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FROM CONCEPT TO PRODUCT – APPLICATION OF INVENTIUM SUITE SYSTEM IN THE DESIGN NEW TECHNOLOGY OF SINK STAMPING PROCESS

OD KONCEPCJI DO PRODUKTU – ZASTOSOWANIE PAKIETU INVENTIUM W PROJEKTOWANIU TECHNOLOGII PRODUKCJI ZLEWOZMYWAKA

A b s t r a c t

This paper shows example results of computer simulations supporting the production process of sink. Design and verification of deep drawing process and tools design were carried out using finite element models implemented in Inventium Suite. Wrinkling and fracture of the material were the main phenomena subjected to the investigation using numerical analysis. A number of computer simulations were carried out in order to eliminate defects and analyze the shape of the final product.

Keywords: *drawing*, *FEM modeling*

S t r e s z c z e n i e

W artykule przedstawiono przykładowe wyniki symulacji komputerowych wspomagających proces produkcyjny zlewozmywaka. Projekt oraz weryfikację narzędzi do procesu tłoczenia przeprowadzono z wykorzystaniem metody elementów skończonych z użyciem systemu Inventium oraz eta/Dynaform. Typowe trudności napotkane w trakcie analiz numerycznych to pofałdowanie oraz zrywanie materiału wytłoczki. Przeprowadzono szereg symulacji komputerowych mających na celu wyeliminowanie pojawiających się wad, a także analizę kształtu wyrobu.

Słowa kluczowe: *tłoczenie*, *metoda elementów skończonych*

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1. Introduction

In the last years, in the technology of sheet metal forming has undergone a number of innovative changes. The main ones are new forming techniques (e.g. rubber-pad forming [4]) and application of advanced computer technology of which the most popular is Computer Aided Engineering (CAE). The main objective of CAE systems is to reduce costs and shorten the design and production analysis time of production through the use of fast and accurate computer simulations. One of the main benefits of such systems is lowering project and production costs due to application of fast and accurate design with the help of computer systems. The systems can help not only in the development of a new technology but also in improvement of production. The process can be constantly updated according to the simulation outcome, which results in process optimization [4]. Information obtained from application of CAE helps to refine and optimize product design and manufacturing of products.

The quality requirements for sheet metal products are very high, mainly due to the technology of automatic assembly of components in the automotive industry, where the deep-drawing is the most widely used. The requirements apply to the appropriate material properties and the shape of the finished products. Wrinkles, excessive thinning and springback effects are the main disadvantages of the drawpieces. The elimination of such undesirable defects is very difficult and time-consuming. It is therefore necessary to design the appropriate technology and tools. This can be done effectively using computer simulation methods (mainly FEM).

Decisions made at the design stage of a technological process influences both its later realization and the total production costs [1]. There are a lot of commercial packages that are used to simulate metal forming. In the field of drawing the Inventium Suite system and LS-DYNA solver are the leaders. Inventium (Fig. 1) offers a streamlined product architecture, provides users access to all of the suite's software tools. Moreover it provides a high performance modeling and post-processing system. The Inventium system consists of: PreSys – excellent tool for modeling, with extensive graphics capabilities, VPG – offering a set of tools which allow engineers to create and visualize, through its modules – structure, safety, drop test and blast analyses, eta/Dynaform – the most accurate die analysis solution available today, allowing a very accurate assessment of defects in the finished product, and Nisa – a robust and comprehensive module for technical analysis using FEM.

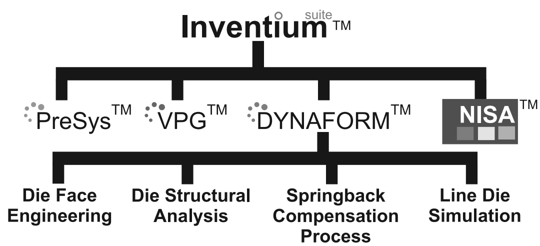

Fig. 1. The Inventium Suite

Rys. 1. Podział pakietu Inventium

Engineering Technology Associates has developed a specialized package of sheet metal forming software and additional modules such as formability module, die face engineering (DFE), blank size engineering (BSE), die structural analysis (DSA), springback compensation process (SCP) module, and line die simulation (LDS) module. [2].

