The Dynamic Problems in High Speed Transfer Stamping System

Ming-Chang Yang, Hsing-Chih Tsai and Tien-Chi Tsai

Metal Industries Research and Development Centre
1001 Kaonan highway, Kaohsiung 811, Taiwan

Abstract

In this paper the authors would like to disclose the application of LS-DYNA, the dynamic explicit finite element method, in high speed transfer stamping system development. Transfer stamping process has the advantages of material saving and automation especially for stamping parts with complicated geometry. The dynamic effects will be induced as the stamping speed up to 200 SPM i.e. the contact dynamics of barrel cam and followers, transient dynamic effect as grippers contact with blanks and the die swell caused dimension inaccuracy problems, etc. According to the numerical results, we have modified the original design for barrel cam structure and dimension, roller size and transfer bar diameter to enhance the component endurance life. We used the NURBS curves in the cam curves design, which reduced the impact force as the rollers crossed over the contact sides at each groove and traveled smoothly. The gripper designer referred the simulation results to avoid the parts tilting after the grippers closed. All the dynamic problems of transfer system were under controlled via the computer simulation and we have designed our system stamping speed up to 250 SPM successfully.

Introduction

There are two categories of automatic stamping systems applied in industries, progressive tools and transfer tools. The progressive system uses bridges in the blank strip to hold and carry the stamping parts as the feeder machine pushing forward the blank strip, as shown in figure 1. Its stamping speed can be up to hundreds SPM., especially in thin and simple piecing or blanking parts, the stamping speed usually up to 500 SPM. Although it has the high speed capability, but there are many restrictions for complicated geometry and deep drawing parts, another drawback is material waste. For these reasons, transfer stamping system usually dedicated in deep drawing problems and material saving. It uses gripers as shown in figure 2, which located at the transfer bars to carry the stamping part to the next stage, so that dynamic problems are more important than progressive die.
In this paper, we disclosed the simulation results of transfer stamping system for ball bearing retainer, which with a barrel cam to control the timing. As we know that the cam mechanism can not have high positioning characteristics except the shock and vibration problems are under controlled for high speed motion. The barrel cam controlled the rise, fall and dwell time for every ram stroke cycle. The NURBS (Non-Uniform Rational B-Spline) curve was applied in the cam grooves [1], which controlled the acceleration and deceleration smoothly. We applied LS-DYNA to compute the crossover shock force as cam follower traveling through the cam groove. The results help us to make sure that the dimension of cam followers and the other components size can endure the impact force or not. We also used LS-DYNA to simulate the dynamic behavior as grippers clamping the stamping part. These results tell us the end face geometry will affect the stability of gripper in picking and placing.

Figure 1. Blank layout of progressive die.

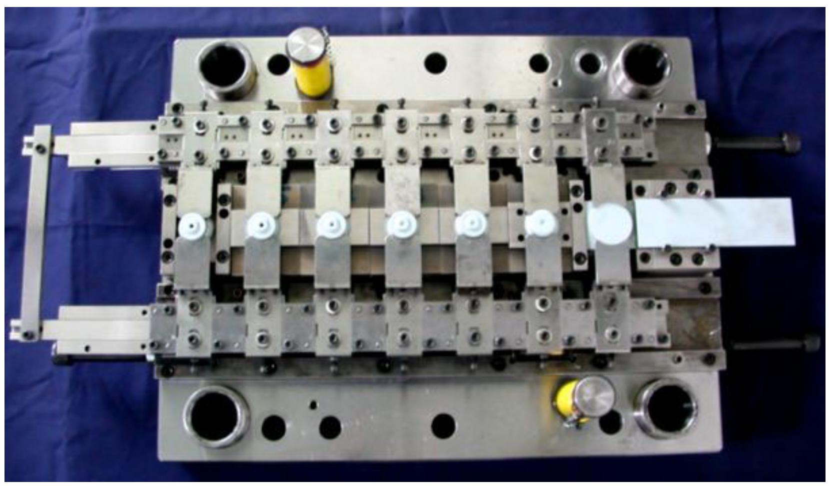

Figure 2. Transfer die.

