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COMPARISON OF NUMERICAL MODELS FOR HYDROFORMING OF X-SHAPES

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Abstract

Numerical modeling has proved to be a powerful tool for development of hydroforming processes. There have been used various numerical models but it has been difficult to choose a model which would be good enough for a specific application. Both 3D-shell and 3D-solid models for numerical modeling of hydroforming of copper X-shapes are presented in this paper. The results of calculations have been compared with the results of experiments. Numerical models have provided quite high accuracy in getting the X-shape geometry for various process parameters. However, only 3D-solid model has been useful to analyze thickness distribution in X-shapes. What more, 3D-solid model has shown better results on load history.

Key words: hydroforming, X-shape, numerical modeling

1. INTRODUCTION

Hydroforming is regarded as one of the most advanced and complicated processes of metal forming. The common way of hydroforming is to deform sheet metal or tube by means of fluid pressure. By this way some products of very complicated shapes could be obtained. The hydroforming is very useful for producing whole components that would otherwise be made from multiple stampings joined together. For example, such shapes are difficult or impossible to produce by another processes like welding or casting. Hydroforming processes are usually associated with very high strains which lead to failures commonly observed in sheet metal forming, e.g. fracture or wrinkling. These failures are difficult to avoid by designing the process in a traditional way and finding the process parameters by trial and error method. Recently numerical modeling has proved to be a powerful tool for development of hydroforming processes.

Hydroforming is considered as a kind of sheet metal forming process. Majority of numerical models for sheet metal forming are based on 2D geometry and shell elements in order to simplify the calculations. As for hydroforming, applications of mainly two models, with shell (Hama et al., 2006, Jirathearanat et al., 2004, Kim et al., 2004, Plancak et al., 2005, Ray & Mac Donald, 2004) and solid elements (Aydemir et al., 2005, Mac Donald & Hashimi, 2000& 2001, Zadeh & Mashadi, 2006) have been reported in most of the recent papers. It is rather difficult to say which model would be good enough for a specific application. Hence, a comparison of calculated results obtained by means of different numerical models could be very helpful in finding some indications for using those models. In this paper, there are presented both 3D-shell and 3D-solid models for numerical modeling of hydroforming of copper X-shapes. The results of calculations are compared with the results of experiments.

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2. X-SHAPE HYDROFORMING

The X-shape hydroforming has been chosen because of many difficulties in finding proper process parameters by a common designing way. The X-shape hydroforming is conducted to bulge a cylindrical tube with internal pressure p and axial load using the displacement s of the compressing punches, figure 1. Proper process parameters, i.e. internal pressure and axial feeding, allow to obtain X-shape without failures. If internal pressure is too high, the bursting will occur. On the other hand, if the axial feeding force is too high then the wrinkling of the tube will occur.

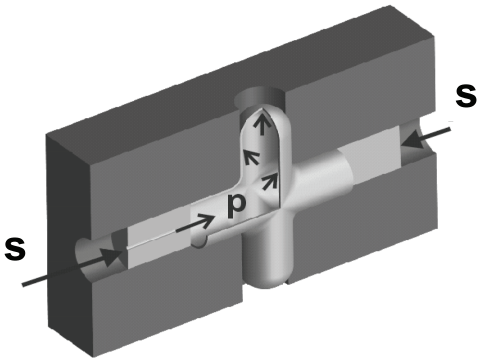

Fig. 1. Schematic presentation of X-shape hydroforming

Experimental tests on hydroforming of X-shapes have been performed. Tubular copper blanks with the initial outer diameter 22 mm and the wall thickness 1 mm were used to make X-shapes. A straight tube blank of 120 mm in the length was placed and restrained in the die that determined the final shape of the component. The tube was sealed at the ends by the axial punches. As the velocities of the left and right axial punches were kept constant during deformation process, then the axial feeding force was a result of deformation resistance of a tube blank. On the other hand, the internal pressure was changing according to specified internal pressure versus punch displacements curve, figure 2.

3. NUMERICAL MODELLING

The computer simulations of hydroforming of X-shapes were made using MSC.MARC software. The geometrical models and process parameters corresponded with experimental ones. There were created two numerical models. 3D thin-shell four-node elements describing hydroformed tube were used in the first model. These elements have usually been used in curve shell analysis and they have not been very sensitive to distortion. The second model was built with 3D-solid eight-node arbitrarily distorted brick elements. These elements have been very useful for analysis of structure in the fully plastic range. Model of tube material was determined experimentally in the form of stress strain curve $\sigma=428\varepsilon^{0.06}$. An elastic Coulomb friction law defined the contact between tube and tools and the coefficient of friction was 0.1. The results of numerical modelling were verified by comparing with the results of experimentally obtained X-shapes.