Currently there are several approaches to the development of new products. The concurrent engineering, in addition to the traditional development process, are increasingly being used. They depend primarily on how the FEM simulations are used in the design and analysis of a manufacturing process, as well as tools and products. Various algorithms and procedures, ranging from explicit and implicit FEM models to one-step solvers, are develop for analysis of metal forming processes. This methods, in conjunction with new computational capabilities of current computers, provides useful tools for the implementation of parallel approach of design and manufacturing. The concurrent engineering in the development of new components stamped suggests that steps such as design of the product, process, tools, manufacture of tools and industrial tests can be carried out simultaneously [3]. The traditional process (the so-called sequential engineering) of new product development is presented in Fig 2.

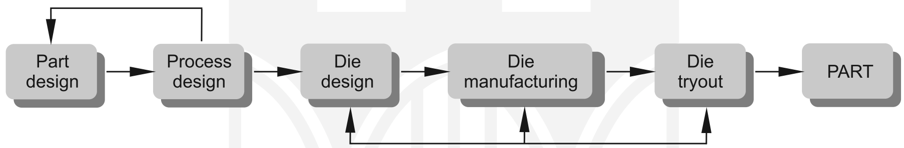

Fig. 2. The traditional process of new product development

Rys. 2. Tradycyjny process rozwoju produktu

CAD/CAE software allows for accurate analysis of the process of creating a new finished product, resulting in measurable benefits in the form of reduction in the duration the design, implementation and reduce overall costs. This behavior allows you to meet the demands of increasingly competitive and high quality products, which is especially important from a consumer perspective. CAE has another important task in the development of new products, namely one hundred percent assurance of repeatability of the product, and there by a guarantee of a modern production [4].

In order to present the expected role of the FEM simulation and CAE systems, in this paper the design process of the product (drawpiece) and design tools used in the manufacture of sink shown. Computer simulations which are using in the different phases of design, allow preliminary assessment of the correctness of the product, the number of operations needed to complete the process and finally the search for solutions in order to get a high quality product.

2. Mechanical properties of starting material

The sink is made of steel of grade SS304L of 1mm thickness. It is a steel with good weldability, corrosion-resistant, which widely used for kitchen equipments, welding elements in chemical industry, in the textile, paper, pharmaceutical and chemical industries. The main objective of the project was to develop a production technology of sink and avoid the typical stamping defects such as wrinkling, cracking or excessive thinning. A very important aspect of the process is the precise metal flow during the forming and selection of appropriate parameters defining the process.

Some further information about material are given below:

- Young modulus: 207.0 GPa,
- Yield strength: 290.58 MPa,
- Poisson's ratio: 0.28,
- Hardening exp. *n*-value = 0.52,
- Anisotropy *r*-value = 0.905.

Stamping process parameters:

- die velocity: 5000mm/s,
- binder close velocity: 2000mm/s,
- friction coefficient: 0.125,
- thickness of drawpiece: 1 mm.

The other process parameters, such as blank holder pressure, was set differently for the different stamping conditions. The influence of pressure was analyzed to eliminate wrinkles and cracking.

