VIII International Conference on Computational Plasticity
COMPLAS VIII
E. Oñate and D. R. J. Owen (Eds)

SIMULATION OF MULTI-STEP DEEP-DRAWING PROCESSES PERFORMED IN TRANSFER PRESSES

Miklós Tisza[†], Zsolt Lukács[*] and Gaszton Gál[†]

[†] Department of Mechanical Engineering (DME)
University of Miskolc
3515 Miskolc-Egyetemváros, Miskolc, Hungary
e-mail: tisza.miklos@uni-miskolc.hu, web page: http://www.met.uni-miskolc.hu/

[*] Metal Forming Research Group (MTA TKI)
Hungarian Academy of Sciences
3515 Miskolc-Egyetemváros, Miskolc, Hungary
e-mail: lzsolt@kugli.met.uni-miskolc.hu - web page: http:// www.met.uni-miskolc.hu/

Key words: Multi-step Deep-drawing, Finite Element Modelling, Transfer presses.

Summary. *Multi-step deep-drawing performed in transfer presses is an economic and highly competitive alternative to individual presses particularly for complicated components requiring several forming steps. This production procedure is widely applied in mass production, particularly in the automotive and automotive sub-supplier industry, as well as in the electrical- and home appliance sector. In this paper, the multi-step deep-drawing production of axisymmetric automotive parts with complex geometry will be analysed. Besides the complex geometry, high shape and dimensional tolerances should be fulfilled resulting in further difficulties both in the process design and in the production.*

1 INTRODUCTION

Today's competitive market imposes continuously increasing demands on the products and product development. Industrial companies are very keen on reducing development and manufacturing costs, as well as total lead time-to-market to ensure profitability. The challenge to successfully execute a product program is to develop and design products and manufacturing processes "just right the first time" eliminating the cost- and time-expensive „trial and error" methods, which were very characteristic particularly in sheet metal forming for many years. In order to meet the above challenges, significant developments in sheet metal forming simulation were performed. This approach involves stamping evaluation using simulation at every stage of product and process development from conceptual design through product and process design up to the manufacturing phase leading to continuous improvement in the quality of part design, as well as to significant reduction in total cost and time in producing sheet metal parts. Simulation software is a strategic component of the above engineering approach. The use of simulation software in sheet metal forming has increased radically in the recent years, due to its benefits both in optimization and in trouble-shooting.

Multi-step deep drawing is very widely applied process due to its high productivity and relatively low-cost characteristics. Multi-step deep drawing performed in transfer presses should be designed without any interruption for additional processing, e.g. intermediate annealing. In multi-step deep drawing, the material undergoes heavy additional complex deformation in each stage comparing to conventional single-step deep drawing. Since the deformation mechanism is quite complicated, it is usually very difficult to design successful process for the very first time using conventional trial-and-error based design procedures.

2 DESCRIPTION OF THE FORMING TASK

The component to be produced with the multi-step deep drawing process can be seen in Fig. 1. This is a motor housing of a windscreen wiper widely applied in automotive industry. There are some special prescriptions on this component, which can be summarized as follows:

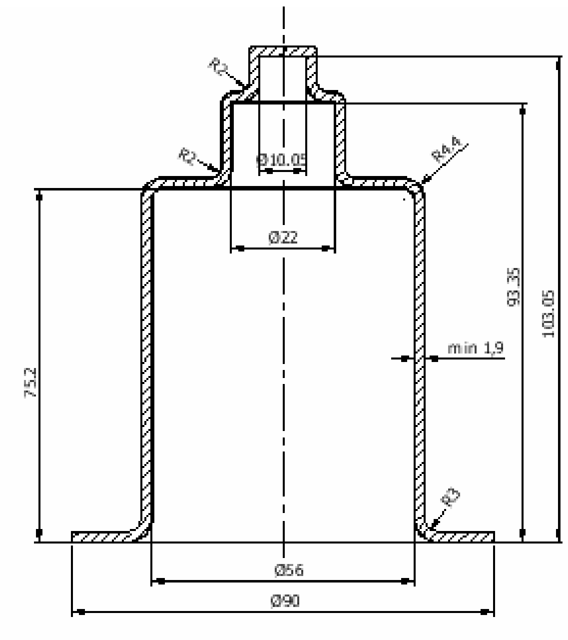

Fig. 1. The component to be produced by multi-step deep drawing on a transfer press

- strict dimensional tolerances on the diameter of the main cylindrical part (± 0.10 mm);
- even more strict tolerance on the diameter of the bearing housing (± 0.05 mm);
- the wall thickness of the entire component should not be less than s ≥ 1.9 mm =as it will be seen later, it imposes very strict conditions on the forming processes);
- small (sharp) radii at certain zones;

The above prescription relate for the component to be manufactured. However, there is another strict restriction arising from the manufacturing facilities: the company, which will produce this component has a transfer press with 10 working positions. It means that the component should be produced with 10 or less subsequent forming steps. (The cutting of the blank is done in a separate position on the transfer press, which does not reduce the number of available working positions.

