POLISH ACADEMY OF SCIENCES - COMMITTEE OF MATERIALS SCIENCE
SILESIAN UNIVERSITY OF TECHNOLOGY OF GLIWICE
INSTITUTE OF ENGINEERING MATERIALS AND BIOMATERIALS
ASSOCIATION OF ALUMNI OF SILESIAN UNIVERSITY OF TECHNOLOGY

Conference Proceedings

12th INTERNATIONAL SCIENTIFIC CONFERENCE
ACHIEVEMENTS IN MECHANICAL & MATERIALS ENGINEERING

Numerical modelling and simulation in sheet metal forming*

M. Tisza

University of Miskolc, Department of Mechanical Engineering
MTA ME Research Group of Hungarian Academy of Sciences
3515 Miskolc-Egyetemváros, Hungary

In recent years, the role of modelling and simulation in engineering and in manufacturing industry has been continuously increasing. Due to the recent developments both in the methods of modelling and simulation, as well as in the computational facilities, modelling and simulation has become an everyday tool in engineering practice. Beside the aforementioned facts, the emerging role of modelling and simulation can also be explained by the growing globalisation and competition on the world market requiring shorter lead times and more cost effective solutions. The purpose of this paper is to overlook the present situation of numerical modelling and simulation in sheet metal forming mainly from the viewpoint of scientific research and industrial applications.

1. INTRODUCTION

In sheet metal forming, modelling and simulation can be used for many purposes, e.g. to predict material flow, to analyse stress-, strain and temperature distribution, to determine forming forces, to forecast potential sources of defects and failures, to improve part quality and to reduce manufacturing costs. Nowadays, modelling and simulation are often integrated parts of product and process design in an integrated manufacturing environment. It is very essential to apply modelling and simulation in the design phase: though design costs are usually between 5 to 15 percent of the total production costs but the decisions made in this early stage significantly determine the overall manufacturing costs, as well.

In simulation, several parameters and influencing factors should be considered. Material properties and constitutive laws, tribological and frictional conditions are of significant importance, but geometrical representations and computational time should also be considered for a cost effective and reliable numerical modelling and simulation in sheet metal forming.

* Autorzy uczestniczą w realizacji projektu CEEPUS Nr PL-013/03-04 kierowanego przez Prof. L.A. Dobrzańskiego.

2. SHORT HISTORY AND MAIN CHARACTERISTICS OF SIMULATION CODES

The application of finite element simulation for sheet metal forming applications is growing rapidly. Looking back in the history of numerical simulation in stamping, several main time-periods can be distinguished. In this respect, the first period may be regarded as a pre-industrialisation time (before 1990). At that time, people started using computers to understand how to improve the forming process. At this stage, the different attempts were mainly focused on approaches such as expert system and knowledge based methods. An important breakthrough occurred when successful forming simulation codes suitable for handling real industrial problems appeared on the market. While this technology was already becoming common for R&D purposes, its real industrial application started only around 1990.

Concerning the geometrical complexity, sheet metal forming processes in some cases can be simulated as two-dimensional, but in most cases three-dimensional solutions are required. Since in forming processes, the component usually subjected to large plastic deformation, as the simulation proceeds, the distortion of the mesh is also significant, hence, it is necessary to perform remeshing and interpolate the data from the old mesh to the new one to get accurate results. This feature makes indispensable an automatic and adaptive remeshing capability of the simulation code as a built-in technique.

3. EXPECTED ROLE OF FINITE ELEMENT SIMULATION IN STAMPING PROCESSES

Most of industrial companies are very keen on reducing the time for manufacturing of new stamping tool sets and consequently saving costs and resources. We can state that the expected role of finite element simulation is to meet these requirements.

Simulation may be effectively performed at different stages of design and manufacturing to support decision-making. The first simulation need arises at the design stage. The purpose of the simulation at this stage is to make a rough estimation whether the parts to be manufactured can be formed or not. If the answer is "no", the design must be modified. However, at this stage, the geometry of parts is not fully described in CAD system and no tool data exists, thus it is not possible to make full simulation. The so-called one-step simulation codes are particularly suited for these purposes: they are easy to use and provide fast results, which allow the product designer to make the necessary changes at the right time.

As the product has been designed and validated as “formable” the development cycle enters the process and die design stage where more precise simulation is required. At this stage, it is necessary to determine the number of stamping steps, such as first drawing, second drawing, trimming, edge bending, and to design die geometry used at each stamping step. At this stage die geometry is modelled by CAD surface description and thus modification of die data can be made rather easily according to the simulation results. The performance of integrated CAD and simulation system is crucial for obtaining well optimised stamping steps and die shape in very limited time allocated to the production tool design. Incremental FEM simulation codes are particularly suited for these analyses since these require the knowledge on binder, addendum and process conditions. Thus, incremental FEM simulation suitable for modelling the process and die design, and to make the necessary changes and even optimise the process parameters to ensure feasible processes and acceptable product quality.

The simulation is also required at the tryout stage to find a solution to avoid the forming defects appeared during tryout. In order to study the mechanism of origination and propagation of defects, a systematic series of simulation should be performed and the information obtained should be efficiently used in the next new model.