3. The equivalent and geometrical drawbead model

In the analysis process, the sheet was pulled through drawbeads which are very often used in the forming technology. Their proper shape and positioning require multiple and time-consuming computer simulations. In this paper, the geometrical drawbeads was used. Drawbeads allows such forming to flow resistance of the material were distributed evenly. They meet the very important role of causing additional tensile stress, which prevents the formation of wrinkles on the surface of the drawpiece [4]. Drawbeads should be modeled as a large number of the smallest elements in order to reflect more accurately the effects of transitions metal. Simulations with geometrical drawbeads are very time consuming, so very often, in numerical analysis, effective model of drawbeads are introduce. The restraining force exerted by the actual drawbead is assigned distributively to the nodes in the regular mesh

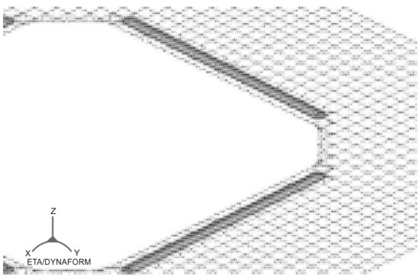

Fig. 3. The geometrical FEM drawbead model

Rys. 3. Model geometrycznego progu ciągowego of the equivalent drawbead. The assigned restraining forces are then assumed to act on the sheet metal which moves through these nodes. Such operation allows reduction of simulation time without influence on very good calculation accuracy. In Fig. 3 and Fig. 4 are shown, respectively the geometrical drawbeads and compare of geometrical model and effective model of drawbeads.

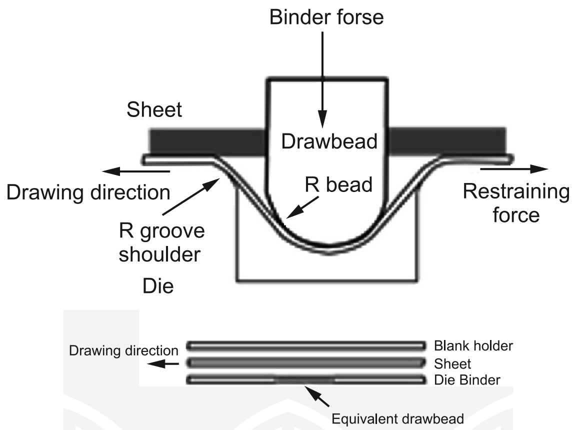

Fig. 4. Geometrical and effective drawbead models

Rys. 4. Geometryczny i efektywny próg ciągowy

4. FEM model

Main parts of the tool set: die, blank, binder and punch are presented in Fig. 5. The upper die was the moving tool.

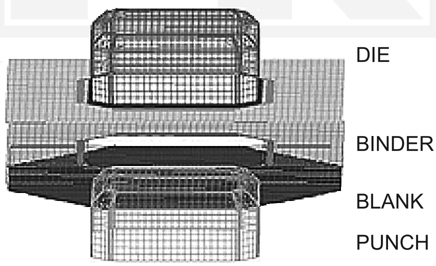

Fig. 5. FEM tools model

Rys. 5. Model MES narzędzi

FEM tools model for stamping process has been developed using DFE module, which is module of the eta/Dynaform system. An optimum sheet blank shape determined by the finite element analysis was used for all die designs by using BSE (Blank Size Estimated) module of eta/Dynaform system. The condition contact proceeding during stamping of sink was identified by algorithms coded in eta/Dynaform system. In the present work, the four node shell element was used to construct the meshes as shown in Figure 5. The numbers of elements and nodes used for all parts of the model are listed in Table 1.

Table 1

Number of elements and nodes

Mesh	Elements	Nodes
Low Die	4929	4998
Punch	8309	8418
Binder	3380	3420
Blank	7864	7941
Total	**24482**	**24777**

5. Results of computer simulation

An sheet blank shape was determined by the finite element analysis. The BSE module is used, among others to optimize the shape of the blank (BSE – Blank Size Engineering), which is a module of the system of eta/Dynaform, was used for this purpose. The four corners of this optimum sheet blank were cut off to facilitate metal flow at the edges The shape of die cavity conforming to the geometry of the sink was also maintained as the same for all of the die face designs since the bathtub was drawn to the desired shape in one operation. A clamping force of 1.5 MPa exerted by the blank holder for the initial die design. A coefficient of friction of 0.125 was used for all analysis.The final shape that results from which design being show in Figure 6.

