3rd INTERNATIONAL CONFERENCE ON THERMAL PROCESS MODELLING AND SIMULATION

Budapest, Hungary, 26-28 April 2006

Organized for IFHTSE by
the Hungarian Scientific Society of Mechanical Engineering (GTE)
and the Materials Science and Technology Committee of Hungarian Academy of Sciences

WELCOME ADDRESS

This *International Conference on Thermal Process Modelling and Simulation* is the third in a series of conferences organised by the International Federation of Heat-treatment and Surface Engineering (IFHTSE). This conference series started in Shanghai, China, in 2000. The second conference was held in Nancy, France, in 2003, and now in 2006, it is continued in Budapest, the beautiful capital of Hungary.

The aim of this conference is to bring together specialists in modelling in materials science and manufacturing processes, solid-state and fluid mechanics, as well as in numerical simulation to discuss the state of the art from both theoretical and applied viewpoints.

The conference will focus mainly on modelling and computer simulation of heat treatment and surface engineering processes such as quenching, tempering, high energy rate heat treating (e.g. induction, laser and electron beam heating), carburizing, carbo-nitriding, nitrogen-carburizing, coatings, etc. however, other thermal processes such as casting, rolling, forging, welding are also included. The emphasis is on metallic alloys, but there are contributions on other materials (polymers, ceramics, and composites), too.

The Proceedings and the CD contains respectively the abstracts and the full text of the 64 papers submitted for presentation at this Conference. The authors are from leading industrial companies, research institutes and universities representing 26 countries worldwide. The papers have been selected by the Scientific Committee of the Conference for oral and poster presentations.

The Proceeding and the CD is organised according to the Conference Programme into three main parts: plenary lectures, oral sessions and posters. The papers cover a very wide range of topics including materials science, solid- and fluid mechanics, process related phenomena and various manufacturing aspects of thermal process modelling.

There are many people and various organisations to be acknowledged for their contribution and support. First, the contribution of the *International Federation of Heat-treatment and Surface Engineering* (IFHTSE), the *Hungarian Scientific Society of Mechanical Engineering* (GTE) and the *Materials Science and Technology Committee of the Hungarian Academy of Sciences* (MSTC HAS) as the official organisers should be mentioned. Furthermore, as the Chairman of the Organising Committee, I would like to thank all the authors and co-authors of the papers and the members of the Scientific Committee, as well as the Diamond Congress as the Organising Secretariat, all who contributed to the quality of Conference and the contents of this Proceedings.

Finally, I would like to welcome all the participants of the Conference from all over the world and I wish a very successful and fruitful discussion during the Conference and a pleasant stay in Hungary.

Prof. Dr. Miklós Tisza
Chairman of the Organising Committee

Budapest, 26. April 2006.

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GENERAL INFORMATION

Venue
The conference will be organised in the
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H-1088 Budapest, Rákóczi út 43-45.
Phone: +36 1 477 5400
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Registration
The Registration Desk is open 8.00–18.00 every day except Tuesday 25 April, when the registration starts at 15.00h Conference delegates and their companions will receive their badges, conference materials, meal tickets at the desk. Participants are kindly requested to wear their name badges during all events of the meeting.

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Incoming Messages and Message Board
Messages received by the desk will be posted on the message board located at the Registration Desk at the ground floor (Level 0). Participants may also use this board to leave messages to other delegates.

Conference Website
The Internet homepage of the Conference is kept up-to-date all the time:
http://www.diamond-congress.hu/ifhtse2006

Events Included in the Full Registration Fee
The **Welcome Buffet** will be held restaurant of Rakóczi of Novotel Budapest Centrum (conference venue) at **18:00 on Tuesday, 25 April.**
The **Banquet** will be held at **20:00 on Thursday** evening **27 April** in the "Rákóczi" boat cruising on the river Danube from where you will be able to admire the evening lights of the capital city. The boat will be boarded at pier Batthyány square located at the river bank. Organised transportation will provided at the end of the Banquet to the conference venue. Participants are requested to get to the place of the Banquet on their own.

Conference language
English is the official language of the Conference.

Projection
Test projectors will be available for the speakers for checking their presentation material. Speakers are requested to submit their slides/CDs to the operator at least 30 min before their lecture and to collect them afterwards.

Instructions for Poster Presenters
Poster presenters of Poster Session are kindly requested to hang up their posters at the begining of the conference from Tuesday 25 April, but latest on Wednesday morning 26 April. Pins and adhesive tapes will be provided to fix the posters. The useful area of the poster board is 92 cm at width and 125 cm at height. The recommended size for your poster is about the A/0 standard (cca 90 x 120 cm). **Poster Session** will take place on **Thursday from 12:00 to 14:00.** Presenting authors should be at their posters during this period. Authors should remove their posters after the session, but lastest on 28 April, till 12:00h.

PLENARY SESSION

Chairmen: József Gyulai and Zoltán Kolozsváry

(ABSTRACTS)

PL-1

Modelling heat treatment: recent developments

Jean Pierre Bellot, Sabine Denis, Pierre Archambault and Elisabeth Gautier

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Due to the growing interest in high pressure gas quenching, an important study on this topic has been launched in order to develop a comprehensive numerical model with the aim of predicting the microstructural and mechanical state of steel bodies knowing the quenching operating conditions [1]. This modelling combines the calculation of fluid flow and heat transport for the gaseous phase (using Fluent software) and calculation of heat conduction, solid state phase transformations and residual stresses and distortions in the solid body (using Sysweld software) [2, 3]. In former studies, the interest of the model has been emphasized [1] and applications examples for steel cylinders have been illustrated [1-3].

Our numerical results are now compared to experimental ones obtained on a laboratory gas quenching device developed at Ecole des Mines d'Albi. Helium and nitrogen quenching experiments at pressures of 1 and 4.5 bars were performed for nickel and 27MnCr5 steel cylinders. The gas flow velocities have been measured in situ using a PIV method (laser imaging method) and compared to gas velocities calculated with the Fluent - Sysweld coupling, as well as the temperature evolutions at different locations in the cylinders. The microstructure and hardness distributions in the quenched steel cylinders are then then compared to simulation results. In addition, in situ measurements of distortions during quenching have been done and also compared to simulations.

The comparison between calculated and experimental results is analysed and discussed taking into account experimental errors and modelling assumptions. As a result, all phenomena involved in a high pressure gas quenching process have been investigated to ensure a comprehensive validation of our numerical model.

References:

[1] J.F. Douce, S. Denis, J.P. Bellot, F. Chaffotte, G. Pellegrino, “Modelling of high pressure gas quenching: from gas flow to phase transformations”, HK 2004, 60. Kolloquium für Wärmebehandlung, Werkstofftechnik, Verfahrenstechnik und Fertigungstechnik, 6-8 Oktober 2004, Wiesbaden (to be published in Haerterei Mitteilungen)

[2] J.F. Douce, S. Denis, J.P. Bellot, P. Lamesle, F. Gouhinec, F. Chaffotte, G. Pellegrino, “Coupled numerical model for gas quenching and experimental validation”, Proc. 1st Int Conf. on Distortion Engineering (IDE 2005), Bremen (Germany), 14-16 September 2005, Eds H. W. Zoch, Th. Lübben, p. 437-444.

[3] J.F. Douce, S. Denis, J.P. Bellot, P. Lamesle, F. Gouhinec, F. Chaffotte, G. Pellegrino, “Modèle pour la simulation de la trempe gazeuse haute pression", Traitement Thermique, N°365, Août-Septembre 2005, p. 17-24.

PL-2

Contact Mechanics Modelling of Surface Engineered Systems

T Bell[1], Y. Sun[2] and H. Dong[1]

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The ever-increasing demands for combined properties in modern machinery operating under ever more severe conditions have been the driver for the rapid developments of many advanced surface engineering technologies. Designers thus have many surface engineering technologies to select from in the design of components. However, it also presents challenges to designers to select an optimal surface engineering process for a specific application. Clearly, design tools are urgently needed to assist engineers in their design of components with the surface and substrate as a system, and to predict the performance of the surface engineered components.

To this end, a contact mechanics model has been developed based on modern theories of multi-layered surface contact, taking into account the multi-layered structure, real surface roughness and friction effects. With this model, the performance of surface engineered components can be successfully predicted thus making possible the design of optimised surface engineering systems to meet particular engineering demands within the shortest possible time and with least cost. In this paper, the development of Hertz contact theory is first reviewed, the Birmingham multilayered real rough surface contact mechanical model is discussed and a number of major steps towards designing dynamically loaded surface engineered components are demonstrated by case studies.

Keywords: Contact mechanics, modelling, surface engineering

PL-3

Numerical Modelling of Hot Forming Processes

Miklós Tisza, Zsolt Lukács and Gaszton Gál

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There has always been a very intense activity in the field of finite element simulation in metal forming processes; among them hot forming has gained a special attention. It is mainly due to the high importance of hot forming on the one hand, and also to the rather challenging nature of this process since simulation of hot forging processes implies most of the numerical difficulties what usually one can meet in finite element simulation, i.e.: complicated temperature evolution during these processes, therefore, thermal and mechanical coupling should be considered; severe, large deformations, contact phenomena and friction play an important role, significant microstructure changes of the parts occur, which affects the final properties, etc.

The main objectives of finite element modelling in bulk forming processes are the development of adequate process sequence and die design by process simulation of die cavity filling, prediction of temperature distribution and process limits to avoid internal and surface defects, improvement of part quality by improving material flow, grain flow and microstructure changes, increasing process economy by reducing die tryouts and lead times, reducing rejects, etc.

While forging is a process with many centuries of history, its theoretical basis is a relatively young science; however, it is of utmost importance to understanding the process itself and to the development and application of finite element modelling. Various useful methods and techniques were developed to analyse metal forming processes, but accurate determination of the effects of various process parameters and detailed material flow analysis have become possible by developing finite element procedures to metal forming processes. An important step was the development of process-oriented special purpose FEM codes that are nowadays widely available in the market. The user interface of these packages is continuously improved to make their industrial application more user-friendly that have reached such a degree of sophistication that finite element codes are now available for and are being used by the industry.

In this paper, first, the state-of-the-art of numerical modelling in hot forming processes will be overviewed. Then the paper briefly reviews the theoretical background of metal forming simulation including the basic constitutive equations, and the information flow in process modelling. The important process variables and the main characteristics of various hot forming processes will also be discussed. Finally, some industrial examples will be shown including closed die forging, process simulation of multi-stage forging sequences. An integrated approach of forging and heat-treatment will also be illustrated.