3 PROCESS PLANNING BY KNOWLEDGE BASED EXPERT SYSTEM – DEEPEX

A knowledge-based process planning system (called DEEPEX) was developed for deep drawing of axisymmetric components at the University of Miskolc. This system has a feature-based, object oriented module for the geometric description of the component to be drawn. In this system, a two-stage process planning strategy is applied. In the first stage, the system is capable to generate an initial – so-called geometrical – process sequence. This task is based on the principles of the group technology, and it is done by an automatic shape and feature recognition processing. This is purely a geometry based first pass not considering any technological constraints. It will serve as the input to the formability based second stage that is used to refine this initial sequence. In the second stage of the process planning, a technologically feasible process plan is determined starting out of the geometrically possible process plan and taking into consideration the technological (formability) limitations. It means that the geometrically feasible process plan is tested and checked against the technological constraints and rules stored in the knowledge and database of the system. Obviously this approach means that either more or less operations may be technologically necessary than it was determined just from the geometry based on the feature recognition.

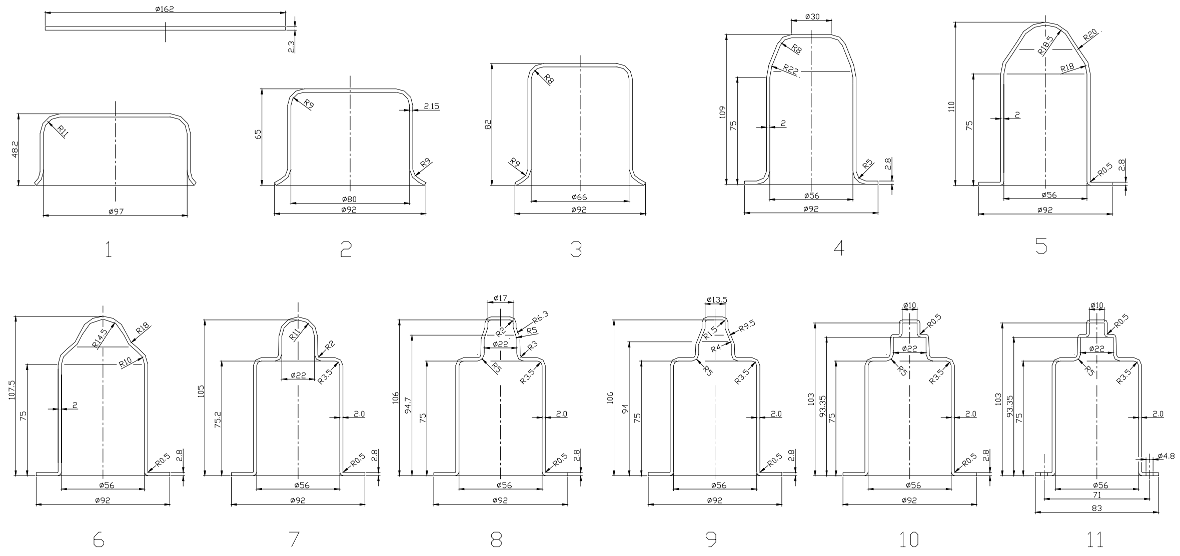

Fig. 2. Process plan generated by the knowledge based approach

This is illustrated in Fig. 2. – where a geometrically feasible and technologically acceptable – process plan generated by the system is given for the component shown in Fig. 1. (There are obviously more than one possible solutions for the production of a given component. The system is capable to offer alternative solutions.) As it can be seen from Fig. 2., the proposed process sequence contains eleven forming stages, which higher than the number of working positions on the transfer press available for manufacturing. It will be shown that applying a step-by-step finite element analysis, the number of necessary drawing stages can be reduced successfully whilst the required dimensional and shape tolerances can be kept within the very strict prescribed limit, i.e. the required quality of the component can be assured. This analysis will be given in the next section.

