USING ANSYS AND LS-DYNA IN THE DESIGN OF A PRESS DIE - SIMULATION AND VALIDATION

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The paper presents the modeling and simulation of the pressing process of an axisymmetric aeronautic part manufactured from a sheet of a martensitic high alloyed steel. The model of the final part is generated with ANSYS software, and the dynamics of the press process is studied with LS-DYNA software. The dynamic simulation process points out the need of perform the whole form process in three phases, in order to regenerate by reheating the microscopic structure of the material which offers the possibility to avoid the occurance of some undesirable cracks. The simulations were found in good agreement with the experiments. The press process stages were performed with a modern electrohydraulic press which allows the stroke control and the force limitation by the aid of a high speed digital controller. A long series of experiments has pointed out the cracks occurance in the same position as the predicted ones, leading to the redesign of the whole manufacturing process.

Keywords: simulation, form process, digital press, cracks prediction

1. Modern methodology for building a die assembly

Many shaped aeronautic components need special mechanichal properties, obtained by presssing sheets of high alloyed steel or similar special materials. The modern metal processing companies are using electro hydraulic digital presses in order to control the process of forming without reducing too much the walls thickness. The cracks are especially generated in the martensitic alloys, which need a complex forming process including at least an intermediate reheating for recovery the microscopic structure. Such a technological process is always modeled and simulated with advanced languages validated step by step in similar processes. In the first step the part model is generated with ANSYS software [1], and the forming

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process dynamics is studied with LS-DYNA software [2]. Such a process was developed by the authors for an aeronautic component (Figs.1 and 2).

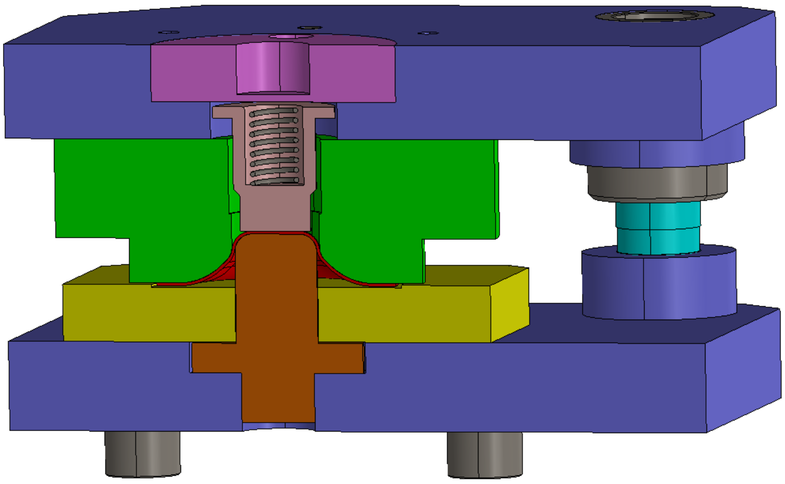

Fig. 1. Main section of the forming die assembly, including the final component (in red) [3]

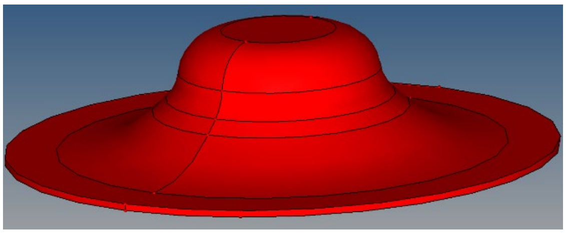

Fig. 2. The 3D model of the aeronautic component generated from the user specifications

2. Numerical simulation of the basic press process

A realistic mathematical model of a press process needs the iterative tuning of the dynamic behavior of all the components. The basic model of the press used in such attempt (Fig. 3) includes the position closed loop of the active cylinder, and an open position loop for the brake cylinder.

The main problem of a realistic simulation is generated by the variation opposing force by the pressed sheet of metal. Normally, a short press cycle seems to be like a hammer strike, but this working manner has a very bad influence on the material uniform elongation. The relation between the active piston displacement, and the metal sheet extension could be established by the aid of a position transducer, combined with a differential pressure transducer, because the anisotropic elasto-plastic behavior of the steel is strongly non-linear. In a first simulation, the load of the active hydraulic cylinder is modeled by a combination of two mass, two different linear spring, and two common dampers, according to the phases of the process.

A typical 500 kN press process can be understood by the aid of some diagrams (Figs. 4…8) supplied by a high accuracy simulation language as AMESIM [4]. The typical settings of the experimental press introduced by the operator in the Delta Controller HMI are presented in Figure 9.

