3rd MATFEM Conference

21 October 2014
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 3rd MATFEM Conference at Schloss Hohenkammer. We are looking forward to the lectures and hope that they inspire discussion.

Welcome and introduction
8:30

Assessing and modelling polymers with plastic compressibility
8:45

G. Oberhofer*[1], H. Dell[1], V. Yelisseyev[2]
[1]MATFEM, [2]MATTEST Voronezh

Advanced crash simulation of natural-fibre reinforced thermoplastics with MF GenYld + CrachFEM
9:10

M. Franzen • Ford R&A Europe

Mechanical properties and failure behaviour of hybrid organic sheets under quasi-static tensile load
9:35

A. von Hehl*, A. Kunze, H. Hasselbruch
IWT Bremen

Coffee break
10:00

Increased accuracy for forming and crash simulation using the Vegter yield locus
10:30

C. ten Horn, H. Vegter, J. Cafolla
Tata Steel

Calibration and application of fracture models for modern high-strength steel materials
10:55

H. Richter*, D. Pieronek, H. Rösen
ThyssenKrupp Steel Europe

Crash performance of the new press hardenable steel 15MnB6
11:20

H. Block*, T. Marten, N. Weiß, T. Tröster
LiA, University of Paderborn

Fracture prediction at Jaguar Land Rover
11:45

M. Buckley • Jaguar Land Rover

12:10 Lunch

13:40 Improved prediction of material fracture with CrachFEM
H. Gese*, H. Dell • MATFEM

14:05 Prediction of orthotropic fracture of high-strength aluminium plate
S. van der Veen
Airbus Toulouse

14:30 Anisotropic damage failure on dual phase steel simulated with CrachFEM
M. Meyer*, M. Kampczyk
Faurecia Autositze GmbH

14:55 Coffee break

15:25 Radioss Multi-Domain – Innovative simulation technique for CPU-time efficient prediction of material failure in full vehicle crash simulations
A. Bach*[1], H. Cakir[1], V. Dampure[2]
[1]Ford R&A Europe, [2]Altair

15:50 MF GenYld + CrachFEM, the safeguard for innovative magnesium components
S. Rudzewski
Semcon

16:15 Ongoing developments in MF GenYld + CrachFEM
G. Oberhofer,
M. Oehm*
MATFEM

16:30 Conclusion

Assessing and modelling polymers with plastic compressibility

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H. Dell[1]
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G. Oberhofer[1*]

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The specific behavior of non-reinforced and short-fiber reinforced polymers in crash or drop test load cases imposes special demands on the material model as well as on the experimental determination of material parameters. If plastic compressible behavior is taken into account the visco-plastic material characterization must also account for compressible behavior for the failure characterization; the relevant material parameters must be adjusted in an appropriate way.

Among other methods, the material model MF GenYld + CrachFEM describes the evolution of the volumetric plastic straining with reference to the equivalent plastic straining, which is based on plastic work, through an equation of state. Parameters for this equation can be determined from uniaxial tensile tests (standard tensile tests), plane strain tensile tests (e.g. tests with waisted tensile specimen) and equibiaxial tensile tests (e.g. Erichsen test). Per definition the fracture strain is defined based on the "geometric" equivalent plastic strain, which includes volumetric straining in its general definition. In order to obtain the fracture strain at different stress states all three principal strains have to be measured. The described simulation method makes it possible to describe the failure behavior of polymers with comparatively high compressibility (low plastic Poisson's ratio of 0.1 and below) correctly even if the material shows very ductile behavior.

In this study, examples for a material characterization in consideration of plastic compressible behavior are shown. Results are compared to standard approaches without consideration of plastic compressible behavior and the additional experimental expenses are opposed to the increase in accuracy.

2 Advanced crash simulation of natural-fibre reinforced thermo-plastics with MF GenYld + CrachFEM

M. Franzen*
M. Magnani
T. Baranowski

Ford R&A Europe

As it is well-known, Ford Motor Company makes efforts to implement recycled and renewable materials in their vehicles. In the early twentieth century it was Henry Ford himself who lead those efforts. Today, Ford Motor Company has a comprehensive team who are working on the broad application of those sustainable materials without compromising product quality, durability, performance, or economics, giving Ford Motor Company a leadership role in this area.