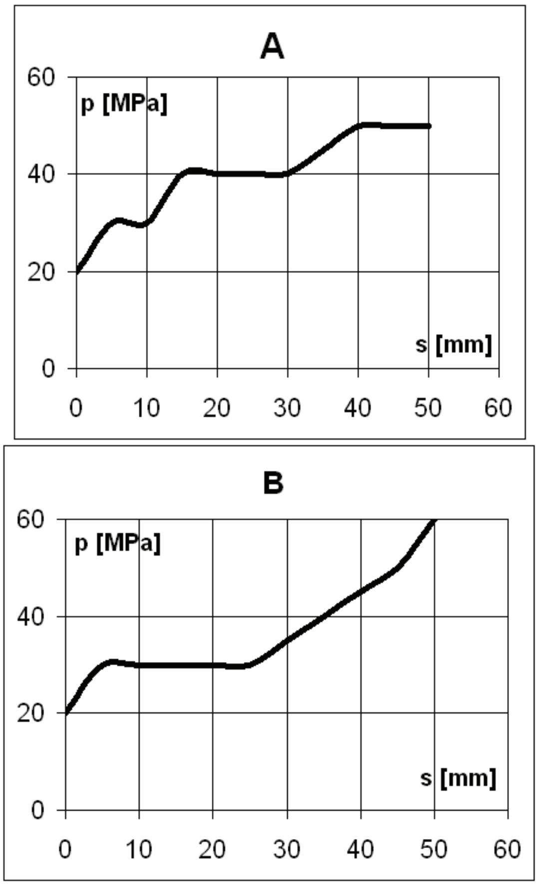

***Fig. 2.** Examples of internal pressure versus punch displacement curves used for the analysis; specimens A and B.*

First, the overall geometry of calculated X-shapes was compared. As an example, a comparison of branch heights H obtained from calculations for 3D shell model and 3D solid model is presented in figure 3. The heights were very close to the experimental results and the difference was about 7-8% for 3D solid model and only up to 3% for 3D shell model.

Next, wall thickness distributions in X-shapes obtained by means of 3D shell and 3D solid models were compared in longitudinal and transverse cross sections. Thickness changes have been quite well projected by these two models. However, the differences between calculated and experimental results have been two times bigger for 3D shell model than for 3D solid model, both in longitudinal (figure 4,6) and transverse (figure 5,7) cross sections. These differences have been the same for two different load paths (figure 2).

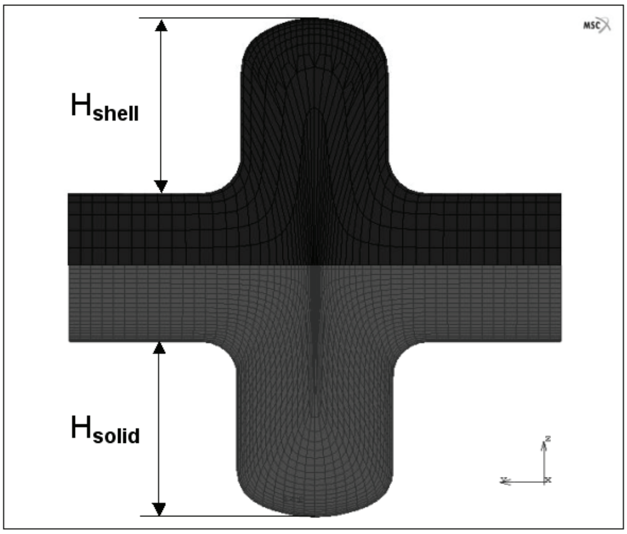

Fig. 3. *Comparison of two branch heights H_{shell} and H_{solid} obtained from calculations; upper branch – 3D shell model, lower branch– 3D solid model.*