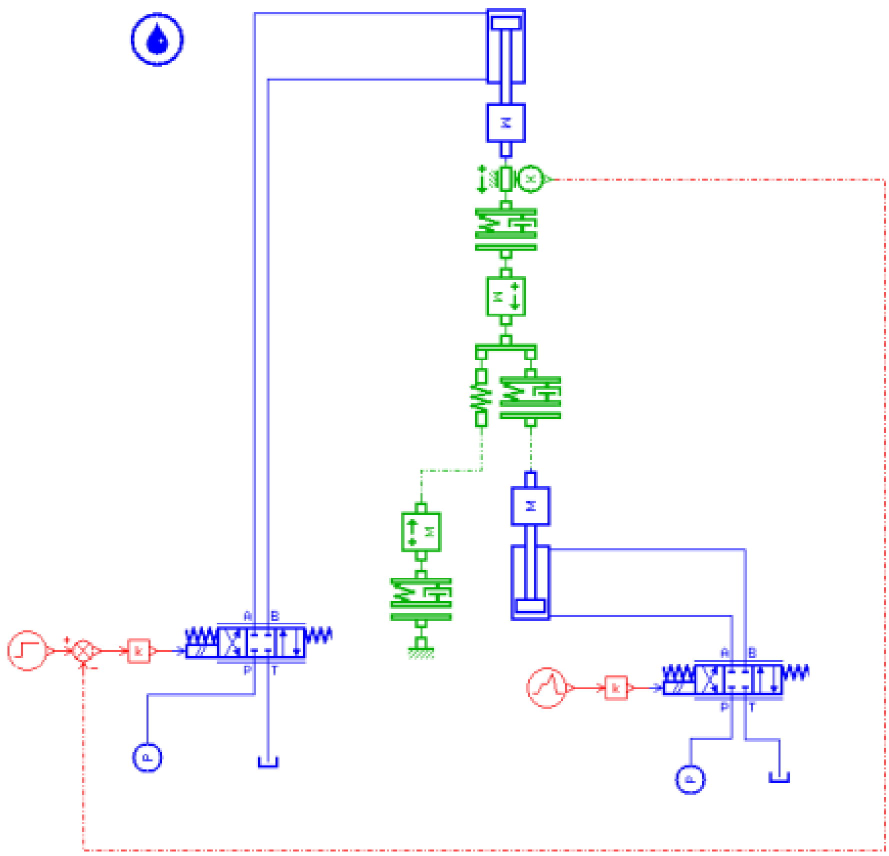

Fig. 3. Basic simulation model of the press process [4]

