Editorial

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Biographical notes: Professor Dr. Miklós Tisza, DSc, obtained his MSc degree in Mechanical Engineering from the Technical University for Heavy Industry in 1972 and his PhD degree from the University of Miskolc in 1977. Professor Tisza has a DSc degree from the Hungarian Academy of Sciences (1994). He is a Fellow of the ASM International, the Past President of IDDRG and a member of the Board of Directors of the European Scientific Association of Forming Materials (ESAFORM). He is the author of more than 20 books and has over 350 publications in leading international journals and conferences on various aspects of metal forming, computer-aided engineering, and numerical modelling and simulation. Currently, Dr. Tisza is the Head of the Department of Mechanical Engineering at the University of Miskolc, Hungary.

Janez Grum is a Professor of Materials Science at the University of Ljubljana Faculty of Mechanical Engineering in Slovenia. He is also the Founder and Editor-in-Chief of the journal, *International Journal of Microstructure and Materials Properties* (IJMMP) and has been the Editor of the journal *News of Society for Non-destructive Testing*, *Slovenian Society for Non-Destructive Testing*, Ljubljana since 1994. He is the Editor of the six NDT conference proceedings, two ASM and Marcel Dekker book chapters and five books with several reprints. He has also published more than 100 refereed journals and more than 300 conference papers on heat treatment, laser materials processing and materials testing, including nondestructive testing.

Selected papers in this issue of the *International Journal of Microstructure and Materials Properties* were presented at the Third International Conference on Thermal Process Modelling and Simulation in Budapest, Hungary in 2006. This conference series started in Shanghai, China in 2000 and continued in Nancy, France in 2003, followed by the one in 2006. All of these international conferences were organised by the International Federation of Heat Treatment and Surface Engineering (IFHTSE).

Bell *et al.* presented the state of the art of their topic in 'Contact mechanics modelling of surface engineered systems'.

The ever-increasing demands for combined properties in machinery operating under ever more severe conditions have been the driver for the rapid developments of surface engineering technologies. Engineers have many surface engineering technologies for selecting the design of various machine components. A contact mechanics model has been developed by the authors based on modern theories of multilayered surface contact, taking into account the microstructure, surface roughness and friction conditions. With this model, the performance of surface engineered components can be successfully predicted, making use of optimisation surface engineering systems. 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 in designing dynamically loaded surface-engineered components are demonstrated.

Tisza *et al.* presented a very intensive activity in the field of their paper, 'Numerical modelling of hot forming processes'.

The simulation of hot forming processes involves most of the numerical difficulties that one usually meets in finite element simulation, *i.e.*, complicated temperature evolution, thermal and mechanical coupling should be considered, large deformations and significant microstructure changes occurred in the parts, contact phenomena and friction play a significant role which affects the final properties of the parts.

The main objectives of finite element modelling in bulk forming processes are the development of an adequate process sequence and die design by process simulation of die cavity filling, the prediction of temperature distribution and process limits to avoid internal and surface defects, the improvement of part quality by improving material flow, grain flow and microstructure changes, and the increase in 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 the understanding of 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 analyses have become possible by developing finite element procedures for metal forming processes. An important step was the development of process-oriented special purpose Finite Element Modelling (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. They have reached such a degree of sophistication that finite element codes are now available for and are being used by the industry.

In Tisza's paper, first, the state of the art of numerical modelling in hot forming processes is 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 are also discussed. Finally, some industrial examples are shown. An integrated approach to forging and heat treatment is also illustrated.

Surm *et al.* presented the paper 'Modelling of austenitising with non-constant heating rate in hypereutectoid steels'.

The process of heat treatment of steel is closely related to the heating and overheating of machine parts of different sizes and shapes to an adequate temperature, followed by quenching with a suitable quenching agent. With the heat-treatment processes applied to machine parts, engineering personnel will often encounter numerous difficulties, which most often consist of volume changes of parts, their distortion and the presence of residual stresses. It is very important to know the volume changes of machine parts in the course of a heat-treatment process applied since only in this way can a product having the right size be obtained at the end of heat treatment.

The problems of the quenching and distortions of machine parts are known and always present, which results in a permanent search for new opportunities to reduce such distortions. Consequently, the papers in Surm *et al.*'s overview were selected from the most recent studies by the authors. Particular attention should be given to the papers presented at the conferences on Quenching and The Control of Distortion, the first held in 1992 (Chicago), and the succeeding ones in 1996 (Cleveland), 1999 (Prague) and 2003 (Beijing). In addition to the conferences on Quenching and The Control of Distortion organised periodically by the American Society for Materials (ASM), the annual conferences of the ASM also included contributions from the field of heat-treatment processes and surface engineering, particularly those dealing with quenching. Further contributions dealing with the theme of quenching and heat treatment were periodic conferences titled *International Conference on Thermal Process Modelling and Computer Simulation (ICTPMCS)* held in Shanghai in 2000, Nancy in 2003 and Budapest in 2006. They treated simulations and the modelling of the heat-treatment process and phenomena in materials. In addition to these papers, papers published at the conferences organised by the IFHTSE should also be mentioned. And last but not least are the papers dealing with the problems mentioned in various scientific journals dealing with materials, heat treatment and surface engineering.

