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APPLICATION OF NUMERICAL SIMULATION FOR OPTIMIZATION OF DEEP DRAWING TECHNOLOGY ON THE EXAMPLE OF REDESIGNED FILTER CUP

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ABSTRACT
The complexity of process conditions and a many of influencing factors make the process of sheet forming by deep drawing very complex. Traditionally, technology definition and the design of sheet metal tools are based on years of experience of engineers. Instead of that, software applications are being used today more and more to simulate the metal forming process. They allow them through the detailed analysis of the process to check the preliminary design solution and resolve any dilemmas that may arise in the design process. In addition, the deep drawing process simulation enables you to quickly identify the most important influence parameters and choose their optimal values without make the tools and their probes, which in traditional design and control procedures requires significant financial investments. Also, with a traditional approach, there is a risk of unsuccessful shaping of the material and the appearance of various defects of the parts.
An example of numerical simulation application is presented in this paper as a useful tool for checking the possibilities of making a redesigned filter housing according to the projected deep drawing technology. FormingSuite software was used to simulate the deep drawing process.
Keywords: deformation process, deep drawing, numerical simulation, filter cup, Forming Limit Digram - FLD, FormingSuite

1. INTRODUCTION
Using the modern software for analysis and simulation of the metal forming process over the last decade is a highly efficient tool that enables the design of components to be designed according to the design technology, avoiding expensive testing and unnecessary costs of developing their prototypes.
Also, numerical simulation can be efficiently used to redefine part creation technology to optimize it or to achieve savings and other production effects. Particularly important for large scale production of many products, as the minimal improvements in production can lead to significant financial effects. A lot of that products are applied in different industrial branches, especially in the automotive industry. Different types of oil, air and fuel filters can be included in that products. Filter casings are most often made of sheets with deep drawing technology. A multitude of influencing factors and complex processing conditions make the process of their deep drawing extremely complicated. For this reason, the deep drawing process simulation is an efficient tool that provides a great deal of information about the process itself. This information enables the technicians and tool builders to optimize the process without the prior art tools and their probes. With a traditional approach to design, this would require significant financial investment with real danger of unsuccessful formatting of the material and the occurrence of various defects.

In several years practice in one production organization, the design of the casing / filter pot shown in Figure 1. was carried out by a deep drawing technique from two parts.

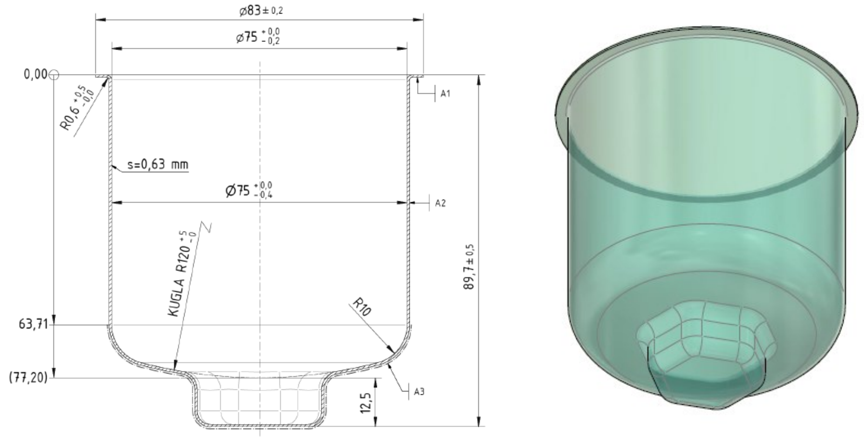

Figure 1. Filter cup with partial surface distribution for calculating platinum diameter[2]

In this case, the enclosed part of the enclosure with the reduction of the diameter of the welding technology is connected to the cylindrical housing of the filter making one functional unit. In order to optimize the technology, there is a need to fabricate the filter housing from one part. The design of deep drawing technology has been completed in a classic way with all the necessary principles for determining the platinum diameter and the dimensions of the work according to the stages of fabrication. Numerical simulation was performed to check the possibilities of efficient formatting and fabrication of the filter housing from one part to the designed technology. In this way, following the flow of formatting and simulation results, a preliminary design solution was obtained before the tool design and its putting into function checked by solving certain dilemmas that occurred during design. The basic elements of the projected below manufacturing technology and the results of the simulated deep drawing process of the subject filter cup will be presented below.

2. CHARACTERISTICS AND DESIGN OF HOUSEHOLD TECHNOLOGY

This product is a casing (pot) of oil filters made of steel sheet marked DC04-1.0338, 0.63 mm thickness. This material belongs to a group of structural steel and according to EN 10130:2006 is a non-alloy steel with the following chemical composition requirements: C: max. 0.08%, Mn: max. 0.04%, P: max. 0.03% and S: max. 0.03% and the mechanical properties of R_{eH}=210 N/mm^2 and R_m=270-350 N/mm^2.

