MATFEM

5th MATFEM Conference

7 May 2019

Schloss Hohenkammer

Welcome!

Comprehensive material models with reliable material data are a key enabler for predictive finite-element simulation. In 2010, we organised the 1st MATFEM Conference, where material scientists, CAE engineers and users of MF GenYld + CrachFEM met to discuss the many aspects of material testing and material modelling and to share their experience. Meanwhile, the MATFEM Conference is established as a biennial event.

We now welcome you to the 5th MATFEM Conference at Schloss Hohenkammer. We are looking forward to the lectures and hope that they inspire discussion.

Welcome and introduction **8:30**

Crash of Polymers & Composites

Chair: F. Duddeck, TU Munich

Experimental assessment of composites **8:35** 1
• H. Körber • ZwickRoell Gmbh & Co. KG

Modelling composites with CrachFEM **9:00** 2
• G. Oberhofer[1]*, M. Franzen[2], M. Richter[1]
• [1]MATFEM, [2]Ford Werke GmbH

Integrative Crash simulation of short fiber reinforced thermoplastics **9:25** 3
• M. Groß[1]*, M. Oehm[2], M. Richter[2], F. Brenner[2], G. Oberhofer[2] • [1]BMW Group, [2]MATFEM

Utilizing the results of process simulation for an effective design of thermoplastic components **9:50** 4
• M. Stojek • PART Engineering GmbH

Coffee break **10:15**

Material Models for Metals

Chair: K. Wiegand, Daimler AG

Nakajima test based method for the evaluation of the correctness of the yield locus models and a new Fourier Asymmetric Yield locus model for a better strain distrubution prediction • P. Hora*, H. Hippke, N. Manopulo, C. Raemy • ETH Zürich **10:45** 5

Investigation of ductility and damage characteristics of severely pre-strained 5000-series aluminum alloy sheets at non-isothermal forming conditions **11:10** 6
• A. Camberg[1]*, T. Tröster[1], F. Bohner[2], J. Tölle[2], H. Gese[3]
• [1]University of Paderborn, [2]Benteler Automobiltechnik GmbH, [3]MATFEM

A guided tour through a CrachFEM material card **11:35** 7
• H. Gese*, G. Metzmacher • MATFEM

12:00 Lunch

Crash of Metallic Components

Chair: A. Bach, Ford Werke GmbH

8 13:30 **MFGenYld + CrachFEM as integrative CAE standard for seat track profiles** •
D. Biniszewski*, P. Weidinger, S. Sinne, S. Dreyer •
Brose Fahrzeugteile GmbH & Co. KG

9 13:55 **Investigation of instability at high strain rates and multi-axial loadings of tailored tempered components** •
N. Weiß-Borkowski[1]*, A. S. Schulz-Beenken[1], T. Tröster[2] •
[1]FH Südwestfalen, [2]University of Paderborn

10 14:20 **Application of CrachFEM on cast aluminum component fracture assessment** •
S. Wu*, F. Pan •
ShareFEA Shanghai

11 14:45 **Material properties of selective laser-melted materials – chance, use and challenges in finite element simulation**
• P. Holfelder[1]*, F. Brenner[2]*, M. Rund[3], A. Witte[1], S. Junghans[1], C. Seyfert[1], H. Dell[2], J. Džugan[2] •
[1]EOS GmbH, [2]MATFEM, [3]COMTES FHT a.s.

15:10 Coffee break

Material Testing

Chair: P. Hora, ETH Zürich

12 15:40 **Impact material characterization of challenging metallic materials and test tasks** •
T. Hahn*, N. Herzig • Nordmetall GmbH

13 16:00 **Ductile fracture model characterization on small and standard samples with evaluation of void deformation**
• M. Mašek*, M. Rund, J. Nacházel • COMTES FHT a.s.

14 16:20 **Experimental research of Bauschinger's effect of magnesium alloy** •
V. Yelisseyev[1]*, H. Dell[2], L. Khlivnenko[1] •
[1]MATTEST Voronezh, [2]MATFEM

15 16:40 **Strain rate controlled hydraulic bulge test for analysing various strain paths** •
S. Suttner*, M. Merklein • LFT Erlangen

17:00 Conclusion

Experimental assessment of composites

1

H. Körber

ZwickRoell
GmbH & Co. KG

The global composites market and industry has seen a steady increase over the past decades with annual growth rates of 8% from 1960 to 2010 and 4% since 2010. Typical application areas are aerospace, marine, wind energy, sports and leisure, construction and transportation, with increasing penetration of composite materials in all areas.