PL-4

Industrial Application of Simulation of Heat Treatment Processes

Josef Tejc

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Simulation of heat treatment processes using finite element code SYSWELD is presented. There are mentioned possibilities of usage of the program for simulation of technological processes of heat treatment (HT) like quenching, combined thermo-chemical treatment, induction HT, laser surface HT etc. Demonstration of analysis of a realistic HT process (case-hardening of a gear) is made and the results are commented. Analysis of carbon diffusion is performed and influence of variable carbon content on material properties is described. Thermo-metallurgical analysis of the problem is done, the modified heat convection equation extended in terms describing effects of solid state phase transformations is presented. Thermo-mechanical analysis of the problem is performed to determine residual stresses and distortions. Comparison of results obtained from simulation including effects of phase transformations against a simulation, where the phase transformations were not taken into account is done.

ORAL PRESENTATIONS

Simulation of heat-treatment processes

Chairmen: Jozef Tejc, Reza Rowshan, Thomas Bell and Tamás Réti

(ABSTRACTS)

O-I/1

Simulation of the Heat Treatment Distortion of Cylindrical Shafts due to Segregations in a Carburizing Steel Grade

Martin Hunkel, Franz Hoffmann and Hans-Werner Zoch

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One of the goals of the Collaborative Research Center "SFB 570 Distortion Engineering" at the University of Bremen is to determine the reasons of distortion experimentally and integrate relevant distortion effecting parameters into simulations. It is known for long that segregations are one of these parameters and can lead to large distortion of steel parts. But this effect is mostly not regarded in simulations of the distortion of steel parts up to now. Due to this the prediction of distortion can fail.

The presented paper focuses on this influence. A conventional low alloy steel (SAE 5120, EN 20MnCr5) had been extensively investigated by dilatometric experiments and with cylindrical shafts to determine the 3-dimensional anisotropic change in length and curvature due to segregations. Mainly the change in length due to the transformations during heating as well as during cooling can be detected as main reason for distortion.

Segregations are too small in relation to the whole part dimensions to simulation them for the entire part. This is the main problem of including segregations into a simulation model. Due to this a mean substitution had to be used. Segregations had been taken into account by 3-dimensional anisotropic transformation strains, which were implemented into the FEM-simulation program. Thereby, heating as well as cooling -including the transformations and mechanical behaviour -had been regarded, because anisotropy occurs in both cases and its overlapping leads to the distortion.

It is shown, that the simulation results can reproduce the experimental results, anisotropic volume change as well as curvature changes. The agreement between simulation and experiment shows, that the anisotropy in the strain due to segregations can explain large distortions and that for prediction of distortion of industrial work-pieces the anisotropy in the volume change has to be regarded, as shown in the paper concerning this effect.

O-I/2

Finite Element Modelling of Laser Transformation Hardening of Steels

Reza Rowshan[1] and Maria Kocsis Baan[2]

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The purpose of Laser transformation hardening (LTH) of steels is to harden a localised surface area of the specimen, which results in high hardness value for a defined width and depth of the material.

Due to high heating rate of LTH processes, temperature needed for phase transformation, austenite formation, will be shifted to much higher value considering the austenisation diagram of the steels.

To assure the hardened zone and keep the maximum temperature of the surface below the melting point we have applied a finite element method (FEM) to compute the heat distributions and the phase transformation of the steels during single pass LTH.

Using System Interface Language, which is a communication interface between the user and the finite element code used, we introduce a solution to achieve a constant temperature interval by varying the maximum heat flux density applied on the surface of the work piece.

Furthermore, we present solutions to different practical applications of LTH processes by controlling the temperature of the specimen at the surface and a defined depth.

O-I/3

Finite Element Modeling of Induction Hardening Process

Krich Sawamiphakdi[1], Wei-Tsu Wu[2] and Jaebong Yang[2]

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The development of induction hardening process which includes the design of coil geometry and selection of electric frequency, current, voltage, power and heating time is very complicated. "Trial and error" approach has therefore been widely used obtain a working induction hardening process. Because of the large number of variables and their possible combinations, the trial and error approach becomes very time consuming. In order to shorten the process design cycle and to better understand the process, continuous effort has been made to develop the methodologies to model the induction hardening process using the Finite Element Method. The finite element analysis of induction hardening process is as complicated as the design.

The paper outlines theories of electro-magnetic, thermal, mechanical, and metallurgical models. Examples of actual induction hardening process are presented to demonstrate the capabilities of the methodologies. The predicted numerical results were compared with measured data from experiments and productions and excellent agreement was obtained.

Keywords: induction hardening, finite element method

O-I/4

Optimization of Controlled Heating and Cooling in a Continuous Annealing Line by a Thermodynamic Model

Lorenzo Croce and Antonius Grosse-Gorgemann

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Often optimized control systems or models, based on data tables, are used to control the temperatures and volume rates in the different heating and cooling sections in a continuous annealing line for thin steel sheets to achieve the desired mechanical properties for the different ranges of thickness, width and alloys. In normal cases the material temperature set points are insufficiently fulfilled during a coil transition or/and a change in coil speed. Furthermore the cooling power in the different furnace sections depends on the type of cooling system (air, jet and water cooling) and the properties of the used cooling fluid and the steel sheet. As a consequence of this unknown cooling power and the unknown material temperatures, the coils do not reach the desired set point temperature values or the coil speed has to be reduced to achieve the quality specifications.

To enhance the temperature control in a continuous annealing line, the model named celFCS, presented in this paper, was developed. CelFCS is able to control different kinds of continuous annealing lines, e.g. consisting of a indirect or direct fired section and different types of cooling, e.g. cooling tubes / jet cooling. If a pyrometer exists, the model can take into consideration the variation of steel sheet emissivity for different qualities and furnace situations.

In the presentation the implementation of this model in the control process of a continiuous annealing line is explained. The different parameters of the model are discussed to take the most important boundary conditions of this production process into consideration. By showing different furnace situations, the differences between a common actual control situation and a new situation achieved by this model will be presented.

O-I/5

Simulation of Quenching Treatments on Bearing Components

M. Burtchen[1], M. Hunkel[2], Th. Lübben[2], F. Hoffmann[2], H.-W. Zoch[2], P. Neuman[1], S. Lane[3] and U. Sjöblom[1]

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Current trends towards 'downsizing' of rolling bearings result in higher demands on the product properties with respect to higher load carrying capacity and resistance to rolling contact fatigue. The objective to further improve the product performance is a challenge, especially considering the high quality standard of modern bearing steels. Heat treatment and specifically quenching are important for producing the desired product properties and therefore further development of these processes are considered relevant for future generation products. To minimize the amount of testing, computer simulations of the effects from heat treatments on the resulting properties are used more and more as a development tool. This presentation describes work performed to simulate two different quenching cycles, quenching in oil and salt, applied during through hardening treatments of SAE 52100 bearing steel, in order to understand and predict the hardening process with respect to phase transformations and residual stress generation.

All simulations are performed with the FE-software SYSWELD. The calculations are divided into two parts: a thermo-metallurgical calculation, in which the temperature field and the resultant phase transformations in the steel are simulated and calculation of the mechanical response of the component. Cooling curves were measured with a probe equipped with thermocouples and used to derive heat transfer coefficients as input for the simulation of martensite hardening. The heat transfer coefficient value for salt quenching is assumed to be constant due to continuous convection. Dilatometer measurements were utilized in order to establish the phase transformation behavior. Temperature and residual stress measurements were performed on all tested components to verify the results from the simulations. A comparison of the measurement and simulation results is given and discussed.

O-I/6

Measurement and Numerical Analysis of Surface Residual Stresses Occurring under Different Quenching Conditions

Janez Grum, Tomaž Kek, Martin Zupančič, Milan Batista and Franc Kosel

Faculty of Mechanical Engineering, University of Ljubljana
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The paper presents the results of residual stresses modelling and experimental stress measurements after quenching of AISI 4140 heat-treatment steel specimens. In the research, cylindrical specimens of Ø 40 x 160 mm in size were used whereas in modelling specimens of the same diameter, i.e. Ø 40 mm, but of infinite length were employed. One quenching agent was selected, i.e., a 15% polymer water solution.

The influence of residual stresses due to martensitic transformation and temperature differences was investigated with different initial specimen temperatures above and under T_{AC1}. Residual stresses were measured with the hole drilling relaxation method.

Keywords: quenching, mathematical modelling, residual stress

O-I/7

Simulation and Experimental Verification of Carburised and Nitrided Quenching Process

Dong-Ying Ju[1], Yosuke Ito[2] and Tatsuo Inoue[3]

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[2]*Department of Technology Development, Tobuyakin Ltd. Japan*
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A model considering quantitative effects of diffused carbon and nitrogen gradients and kinetics of phase transformation is presented to examine metallo-thermo-mechanical behavior during carburized and nitrided quenching. Coupled simulation of diffusion, phase transformation and stress/strain provides the final distribution of carbon and nitrogen contents as well as residual stress and distortion. Effects of both transformation and lattice expansion induced by carbon and nitrogen absorption are introduced into the calculating the evolution of the internal stress and strain. In order to verify the method and the results, simulated distributions of carbon and nitrogen content and residual stress/strain of a ring model during carburized and nitrided quenching are compared with the measured data.

O-I/8

Quenchant evaluation by using quality functions

I. Felde[1], I. Czinege[2], T. Réti[2], B. Smoljan[3] and R. Colas[4]

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[2]Széchenyi István University, Győr, Hungary
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[4]Faculty of Engineering, Universidad Autónoma de Nuevo León, Monterrey, Mexico

A novel numerical approach for testing and evaluation of quenching media and quenching systems is outlined. The technique proposed is based on determination of heat transfer coefficient from temperature signals recorded and applying it as input for simulation of quenching process. The evaluation method is based on the calculated microstructural and mechanical properties of cylindrical samples.

Keywords: Quenchant evaluation, heat treatment, simulation, inverse heat conduction problem, property prediction

O-I/9

Computer Simulation of Hardness Distribution in the Quenched Round Bar Cross-Section

J. Grzyb, S. Jończyk, T. Babul and A. Nakonieczny

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In the paper described useful computer program which calculate hardness distribution on the round bar cross-section of the quenched bar. In the program used J.L. Lamont and W. Craft method for hardness prediction.

