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Guest Editorial

Advances in Plastic Forming of Metals

Metal forming through plastic deformation is one of the most efficient, robust, and economical manufacturing processes available to produce products for unique applications at various length scales. To assist manufacturers address ever increasing and often seemingly conflicting demands (e.g., lightweight products with increased structural rigidity), researchers from around the world are actively engaged in efforts to continuously improve the processes. In this special issue, 28 research papers and four technical briefs are presented to highlight such efforts. These submissions are from researchers in academia, industry, and national laboratories from 12 countries and include experimental, numerical, and analytical efforts. The goal of this special issue is to present the latest developments, trends, and research solutions pertaining to plastic forming of metals to aid both industry and researchers alike. Highlights of the papers categorized by topic areas are given below.

Numerical Modeling

A paper on advances in sheet forming is presented by Barlat's group at Pohang University of Science and Technology. This paper reviews the key developments in the fields of numerical simulation of sheet forming processes, the material models required to obtain accurate results, and the advanced stamping presses and approaches for shaping modern steel sheet materials into desired shapes. Present research trends are summarized, which point to further developmental possibilities. Kinsey's group at the University of New Hampshire has presented a paper entitled "Effect of Element Types on Failure Prediction Using a Stress-Based Forming Limit Curve." This paper investigates the sensitivity of numerical models to the selection of element type. Elements that are investigated are shell, solid, and solid-shell elements. Strano's group at Milano Polytechnic University has presented "A New FEM Approach for Simulation of Metal Foam Filled Tubes." The approach is based on meshing the metal foam by replicating a unit cell made of 32 triangular shell elements and then by randomizing the nodal position in order to emulate the intrinsic homogeneity of foam morphology.

Materials Characterization

A paper on the "Effect of Cross Section Reduction on the Mechanical Properties of Aluminum Tubes Drawn With Variable Wall Thickness" is presented by Fafard's group at Laval University. In this paper, extensive tube drawing experiments featuring different tube materials and sizes are carried out to study the microstructure and mechanical properties evolution during tube drawing process with variable tube wall thicknesses. Abu-Farha's group at Penn State University-Erie has presented a paper entitled "Sheet Orientation Effects on the Hot Formability Limits of Lightweight Alloys." In this paper, disparities that can be encountered in the limiting strain under the conventional FLD for AZ31B magnesium and 5083 Aluminium alloys sheet are discussed. To offset these disparities, a "composite FLD" is introduced as an improved means for characterising material formability limits. Cao's group at Northwestern University has contributed a paper on "Characterization of Tensile and Compressive Behavior of Microscale Sheet Metals Using a Transparent Microwedge Device." This paper discusses the development of a transparent wedge device, which is capable to prevent the buckling of thin sheets under compressive loads, while also allowing full field strain measurements of the specimen using digital imaging methods. By this technique, compressive and cyclic mechanical behavior of sheet metals can be examined. Schmid's group at University of Notre Dame has contributed a paper entitled "Formability of Porous Tantalum Sheet-Metal." In this paper, the formability of tantalum was evaluated using a novel camera-based system for measuring surface strains. This study explores the possibility of forming tantalum sheet metal created by chemical vapor deposition. Hu's group at the University of Michigan has contributed a paper on the "Postanneal Mechanical Properties of Prestrained AA5182-O Sheets." The effects of different prestrain levels, paths and subsequent annealing on the postannealing mechanical properties of AA5182-O are discussed in this paper. This study employs three-dimensional digital image correlation to capture the onset of local necking for the FLD development, whereas an electron backscattered diffraction technique is used to study the texture in the as-received and deformed sheets. Finally, prestrain and static recovery are linked to the microstructure. Tekkaya's group at the Technical University of Dortmund has presented a paper on "Experimental and Numerical Assessment of Sheet-Bulk Formability of Mild Steel DC04" as a new method of gear teeth-forming. This study combines quantitative/qualitative metallurgical survey on undeformed specimens to illuminate microstructural aspects in the context of nonmetallic inclusion content, distribution, and size, which act as prime failure factors. These surveys are extended to monitor ductile damage accumulation with cavitation at different stages of an incremental sheet indentation process over certain sections.