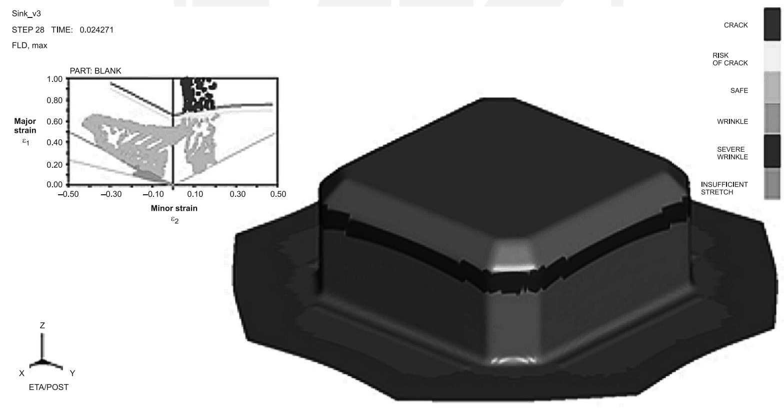

Fig. 6. Final shape of a sink and the minor and major strain and Forming Limit Diagram (FLD) for blank holder pressure 1.5 MPa

Rys. 6. Końcowy kształt umywalki oraz rozkład odkształceń głównych na tle Granicznej Krzywej Tłoczenia (GKT) dla nacisku dociskacza 1,5 MPa

The material flow is quite irregular, especially in the corners, as can be seen in Figure 6. However, the final shape of the drawpiece appeared to be cracking of the material, which is unacceptable in the finished product. The force exerted by the binder was too high and consequently led to the appearance of the typical defects of the stamping process. Cracking can be eliminated by reducing the force of binder, so in the subsequent analysis, this value was reduced to 1.4 MPa.

The major and minor strain distributions plotted on the forming limit diagram, as shown in Figure 7, indicate that the sheet metal are cracking and many of the points are above the

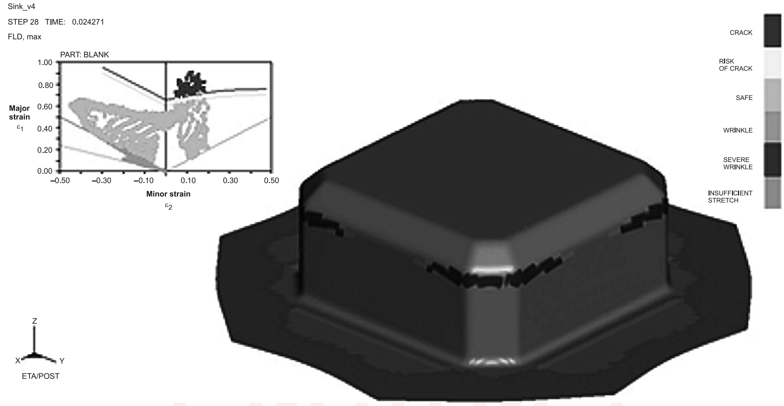

Fig. 7. Final shape of a sink and the minor and major strain and Forming Limit Diagram (FLD) for blank holder pressure 1.4 MPa

Rys. 7. Końcowy kształt umywalki oraz rozkład odkształceń głównych na tle Granicznej Krzywej Tłoczenia (GKT) dla nacisku dociskacza 1,4 MPa

