41st International Deep-Drawing Research Group (IDDRG) conference

BOOK OF ABSTRACTS
Industrial communications

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ACADÉMIE MILITAIRE SAINT-CYR COËTQUIDAN

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WELCOME TO IDDRG.bzh!

We are proud and delighted to welcome the 41st International Deep-Drawing Research Group (IDDRG) conference in Lorient, France, from 7 to 10 June 2022. This is a fantastic opportunity to gather the IDDRG community after the pandemics, though some colleagues are still not able to travel due to COVID-19.

IDDRG conferences are a long story. The International Deep-Drawing Research Group was started in the late 1950s as an organization of national groups devoted to the study of sheet metal forming including forming processes, materials, formability issues, tooling, tribology and many other interesting aspects of sheet metal forming research and industrial practices. Since 2003, yearly conferences are organized worldwide, alternatively in Europe, Asia and North America. One IDDRG conference already took place in Paris, France, in 2014, organized by CETIM (Centre Technique des Industries Mécaniques[1]) and 8 years later, it is the turn of *Université Bretagne Sud*/University of South Brittany to organize the 41st conference in Lorient, in *Région Bretagne*, in the West part of France.

The conference is scheduled over three days, with plenary talks, thematic mini-symposia and classical presentations. Then, a technical tour to *Chantiers de l'Atlantique*, in Saint-Nazaire, is scheduled on Friday 10 June morning. And coffee breaks, lunches, and two social events on Tuesday and Wednesday, to catch up again and make fond memories!

The core topics of IDDRG are well represented, with plenary talks on mechanical joining, tribology, hot stamping and advanced numerical tools on Tuesday, along with new ones, like appropriate material testing on Wednesday. And Thursday's plenary speakers will focus on artificial intelligence in sheet metal forming and environmental issues in steel production and sheet metal forming.

We wish you a very enjoyable stay in Lorient and a very fruitful conference in all the topics related to sheet metal forming!

Prof Sandrine THUILLIER
Université Bretagne Sud

Dr Patrick DUROUX
ArcelorMittal

[1] http://www.cetim.fr

CONFERENCE TOPICS, ABSTRACTS AND PROCEEDINGS

The topics covered by IDDRG 2022 are the core topics related to forming and mechanical joining of metallic sheets and organized in the following topics:

- material constitutive modelling
- warm and hot forming
- damage and fracture in sheet metal forming
- shear cutting, blanking and sheared edged formability (MS). *Coordinator Prof. Dr.-Ing. Wolfram Volk (Technical University of Münich) - Co-organisers: Dr. Christoph Hartmann, Florian Steinlehner*
- necking, instability and formability limit prediction
- non-conventional testing methods for appropriate material characterization (MS). *Coordinators: Dr Lionel Léotoing (INSA Rennes) and Prof. Hervé Laurent (Université Bretagne Sud)*
- tribology, friction and wear in forming
- AI in sheet metal forming (MS). *Coordinators: Prof. Dr.-Ing. Mathias Liewald and Dr. sc. techn. Celalettin Karadogan (Stuttgart Universität)*
- intelligent tools for sheet metal forming
- advanced simulation methods for sheet metal forming
- mini-symposium in the honor of Prof Dr Pavel Hora
  Coordinators: Prof. Dirk Mohr and Prof Vincent Grolleau, ETH Zürich.

Scientific presentations are possible either with a paper published in the conference proceedings or with only an abstract. The papers are published in gold open access by IOP conference series: Materials Science and Engineering, follow the link:

https://iopscience.iop.org/issue/1757-899X/1238/1

Moreover, the abstracts of the industrial communications are given in the following pages.

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Correlation between laboratory scale local formability data and tension test based performance indicators for 780 MPa grade advanced high-strength steels

Ji-young Kim[1,3]*, Ju-sik Hyun[1], Brandon Hance[2], Myoung-Gyu Lee[3]

[1] *Automotive Steel Applications Engineering Team, Hyundai Steel Company, Dangjin City, Korea*
[2] *Applications Engineering Group, Hyundai Steel Company, Dangjin City, Korea*
[3] *Seoul National University, Seoul, Korea*

* *jiyoung@hyundai-steel.com*

Keywords: Advanced high strength steels, formability, formability index, local formability, fracture strain

Abstract

As the application of advanced high-strength steels (AHSS) and the complexity of automotive parts continue to increase, attention to the “local formability” (or “fracture resistance”) has been increasing among global automakers and steelmakers. Furthermore, alternative characterization methods are required because the local formability has not been able to be predicted by conventional measurements.

This study investigates the local and global formability parameters derived from standard uniaxial tension tests on a series of 780 MPa grade AHSS. The primary purpose of this study is to provide insight into the correlation between the laboratory scale local formability test results and various formability indicators.

The preliminary results show that meaningful correlations can be derived from the tension test data under different deformation modes. It is also shown that the local formability such as the hole expansion ratio and sheet bendability correlates well to performance indicators such as the measured fracture strain.

Distortional plasticity framework for the forming of advanced high strength steels

Baptiste Reyne[1*], *Frédéric Barlat*[1]

[1] *Graduate Institute of Ferrous & Energy Materials Technology, Pohang University of Science and Technology*
[*] *corresponding author:* `breyne@postech.ac.kr`

Keywords: plasticity, metals; forming; advanced high strength steels; distortional hardening

Abstract

With the evolution of advanced high strength steels (AHSS) and flow stresses exceeding a gigapascal, springback predictions in sheet metal forming demand more quality and accuracy in constitutive modeling. The homogeneous anisotropic hardening (HAH) concept [1] introduces an alternative to kinematic hardening, and has been improved during the last decade. It relies on the notion of microstructure deviator (MD), a tensorial direction representing the set of activated slip systems.

In this new framework called homogeneous extended anisotropic hardening (HEXAH), we introduce an original way to transition from one loading direction to another while avoiding large rotations of the yield loci. To do so, we allow the existence of several MD to represent the successive sets of activated slip systems. The parameters of the HEXAH model are calibrated for an AHSS and its performance analysed for several loading paths.

The theory is adapted and leads to an augmented equivalent stress function illustrated in figure 1. The results focus on the strain path changes capabilities of the model, as well as its ease of identification.

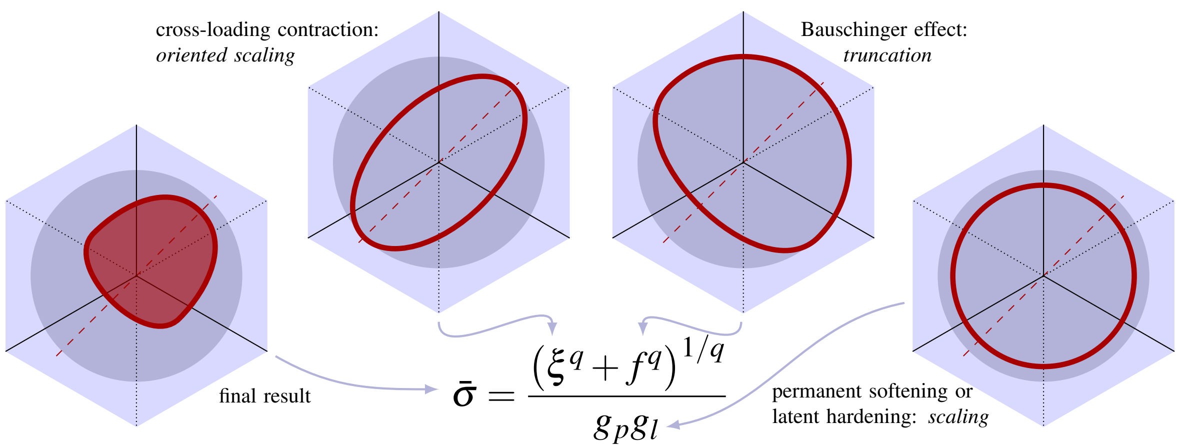

Figure 1: Summary of the equivalent stress function in the stress deviator plane. The plots illustrate contributions of each term to the yield surface, for a loading direction represented by the dashed line. The present work permits to take into account transitions of loading directions while avoiding large rotations of the yield loci.