Process Innovation

A paper on the "Effect of Severe Prior Deformation on Electrical-Assisted Compression of Copper Specimens" is presented by Kinsey's group at the University of New Hampshire. In this paper, an investigation is carried out to determine the influence of electric current on perceived dislocation generation and dislocation motion through the lattice structure. Equal channel angular extrusion is used to induce severe plastic deformation into the material. On a similar subject, Mears' group at Clemson University has presented a paper entitled "Factors Affecting the Electroplastic Effect During an Electrically Assisted Forming Process." The factors that are explored in the experimental investigation are various levels of cold work and contact force on Titanium alloys. Kim's group at Iowa State University has contributed a paper on an "Experimental Study of High-Frequency Vibration Assisted Micro/Mesoscale Forming of Metallic Materials." Investigation on the use of high-frequency vibration for potential application in micro/mesoscale forming is carried out in an attempt to

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alleviate some of the challenges facing microforming. Vibration assisted micro/mesoscale upsetting, pin extrusion, and cup extrusion are conducted to understand the effects of workpiece size, excitation frequency, and the contact condition. Tekkaya's group at the Technical University of Dortmund has contributed a paper on "Newest Developments on the Manufacture of Helical Profiles by Hot Extrusion." The application of such profiles can be seen in screw rotors for compressors and pumps. The investigations concentrate on experimental and numerical analyses by 3D-FEM simulations to analyze the influence of friction and the material flow on the twisting angle and contour accuracy. Merklein's group at University of Erlangen-Nürnberg has contributed a paper entitled "Improved Sheet Bulk Metal Forming Processes by Local Adjustment of Tribological Properties." This paper discusses a combined deep drawing and extrusion process, which can be classified as sheet bulk metal forming process. By this process, local functional features through an intended and controlled change of the sheet thickness can be formed. Investigations on the form filling and the identification of significant influencing factors on the material flow are carried out through both FE simulations and experimentations. Hwang's group at National Sun Yat-Sen University has presented a paper on "T-Shape Tube Hydroforming of Magnesium Alloys with Different Outlet Diameters." In this paper, design guidelines for die surface shapes are discussed. An adaptive control algorithm to determine appropriate loading paths for the forming process is also proposed. Yuan's group at Harbin Institute of Technology has presented a paper entitled "Deformation Optimization for Inconel 718 Superalloy Sheet Hydroforming Numerically and Experimentally." The study involves analyzing different deformations for hydromechanical deep drawing and reverse hydromechanical deep drawing under the condition of optimal pressures. Ngaile's group at North Carolina State University has presented a paper on "Preform Design for Tube Hydroforming Based on Wrinkle Formation." An analytical model based on bifurcation analysis of the elastic–plastic circular cylinder under axial compression and internal pressure is used to study the wrinkle evolution. The paper discusses how the initial wrinkle evolution data gathered from the analytical model can be used in conjunction with FEA to design a two-stage preforming process. Damsgaard's group at Technical University of Denmark has presented a paper on "Microcutting and Forming of Thin Aluminum Foils for MEMS." In this paper, a procedure for simultaneous cutting and forming of thin Al foils for use in MEMS components is discussed. The procedure makes use of scaled down macroscopic sheet forming and cutting techniques by using a hydraulic press, a soft counterpart, and a microfabricated stamp tool. Altan's group at The Ohio State University has presented a paper entitled "Evaluation of Stamping Lubricants in Forming Galvannealed Steels for Industrial Application." Different types of lubricants were evaluated using strip draw test and deep draw test for stamping of galvannealed steel sheets. The criteria used for evaluating the lubricants in both tests were dimensions of the formed strips and cups, and the maximum applicable blank holder force to draw parts without fracturing. Water-based synthetic lubricants were found to exhibit better lubricity than petroleum-based lubricants. Cao's group at Northwestern University has contributed a paper on "An Investigation on Deformation-Based Microsurface Texturing". In this paper, a novel desktop microsurface texturing system is proposed for efficiently and economically fabricating microchannels on the surface of thin sheet material for microfluid and friction/wear reduction applications. Both experimental and numerical studies were employed to analyze the problems of the flatness of the textured sheet, the uniform of the channel depth, and pile-ups built up during the microsurface texturing process. This study demonstrates that a strategy can be made to obtain a flat sheet textured with deeper channels based on the design of relative velocity between the upper and bottom rolls. Researchers from the Automotive Center of United States Steel Corporation, H.-C. Shih and M.F. Shi, discuss the optimization of the beveled shearing process and identify optimal shearing conditions for advanced high strength steels. Their results show that an optimal selection of the die clearance and the shearing angle leads to a less damaged edge, which significantly delays edge fracture in the forming process and increases edge stretchability.