Presented program cooperated with portable tester of quenchants. The of software tester quenchants enable determine a cooling rate for given quenching fluid in laboratory conditions according to ISO 9950 and in production quenching tank. This cooling rate is determined by Grossmann Number (H [1/in]) which is characteristic for given quenching fluid in the real production tank.

A Grossmann number generated by tester software is it used in discussed program. This situation entitle to assertion that calculated hardness distribution is very near a hardness which will be obtained in real quench tank.

It is assumption that such a computer program will be useful in selection of quenchants for given items.

O-I/10

A Numerical Model for Predicting Microstructure and Strain Change During the Tempering of S45C Martensitic Steel

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Virgin martensite, the hardest phase in steels, naturally possesses poor toughness and ductility. Even if the tempering of martensitic steel improves toughness and ductility and reduces the residual stress without a great loss of the strength, it may also cause some problems like distortion. Therefore, a numerical model to predict distortion and microstructural change during tempering is proposed in this paper. The strain change and carbide precipitation behavior during the tempering of S45C martensitic steel have been investigated by dilatometric tests with different heating rates and by optical and electron microscopes. Precipitation of ε transition carbide occurs between 70 to 220°C and cementite precipitated between 200 to 450°C during the tempering of the S45C martensitic steel, respectively. The tempered martensite fractions were calculated using the relationship between the lattice parameters of the martensite, ferrite and cementite and measured dilatometric data. From the results, continuous heating tempering diagram was constructed and the tempering kinetic model was proposed as Zener-Hillert type equation. This model allows the accurate prediction of tempered martensite fraction for different heating rates. Finally, strain change during tempering could be predictive from both tempering kinetic model and thermal expansion coefficients of martensite, transition carbide, cementite and ferrite.

O-I/11

3D Simulation of Quenching of Steel Specimen

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The simulation of quenching of steel specimens has been investigated using 3D numerical simulation. Numerical simulation of quenching consists of the simulation of specimen cooling and simulation of hardness in specimen points. Applied 3D numerical simulation has been done using the unstructured mesh.

Hardness in specimen points was predicted based on calculated cooling time from 800°C to 500°C. Investigated 3D model of steel quenching has been tested by the comparison with experimental results. It has been concluded that the established 3D model can be successfully applied in computer simulation of steel quenching.

Keywords: numerical simulation, 3D modeling, steel quenching

ORAL PRESENTATIONS

Modelling of phase transformations

Chairmen: Bozo Smoljan, András Roósz, Victor Li and János Takács

(ABSTRACTS)

O-II/1

Creation of TTT Diagrams Using Macro Elements

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The TTT phase transformations diagrams based on FEM based phase elements make possible the creation of virtual TTT diagrams. Using macro elements the creation of the approximated TTT diagrams become more simple and easier. The work shows the method of the generation of approximated TTT diagrams with macro elements.

Keywords: TTT diagram, FEM method, Macro elements

O-II/2

A Finite Element Procedure Using an Implicit Approach for Phase Changes

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Finite element is widely used for modelling heat treatment, casting, welding processes which involve different physical interactions such as mechanical, thermal and metallurgical phenomena. As far as the thermo-metallurgical coupling is concerned, the numerical modelling of phase changes is a complex problem. It requires the modelling of high physical interactions due to latent heat effects on the temperature fields, and the thermal history influence on the phase changes.

At first, a finite element method is presented for heat transfer including latent heat effects without transformation kinetics. This approach allows to simulate isothermal solidification problems. An example composed of the Stefan problem is described. The results are compared with the analytical solution.

The metallurgical model with transformation kinetics is given in detail for a step by step analysis. Moreover, an example is described for phase changes in steels. This shows the numerical capacity of the procedure to model recalescence phenomena.

At last, the numerical method is extended to the diffusion-convection approach which is useful for the steady-state analysis of welding processes.

O-II/3

Modelling of Austenitization Kinetics of Ferritic Nodular Cast Iron

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The kinetics of phase transformations including the austenitization is usually described by the Johnson-Mehl-Avrami-Kolmogorov (JMAK) equation. On the other hand, already a row of papers shows that substantial deflections from the JMAK equation have been observed during studies of phase transformations. Therefore, different extensions and modifications of the JMAK model have been made but, unfortunately, they loose the simplicity and rationale of the JMAK equation without fully removing its main drawbacks.

The present contribution shows that, for the experimental data obtained from a study of austenitization kinetics of ferritic nodular cast iron, the JMAK equation is not able to give sufficiently general description of this phase change, in particular the partial conversion at insufficient overheating. Therefore, another simple kinetic equation has been proposed, which catches the main circumstances and substance of austenitization more accurately than the JMAK equation. Its successful application seems to support the idea that the crucial role in this transformation is not played by the processes of the creation of new austenite grains and of the dissolution of graphite nodules as usually considered but by the retardation of the conversion due to the difference in specific volumes of the transforming and the transformed phases, which creates mechanical stress acting against the following conversion or even stopping it. In the connection with the Arrhenius equation the proposed equation allows modelling simultaneously the temporal and temperature dependence of austenitization conversion including the partial transformation in the case when the overheating of transformed iron is not sufficiently high. It has been verified by successful regression of experimental data. The results of this regression allow drawing predictive curves for those temperatures from experimental temperature region or from its near vicinity, for which the conversion measurements were not performed. Fitted as well as predictive curves can be supplemented by tolerance bands.

O-II/4

A Computational Model for Phase Transformation–Temperature–Distortion Coupling of AISI 5120 Steel

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A coupled model for predicting the phase transformation, temperature, and distortion of a AISI 5120 steel has been developed for its cooling process. The phase transformation kinetic models using the modified ordinary differential type formulae proposed by Zener and Hillert were made based on the theoretical thermodynamic model and the experimental dilatometric data. Especially, the transformation strains measured during cooling were converted to the volume fraction of each phase for the kinetics models using a program routine. The heat transfer coefficients in quench media were calculated by applying an inverse solution of the heat transfer equation to the measured surface temperature history. To predict the temperature and distortion accurately, the thermal and mechanical data were used as a function of temperature and each phase based on the experimental data. The coupled model for phase transformation, temperature, and distortion has been implemented in the commercial finite element software ABAQUS as user subroutines. The coupled model was validated with some experimental results.

O-II/5

Modelling of Austenitizing with Non-Constant Heating Rate in Hypereutectoid Steels

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The calculation of distortion during heating for quench hardening needs an accurate modelling of the austenitizing process. In dilatometer tests with constant heating rates, the parameter of a transformation model, which is based on a Johnson-Mehl-Avrami equation, can be determined in a simple manner. Whether the model and the transformation parameters are also valid for austenitizing with non-constant heating rates is tested in this work. For this purpose, dilatometer tests were conducted with a change in heating rate during the transformation process of the hypereutectoid steel AISI 52100 (EN 100Cr6). With transformation parameters, determined from austenitizing with constant heating rates, the experimental and the calculated strain show no sufficient correlation during continuous heating with a non-constant heating rate. Transformation parameters have to be adjusted to get a good agreement between experiment and simulation.

Keywords: dilatometer test, austenitization, heating rate

O-II/6
Structural Models Application for the Development of Strengthening Technologies

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Models and quantitative regularities of dislocation theory, describing the connection between the structural parameters and characteristics of constructional strength of metals and alloys are discussed. Several mechanisms of dislocations braking are taking into account: deformation mechanism and uncoordinated dislocations density increase; forming of solid solutions (substitutional or interstitial); grain boundary mechanism; sub-structural mechanism; dispersion hardening by precipitated particles of secondary phases, and etc. The influence of these strengthening mechanisms on yield stress, from the one side, and on characteristics of ductile fracture, form the other side, is analyzed. On the base of the theoretical rules the calculations of predicted level of hardening are implemented for several technological processes of treatment of metals and alloys: laser heat treatment, laser alloying, and nitriding of binary alloys. Suggested calculation scheme is used for the development of combined technology of surface hardening of steels including laser alloying by nitride-forming elements and following nitriding.

Keywords: strengthening mechanism, laser alloying, nitriding

O-II/7

Transformation Plasticity at Different Phase Transformations of a Throughhardening Bearing Steel

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During the industrial heat treatment of components strains result from different influences of individual process steps. Total strain consists of elastic ε_{el}, plastic ε_{pl}, thermal ε_{th}, transformation-conditioned ε_{tr} and transformation plastic ε_{tp} portions of the strain.

$$\varepsilon = \varepsilon_{el} + \varepsilon_{pl} + \varepsilon_{th} + \varepsilon_{tr} + \varepsilon_{tp}$$

A simulation of the heat treatment processes requires material data for the description of the phase transformations. Those refer not only to the transformation without external loads, since during the heat treatment transformation and thermally caused stresses develop, which affect the behaviour of the phase transformation. Interaction between phase transformation and internal stress is the subject of the reported investigation.

The investigations show the influence of constant tension and compression stresses on transformation kinetics during the isothermal pearlitic and bainitic transformation and also the martensitic transformation of the bearing steel 100Cr6 (SAE 52100). The tests were performed using a testing machine type Gleeble 3500. The machine combines the characteristics of a servo hydraulic testing machine and of a quenching dilatometer.

It is shown that an acceleration of the phase transformation by external tensile stresses takes place only in limited temperature ranges. The transformation plasticity parameter K seems to depend on the mechanism mainly causing the transformation plasticity, either the Magee effect for low temperature transformation or the Greenwood-Johnson effect for high temperature transformation. K increases linearly during pearlitic transformation with increasing transformation temperature. In case of the bainitic transformation K decreases linearly with increasing temperature.

O-II/8

Virtual TTT Diagrams

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The TTT phase transformations diagrams based on FEM based phase elements make possible the creation of virtual TTT diagrams. All the points of the virtual TTT diagrams are results of multiple linear regression calculations. The base TTT diagrams are created on the basis of measured published data. Virtual TTT diagrams are presented for different austenitisation temperatures and different chemical compositions.

Keywords: TTT diagram, Phase Element, Multiple Regression.

O-II/9

Austenite Decomposition Models for the Prediction of Steel Hardenability

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Explicit overall kinetic rate equations are developed for the prediction of austenite decomposition reactions. They are based on the theory of Zener, Hillert and Kirkaldy and empirically calibrated to CCT and TTT data presented in the open literature. The equations are integrated into a finite element model for the prediction of heat transfer and microstructure evolution in Jominy end quenching tests. Thermal boundary conditions are taken from the published experimental results. Microstructure dependent thermal physical properties are used in the heat transfer analysis. Hardness distribution profile along the Jominy bars are predicted based on the microstructure and compared favorably with experimental results. They are also compared with other predictive methods for steel hardenability.