References

[1] F. Barlat, J. J. Gracio, M.-G. Lee, E. F. Rauch, and G. Vincze. An alternative to kinematic hardening in classical plasticity. *International Journal of Plasticity*, 27(9):1309–1327, 2011.

[2] B. Reyne and F. Barlat. The homogeneous extended anisotropic hardening framework: HEXAH. Submitted to *International Journal of Plasticity*.

Prediction of macroscale hardening and fracture behavior based on the reduced texture approach

D. Noh[1] and J. W. Yoon[1,2]*

[1] Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology, 291 Daehak-ro, Yuseong-gu, Daejeon 34141, Republic of Korea
[2] School of Engineering, Deakin University, Geelong Waurn Ponds, VIC 3220, Australia

* j.yoon@kaist.ac.kr

Keywords: Crystal plasticity, Anisotropy, Reduced texture approach, Damage model

Abstract

Crystal plasticity finite element analysis has been mainly used to predict the microscale material behavior due to computational cost. In order to increase the computational efficiency for the macroscale application, the reduced texture approach is employed by using User MATerial (UMAT) interface in Abaqus. The reduced texture approach where the number of crystallographic orientations is reduced was developed by Rousselier et al. (2009, 2010) to apply the crystal plasticity theory for industrial application. Based on the material test results, such as the stress-strain and transverse strain curves, the material parameters including the crystallographic orientations are characterized for AA6260-T6. Single element simulation is used for the characterization, and eight grains are employed at one integration point for the hardening anisotropy. With the reasonable number of crystallographic orientations, the predicted results show good agreement with the experimental results. In addition, the reduced texture approach is extended for the macroscale fracture prediction. Various stress states and anisotropy in fracture are considered to evaluate the applicability of the damage model in the reduced texture approach . It shows a potential that the macroscale hardening and fracture behavior could be predicted using crystal plasticity theory.

Understanding the Properties of TRIP-Assisted Steels at Elevated Temperatures using Mechanical Testing, Synchrotron X-Ray Diffraction, and Empirical Models

C.B. Finfrock[1]*, B. Ellyson[2], S.L.J. Likith[2], D. Smith[1], C. Rietema[2], A. Saville[2], B.N.L. McBride[2], M.M. Thrun[1], D. Bhattacharya[1], C.G. Becker[2], J.S. Park[3], J. Klemm-Toole[4], A.J. Clarke[1,2], and K.D. Clarke[1,2]

[1]Colorado School of Mines, Advanced Steel Processing and Products Research Center, Golden, CO, USA
[2]Colorado School of Mines, Center for Advanced Non-Ferrous Structural Alloys, Golden, CO, USA
[3]Advanced Photon Source, Argonne National Laboratory, Lemont, IL, USA
[4]Colorado School of Mines, Center for Welding, Joining and Coatings Research, Golden, CO, USA

** corresponding author's e-mail: cfinfroc@mines.edu*

Keywords: Transformation-induced plasticity, martensitic phase transformation, x-ray diffraction, advanced high strength steels, formability

Abstract

The "TRIP-effect" is increasingly used in engineered materials where enhanced property combinations are desired, particularly under severe deformation conditions such as sheet metal forming. Empirical models for deformation-induced phase transformations often lack the ability to correctly predict phase evolution during deformation, particularly in complex-phase TRIP-assisted steels. Here, we couple bulk mechanical testing of TRIP-assisted steels with high energy X-ray diffraction, to measure phase evolution, dislocation density, and stress partitioning in-situ. With these data, we propose a novel modification to the Olson-Cohen model for deformation-induced phase transformations in complex microstructures. The model is used as a framework to show that strain partitioning between phases can enhance the plasticity of austenite, leading to improved work hardening rates and formability.

Bulge testing metal sheets at elevated temperatures

D. Staupendahl

Erichsen GmbH & Co. KG, Hemer, Germany

daniel.staupendahl@erichsen.de

Keywords: bulge test, hot forming, warm forming, heated liquid, isothermal

Abstract

The hydraulic bulge test is generally used alongside the uniaxial tensile test to generate stress data at higher strain values. This allows for a more accurate flow curve extrapolation than relying solely on the tensile test. Additionally, it can be used to evaluate and calibrate damage models. The steadily rising demand for lightweight vehicle structures and high passenger safety leads to the increased use of high-strength steels, aluminum alloys, and magnesium alloys in structural designs. To increase the formability of these metals during production, hot forming is commonly used. In this work, a new test method is proposed that allows bulge testing at temperatures up to 500°C using a heated liquid forming medium. The heat transfer in between the forming medium and sheet permits a precise temperature control of the sheet during forming, generates a uniform heat distribution in the forming zone and allows for isothermal forming. Besides these advantages, the use of an incompressible medium is not limited by the strict governmental regulations set upon the use of highly compressed gaseous media.

Anisotropic rate-dependent ductile fracture of AA5754 cold-rolled sheets

B. Erice[1,2]*, C.C. Roth[3], E. Saenz de Argandoña[1], B. Rolfe[4] and J. Mendiguren[1]

[1] *Department of Mechanics and Industrial Production, Mondragon Unibertsitatea, Loramendi 4, 20500 Mondragon, Spain*
[2] *IKERBASQUE, Basque Foundation for Science, Bilbao, Spain*
[3] *Chair of Computational Modeling of Materials in Manufacturing, Department of Mechanical and Process Engineering, ETH Zurich, Switzerland*
[4] *School of Engineering, Deakin University, 75 Pigdons Rd, Waurn Ponds, VIC, 3216, Australia*

**berice@mondragon.edu*

Keywords: Plasticity, Ductile fracture, Anisotropy, Strain rate sensitivity, Finite Elements

Abstract

The effect of the anisotropy and loading rate dependency on the ductile fracture of AA5754 cold-rolled sheets is investigated. Biaxial and uniaxial tensile specimens electro-discharge machined at several orientations with respect to the rolling direction are employed to analyse the quasi-static plastic flow behaviour and to calibrate a three-dimensional version of the Yld2000 yield criterion. The force-displacement curves of notched tension specimens tested at different loading rates, exhibiting negative strain rate sensitivity, are used to calibrate the material parameters of a modified isotropic Johnson-Cook-type law through inverse modelling employing finite element analysis. In a hybrid numerical-experimental approach, the experiments on central hole, notched, shear and biaxial specimens conducted at several loading rates and orientations, monitored with three-dimensional digital image correlation measurements, are combined with finite element simulations. The effect of the anisotropic stress state, given by the Cauchy stress tensor normalised with the von Mises stress, is analysed extracting the loading paths to fracture of the elements in the vicinity of the zones showing the largest equivalent plastic strains and graphically projecting them onto planes that contain the normalised stress components, constructing two-dimensional polar plots for the sake of visualisation.