While manual production processes (e.g. hand-layup) are declining, quality of manufactured composite parts and structures increases in general with increasing implementation of automated manufacturing processes such as resin infiltration or fiber placement technologies.

The share of fiber-reinforced thermoplastic matrix composites is still increasing and the need for applications at higher service temperatures, or the need for recycling and waste reduction triggers the development of new composite material systems.

Due to the orthotropic material response, complex interactions of stress states, a variety of failure modes and the influence of the manufacturing process on the mechanical response, to name some major influencing factors, the development and design of composite structures must rest on a solid foundation of material parameters derived mainly from quasi-static testing.

This presentation provides an overview of typical static test procedures and test standards. In addition to ambient temperature testing, material characterization at low and high temperatures is required to derive temperature dependencies and verify service temperature ranges.

Proper alignment of the load chain is particularly important for quasi-static and fatigue tensile testing and methods for achieving the demanding alignment criteria will be presented.

The response of composite materials at high strain rate loading, as occurring during impact and crash loading scenarios, will also briefly be discussed.

2

The predictability of material behavior in virtual vehicle development is an indispensable requirement in order to optimize structures with respect to passive safety, e.g. occupant protection, pedestrian protection and fuel system integrity as well as weight. Based on virtual development processes new materials can be introduced, which precisely meet the individual requirements of a specific component as part of a complete vehicle structure. Besides new metallic materials, a growing number of plastic materials are introduced. For high performance plastic components that require a high stiffness, thermoplastics reinforced by either continuous carbon fibers or continuous glass fiber fabrics (so called organic sheets) can be used.

Modelling composites with CrachFEM

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In case of crash and misuse load cases the prediction of material behavior including possible nonlinearities and failure is still a challenging task and standard modelling approaches still show deficits. Here enhanced material models can support the virtual design processes significantly. Whereas in case of metallic materials as well as non- and short fiber reinforced polymers non-linear material behavior can be observed for basically all load cases, continuous fiber reinforced composites can show close to linear elastic material behavior under certain loading conditions. Therefore, simplified material modelling approaches have been developed which describe material non-linearities only for discrete loading conditions. Due to this simplification, the prediction of energy absorption can significantly deviate from real behavior.

The modular CrachFEM approach is widely used in industrial applications for the enhanced and solver independent simulation of materials. Combining different modules allows an efficient description of the visco-elastic / visco-plastic material behavior including failure of different material groups ranging from metallic materials to non- and short-fiber reinforced polymers. New extensions for the modelling of continuous fiber reinforced plastics, e.g. carbon composites and organic sheets, are now available. The CrachFEM approach can account for pre-failure non-linearities without significant restrictions. To describe failure comprehensively, a separate strain and stress based criterion is available. Concepts for the description of composite structures, which cannot be described by orthotropic approaches any more, are introduced.

Combining these different materials such as aluminum and polymers demands load-bearable, hybrid joints, which can be fabricated in an efficient and reproducible manner. To account for these hybrid material joints in a structural simulation, mechanical substitute models are needed for a correct assessment of the deformation and failure behavior of the joints. The CrachFEM approach facilitates the development of these substitute models by a comprehensive description of the base materials (e.g. organic sheets) and the initialization routine (MFInit) which allows to scale the locally altered material parameters and to introduce the damage induced by the joining process.

Within this study, the CrachFEM material model approach is validated for composite structures based on specimen forms and on component level. It is shown that the approach is robust, computational effective and therefore generally applicable on industrial level. It is moreover possible to determine material parameter effectively in a systematic way.

Integrative Crash simulation of short fiber reinforced thermoplastics

3

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Both interior and exterior parts of modern vehicles must fulfil several requirements: They should be light and robust while guaranteeing passenger and pedestrian safety. Fiber-reinforced thermoplastics are used increasingly to fill this role: They can be produced easily with mold injection, they have few restrictions on geometry and they are usually stronger and stiffer than unreinforced polymers. However their superior material properties are highly dependent on the local fiber distribution and the markedness of anisotropy can vary within a part. Structural FE analyses must account for the local anisotropy direction and degree, which is a result of the mold-injection process.

In this presentation a comparative study of different modelling approaches is introduced using the phenomenologically motivated, modular material model MF GenYld+CrachFEM. The comparison of these different approaches listed below with increasing complexity not only outlines the necessity for a comprehensive material description but also points out the limitation of a simpler description.

