Finite element simulation in metal forming

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Simulácia metódou konečných prvkov pri tvárnení kovov

The following paper briefly includes the basics of simulation as well as the way from a real problem to the model. The implementation of various simulation techniques in metallurgy is shown by means of concrete examples. Process simulations, parameter studies and simulations of the properties of products are explained. The development of new processing methods by means of simulation is also described.

Key words: *Simulation, process simulation, parameter studies of rolling, studies concerning properties of products, development and simulation.*

Introduction

The term simulation is derived from the Latin word "simulare" what means "to pretend". However, the technical meaning of simulation is the description and reproduction of physical and technical processes by use of mathematical and physical models. In comparison with practical tests the simulation often is cheaper and not so dangerous. Combined with modern methods of computation the simulation is a powerful tool which gains more and more importance for describing and developing new processing methods.

Because of higher requirements on the quality of products and narrow tolerances of measures, optimising, planning and simulating of forming processes becomes more and more important. As the computational power has increased during the last years, numerical methods play an outstanding roll. The most important numerical method is the method of finite elements (FEM). Numerous finite element programmes have been developed which are able to solve linear, non linear, static, dynamic, elastic, plastic, elastic – plastic, steady state, transient, isotherm as well as non isotherm problems, during the last years. In this case we have to differ between "general purpose" and "special purpose" programs.

Today many forming processes are carried out without a previous or accompanied finite element analysis of course. However, if the material flow or the loads of the rolling devices have to be investigated exactly, the numerical simulation is a must, if one does not want to invest too much money and time in practical experiments. Furthermore practical experiments cause a loss of production of a rolling plant, for example. If the material flow and the stresses in the rolling pieces as well as the forming tools are well known, critical forming steps and deformations can be corrected and avoided.

From the problem to the model

A given technical problem must be expressed by physical terms so that it can be formulated mathematically, what means modelling. The model should reflect the reality as exactly as possible. However, it should also be as simple as possible. Furthermore, the model must be described this way that it can be implemented in computers. Numerical problems like divisions by extremely low numbers or poor convergences of iterations, respectively, have to be mastered or to be avoided. Trial runs of the computational simulations and a subsequent check of the results by comparison with reality or physical experiments are a must. A special attention has to be directed to the boundary and initial conditions during modelling, because they have a decisive influence on the extent of the model as well as on its reliability. If the results do not coincide with reality or with the expectations close to reality, the model must be checked and possibly modified, whereby it will become bigger and more complicated.

Depicted examples of simulation

Parameter studies of rolling

At the beginning of rolling heavy plates often bend upwards or downwards in an unexpected way. This development of ski ends shows Figure 1 (Philipp, Harrer, Schwenzfeier, Wödlinger and Fischer, 2002). Furthermore, in practice the rolled stock often warps by changing its bending direction as well as its bending radius. The failures mentioned afore often cause lacks in productivity, bad product quality and sometimes even

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heavy impacts with expensive downtimes. The status quo of a modern heavy plate rolling mill has been recorded by means of extended measurements. A subsequent FEM-simulation which included the status quo got by the measurements allowed to ascertain the main influences on turn up and turn down as well as on warping.

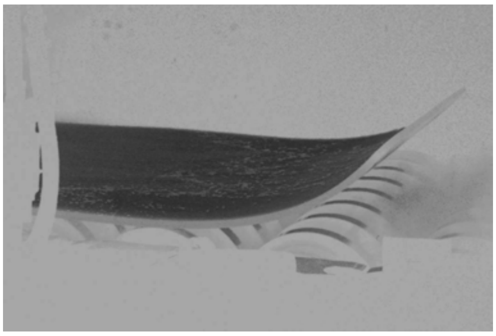

Fig.1. Ski ends.

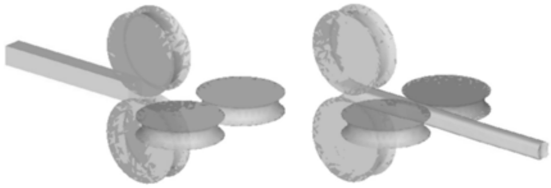

Fig.2. Simulation of rolling in a roughing train of a wire rod mill.

