## Chapter 1 : Metal Forming and the Finite-Element Method - Knovel

*The application of computer-aided design and manufacturing techniques is becoming essential in modern metal-forming technology. Thus process modeling for the determination of deformation mechanics has been a major concern in research.*

History Abstract The paper presents an overview of the advances in recent years on the finite element method FEM and on particle-based methods for the simulation of industrial metal forming processes. Also the paper describes the state of the art in the new rotation-free shell elements for simulation of sheet stamping processes. Finally, we present the so-called Particle Finite Element Method PFEM , as a component of a family of new computational techniques integrating particle-based methods and mesh-based procedures. The PFEM is particularly suited for large deformation problems in solids and fluids involving nonlinear mechanical and geometrical effects, fluid-structure interactions and frictional contact situations. Most FEM developments in the field at that time were based on standard rigid-plastic theory [Pittman et al. In those days Zienkiewicz et al. The flow analogy establishes that the velocities, strain rates, stresses and viscosity in the non Newtonian fluid can be interchanged with the displacements, strains, stresses and the shear modulus in the equivalent incompressible elastic solid. The resulting system of equations in the FEM can be thus seen as the solution of a non linear incompressible elasticity problem in which the shear modulus is a non linear function of the strain and stress levels. The flow approach was successfully applied in conjunction with the FEM for the analysis of many bulk forming problems rolling, extrusion, forging, etc [Pittman et al. Extensions of the flow approach and the FEM to account with thermal-coupling effects in hot forming processes were presented in [Zienkiewicz et al. The flow analogy was also applied to sheet metal forming problems via the so called viscous shell formulation. The flow approach was soon extended to incorporate elastic effects. Different FEM formulations based on non linear continuum mechanics theory were reported in the period  The basic differences here are the constitutive model chosen and the use of displacements or velocities as the main nodal variables. Extensions of the FEM to account with adaptive mesh refinement procedures for bulk forming analysis can be found in Zienkiewicz et al. Stabilized FEM for Multiphisics Bulk Forming Problems The application of the FEM to bulk forming problems expanded rapidly to problems of multiphysics nature were coupled interactions between fluids and solids appear. Two characteristic problems of this kind are the analysis of polymer moulding and casting processes. The solution typically requires using stabilized FEM for modelling the turbulent flow of the melt in the mould during the filling, as well as for analysis of the deformation of the part and the mould during the solidification and cooling phases accounting for thermal-mechanical coupling effects and frictional contact conditions [Celentano et al. Application to aluminium casting simulation A numerical simulation of an aluminium casting process is presented as a demonstration of the accuracy of the stabilized formulation. The full mesh, including the mould has  The pouring temperature is oC. Initial temperature for the mould is obtained through a thermal die-cycling simulation. The cooling system has been kept at 20oC. The final temperature field obtained after the filling simulation is taken as the initial condition for the solidification and cooling analysis. The temperature distribution during solidification is shown in Fig. Discretization of aluminium casting into 4-noded tetrahedral elements. Liquid-fraction evolution during phase-change. The initial set-up of the tooling and band is shown in Fig. A series of grooves are forged in the band by the roll passing over the band placed on the toothed punch. The band thickness is 0. Plane strain conditions are assumed. Forming of a hose-clamp band. A hose clamp-initial set up. Simulation was carried out using stabilized linear triangular elements. The finite element mesh was regenerated when element distorsion was excessive. The purpose of the simulation was to check if the expected groove depth and tooth height in the band were obtained. The results are in good agreement with values obtained in the real process. Deformed shapes at different stages of forming with distribution of effective plastic strain. Detail of the deformed shape with finite element discretization