In order to reduce distortion to a minimum, the Collaborative Research Center Distortion Engineering established in Bremen at the Department of Heat Treatment, Institute of Material Science, investigates the effects of all manufacturing steps on distortion. The sum of all the possibilities to provoke phenomena that can influence the dimension and shape of a component in a negative way is defined as the distortion potential.

The calculation of distortion during heating for quench hardening needs an accurate modelling of the austenitising 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 austenitising with nonconstant heating rates is tested in this work. For this purpose, dilatometer tests were conducted with a change in heating rate during the transformation process. With transformation parameters, determined from austenitising with constant heating rates, the experimental and the calculated strain show no sufficient correlation during continuous heating with a nonconstant heating rate.

Transformation parameters have to be adjusted to get a good agreement between experiment and simulation.

Dalgic *et al.* contributed their study, 'Transformation plasticity at different phase transformation of a through hardening bearing steel'. A simulation of the heat-treatment processes requires material data for the description of the phase transformation. The interaction between phase transformation and external stress is the subject of the reported investigation. The investigation shows the influence of constant tension and compression stresses on the transformation kinetics during the isothermal pearlitic and bainitic transformation and also the martensitic transformation of the bearing steel.

Wielage *et al.* presented the paper ‘Numerical simulation of the thermo-elastic behaviour for textile structured ceramic matrix composite bearings’.

With the aim of simulating the thermo-elastic behaviour of a slide bearing with a sleeve made of woven fabric-ceramic composite material, a new approach was used to determine the material properties of the composite.

For new high-performance and high-accuracy turning machines, it is necessary to reduce dissipation loss and abrasion on the one hand and to improve the damping behaviour on the other hand. One way to achieve this aim is the use of new materials for the bearing sleeves. At the time the idea to use CMC was researched, it needed a special view of the thermo-elastic behaviour of these materials.

The physical properties of composite materials can be determined by measuring or by calculating. Measuring is very complex especially with fibre-reinforced composites because of the anisotropic behaviour of the properties. For an orthotropic view, it is necessary to measure nine different values which describe the elastic behaviour and three values for the thermal extension without other thermal effects like thermal conduction and specific heat. Examining different compositions, volume fractions and woven fabric types needs a lot of tests and therefore takes a lot of time and money. For model creation and simulation, the FEM-Software ABAQUS was used.

This software contains tools for the automation of the model generation so that the model can be adapted to further fabric configurations at comparatively small expenditure.

Halimi and Ferah presented the paper ‘Thermodynamic description of the systems Cd-Te, Hg-Te and Cd-Hg-Te using the model of associated liquid solution’.

They used the model of the Subregular Associated Solution (SAS), in which they supposed the existence of associated species Cd-Te and Hg-Te with the simple species Cd, Hg and Te. For the solid phase in the ternary diagram, the excess free enthalpy is expressed in the model of Pseudoregular Associated Solution (PRAS), used as coefficients of parameters of interaction between the solid species Cd-Te and Hg-Te. The value of these parameters, the thermodynamic quantities of dissociation, for the associated species is calculated by the numerical resolution of the phase of equilibrium equations. The phase diagrams calculated from the thermodynamic quantities describe the experimental date very well especially for the binary systems.

In their paper ‘Measurement and numerical analysis of surface residual stresses occurring under different quenching conditions’, Grum *et al.* compared the measurement and analysis of said stresses of 4140 AISI steel.

In the research, cylindrical specimens of Ø 40 × 160 mm in size were used, whereas in modelling, specimens of the same diameter, *i.e.*, Ø 40 mm, but of infinite length were used. One quenching agent was selected, *i.e.*, a 15% polymer-water solution, and different initial temperatures of quenching were chosen (860°C and 620°C). Residual stresses were measured with the hole drilling relaxation method. The maximum residual stresses were found in a tangential direction. The maximum residual stress after quenching from an austenitisation temperature of 860°C was of a compressive character

(270 MPa) with its gradient, which was 80 MP in the subsurface. The residual stress after quenching the steel bar from 620°C was relatively higher at –360 MPa. The maximum calculated residual stress was of a compressive character, that is, 400 MPa at quenching from 860°C and –200 MPa at quenching from 620°C.