Damage and Fracture Prediction of 3rd Generation Advanced High Strength Steels using Hosford-Coulomb Model and Extended Finite Element Method

Manuel Jimenez[1]*, Abel. D. Santos[1,2], Rui Amaral[1], Daniel Cruz[1,2] and Jose M. Cesar de Sa[1,2]

[1] *Institute of Science and Innovation in Mech. Industrial Engineering, Porto, Portugal*
[2] *Dep. Mechanical Engineering, Faculty of Engineering, University of Porto, Portugal*

* *mjimenez@outlook.pt*

Keywords: sheet metal forming, damage modelling, fracture simulation, finite element method

Abstract

There is a current need to characterize the fracture behavior of third generation advanced high strength steels due to their novelty. This study addresses this gap by experimentally identifying the Hosford-Coulomb damage model parameters for the numerical fracture prediction of 980T third generation advanced high strength steel. The Hosford-Coulomb damage model requires four experimental tests: biaxial, plane strain, uniaxial and shear tests to determine the strain at fracture initiation of the material for a full range of load cases.

Defined geometries promoting shear loading and a central hole geometry are machined from a sheet of 1.6 mm thickness of 980T third generation advanced high strength steel. The experiments are carried out in a tensile testing machine, with digital image correlation used to extract the strains at fracture initiation. The Hosford-Coulomb damage parameters are calculated using this information and the damage behavior is implemented in numerical models. The proposed simulations use the extended finite element method to predict the fracture initiation locus and crack state in the specimens from experimental tests.

Microstructural and Mechanical Property Response from Prior Cold Work and Heat Treatment of Quenched and Partitioned Steels

M. Thrun[1]*, V. Euser[2], A. Clarke[1], and K. Clarke[1]

[1] *Colorado School of Mines, Golden, CO, USA*
[2] *Los Alamos National Laboratory, Los Alamos, NM, USA*

* *mthrun@mines.edu*

Keywords: Quenching and Partitioning, Retained Austenite, Transformation Induced Plasticity

Abstract

The quenching and partitioning (Q&P) process is a useful heat treatment for creating high strength steels while keeping manufacturing costs low. However, there has not been significant research into understanding and quantifying the effect of prior microstructure on the heat treatment response. An understanding of the heat treatment response of differing starting microstructures is critical to processing and creating steels with complex microstructures and retained austenite. This study investigates the differences resulting from prior heat treatment and/or cold working of the starting microstructures prior to quenching and partitioning processing for a 0.2C-2.0Mn-1.5Si (wt pct) steel. The samples subjected to a pre-treatment to create a martensitic microstructure prior to Q&P resulted in higher retained austenite fractions as well as created a more homogenous microstructure. Pre-treated samples displayed higher work hardening rates, higher strengths, and increased elongation. Steels subjected to larger cold reductions saw accelerated kinetics of dissolution and growth during an intercritical anneal.

On the evaluation of fracture strains from shear tensile tests of sheet metal

Leopold Wagner[a]*, Benjamin Hackl[b], Erich Berger[a], Anton Grünsteidl[a]

[a] *voestalpine Stahl GmbH – R&D – Forming and Component Behaviour, Linz, Austria*
[b]*IWAS e.U., St. Florian, Austria*
* *leopold.wagner@voestalpine.com*

Keywords: shear tensile test, fracture strain, material characterization

Abstract

The calibration of damage models for forming and crash simulation relies on the adequate evaluation of parameter identification tests. Especially the evaluation of tensile-based shear experiments represents a challenge, since most of these tests yield a combined tensile-shear stress state and strain path. Herein a simple evaluation framework for shear tensile tests is presented, which yields reasonable fracture strains using commonly available test equipment, namely a tensile testing machine and a calibrated microscope only. The strain state is described in detail and the equivalent strains in Hencky formulation are derived accounting for both the shear as well as the tensile deformation of the test specimen. The results are validated by means of digital image correlation measurements, which would then no longer be mandatory to access the shear fracture strains using the methodology presented herein.

Uncertainties on the mechanical behaviour for bronze sheets: influence on the failure in bending

G. Ouaidat[1]*, A. Lagroum[1], A. Kacem[1] and S. Thuillier[1]

[1] *Univ. Bretagne Sud, UMR CNRS 6027, IRDL, F-56100 Lorient, France*

* Corresponding author: *ghinwa.ouaidat@univ-ubs.fr*

Keywords: Fracture, CuSn6P, Finite Element Analysis, Design of experiments, Statistical analysis, Uncertainties.

Abstract

This study is focused on one step of the process allowing the manufacture of plug-in type connectors made of CuSn6P sheet material. During one of the forming step and when changing the material batch, a crack may appear in the components, in the bent area subject to high strain. Following this phenomenon, two CuSn6P sheets are considered, coming out of two different batches: material S, with which acceptable components are produced, and material T, which leads to cracked components. The aim is to investigate the effect of the uncertainties of the material mechanical behavior on the failure of CuSn6P bronze sheets. Indeed, the failure criterion depends on the material parameters. These parameters can be subject to variations so it is necessary to consider the reliability of their value via modeling/simulation by the integration of uncertainties.

In this study, a 3D parametric finite element model is proposed to investigate the role of the mechanical behaviour of these two materials (S and T) on the formability limit in bending. The influence of different material parameters is evaluated through a design of experiments, with the aim of highlighting the influence of the uncertainties of the mechanical behaviour on the fracture criterion, using a probabilistic approach with Gauss's law.

Acknowledgements. The authors are indebted to Axon'Mechatronics for providing the case study. Also, financial support from BPIfrance through EXPRESSo project is acknowledged.

Impact of diffusible hydrogen content on the deep drawing ability of AHSS, application on a DP1180 steel

Flavien Vucko[1*], Varvara Helbert[1], Younes Demmouche[2], Matthieu Dhondt[2], Thomas Dieudonné[3], Anis Aoufi[3], Thierry Sturel[3], Bastien Weber[3]

[1] Institut de la Corrosion, RISE, 220 rue Pierre Rivoalon, 29200 Brest, France
[2] Ecole Nationale Supérieure de Techniques Avancées Bretagne, ENSTA Bretagne, UMR CNRS 6027, IRDL, 29200 Brest, France
[3] ArcelorMittal Research SA, Voie Romaine BP 30320, 57283 Maizières-lès-Metz, France

[*] Corresponding author

Abstract:

The properties of steels, both in terms of strength and ductility, have significantly improved over the last few decades with the development of successive generations of advanced high strength steels. However, hydrogen embrittlement, as a phenomenon of alteration of the mechanical properties, is affecting all high strength steels over 1000 MPa and must be well understood to anticipate the risks of cracking and failure during processing and use of the steel. The objective of this study was to develop a method to artificially introduce and control the level of hydrogen content prior to the mechanical testing and the forming of high strength steel parts. Flanges of DP1180 steels were severely hydrogen charged, specifically for the purpose of the study, by cathodic charging and coated with a zinc layer to maintain the hydrogen inside the material. The hydrogen content introduced into the samples was controlled using thermal desorption analysis. Finally, the flanges were formed by deep drawing into cup specimens. The results are discussed in terms of critical drawing ratio and delayed fracture as a function of the level of diffusible hydrogen.

