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Prediction of Fineblanked surface characteristics using the finite element method (FEM)

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ABSTRACT

The requirements for the fineblanking (FB) technology that the precision blanked products could be obtained are more demanding. Therefore, the optimal die design and working conditions determined by a proven database and trial-and-error processes are insufficient. In this study, the possibility of using the finite element method (FEM) was investigated to analyze the blanked surface in FB process by using 2D-FEM, and the mechanism of tearing and/or secondary shear surface formation on fineblanked surface was also clarified. The reasonable number of meshes, adaptive remeshing technique and suitable ductile fracture criterion equation were used. The results initially indicated that the occurrence of tearing and/or secondary shear surface can be analyzed by the FEM simulation and its mechanism can also be explained. From those results, the FEM model of the fineblanking process enabling surface flaws to be predicted could be created. The FEM simulation results compare well with experimental results, thus validating the method for predicting the blanked surface quality. Therefore, it was indicated that FEM simulation could be a useful tool for predicting a fineblanked surface and determining design and working parameters in the FB process.

1. Introduction

The fineblanking (FB) process is well known as an effective process to obtain the precision blanked products with a smooth and precision blanked surface. Nowadays, this technology is expanding to be used in the automotive, information and electric industrial fields, for several kinds of brackets, gears and brake parts. The advantages of the fineblanking technology are as follows: improvement of product precision, cost-effective production by converting from a machining process to a press process, and improved productivity.

However in recent years, technological requirements for the fineblanking are more demanding. For example, a complicated contour product shape, difficult-to-blank materials such as stainless steel and hard steel, and sheet forging combined with the fineblanking process. It is difficult to determine the optimal die design and working conditions by traditional approaches, such as the use of a proven database and trial-and-error processes using trial die.

In this study, to solve the above-mentioned problem, the possibility of using the finite element method (FEM) was investigated. The FEM approach will be used as a tool for determining die design and working parameters in the FB process instead of a proven database and/or a trial-and-error approach. The FEM approach has been verified for many metal-forming processes, such as blanking, wire drawing and

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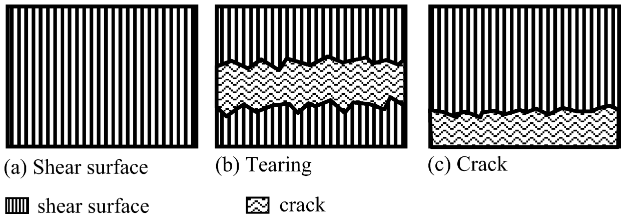

Fig. 1 – Characteristics of blanked surface in FB product.

deep drawing (Maiti et al., 2000; Brokken et al., 2000; Hayashi et al., 2003; Lang et al., 2004). However, in the FB process, it is very difficult to run the accurate FE-calculation because of a large strain concentrated on the blanked zone, and a calculation for crack formations is needed for the FEM simulation of the FB.

In this report, as the first step of this study, the possibility of using the FEM simulation on the FB process by using 2D-FEM was investigated. In the FEM simulation, an elastic–plastic type for blanked material, a reasonable number of meshes, adaptive remeshing techniques and ductile fracture criterion equation were used. In addition, exact blank holder and counterpunch forces are set for FEM, which are investigated by the actual FB experiment. As a result of this study, FEM and experimental results substantially agree well with each other, thus the possibility of the FEM approach is indicated for determining the optimal die design and working parameters in the FB process.

2. Problems on a fineblanked surface and the validity of the FEM simulation

Fig. 1 shows a classification of a fineblanked surface. Fig. 1(a) shows a shear surface which is a good surface obtained in the FB. In contrast, Fig. 1(b and c) show a tearing and a crack formation, respectively, which cause problems of poor precision on blanked surface geometry and decreased product strength. Therefore, to obtain the shear surface as shown in Fig. 1(a), a well-designed die structure and an optimal process condition are required.

A mechanism was considered on the FB process to suppress tearing and crack formations in order to obtain only shear surface on blanked part. Fig. 2 shows a high pressure on a V-ring blank holder and the counterpunch is pressed onto the blanked material outside the blanking contour. Therefore, a compressive stress is added into the blanked material causing a tensile stress near the punch and die cutting edges is suppressed. Next, a small clearance of approximately 1% of the punch and die is set. Crack propagation cannot directly grow from the punch side to the die side, or vice versa. Finally, a larger die radius compared with a conventional blanking is used. Crack formation on the blanked surface of a product that is formed by die is prevented (Lange, 1997; Nakagawa, 1998). The blanked surface quality is affected by the product contour shape, blanked shape and blanked material. It is very difficult to obtain a smooth shear surface as shown in Fig. 1(a) and tearing and cracking frequently occur as shown in Fig. 1(b and c).

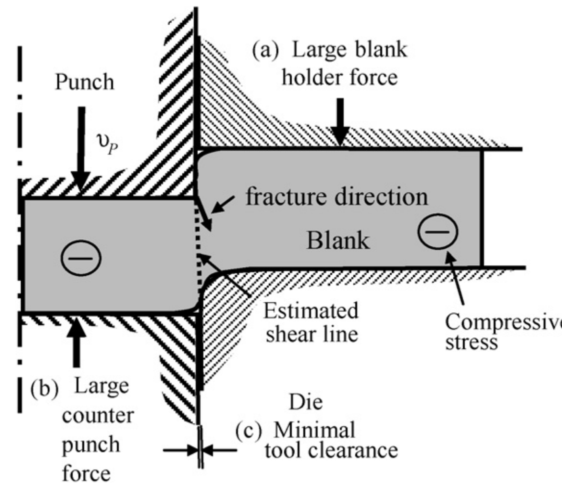

Fig. 2 – Crack prevention mechanism in FB.

In the FB process, if an optimized die structure and process condition can be predicted by the FEM simulation, it can be used to explore capabilities of FB technologies in industrial applications and materials. In order to achieve this, several principal researches about the FEM simulation on the FB process have been conducted. For instance, (Samuel, 1998) and (Lee et al., 1997) studied stress and strain occurrence in the blank material by using the FEM. The results showed the tensile stress near the punch and die cutting edges was reduced. Hambli (2001) studied crack propagation in the FB. The results showed crack did not directly propagate from each tool cutting edge in the FEM simulation. Nakagawa et al. (1971) carried out a study about a contour gear shape by the FEM and experiments. The results showed shear droop and tearing easily occurred on gear teeth but hardly occurred on bottom land. In addition, although most researches showed that the shear surface ratio on blanked surface increased as blank holder force increased, a simulation of a tearing and/or secondary shear surface was never verified. Up to now, the researches on the FB have not been clarified to predict the relationship of die structure, process condition and especially crack formation on fineblanked surfaces.

3. The FEM simulation and experimental method

3.1. *The FEM simulation method*

The fineblanking process was simulated using a two-dimensional axisymmetric model. The FEM simulation model and its boundary conditions, which were similar to conventional blanking, were set as shown in Fig. 3. In this study, a simple blank holder without V-ring was used in order to adopt a simple model. The two-dimensional static implicit finite element method (commercial code DEFORM-2D Ver.8.1) was used for the FEM simulation. The shape of the elements of the blanked material was rectangular element (4-noded rectangular element type). It was also noted that approximate 3000 elements were designed for the blanked material. Calculations were performed by remeshing so that the divergence of