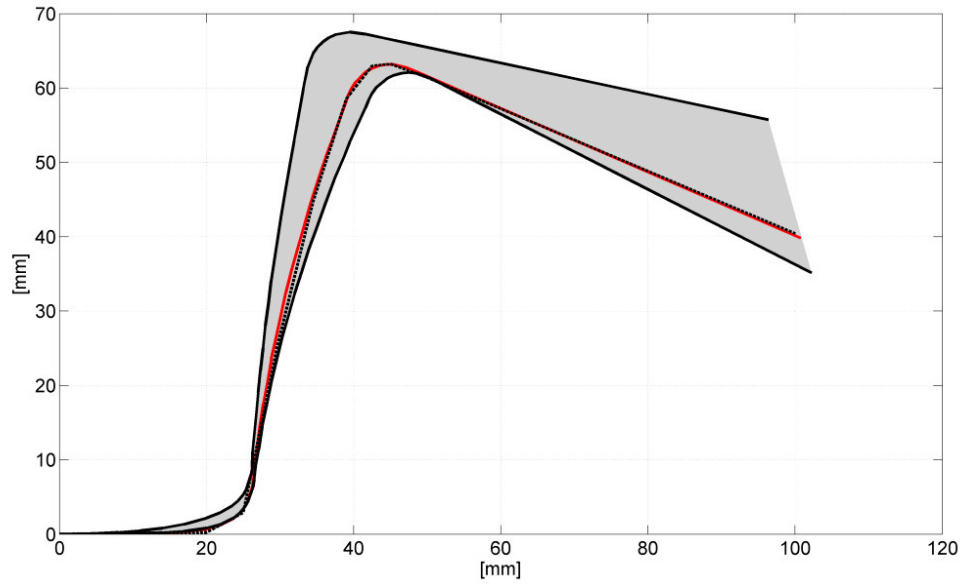
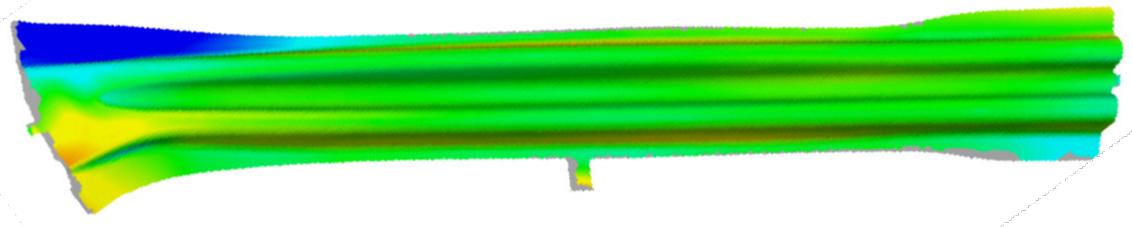
2010-01085: Simulation of springback in sheet metal forming





Project within: Sustainable Production Technology

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Content

FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which half is governmental funding. The background to the investment is that development within road transportation and Swedish automotive industry has big impact for growth. FFI will contribute to the following main goals: Reducing the environmental impact of transport, reducing the number killed and injured in traffic and Strengthening international competitiveness. Currently there are five collaboration programs: **Vehicle Development, Transport Efficiency, Vehicle and Traffic Safety, Energy & Environment and Sustainable Production Technology.**

For more information: www.vinnova.se/ffi

1. Executive summary

This research project has studied the influence on the accuracy of FE-predictions of springback in sheet metal forming from different material models. The objective for the project was to improve the accuracy by the use of advanced material models so that the FE-prediction later could be used for springback compensation. An additional objective was that a PhD-student could finalise his studies and defend his thesis. The results from the project show that accuracy of springback predictions is much higher when advanced material models are used. This improvement would then yield reductions of lead time and cost for the design and manufacturing of stamping dies for sheet metal components. The project results also enable a cost effective implementation of new light weight materials in the automotive industry. The PhD student was also able to defend his thesis during the project. Due to the bankruptcy of SAAB Automobile the project was closed earlier than planned.

2. Background

The change of a sheet metal part shape that occurs when it is removed from the stamping dies is called spring back. Internal stresses in the sheet metal are developed during the manufacturing process, i.e. when the sheet is deformed and holes and excessive material are removed, and these stresses are balanced by the contact pressure from the stamping dies. After the part is removed from stamping dies, a new equilibrium is established. In order to reach the new equilibrium the part has to change its shape.

The magnitude of springback depends on a number of different parameters, e.g. the shape of the part, the friction conditions during the stamping, and the mechanical properties of the sheet metal. For the sheet metal, the ratio between the strength of the material (σ) and it's Young's Modulus (E) important. Generally, if no countermeasures are implemented, the magnitude of springback is increasing with increasing value of the ratio σ/E. This is the explanation for large spring back of new light weight materials. For high strength steels the high stresses are the root cause, and in case of aluminium alloys, the low Young's Modulus is the cause for large springback.

Since more than a decade, FE-simulations of sheet metal forming is an essential part of production engineering of new vehicles. Some results are predicted with high accuracy, e.g. strain distribution in the part and risk for fracture after forming, while the accuracy of other predictions, e.g. part shape after springback, is much less accurate. This has been a challenge for CAE-engineers for a long time, and a lot of time and money has been spend trying to solve the issue with springback prediction accuracy. A major part of the explanation of the problems is due to the fact that springback is driven by the internal stresses of the material. It is also a well known fact that the FE-predictions of stresses

generally are less accurate the strain predictions. This is due to the order the different results are calculate in the FE-simulation. In each increment, first the nodal displacements are determined, then the strains are calculated by derivatives of the displacements, and, finally, the stresses are calculated by the use of a constitutive model (also called material model) and the predicted strains. Therefore, if the purpose of the FE-simulation is to predict the stresses accurately, one must have an accurate FE-model together with an accurate material model and accurate material data for the used material.