Due to today's short vehicle development time and multifaceted requirements, a crucial area to enable series implementation of new materials is the requirement that all car components are developed using CAE methods and models. In order to fulfil this demand, the Ford Research and Advanced Engineering team in Aachen has been leading a public funded project to generate data and develop CAE methods that allow natural fiber (NF) composites to be simulated.

The project, funded by the Federal Ministry of Food and Agriculture (BMEL) through the Agency for Renewable Resources e.V. (FNR), aims to generate a complete and integrated solution for the simulation of NF composites, from material processing to crash simulation of automotive parts. In order to achieve these capabilities, many technical and scientific problems had to be solved in detail and the results integrated into a complete solution.

Mechanical properties and failure behavior of hybrid organic sheets under quasi-static tensile load

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A. von Hehl*
A. Kunze
H. Hasselbruch

IWT Stiftung Institut für Werkstofftechnik, Dept. Lightweight Materials, Bremen

Unlike thermoset fiber reinforced plastics (FRP), thermoplastic FRPs, so called organic sheets, provide excellent workability under elevated forming temperatures. Thus, complex shaped components made of organic sheets become increasingly important for advanced lightweight applications, such as multi-material automotive bodies in white. To enable transition bonding between metals and FRPs, connective elements like rivets are generally used. However, hole drilling prior to riveting leads to weakening of the fiber structure. Open metallic structures like perforated plates, grid-like sheets or wire meshes enable reinforcement and stabilization of the fibre structure, even if inserts are integrated into the composite. Inlaid between two thermoplastic FRP layers during the forming operation, the open metallic structure is penetrated by the molten thermoplastic polymer, and consequently, the metallic structure is completely embedded into the polymer matrix hole.

The performed experimental investigations on carbon fiber reinforced organic sheets and wire mesh of steel are presented. The results show that these advanced hybrid composite sheets can be successfully realized by forming at elevated temperatures. Starting with a description of the manufacturing process and the used experimental procedure, this article is focused on the analysis of the relationships between the tensile test results and the failure pattern based on metallographic sections. It can be concluded that the manufacturing process itself has a considerable impact on the mechanical characteristics of the hybrid composites. On the other hand, this procedure allows selective modulation of the material behavior.

At the end of the presentation brief outlook for further research need and possible applications is given.

4 Increased accuracy for forming and crash simulation using the Vegter yield locus

C. ten Horn*
H. Vegter
J. Cafolla

Tata Steel

The need for cost reduction and increased fuel efficiency in the automotive industry has lead to an increased importance of accurate simulations and the need for more advanced material models to achieve highly reliable forming, springback and crash predictions. Accurate prediction of stresses and strains are also a prerequisite for reliable fracture simulations.

This means that the material models used must accurately describe the plastic behaviour of the material and choosing a material model becomes an important issue.

Experience shows that for a wide selection of materials the standard plasticity models (e.g. Hill '48 and Hill '90) rarely agree completely with measurements. To meet the demand for an accurate description of the plastic behaviour, the Vegter yield criterion was developed. Where conventional material modelling is based only on data of uniaxial tensile tests, the Vegter yield criterion also incorporates results from plane strain, biaxial and shear tests at different angle to the rolling direction.

The Vegter yield criterion is now available in MF GenYld + CrachFEM.

In this contribution the mathematical description of the different material models are explained and how the parameters can be obtained easily. Results of the Vegter model are compared with other material models and experiments. It also shows the benefits of using the Vegter model for both simple cases of sheet metal forming and more complex parts.

In comparison with the conventional material models, forming simulations on these parts demonstrate a considerably better prediction of strain distributions and failure limits.

Calibration and application of fracture models for modern high-strength steel materials

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H. Richter*
D. Pieronek
H. Rösen

ThyssenKrupp Steel Europe

The failure behaviour of modern high strength steels is no more determined alone by the forming limit curve which indicates the onset of necking of sheet material forming operations. Fracture models increasingly gain in importance in automotive industry for an early but reliable failure prognosis in forming and crash FE simulations. The calibration of these fracture models plays an important role. Industrially relevant strain based fracture models like CrachFEM require the determination of the fracture curve from experimental tests under different stress states. This presentation provides an overview about the methodology at TKSE regarding the fracture characterization of modern steel materials as well as its application to customer relevant FE material models. Examples of model validation will be given for AHSS but also for modern layered steel products, e.g. Tribond®. Besides CrachFEM also other industrially applied fracture models (GISSMO) will be discussed.

