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An analysis of the influence of decompression cavity on the cold hobbing processes

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Analysis and modelling

ABSTRACT

Purpose: This study aims to investigate the influence of decompression cavity on the cold hobbing processes.
Design/methodology/approach: In the current study, the rigid-plastic finite element method would be used to analyze the influence of billets with different decompression cavity on cold hobbing processes.
Findings: There must be an optimal shape of decompression cavity which requires the minimum hobbing load, but achieves the optimal profile precision and strengthened results needed in formed workpiece.
Research limitations/implications: There were four different designs in billet. One was a cylinder without decompression cavity, and the others were the cylinders with truncate-cone, point-cone and semispherical decompression cavity respectively, with different shapes but almost the same volumes.
Practical implications: Through the simulation analysis, the influence of decompression cavity with the same volumes but different shapes on the load needed in process, the change of workpiece features, and the strengthened effects on workpieces in both open type and closed type cold hobbing processes, would be explored.
Originality/value: The finite element method is employed to analyze the influence of different decompression cavity of billets on the cold hobbing process.
Keywords: Finite element method; Decompression cavity; Cold hobbing; Die manufacturing

1. Introduction

Cold hobbing is a die manufacturing method using the quenched-hardening punch to slowly penetrate into die blank by high pressure at room temperature, and with the plastic deformation of blank, the die cavity with the reverse shape and the same punch geometry was created. This method has developmental potential in meeting the tendency of high quality, low cost, and short delivery. But regardless of any type of cold hobbing, high pressure in forming is needed especially in deeper extruded depth and higher billet strength. Through the change and design of die blank shapes, the hobbing load could be reduced, so the punch subjected load and the hobbing facility tons would be reduced too. Generally, there are two methods in reducing force through billet design, one is designing a decompression cavity in the billet bottom and the other is to design decompression slot in the billet around.

Many research topics using the finite element method are found to explore the deformation analysis, such as loading, in the forging and extrusion of metal bulk deformation processes [1-10]. But the study focus of blank shape design in forming process is mainly on the analysis and optimal design of performing. For example, Lorenzo et al. [11] used reverse methods to study the optimization of perform shape for the billet width, height and position in forging. Santos et al. [12] also utilized the simulation method, through the evaluation of billet shape and size, to explore the forging loads and the probability of product defects. The design principle of equivalent electrical potential line in electrical field was used for performing design in hot forging by Lee et al. [13]. However, related research of die manufacturing in cold hobbing processes, especially focusing on the analysis of billet shapes design, is limited.

Therefore, in the current study, the rigid-plastic finite element method would be used to analyze the influence of billets with different decompression cavity on cold hobbing processes. Namely, the influence of decompression cavity, with the same volumes but different geometry, on the loading, the change of workpiece profile, and the strengthening of workpieces in both open-type and closed-type cold hobbing processes would be investigated.

2. Finite element simulation and analysis

In this study, the cold hobbing process involved two types: open-type and closed-type. As shown in Fig. 1, the upper forming die was a stepped punch with flatted cone profile, and the bottom die was a cupped shape and flatted shape in closed-type and open-type cold hobbing respectively. There were four different designs in billet. One was a cylinder without decompression cavity, and the others were the cylinders with truncate-cone, point-cone and semispherical decompression cavity respectively, with different shapes but almost the same volume.

The finite element method, used for the modeling of metal flow deformation, has become the most popular analysis tool utilized in die industry now [14]. In this paper, the commercial package DEFORM-2D [15] has been used for the FEM modeling and analysis of the axis-symmetrical cold hobbing processes. The configuration of the billet and die used for simulation was illustrated in Fig. 2. The punch and die was set as a rigid body, the billet as a plastic body being meshed into 2000 quadrilateral elements. During simulation, the punch was compressed downward for 18mm, and the bottom die stayed in fixed position. The constant shear frictional factor was 0.3 at the billet/die interface. Fig. 3 showed one of the examples of billet deformations, which billet had no decompression cavity in the open-type processes, in the steps of cold hobbing.

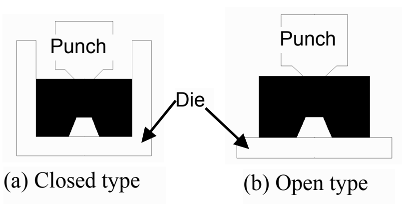

Fig. 1. Hobbing types of cold hobbing

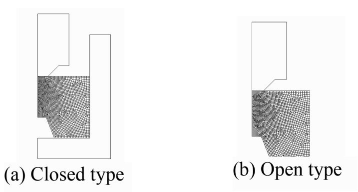

Fig. 2. The configurations of die and billet during finite element simulation

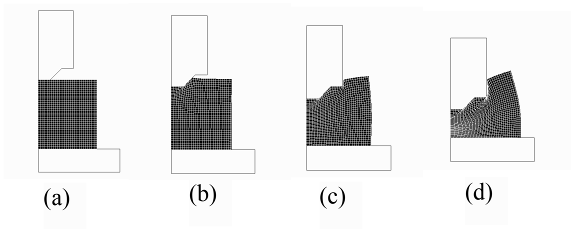

Fig. 3 the deformations of workpiece in the different steps of opened-type cold hobbing(right half view)