Problem Description

Transfer toolmakers always wish the stamping die operated in harmony and in precision with transfer system every day and night. Any alarm or unexpected stop is undesirable. The first topic of how to design a reliable and robust transfer system is to understand the source of impact force. We can say that the high speed stamping system is some kind of impact machine. Shock and vibration problems are always at there and never disappear as it is stamping. Although impact force does not make the components broken immediately, but there are some damages in them and which dominate the fatigue life of components. Figure 3 showed that the needle bearing worn out of stud-type roller after million cycles. From this photo we can realize that the failure is happened step by step, i.e. over shock force, galling, and wearing [2]. It is difficult to measure the shock force happened at those key components. The CAE is the easy way to estimate the value of impact force and help us to choose correct size for key components to withstand the loading. The key components for our system are the

barrel cam and its stud-type followers. We have to make sure that those cam followers can endure the loading over millions cycles for 24 hours on line running per day.
The transfer system has to pick and place the stamping parts precisely. If it had something wrong, the crash could be happened or the stamping part can not full fill the specification. That is why we need to pay more attention to the dynamics problem of gripper as it contact with stamping parts.

Figure 3. Worn out of needle bearing in stud-type roller

Methodology

The NURBS based controllers are widely used in high speed CNC machining center for which has the excellent performance in acceleration and deceleration for cutter location, as shown in figure 4. For this reason, we used the NURBS curve as our cam curve to satisfy the critical positioning requirement in high speed transfer system. The first thing for us have to do is to design the timing diagram for transfer and pick-place with respect to the ram stroke. After that, we used NURBES curve to fit every cam curve and continued the adjacent curves. By adjusted the control point's order and number to minimize the curvature, the acceleration and deceleration of each cam curve can be sufficiently smooth as shown in figure 5. The curvature of cam curve is sensitive for contact force between the cam and its follower which will affect the fatigue life of cam followers apparently.
The 3D solid CAD model of cam grooves were generated by projected the 2D cam curves in the normal direction to cut out the groove area in the cam cylinder. The whole cam box was as shown in figure 6. The mechanical properties of barrel cam, for example, mass and moment of inertia are essential for contact impact forces. For the purpose for saving CPU time, we assumed the cam was rigid and the others were deformable bodies. Because the impact source is coming from the kinetic energy of cam, as shown in figure 7, we have to scale up the mass density of cam mesh in LS-DYNA to make it consisted with the CAD solid model. The mesh model was shown in figure 8.
LS-DYNA, the explicit dynamic finite element software [3], which with high performance in multi-body contact analysis, we prescribed the rotational speed up to 250 RPM and computed the impact forces, stress and deformation. The oscillation or trembling effects were also concerned in our design.