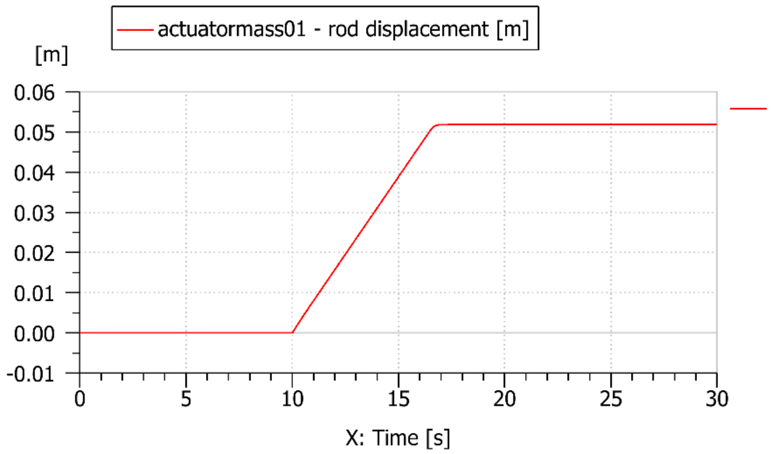

Fig. 4. The active piston displacement evolution

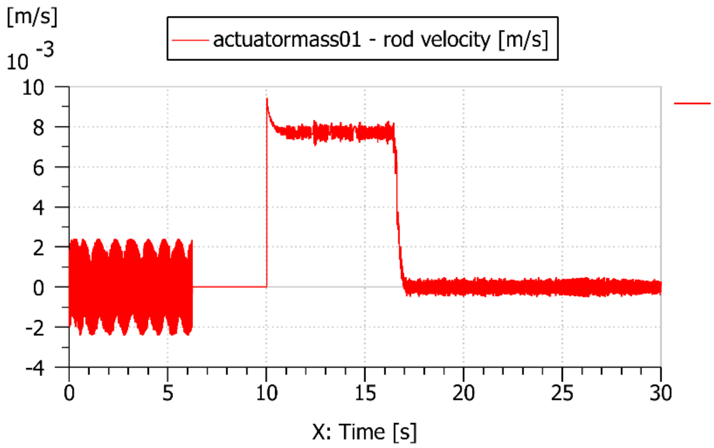

Fig. 5. Evolution of the active piston rod velocity

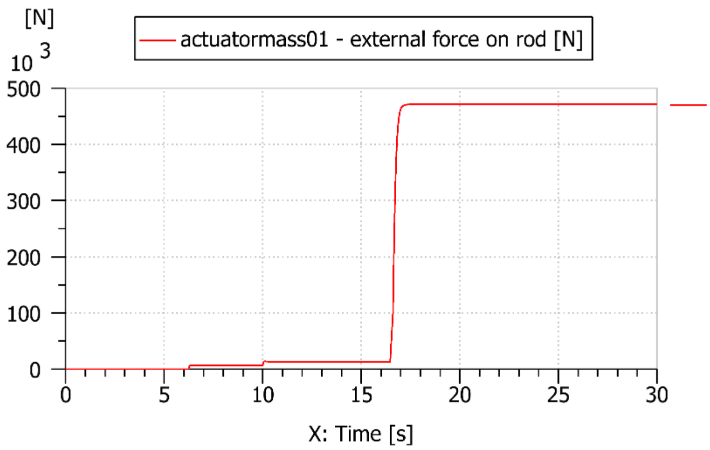

Fig. 5. Variation of the force developed by the active piston

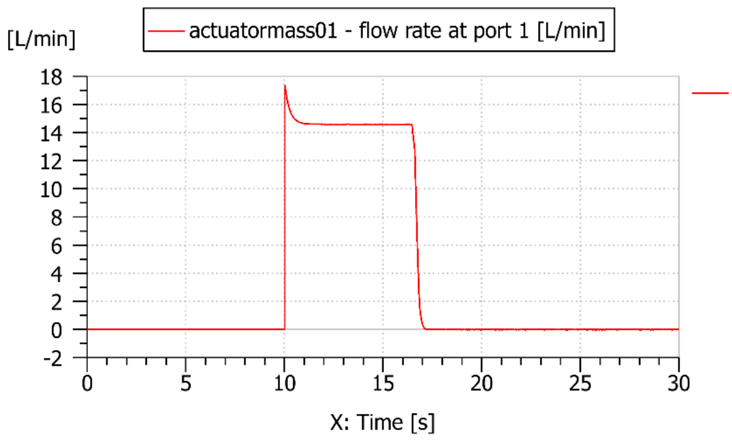

Fig. 6. Variation of the flow rate at the input of the active hydraulic cylinder

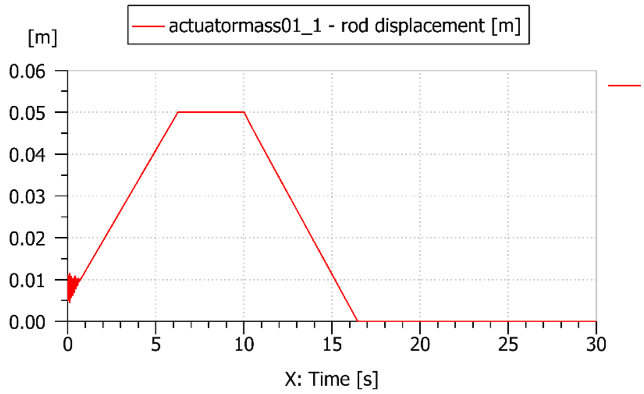

Fig. 7. Active piston rod displacement during a press cycle

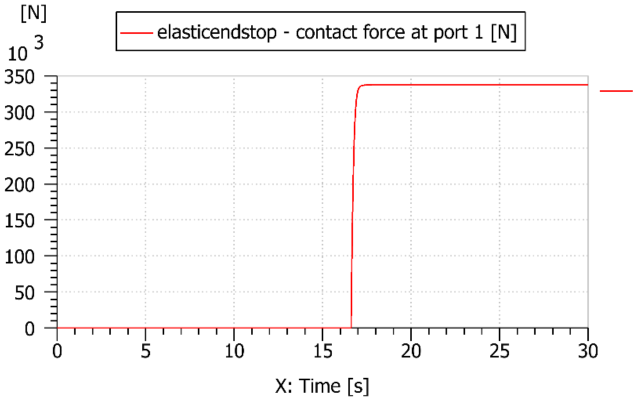

Fig. 8. The contact force between the active piston and the upper plate of the matrix

Fig. 9. Typical settings of the experimental press introduced in the Delta Controller HMI [5]

The setup of a press proces for a special shape and material component needs a lot of stages due to the need of checking of the shape of the matrix components, and the material capabilty of taking the designed shape without cracks. In the case studied by the authors (Fig. 10) the first settings step was the preliminary validation of the matrix design by the aid of an alloyed stell round plate of 1.2 mm only instead 2.5 mm. Consequently, the values of the maximum working pressure of the ram and the cushion are about four time lower that the ones needed for the real material with special mechanical properties (Figs. 11 and 12).

Fig. 10. Final shape of a good quality component made from martensitic steel (face and back)

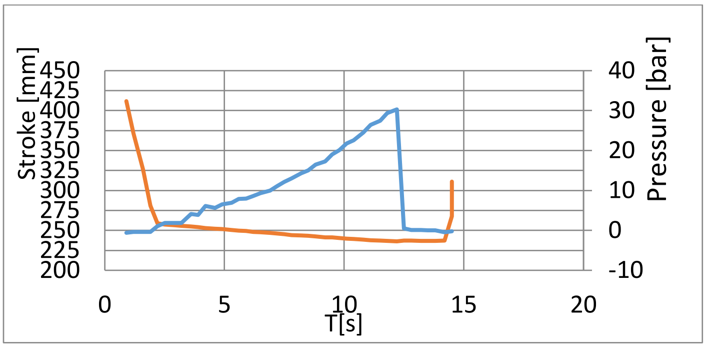

Fig. 11. Stoke and pressure of the ram piston for a test press with a round disk of 1 mm

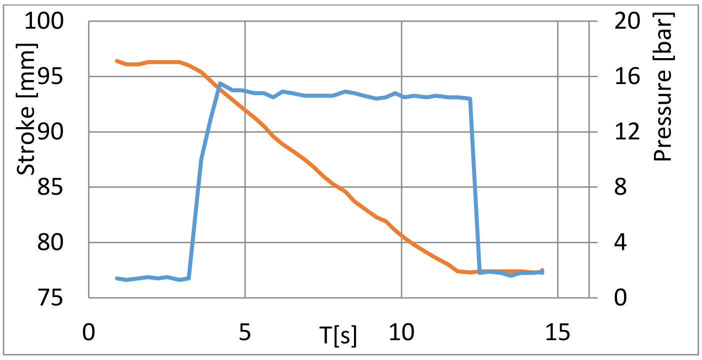

Fig. 12. Stoke and pressure of the caushion piston for a test press with a round disk of 1 mm

3. Building the ANSYS model of the final part

The preparation of the model for the analysis and simulation of the embossing process is usually carried out in specialized programs. The Hyperform program [6], part of the Altair system [7], was used for this. This program allows the automatic generation of the components of the embossing system, starting from the 3D model of the part. At the same time, this program allows the optimization of the FEM model, so that no errors occur when running the analysis program. The simplified model imported into Hyperform is presented in figure 13. The first FEM elements mesh used for the dynamic process analysis is shown in figure 14.