3. Results and conclusions

3.1. The influence on forming loads

Fig. 4 and Fig. 5 showed the load-stroke curves for the open-type and the closed-type cold hobbing respectively. Fig. 6 was the influence of the four different decompression cavity shapes in closed-type and open-type related on the maximum cold hobbing loads. It was shown, from this figure, that the loads needed in closed-type were higher than those in open-type. The influence of frictional force produced from the contact between the billet and the sided wall of bottom die might be the major reason. It can be found, regardless of closed-type or open-type, the loads needed in truncate-cone cavity was the lowest and the point-cone cavity highest, and the variance between them was approximately 3.7 %.

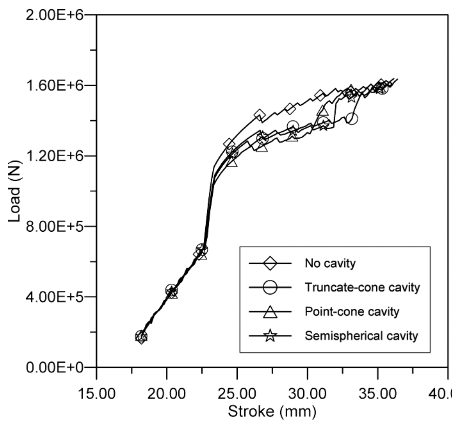

Fig. 4 . The curved diagrams of stroke-load in opened-type cold hobbing

3.2. The influence on workpiece shapes

Fig. 7 was the final profile of workpiece formed by cold hobbing. The exterior wall of the workpiece formed by open-type cold hobbing would emerge the bulging inclination, and the interior wall also appeared the clearance without fully close to punch outside diameter. The phenomenon of the differences in the height discrepancy between the interior and exterior wall would exist in cold hobbing regardless of open-type or closed-type. All these results would affect the precision and post machining allowance of the products after cold hobbing.

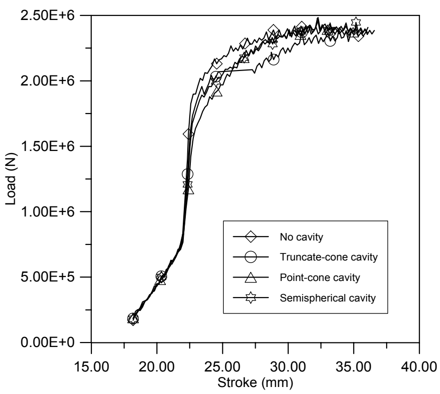

Fig. 5. The curved diagrams of stroke-load in closed-type cold hobbing

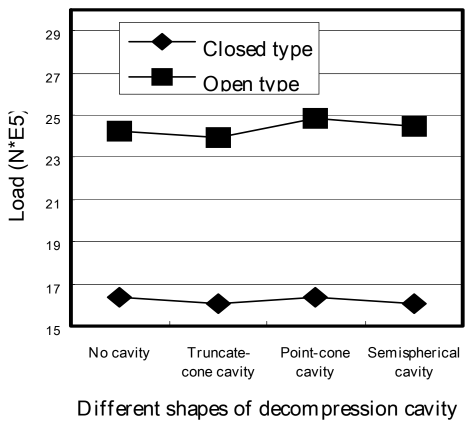

Fig. 6. The influence of four different decompression cavity shapes on the maximum cold hobbing loads

The comparison of inclination in workpiece exterior wall formed by the open-type cold hobbing, which billet has four different types of decompression cavity, was shown in Fig. 8. The exterior bulging tendency in the outside diameter of billet would be found during the periods of the billet starting to contact punch and in the former 4 mm strokes. But afterwards, the inward inclination bulging appeared gradually. In the stroke end, the workpiece with point-cone cavity had the maximum inclination, while the one with semispherical cavity was the minimum, and the variance of these twos equaled to 8 %. Fig. 9 showed the comparison of the clearance between the interior wall of workpiece and the punch in the open-type cold hobbing. It could be found, from this figure, the clearance in the billet with truncate-cone decompression cavity was the minimum, but the point-cone cavity one was maximum, and the variance of these twos was almost 29 %.

The comparison of height between the interior and exterior wall in the impression cavity of workpiece was shown in Fig. 10. It was found that the height variance of closed-type cold hobbing was more than that of those open-types. The height variance of truncate-cone cavity was minimum in closed-type cold hobbing, but the no cavity ones maximum, and their difference was about 47.3 %. Similarly, in the opened-type cold hobbing, the height variance of die blanks with semispherical-cavity was maximum and no cavity ones minimum, but their difference was only 6.9 %.