Investigations on thermal assisted Fineblanking process

C. Maurer[1]*, Dr. R. Schober[2] Prof. Dr. P. Hora[3]

[1] *Feintool Technologie AG, Lyss, Switzerland*
[2] *Eidgenössische Technische Hochschule (ETH), Zürich, Switzerland*
[3] *Eidgenössische Technische Hochschule (ETH), Zürich, Switzerland*

christian.maurer@feintool.com

Keywords: Fineblanking, materials, cutting, temperature

Abstract

Fine blanking is a high precision metal cutting process, which conventionally is carried out at room temperature. Cutting surface quality of the produced parts and tool loads are common limiting factors to the fine blanking process.
These limitations mainly relate to blanking-material properties, which narrow down the field of application. A viable option to overcome such limitations is based on the fact that material properties tend to be significantly altered at elevated temperatures. As a general trend, reduced forming resistance as well as increased ductility occur within a certain temperature range.
The aim of Thermal Assisted Fineblanking (TAF) is to make use of the improved material properties at elevated temperatures and create a larger field of application. As part of a project, the temperature behavior of different material properties was investigated with different material tests and then validated within the Fineblanking process.

Development of a plane strain tensile test to characterize the formability of Al alloys for automotive applications

M. Gille[1], F. Mas[2]*, J-C. Ehrström[2], D. Daniel[2]

[1] *Mines Paristech, PSL University, Centre des Matériaux, Evry, France*
[2] *Constellium C-TEC, Voreppe, France*

* *fanny.mas@constellium.com*

Keywords: Plane strain, Tensile test, Formability, DIC, Aluminium alloys

Abstract

The development of alloys for automotive applications requires the assessment of material formability. The Forming Limit Curve is the default engineering tool for mapping the conditions of occurrence of plastic strain localization for stress states ranging from uniaxial to equi-biaxial tension. The procedure is time-consuming and expensive. The result is affected by friction (surface aspect, lubricant) and tool geometry. Furthermore, most automotive stamping failures occur near plane strain deformation paths. For all these reasons, it is of interest to develop in-plane tensile tests independent of friction to evaluate the intrinsic formability of materials and compare the performance of different alloys and processes, especially during prototyping steps.
A finite element parametric study on 3 different specimen designs inspired by the literature is performed to adapt the available geometries to aluminium alloys. An optimized geometry is then used to test 5 different aluminium alloys in three directions, the plane strain tests being instrumented by Digital Image Correlation. Several criteria are proposed to assess necking and fracture. Their relevance for the ranking of alloy formability is evaluated by comparison with standard measurements (Limiting Dome Height, 3-point bending). Differences between steel and aluminium alloys' behaviours under plane strain conditions are also discussed.

Enhanced formability through continuous bending superposed with uniaxial tension and recovery heat treatment in AA5182-O aluminum alloy

Jinjin Ha[1*], Sarah M. Mayer[1], Nikolai Matukhno[1], Marko Knezevic[1], and Brad L. Kinsey[1]

[1] *Department of Mechanical Engineering, University of New Hampshire, Durham, NH USA*

* jinjin.ha@unh.edu

Keywords: Continuous bending-under-tension, annealing heat treatment, deformation texture, EBSD

Abstract

As interest in stronger and lighter automotive materials continuously increases, the development of new innovative forming processes is essential to improve formability of these materials. In this regard, the current study investigates the continuous-bending-under-tension (CBT) process, in which the bending moment is superposed with simple tension by three rollers and a hydraulic cylinder. Past research has shown that a <111> texture is produced in the material during CBT processing. The testing plan is constructed on AA5182-O in four steps: 1) a sample is CBT processed to 10 cycles; 2) a subsize uniaxial tension specimen is extracted from the center of the CBT one; 3) the specimen is heat treated at temperatures from 220 to 280 ^{o}C with time ranging from 0.5 to 4 hours; and 4) a subsequent uniaxial tension test is performed to evaluate the stress-strain curve and plastic anisotropy, i.e., r-value. The results show that the stress-strain curves in the subsequent uniaxial tension tests continuously decreases at the temperature and time increase, but the r-values are varied depending on the heat treatment conditions. Electron Backscatter Diffraction is used to measure the texture introduced by the CBT processing and heat treatment.

On the formability of aluminum alloy processed by asymmetric rolling

G. Vincze* and M.C. Butuc

Center for Mechanical Technology and Automation, Department of Mechanical Engineering, University of Aveiro, Campus Universitário de Santiago, Aveiro, 3810-193, Portugal

* *gvincze@ua.pt*

Keywords: formability, asymmetric rolling, anisotropy

Abstract

Aluminum alloys are largely used due to their advantageous strength to weight ratio. However, their formability at room temperature sometimes is very limited. The aim of this work is to analyze the effect of the production method of the aluminum sheet on its mechanical characteristics and its formability. Specifically, the asymmetric rolling is applied on commercial aluminum alloys sheet as last steps to obtain the final thickness. The mechanical characteristic of the new sheet is determined experimentally using digital image correlation technics. The formability of the new sheet is evaluated from experimental and theoretical point of view. The onset of localized necking is simulated by an advanced sheet metal forming limit model based on the Marciniak-Kuczynski analysis. The initial shape of the yield locus is given by Yld2000-2d yield condition. The strain hardening of the material is described by the Voce saturation strain-hardening law. The ability of the selected models on the description of the mechanical behavior of the studied material is evaluated and discussed. A good accuracy of the FLDmodel on the reproducibility of the experimental results is found. The evolution of the mechanical properties and formability through the asymmetric rolling process is pointed out.

Fully coupled damage model accounting for yield surface distortion, stress triaxiality and Lode angle dependency: Application to metal forming simulations

H. Badreddine[1], C. Labergere[1]*, S. Thuillier[2], K. Saanouni[1], J.L. Duval,
[1] *University of Technology of Troyes, Troyes, France*
[2] *Univ. Bretagne Sud, UMR CNRS 6027, IRDL, F-56100, Lorient, France*

* *carl.labergere@utt.fr*

Keywords: Plasticity, Distortion, Damage, Metal forming, Finite Element method

Abstract

In the present work, an advanced CDM elastoplastic model accounting for stress triaxiality and Lode angle effect is proposed. The initial as well as the induced plastic anisotropies are taken into account through a non-associative plasticity theory. The framework of thermodynamics of irreversible processes with state variables is used to build constitutive equations accounting for strong and full coupling between all the dissipative phenomena. The proposed model is implemented into Finite Element (FE) code ABAQUS/Explicit via a user material subroutine (VUMAT). A detailed parametric study with various values of the new material parameters is conducted in order to show the predictive capability of the proposed model. Applications to sheet metal forming simulation have been performed to validate the damage prediction capability of the proposed model, and the numerical simulation results are analysed and discussed.