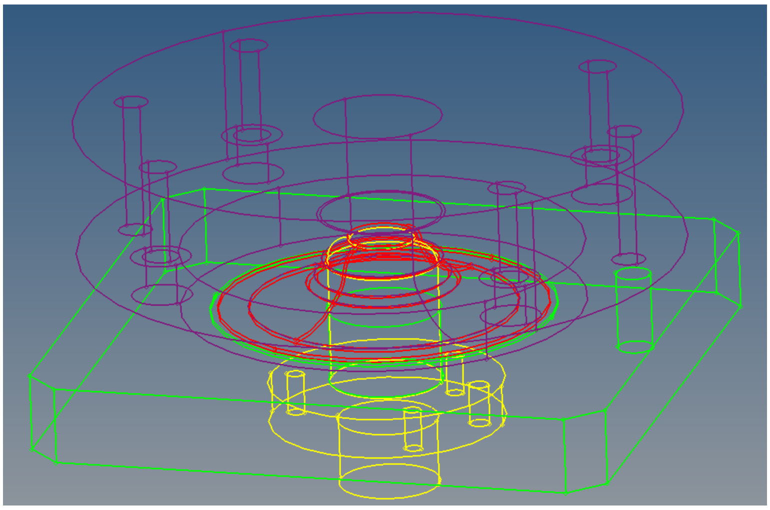

Fig. 13. The simplified Hyperform 3D model of the matrix assembly

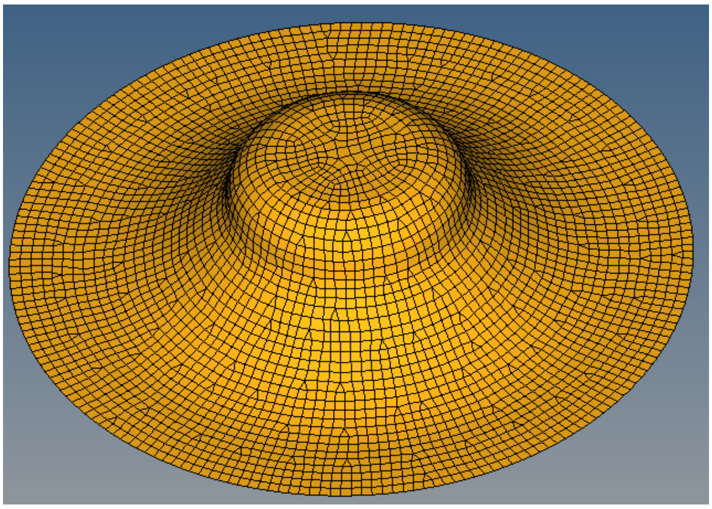

Fig. 14. The FEM elements mesh used for the dynamic process analysis

The Hyperform program allows the optimisation of the first FEM model elements using some shape and geometrical parameters as the ratio between the longest and the shortest side of each element, the flatness deviation for all elements with four nodes, the minimum and maximum angels between the sides etc. The non-conforming elements are graphically indicated in order to be corrected (Fig. 15).

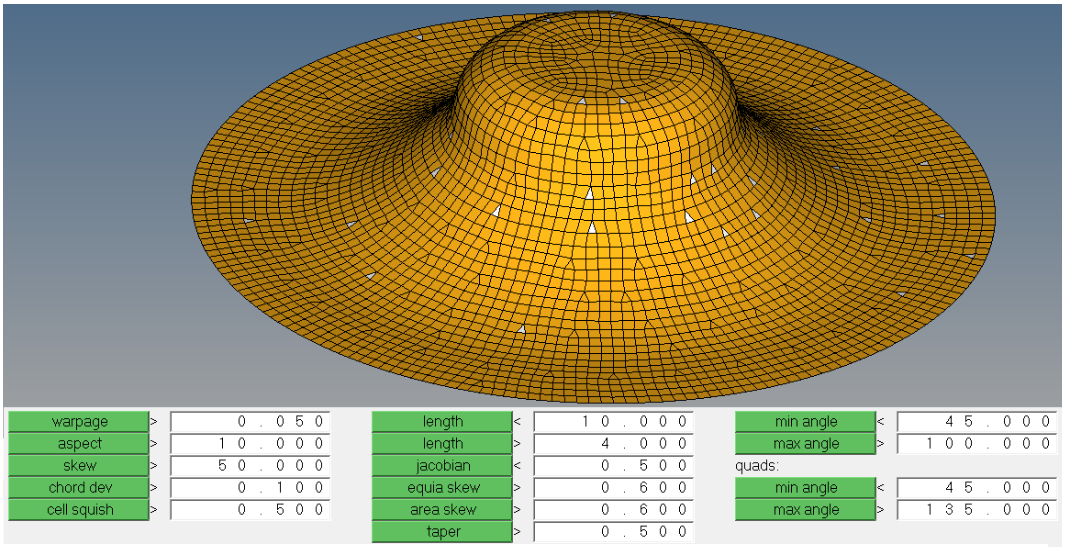

Fig. 15. The check of the mesh quality

The next step of the analysis is the computation of the diameter of the half-finished material, as it is shown in figure 16.