3. Objective

The main objective of this research project is to analyse how the accuracy of FE-predictions of springback are effected by using different material models. After the study, the intension is to be able to recommend a material model available in commercial FE-softwares that yields the most accurate springback predictions. Also development of experimental procedures for material data determination for the chosen model is a part of the project. Finally, the project would finance the remaining part of a PhD-project that was started in the proceeding MERA-project on sheet metal forming simulation. The plan is that the PhD-student would defend his thesis within this project.

4. Project realization

In recent years, the research on FE-prediction of springback has been focused more and more on different aspects of material modelling. The current project has had the ambition to cover all aspects of accurate and effective material modelling in sheet metal forming simulations, and that has to our knowledge never been done before. Another strength of the current study is that experimental work has been performed in parallel with development of new theoretical models. Therefore, material characterisation for the application at hand has been an essential part of the study.

Also different types of commercial FE-softwares have been used in the study. Within the PhD-study a general purpose FE-software was used. One of its features was the possibility of own implementations of for example new material models. In the study of springback behaviour of aluminium alloys, and in the industrial studies, an FE-software dedicated for sheet metal forming simulations was used

5. Results and deliverables

As a result of the current research project springback of sheet metal components, made of steel, as well as of aluminium alloys, can be predicted by FE-simulations with high accuracy. This will then result in large reductions of lead time and cost for the design and manufacturing of stamping dies for sheet metal components. The results of the project also make it possible to implement new light weight materials in the automotive industry

in a cost efficient way. Finally, the project contributed so that the PhD-student could finalize his thesis. He is now employed by Volvo Cars as crash CAE-engineer.

5.1 Project delivery to FFI-goals

The research project has made contributions to the following objectives of the FFI-program:

- contribute to a continued competitiveness of Swedish automotive industry
- perform development that is relevant for the industry
- contribute to development of new technology and competence in the industry
- contribute to secured employments, growth and strengthen R&D partners
- contribute to real improvements of productivity are made at the participating companies
- strengthen selected research areas in the field of production engineering research
- contribute to determination and implementation of knowledge in industrial applications
- strengthen the corporation between automotive industry, authorities, universities and institutes
- secure competence for Sweden in combination with R&D with international competitiveness are established

The main part of the project has been performed by the PhD-student. Results from this work have continuously been published in international scientific journals. The thesis was written and defended in English. The opponent was Professor Luiz Menezes, Department of Mechanical Engineering, University of Coimbra, Portugal. The results from the PhD-project have then been tested at the participating companies.

6. Dissemination and publications

6.1 Knowledge and results dissemination

The fierce competition within the automotive industry makes all actions that reduce lead time and cost for the development of new vehicles very important. Demands on increased passive safety and reduced environmental impact raise demand on new types of materials. The results from this project enable the industry to meet these challenges, and this could help the dissemination of the results.

6.2 Publications

[1] Eggertsen PA, Mattiasson K (2011). A phenomenological model for the hysteresis behavior of metal sheets subjected to unloading/reloading cycles. J Man Sci Eng ASME, Vol 133/061021.

[2] Eggertsen PA, Mattiasson K (2011). On the identification of kinematic hardening material parameters for accurate springback predictions. Int J of Mater Form (2011) 4:103–120.

[3] Eggertsen PA, Mattiasson K, Hertzman J (2011). Experiences from experimental and numerical springback studies of a semi-industrial forming tool. Int J of Mater Form. DOI 10.1007/s12289-011-1052-9.

[4] Eggertsen PA. Prediction of springback in sheet metal forming, Doctoral thesis, Chalmers University of Technology, 2011

7. Conclusions and future research

The conclusion of the project is that it is possible to predict springback with high accuracy by using FE-simulation of the sheet metal forming process. The prerequisites for high accuracy are the use of both accurate material models, as well as of accurate material data in the FE-simulations. Furthermore, the accuracy of springback prediction after the project is judged to be so good that springback compensations can be made in the FE-simulations before manufacturing of the stamping dies.

Although the results of the project are very promising, there is still room for further improvements. The project participants suggest the following areas for future research:

- Material testing of different sheet materials in order to build up knowledge of the behaviour of different materials, and to collect data for a material data base. From this "standard values" for different types of materials could be determined. These values could then be used in FE-simulations in early stages, when a full characterisation of a new material has not yet been performed.
- Only two aluminium alloys have been tested in the project. However, the suppliers of aluminium alloys to the automotive industry are developing a lot of alloys at the moment. The most interesting of these alloys must be tested to once again build up knowledge. Some of them may demand new material models and new procedures for the determination of material parameters.
- The friction conditions in the stamping dies influence the amount of springback. It is therefore also important to model the friction accurately in the FE-simulations and use appropriate data for different lubrications systems available on the market. Friction modelling is especially important for aluminium alloys.

The two latter points are addressed in an approved FFI-project: 2012-02168 High volume production of aluminum sheet metal components – ALKOMP.

8. Participating parties and contact person

Party	Role and area of responsibility	Personnel and other resources
Volvo Cars	Project management Industrial implementation	Mats Sigvant
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SCANIA	Industrial Partner	Lars Gunnarsson
Chalmers	Research executer	Research leader: Adj. Prof. Kjell Mattiasson PhD student: Per-Anders Eggertsen

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