4 FINITE ELEMENT ANALYSIS OF MULTI-STEP DEEP DRAWING

Application of finite element method to analyze and support technological process planning seems to be very promising in multi-step deep drawing processes, as well. In this paper, a simulation based design and process-planning approach will be described for the production of axisymmetric components produced on transfer presses. This solution applies expert system like preliminary process planning as shown in Section 3. Then, the preliminary process plan is analyzed by the DEFORM 3D finite element code. The simulation provides valuable information on the deformation process clearly indicating the problems in material flow during the subsequent operations. Based on finite element analysis, the modification of process plan can be performed to reduce the risk of failures during the multi-step operations.

Our primary aim during the finite element analysis was to reduce the number of forming stages to less than 10 in such a way that the strict dimensional and shape tolerances should be fulfilled and a robust process can be performed in industrial conditions, too. During the FEM simulations, we have analyzed the effect of various technological and tool parameters. Among the technological parameters, the effect of blank holder pressure and the drawing gap was analyzed. We have also analyzed the effect of various punch ends (e.g. flat-, conical-, semispherical and combined conical-semispherical punch ends were examined) on the material flow.

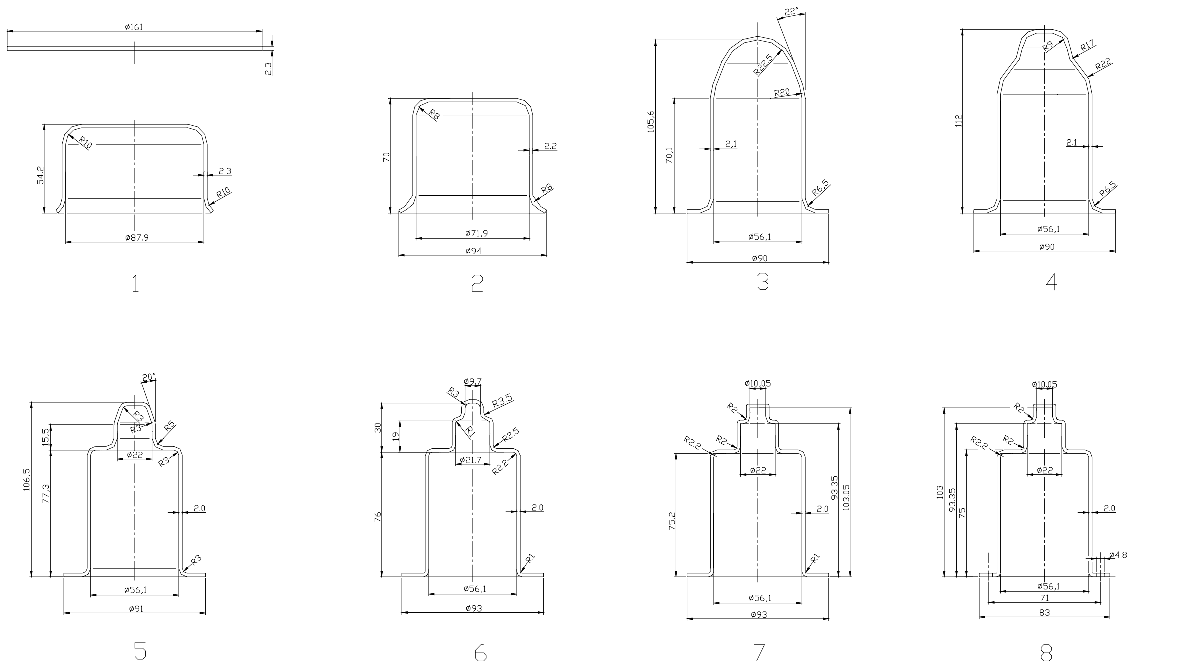

Fig. 3. Final process plan determined by finite element analysis

5 CONCLUSIONS

In this paper, a simulation and knowledge based approach of multi-step deep drawing of axisymmetric automotive parts with complex geometry performed in transfer press was analyzed. Besides the complex geometry, high shape and dimensional tolerances are prescribed. Possible process plans were determined based on experiences stored in the knowledge base of CAE system. Then, the process plan modification was performed applying elasto-plastic finite element modelling. Successful process plan was determined analysing various technological and tool parameters. The elaborated process plan was checked by experimental production, which proved the suitability of the obtained simulation results.