- isotropic
- orthotropic plasticity and orthotropic fracture
- interpolation between different degrees of anisotropy

The complexity of the material behavior requires that many aspects of that behavior should be characterized with experiments. In this study, a comprehensive test program for orthotropic plasticity and fracture behavior was carried out at different strain rates with specimens produced with a diffusely distributed fibers and with ideally aligned fibers. To account for the difference in the local fiber distribution, the degree of anisotropy is introduced. This scalar value can range from 0 (diffuse; isotropic) to 1 (fully aligned; orthotropic). It is used to interpolate between the material parameters obtained with the different specimens allowing to derive all intermediate conditions. Like the local fiber orientation, the degree of anisotropy is a result of the mold-injection process. Fiber direction and degree of anisotropy should be initialized at the beginning of a structural simulation. These modelling approaches will be validated on a component level for quasi-static and dynamic load cases.

Further, an outlook is given to reduce the experimental effort for the material characterization as well as a discussion of the transferability of the experimental results for different fiber contents.

4 Utilizing the results of process simulation for an effective design of thermoplastic components

M. Stojek

PART Engineering GmbH

The prediction of the mechanical behavior (strength, stiffness, modal behavior) of technical components by structural simulation in many cases is based on nominal CAD geometries and homogeneous, isotropic material properties. Especially for injection moulded, short fibre reinforced components none of these assumptions is true. Local fibre orientations affect the parts stiffness and strength. Weld lines can result in significant weak points and the component can undergo considerable deformations due to shrinkage and warpage, causing substantial stresses in subsequent assembly steps.

All of these information can be transferred from process simulation results into structural FE models. In several examples the required steps for this transfer are outlined and the effects on the simulation results are discussed. As, for anisotropic material models, the calculated local fibre orientation distributions have a strong influence on the prediction of mechanical behavior, computed fibre orientations are compared to measured data.

The mapping is performed by the commercial tool Converse, which provides (amongst others) an easy to use interface between most commercial injection moulding solvers and MF GenYld + CrachFEM.

Nakajima test based method for the evaluation of the correctness of the yield locus models and a new Fourier Asymmetric Yield locus model for a better strain distrubution prediction

5

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At the present time, the numerical pre-design of sheet metal forming processes plays a decisive role in the economic manufacturing of components. Besides the process limits, the final shape of the component can be calculated at an early stage of the design process, which enables a virtual adaption of the tools geometry and thus a reduction of subsequent optimization cycles on the physical tool. However, especially for lightweight materials, like high strength steels or aluminium alloys, the springback calculation is still limited and does not reach the required prediction accuracy. Since springback is the elastic release of in-ternal stresses, its realistic prediction is influenced by two major aspects: on the one hand the correct calculation of the internal stresses occurring after the forming operation and on the other hand the precise description of the Young's modulus.

Dual phase steels tend to feature a significant Bauschinger effect that means a reduction of flow stress after a load reversal and a strong dependence of their Young's modulus with respect to the level of plastic strain. Within this research, both material characteristics are analysed for a HCT780X and reviewed with respect to their influence on a bending as well as a deep drawing operation. The behaviour of the Young's modulus is observed via tension tests with cyclic loading and unloading. To evaluate the Bauschinger effect, the kinematic hardening model according to Chaboche and Rousselier is calibrated on basis of compression-tension tests and compared to a conventional isotropic hardening model.

6 Investigation of ductility and damage characteristics of severely pre-strained 5000 series aluminum alloy sheets at non-isothermal forming conditions

The limited formability of non-heat treatable 5000 aluminum alloys can be enhanced through warm sheet forming methods. Nevertheless, common heat assisted forming processes, as for example the super plastic forming or isothermal warm forming, do not satisfy the discerning automotive industry due to low cycle times and high costs. A possible approach to overcome the drawbacks of limited ductility and strain rate is the so-called „flash-forming process“ (FFP) consisting of a rapid blank heating and a subsequent cold die stamping. Novel in the FFP is the usage of aluminum blanks in a fully work hardened H18 state which allows to manufacture parts with a strength usually achievable only with 6000 aluminum alloys. However, the ductility and damage behavior during this non-isothermal forming process depend upon a number of non-steady state variables which are activated and affected by temperature and deformation. In order to characterize the predominant damage mechanisms a series of uniaxial tensile tests is carried out. By varying the testing temperature between room temperature and 300 °C the influence of crystal lattice recovery and increased diffusion processes on deformation and fracture is investigated. Subsequently, the damage mechanisms are qualified by scanning electron microscopy. It is shown that elevated temperatures lead to an altered strain hardening behavior that affects the ductility of the material and leads to an excessive void growth. Moreover, the capabilities of the Crach algorithm for predicting Form Limiting Curves of severely pre-strained aluminum sheets under isothermal conditions are investigated and compared with experimental data.