ORAL PRESENTATIONS

Modelling of physical phenomena

Chairmen: Leszek Dobrzanski and Tamás Tóth

(ABSTRACTS)

O-III/1

Simulation of Photo-Induced Diffusion in Amorphous Chalcogenide Multilayers

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Amorphous chalcogenide semiconductors are known to exhibit a number of light memory effects: photodarkening (or bleaching), photo-induced refractive index and volume change, photocrystallisation. The elucidation of the mechanisms of these effects on the atomic level is controversial. The common first step in most recent models is the local enhancement of structural relaxation due to the absorption of a band gap photon. In compositionally modulated on nanometer scale multilayers photo-induced diffusion becomes important besides the above mentioned effects, as it has been observed in several types of multilayers, such as Se/As_2S_3 [1], $As_{0.2}Se_{0.8}/As_{0.2}S_{0.8}$ [2], $Se_{0.8}Te_{0.2}/As_{0.06}Se_{0.94}$ [3]. Photoinduced volume changes up to 10-15 % can be achieved in some multilayers [1,2], while in homogeneous layers made of such materials only ±0.5 to ±2 % have been observed. This volume change makes these multilayers promising for holgraphic recording and surface pattern production.

We have carried out some computer simulations of laser-stimulated diffusion in amorphous chalcogenide multilayers, based on the numerical solution of the Fick's second law, with the aim of better understanding of the peculiarities of the photodiffusion process. The calculations were carried out for a model multilayer consisting of a wide and a narrow band gap material with an initially sharp interface illuminated with He-Ne laser light (λ = 0,63 μm). It is assumed, that initially the light is absorbed exclusively in the narrow band gap material. These conditions are tipical for the first two mentioned type of multilayers where the Se and the $As_{0,2}Se_{0,8}$ are the narrow band gap materials. With the aim to be close to tipical experimental conditions the compositional modulation period was taken 7-10 nm and the most of material constants were taken for amorphous Se.

Theoretical considerations have shown that the effective diffusion coefficient has to be proportional to the amount of the absorbed light that correlates with the absorbtion distribution profile which is finally determined by the concentration profile. It means that in the wide band gap layer the diffusion is rather slow and it is faster in the narrow bad gap layer and at the interface. This resulted in the nonlinearity of the photo-diffusion and in qualitatively different profile with respect to the case of thermo-diffusion.

In our model the photo-diffusion is resulted from the localisation of the energy of the absorbed photon in a very small volume (i. e. local heating for a very short time) which is connected to the special structural and electronic parameters of amorphous chalcogenide semiconductors especially the strong eleectron-phonon coupling and the essential role of the bridging chalcogenide atoms in electron-hole pair generation and in structural transformations. The magnitude of the photo-diffusion coefficient is determined by several material constants: the absorptiontion coefficient, heat capacity and thermal conductivity of the light absorbing material and on the magnitude of the thermo-diffusion coefficient. This model can explain the experimentally observed phenomena in general but some important details need additional experimental proof.

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O-III/2

Numerical Analysis of Distortion due to Inhomogeneous Distribution of Martensite Start Temperature within SAE 52100 Bearing Rings

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Causes for distortion phenomena during heat treatment e.g. are inhomogeneities or asymmetries of the distributions of mass, alloying elements, microstructure and residual stresses. Recently published papers clearly pointed out the influence on distortion of residual stresses and their spatial distribution within a work piece. Further the influences of microstructure and alloying elements especially on transformation kinetics are well known too. However up to now influences of local asymmetries of phase kinetics on distortion effects were not systematically investigated.

This paper will report about numerical investigations regarding the spatial distribution of Martensite start temperature (M_s) within bearing rings made out of SAE 52100 (100Cr6). Concerning the local asymmetries of M_s within bearing rings, distributions in circumferential, axial, and radial direction will be calculated by means of FE simulations. In a first step the distribution of M_s will be modelled with simple trigonometric functions with different wavelengths and amplitudes of M_s. Further superposition of different trigonometric functions of M_s will be investigated.

Simulations with the commercial FE simulation program SYSWELD® yield dependencies of out of roundness values of the bearing rings on wavelength and amplitude of M_s. The numerical study will be supplemented by experimental investigations concerning the distribution of M_s. Typical scatterbands of M_s within a work piece were found to be ± 10 K. Concerning this scatterband, different possible distributions of M_s will be analysed by Fourier transformation. With the resulting trigonometric functions the out of roundness values will be calculated and compared with experimental data.

O-III/3

Computer simulation and modeling of interface motion and transformation during heat treatment

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In the last 5-10 years, we have been intensively working on computer simulations of interface motion and transformation. With still continuously shrinking device structures, the question of how the microscopic laws may change on the nanoscale appears of utmost importance. This is not only interesting from fundamental point of view but also of practical interest. To plan and fabricate nanoscale devices need better understanding of the atomic scale processes. A possibly new behaviour could help to improve device properties or hinder its destruction.

It is known form Fick's phenomenological laws that during annealing of diffusion couple the displacement of a plane with constant composition (or an abrupt interface) is proportional to $t^{1/2}$. However, we have shown first from computer simulations that this rule can be violated on the nanoscale either in completely [1] or restricted miscible systems [2]. This is strongly related to the discrete character of the system on the nanoscale and to the highly neglected fact in the literature that the diffusion coefficients or mobilities depend on the composition.

Computer simulations also have shown that on the nanoscale, for strongly composition-dependent diffusion coefficients, diffuse interfaces can sharpen rather broaden in completely miscible binary systems during annealing [3-4]. This sharpening is surprising at first sight, because the direction of diffusion is always opposite to the direction of the composition gradient. This phenomenon could provide a useful tool for the improvement of interfaces and offer a way to fabricate of e.g. better X-ray or neutron mirrors, microelectronic devices or multilayers with giant magnetic resistance.

These phenomena predicted by computer simulations have been later proved experimentally (violation of Fick's laws: Ref. 5; interface sharpening: Ref. 6) as well. This shows the efficiency and importance of the computer modeling in planning and fabrication of new devices.

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O-III/4

Simulation of the Influence of Carbon Profile and Dimensions on Distortion Behaviour of SAE 5120 Discs

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In order to detect the most important influencing factors on distortion in carburizing processes, it is helpful to use a simulation tool. Additionally, design of experiments (DoE) can help to perform the needed simulations in a well structured, clearly arranged manner. Besides the possibility to analyse influencing process parameters, this approach also allows to test software packages concerning their sensitivity on input parameters.

The objective of this work was to detect the influencing factors of carburizing processes on the simulated results of distortion of a disc with a center hole. Therefore, a full factorial design of experiments was set up and analysed. The advantage of this procedure is the possibility to find out not only the influence of the main factors, but also the interactions between the different ranges. In this work, the varied factors were the surface carbon content, the carburizing depth and as a geometrical dimension the thickness of the disc. The responses to the design are distortion modes like flatness and straightness of the discs.

In order to analyse the design of experiments, two different ways were used. At first, the influencing factors were identified by using a probability plot. Secondly, the method "Analysis of Variance" was used, which needs a scattering in results. Therefore, an artificial scattering was implemented based on experimental scatter bands.

Within this work, the two possibilities have been compared. All simulations were done with the software package SYSWELD.

Within the scope of this paper, a survey of the described work will be presented.

O-III/5

Numerical Modelling of the Laser-Surface Interaction During Laser Induced Modification Processes of Ceramic Substrates

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Laser surface melting and alloying are important techniques to improve the properties of a material locally without affecting the bulk. In ceramic components these methods can be used to optimise the fracture toughness, friction and wear but also the thermal and electrical conductivity. This process is characterised by a very fast laser-surface interaction which induces phase changes within the sub-second time scale with fast moving melting and solidification boundaries. Within this paper we report on the development of a finite element model (FEM) which can be used to model the dynamic laser-solid interaction and the resulting heat and mass transport during laser induced surface modification of ceramic substrates.

Numerical computations has been performed on the basis of a finite element model (FEM) in order to get more insight in the dynamic heat and particle transport during melting and solidification. The model considers the transient liquid-solid phase change and also the heat and mass transport due to convection within the molten pool. Commercial software packages (FEMLAB, PHOENICS) has been used to solve the Navier-Stokes equations which describes the fluid flow within the melt pool. The heat source is generated by a focused laser beam with a rectangular-shaped intensity profile. Temperature dependent material properties like the thermal conductivity and the heat capacity has been included in the model. In order to simulate the phase change at the moving liquid-solid boundary on a fixed grid the enthalpy-porosity model has been implemented in the FE-model, which fixes the velocity components to zero in the solid phase and allows for a reconstruction of the solid-liquid interface.

Two different substrate materials were included within this study, namely Al_2O_3 and a zirconia reinforced alumina with the composition of $90Al_2O_3$-$10ZrO_2$. As modifying materials within the laser dispersing process hard metal powder particles of TiN and WC were considered within the model calculations. Using two phase flow techniques the temperature distribution, the velocity field within the molten ceramic pool and the final distribution and concentration of the hard metal particles in the solidified ceramic matrix could be predicted by the model. The results of the model calculations have been validated against experimental results.

ORAL PRESENTATIONS

Materials and process parameters

Chairmen: Sabine Denis, István Artinger

(ABSTRACTS)

O-IV/1

Thermal Conductivity of Steels for Thermal Process Simulations

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Thermal process simulations often involve transient heat transfer analyses which require such thermophysical properties as thermal conductivity, specific heat or enthalpy change, and density. Specific heat of low alloy steels is not significantly affected by steel chemistry. Thermal conductivity shows moderate dependence on steel chemistry.

This study first reviews the basic theories of thermal conductors in metals and existing methods for the prediction of thermal conductivity of steels. It highlights the development of new empirical equations for the prediction of thermal conductivity of steels for the microstructure that consists of ferrite and pearlite. The amounts of ferrite and pearlite are determined by the level rule based on the steel chemistry and eutectoid point. Thermal conductivity of ferrite and pearlite are determined from regression analyses and are expressed as functions of steel chemistry.

The performances of these new equations are evaluated against existing experimental data from various sources. Good agreement between the predicted and report experimental data are reported.

