Virtual Die Tryout of Miniature Stamping Parts

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ABSTRACT

The authors would like to present the whole procedure of using dynamic explicit finite element method to aid multi-stage miniature stamping die design. How to cost down and time saving are the key issues for tool maker in Taiwan. It has been applied to many automobile components and metalwork successfully by computer aided design and engineering analysis. In this paper, we dedicated our application of these technologies to small scale stamping parts. The trick of mass scaling for speed up the computation of LS-DYNA and control its effect in dynamic behavior for miniature blank sheet will be described in this paper. Die designers can operate die try out many times during one day on their desk top personal computer for their different processes changed. A mini scale ball bearing retainer stamping part was demonstrated. The history of metal flow and its thickness variation for pre-form stage and finished-form stage in real test were matched with the simulation results. It has been approved that the accuracy of numerical result is good for miniature sheet metal part. By this way, we have saved many try and error tests for die modify and try out in reality.

INTRODUCTION

Downscaling is the trend for many commercial products and their peripheral instruments. More and more challenges come from how to have high precision, yield rate and speed up the development of miniature products. Today, die designers have to try any methodology to compress their delivery and cost. Computer aided engineering accompanied with the computer development for a long time and there are so many successful applications in the world. It seems to be a part of standard procedure for designers to verify their concepts and to realize it.
In this paper we have an example for stamping die design about tiny retainer (or cage) of ball bearing. In which we describe the application of dynamic explicit finite element method for tiny and high speed sheet metal with two stages stamping process. For miniature blank sheet the gravity force is not important which can be neglected and will not influence the finial result apparently. Another benefit for our study is dynamic explicit solver is especially good for high speed stamping that we can have a large scale of material density to speed up our computation and we will have good numerical result.

Problem Description

For the reason of automatic assembly for small ball bearing, the retainer has been modified with fingers as shown in Figure 1 to clamp together which replaced the rivets applied in the large size bearings as shown in Figure 2. For avoid cracking happened after bending clamped process, the thickness variation control is very important in metal forming process. The dimension requirement is shown in Figure 3. We will use high speed (250 SPM) transfer press for this stamping process which with blanking, pre-form, finished form and bending stages on our die layout. Blank material is SPCC and its thickness is 0.35mm.
We have to make the decision of how many stages to finish the product and make sure they can work. Because the part is tiny, so the positional problem is very important in the forming process. It would be better in high speed transfer stamping process, if we have fewer stages. In this paper, we tried to finish the forming with pre-form (i.e. material pull inward) and finished form stages (i.e. ball cages drawing and fingers bending at the same time).

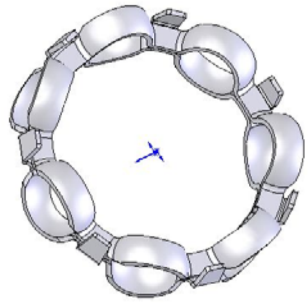

Figure 1 Small ball bearing with fingers for retainers clamped.

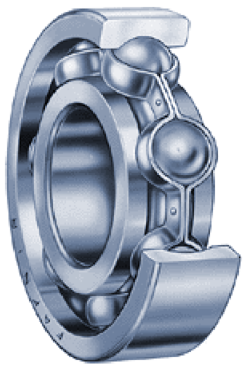

Figure 2 Large ball bearing with rivets for retainers clamped.

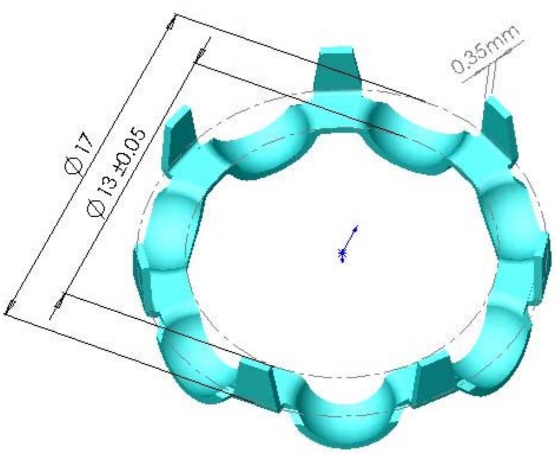

Figure 3 Dimension for miniature retainer with fingers.

Die design and Simulation

We use 3D parametric solid CAD system to perform the top-down design for our transfer and die systems. After the pre-form die CAD model finished as shown in Figure 4 via the solid interface Parasolid (*.x_t) exported the assembly data to finite element mesh generator software (MSC/PATRAN) to create the mesh as shown in Figure 5. For time saving of CPU, the half model was made. It has been created as the same way for finished stage CAD model as shown in Figure 5 and mesh model as shown in Figure 6. After the boundary condition defined, use the interface program PTN2DYN by MIRDC as the translator between PATRAN neutral file and LS-DYNA keyword input file. By the whole procedure as the above mentioned, the designer will finish the input file for the next round for geometric changed in one hour. The next step is how to save the CPU time as LS-DYNA running. As usual, mass scaling, velocity scaling and sub-cycling are frequently applied in sheet metal forming simulation. The velocity scaling is very straight forwardly to increase the punch speed to reduce the cycle time, but this way will directly influent the material strain rate. If the velocity increases dramatically, it will have a fatal thinning phenomenon and does not correct with real die tryout in drawing problem. The mass scaling is to increase the material density in order to increase the time step for saving the total CPU time [1]. From the stability criterion in dynamic explicit finite element method, the time step is followed the equation (1).