Incremental Forming

A paper on the "Improvement of Geometric Accuracy in Incremental Forming by Using a Squeezing Toolpath Strategy With Two Forming Tools" is presented by Cao's group at Northwestern University. This paper explores the capabilities of double sided incremental forming in terms of improving the geometric accuracy when compared to single point incremental forming by using a novel toolpath strategy in which the sheet is locally squeezed between the two tools. Experiments and simulations are performed to show that this strategy can improve the geometric accuracy of the component significantly. Reddy's group at the Indian Institute of Technology has presented a paper entitled "Formability and Surface Finish Studies in Single Point Incremental Forming." In this paper, an experimental study is carried out to study the effect of incremental sheet metal forming process variables on maximum formable angle and surface finish. Box-Behnken method is used to design the experiments for the formability study and a full factorial method is used for a surface finish study.

Springback and Wrinkling

A paper on "A Phenomenological Model for the Hysteresis Behavior of Metal Sheets Subjected to Unloading/Reloading Cycles" is presented by Eggertsen's group at Chalmers University of Technology. In this paper, a constitutive model that can accurately predict the unloading of a material is formulated. The new model is based on the classic elastic–plastic framework and works together with any yield criterion and hardening evolution law. Schmid's group at University of Notre Dame has presented a paper on "The Springback Characteristics of a Porous Tantalum Sheet-Metal." This paper examines the elastic recovery (i.e., springback) of a porous tantalum foam after sheet forming operations. The foam and sheetlike form is applicable to bone ingrowth surfaces on orthopedic implants and is desirable due to its combination of high strength, low relative density, and excellent osteoconductive properties. To study the effect of the foam microstructure, bending is also examined numerically in this paper. Reddy's group at the Indian Institute of Technology has presented a paper entitled "Prediction of Wrinkling and Determination of Minimum Blankholding Pressure in Multistage Deep Drawing." In this paper, an analysis methodology, based on a combination of upper bound and energy approaches, is proposed for the prediction of the number of wrinkles and minimum blankholding pressure necessary to avoid wrinkling in a redrawing operation. Thickness variation predicted by the upper bound formulation is used as input for the wrinkling analysis by assuming a suitable waveform based on geometrical and process conditions.

Forming Presses, Tooling, and Control

A paper on "Using Servo-Drive Presses to Determine the Effect of Blank Holder Pressure on Temperature Change in Warm Forming of Sheet" is presented by Altan's group at the Ohio State University. This paper explores the flexibility of servo-drive presses to study the effect of blank holder pressure on temperature change and surface roughness of aluminum and magnesium sheets. Qin's group at the University of Strathclyde has presented a paper on the "Development of a New High-Precision Feeder for Micro-Sheet-Forming." The design is conceived through motion analysis and feeding simulations. Emblom's group at University of Louisiana at Lafayette has presented a paper entitled "A Control Strategy for Intelligent Stamp Forming Tooling." This paper

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describes the development and implementation of closed-loop control for an oval stamp forming die using Matlab's Simulink and the dSPACE ControlDesk. A traditional PID controller is used for the blank holder pressure and an advanced controller utilizing fuzzy logic combining a linear quadratic Gauss controller and a bang-bang controller. Kevin Russell at the US Army's Armament Research Development and Engineering Center has presented a paper on "Experimental Primer Seating-Stamping Tool Study in Small Caliber Cartridge Production." This paper compares the results of small caliber ammunition manufacturing process trials using a concept four-prong triangular stamping tool, a concept four-prong wave stamping tool, and the conventional circular stamping tool. Comparison data include cartridge case material movement after stamping, stamping tool stress distribution, stamping tool life, and stamping forces required to achieve the objective primer seating depths. Johansson's group at Jonkoping University has presented a paper entitled "How to Build Flexible Design Automation Systems for Manufacturability Analysis of the Draw Bending of Aluminum Profiles." This paper investigates ways to automate the process of finding manufacturing limits of the rotary draw bending of aluminum profiles with focus on the system architecture needed to make such systems flexible. Ngaile's group at North Carolina State University has presented a paper on "Real-Time Friction Error Compensation in Tube Hydroforming Process Control." In this paper, a THF process control model that can compensate for the loading path deviation due to frictional errors in tube hydroforming is discussed. In the model, an algorithm and a software platform have been developed such that the sensed forming load from a THF machine is mapped to a database containing a set of loading paths that correspond to different friction conditions for a specific part.

Closing Remarks

As is evident by the paper descriptions above, research in the area of plastic forming of metals is ongoing and essential in order to improve processes for industry, defense, and society in general through reduced costs, enhanced performance, and environmental improvements. We hope this special issue will inspire further research and development activities in the area of plastic forming of metals and will be a valuable resource for our colleagues and friends.

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