6 Crash performance of the new press hardenable steel 15MnB6

H. Block*
T. Marten
N. Weiß
T. Tröster

LiA,
University of Paderborn

Today, lightweight design is very important in order to improve fuel economy as well as vehicle performance. To reach these goals press hardenable steels (PHS) are increasingly used in automotive structures. The main advantages of these steels are a very high strength level of up to 1900 MPa in press hardened conditions and a very good formability because of the hot forming process.

For assessing the crash performance of automotive components FEM simulations become indispensable in the automotive industry. Due to the lower ductility of high strength steel grades, there is a great demand for comprehensive material models including accurate failure criteria. Therefore, it is necessary to know the material failure limits in detail to exploit the light weight potential of PHS.

To get more ductility than the actual press hardenable steels, the new PHS 15MnB6 with a strength level of about 1200 MPa was developed as a part of the project „P 920 The use of new steels and generation of graded lightweight structures in press hardening process“ which is supported and funded by the Research Association for Steel Application e.V. (FOSTA).

In this research work the material model MF GenYld + CrachFEM has been calibrated for 15MnB6. The performance of the 15MnB6 is compared to the 22MnB5 to exploit the lightweight potential of the 15MnB6. In addition, besides the conventional characterization methods, an experimental set-up for recording dynamic Forming Limit Curves will be presented.

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Fracture prediction at Jaguar Land Rover

M. Buckley

Jaguar Land Rover Ltd.

This presentation will explore the development of Jaguar Land Rover's innovative lightweight body structures and how they are enabling Jaguar Land Rover to achieve a profitable and sustainable business. Specifically, the paper will discuss how CrachFEM is used to support the development of these lightweight structures.

8 Improved prediction of material fracture with CrachFEM

H. Gese
H. Dell

MATFEM
Partnerschaft
Dr. Gese & Oberhofer

The prediction of material failure is one of the core targets of the material model MF GenYld + CrachFEM. There is a continuous development at MATFEM to improve the quality of the existing failure models and to extend the functionality for new groups of materials.

In the first part of the lecture the basic ideas of CrachFEM are summarized. This includes the prediction of localized necking in thin structures and material failure due to ductile normal fracture (DNF) and ductile shear fracture (DSF). All failure criteria include models which are also valid for nonlinear strain paths. Further developments have been made to ensure that the failure prediction is comparable for shell and solid discretization, e.g. post-instability strain model after onset of necking for shells, post-critical model for DNF and DSF for shells. In parallel the experimental process of fracture limit curve evaluation has been improved.

A number of research and development activities in the last years have focussed on cast light metal alloys. This includes mapping process parameters from casting and solidification simulation, defining an initial microporosity distribution and defining material properties scatter for cases where no mapping data is available. Due to the scatter of material properties a deterministic simulation approach is no longer possible with cast materials. A higher number of simulations are necessary to identify all possible fracture scenarios in a component. Besides material properties the discretization of cast parts is a core issue. A shell discretization of the middle plane of thin walled cast components with stiffening ribs can give wrong fracture prediction as the stress state is not represented well at geometrical discontinuities. Simulation results of components are shown which highlight the impact of discretization on the quality of failure prediction.

Another core topic in the recent development of CrachFEM has been the introduction of an orthotropic fracture model for both DNF and DSF. This new model can be used for shell and solid elements. The need for this model has been derived from the pronounced orthotropy of some metallic materials (extruded materials, cold rolled sheets and plates) and from short/long-fiber reinforced polymers. In orthotropic materials the fracture plane is not necessarily normal to the first principal stress (DNF) or parallel to the highest shear stress (DSF). The new approach probes multiple potential fracture planes and identifies the weakest plane for the given load.