and effective plastic strain distribution. The obtained dimensions are compared with the required ones shown in brackets. Effects of elastic springback can be clearly seen. The two numerical schools in the field basically differ from using either an implicit or an explicit dynamic solution approach. The former allows larger time steps or load increments for the transient or quasi-static solution. The explicit dynamic scheme, on the other hand, is simpler to implement and facilitates the treatment of frictional contact conditions which are a challenging problem in sheet stamping analysis. The drawback of the explicit method is the limitation in the maximum time step size for numerical stability, which results in very small time increments for thin metal sheets. The debate between using implicit or explicit methods for metal forming simulations is still open in the computational mechanics community and different codes based on one or other procedure are available in practice. The name refers here to the formulation of shell elements using the displacements as the only nodal degrees of freedom. The simpler rotation-free shell triangle has three nodes and three displacement variables per node. The curvature field is computed using information from the nodal displacements of the patch of elements formed by a central triangle and the three adjacent triangles. Stamping of a S-rail. Final deformation of the sheet after springback obtained in the simulation. The triangular element mesh of the deformed sheet is shown. S-rail Sheet Stamping The analysis comprised two parts, namely, simulation of the stamping of a S-rail sheet component and springback computations once the stamping tools are removed. The tools are treated as rigid bodies. Explicit and implicit simulations are considered as different curves. The top surface of the sheet does not remain plane due to some instability due to the low blank holder force used. Simulations results compare very well with experimental values. Stamping of Industrial Automotive Part Fig. The outputs of the simulation have been translated into graphical plots indicating the quality of the stamping process and the risk of failure in the different zones of the panel. This helps designers for taking decisions on the adequacy of the stamping process and for introducing changes on the design of the stamping tools dies, punch, blankholders, etc. Lateral panel of an automotive. Finite element mesh of EBST1 triangles used for the simulation. FE results of stamping of lateral panel of a car. In the PFEM nodes are considered as lagrangian particles which move under external or internal forces. A mesh connects the nodes at each time step defining the computational domain where the equations of continuum mechanics are solved with the standard FEM. The PFEM has a big potential for the analysis of bulk forming processes involving very large deformations of deformable continua both fluids and solids , fluid-structure-thermal interactions and multiple frictional contact conditions. Filling of moulds Fig. The essential feature of the filling process are well reproduced. The mesh used for the computation at a certain instant is shown in Fig. This ilustrates the fact that the PFEM is, in fact, a blending of particle and finite element procedures. The mesh discretizing the casted region is progressively generated as the mould is filled. Initially the particles are thrown into the container and mix within the fluid as shown. As time evolves the particles move up towards the surface of the fluid due to their lower density. This example clearly shows the possibilities of the PFEM for analysis of material mixing situations. Conclusions We have presented an overview of the advances on the finite element method FEM and on the new particle-finite element method PFEM for industrial metal forming processes. The new stabilized FEM offer many possibilities for analysis of multiphysics bulk forming processes. Also the new rotation-free shell elements are a powerful technique for simulation of sheet metal stamping processes. The PFEM is particularly suited for simulation of bulk metal forming problems involving coupled fluid-structure interaction, material non linearity and complex frictional contact situations. Circles indicate external and internal free surfaces. Mixing of particles in a fluid using PFEM. This support is gratefully acknowledged. References Agelet de Saracibar, C. On the Formulation of coupled thermoplastic problems with phase-change. Agelet de Saracibar, C. 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## Chapter 2 : Sheet metal forming simulation - Wikipedia

