

Trends in Forming Simulation and Optimization of Sheet Metal Products

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Sheet metal forming is a widely used production process. Although most sheet metal forming processes are successfully applied for decades, the entire process is still not fully understood. The lack in understanding is becoming even larger since industries tend to favor light construction principles, leading to the usage of new materials and new production processes.

Without extensive knowledge of the production process and the materials used, it is hardly possible to adequately design the forming tools and make a proper choice of blank material to manufacture a product with the desired shape and performance. As a result, a costly and time consuming trial and error process is started to determine the proper tool design and all other variables, leading to the desired product. To reduce this waste of time and cost, process modeling for computer simulation can be used to replace the experimental trial and error process by a virtual trial and error process. Rapid developments in computer hardware make the finite element analysis of complex deformation responses increasingly applicable. Although finite element programs are quite sophisticated nowadays, their accuracy and reliability do not yet satisfy the industrial requirements. The main reasons are the lack in knowledge of the behavior of the applied new materials and the inability to accurately predict the spring back behavior. Therefore, research in these fields is necessary to improve the usability of numerical simulations in sheet metal forming.

The presentation starts with some recent developments in the field of material characterization. To improve the constitutive modeling of metals, more flexible and more material-specific yield loci are needed compared to the conventional models. The same holds for the hardening laws; an improvement is the addition of kinematic to isotropic hardening and all kind of intermediate forms. This article describes the current state of progress in this field. Experimental results are presented that show new combinations of strain rate and strain path sensitivity. It is argued that especially in full process simulations these aspects have to be taken in account. Besides, the need for physically valid constitutive models arises with the introduction of advanced materials. One group of these materials is the meta-stable steels. These steels undergo phase transformation during forming operations. Owing to the transformation it is possible to achieve much higher formability, strength and corrosion resistance. On the other hand, the transformation is hard to predict. Conventional material models use curve-fitting methods to simulate the behavior but it has become clear that this in itself is an expensive procedure since many tests need to be carried out. In this work, a physically valid constitutive model is presented that in turn will reduce the need for mechanical tests.

The next point of discussion is the damage and fracture behavior of material during sheet forming. A commonly used method to predict geometrical instabilities is the Forming Limit Curve. However the use of an FLC has some limitations in cases of bending deformations and non-proportional strain paths (e.g. multiple forming steps). Furthermore less ductile materials like aluminum and high-strength steels often fail due to physical instabilities, even before necking starts. To improve the prediction of failure, ductile damage models can be used instead or complementary to the FLC approach. A non-local damage model will be presented, which removes the mesh dependency of standard softening continua.

Subsequently, the prediction of spring back remains a challenge in finite element modeling of sheet metal forming processes. Accuracy of prediction of this complex phenomenon is affected by factors that control the quality of forming simulation. Various simplifications, introduced for making a simulation of forming more efficient, may have a significant influence on the accuracy of spring back prediction and are reanalyzed in this paper. A new algorithm is developed to improve the accuracy of a spring back analysis, i.e. an adaptive through-thickness integration scheme for plate elements is developed, which improves the accuracy of spring back prediction at minimal costs. When the tools are released after the forming stage, the product springs back due to the action of internal stresses. In many cases the shape deviation of the sprung back part and the desired product is so large that spring back compensation is needed. The tools of the deep drawing process must be changed such that the product becomes geometrically accurate after spring back. In this paper a procedure is described to automatically compensate the CAD tool shape numerically to obtain the desired product shape. The potential of this method is successfully demonstrated by an industrial automotive part.

The final topic in this presentation is optimization. Cost saving and product improvement have always been important goals in the metal forming industry. To achieve these goals, metal forming processes need to be optimized. Until recently, a trial-and-error process in the factory primarily did this optimization. Nowadays, numerical simulations, and the possibility of coupling these numerical simulations to mathematical optimization algorithms, are offering a promising opportunity to design optimal metal forming processes instead of only feasible ones. An overview will be given of possible optimization algorithms that can be applied to optimize metal forming processes using time-consuming FEM simulations. A promising optimization strategy is proposed that assists an engineer to model an optimization problem that suits his needs, includes an efficient

algorithm for solving the problem, and also addresses a future trend in metal forming simulation: optimization for robust metal forming processes.