Finally an outlook on running research activities for CrachFEM is given. One major project tries to improve the prediction of ductile shear fracture. For ductile sheets shear fracture is typically a two-step process. After a stable deformation a shear band localization happens first. After further deformation within the shear band final fracture occurs. Within the research project a new module for the numerical prediction of a shear band localization – both in-plane and out-of-plane – has been introduced. This new model is combined with the final shear fracture limit curve.

Prediction of orthotropic fracture of high-strength aluminium plate

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S. van der Veen

Airbus Toulouse

Certain high-strength aluminium alloys show anisotropic behaviour in plasticity, and in some cases strongly anisotropic behaviour in fracture. New numerical methods to deal with this behaviour have been developed and validated in a collaboration between MATFEM, Airbus Group Innovation and Airbus. The presentation will show an example of orthotropic fracture, detail the engineering method developed to predict it in Virtual Testing and show a number of comparisons with experimental tests.

10 Anisotropic damage failure on dual phase steel simulated with CrachFEM

M. Meyer*
M. Kampczyk

Faurecia Autositze GmbH

In this presentation we want to show the need for anisotropic damage failure on dual phase steels. In particular:

Bending/unbending test setup longitudinal and transversal to rolling direction: In the first step a sheet is bend around a radius to 90°. In the second step the sheet is bent back into a flat sheet.

Simulation of the bending/unbending test with isotropic and anisotropic CrachFEM damage failure model. Here the need for anisotropic damage fracture model will be shown

Influence of mapping on the bending/unbending simulation

Validation of the results and conclusion on a real component of a seat used in project. The component is loaded in three different positions. The fracture mode is once transversal and in the both other positions longitudinal to rolling direction.

Radioss Multi-Domain – Innovative simulation technique for CPU time efficient prediction of material failure in full vehicle crash

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A. Bach[1*]
H. Cakir[1]
V. Dampure[2]

[1] Ford R&A Europe
[2] Altair

Light-weight design and vehicle safety are just a few challenges during the vehicle development process. They can only be achieved by using innovative CAE approaches.

In order to be able to accurately represent crash events the complexity of Finite Element models is continuously increasing. This is true for the discretisation of component geometries as well as for the description of material properties with models including failure criteria (material failure and failure of any kind of joinings). Such detailed full vehicle crash models for explicit solvers may become computationally very expensive.

In particular mesh refinement is essential for a more precise prediction of deflections or even material failure of loaded components. A reduction of the element size leads in general to a reduction of the explicitl time step, which is in addition to the total amount of nodes and elements highly impacting the computation time of an explicit crash solver.

For this reason the innovative Multi-Domain simulation process was developed by Altair for the FE code Radioss. It allows the simulation of complex full vehicle crash models with highly detailed components. By splitting the model in multiple domains with own explicit time steps the computational performance can be maintained compared to conventional approaches (mono-domain with a single time step).

The Multi-Domain approach for the crash solver Radioss and in combination with the material model MF GenYld + CrachFEM has been implemented on the Ford Motor Company high performance computing cluster. First benchmarks at Ford R&A Europe have shown promising results regarding the efficient prediction of material failure, revealing a further potential within the industrial environment of crash analyses.

12 MF GenYld + CrachFEM, the safeguard for innovative magnesium components

S. Rudzewski

Semcon

Currently there is little to no experience for innovative magnesium components, which basically means a high development risk. Using the example of novel components of the innovative ME100 magnesium material it is demonstrated that its complex properties can be determined accurately with the process chain LS-Dyna/PAM-Crash, CrachFEM, MF GenYld. Thus this process chain contributes significantly to a risk limitation, especially in far-reaching innovations and with complex mechanical requirements.

13 Ongoing developments in MF GenYld + CrachFEM

G. Oberhofer
M. Oehm*

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The aim of MF GenYld + CrachFEM is to provide one material model for a wide variety of different materials that is compatible to different solvers with focus on accuracy and robustness in forming and crash analyses.

Therefore, our material model MF GenYld + CrachFEM is under continuous development. In addition to new functions of the material model itself, which are implemented in accordance with ongoing projects, the user experience and integration into the simulation process and our customers' CAE enviromnents are improved.

This short presentation highlights recent and ongoing developments and gives a short outlook on future enhancements.

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