$$\Delta t \propto \sqrt{\frac{\rho}{E}} \qquad (1)$$

In the above equation, where ρ is the density and E is the Young's modulus of blank sheet. Apparently, time step is depended on the square root of density. Although this reduction of CPU time will induce the error in high frequency effects, but this error is not important for sheet metal forming problems [2]. We have tried to scale the sheet metal density to 100 times, the numerical result of thickness was matched with real tryout and it only took us one-tenth of CPU time for normal execution.

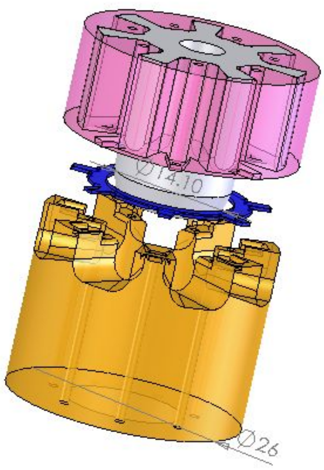

Figure 4 The pre-form stage Punch, Holder and Die CAD model.

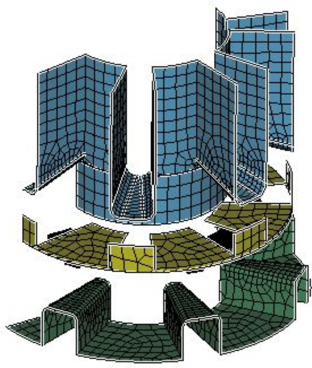

Figure 5 The pre-form stage Punch, Holder and Die mesh model.

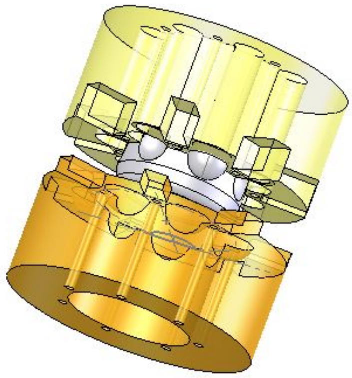

Figure 6 The finished-form stage Punch, Holder and Die CAD model.

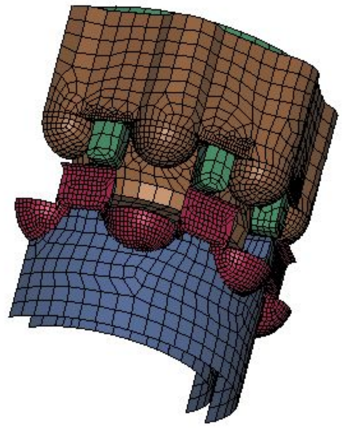

Figure 7 The finished-form stage Punch, Holder and Die mesh model.

Through the computation of LS-DYNA with mass scaling of 100 times density of blank sheet, the rapid result was achieved in one hour on desktop personal computer with INTEL Pentium 4 2.0GHz CPU. Figure 8 is the thickness distribution of pre-form, from this result we can make sure the punch with angle of 15 degree at the bottom to pull material inward in pre-form stage is reasonable. The uniform thickness distribution of pre-form will make the finished form stage with perfect plastic strain as shown in Figure 9 to avoid material spring back as die opening.

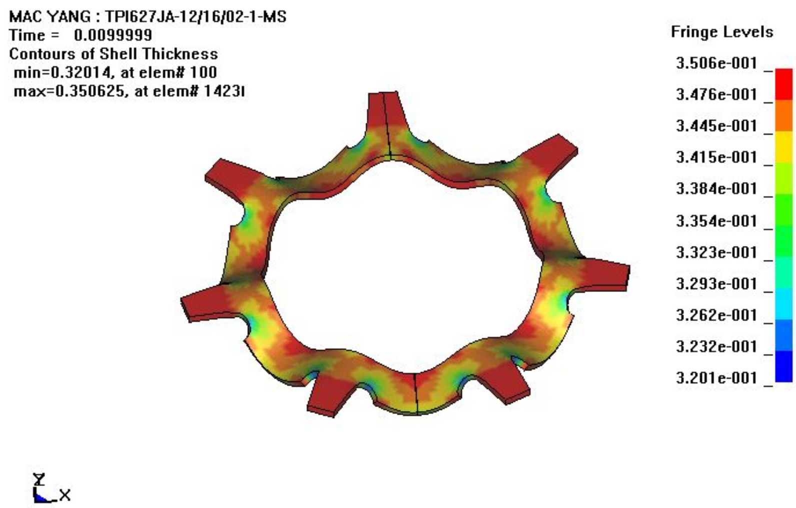

Figure 8 The uniform thickness distribution of pre form stage.