Mechanical properties and interfacial damage of carbon steel/stainless steel cladding plate: application to FE simulation of JCOE pipe forming

Chanmi Moon[1], Jung Yun Won[1], Sung-Woong Kim[2], and Myoung-Gyu Lee[1*]

[1] *Department of Materials Science and Engineering & RIAM, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 08826, Korea*
[2] *SeAH Steel, 45,Yanghwa-ro, Mapo-gu, Seoul, Korea*

* *myounglee@snu.ac.kr*

Keywords: Cladding, mechanical properties, damage, JCOE pipe forming, finite element analysis

Abstract

The cladded plate with stainless steel (STS) on conventional carbon steel (CS) is a representative metal-metal composite for large applications to offshore structures and gas transport owing to its high corrosion resistance. In the manufacturing process of the cladding plate, stacked and pre-wedged layers of CS and STS experience mechanical bonding through hot rolling, which results in inevitable interface between the two base materials. Also, microstructure and mechanical properties of each layer are significantly affected by the diffusion of carbon atoms during the bonding process. In this study, the CS-STS cladding plate is applied to the JCOE pipe forming to take advantage of the corrosion resistant cladding material. Since the JCOE forming consists of press-brake bending with large plastic deformation, the optimum forming process should be investigated by analyzing the deformation and damage behavior of cladding plate. For this purpose, finite element (FE) analysis of the JCOE pipe forming is conducted by implementing properly identified mechanical properties and interface characteristics of the CS-STS cladding plate. Then, the plastic deformation and formability of cladding pipe are analyzed in relation to the deformation and failure of base metals and their interface.

Experimental investigation of DP600 strain rate sensitivity with hydraulic bulge test

T. Barret[1]*, B. Galpin[1,2], V. Grolleau[1,3], A. Andrade-Campos[4] and S. Thuillier[1]

[1] *Univ. Bretagne Sud, UMR CNRS 6027, IRDL, F-56100 Lorient, France*
[2] *Ecoles Saint-Cyr Coetquidan, CREC, F-56380 Guer, France*
[3] *Department of Mechanical and Process Engineering, Swiss Federal Institute of Technology (ETH) Zurich, Switzerland*
[4] *Department of Mechanical Engineering, University of Aveiro, Aveiro, Portugal*

* *thibault.barret@univ-ubs.fr*

Keywords: Strain rate sensitivity, Dual Phase Steel, Hydraulic bulge test, Uniaxial and biaxial strain states

Abstract

The strain rate sensitivity of metallic sheet has arisen some interest, first as forming speed can be high and also as the impact resistance of the structure is an important design parameter. Several studies have focused on the strain rate sensitivity analysis of a dual phase DP600, with strain rates ranging from the quasi-static value (10^{-3} s^{-1}) and up to 1000 s^{-1} [1]. This large range of values is obtained using Hopkinson bars with a tensile test device. Another study has focused on the characterisation in biaxial tension of the strain rate sensitivity, for a maximum value of 20 s^{-1} and using a dedicated biaxial tension rig [2]. Lafilé [3] used an original hydraulic bulge test rig, either settled on a classical tensile machine or on Hopkinson bar system, to investigate the strain rate sensitivity of an aluminium alloy and a DP450 steel up to 100 s^{-1}.
This paper presents an experimental investigation of the strain rate sensitivity of a DP600 steel using the dedicated rig developed in [3], from quasi-static to dynamic conditions. The strain field is measured by digital image correlation, using high speed cameras and the analysis is performed with the software MatchID. The strain rate sensitivity in uniaxial and biaxial tension is compared, using both results previously published [1,2] and original ones.

Acknowledgements. This study has received funding from the Research Fund for Coal and Steel for the project VForm-xSteels under grant agreement n°888153.

[1] T. Rahmaan, A. Bardelcik, J. Imbert, C. Butcher, M.J. Worswick, Effect of strain rate on flow stress and anisotropy of DP600, TRIP780 and AA5182-O sheet metal alloys, International Journal of Impact Engineering 66 (2016) 72-90
[2] W. Liu, D. Guines, L. Letoing, E. Ragneau, Identification of strain rate dependent mechanical behavior of DP600 under in-plane biaxial loadings, Materials Sciences an Engineering A, 676 (2016) 366-376
[3] V. Lafilé, Comportement et déchirure de matériaux métalliques : développement d'essais expérimentaux pour l'étude de l'influence de la vitesse de déformation et de l'historique de chargement, PhD thesis, Université Bretagne Sud, 2018

Validation of Finite-Element Models using Full-Field Data

L. Wittevrongel[1]*

[1] *MatchID nv, Ghent, Belgium*
* *info@matchid.eu*

Keywords: Validation, Finite-Element Models, Full-Field Data, Digital Image Correlation

Abstract

As a result of increasing processing power of computers and machine vision systems, a transition is being made from single point measurements to full-field measuring techniques. A major benefit of these techniques is that they provide rich information which can be used for a finite-element analysis (FEA) validation. In this work, the FEA is validated using Digital Image Correlation (DIC). Although both methods can determine the deformation information at the surface of the test object, there are multiple inherent differences between FEA and DIC that need to be addressed before a correct FEA validation can be performed. The used coordinate system, applied strain formulation, calculated data point locations and data filtering are a few of the differences that need to be addressed before validation. In this work, a quantitative scheme is presented to compare DIC with FEA based on the concept of leveling technique and virtual experiments. The virtual experiment can be processed in the same way as the true experiment. By doing so we bring FEA and DIC to an identical regularization level yielding a meaningful, quantitative comparison [1].

[1] Validation of finite-element models using full-field experimental data: Levelling finite-element analysis data through a digital image correlation engine. P. Lava, E. Jones, L. Wittevrongel, F. Pierron (2020). Strain, 56(4)

Automated Fracture Detection from DIC Images: A Machine Learning Technique Based On Optical Texture Features

Christian C. Roth*, Adrien Müller, Nikos Karathanasopoulos, Dirk Mohr

Department of Mechanical and Process Engineering, Swiss Federal Institute of Technology (ETH), Zurich, Switzerland

**ccroth@ethz.ch*

Keywords: Ductile Fracture, Classification, Haralicks, Machine learning

Abstract

When performing mechanical experiments, the correct determination of the onset of fracture is crucial to assure accurate post-processing. Commonly this is performed by visual inspection or through load drop criteria. To remove sources of uncertainty (in particular human bias and error) in the post-processing of the experiments, an image-based machine learning approach is proposed to classify cracked and un-cracked specimens. More than 30’000 images of deformed speckle-painted specimen surfaces from 77 experiments are evaluated, comprising data from uniaxial tension, notched tension as well as axisymmetric V-bending experiments. Both first-order (variance, skewness, kurtosis) and higher-order statistical texture features (i.e. Haralick features) are extracted from all images. Based on Fisher's discriminant ratio, the discriminatory power of the texture information is evaluated and the respective feature correlations are quantified. It is found that a small subset of the investigated texture features is highly significant for all experiments. A non-linear and low complexity feed-forward network architecture is used in conjunction with these features to obtain prediction accuracies of the order of 99%.