O-IV/2

Experimental Determination of Heat Transfer Coefficients

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A series of tests were carried out to evaluate the magnitude of the heat extraction capacity of various mixtures of polyalkylene glycol and water. Inconel probes instrumented by the insertion of two K-type thermocouples were used; one of these couples was located at the geometrical centre of the sample, whereas the second one was close to the surface at mid-height. The probes were heated at various temperatures and immersed in a room temperature quenching bath. The analysis was conducted assuming that conduction within the probe is one-dimensional. The heat transfer rate at the surface of the probes is extrapolated from the recorded temperatures.

O-IV/3

Modeling of Magnetic, Mechanical Properties and Corrosive Wear of Hard Magnetic Composite Materials Nd-Fe-B

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The paper presents a neural network model for evaluation of the magnetic/mechanical properties and the rate of corrosive wear of the polymer matrix hard magnetic composite materials with particles of the powdered rapid quenched Nd-Fe-B strip with addition of metallic powder: iron, aluminum, CuSn10 type cast copper-tin alloy and X2CrNiMo17-12-2 high-alloy steel. Simulation approach to model the magnetic/mechanical properties in metallic powder added polymer-matrix composite materials filled with magnetically hard Nd-Fe-B particles in function of the chemical composition, employing a neural network technique was proposed. A neural network model of corrosion wear was established based on the research results from the investigations carried out in two corrosive environments. Simulation approach to model the corrosive wear in metallic powder added polymer-matrix composite materials filled with magnetically hard Nd-Fe-B particles in function of the chemical composition, nature of the corrosive environment and the test duration was proposed. Three types of input data were used in the investigation: the contribution of the added powder, the nominal variable that defined the corrosive environment and the time duration of the test. The percentage corrosive wear of the surface was the output produced from such input data. The obtained results indicate that the developed neural networks are able to generalize which justified using these models to the simulation of magnetic/mechanical properties and corrosive wear of hard magnetic composite materials.

O-IV/4

Mechanical Consequences Induced by Heat and Mass Transfers During Wood Drying Process

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General thermo-hydro and mechanical tools with cylindrical orthotropy have been developed to model the wood behaviour during drying. First, 1D and 2D computations are carried out in the radial and tangential directions of wood. It permits us to determine the evolution of coupled temperature, moisture content and internal gas pressures by considering the different water phases and states in wood (based on TRANSPORE formulations (Perré and al. 1990, 1996, 1999)). Secondly, a 3D mechanical computation is held by introducing the moisture fields computed previously. The moisture content is assumed to be constant in the L direction. This module takes into account swelling and shrinkage in the hygroscopic field, delayed effects (creep) and mechanosorption effects during time. The approach presented here aims at predicting cupping distortions and residual stresses of a wooden board during a drying operation.

Keywords: heat and mass transfer, distortions, creep

O-IV/5

Time and Frequency Domain Dielectric Measurements Used As Nondestructive Evaluation Technique for the Characterization of Micro-Size Particle of Alumina (Alfa-Al2o3) Reinforced Polymeric Matrix Composites

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Abstract nondestructive evaluation (NDE) techniques are developed for characterizing semi-conductive particle reinforced polymeric matrix composites. In this report, the electrical properties of epoxy matrix filled with Alumina (α-Al_2O_3) of three different sizes were investigated. Preliminary results from composites consisting of a matrix of Bisphenol A type epoxy (DGEBA) with a phthalic anhydride hardener filled with Alumina (α-Al_2O_3) with particle sizes of 9, 22 and 50 μm are presented. For each filler size, specimens with volume concentration from 5 to 40% were characterized. The evaluation techniques consisted of both time and frequency domain dielectric measurements. For the studied composites the applicability of bounds on the composites complex permittivity and different mixing formulas for estimating the effective complex permittivity and the effective conductivity is examined. The influence of particle size on the effective complex permittivity and conductivity is also examined and discussed.

Keywords: Particle reinforced composites, electrical conductivity, polarisation current, complex permittivity, filler size.

O-IV/6
Thermal State Modeling of Metal-Polymer Composite Powder Materials under the Effect of Ellectric Current

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Heat transfer and heat state problems of the powder system components present just as scientific so practical interest from the viewpoint of materials science and novel technologies of their formation.

Of specific importance in this respect turn to be investigations in transfer processes and heat distribution in the metal-polymer powder materials under the effect of electric current. This process is accompanied by intensive generation of heat in the sintering region of the powder composite. The mathematical models of heat transfer allowed us to simulate and consider the phenomena connected with the effect of technological factors on heat processes both inside the powder composition and at the interface between the powder material and molding unit.

The models of temperature field and gradient of the composite material in the needed region have been obtained and calculated as a function of polymer filler content in the metal matrix.

Based on the methods of mathematical modeling it's proved that introduction of 10, 20 and 50 mass% of the polymer filler into the metal-polymer charge leads to considerable changes in the thermal state in both powder composite and electrode-punch. Consideration of localized temperatures in the contact zones between the metal matrix particles, as well as between the powder particles and electrode surface plays a significant role in distribution of temperature fields in the metal-polymer powder system. Variations in temperature fields are proved to occur inside the particles of polytetrafuloroethylene and low-density polyethylene found in the copper powder matrix in the moment of reaching the sintering temperature.

ORAL PRESENTATIONS

Simulation of industrial processes

Chairmen: Robert Wood, Mária B. Kocsis, Imre Felde, György Krállics, László Dévényi and Tamás Tóth

(ABSTRACTS)

O-V/1

Thermo-inelastic Simulation of Aluminum Direct Chill Casting Process for Crack Sensitivity Evaluation

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In an industrial DC casting of aluminum alloys, a longitudinal crack (hot tearing) sometimes appears at a slab surface. In order to evaluate the tendency of hot tearings from inner stress viewpoint, a thermo-mechanical finite element model has been developed, in which thermally induced strains and stresses with phase transformation (solidification phenomena) are simulated using an elasto-plastic constitutive equation based on an isotropic hardening rule and the Mises yield condition. As a result, it is found that a cracking susceptibility defined by a ratio of calculated principal stresses to temperature dependent tensile strength can describe almost the same behavior of hot tearing propagation during the casting process. In addition, the discussion for a nucleation of hot tearing is given that the high cracking susceptibility region may interact with undesirable phenomena around the slab surface; e.g., penetration of oxide films and/or cold shuts non-uniformity of secondary cooling, when the sump profile approaches close to the slab surface. In the same manner, the longitudinal cracks are predicted to occur more easily under condition of higher pouring temperature or larger slab size, and these are revealed to be consistent with practical experiences in the cast house.

O-V/2

IDS – Simulation Tool for Solidification and Material Properties of Steels

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The IDS solidification analysis package is developed at the Helsinki University of Technology. The model is based on the thermodynamic theory connected to thermodynamic assessment data, as well as regression formulas of experimental data. IDS includes two main modules, the IDS module and the ADC module. Both modules have their own recommended composition ranges.

The present version of the IDS module simulates the solidification of low-alloyed steels and stainless steels (Cr up to 24wt% and Ni up to 16wt%). The model applies a thermodynamic substitutional solution and magnetic ordering model and Fick's diffusion laws to determine the stable solution phases, liquid L, delta ferrite δ and austenite γ, and their fractions and compositions as a function of temperature. These calculations take into account the effect of solutes C,Si,Mn,P,S,Cr,Mo,Ni,Cu,Al,N,Nb,Ti,V,Ca,B,O,H, cooling rate and dendrite arm diameter.

ADC is a semiempirical solid-state phase transformation model for steels and it simulates the austenite decomposition process below 1000°C. In the case of low-alloyed steels, the simulation involves the formation of proeutectoid ferrite, proeutectoid cementite, pearlite, bainite and martensite, and in the case of stainless steels, the formation of martensite only. The ADC model applies a thermodynamic substitutional solution and magnetic ordering model, a carbon diffusion model and special regression formulas based on the German and the British CCT experiments. The simulation takes into account the effect of solutes C,Si,Mn,Cr,Mo,Ni, cooling rate and austenite grain size. The ADC model also calculates temperatures A_{e3} and A_{cm} taking into account the effect of the 18 solutes of IDS simulation mentioned above.

The IDS package also calculates solidification-related thermophysical material properties (e.g. enthalpy, specific heat, density and thermal conductivity) from the liquid state down to the room temperature as well as austenite grain size and as-cast hardness. The calculations of the IDS package have been compared with many experimental measurements. The ADC module has also been applied to heat treatment cases.

The characteristics of the IDS package and some calculation results are presented in this paper.

O-V/3

Finite Element Analysis of Air Gap Thickness Effect in Electro Slag Remelting Process

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In simulation of casting process, the metal-die intersection plays a very important role.

In this research the intersection between the metal and die in electro slag remelting (ESR) process and also its heat transfer mechanism have been analyzed. For this purpose, the effect of air gap according to the heat transfer has been analyzed via finite element method and ANSYS software. The results which are simulated and solved for four air gap thickness show that, increasing in air gap thickness has a little affect on increment of radiation heat transfer. But, heat conduction rapidly decreases with increasing in this air gap thickness. The share of heat radiation especially in air gap with short thickness is very small in comparison with the heat conduction of glass.

Keywords: Electro Slag, Molding, Conduction, Radiation, Heat.

O-V/4

Real-time monitoring of laser bending process

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This paper present an on-line method to measure the temperature and the deformations versus time during laser bending of sheet materials. For measuring the temperature an Infrared Thermovision System and for the measuring the deformations a Deformation Amplifier System was used.

With this complex method it was possible to connect the deformation and thermal data during the laser treatment. These data give suitable parameters for creating a model which describe more precisely the laser bending process.

Keywords: laser bending, thermovision, real-time measuring, deformation

O-V/5

Effects of Viscous Dissipation in the Flow Influenced Tube Hydroforming

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Tube hydroforming is an advanced technology for the manufacturing of lightweight components with complex shape which is already established in wide areas of automotive industry. The forming results can be usually improved if axial feeding at one or both tube ends is enabled. For very long parts, however, due to the high friction forces acting between tube and die at high pressure, no material flow to the forming area occurs. With the flow of a high viscous fluid on the tube's surfaces, external pressure and tangential axial forces are generated, which reduce the normal contact force between tube and die and help the sliding of the tube in the forming zone.

In this paper the effects of viscous dissipation and conductive and convective heat transfer in various non isothermal ring shaped flow for a Newtonian fluid with temperature depending viscosity have been analyzed. With new generation software, which allows the coupling of multidisciplinary problems, the behavior of the fluid and his interaction with the hydroforming tool and the work piece was simulated. The coupling of the fluid dynamical and thermo dynamical problem allowed the determination of the temperature distribution in channel and tool and the development of velocity and shear stresses during the whole hydroforming process. The results of the simulation were finally validated with flow experiments on the hydroforming tool.

