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FEA ANALYSIS OF HOLLOW PART PERFORATION

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Abstract:

1. INTRODUCTION.

Hollow part perforation is used at a very large scale in stamping operations. That is the reason why, improvements in stamping tools design can bring high profits by decreasing the tooling costs. The usual method of perforation of the bottom of hollow parts using stamps with the diameter equal to the part's inner diameter, presents the disadvantage of premature wear of stamp edges due to friction with the part's walls. In [1] there has been presented a method of perforation with a stamp of a smaller diameter than the part interior diameter. According to this method, the bottom of the part is processed previously to have a reverse radius in order to make possible the use of stamp with smaller diameter than the parts inner diameter. The dimensional range in which the process has can be applied was studied in following papers by the same author. In these papers there a computer program written in MATLAB had been developed in order to study the optimal part geometry suitable for minimal energy perforation.
The present paper is a continuation of the previous ones, but now a professional FEA program (CosmosWorks) was used to study the evolution of stress and displacement during the stamping process for a modified stamp design. Parts cut with the newly designed stamp were analyzed in order to find the suitable values of geometrical parameters

2. NONLINEAR ANALYSIS CONSIDERATIONS

Linear stress analysis assumes that the relationship between loads and the induced response is linear. If for example, the magnitude of the load is doubled then the response of the model (displacements, strains, and stresses), will also be doubled. All real structures behave nonlinearly in one way or another at some level of loading. In many cases, linear analysis may be adequate. In many other cases, the linear solution can produce erroneous results. In such cases, nonlinear analysis must be used. Developing a reliable software program that is capable of predicting the behavior of structural systems represents one of the most difficult tasks in the software industry. The finite element method provides convenient tools for performing this task due to its versatility and adaptation to software programming. The success of a finite element analysis depends largely on how faithfully the geometry, material behavior, and loads and boundary conditions are modeled. While elements with their geometric characteristics and boundary conditions are used to simulate the geometric domain of the problem, material models (constitutive relations) are introduced to simulate the material behavior. For nonlinear problems, the stiffness of the structure, the applied loads, and/or boundary conditions can be affected by the induced displacements.

The equilibrium of the structure must be established in the current configuration, which is unknown from start. At each equilibrium state along the equilibrium path, the resulting set of simultaneous equations will be nonlinear. Therefore, a direct solution will not be possible and an iterative method will be required. Several strategies have been devised to perform nonlinear analysis. As opposed to linear problems, it is extremely difficult, if not impossible, to implement one single strategy of general validity for all problems. Very often, the particular problem at hand will force the analyst to try different solutions procedures or to select a certain procedure to succeed in obtaining the correct solution. For example, "Snap-through" buckling problems of frames and shells require deformation-controlled loading strategies such as Displacement and Arc-length based controls rather than Force-controlled loading. For these reasons, it is imperative that a computer program used for nonlinear analyses should possess several alternative algorithms for tackling wide spectrum of nonlinear applications. Such techniques would lead to increased flexibility and the analyst would have the ability to obtain improved reliability and efficiency for the solution of a particular problem. For nonlinear static analysis, the loads are applied in incremental steps through the use of "time" curves. A time curve prescribes how a load or a restraint changes during the solution steps. For nonlinear dynamic analysis and nonlinear static analysis with time-dependent material properties (e.g., creep), "time" represents the real time associated with the loads' application (figure 1).

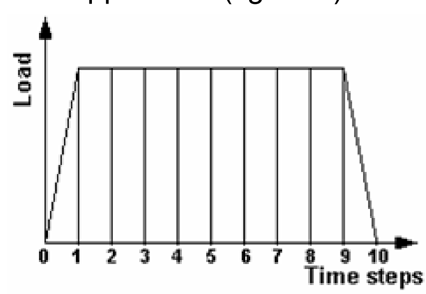


Fig. 1. Time – Load diagram for nonlinear analysis.

The choice of "time" step size depends on several factors such as the level of nonlinearities of the problems and the solution procedure. A computer program should be equipped with an adaptive *automatic stepping* algorithm to facilitate the analysis and to reduce the solution cost.

3. ANALYSIS RESULTS

Previous works of the same authors had studied the possibility to make part perforations in two steps: first bend the bottom of the part in a reverse direction with a spherical shape and then push the bottom with a tool that has no contact with the side walls of the part, until the bottom is ripped away and the perforation is made. Geometric parameters of the part, after the reverse bending is presented in figure 2.

In the previous papers the exact position of bottom crack had been studied, for different values of geometric parameters (R1 and R2), by evaluating the stress induced by axial load on the spherical surface. Stress diagrams had been obtained which are showing clear influence of geometrical parameters on the yielded stress.

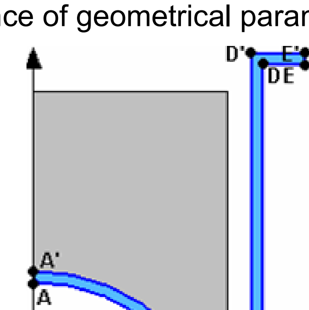


Fig. 2. Geometric parameters of the studied part.