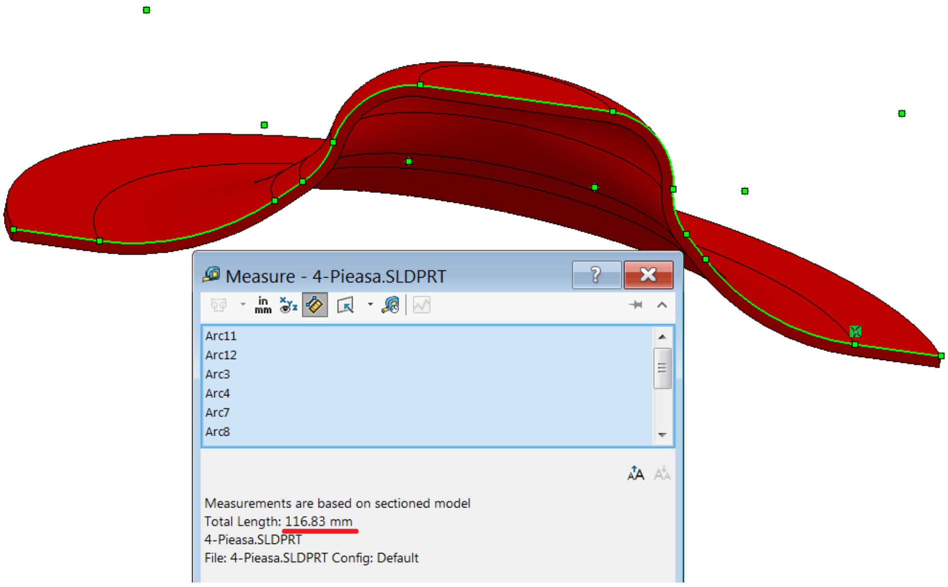

Fig. 16. Finding the diameter of the semifinished metal

These steps are leading to the model used in the analysis (Fig. 17).

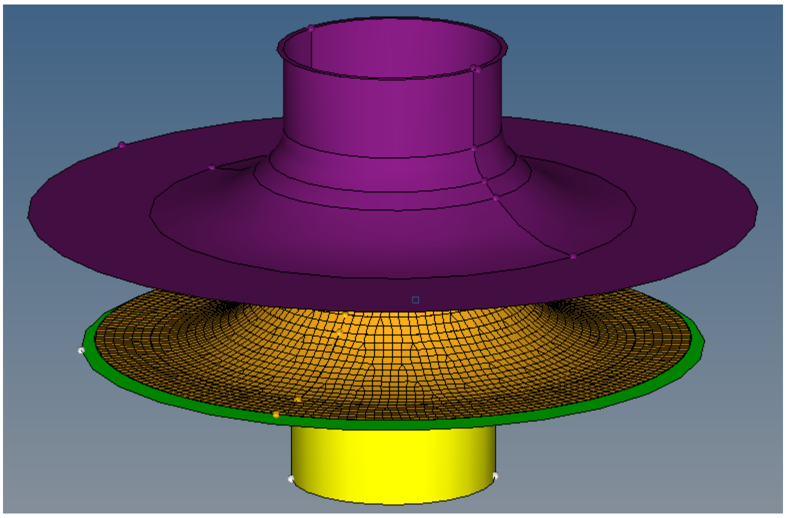

Fig. 17. The final FEM model of the press assembly

The Hyperform program includes a wide library of common and special materials used in the modern aerospace technology. The forming die assembly in contact with sheet have rigid boundaries. The pressed round plate material behavior is an elastic-plastic type, having the real characteristic curve from figure 18.

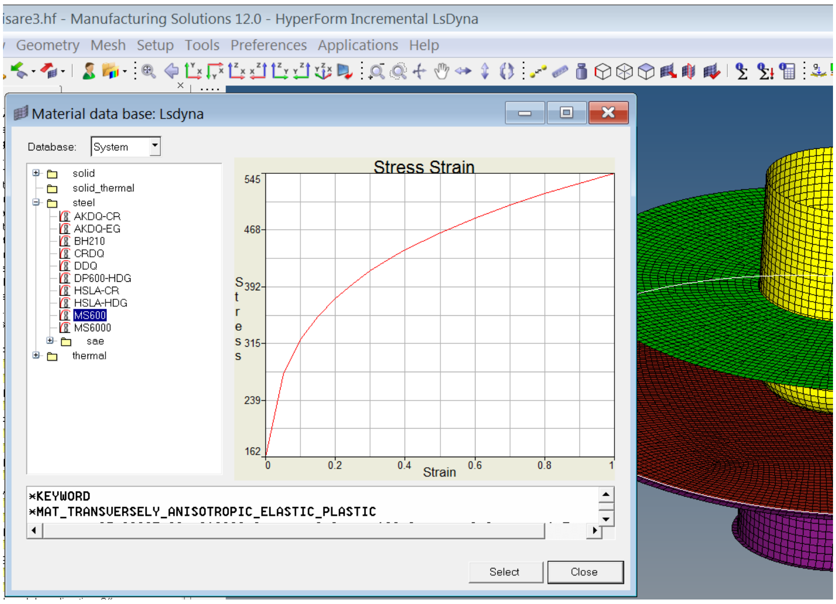

Fig. 18. The material stress-strain characteristic included in the materials library of LS-DYNA

4. Analysis of the press process with LS-DYNA

For a better understanding of the whole press process, the rigid components are hidden in the results of the dynamic simulation. Three categories of the information are given during the process development: the resultant displacement of the material, the effective stress distribution, and the shell thickness map. The overall piston displacement was set at 21 mm, according the component manufacturing drawing, and the forming time was divided into 21 steps. The equivalent stress was computed according the von Mises criteria for homogeneous and isotropic materials. The results obtained for the first step are presented in figures 19, 20 and 21.