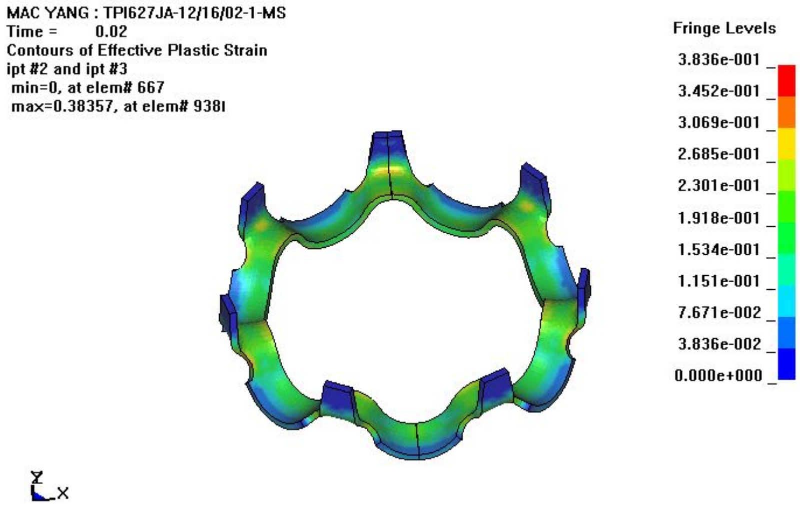

Figure 9 The plastic strain distribution of finished form stage.

The thickness distribution of finished form is shown in Figure 10, which with thinner area at the circular stress relief between each finger and ball cage. The numerical result was good to compare with the real stamping part as shown in Figure 11.

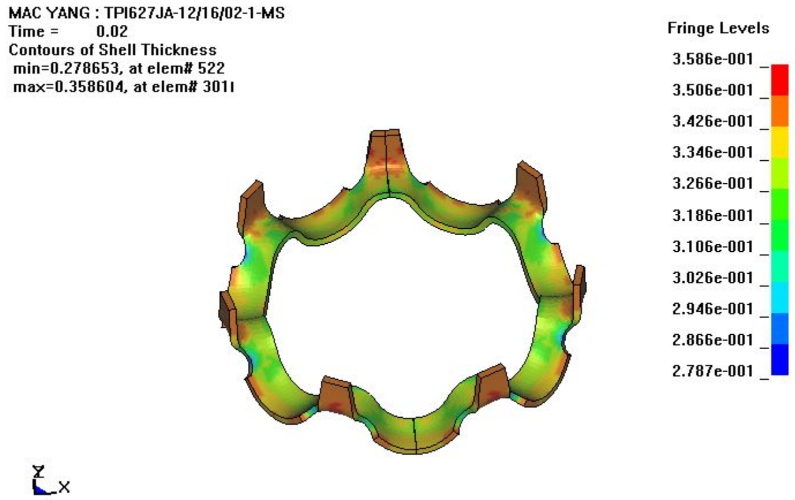

Figure 10 The thickness distribution of finished form.

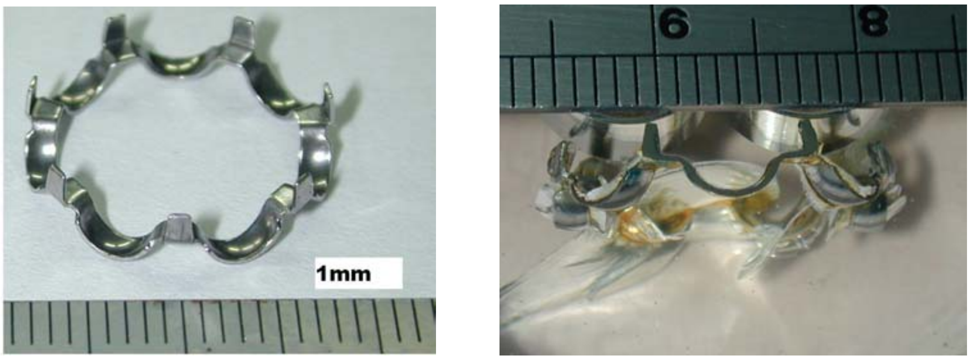

Figure 11 The finial stamping part and its cross section at the cage.

Conclusions

The delivery time is highly compressed today. For this reason, the tooling or die makers have no much time to mock up their molds or tryout their design. Integration of computer aided design, engineering and manufacture makes the new development products could be faster than before. Especially, the designer can get the verification by personal computer for his or her idea in one day. But, there are some knowledge of computational solid mechanics and tooling experiences the users must with. Otherwise, the designer could get lost in these error data.

We believe that die designer can execute at least two rounds for his or her design changed on day shift with speed up computation for any parameters setup. Do not forget to tune back what you scaled before you launch a normal run as you come off duty. Tomorrow morning you will have the full results.

References

1. HALLQUIST, J.O. (1998) "LS-DYNA Theoretical Manual", Livermore Software Technology Corp., Livermore.

2. BELYTSCHKO, T. (2000) "Nonlinear Finite Element for Continua and Structures”, John Wiley &Sons, Ltd.