Now the authors had studied another important issue related to the deformation of the part, which is the deformation of the lower section of the part The study was led to find out what are the values of geometrical parameters R1 and R2 (see figure 2) for a minimal deformation of the lower section. as it can be previewed R1 has to be selected in a way that will generate a downward force on the arc described by radius R2. So the two arcs has to be linked in a way to be tangent in points B and B'. That implies that if we increase the radius R2, the radius R1 will decrease with the same quantity. So the study was made for different values of radius R2, R1 changing consequently. To show how the value of R2 is altering the deformation of the part, designed several 3D models of the part with smaller and smaller values for R2. The following 3D stress and deformation diagrams are presenting the results of FEM analysis made under COMOSWORKS nonlinear study. The time curve used is similar to the one presented in figure 1. Figures 3 to 8 are showing the analysis results. Displacements are shoed in axial sections and only displacements in Z direction are presented, which are influencing the increase in part diameter.

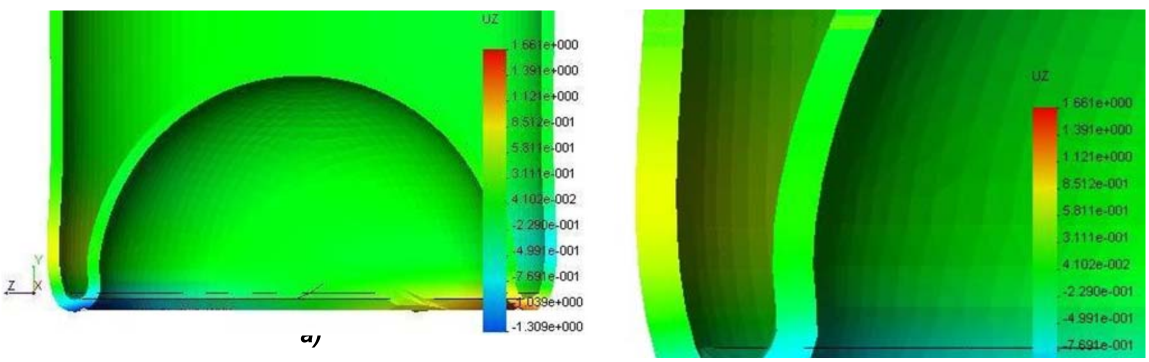
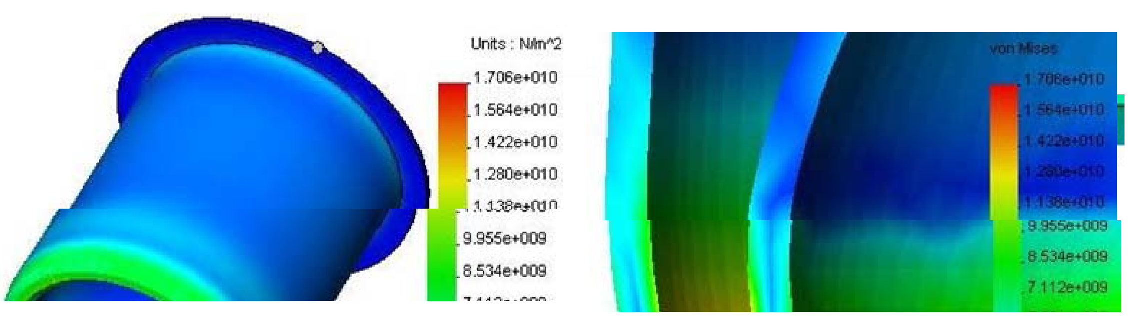
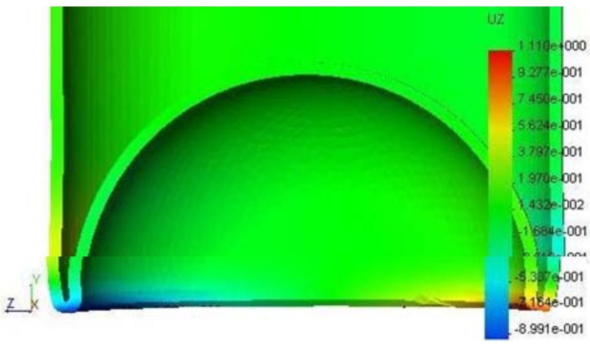


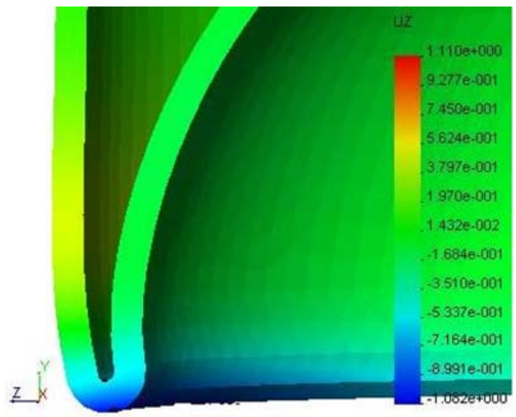
Fig. 3. 3D Diagrams for radius R2 = 2 mm, nonlinear displacement (a) and zoomed area (b).



a) *b)*

Fig. 4. 3D Diagrams for radius R2 = 2 mm, nonlinear stress (a) and zoomed section area (b).





a) *b)*

Fig. 5. 3D Diagrams for radius R2 = 0.5 mm, nonlinear displacement (a) and zoomed area (b).