Discrepancies between the calculated and measured maximum residual stresses are attributed to the choice of materials, to the technique of residual stress measuring, and to not considering previous residual stress in steel prior to the quenching process.

Dal Bó and Geiger presented the paper ‘Effects of viscous dissipation in the flow-influenced tube hydroforming’.

Due to the shortage and increasing cost of energy and materials, the automotive industry wants to improve manufacturing processes and technologies. In tube hydroforming, the forming results can usually be improved if axial feeding at one or both tube ends is impossible. For very long parts, however, due to the high-friction forces acting between the tube and the die at high pressure, no material flow to the forming area occurs. In this paper, the behaviour of a flowing, highly viscous Newtonian fluid was analysed and thermomechanical multidisciplinary FE analyses were done to study the effects of viscous dissipation and conductive and convective heat transfers between fluid and tool.

The results of the simulation were validated with temperature measurements during the experiments on the hydroforming tool.

Rohde contributed the work ‘Numerical modelling of the laser-surface interaction during laser-induced modification processes of ceramic substrates’.

Laser-supported processes can be used to locally modify the properties of ceramic substrates regarding applications. These processes are characterised by a strong thermal interaction between the laser beam and the ceramic material, which leads to melting. During the melting process, added material is injected into the melt pool in order to modify the physical properties of the surface layer. The heat and mass transfer during the melting and solidification process was studied numerically. Simulation tools based on a finite volume method were developed to describe the heat transfer, fluid flow and phase change during the melting and solidification. The calculated results were compared to experimental results.

Dobranszky *et al.* presented the paper ‘Characterisation of the plasma shape of the TIG welding arc’.

The 36 investigated electrodes were LaO_2 and ThO_2 alloyed. Tip-flattened electrodes were ground. The plasma geometry was measured by image analysis and measured values were represented as a function of taper angles. The maximal values of taper angles, at which the plasma geometry characteristics were obtained for sharpened electrodes, were 20 and 30 degrees. There was no clear correlation between the electrode taper angle and the plasma shape characteristics for the blunt electrodes.

Markovits *et al.* presented the paper ‘Real-time monitoring of laser bending process’.

An online method to measure the temperature and the deformations versus time during the laser bending of sheet materials was applied. For measuring the temperature, an Infrared Thermovision System was used, and for measuring the deformations, a Deformation Amplifier System. In the experiments, two different steels and different sheet thicknesses were investigated. The results show that material thickness and laser power affect the temperature distribution and the bending angle.

The authors' data give suitable parameters for creating a model for a more precise description of the laser bending process.

Douce *et al*. presented the paper 'Coupled fluid flow, heat transfer, phase transformation, stress and deformation numerical model for gas quenching'.

Their approach is based on the coupling Fluent® code, which simulates the turbulent fluid flow and the thermal transport of the gas around the workpiece, and the Sysweld® code, which allows calculation of phase transformation kinetics and microstructure stress and distortion. The numerical results are compared with experimental data obtained from their laboratory gas quenching device set-up. The gas flow velocities were measured *in situ* using a laser imaging method and were compared to gas velocities calculated with the Fluent-Sysweld coupling, as well as the temperature distribution in the cylinder. A complete numerical simulation was performed in the particular case of a 60NiCrMo11 steel cylinder quenched at 20 bars of helium and which underwent a martensitic transformation.

Hunkel *et al.* gave the paper 'Simulation of the distortion of cylindrical shafts during heat treatment due to segregations'.

Low-alloy steel had been investigated by dilatometer experiments and at heat-treated cylindrical shafts to determine changes in length and curvature due to segregations. Segregations were taken into account by three-dimensional anisotropic transformation strains, which were implemented in the FEM simulation program Sysweld®. Mainly the change in length due to the transformations during heating as well as during cooling can be detected as the main reason for distortion. Thereby, heating and cooling – including phase transformations and mechanical behaviour – were considered, because anisotropy occurs in both cases and its overlapping leads to the final distortion.

These papers offer to a reader numerous scientific results obtained in the field of thermal process modelling and simulation and provides him/her with numerous references to the researchers treating the problems concerned in a comprehensive way. It also gives him/her good insight into the present state of research in the field, widens his/her knowledge of the issues and is, as such, very suitable as a study aid undergraduate students and even more so for postgraduate students.

Special thanks are due to the authors who contributed their papers to this special issue. The contributions are the result of the very critical work of the reviewers and the authors. It can be said that the papers satisfy high standards of quality.

Our great thanks are due also to our coworkers, Mr. Franc Ravnik and Ms. Nevenka Majerle, who took care of coordination among the reviewers and the authors, and prepared the papers for publication.

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We sincerely hope that the papers presented on thermal process modelling and simulation will be a valuable source of information to researchers in various scientific fields and practitioners in the field of materials design and production.