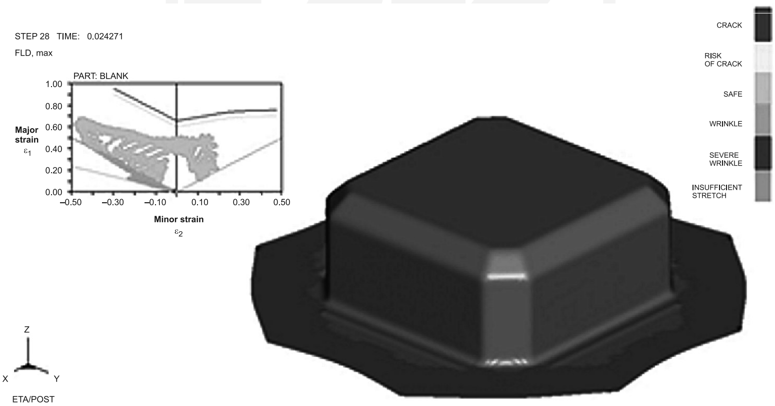

Fig. 8. Final shape of a sink and the minor and major strain and Forming Limit Diagram (FLD) for blank holder pressure 1.2 MPa

Rys. 8. Końcowy kształt umywalki oraz rozkład odkształceń głównych na tle Granicznej Krzywej Tłoczenia (GKT) dla nacisku dociskacza 1,2 MPa risk of crack line. Reduction of binder force of 0.1 MPa allowed to obtain the final shape of the drawpiece with a limited cracking and wrinkling. However, this shape can not be accepted due to the defects in a drawpiece. The formation of wrinkles resulted from a significant metal flow at these areas.

Based on initial analysis the binder force was reduced to 1.2 MPa. This value allowed to obtain the final shape without defects such as wrinkling, excessive thinning and cracking. In the Figure 8 the final shape of a sink for the modified parameters is presented.

Appropriate modification of stamping technology parameters based on computer simulations allowed to receive the final part which is in accordance with the objectives of the technological process. Binder force reducing allowed to reduce the occurrence of wrinkling and cracking. Analysis of thinning distribution (Fig. 9) indicates that the minimum and maximum thinning was –11% and +49%, respectively. The highest values of thinning occurred spot on the corner in drawpiece.

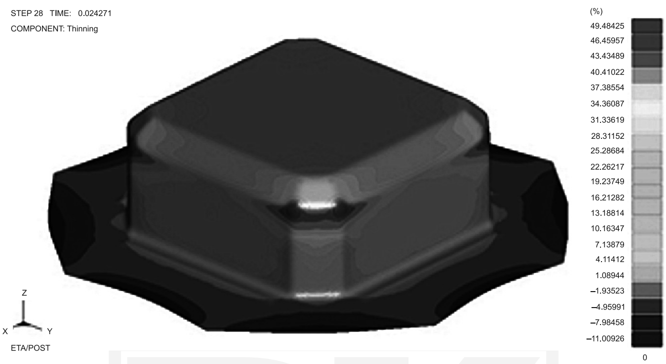

Fig. 9. Thinning distribution for the final part

Rys. 9. Rozkład pocienienia na końcowym wyrobie

6. Industrial tests

As predicted by the finite element analysis, the production part is free from defects. The Figure 10 shows the lines of final shapes from simulations and industrial tests. The final

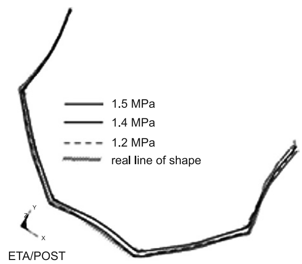

Fig. 10. Lines of final shapes from simulations and industrial tests

Rys. 10. Porównanie obrysów końcowego kształtu dla symulacji i prób przemysłowych shape of sink is cousistent with the shape obtained by computer simulations. This confirms the benefits of using FE systems to design and verifications tools in stamping industry.

7. Conclusions

In the present work the die face design for stamping of a sink was investigated using FEM system. In the investigation the binder force on the shape and quality of drawpiece was analyzed. In the present work, an optimum tools design was performed on the basis of finite element analysis. The industrial tests have confirm achievement of defect free products. The finished product had no typical stamping process defects such as wrinkling, cracking or excessive thinning of the sheet material.

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