How influential are lubrication properties on defining the process window of drawing process? A numerical and experimental study

Sanaz Berahmani [1], Toni Chezan[2], Mary Roelofsen[2], Michael Stippak[3], Bart Carleer[3]*

[1] TriboForm Engineering, Hengelosestraat 500, 7521 AN, Enschede, the Netherlands

[2] Tata Steel, P.O. Box 10.000, 1970 CA IJmuiden, the Netherlands

[3]AutoForm Engineering Deutschland GmbH, Joseph-von-Fraunhofer-Straße 13a, D-44227 Dortmund, Germany

* *s.berahmani@triboform.com*

Keywords: Tribology, Friction, Lubricant, Cold Stamping, Finite Element

Abstract

Process and material variations might result in unexpected defects occurring in series production of automotive body panels. Hence, to minimize these unwanted effects, variation of the physical properties of the sheet metal is monitored by using in-line measuring technologies. One major source of variation is introduced by lubricant distribution fluctuations on the surface of the sheet metal. Such fluctuations are caused by the physical laws governing lubricant migration in sheet metal coils under the influence of time, temperature, gravity and capillarity forces. It is challenging to characterize the lubricant effect on the final part quality due to a complex interplay between many process parameters. This study therefore aims to first understand the capability of a controlled testing device to isolate and then determining the effect of lubricant on the deep drawing process. For this purpose, lubricant quantity is measured accurately prior testing and formability is expressed as average draw in and as 3D plastic deformation measurements of the deep drawn part. The experimental results are then used to validate the finite element modeling while implementing a physical based friction model. Such a validation study is essential for improving the prediction capability of finite element modeling of industrial deep drawing processes. Validated FE models can be used to design processes that are intrinsically more robust to fluctuations of the tribological parameters.

Identification of the industrial automotive stamping contact pressure distribution and blue pattern identification

E. Sáenz de Argandoña[1], J. Cillaurren[1], J. Trinidad[1], I. Llavori[1], A. Zabala[1], J. Mendiguren*[*]

[1] *Mondragon Unibertsitatea, Faculty of Engineering, Mechanics and Industrial Production, Loramendi 4, Mondragon 20500, Gipuzkoa, Spain*

* *esaenzdeargan@mondragon.edu*

Keywords: tribology, stamping, drawing, roughness

Abstract

In the last decade a new interest of the friction coefficient evaluation on sheet metal forming processes has been shown. Numerous authors have evaluated the influence of the contact pressure over the friction coefficient for sheet metal forming simulations. However, there is a critical discrepancy on the range that must be analysed. Some authors evaluated pressures ranges between 0 and 10 MPa while others increased the pressure range up to 100 MPa. In this work, 17 industrial automotive components have been analysed and the pressure ranges for each contact zone have been analysed (as well as the sliding velocity). In addition, the real contact pressure distribution has been evaluated by the description of the blue pattern during spotting. On the one hand, the pressures ranges < 10 MPa have been identified for flat areas while pressure ranges up to 100 MPa have been observed for curved areas. At blue pattern level, a range of contacts can be identified between no-blue to strong-blue with pressure vales between 0<0.5 MPa up to 15 MPa-25 MPa ranges.

Local roughness impact on automotive outer panel forming

A. Zabala[1],E. Sáenz de Argandoña[1], D. Cañizares[2], I. Llavori[1], N. Otegia[1], J. Mendiguren[1]*

1 Mondragon Unibertsitatea, Faculty of Engineering, Mechanics and Industrial Production, Loramendi 4, Mondragon 20500, Gipuzkoa, Spain
2 Autoform Engineering S L, Carrer de Joan d'Àustria, 116, 08018 Barcelona, Spain

** jmendiguren@mondragon.edu*

Keywords: tribology, stamping, drawing, roughness

Abstract

The impact of the tribological behaviour has gain relevance on the sheet metal forming simulations field in the last years. The research has shown that the impact of the frictional behaviour is at the level of the, so deeply analysed, material behaviour for some industry cases. Numerous works have been focused on the dependency of the friction coefficient on the contact pressure while lately the temperature and sliding velocity are being studied. It also has been proven that the tool roughness (combined with the sheet roughness) has a great impact on the tribological behaviour. However, it has never been taken into consideration the fact that not every zone of a stamping tool is polished with the same finish. Therefore, each area has a different roughness. In this study, the local roughness distribution of three industrial benchmark components: a door inner, two different fenders are considered, and simulations with different friction models performed. The results show that considering the local roughness slightly modifies the results of the conventional hypothesis of a constant tool roughness to a lower restriction values.

Wear of crashforming coated tool steel dies

A. Mussa[1]*, M. Fallqvist[1], J. Bergström[1], J. Contero-Castillo[2] and L. Hernandez-Castillo[2]

[1]*Karlstad University, Department of engineering sciences and physics, 651 88 Karlstad, Sweden*
[2]*Metalsa Mexico, Apodaca Nuevo León 66629, Mexico*

* *Abdulbaset.mussa@kau.se*

Keywords: Crashforming, Galling, PVD coating, Scratch test.

Crashforming is widely used in automotive industry where metal sheets are deformed plastically into desired net-shape products against dead hit dies. This process is a cost-effective manufacturing route for mass production of parts with complex geometry and thicker sheets. However, with the increased usage of advanced high strength steels, wear of forming tools and material transfer from sheets to the forming tools become a remarkable challenge. To decrease wear in the crashforming process, hard coatings may be applied to the surface of forming tools. The coating prevents metal to metal contact, and it contributes to a lower friction between the sheet and the forming tools. In the present work, friction properties and wear characteristics of a multilayered PVD/TiAlCN coating was investigated. For evaluation of the influence of substrate on coating performance in sliding contact, four different tool steels, conventional and advanced grades, commonly used in sheet metal forming were used as substrate. Wear testing in a Slider-On-Flat-Surface tribometer and coating system scratch testing were used. Wear mechanisms and damage analysis of the tested coating were investigated, and related to an actual crashforming case. The overall surface damage was discussed in relation to test conditions, material's properties and observed wear mechanisms.

Using Artificial Neural Networks on Identification of Material Parameters and Press-Brake Bending

Daniel J. Cruz[1]*, Manuel R. Barbosa[2], Abel D. Santos[2], Sara S. Miranda[1] and Rui L. Amaral[1]

[1] *INEGI, Institute of Science and Innovation in Mechanical and Industrial Engineering, R. Dr. Roberto Frias 400, 4200-465 Porto, Portugal*
[2] *FEUP, Faculty of Engineering, University of Porto, R. Dr. Roberto Frias, 4200-465 Porto, Portugal*

* *dcruz@inegi.up.pt*

Keywords: sheet metal forming, artificial neural networks (ANNs); press-brake bending; three-point bending test

Abstract

Artificial neural networks (ANNs), among the various types of learning algorithms, can be used in sheet metal forming processes due to their ability to overcome the limitations imposed by nonlinearities and the multiple parameters involved in material characterization and forming problems. The purpose of the current study is to explore the modeling capabilities of ANNs to solve two distinct problems directly related to bending processes.

The first problem incorporates a novel methodology to characterize the hardening behavior of a material, based in a standard three-point bending test. The developed ANN is based in a multi-layer feedforward conventional structure and considers as input the information obtained in a three-point bending test and as output the characteristic parameters of a Swift hardening law.

The second problem is related to the forming and springback problem in sheet metal press-brake air bending. The objective is to predict the punch displacement required to achieve a desired bending angle providing additionally the springback angle information. It is proposed in both approaches to use a learning tool associated with a simulation and data generation tool (FEA) to train the developed ANNs, which is then validated by experimental results.