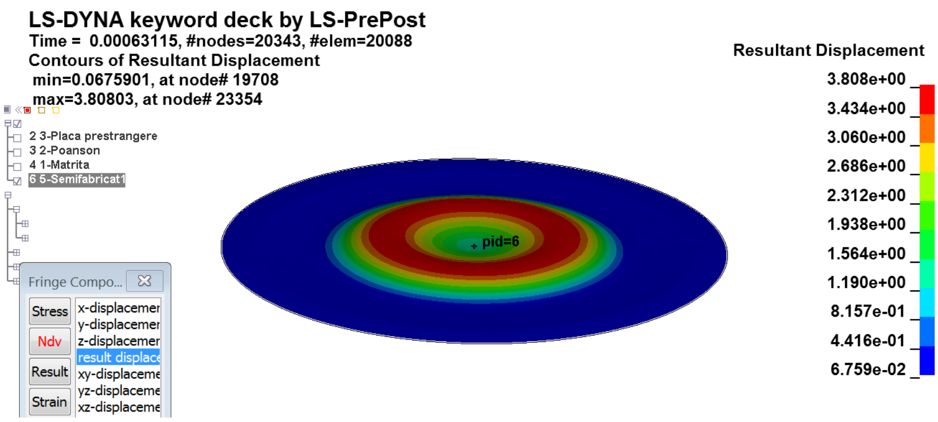

Fig. 19. Resultant displacement after the first step (max. displacement - 3.808 mm)

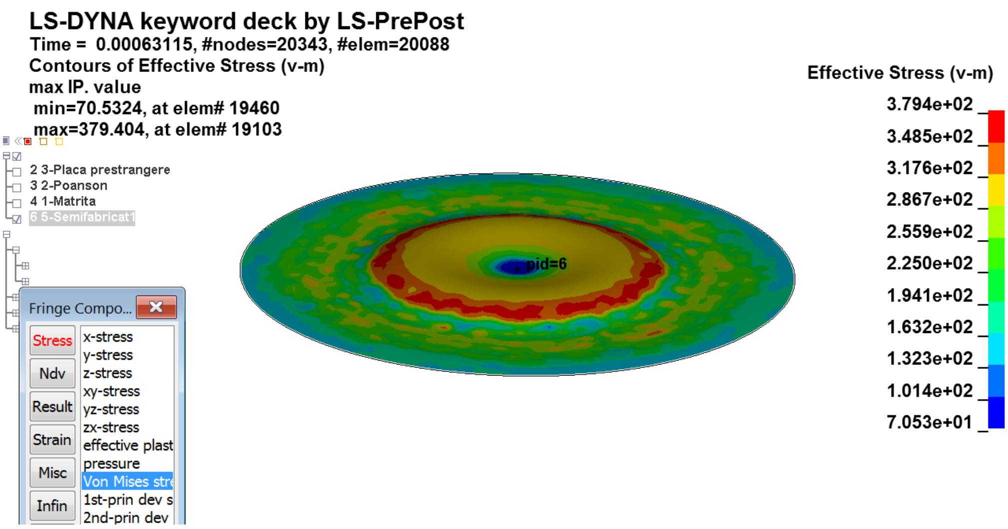

Fig. 20. Effective von Mises stress distribution after the first press step

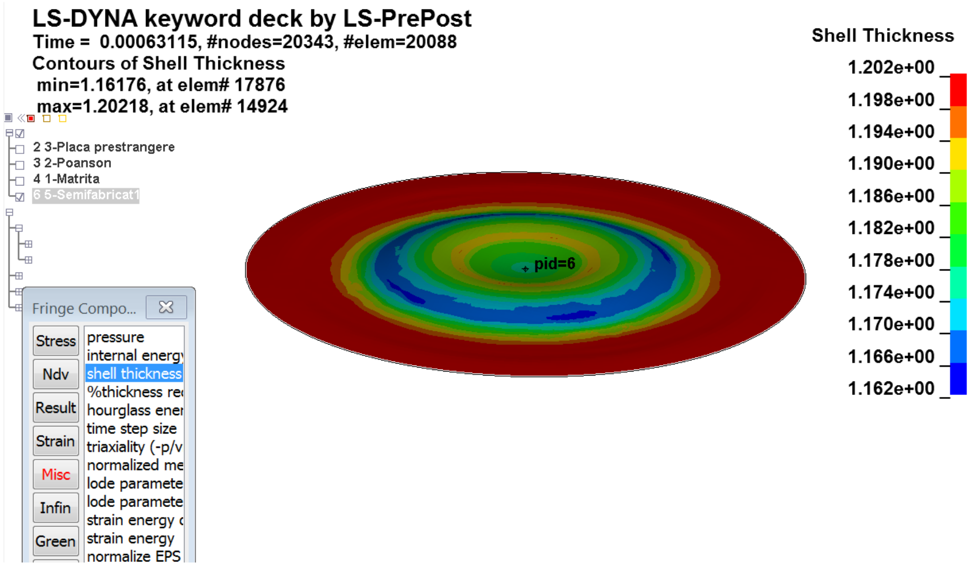

Fig. 21. Shell thickness map after the first step

A small displacement of the die generates a small reduction of the shell thickness, but the material enters the plastic region. After 8th step, a die displacement of 8 mm generates a reduction of the shell thickness of more than 50%. Between steps 15 and 16, generated by a die stroke over 17 mm, the simulation points out a sudden reduction of the shell thickness from 0.753mm to 0.374mm. The same time, the effective equivalent strass increases over 710 MPa, leading to the material breaking! This stage of the simulated process is presented in the figures 22, 23 and 24.