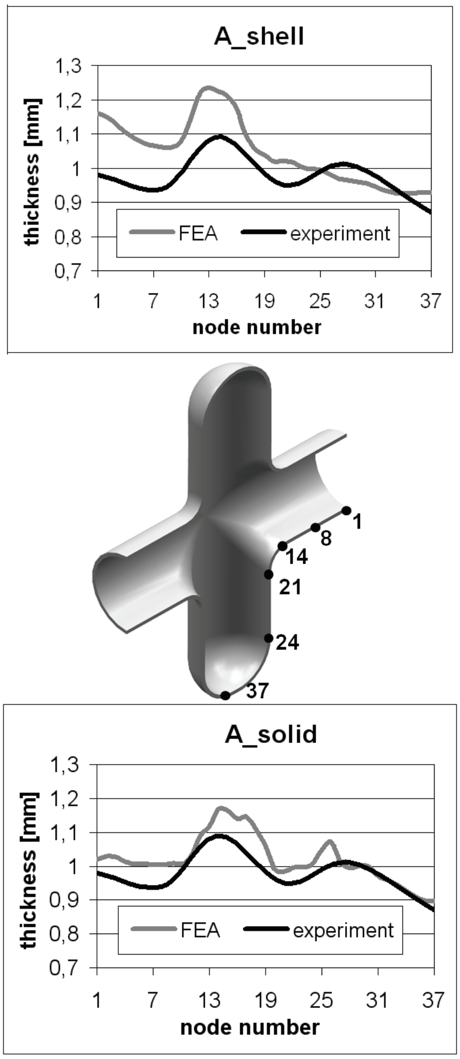

Fig. 4. *Wall thickness distribution in X-shape obtained by means of 3D shell and 3D solid models; A-internal pressure curve from figure 2.*

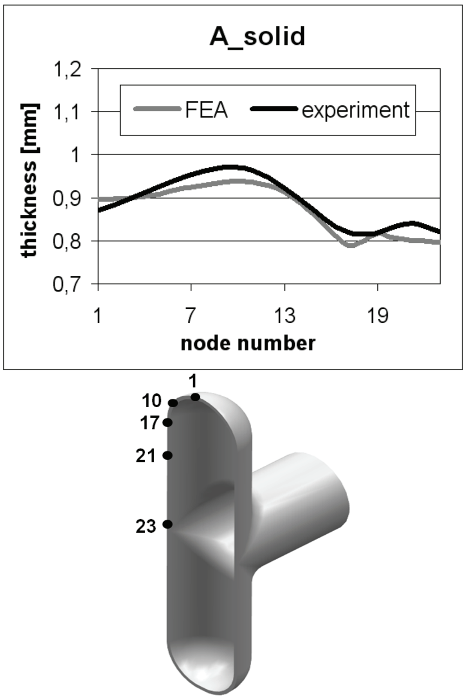

Fig. 5. *Wall thickness distribution in X-shape obtained by means of 3D solid models; A-internal pressure curve from figure 2.*

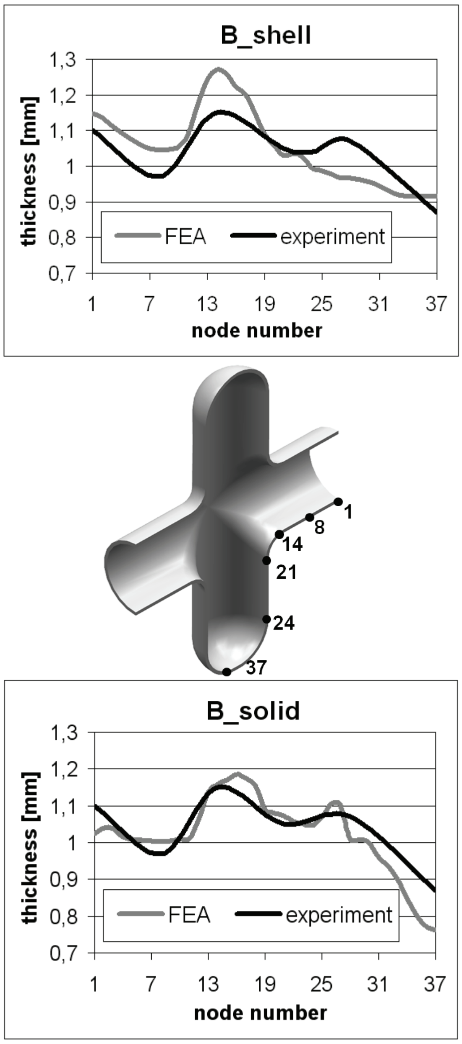

Fig. 6. *Wall thickness distribution in X-shape obtained by means of 3D shell and 3D solid models; B-internal pressure curve from figure 2.*

Finally, the punch load history for experimental and calculated results has been compared, figure 8. Calculated punch force values have been considerably smaller than the experimental ones, especially for A load path. The shape of punch load curve has been much better projected by 3D solid model results.