Keywords: tube hydroforming, viscous dissipation, coupled FE-analysis

O-V/6
The Effect of the Heat Treatment on the Deep-Drawing and Earing Properties in Case Of 99.5al Alloy

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Effect analysis of the different preheating technologies on the deep-drawing and earing properties was performed in case of the cold rolled final product. The effect of final heat treatment on the anisotropy was analyzed in case of different preheated, hot rolled and cold rolled DC (direct-chill casting processes) cast rolling ingots. Some experimental heat treatments were carried out in order to obtain quasi isotropic products. On the basis of the

results of these experiments, the whole process (preheating, hot and cold rolling, final heat treatment) was optimized to take into consideration the furnace capabilities

O-V/7

FEM Simulation of Vacuum Hot Bulge Forming Process of BT20 Titanium Alloy Cylindrical Workpiece

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Bulge forming is an innovative manufacturing process which is used to manufacture many industrial components. Common components are bugled by restraining the blank in a die bearing the desired shape and applying an internal hydrostatic pressure to the tube via a liquid or solid medium. But bulge forming using a different expand coefficient of components and die by heating and holding temperature in vacuum reported in literature has been limited. A 2-D thermo-mechanical coupled elastic-plastic finite element model was developed in which the nonlinear radiation heat transfer and thermal physical properties of material were considered. This paper carried out numerical simulation of vacuum hot bulge forming of BT20 titanium alloy cylindrical workpiece by using finite element software MSC.Marc. The temperature field and the displacement field of vacuum hot bulge forming of BT20 titanium alloy cylindrical workpiece were calculated. The corresponding experiments were carried out. The simulated results agree well with the experimental results. This work lays a theoretical foundation for vacuum hot bulge forming process.

O-V/8

Static and Dynamic FE Analysis of 304 Stainless Steel Rod and Wire Hot Continuous Rolling Process

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Three-dimensional FE models were developed to analysis 304 stainless steel rod and wire hot continuous rolling process. The whole 30 passes deformation process and the actual parameters of production line were taken into account. Static and dynamic deformation behaviors of the continuous rolling process were studied with the aid of the thermo-mechanically coupled FEM of elastic-plasticity. A commercial finite element package MSC.Marc was employed in the simulation. MSC.Marc used an implicit procedure for both static and dynamic analysis. Theories of the two methods were overviewed in this paper. Due to the complicated three-dimensional geometry and deformation process, the whole 30 passes rolling process was separated to simulate. A data transfer technique based on interpolation mapping method was involved to ensue the simulation results continuous as the actual process was. Deformation and temperature field of billet were mainly discussed. To illustrate the feasibility and accuracy of the proposed FEM models, the measured and calculated data for billet temperature were compared. The simulation results are found to agree well with the measured values, which means that the rod and wire rolling process can be analyzed by the two developed models. A comparison of the analysis results obtained using static implicit finite element method and dynamic implicit method was presented. It is found that the dynamic analysis shows a higher efficiency than the static analysis.

O-V/9

Thermal and Mechanical Stress Comparison in Turning Machine's Spindle

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Spindle is a main part in turning machines, so that it defines the precision of the machine. As a result, the dimensional accuracy of the workpiece wholly depends on the precision of machine's spindle. From this point of view, the behavior of spindle under some inputs is very important.

This precision of spindle becomes more serious when it is used for a period of long times. Therefore, stress and strain analysis of spindle is very important in the behavior and preservation of its precision. In this paper, the force applied to the spindle of a turning machine is calculated. Afterwards, the spindle is simulated with MS_C Visual Nastran software and analyzed due to the application of boundary conditions. According to the spindle's stress the modal analysis has been done and the natural frequencies of the spindle are determined. Finally, the mechanical and thermal stresses are compared. These stresses will be increased with feed and dept of cut. When these feed rates and depths of cut become less, the created stresses at the least speed of spindle are more in comparison with the other speeds.

Keywords: Spindle, Turning machine, Thermal Stress, Modeling

O-V/10

Coupled Analysis of Heat Transfer, Microstructure Evolution and Residual Stress in HSLA Pipeline Steel Welds

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Heat transfer, microstructure evolution and residual stress development in seam and girth welds of high strength low alloy pipeline steels are simulated with advanced finite element models. The analyses emphasize the coupling of thermal solution and metallurgical changes. Also emphasized are the effects of phase transformation induced property changes and transformation plasticity on the development of residual stresses. Commercial finite element code ABAQUS provides the platform of the finite element analyses. User subroutines are used to add capabilities and functionality for the coupled analyses. Thermal constitutive behaviors of the materials are considered in the user subroutine UMATHT, within which the coupling of thermal solutions and metallurgical changes is achieved. Microstructure components are treated as state variables and are computed and updated at each time increment. Enthalpy change is utilized in the numerical algorithm to keep track of the change of internal energy. It allows the absorption and release of heat associated with phase transformations be considered in a more realistic and accurate manner. With the UMATHT, Thermophysical properties can be evaluated as dependent on both temperature and the instantaneous microstructural constituents. User subroutine UMAT is used to implement the mechanical constitutive model of the materials subjected to welding, which considers the effects of phase transformations on mechanical properties, volumetric expansions, and transformation plasticity. The predicted microstructure, property and residual stress results are in good agreement with experimental observations. The modeling results offer detailed information on the microstructure evolution and residual stress development.

O-V/11

Laser Beam Welding Modelling of Aeronautical Structures

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This paper presents the numerical modelling of the Laser Beam Welding of aeronautical structures such as fuselage panels.

The objective was to compute the welding-induced distortions. To achieve this, two difficulties had to be overcome. The first one was to develop an accurate model of the thermo-mechanical response of the welded structure. The procedure encompasses two steps:

- a semi-analytical simulation of the heat source, providing the thermal field in the vicinity of the joint as a function of the welding parameters.
- A thermo-mechanical Finite Element model, using the previously defined heat source to compute the distortions of the structure. This model has been applied on a small coupon and has been successively compared to relevant experiments.

The second difficulty was to apply the simulation to a large structure. Indeed, welding simulations are computationally intensive and are difficult to apply to large models. Two approaches have been used and compared:

- a local/global approach using successively a local 3D model, a local shell model and a global shell model,
- a semi-direct approach for which the thermal field computed on a small-scale model is applied and moved on a global shell model.

Distortions obtained for both approaches are compared to those observed on an experimentally welded panel. Results are discussed in terms of accuracy, computations times and limitations.

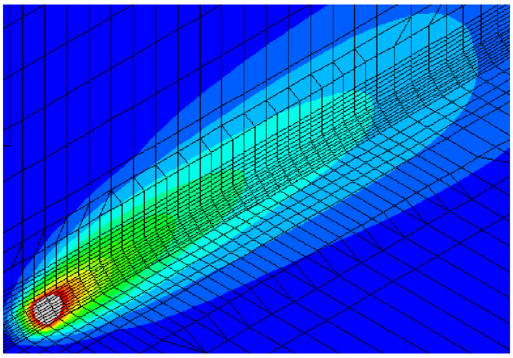

Figure1.: Local thermal Field

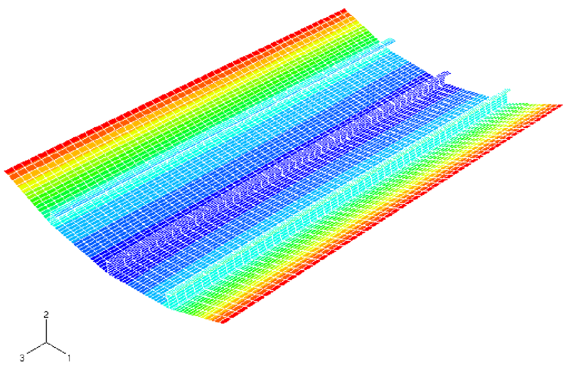

Figure2.: Global shell model (vertical displacement x 10)

O-V/12

Reliability of Hardening Model to Predict the Welding Residual Stresses

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This study contributes to the NeT European Network formed in 2002 (Smith M.C *&* *al.*, 2005). The aim is to simulate the benchmark problem of a single weld bead laid down on the top surface of a 316L austenitic steel plate (TG1b problem).

Welding processes generally involve complex loadings and material nonlinearities. Combinations of heating and cooling operations commonly induce mechanical cyclic loads with different strain paths in plastic zones. In order to properly represent such an effect, it is required to accommodate an appropriate hardening model. In this work, we discuss the reliability of hardening model to predict the welding residual stresses. The residual stresses were predicted using finite element method performed with Code_Aster 7.4 from EDF. The numerical results are validated by comparing with experimental data collected in the frame of "NeT-TG1" task.

Keywords: Numerical Welding Simulation, Cyclic Loads, Hardening Model, 316L Austenitic Stainless Steel.

O-V/13

Characterization of the Shape of Plasma Geometry in case of TIG-welding

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Testing samples of three tungsten electrode types were prepared with different taper angles to analyse the geometry of TIG-welding plasma. The 6 different taper angles are: 10°, 20°, 30°, 45°, 60°, 90° and the electrodes types are two lanthanum dioxide containing (colour code "gold" with 1,5% LaO_2, colour code "black" 1,0% LaO_2) and one thorium dioxide (colour code "red" with 2% ThO_2). Beside these specimens, tip flatted (at 30% of the tip height) electrodes were grinded as well. It means that the shape of TIG welding plasma were analysed for 36 different electrodes.

Three digital pictures were taken from each case during arc-spot welding.

During the plasma shape analyses on the digital pictures, the height, the width and the most intensive part of the plasma were measured, furthermore the width at the half-height and height at the maximal width were determined as well. Additionally the whole area and the brightest area of the plasma were checked. The measured values were represented as a function of taper angles.

Regarding the analyses, the main conclusion is first and foremost that the maximum of the curves, which characterise the effect of taper angle on the shape of plasma, for the sharpened electrodes, were at taper angle of 20-30°. The properties of the red and the black electrodes are running collaterally. Despite of them the curves of the gold electrode shift to left. Probably it is caused by the high LaO_2 content of the tungsten electrode. Unfortunately there was no clear correlation between the electrode geometry (taper angle) and the shape characteristics of TIG-plasma for the electrodes, which were prepared with a flat tip. The diagrams of flatted electrodes show no correlation.