Assuming that the finite element simulation is powerful enough to predict all the forming defects and provide optimum stamping tools and conditions, we may completely eliminate the prototype tools from the design and manufacturing procedure, and the number of trial and modification can be significantly reduced.

4. NEW REQUIREMENTS AND RECENT DEVELOPMENTS IN SHEET METAL FORMING SIMULATION

As we could identify formerly, the main parameters influencing the stamping processes are the part geometry and the die design, the materials' selection, the manufacturing hardware and process and final quality control. Over the last decade, typically the drastic lead-time and cost reduction have come from overall process optimisation based on the introduction of concurrent engineering and parallel tasking. Simulation has allowed the reduction of physical testing, as well as the anticipation of costly downstream problems by enabling the application of the up-front approach. The recent developments in overall design and its related factors state new requirements against stamping simulation codes. These new requirements will be shortly summarised below.

4.1 Part geometry

Depending on the geometrical complexity, sheet metal forming processes in some cases can be simulated as two-dimensional, but in most cases three-dimensional solutions are required. In order to have an efficient simulation, it is often necessary to remove all minor geometrical features that do not have significant effect on the metal flow.

It can also be observed that in certain industries part design have evolved dramatically. It is particularly true for the automotive industry: part geometry is significantly influenced by the aesthetics of automobile design. Since the part geometry serves as a reference for any further design and simulation, more sophisticated part geometry description is required.

4.2 Workpiece and Tool Materials

For accurate prediction of material flow and forming loads, it is necessary to use reliable data. In most simulations the tools are considered rigid, thus the die deformation and stresses are neglected. However, in many cases, and particularly in certain sheet forming processes, the relatively small elastic deformations of the dies may influence the contact stress distribution at the die-workpiece interface. Therefore, elastic deflection of the die must be considered whenever the conditions require it.

With the increasing demand for fuel-efficient automobiles with improved safety, manufacturers have had to evaluate and use new materials for structural components. Due to these requirements, new aluminium alloys and new grades of steel such as ultra-high strength steel, dual phase and TRIP steels have been developed pushing the boundaries of what was previously possible with conventional steel grades. Applying these new materials, the need to investigate materials' behaviour is an emerging field in forming simulations, i.e. to study the behaviour of these materials during forming processes. The main advantage of using these new materials is that they contribute to reducing weight, while increasing safety. For a component to be manufactured effectively, these new materials require a much greater degree of precision and parameterisation to answer the needs of forming simulation. A customisable model that keeps track of part material history and parameters such as strain rate, hardening, etc. has become a basic requirement.

4.3. Manufacturing Process

During the recent years, new equipment, new forming machines have been invented and introduced to accelerate production. Also, in the last decade we observed the successful introduction of several new innovative forming technologies such as hydroforming, forming of tailored blanks, application of controlled blank holder, etc. This was a very good example on how collaborative work led to real success with relatively short lead-time. The simulation was an essential tool to bring together the material suppliers, the equipment providers from the feasibility phase up to the final validation.

Another example of a new requirement for simulation can be seen from the evolution in welding technology. The increased use of laser welding requires a more sophisticated system and a very low flange tolerance. This technology has a large impact on tolerance control, which translates to springback problems on the part at the forming stage. This evolution in process again illustrates the need for increased precision and tighter control during stamping simulation.

4.4. Computers evolution

The traditionally expensive and time-consuming formability and try-out phase has already been significantly reduced over the last decade. Further speed-up in this area is expected with the emerging of new computer technologies and the industrialisation of Massive Parallel Processing (MPP) technique such as the application of clusters, etc.

SUMMARY

The recent changes and trends in sheet metal simulations clearly indicated that there is a need for a complete, integrated stamping solution, covering the entire design process from part design, through die-design and die-evaluation, tuning and validation of the process.

The industry requirements for forming simulation software have also changed deeply over the past decade: from “simple formability” analysis to a “complete quality” solution for the entire stamping process. Consequently, new solutions are needed to fulfil these demands. The new generation of stamping software should be able to handle the entire sheet metal forming simulation chain from part geometry via die design to final process validation and quality control. The different modules should be integrated and supported by advanced simulation technique and state of the art computers. This concept provides significant advantages both in the design and in the manufacturing phase. Applying these principles, theoretically more reliable results, i.e. more optimum design can be achieved throughout the development cycle. This integrated approach will lead to significantly shorter lead times, better product quality and as a consequence more cost-effective design and production.

REFERENCES

1. W. Thomas and T. Altan: Application of Computer Modelling in Manufacturing of Automotive Stampings, Steel Research, 69**.** No. 4-5. (1998) p. 181-187.
2. A. Makinouchi: Sheet Metal Forming Simulation in Industry, Journal of Materials Processing Technology, 60. (1996) p. 19-26.
3. M. Tisza: An Expert System for Sheet Metal Forming, Journal of Materials Processing Technology (1995) p. 423-432.
4. El-Khaldy et al.: Industrial Validation of Finite Element Simulation of Drawn Autobody Parts, IDDRG Biannial Congress (1992) Shenyang, China
5. R. Kergen: Computerised Process Control of Blankholder in Deep-drawing, Sheet Metal Industries, (1992) No. 8. p. 12-15.