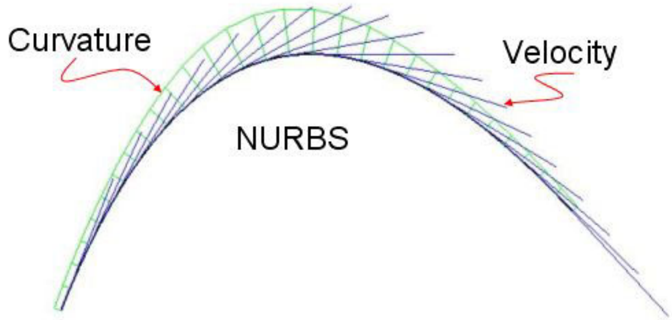

Figure 4. The NURBS curve

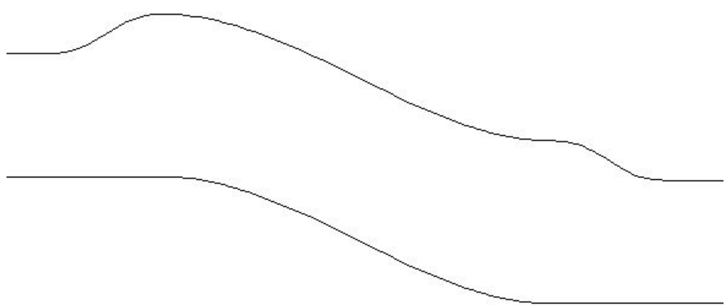

Figure 5. The NURBS based cam curves

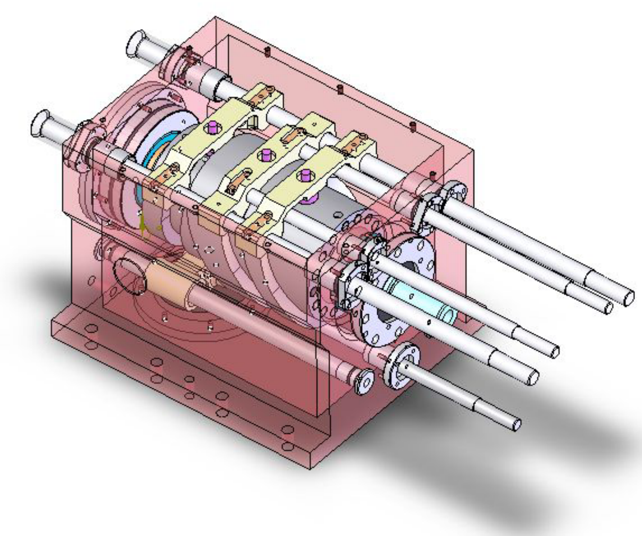

Figure 6. Cam box structure

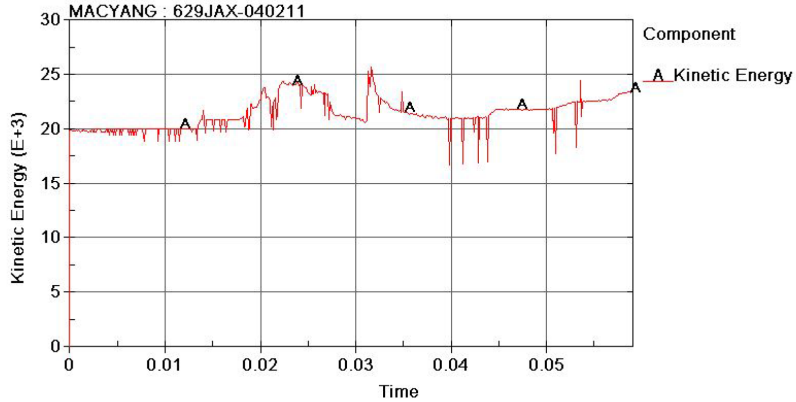

Figure 7. The kinetic energy of cam rotation at 250 RPM

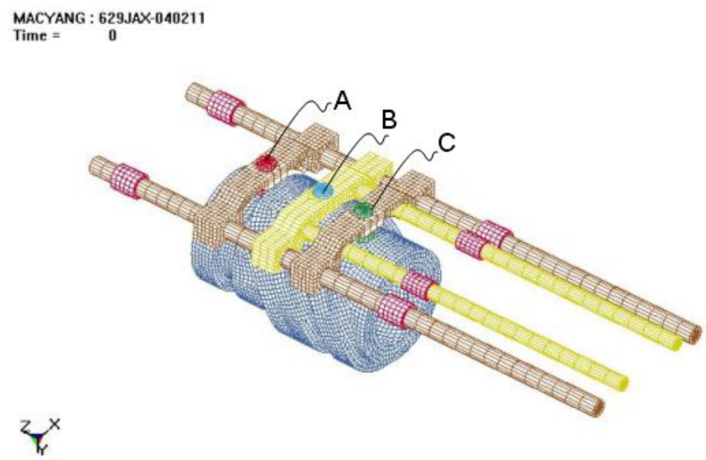

Figure 8. Mesh model of cam system

Results of Cam Dynamics

The resultant forces of these 3 stud-type rollers were showed at figure 9, the actual value could be smaller than this figure showed for the finite element caused the discontinuous contact surfaces and we assumed the rigid cam without damping, etc. From the THK catalog [4] showed that type CF 10-1-A can endure the dynamic force 5330N and we assured the roller was safe. We manufactured a cam system based on the simulation data and found the endurance test was better than before. According to the figure 10, we found that position accuracy was depended on the clearance between roller and cam groove for it could induce additional vibration as the roller approaching the change over point. The trembling will affect the gripper to pick up the part precisely or not. According to the result, the clearance value and the diameter of transfer bars were defined to increase the system accuracy. We used 0.04mm as the clearance for positioning accuracy and manufacturing concern.

