. Živković; *Steelworks Split, Split, Croatia*
Results of Reconstructure of Reinforcing Steel Bars Mill in Steelworks Split. The old rolling mill in Steelworks split, was reconstructed by installing a new continuous type furnace, two break down stands for reforming billets 125×125 into 90×90 mm, new continuous rolling stands with 13 stands (5 new stands already installed) and new thermal treatment of bars or coils capacity in 170000 t/per year. The first results of this reconstruction are encouraged.

65. N. Devčić, I. Mamuzić*; *Sisak, Croatia, *Faculty of Metallurgy University of Zagreb, Sisak, Croatia*
Modernisation of Pilger Rolling Mill. The goal of the work is to improve shortcomesfirm in addition of usage and advantages in relation to rolling mills with more up-to-date technology. Modernisation should concern improving plants pilger rolling stands plants and push machine in the Tube Rolling Mill Sisak, Croatia.

66. I. Mamuzić, J. Črnko; *Faculty of Metallurgy University of Zagreb, Sisak, Croatia*
Survey of Research and Technology Development in Mechanical Metallurgy. First the paper presents the situation and development of research and technology of processing by reformatting (at heating process) all round the world, then the situation is parallel described in Croatia. By this comparison of basic and applicative research it was found out that a part of the research activities is successfully performed in Croatia. Unfortunately, as for technology there is a great falling behind which is difficulty to be recovered.

67. P. Cvahte, R. Turk*, G. Kugler*, A. Smolej*, P. Fajfar*, T. Rodič*, M Terčelj*; *Impol d.o.o, Slovenska Bistrica, Slovenia*, ******Faculty of Natural Science and Engineering, University of Ljubljana, Ljubljana, Slovenia*
Technological Chain of Bar Production From 6262 Alloys with Uses Up-Todate Numerical Models. Increasingly prices of row materials and energy means that experiments in industrial condition causes big expense and production jam. Industrials demands for making the numerical models, which are able to predict each phase of technological operations and interacting data between the models, are growing. Knowing buyers demands, which determinates product quality, it is necessary to adapt the whole technological product production chain. With the numerical models, adapted for users, we are in position for planning the process parameters and predicted their influence on products microstructure.

Miscellaneous

68. J. Zrnik*,, S. V. Dobatkin***,****, L. Kraus*, I. Mamuzic*****;** **Comtes FHT Ltd., Plzen, Czech Republic, **West Bohemian University, Plzen, Czech Republic, ***Baikov Institute of Metallurgy and Material Science, Russian Academy of Science, Moscow, Russia, ****Moscow Institute of Steel and Alloys, Moscow, Russia, *****Faculty of Metallurgy University Zagreb, Sisak, Croatia*
Low Carbon Steel Processed by Equal Channel Angular Warm Pressing. Commercial low carbon steel AISI 1010 was subjected to a severe plastic deformation technique called Equal Angular Channel Pressing (ECAP) at different increased temperatures. The paper describes the refinement of a course grained microstructure to submicrocrystalline structure by high strain plastic deformation. As temperature of ECAP straining is increasing the process of dynamic polygonization and recrystallization proceeds more effectively and subcrystalline structure is

formed by sectioning of ferrite elongated grains. The size of newly born polygonized grains is in range of 300 - 500 μm. The warm ECAP of the low carbon steel under specific testing condition leads to the formation of predominantly submicron grain structure. The formation of such of predominant submicrocrystalline structure resulted in significant increase of yield stress and tensile strength of the steel.

69. I. Alfirević; *Faculty of Mechanical Engineering and Naval Architecture University of Zagreb, Zagreb, Croatia*
A Yield Criterion of Isotropic Materials with Different Tensile and Compressive Yield Point. General tensor expression for a yield criterion containing stress tensor raised to the zeroth, first and second power has been considered, if tensile and compressive plasticity (strength) properties are different, then three independent parameters rather than one, as it is the case of materials with equal tensile and compressive properties, have to be used. It is convenient to define these properties as tensile and compressive yield points as well as shearing yield point. Furthermore, it has been shown that the first stress invariant explicitly influences yielding, unlike materials with equal tensile and compressive properties.