Based on calculation according to presented order in the published literature of deformation processing, it was concluded that the product can be efficiently made in 3 deep drawing operations, with the additional operation of the initial platinum band platinum operation, two complementary shaping operations of the six-shaped profiled cap shape SW 30 and the ultimate cropping of the finished product crown. Consequently, platinum diameter was calculated using the partial surface method (D_o = 176 mm), certain dimensions of the workings by design phases and force analysis and deformation work. Figure 2. shows the shapes and dimensions of the workings after the first deep drawing operation and the last stage of shaping.

3. SIMULATION OF THE FILTER CUP PRODUCTION PROCESSES

Finite Element Method (FEM) is a very powerful and mass-driven tool for numerical simulation of the processing process. Thanks to the rapid development of computer technology, a lot of commercial software packages have been developed, based on the finite element method, to solve problems in metal forming processes.

In order to examine the possibilities of making the filter housing according to the redesigned manufacturing technology, numerical simulation has been performed in this paper. The finite element method (FEM) was used to simulate the individual phases of the formulation, and simulation was performed using the FormingSuit software. FormingSuit is a specialized software package developed by Forming Technology Incorporated for computer simulation of sheet forming processes. It is based on LS-DYNA solver.

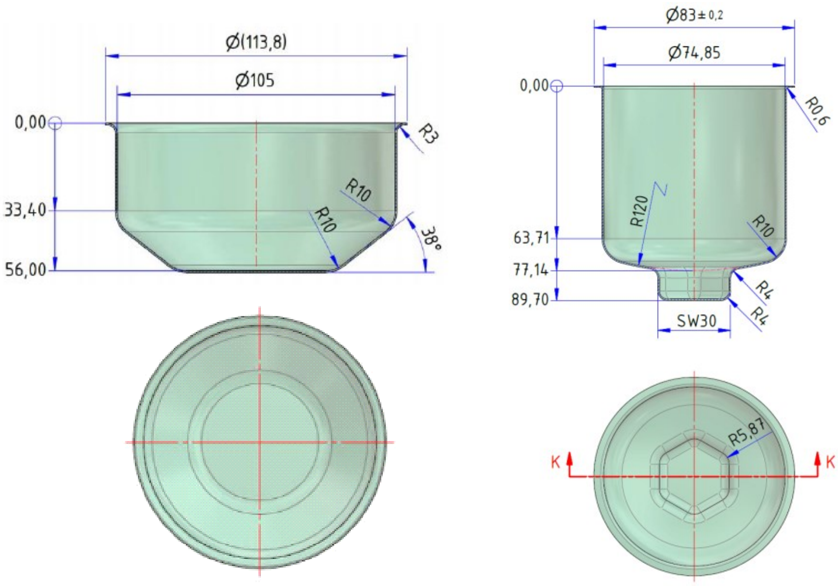

Figure 2. Dimensions of the filter cup after the first deep drawing operation and the last stage of shaping [2]

The aim of the analysis is to perform a numerical simulation for deep drawing operations and to show output results by evaluating the performance of the process by entering the data by displaying critical site locations, changes in material thickness and process parameters in the boundary deformability diagram. Otherwise, when deforming the sheets, deformability is most often expressed through the intensity of the main deformation in the flat sheet at the time of localized deformation and destruction. The greater major deformation (φ_1) dependence of less (φ_2) at the boundary conditions is the forming limit diagram (FLD) in the sheets. The diagram is determined experimentally in a relatively simple manner, mostly by applying electrochemical circuitry to the surface of the sheet preparation. Thereafter, deformation of that preparation into the work is carried out, with the circles deforming into the ellipse. Cores of the ellipse symmetry represent the main lines of deformation. Deformation continues until the first cracks occur. By measuring the size, logarithmic deformations occur in the directions. By combining critical points, the FLC (Forming Limit Curve) formation for the tested metal is obtained. All the points below the curve of the deformation deflection represent deformations in which the cracks in the material do not occur, while the points on the curve and above the curve indicate the deformations that cause cracks in the material during forming. When designing the technological process, such a ratio of sheet deformation should be ensured that the system stays in function-under the FLC. Figure 3. shows the FLC diagram for steel DC04.