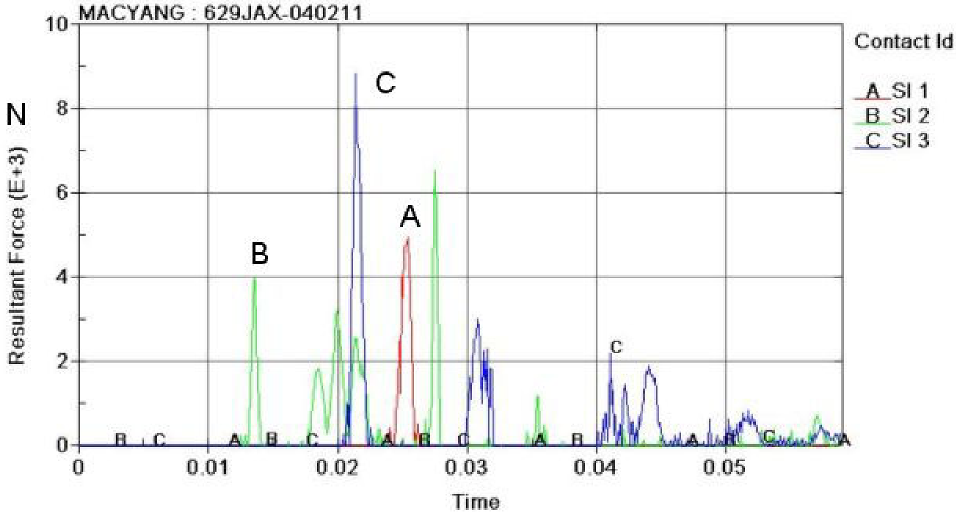

Figure 9. Force for stud rollers

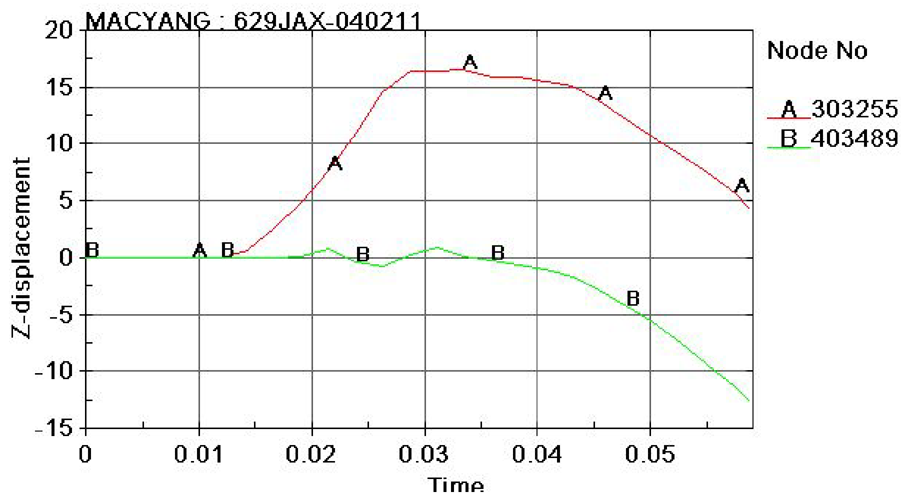

Figure 10. The displacement of rollers in longitudinal direction

The roller B in figure 8 was the most crucial component as it traveled through the area of cam groove for opening the gripper as shown in figure 11. The stress history was shown in figure 12, which showed that the roller B was safe for this condition.