Experimental and numerical study of a bending process on ultra-thin sheets of copper alloys

S. Thuillet[1,2]*, P.Y. Manach.[1], F. Richard[2], S. Thibaud[2]

[1] *Univ. Bretagne-Sud, IRDL, UMR CNRS 6027, 56100 Lorient, France*
[2] *Univ. Bourgogne Franche-Comté, FEMTO-ST Institute, CNRS/UFC/ENSMM/UTBM, France*
* *stephanie.thuillet@univ-ubs.fr*

Keywords: Bending process, copper alloys, Numerical simulation, Non-associated flow rule

Abstract

Nowadays the demand for miniature components is more and more important. To meet this expectation, forming processes were then strongly developed in order to provide necessary tools for their manufacture. The watchmaking industry is one of those industries that has a high demand for small components, especially in copper alloys for their mechanical properties.

So, in this work, two copper alloys are studied. A 0.2 mm thick beryllium copper alloy, which is mainly employed for industrial use and a 0.2 mm thick pure copper sheet which is used as a reference material.

In this paper we focus on a watch component which is more particularly the clutch fork of a minute repeater movement. An experimental bending device has been specifically developed to reproduce the bending effects that the part undergoes during its forming. This assembly is instrumented and allows us to collect the force and the displacement necessary to form the part in order to compare results obtained during simulations. Some experimental values are difficult to access on small parts such as the thickness, the profile of the sheets and the displacement due to springback. Geometrical parameters are measured by using Xray CT Scan.

The bending process is simulated using an elastoplastic constitutive law with a non-associated plasticity flow rule developed on the finite element software Abaqus Standard and springback effect is particularly investigated and compared to the experimental results obtained using Xray CT Scan.

Multistage forming process of copper thin sheet for electronic applications

A. Lagroum[1]*, L. Poupon[2], C. Le Graët[2], P.Y. Manach[1] and S. Thuillier[1]

[1] *Univ. Bretagne Sud, UMR CNRS 6027, IRDL, F-56100 Lorient, France*
[2] *Axon' Mechatronics, 103 Avenue de Ty-Bos, CS45035, 29556 Quimper Cedex 9, France*

*C*orresponding author: amine.lagroum@univ-ubs.fr*

Keywords: Copper Thin Sheet, Progressive Die Stamping, Blanking, Bending, Finite Element

Abstract

In the electronics industry sector, different types of parts are used, such as metal supports (lead frames) on which the chips are assembled. These metal supports are usually made from thin sheet of copper alloys for their good mechanical, thermal and electrical properties. Parts are produced using progressive tools, which includes several blanking and bending stages necessary to obtain the final part. Specifications require higher and higher production rates and severe dimensional tolerances on produced parts. The design of the tools is essentially based on empirical rules and the know-how of the toolmakers. There is a huge interest to numerically predict these multistage forming processes, to decrease the mechanical design step time and to anticipate production problems such as non-compliance with dimensional tolerances depending on the material used. Moreover, variability of material mechanical properties from material suppliers can lead to production waste. In the frame of this work, experimental investigation for a single operation of blanking and bending in industrial conditions was performed for pure copper sheet (Cu-ETP R290). Experimental data are obtained in terms of load, cut edge profile and springback. Finally, a multistage process simulation of an electrical contact with several bending operations is proposed with Abaqus/Standard®.
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Modeling and prediction of the differential expansion of a multi-material structure subjected to a heating process with automotive application

L. M. da Silva[1,2,3]*, C.Cellard[3,4], L. Sohier[3,4], O. Ponte-Felgueiras[2,3], R. Créac'hcadec[1,3]

[1] *ENSTA Bretagne, IRDL UMR CNRS 6027, F-29200 Brest, France*
[2] *Stellantis,F-35131 Chartres de Bretagne, France*
[3] *ExcelCar, F-35131 Chartres de Bretagne, France*
[4] *Université de Bretagne Occidentale, IRDL UMR CNRS 6027, F-29200 Brest, France*

* *leandromauricio.dasilva@stellantis.com*

Keywords: Industry 4.0, body-in-white, multi-material structures, "Projet AM2", thermal buckling

Abstract

Nowadays, the new requirements of the European Union in terms of CO_2 emissions, the advance of the Industry 4.0 and the new energy variants are stimulating the automotive industry to carry out research to incorporate lightweight materials in the future vehicles[1][2][3][4]. Consequently, the vehicle of the future will consist of a patchwork of materials in order to avoid unnecessary excess weight in some areas of the cars. Thus, Stellantis (Rennes, France) has launched with some partners a new project called "Projet AM2"[5] with the aim of introducing an aluminum alloy roof on a body-in-white made by steel.

Even though the use of multi-materials is a very interesting solution to mass reduction, it encounters some problems with regard to the heating of the body-in-white during the painting phase. These large temperature variations result in a state of strain that is necessary to predict. Moreover, among the various components of the car, the roof is the one that presents the biggest problem, due to its thin thickness and large heat exchange surface. Some bibliographies even indicate that this state of strain in the roof may be linked to a phenomenon called thermal buckling[6], which will be discussed in the conference.

Bibliographies

[1] European Council. (14th March 2021). Source: https://www.consilium.europa.eu/pt/policies/climate-change/paris-agreement/
[2] European Commission. (14th March 2021). Source: https://ec.europa.eu/clima/policies/transport/vehicles/regulation_en
[3] The European Parliament and the Council ofthe European Union. (2019). Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 setting CO2 emission performance standards for new passenger cars and for new light commercial vehicles. Official Journal of the European Union, L 111/13.
[4] Vaidyaa, S., Ambad, P., & Bhosle, S. (2018). Industry 4.0 –A Glimpse. Procedia Manufacturing 20, pp. 233-238. Source: https://expertise.boschrexroth.fr/tout-comprendre-de-industrie-4-0/
[5] Stellantis. (19th May 2021). Source: https://www.media.stellantis.com/fr-fr/corporate-communications/press/stellantis-et-ses-partenaires-du-consortium-am2-co-innovent-pour-acclrer-le-dploiement-de-solutions-multi-matriaux-dans-l-industrie-automobile
[6] Ko, W. L. (2004). Thermal Buckling Analysis of Rectangular Panels Subjected to Humped Temperature Profile Heating.Edwards, California: NASA.

Advanced Formability and Surface Failure Analysis: Moving beyond the traditional FLD

Niko Manopulo

AutoForm Development GmbH, 8005, Zürich, Switzerland

Keywords: Sheet metal fomring, Necking, Fracture, Formability, FLD

Abstract

The sheet metal forming processes are transforming rapidly, especially in the automotive industry. Competitive outer body shapes as well as environmental and cost concerns, drive engineers towards higher tool complexity as well as complex material grades. The traditional FLD analysis, which represented an optimal trade-off between efficiency and simplicity for the past two decades, started falling short in meeting this increased complexity. Advanced Formability and Surface Failure Analysis aims to respond to these challenges by extending the domain of the FLD to nonlinear deformation paths, bending effects and 3D stress states as well as by providing streamlined fracture modelling features. This enables an integral failure analysis covering all its different aspects, without renouncing to the simplicity and elegance of the traditional FLD.