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A guided tour through a CrachFEM material card

7

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The modular material cards for MF GenYld+CrachFEM offer useful features for routine work and provide extended features for advanced users. The Guided Tour should give an overview and may initiate new ideas for the use. The tour starts with the explanation of some general features which might be helpful in all-day work. One example is the velocity scale factor, which defines the ratio between the physical speed of a given load case and the virtual speed in the explicit simulation. By defining that parameter the strain rates in the material model are scaled down to ensure a realistic flow stress. With this feature it is easy to account for the right strain rate effect also in quasi-static and low-speed cases.

MF GenYld+CrachFEM can encrypt material cards. With encrypted cards can be transferred to suppliers for a wider use. General parameters like the velocity scale factor are still visible in the material card after encryption. This ensures that simulations are performed in a correct way in case of outsourcing.

Any material card can be used with shells and solids. The fracture models are fully valid in plane stress condition and general 3D condition. If a material card includes necking prediction for shells, this module is deactivated for solids by default but can be activated manually. Also orthotropic yield loci that are limited to the plane stress condition are deactivated for solids and Mises plasticity is used by default.

The special behavior of a given material is reached by a modular combination of physical effects. The input structure clearly shows which modules are currently activated. Single effects can be easily activated or deactivated. A material card with pure isotropic hardening can be easily extended to a combined isotropic-kinematic hardening by defining parameters for the kinematic hardening module.

Most of the material properties can be a function of strain rate and temperature. However, temperature can be used in a more general way for other physical parameters. For example a single material card can be defined for a MnB-steel in all quenching conditions between press hardened and tailored tempering. Here the physical parameter is the microhardness which can be mapped from a hot-forming & quenching simulation on the crashworthiness mesh. Other physical parameters for metals can be the local solidification time for Al-LPDC-material and flow length for Al-HPDC-material.

Each material card can include a user-definable initialization method, i.e. a definition of the initial properties at each integration point. This can be used to apply a stochastic scatter of mechanical properties on cast components. Assuming homogeneous properties in these parts would give too optimistic results. The stochastic initialization of properties allows for probabilistic studies.

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8 MFGenYld + CrachFEM as integrative CAE standard for seat track profiles

The dimensioning of a seat structure including its adjusting components always targets comfort, low weight and strength at the same time. The main interface between a seat structure and the vehicle is the seat track assembly. It enables the length adjustment and transfers a significant amount of the crash load. The increased demands to lightweight, reduction of development time and increasing cost efficiency require a continuous improvement of simulation models regarding predictability. Additionally the high demands on performance are a challenge for selecting the correct material grades. With progressive enhancement of prediction capabilities, the importance of simulation-based judgement grows and can address all demands at the same time.

This paper illustrates an approach to increase the predictability of the strength of seat track assemblies and its application to virtual material analysis.

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[*continued from 7*]

An advanced use of the CrachFEM material card is its extension to parametric definition of material properties and its use in robustness studies. However it is not meaningful to vary all material parameters individually. There are independent and dependent parameters. Therefore modules of the Crach prediction for localized necking are linked with the corresponding modules of the plasticity model. Currently, the common analytical models are still limited. However more analytical models will be implemented in near future. Also the choice of the analytical model must be meaningful in the frame of a robustness study. The input parameters should be values which can be directly taken from experiment.

Due to restrictions in time and budget, the perfect material card is not always available. A material card for a new material can be derived by calibration of a fully characterized material card of a similar material and a small set of experiments.