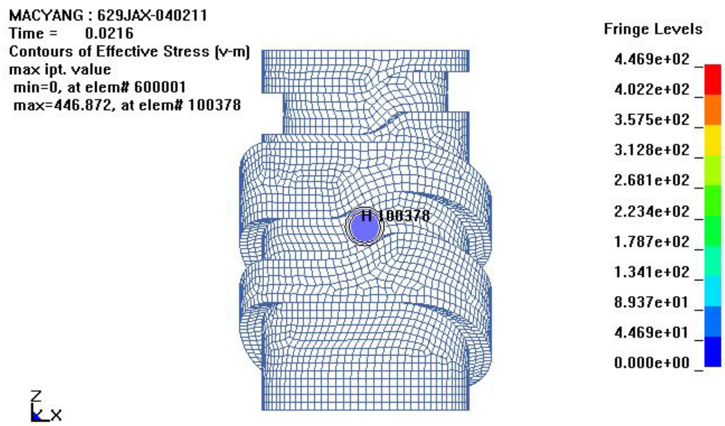

Figure 11. The stress (MPa) of roller B as gripper opening

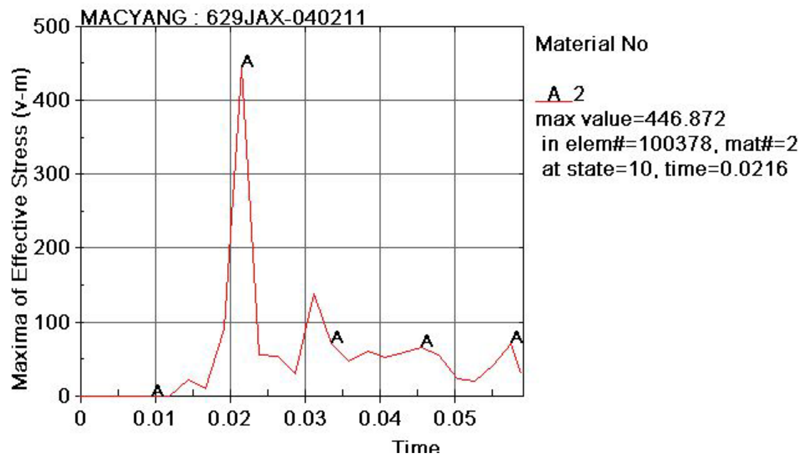

Figure 12. Time history of roller B (Mpa)

Results of Gripper Dynamics

The gripper located at the transfer bar as shown in figure 2. We compared two different gripper end faces to realize the clamping behavior as gripers contact with stamping part. In case 1, the flat end face was shown in figure 13. The simulation results, please see the figure 14 and figure 15, which showed that the tilt happened as grippers clamped (closed). For avoid tilting, we added pit mark on the gripper tip as shown in figure 16. The result of case 2 was showed in figure 17 and figure 18, from that we saw the tilt value was reduced.

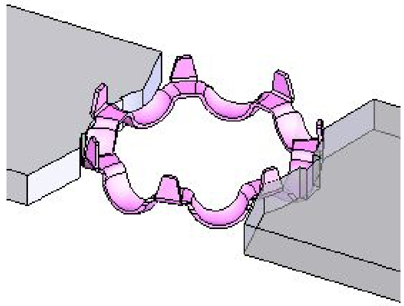

Figure 13. Flat end gripper (CASE 1)

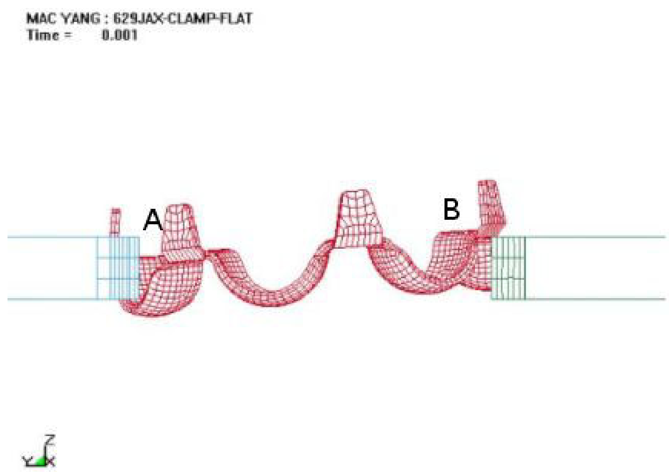

Figure 14. The tilt as flat end grippers clamped (CASE 1)