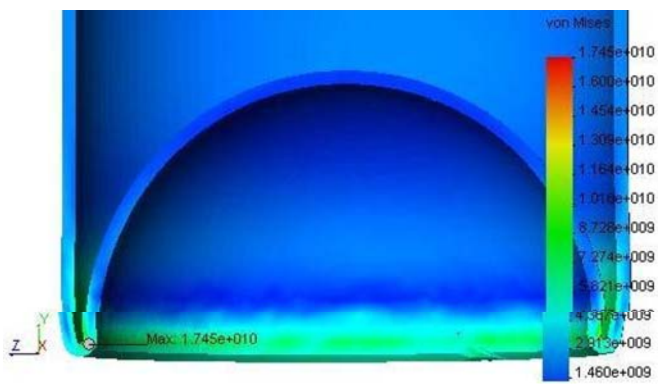
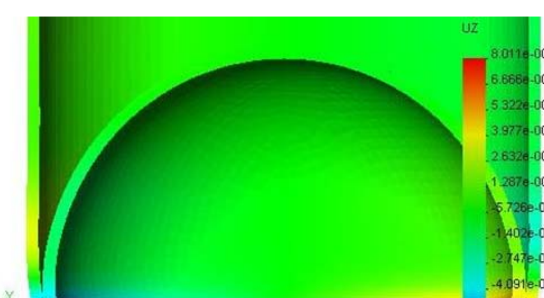
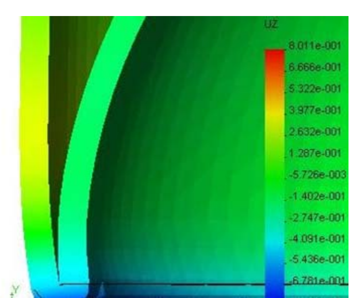


Fig. 6. 3D Diagrams for radius R2 = 0.5 mm, nonlinear stress.





a) b)

3D Diagrams for radius R2 = 0.05 mm, nonlinear displacement (a) and zoomed area (b).

Fig. 8. 3D Diagrams for radius R2 = 0.5 mm, nonlinear stress.

As an important observation on the presented diagrams we can say that the stress concentration during the load of the part is located in the area of the bend with R2 radius arc. This means that the crack of the part bottom will appear in the right place for this kind of perforation technology. This is true for every studied case regardless of the value of R2 parameter (diagrams in figures 4, 6 and 8).

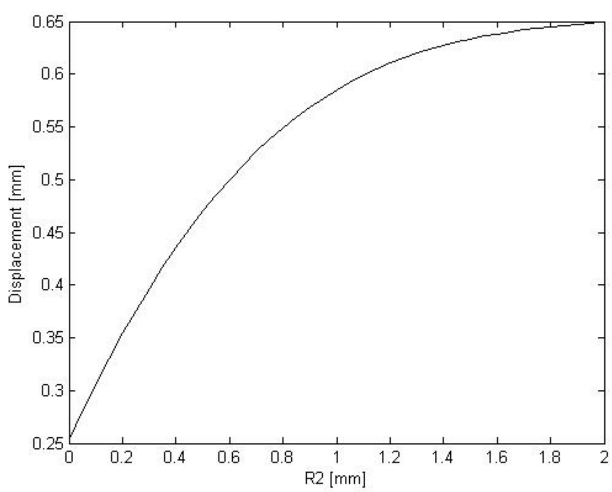


Fig. 9. Displacement as function of R2 radius.

The graph in figure 9 had been by polynomial approximation of the values resulted from 6 different FEM analysis. The best approximation had been obtained by the following function:

$$UZ = 0.0468R_2^3 - 0.2743R_2^2 + 0.5601R_2 + 0.2527 \qquad (1)$$

where UZ is the displacement in Z direction.

4. CONCLUSIONS

Part deformation during perforation can be an important issue regarding the quality of the manufacturing process. As it had been presented in the diagrams yielded by the FEM analysis and also in figure 9, the value of deformation is dependent of the value of radius R2, i.e. the deformation will increase as the radius increases. This result can be used in tooling design, which prepare the operation before the perforation of the part, stating that the value for the radius R2 must be selected as small as possible. If the designer can evaluate the quantity of admitted deformation than this value can be to the value of R2 using relation (1).

5. REFERENCES

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