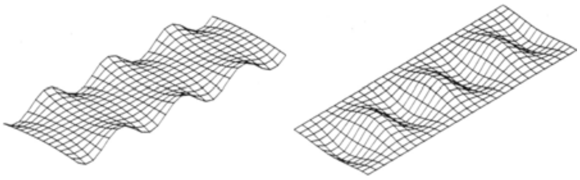

Fig.3. Edge and centre waves of a sheet.

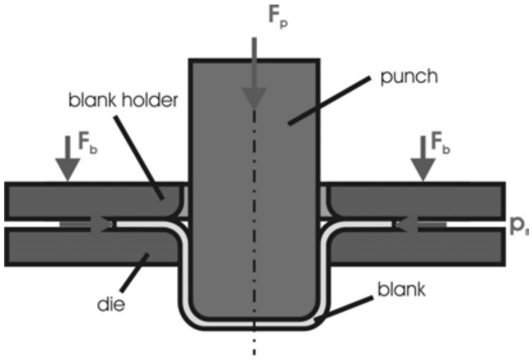

Fig.4. Schematic draft of deep drawing supported by radial pressure.

The main disturbance variable which can be influenced very well is the speed mismatch of the work rolls. Important knowledge like the neutral point, where no bending or warping exists, has been gained be use of a FEM-simulation.

The drift of the neutral point and the serious differences of the rolling torques due to speed mismatches of the work rolls could also be quantified by the simulation. These results will be implemented into a new concept of automation of a modern heavy plate mill

Another example shows the application of numerical simulation for controlling the cross section of rods in a wire rod mill. It is the aim to equalize the failures of the cross section of the rods by tuning the subsequent rolling stands such a way that the final cross section of the wire fulfils the demands of the technical standards. However, the correction of the failures must be immediately during production. As FEM-programmes work very slowly, one must apply methods which are based on simple correlations that can be quickly computed. A powerful aid for finding such correlations is the FEM-simulation. By means of FEM it is possible to investigate various disturbance variables step by step which occur in reality at the same time. The correlations which have been found can be implemented in a quickly working control programme (Harrer, Kvackaj and Pokorny, 2001).

Investigations of product qualities

Strips and sheets must be straightened after rolling. By use of suitable adjustments of the straightening machines it is possible to equalize failures of the flatness of the rolled products. As straightening must be reproducible anytime, it is necessary to know the interdependence between the failures of the flatness and the adjustment of the straightening machine. Therefore the straightening process must be investigated which is often done by FEM (Finstermann, 1989).

Development and simulation

An additional very important field of application for numerical simulation is developing new processes, products and tools. Money and time can be saved by means of numerical simulation. Furthermore, the quality of the products can be increased. With reference to an economical success it is very important to put better and cheaper products faster on the market than your competitors A substantial aid for this is the numerical simulation.

Costs and time for tool adapting could play an outstanding roll. Furthermore, changes in design while fabricating a prototype are usual. By means of numerical simulation, potential forming problems can be recognised during fabricating a first tool.

Despite many advantages of the numerical simulation, it must be said, that there are costs for hardware, software, training and for the simulation itself. However, it is an effective means for making forming processes and new products cheaper. Tool loads can be computed and overloads can be predicted by means of FEM, which is very difficult in practical experiments.

An example for developing a new a process is deep drawing with radial pressure. It is a goal of this project to increase the deep drawing ratio by applying an radial pressure to the convex surface of the disk.

The material flow towards the drawing gap is clearly improved by the radial pressure and therefore the deep drawing ratio will be increased.

A testing stand which is based on the results of FEM has been built. The practical tests confirmed the results of the numerical simulation (Hatzenbichler, 2002).

Conclusions

This work shows various possibilities of the application of numerical simulation methods. The exactness of the solution is influenced by various parameters like flowing law, yield condition and boundary conditions such as friction or heat transfer. Material data combine the yield curve, density, conduction and so on. If all parameters are well chosen, the simulation will give reliable results. However, simulation and practical tests must be concluded together succeed in investigating new processes and production methods.

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