*Metal Forming and the Finite-Element Method (Oxford Series on Advanced Manufacturing) [Shiro Kobayashi, Soo-Ik Oh, Taylan Altan] on theinnatdunvilla.com *FREE* shipping on qualifying offers. The application of computer-aided design and manufacturing techniques is becoming essential in modern metal-forming technology.*

Even relatively small amounts of springback in structures that are formed to a significant depth may cause the blank to distort to the point that tolerances cannot be held. New materials such as high strength steel, aluminum and magnesium are particularly prone to springback. The design of the tooling, stamping process and blank materials and geometry are primarily done by trial and error. Try-out tools are typically made of less expensive materials to reduce try-out costs yet this method is still costly and time-consuming. Simulation accuracy was later increased by applying nonlinear finite element analysis in the s but computing time was too long at this time to apply simulation to industrial problems. A new class of FEA codes based on explicit time integration was developed that reduced computational time and memory requirements. The dynamic explicit FEA approach uses a central different explicit scheme to integrate the equations of motion. This approach uses lumped mass matrices and a typical time step on order of millionths of seconds. The method has proved to be robust and efficient for typical industrial problems. Finite Element Analysis Methods[ edit ] Two broad divisions in the application of Finite Element Analysis method for sheet metal forming can be identified as Inverse One-step and Incremental. Inverse One-step methods compute the deformation potential of a finished part geometry to the flattened blank. Mesh initially with the shape and material characteristics of the finished geometry is deformed to the flat pattern blank. The strain computed in this inverse forming operation is then inverted to predict the deformation potential of the flat blank being deformed into the final part shape. All the deformation is assumed to happen in one increment or step and is the inverse of the process which the simulation is meant to represent, thus the name Inverse One-Step. Incremental Analysis methods start with the mesh of the flat blank and simulate the deformation of the blank inside of tools modeled to represent a proposed manufacturing process. This incremental forming is computed "forward" from initial shape to final, and is calculated over a number of time increments for start to finish. The time increments can be either explicitly or implicitly defined depending on the finite element software being applied. As the incremental methods include the model of the tooling and allow for the definition of boundary conditions which more fully replicate the manufacturing proposal, incremental methods are more commonly used for process validation. Inverse One-step with its lack of tooling and therefore poor representation of process is limited to geometry based feasibility checks. Proof tools in the past were short run dies made of softer than normal material, which were used to plan and test the metal forming operations. This process was very time consuming and did not always yield beneficial results, as the soft tools were very different in their behavior than the longer running production tools. Lessons learned on the soft tools did not transfer to the hard tool designs. Simulation has for the most part displaced this old method. Simulation used as a virtual tryout is a metal forming simulation based on a specific set of input variables, sometimes nominal, best case, worst case, etc. However, any simulation is only as good as the data used to generate the predicitions. When a simulation is seen as a "passing result" manufacturing of the tool will often begin in earnest. But if the simulation results are based on an unrealistic set of production inputs then its value as an engineering tool is suspect. Robustness Analysis[ edit ] Recent innovations in stochastic analysis applied to sheet metal forming simulations has enabled early adopters to engineer repeat-ability into their processes that might not be found if they are using single sets of simulations as "virtual tryout". These and other advanced plasticity models require the experimental determination of cyclic stress-strain curves. Test rigs have been used to measure material properties that when used in simulations provide excellent correlation between measured and calculated springback. Multistep or progressive stamping operations are used to incrementally form the blank into the desired shape through a series of stamping operations. Incremental forming simulation software platforms addresses these operations with a series of one-step stamping operations that simulate the forming process one step at a time. The blank shape can also be optimized with finite element simulations. One approach is based on an iterative procedure that begins with an approximate starting geometry, simulates the forming process and then checks deviation of the resulting formed geometry from the ideal product geometry. The node points are adjusted in accordance with the displacement filed to correct the blank edge geometry. This process is continued until the end blank shape matches the as-designed part geometry. The materials have higher yield and tensile strength than conventional steel so the die undergoes greater deformation during the forming process which in turn increases the difficulty of designing the die. Sheet metal simulation that considers the deformation of not only the blank but also the die can be used to design tools to successfully form these materials. The first prototypes that were produced closed matched the simulation prediction. A simple simulation model was created to determine the effect of blank edge radius on the height to which the material could be formed without tearing. Based on this information a new die was designed that solved the problem. Chandra Mohan Reddy, P.

## Chapter 3 : Metal Forming and the Finite-Element Method by Shiro Kobayashi

*finite-element method (FEM) has assumed increased importance, particu- larly in the modeling of forming processes. There are many excellent textbooks on the principles and fundamentals.*

## Chapter 4 : Metal Forming: Technology and Process Modelling

*The advancements in the application of the finite-element method to metal-forming problems, emphasizing the method based on flow formulation, are presented in this paper. The developments in the areas of workability in forging, friction at the die-workpiece interface, extrusion, drawing and rolling.*