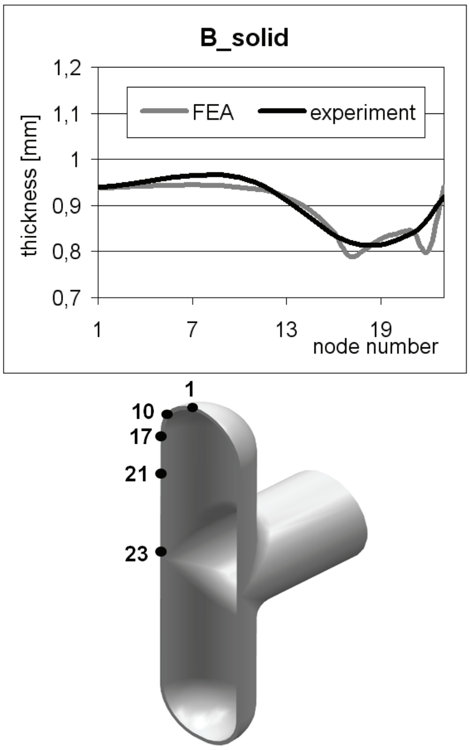

Fig. 7. Wall thickness distribution in X-shape obtained by means of 3D solid models; B-internal pressure curve from figure 2.

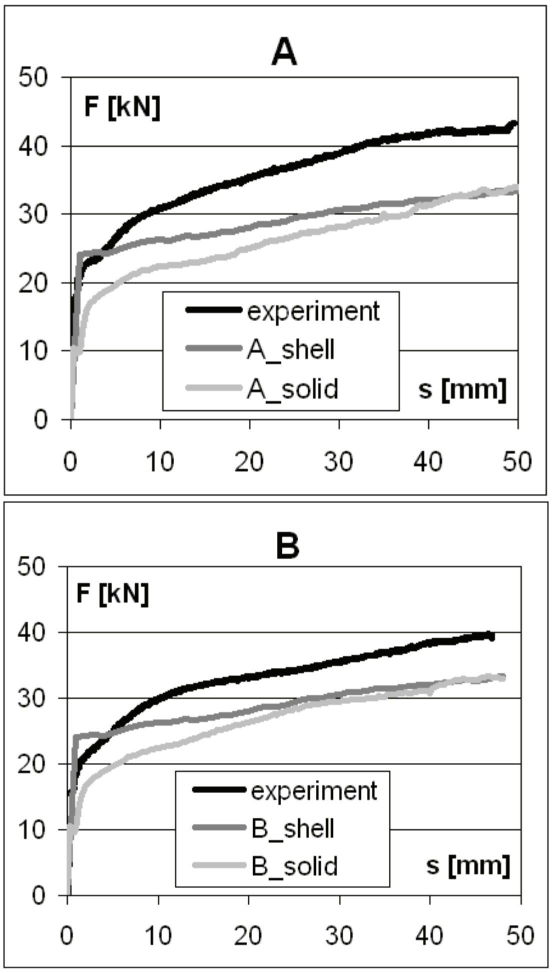

Fig. 8. Comparison of punch load history for experimental and calculated results.

4. CONCLUSIONS

1) Both 3D-shell and 3D-solid models for numerical modeling of hydroforming of copper X-shapes are compared in the paper. These models have provided quite high accuracy in getting the X-shape geometry for various process parameters.
2) 3D-solid model has been better for analysis of thickness distribution in X-shapes.
3) Load history has been better projected by 3D-solid model.

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PORÓWNANIE MODELI NUMERYCZNYCH STOSOWANYCH W MODELOWANIU HYDROMECHANICZNEGO KSZTAŁTOWANIU CZWÓRNIKÓW

Streszczenie

Modelowanie kompurowe jest bardzo pomocne w rozwoju procesów kształtowania hydromechanicznego. Dotychczas stosowano różnorodne modele numeryczne, ale wobec braku porównań trudno było ocenić ich przydatność do modelowania poszczególnych procesów. W referacie przedstawiono wykorzystanie modeli 3D-shell oraz 3D-solid do modelowania hydromechanicznego kształtowania czwórników z miedzi. Wyniki obliczeń porównano z wynikami doświadczeń. Uzyskano bardzo dużą dokładność obliczeń dla obydwu modeli przy wyznaczaniu kształtu czwórników dla różnych parametrów procesu. Jednakże to model 3D-solid okazał się znacznie lepszy i dokładniejszy przy analizie rozkładu grubości ścianek czwórników i historii obciążenia.

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