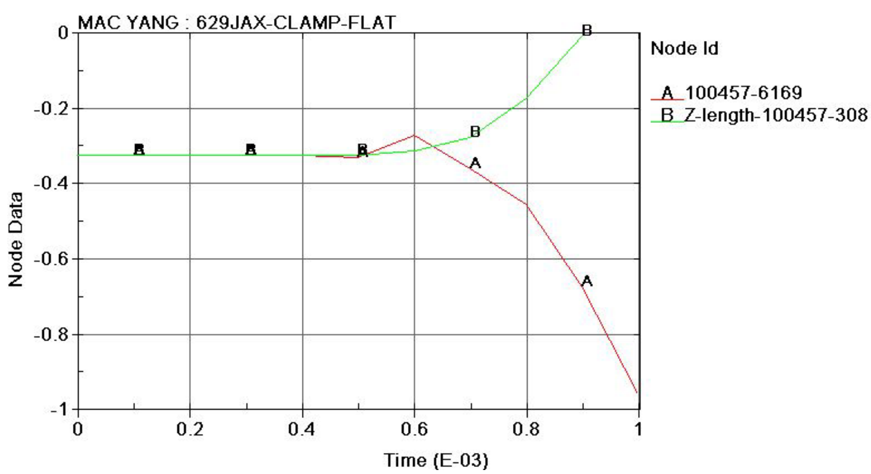

Figure 15. The tilt value time history (CASE 1)

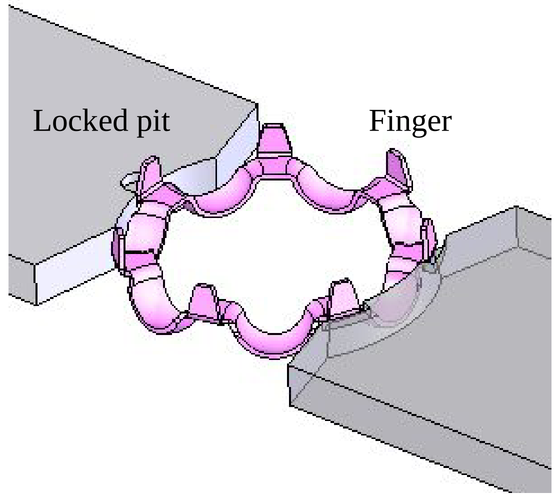

Figure 16. Flat end face gripper with locked pit (CASE 2)

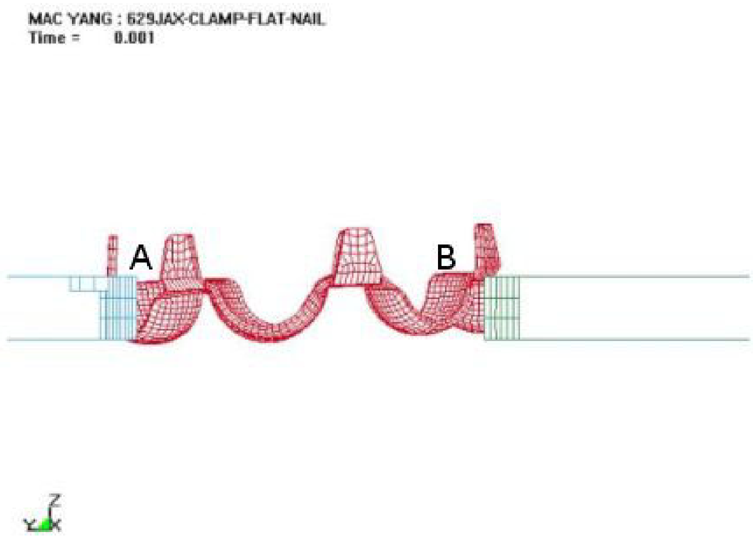

Figure 17. The clamping with modified grippers (CASE 2)