3.3. The influence on workpiece strengthening

The workpiece would be strengthened due to the strain hardening through cold working by cold hobbing processes. But correspondingly, it should be considered that the processes would increase accordingly owing to the need for processes annealing. Fig. 11 showed the comparison of the maximum effective strain in workpieces after cold hobbing. It has revealed that the maximum effective strain in workpiece formed by closed-type cold hobbing were more than those by open-type ones. Despite the closed-type or open-type cold hobbing, the workpiece with truncate-cone cavity would possess the minimum effective strain, but with no cavity being maximum. The variance of these twos was 13.42 %, while in open-type with the minimum variance was only 3.3 %.

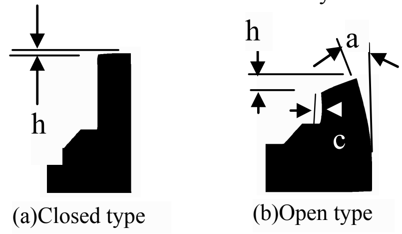

Fig. 7. The final profiles of the workpieces after cold hobbing

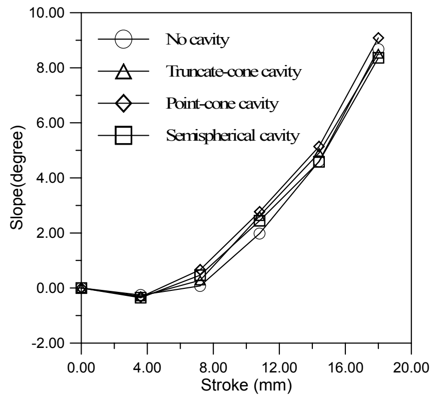

Fig. 8. The inclination comparison of workpiece external wall after opened-type cold hobbing

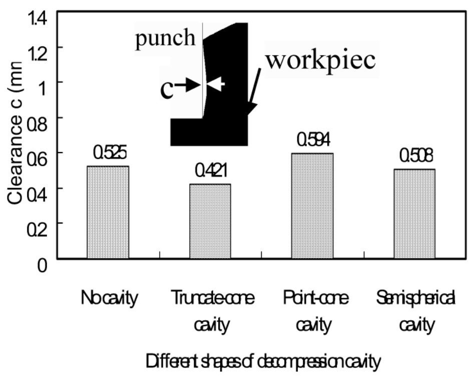

Fig. 9. The clearance between the internal wall of workpiece and the punch in opened-type cold hobbing

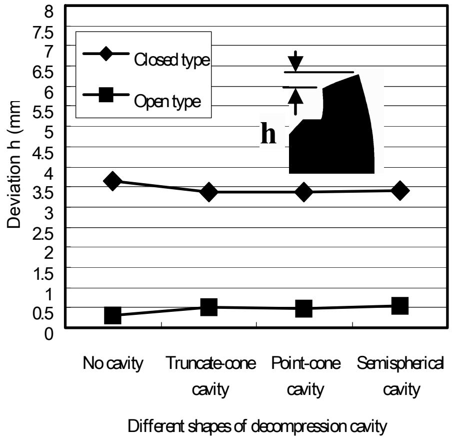

Fig. 10. The height comparison between the internal and external wall in opened-type cold hobbing

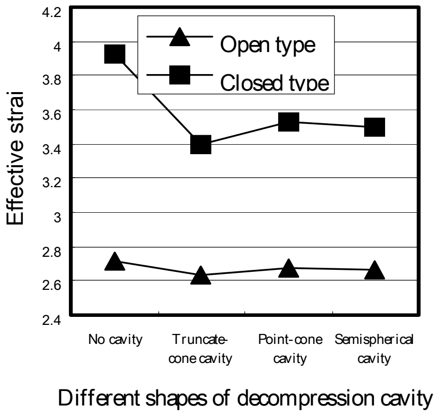

Fig. 11. Comparison of the maximum effective strains in the workpieces after cold hobbing

4. Conclusions

1. The loads needed in closed-type cold hobbing were higher than in open-types. The hobbing loads were also influenced by the different shapes design of decompression cavity, and the truncate-cone cavity was the minimum in all designs.
2. The different shapes design of decompression cavity would influence the profile precision, such as the exterior wall inclination of cold hobbibg workpiece, the clearance of interior wall, and the height variance between the interior/exterior diameter.
3. Various influences on workpiece strength would form due to the different cold hobbing processes and the different shape designs of decompression cavities.
4. There must be an optimal shape of decompression cavity which requires the minimum hobbing load, but achieves the optimal profile precision and strengthened results needed in formed workpiece.

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