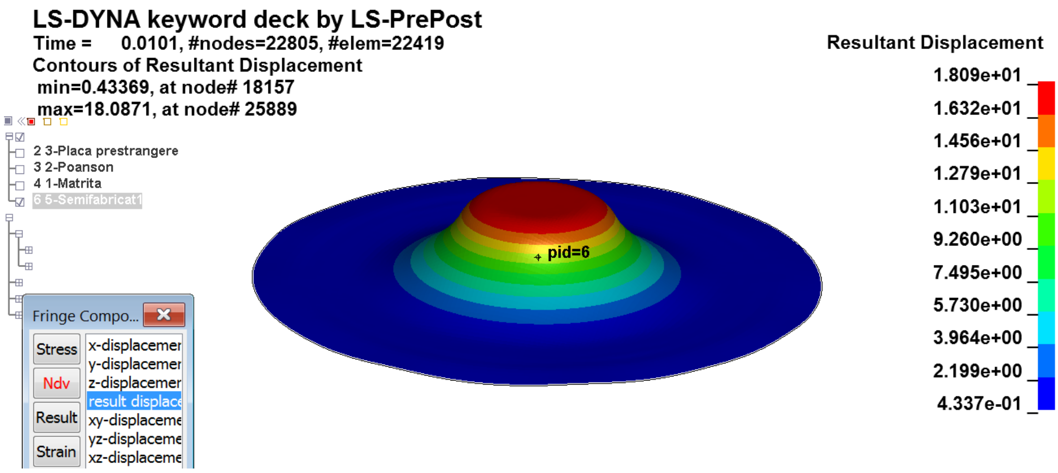

Fig. 22. Resultant displacement of the material after the step no.16

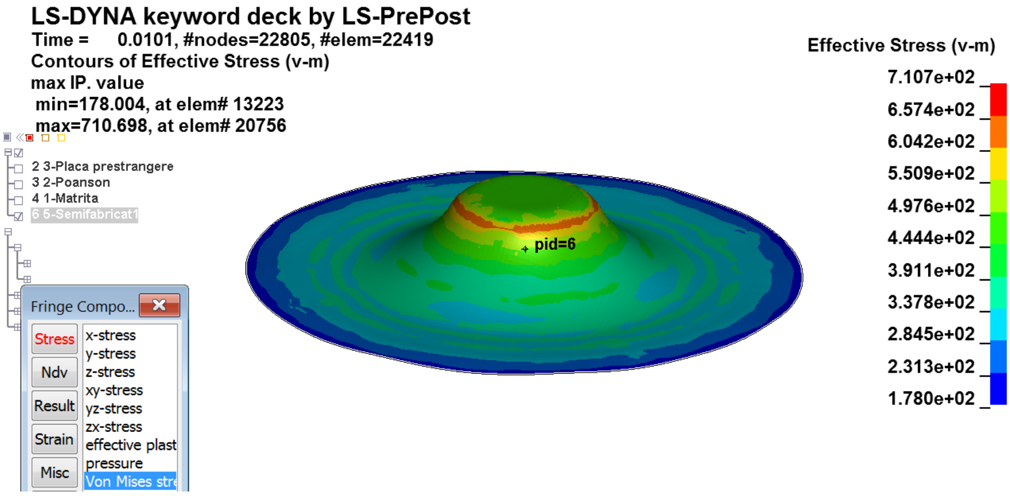

Fig. 23. The effective stress distribution after the step no.16

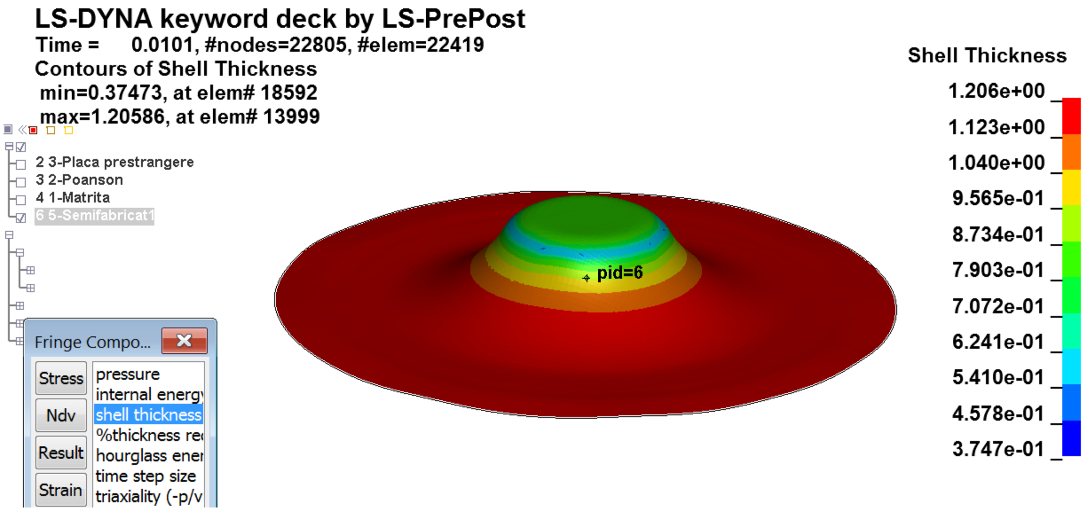

Fig. 24. The map of the shell thickness after the step no.16

An interesting representation of the cracked area, transposed on the unfolded representation of the pressed sheet of metal, shows the important role of the die flat shape (Fig. 25).