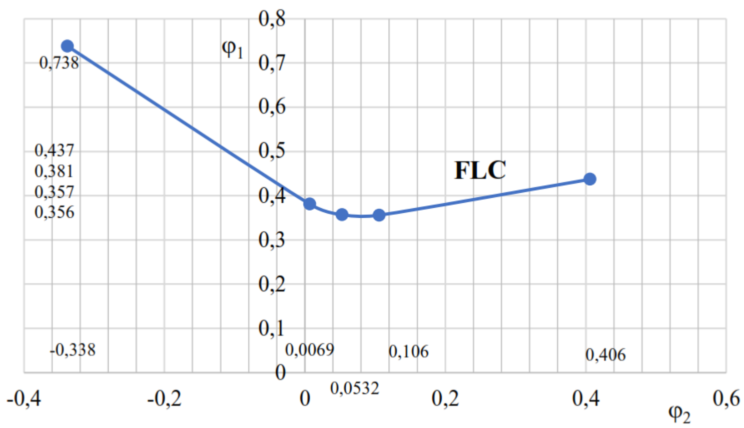

Figure 3. Forming limit diagram (FLD) for steel DC04 [5]

Based on the previous theoretical considerations, through the simple user interface of the FormingSite software, a simulation of each formatting operation was performed, along with the definition of the material, the import of the template, the matrix, the extractor and the sheet holder. The software provides an incremental analysis with six security zones (low strain, strong wrinkle tendency, wrinkle tendency, excessive thinning, safe, fail) that can occur during deep drawing deformation, indicated by different colors. In addition, for each shaping operation, as a result of the analysis, the distribution of sheet thickness is obtained as compared to the wall thickness limit value and the FLC curve with a diagrammatic representation of two major surface

deformations and the position of their combinations relative to the FLC. By simply analyzing these graphs, it is possible to deduce the possibility of efficient formatting according to the design technology in a particular technological operation.
In Figure 4, part of the result of numerical simulation is presented through a representation of the thickness reduction and the forming limit diagram after the last shaping operation.

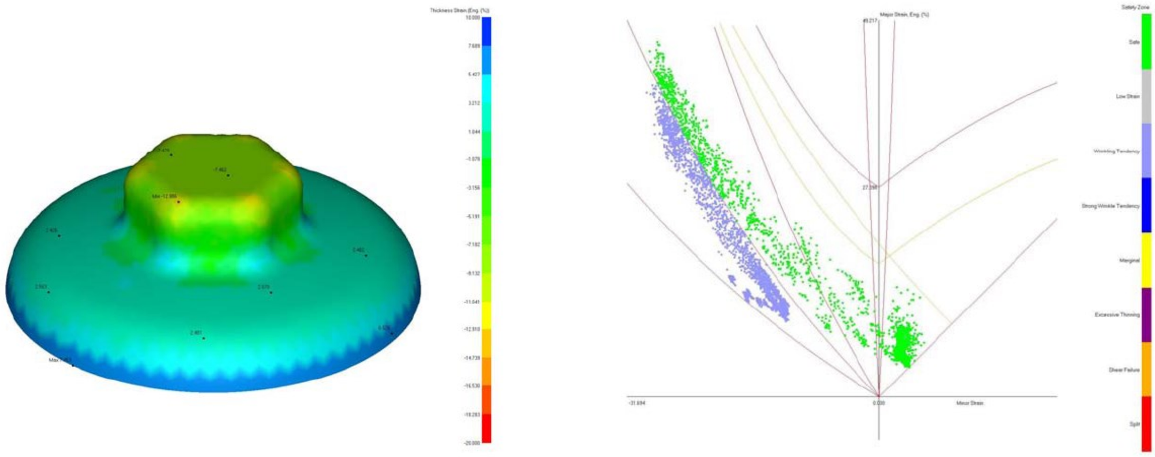

Figure 4. Deformation of wall thickness (left) and FLD (right) after drawing of the final shape

Simulation was performed in all the phases of the shaping, and the results show a reliable design from the aspect of the distribution of the safety zones, the allowed thickness reduction and the main deformation combination in the flat sheets underneath the FLC curve.

4. CONCLUSION

The software simulation of the design of the casing presented in the paper has been used to check the preliminary design solution and to eliminate certain dilemmas regarding the possibilities and plastic properties of the material to be shaped according to the defined geometry and the given working conditions. By analyzing the safety zones, the FLD diagram and the relative sheet thickness distribution at each stage of the projected technology it can be concluded that it is possible to reliably form the filter housing from one part. This can significantly improve the mechanical properties of the casing and make significant savings compared to its current design. The illustrated example of the numerical simulation of the filter housing design process according to the redesigned technology of its fabrication can serve as an initial idea for the re-examination of technological solutions for forming a wide array of similar sheet metal parts. Easy user access, database of many different materials, the ability to import geometric models from a large number of applications, a simple display of simulation results and the ability to quickly analyze the efficiency of the process, and a host of other benefits make the software applied extremely suitable for these purposes and serious use without conducting specialist and long-lasting user training.

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