O-V/14
Numerical Simulation of the Thermo-elastic Behaviour for Textile Structured CMC Bearings

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For new high performance and high accuracy turning machines it is necessary to reduce dissipation loss and abrasion as well as to improve the damping behaviour. A proper way to achieve this aim is the use of new materials for the bearing sleeves. Therefore innovative ceramic matrix composites (CMCs) consisting of SiC-matrix and carbon fibres were selected. Research was done especially with regard to the thermo-elastic behaviour.

This work describes a new method to calculate the thermal and mechanical behaviour of a textile structured composite made with woven rovings. First the woven fabric patterns are divided in the smallest section including all significant parameters. The full textile structure can be built by frequent repeating of this basic section. The size of the basic section depends on the fabric style. Finally, the composite consists of three sections: pure matrix-material, woven rovings permeated with matrix-material and pores.

The properties of the matrix-material and pores are well known. Additionally, the properties of the rovings permeated with the matrix can be considered as a continuous-fibre reinforced composite which is formed to the warp thread or weft thread. The anisotropic properties of this part of the model can be calculated with established analytic or numeric methodes. Because of the anisotropy it is necessary to assign a local material coordinate system to each node in the roving section of the model aligned to the fiberdirection. To get the different elastic and thermic properties the FEM-model has to be loaded in different ways.

The model is implemented in the FEM-System Abaqus. This system offers extensive possibilities to automating modelgeneration and simulation. The new Model was verified by different matrices and fibre material types revealing a high correlation.

The calculated properties were applied to another FEM model to simulate the thermo-elastic behaviour of a bearing combining a steel bearing box and a CMC bearing sleeve. The main problem arises from the different CTE of both materials. In the heating stage the bearing surface changes its shape. Therefore proved models have to be applied to prevent the bearings by well calculated solutions.

O-V/15

Determination of the Effect of Phase Transformation on Residual Stress Distribution in the Quenched Steel Components by Finite Element Modelling

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In this study, an efficient finite element method based model for prediction of temperature field, phase transformation kinetics and evolution internal stresses up to residual stress state during quenching of steel components was developed. The model was implemented into commercial finite element software MSC.Marc by using user subroutines. The effect of thermal stresses, phase transformation stresses and transformation plasticity on the residual stress state was investigated by numerical experiments on the quenched steel cylinders. In calculation of temperature field both the effect of latent heat due to phase transformation and convective heat transfer to quenching medium is considered. Different cooling regimes during quenching process due to Leidenfrost effect was indirectly taken into account by using a surface temperature dependant heat transfer coefficient. Phase transformations were modeled by discretizing the cooling curves in a succession of isothermal steps. Athermal martensitic transformation kinetics was modeled using Koistinen-Marburger equation whereas pearlitic and bainitic transformation kinetics was modeled by using Scheil's additivity principle and Johnson-Mehl-Avrami equation. Transformation plasticity was incorporated into the model by using Leblond's approach.

Keywords: Steel, Quenching, Finite Element Method, Residual Stress, Phase Transformation, Transformation Plasticity

O-V/16
Thermodynamic Description of the Systems Cd-Te , Hg-Te and Cd-Hg-Te Using the Model of Associeted Liquid Solution

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This study is devoted in the search of a model describing the best possible liquid and solid phases of the systems Cd-Te, Hg-Te, and Cd-Hg-Te. For the liquid phases, we used the model of sub-regular associated solution (S.A.S) in which we supposes the existence of associated species CdTe and HgTe with the simple species Cd, Hg, and Te. The excess free enthalpy of mixture $\Delta^{ex}G^{L}$ is then expressed as a polynomial of Redlich-Kistler, it is function of the species concentrations to the order two, using like coefficients, the parameters of interaction between the various species. For the solid phase in the ternary diagram, the excess free enthalpy $\Delta^{ex}G^{S}$ is expressed in the model of pseudo-regular associated solution (P.R.A.S), using like coefficients the parameters of interaction between the solid species CdTe and HgTe. The value of these parameters, the thermodynamic quantities of dissociation, for the associated species is calculated by the numerical resolution of the phase equilibrium equations. The results of this calculation indicate a more marked associated character in Cd-Te than in Hg-Te with a pseudo-regular behavior of the binary liquid Cd-Te. In the ternary we note a prevalence of the interactions Cd-CdTe and Hg-HgTe compared to the interactions Cd-HgTe, Hg-CdTe, CdTe-HgTe and Cd-Hg-Te. The phases diagrams calculated from the thermodynamic quantities, describe very well the experimental diagrams especially for the binary systems.

Keywords: Associated solution, sub- regular solution, pseudo-regular solution.

O-V/17

Prediction of Welding Distortions using an Adaptive 3D/shell Approach

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The determination of residual distortions induced by welding processes is time-consuming because welded structures are often quite large and complex. However, high gradients of temperature, metallurgical phases, stresses and plastic strains are all located within a relatively small zone around the heat source. This zone demands a full 3D mesh, but the rest of the structure may often be safely represented using shell elements. Frédéric Faure [New methods for the numerical simulation of welding of thin structures, PhD thesis, University of Paris VI, 2004] developed an "adaptive 3D/shell approach" based on such simultaneous use of 3D elements in the heat-affected-zone and shell elements outside, the full 3D zone being displaced within the general shell mesh as the heat source moves. However this approach gives rise to difficulties related to the connection between the 3D block and the shell elements. Also, it was developed only for small displacements. In this paper, some proposals are made to improve the thermal and mechanical connection between the 3D block and the shell elements, and to extend the method to large displacements. The validity of this new approach is assessed through comparison of its results with those of a full 3D simulation.

Keywords: Welding, residual distortions, 3D elements, shell elements, adaptive approach.

O-V/18

Numerical Simulation and Experimental Measurement of Residual Stress in Shaped Castings

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Residual stresses in cast components are elastic stresses which remain in the castings after they have been removed from the mould. These stresses which are generated due to non-uniform expansion and contraction rates can have a considerable effect on the quality of castings. Numerical simulation of deformation and thermal stress during casting processes is therefore of substantial importance in understanding the development of residual stress and distortions as well as process improvement. In this research the thermo-elasto-plastic model provided in the finite element analysis software is used to model the thermal stress during casting and to predict the residual stress from point to point in rectangular and triangular shaped steel castings. Numerical simulation results show that stress distribution is related to thermal gradients in these castings, and that the maximum residual stresses are developed at locations which solidify at later stages during casting process. The residual stresses at predicted locations have been experimentally measured, using a cutting technique, and compared for carbon steel and stainless steel castings. The overall results of numerical simulations and experimental measurements are applied to evaluate the effect of mould shape and pouring temperature on residual stress and distortions in shaped castings.

O-V-19

Thermal stress analysis by a Hybrid Technique of FDM and FEM for Casting Process

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In these days, the solidification and flow fluid analysis using computer simulation are performed widely in casting field. Also there are much of requirement on the thermal stress analysis in casting process, because the casting engineer wants to control the defects concerning for thermal stress, such as large deformation and crack generation during casting. However, the thermal stress analysis based on finite element analysis has difficulties in mesh generation and takes lots of computational time. The gate and riser system are essential parts in casting process, and the systems has large influence on thermal phenomena, but the analysis domain is expanded by the gate and riser systems and especially the shallow ingate part of the gate system makes the mesh generation difficult. In this paper, we studied the effects gate and riser system on thermal stress analysis in casting process simulation and the results give us the optimal analysis conditions of gate and riser for stress analysis in order to easy mesh generation and fast computational time.

This paper proposes a systematic field data conversion procedure between FDM and FEM. Today, computational methods like the finite difference method(FDM) and the finite element method(FEM) are very popular for solving engineering problems by resorting to a specific method suited to each problem; for example, FDM is favored for fluid flow or heat transfer, FEM mostly chosen in structure analysis. However, the need is rapidly being increased to use, at one time, a combined method for complex and coupled phenomena. But the use of the combined method leads to interface of data each other. So we proposed field data conversion procedure between FDM and FEM in 3-dimensional space, then applied this procedure to analysis of casting process. The computer simulation carried out mold filling and solidification through applying FDM. The field data such as temperature and pressure distributions were converted for FEM analysis that was employed for calculating thermal stress distributions. The error due to conversion of data was discussed and the proposed combined method gave satisfactory result in casting process analysis.

This paper proposes a new gate and riser system modeling concept for thermal stress analysis in FDM/FEM hybrid technique. The FDM/FEM hybrid technique carried out solidification and heat flow through applying FDM. The field data such as temperature and pressure distributions were converted for FEM analysis that was employed for calculating thermal stress distributions.

O-V/20
3D Coupled Thermo-mechanical FEM Simulation of Hot-forging Process of a Gas Turbine Compressor Blade

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Due to the complicated three-dimensional geometry and the non-steady state contact between the workpiece and the die surface, the simulation of blade forging process performed so far has been restricted to two-dimensional plane-strain problems or simplified three-dimensional deformational cases throughout which some simplifications and assumptions are employed. In this paper, a 3D coupled thermo-mechanical FEM model was developed to simulate hot-forging process of a gas turbine compressor blade. In this model, the temperature dependency of the thermal and mechanical properties of material was considered. Simulation successfully predicted a complete load/stroke diagram and metal flow patterns on the multi-stage forging process. Meanwhile, the distribution of different field-variables, such as velocity, strain and temperature, were obtained. On the basis of these results, the forming laws during hot-forging process of a gas turbine compressor blade are revealed, which can be incorporated into process design. The validity of simulation results was verified through comparisons with industrial trials, which show good agreements with numerical simulation results. The simulation results may be effectively applied to other types of three-dimensional turbine blade forging processes.

POSTER SESSION

(ABSTRACTS)

P/1

Synthetic Fuel from Catalytic Degradation of Waste Polymers Over Solid Acid Zeolites

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The catalytic degradation of polyethylene (PE) into synthetic fuel over H-ZSM-5 catalysts was studied using a SS-tubular batch reactor. The effect of reaction temperature, reaction time and catalyst weight were investigated. Processing under these conditions allowed for a higher conversion into condensable liquid reaction product. Different analytical tools such as GC-FID, IR and NMR have been used to analyze the reaction products. The products were of a narrow range of carbon distribution (C5 to C15). The result showed that the average liquid fraction obtained in the reaction product was 75 by weight.It has been found that the reaction product contains mainly alkane, alkene and aromatics.