AN EXPERIMENTAL STUDY ON FORMABILITY ANALYSIS OF COMPONENTS FORMED DURING INCREMENTAL SHEET FORMING

Abhishek Kumar[1*], Jeet Patil[2], Amber Shrivastava[2] , Sushil Mishra[2] and K. Narasimhan[1]

[1]Department of Metallurgical Engineering and Materials Science, Indian Institute of Technology Bombay, Mumbai, India, 400076

[2]Department of Mechanical Engineering, Indian Institute of Technology Bombay, Mumbai, India, 400076

ABSTRACT

Formability in Incremental Sheet Forming (ISF) can be defined by the maximum wall angle that can be formed in a single pass or by the maximum depth of the component. However, the forming depth value changes according to the wall angle of the component. As the wall angle of the component increases formability decreases. Previous studies show that the formability in ISF is limited by fracture instead of necking. In the present study, various cones were formed at different wall angle by varying the process parameters. After maximum formable wall angle an increase of 1° in wall angle leads failure and crack was observed in the cone. The thickness reduction analysis shows localized deformation occurs in the formed cones during initial stage of forming (10~20 mm). In the failed cones the crack was also observed at the same depth of forming (10~20mm). Thus, further thickness reduction analysis was performed at relatively higher resolution near the crack region in the failed cones. The, results show the thickness gradient in the failed cones and it reveal that failure in ISF occurs due to necking.

Keywords: Incremental sheet forming; wall angle; thickness distribution; formability; necking.

Modeling the influence of hydrostatic stress on plastic behavior of advanced high strength steels

F. Barlat[1]*, J.-M. Kim[1], Shin-Yeong[1], Lee and J.-H. Kim[1]

[1] *Pohang University of Science and Technology, Pohang, Republic of Korea*

* *f.barlat@postech.ac.kr*

Keywords: Plasticity, pressure, constitutive modeling, distortional hardening, load cycles

Abstract

It has been observed that, in high strength metals, the compression flow stress is higher than the tension flow stress, a phenomenon coined strength differential (S–D) effect. Although different theories were advanced to explain these observations, it was demonstrated in the late 1970's early 1980's that the influence of the hydrostatic stress on the plastic behavior was responsible for the S–D effect. In classical theory of plasticity for metals, it is assumed that pressure has no effect on yielding and plastic flow properties. However, this is only an approximation in which the S–D effect is neglected. In this presentation, the critical experiments as well as the relevant models at different scales explaining the influence of pressure on plasticity are reviewed. This work was adopted for the modeling of advanced high strength steel (AHSS) and a few examples are presented to illustrate the concept.

Simplified Distortional Hardening Model with Rate-Dependency for Nonlinear Strain Paths

Hyunsung Choi[1,2] , Jeong Whan Yoon[1,*]

[1]Department of Mechanical Engineering, KAIST, Daejeon 305-701, Korea.
[2]Korea Institute of Materials Science, Changwon 051508, Korea
* Corresponding Author : j.yoon@kaist.ac.kr

Abstract

In sheet metal forming process, material is subjected to nonlinear strain paths where it shows complex hardening behaviors including Bauschinger effect, permanent softening, nonlinear transient behavior, yield surface contraction, and overshooting behavior. It is possible to describe these behaviors by using distortional hardening model in which yield surface is contracted and rotated according to the loading path changes. However, the conventional distortional hardening models are not popular for industry applications because of its complex form of equation and significant simulation time. In addition, material behaviors under nonlinear strain paths are known to be strain rate dependent. However, there has not been reported any strain rate dependent distortional hardening model. Therefore, in this study, a new distortional hardening model has been proposed with a simpler form of equation than the conventional distortional hardening model while preserving the same level of accuracy as the conventional models. In addition, by introducing rate dependent term to the proposed model, the rate dependent material behaviors under nonlinear strain path are accurately described. The accuracy of the proposed model was verified from predicting material behaviors under various nonlinear strain paths. For strain rate dependency, it was predicted the rate dependent tension followed by compression behavior. In order to apply the proposed models for finite element simulation, It was implemented into finite element software ABAQUS by using User-MATerial (UMAT) subroutine through stress integration algorithm based on finite difference method.

Part Tracking and Model Driven Control in Stamping at Volvo Cars: First steps of implementation of evoTrQ and future plans

M. Sigvant[1,3,]*, J.Pilthammar[1,3], V. Gullberg[1], J. Weingarten[2] P. Butzhammer[2],
S. Tatipala[3], A Barlo[3], S. Islam[3], T. Chezan[4], I. Picas[4] and J. Wiberg[4]

[1] *Volvo Cars, Dept. 81110 Strategy &Concept, Olofström, Sweden*
[2] *evopro systems engineering AG, Regensburg, Germany*
[3] *Blekinge Institute of Technology, Mechanical Engineering, Karlskrona, Sweden*
[4] *Tata Steel Europe, IJmuiden, The Netherlands*

* *mats.sigvant@volvocars.com*

Keywords: Industry 4.0, Part Tracking, Barcode, Model Driven Control,
Sheet Metal Forming Simulations.

Abstract

Sheet Metal Forming is a very complex manufacturing process with a number of non-linearities, e.g. large deformations, localisation, elastic-plastic materials, pressure and velocity dependent friction conditions and structural deficiencies in the die and press, present and interacting simultaneously. This could lead to disturbances in running production that results in production waste, e.g. down time for the press line and cost for rework and scrapping of parts. These production problems are hard to understand and solve based on experience and analytical models due to the presence of above stated non-linearities. An alternative is to try to solve production problems proactively before they occur. This could be done with model driven control by creating a digital twin of the die-set and the press line. The digital twin needs different kind of inputs, e.g. mechanical properties of the sheet together with applied oil amount and process settings. These inputs can be gathered in multiple ways and in this presentation is the Volvo Cars approach presented which is using the software evoTrQ. In this solution, data from material suppliers are combined with in-house measurements and recordings of process settings. To be able connect external and internal data together with tracking each blank through the stamping process, a EUROFER barcode is printed at the material supplier on each coil. The digital twins are in this first step AutoForm Sigma models of two different Side Door Inners in Volvo Cars production and results from these simulations are compared with inhouse measurements in the presentation. Finally, a brief outline of the next steps is presented.

The Thermoelastic Effect and its Relation to the Onset of Yielding

W. Volk*

[1] *Technical University Munich, TUM School of Engineering and Design, Chair of Metal Forming and Casting*

* wolfram.volk@tum.de

Abstract

The thermoelastic effect indicates the dependency of temperature and volume change in the material and, due to the heat released during plastic deformation, a temperature minimum occurs in the region of the onset of yielding. This has been known for a long time and the temperature minimum has been demonstrated in several studies. However, the question arises to what extent the temperature minimum is really related to the onset of plastic yielding and hence, to the material behavior. In order to analyze this relationship and to verify existing assumptions, an experimental setup and a measurement concept were qualified with which it was possible to perform a continuous cyclic tensile test under time-synchronous synchrotron irradiation. In this way, the microscopic parameters lattice strain and dislocation density could be correlated with the macroscopic parameters specimen temperature, load and strain. The results proof existing assumptions and show the great potential of the thermoelastic effect for material characterization. This is shown by the introduction of two temperature-dependent elasticity parameters and an unambiguous determination of an elastic loading modulus.