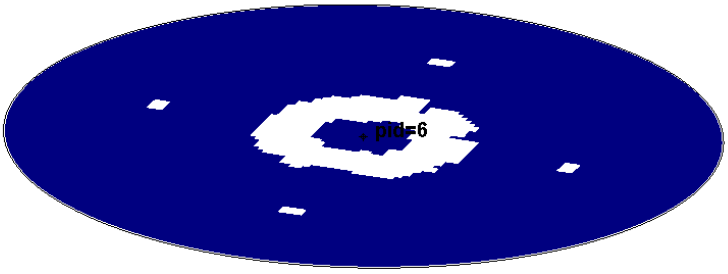

Fig. 25. The positions of the cracks on the unfolded material

The results of the numerical simulations with LS-DYNA software were found in good agreement with experimental results aimed to design a safe technological process. The image from Fig. 26 confirms the accuracy of prediction the failure zone using a language built from the beginning as a tool for predicting the results of the dynamic mechanical events.

Fig. 26. Typical crack position on the real completely pressed component

The forming limit diagram as it is defined in [8], is presented in figure 27, showing that the upper flat surface of the material has a good behavior during the press process.

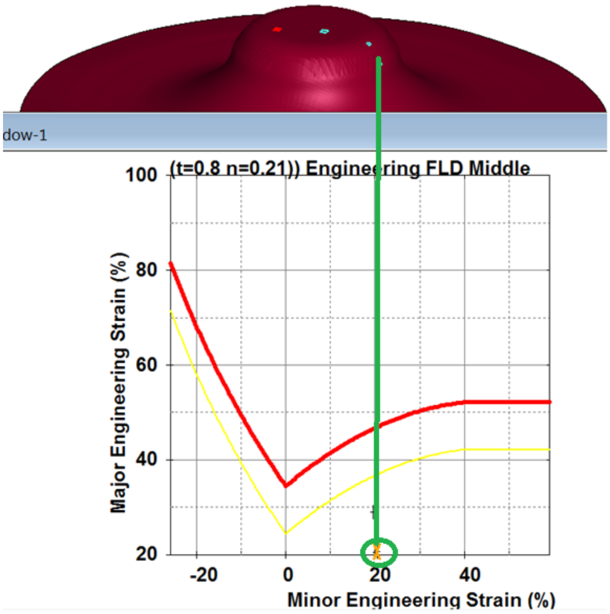

Fig. 27. The forming limit diagram built for the upper flat part of the component

The evolution of the main press process parameters is presented in the following table.

Table 1.

Process parameters evolution

Step number	Maximum Displacements [mm]	Maximum Equivalent Stress [MPa]	Minimum Shell Thickness [mm]
1	3.808	379.4	1.162
2	5.819	377.9	1.162
3	6.585	348.0	1.152
4	6.622	319.2	1.152
5	6.533	341.1	1.152
6	6.640	320.9	1.152
7	7.128	466.3	1.139
8	8.099	575.5	1.094
9	9.345	563.5	1.061
10	10.590	551.1	1.025
11	11.830	551.3	0.991
12	13.080	558.6	0.952
13	14.330	564.0	0.898
14	15.580	621.6	0.836
15	16.830	600.7	0.753
16	18.090	710.7	0.374

5. Conclusions

1. The main conclusion of the above research, demanded by a high technical level company, is the need of including in the design process a complete theoretical approach with modern simulation languages. The prediction accuracy of the errors introduced by a standard design procedure offers a consistent gain of time for launching a new valuable product, especially when the raw material is very expensive, as always happens in the aerospace industry. Consequently, the modern aerospace designers definitely adopted the simulation with FEM as an accurate and time saving tool for optimization of the plastic forming the important components by shaping on digital electrohydraulic press.

2. The research presented in this paper proved that the given part can't be produced with classical technology. The part geometry has a bad influence on the shaping process. The middle region of the surface loose the contact with the matrix at the beginning of the plastic deformation and has to be redesigned.

3. Another possibility is the change of the material properties after 12…16 steps of deformation by reheating, but this process reduces the resistance to breaking. The reheating at 400°C does not avoid the cracks appearing in the same region after a stroke of 20.75 mm of the die.

4. The only successful process found by the authors was the dividing of the press process in two steps, using two different shapes for the matrix.

5. The huge progress of the industrial researchers from the leading companies in the electrohydraulic digital control systems generated new structures of all kind of presses, combining the new hybrid servosystems [9], [10], [11] [12], with the new generation of servopumps [13], [14] and digital servovalves [15], [16]. Both the improving the energy efficiency, and the products quality were obtained by simulating the numerical simulation of the entire press dynamics [17].

6. The natural interest of the aerospace and automotive designers for delivering the die optimisation files to the part manufacturers generated a hybrid community of digital technology designers [18…27].

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