P/2

Methodology of Quality Assessment of Castings from Al-Si

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The aim of this publication is to present the methodology of the automatic supervision and control of the technological process of manufacturing the elements from aluminium alloys and of the methodology of the automatic quality assessment of these elements basing on analysis of images obtained with the X-ray flaw detection, employing the artificial intelligence tools. The methodologies developed will make identification and classification of flaws possible and the appropriate process control will make it possible to reduce them and to eliminate them - at least in part.

Therefore, the goal of this work is presentation of the general assumptions for employing the selected artificial intelligence methods for classification of flaws identified with the radiographical methods in the car subassembly castings from aluminium alloys and presentation of the design requirements of the computer system developed to assist the classification task.

P/3

Experimental and Theoretical Contributions in Studieing Stress Variation of an $AlCu_4Mg_1$ Aluminum Alloy

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This paper presents experimental and theoretical studies regarding the behavior after heat treatment of an AlCu4Mg1 aluminum alloy.

The proposed methodology for studying the improvement of heat treating technology of AlCu4Mg1 aluminum alloy can be resumed in:

- adopting the heat treating technology for the proposed alloy;
- choosing the necessary hot working installations in order to realize the heat treating for the specified alloy;
- choosing the tools and the machines used for studying the mechanical characteristics;
- programming the experiment and analytical interpretation of the results.

On the basis of these experiments and the regression obtained we made a theoretical study regarding the establish of the heating parameters for quenching and aging in order to obtain a certain stress, needed in service for this alloy. For this theoretical study we consider two cases:

- stress and quenching temperature are fixed and we determine aging temperature;
- stress and aging temperature are fixed and we determine quenching temperature

Using the equations determined, we impose some characteristics needed for the final working part and we calculate the parameters for the quenching heat treating and artificial aging heat treating. We must mention that the calculated temperatures must be between standard limits for the studied alloy.

As a conclusion, the paper presents the algorithm for applying the optimum heat treatment in order to obtain the necessary properties for the working parts.

P/4
FEM simulation of the temperature field during the laser metal deposition shaping process

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Recently, a type of direct laser deposition process, called Laser Metal Deposition Shaping (LMDS), has been pursued and developed at Shenyang Institute of Automation Chinese Academy of Sciences. The process incorporates features from stereo lithography and laser surfacing, using CAD file cross-sections to control the forming process. Powder metal particles are delivered in a gas stream into the focus of a 3 kW continuous CO2 laser to form a molten pool. The part is then driven on an X-Y stage to generate a three-dimensional part by layer wise, additive processing. During the laser deposition process, excessive heat is produced by the interaction between the high-power laser and the deposited material. Noticeably, it is important to understand and control the thermal behavior during fabrication. With this control, components can be reliably fabricated with desired material properties. In an effort to understand the thermal behavior of the LMDS process, in-situ high-speed thermal imaging has been coupled with microstructural analysis and finite element modeling. Cooling of the melt is accomplished primarily by conduction of heat through the part and substrate, and depending on the substrate temperature and laser input energy, cooling rates can be varied from 102 to 103 K s-1. This flexibility allows control of the microstructure and properties in the part. The experiments reported herein were conducted on 316 stainless steel, using two different particle size distributions with two different average particle sizes. Thermal images of the molten pool were analyzed to determine temperature gradients and cooling rates in the vicinity of the molten pool, and this information was correlated to the microstructure and properties of the part. Some significant finite element modeling of the LMDS process is also presented. In order to verify the validity of the modeling, simulative results of temperature distribution modeling for multi-layer structures prepared by direct laser remelting of metal powders were numerically obtained and compared with experimental data, which is critical to understand the thermal behavior and optimize the processing parameters.

Keywords: Temperature field modeling; Laser Metal Deposition Shaping (LMDS); Metal parts; Multi-layer direct fabrication

P/5

Modelling of Heat Transfer in Micro Tube Condenser

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This paper describes the numerical results of the dimensioning of a condenser. Dimensioning of a condenser consists of calculating the different phase lengths: gas, liquid part steam part and liquid part. This provides the distribution of the temperature along the condenser using a variety of fluids. A condenser was experimentally tested for some operating conditions such as mass flow rate and radius of the tube. An approach, along with a combination of thermodynamic correlations with several variables was adapted. Heat transfer coefficients were estimated as the functions of input gas flow rate, temperature, diameter. The increase of gas and solution flow affects positively in heat transfer. However, the increase of temperature affects negatively. In addition, from these experimental data, empirical correlations that can explain easily the characteristics of heat transfer are derived.

Keywords: Condenser, Heat transfer; Forced convection.

P/6

Thermal process modeling for laser and powder particles interaction during the laser metal deposition shaping process

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The laser metal deposition shaping (LMDS) process is a laser assisted, direct metal manufacturing process under development at Shenyang Institute of Automation Chinese Academy of Sciences. The LMDS process offers the ability to make a metal component directly from CAD drawings. During the deposition process, numerous metal powder particles sprayed from coaxial powder nozzle are melted due to a high-power laser, and then are re-solidified on the substrate. The laser scanning path is driven by the layered profile data deriving from the CAD model. In this way, the desired fully-dense part can be deposited point by point, line by line, and layer by layer. Analysis of metal powder flow in the feeding system is of particular significance to researchers in order to optimize this technique. Powder flow simulation holds a critical role in understanding flow phenomenon so as to effectively control molten pool temperature and geometry which are significant to the microstructure and properties of the deposited material. Consequently, a thermal process modeling for laser and powder particles interaction during the LMDS process is developed. Interactions between the laser and the powder particles lead to attenuation of the laser and make the powder particles temperatures raise. According to given stream spread and speed of the powder particles, their temperature distribution at the surface of the workpiece is calculated. The attenuation of the laser induced by the cloud is also computed. In addition, the thermal process is systematically simulated according to the various influencing factors, such as processing parameters, powder jet incidence angle, particle size, stand-off distance, and so on. These simulative results are plotted for the case of Gaussian distribution. Results show that with the variation of these factors, both temperature distribution of powder particles and attenuation of the laser have very different profiles. Their effects on the clad should be considered for modeling of the LMDS process, which is essential to confirm optimal integrated factors for fabricating metal parts. The validity of the model is demonstrated through comparison with experiments.

Keywords: Thermal process modeling; Laser and powder particles interaction; Laser Metal Deposition Shaping (LMDS); Metal parts; Direct deposition manufacturing

P/7

Effect of Surface Decarburization on the Mechanical Properties of C % 0.30, Si % 1.01, Mn % 0.88, Cr % 0.86, Steel

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C % 0.30, Si % 1.01, Mn % 0.88, Cr % 0.86, is a high strength low alloy (HSLA) steel with < 5 % alloying elements contents and tensile properties in order of 1100 ~1300 MPa in quenched and tempered state. One of the applications of these steels is casing materials in large welded pressure vessels due to high strength and good weldability. C % 0.30, Si % 1.01, Mn % 0.88, Cr % 0.86, steel sheets (δ=4.00 mm) are rolled, welded and stress relived during manufacturing of pressure vessels. The pressure vessel is finally quenched at 880±10^{0}C for 90 min and tempered at 480±10^{0}C for 50 min in a controlled atmosphere. The specified values of tensile strength, % Elongation and impact toughness after the final heat treatment are ≥ 1100 MPa, ≥ 10 % and ≥ 50 J/cm^2.

Decarburization affects the mechanical properties of these steels and for 4.00 mm thick sheet decarburization depth of ≥ 0.2 mm is permitted after the final heat treatment. In some samples decarburization depth > 0.2 mm was observed, the reason for which is not included in scope of this paper. The current work determines the effect of decarburization depth on the mechanical properties of C % 0.30, Si % 1.01, Mn % 0.88, Cr % 0.86, steel sheet (δ=4.00 mm)

05 samples of C % 0.30, Si % 1.01, Mn % 0.88, Cr % 0.86, steel sheet (δ=4.00 mm), with decarburization depth varying between 0.02mm to 0.5 mm, have been selected in the current work. The mechanical properties studied are tensile strength, yield strength, % elongation and impact toughness. It has been observed as the decarburization depth increases from 0.02mm to 0.50 mm the tensile strength decreases from 1311 MPa to 1056 MPa and the Impact toughness increases from 77 J/cm^2 to 109 J/cm^2.

P/8
Strain and stress analysis of HDPE processed by ECAE at different temperatures and ram speeds

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Equal channel angular extrusion (ECAE) is an innovative forming process to extrude material without substantial change in its geometrical shape. Multiple extrusions from equal channel angular extrusion allow heavy plastic strain to the material. More importantly, by changing the orientation of the workpiece between successive extrusions, sophisticated microstructures and textures can be created in the material. According to the orientation selection for each pass, four fundamental ECAE routes are defined and used for different purposes. It is important to understand the material flow related to each route because it significantly impacts the formation and orientation of the microstructure. Furthermore, the knowledge of the strain and stress distributions in ECAE process according to temperature is very important, in order to achieve the optimal thermo-mechanical conditions and to obtain the desired mechanical properties in the extruded material.

In this work, compressive tests of a typical semicrystalline polymer (HDPE) at different strain rates and temperatures were used to estimate the material parameters of a phenomenological elastic-viscoplastic model. Then, the extrusion of this polymer at different temperatures was analysed using the finite element modelling to investigate the homogeneity of the plastic deformation according to the ram speeds. In a first step, the effects of the material properties on the polymer flow through the ECAE die were first reviewed. Then, the corner gap formation between the die and the workpiece during plane strain ECAE process was treated. It was found that this phenomenon increases with temperature increase. Finally, to illustrate the evolution of the plastic strain, multi-passes using various routes were investigated.

Keywords: ECAE, finite element analysis, temperature effect, ram speed effect, multiple extrusions, polymers.

P/9

A Mesoscopic Approach to Simulate the Damage Induced by Welding

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The main aim of the article is to study and develop welding numerical models under phase transformation and damage condition. The models are based on the study of damage concept in the multiphasic behaviour which occurs during by welding process. The cores of models or constitutive equations are the coupling between ductile damage, small strain elasticity, finite visco-plasticity and phase transformation. Based on the theory of thermodynamics and continuum damage mechanics (CDM), constitutive equations are built to describe damage's growth and crack appearance during and after welding. The thermodynamics of irreversible processes with state variables is used as a framework to develop the phase coupling model. The related numerical aspects concern both the local integration scheme of the constitutive equations and the global resolution strategies.

Keywords: Phase transformation, visco-plasticity, continuum damage mechanics, welding

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