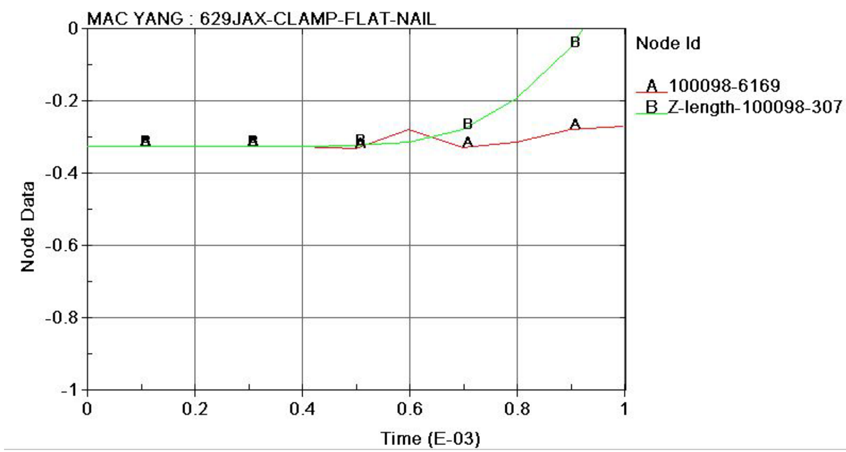

Figure 18. The tilt value time history (CASE 2)

Conclusions

The barrel cam and its followers have endured over 10 million cycle times and keep running day and night now. By checking the bearing of the stud-type roller as shown in figure 18, we assure that our cam system can endure the severe loading condition, 250 SPM.

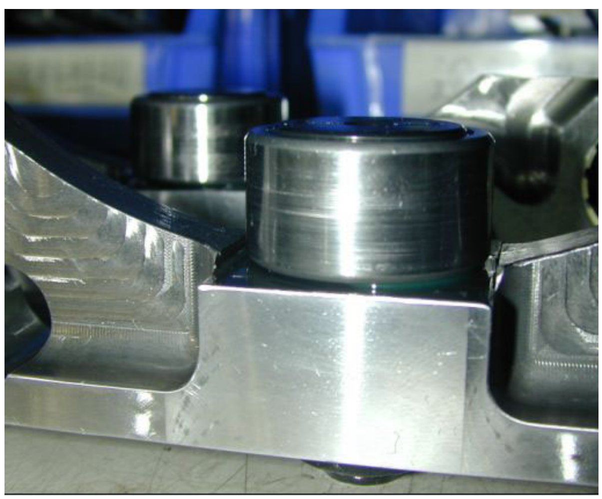

Figure 18. Stud-type roller after 10^7 cycles

There are some comments on the dynamics analysis for high speed transfer tools:

1. For the saving of CPU time, the control of minimum element size is important, especially by using automatic mesh generator.
2. The penalty contact parameter is sensitivity for the peak value of resultant force for 3D solid elements, so that engineers have better with the theoretical background of explicit finite element method in order to correlate the numerical results with engineering design.
3. The resultant force on the roller is depended on the stiffness of transfer bar and cam curve. For lateral displacement increases the resist force as transfer bar moving forward/backward vice versa, which also induces vibration and causes inaccuracy in position.

4. For the gripper design, the tilt value can be reduced by using the locked pit located on the gripper tip near the elbow area of retainer finger to avoid slipping.

References

1. R. L. Norton, "Cam Design and Manufacturing Handbook", Industries Press, 2002.
2. T. E. Tallian, "Failure Atlas for Hertz Contact Machine Elements", ASME, 1992.
3. LS-DYNA keyword user's manual version 970, 2003.
4. THK catalog, THK Co., LTD., 2000.