Investigation of instability at high strain rates and multi-axial loadings of tailored tempered components

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Tailored tempering is a possible technique for reducing sheet thickness and vehicle mass in the field of lightweight constructions. Furthermore, an increased passenger safety can be reached. This technique allows the combination of areas of high structural integrity with ductile areas for energy absorption. Between this load adapted areas, transition areas with undefined properties arise. They mostly consist of different microstructures with different fractions of martensite, bainite and ferrite. For the design of tailored tempered components based on finite element simulations, it is essential to know about the forming behavior of the transition area. Especially in the field of crash simulations, in particular the forming behavior at high strain-rates is of interest because tailored tempered components behave differently at dynamic loadings compared to quasi-static loadings. Therefore, the strain rate dependence of materials for strain-rates up to 1000 s^{-1} and the failure behavior should be taken into account in crash simulations. For the description of failure behavior, models like CrachFEM can be used. They consider different failure modes and multi-axial stress states. In particular, the modular material and failure model MF GenYld + CrachFEM 4.2 applies the forming limit diagram (FLD) to describe the beginning of instability in crash simulations. In general, FLD can be used for the description of the material behavior at multi-axial loadings. In the specific case of CrachFEM, the dynamic FLD used is theoretically calculated by the algorithm CRACH. The numerical algorithm CRACH uses Lankford parameters and the strain rate dependent hardening as input. All input data can be derived from quasi static and dynamic uniaxial tensile tests

Therefore the present work deals with the investigation of forming behavior of the transition areas of tailored tempered components at high strain rates and multi-axial loadings. In a first step, five characteristic cooling-rates occurring in different positions of the transition areas were determined. Afterwards, the tempering of tensile test specimens with five different characteristic cooling-rates has been performed. Due to this tempering, the same microstructures that occur in the five different positions of the transition area can be replicated in each case individual specimens. These specimens were tested in quasi-static and in dynamic tensile tests in order to investigate the influence of strain rate on the mechanical properties. Furthermore, the yield curves were determined and extrapolated by the strain rate depending hardening law of Swift. The yield curves of the different specimens where used in finite element simulations of a tailored tempered component. One simulation considers all five different yield curves of the transition area. Another simulation uses only the yield curve of the entirely hard martensitic and the entirely soft area. [*continues on next page*]

10 Application of CrachFEM on cast aluminum component fracture assessment

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Nowadays cast aluminum alloys are widely used in automobile industry for light-weight-design purpose. And accurate description of their fracture behavior becomes a great concern in serve crash simulation.

ShareFEA, cooperating with several major OEMs in mainland China, carried out study for cast aluminum components in LS-DYNA. By implementing MF-GenYld + CrachFEM and certain modelling methodologies, good consistency was observed between the test and simulation.

A study of engine mount bracket (ADC12) was chosen to represent the simulation methodology. Firstly, subsystem level tests were carried out in order to calibrate the CrachFEM material card. Modelling issues like solid element type, meshing size, etc. were studied at the same time. Then the material card was used in full-scale vehicle crash simulation to predict the damage and failure of the aluminum engine mount.

The presentation reviews: The process of material properties calibration under subsystem tests and non-ignorable deviation of the materials from different suppliers; The impacts of modelling methods on the simulation and the best modelling practice regarding efficiency and accuracy. The final full scale crash simulation predicted correct crack pattern of the engine mounts which shows the application of CrachFEM is very promising cast aluminum crash simulation in engineering point of view.

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The comparison of both simulations reveals the effects on stress distribution if transition areas in finite element simulations are not considered. Furthermore, on the basis of the tensile tests, the specific forming limit curves (FLC) were calculated with the algorithm CRACH for the determination of beginning instability in transition areas of a tailored tempered component at multi-axial loading. In addition, the FLC at dynamic loading for completely presshardened material was investigated in high speed nakajima tests in order to validate the calculated FLC. This validation shows the general accordance of experimental data and predicted, theoretical determined dynamic FLC.

Mechanical properties of selective laser melted materials – chance, use and challenges in Finite Element simulation

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Direct Metal Laser Sintering (DMLS), also known as Laser Powder Bed Fusion (LPBF), is used to produce a component in layers by selective re-melting of a metal powder bed. A powder layer of an alloy is applied to a metal substrate within a process chamber filled under an inert gas atmosphere. This powder layer is locally heated by a laser above the melting point of the used alloy. Only regions of the applied powder which belong to the desired component are exposed by the laser beam. After the exposure of a layer is finished the build platform will be lowered by 30 to 90 μm and a new powder layer will be applied. The procedure will be repeated until the part is finished. After suitable post processing the part can be used.

After melting under suitable process conditions, the relative density of the finished component is close to 100%. Depending on the sintering system the laser spot diameter measures approximately 40 to 80 μm, therefore the size of the resulting melt pools is relatively small while cooling rates and temperature gradients are very high. Hence some resulting material properties of certain laser-melted alloys differ from the properties which can be achieved by conventional production routes. Furthermore, studies have shown that adjustment of certain process parameters can be used to influence the material condition, e.g. the anisotropy of the mechanical material properties. On the one hand this degree of freedom might offer opportunities to realize designed component properties, but on the other hand the modelling of the material condition and the resulting mechanical properties is challenged.

A test program covering different stress states as well as different material orientations has been performed at COMTES FHT. The tests revealed a significant orthotropy of plasticity and fracture which both are taken into account in the derived material card for the material model MF GenYld+CrachFEM. A good accordance between physical tests and finite element simulations of the performed tests is found.

12 Impact material characterization of challenging metallic materials and test tasks

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Numerical simulations in engineering design and processing has become indispensable in today's world. Appropriate material characterization as well as selection and development of suitable material models from the experimental data are the key issues driving high quality simulation in complex loading conditions.

Especially, material strength and material failure data under high dynamic loading are necessary for good numerical prediction of impact processes. Here, Nordmetall GmbH, as a provider of material data for MATFEM, will present the dynamic-impact testing procedure of very small specimens with dimensions of less than 1mm out of thin metal sheets and thin wall metal structures.

The second part of the presentation shows the methodology and the test effort of advanced failure characterization under impact loading of high strength steel sheets with a sheet thicknesses larger than 4mm. New test geometries were developed to determine failure strains as a function of the stress triaxiality, Lode parameter, strain rate and temperature. The focus is on the application-oriented highly dynamic characteristic values, which are determined by tensile and modified notch tensile tests for tension load and by experiments in the compression, compression-shear, shear and tensile-shear ranges. By using these experimental data an improvement in FEM simulation predictability for complex loading conditions could be reached.

Ductile fracture model characterization on small and standard samples with evaluation of void deformation

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The paper deals with investigation of the mechanical properties of micro and standard size specimens from an aluminium sheet Al2024-T351. Specimens were cut in three directions to capture the influence of material anisotropy. Yield ratios of plastic potential using Hill's model are defined in simulation. Also the notched tensile specimen, shear and plane-strain specimens have been manufactured to test the material under a different stress states. Strain paths are evaluated on specified points on surfaces of specimens. Testing is performed under quasi-static loading conditions and at room temperature. All specimens are subjected to fractography to compare the mechanism of fracture between small and standard specimens.

14 Experimental research of Bauschinger's effect of magnesium alloy

Compression tests followed by tensile and tensile tests followed by compression have studied the Bauschinger's effect of the magnesium alloy AZ31. Plane specimens were tested in an experimental setup, equipped with the supports that allow compressing of the plane specimens with a thickness from 1 mm up to strain of 8% without loss of stability. Friction between sample and the holder is reduced by TEFLON films with a thickness of up to 0.5 mm. The longitudinal deformation of the sample is measured on the calculated length of 12 mm by the corresponding extensometers.

The Bauschinger's effect is characterized by the functions of Bauschinger and Backhaus. The results show that the Bauschinger's effect of the studied alloy is asymmetric, i.e. it is different in compression–tension and tension–compression. It was studied dependence of the Backhaus's function, determined in the second stage of deformation, on the deformation in the first stage.

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Strain rate controlled hydraulic bulge test for analysing various strain paths

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In sheet metal forming, the knowledge of the material behaviour is essential for a robust and high quality numerical design of the forming process. Therefore, an exact characterisation of the material behaviour is required to identify material laws, e.g. yield criteria or hardening laws. In this case, characterising the material behaviour under stretch forming condition is still a challenge. Although, there are experimental setups, such as the biaxial tensile test with its cruciform specimen, which allow a characterisation under biaxial tension. However, results can only be achieved at lower strains. In addition, not only equibiaxial stresses occur during an industrial stretch forming process of parts and the strain rate supplementarily affects the results.

For this reason, an improved hydraulic bulge test with online strain rate control during the test was developed to analyse the material behaviour under stretch forming condition with almost constant strain rates. Furthermore, a progression of the test setup is presented, which allows the characterisation of the material under different strain paths.

Within this contribution, the test setup of the strain rate controlled hydraulic bulge test with circular and elliptical die is presented. Moreover, test results for the aluminium alloy AA5182 are exemplarily shown. Finally, the influence of material characterisation on the identified yield criterion Yld2000 2d and the numerical simulation of an equibiaxial hydraulic bulge test is shown.

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