FINITE ELEMENT ANALYSIS OF ROTARY BLANKING: EFFECTS OF PUNCH GEOMETRIES ON CUTTING AREA AND STRESS DISTRIBUTION

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ABSTRACT—It is essential to develop efficient and cost-effective production methods to achieve or maintain international competitiveness. An innovative production method, such as rotary blanking, enables manufacturers to both reduce expenses and economize production time. However, there are not enough numerical analyses for this process. In this paper, numerical simulations of rotary blanking were performed. After comparing the cutting planes generated by conventional and rotary blanking experimental tests, the cutting areas of two punch geometries were analyzed. The influence of punch geometry on part quality was then investigated through simulations. The procedure for die stress analysis was established and stress distributions of the worksheet and the tools were analyzed.

KEY WORDS: Cutting area, Die stress analysis, Finite element analysis, Punch geometry, Rotary blanking, Stress distribution

NOMENCLATURE

- \(\varepsilon\): effective strain
- \(\varepsilon_0\): initial effective strain
- \(\varepsilon_f\): fracture effective strain
- \(\sigma\): max. principle tensile stress (MPa)
- \(\sigma\): effective stress (MPa)
- \(C_0\): critical damage value
- \(E\): young’s modulus (GPa)
- \(K\): strength coefficient (MPa)
- \(n\): strain hardening exponent
- \(\nu\): poisson’s ratio

1. INTRODUCTION

Blanking is a metal forming technique that is used in various ways at the site of manufacturing. The process produces the desired plain shapes by shearing sheet metal in the thickness direction using mechanical presses. It is usually employed for engineering applications such as parts of automobile, general machine pieces and structural elements of electrical equipment, which are able to be mass-produced and superior quality is required at once (Kim et al., 2004). It is therefore important to manufacture products that have a fine cutting surface, as well as precise size and shape, on a large scale. Thus, manufacturers currently consider fine-blanking to be an alternative technique (Edelstahlwerke Buderus AG, 1997; Lee et al., 1995).

However, conventional blanking process sets physical limits on productivity because it uses a press. A press not only requires massive tools and installation space, but because it is a continuous process, it also cannot be executed in the intermittently translative sequence. In contrast, rotary blanking is an alternative method that overcomes the physical drawbacks of conventional blanking (Hoffmann and Schweitzer, 1999).

The construction of rotary blanking process is shown in Figure 1. This construction was made by Baust Werkzeugtechnik GmbH, Germany. The test equipment is installed at the Institute of Metal Forming and Casting (utg, Technische Universitaet Muenchen). The machine consists of two rollers that rotate in opposite directions. The punch is positioned at the top roller and the die is set on the bottom roller. As the top and bottom rollers operate mechanically together, the worksheet is fed between punch and die. Pressure rollers located on both sides function to maintain tension by pressing the worksheet over the bottom roller (Blumauer, 1975; Noak, 1982).

The operation using the rotational movement of the tools offers numerous advantages over conventional presses. The main merit of the rotary process is its rapid production speed. Since the worksheet is fed continuously without stopping or acceleration for each stroke, output can be maximized. Moreover, tools for rotary blanking can be
made much more compact than those used in a conventional press because high pressure is not required. In addition, incremental blanking significantly reduces the blank force and thus the operational noise of the blanking process.

However, one problem with the technique is that the quality of the cutting area is lower relative to that of the conventional blanking process, since rotary blanking is based on rotation motion. In addition, punch geometry has a great impact on cutting areas of the part. First, the ability to produce a cutting area comparable to conventional blanking is a necessity. Therefore, the development of optimized punch geometries and improvements in the quality of the cutting area remain urgent problems.

In the theory and experimental research of rotary blanking, the equation for estimating the load of the punch in rotary blanking was proposed by experiments (Schweitzer, 2001). The Machine construction and process conditions were suggested by comparison and analysis of cutting areas with the material and thickness of worksheet (Schmidt, 2004). Additionally, advanced punch geometry was designed by comparing the cutting area to conventional blanking (Schmidt, 2004). The advanced punch has an undercut at the bottom of the punch and it reduces the contusion of the cutting area so that the cutting area of rotary blanking approaches that of conventional blanking (Schmidt, 2004). The mechanical properties of tools influencing manufactured goods in rotary blanking were analyzed experimentally. The effects of tensile and compression stress for punch were analyzed by simulation (Hoffmann et al., 2007).

In this paper, based on the processing characteristics of rotary blanking, punch geometry was used as the process parameter and the results were compared and analyzed after 2D- and 3D-simulations were performed using the rigid-plastic finite element method. The influence of punch geometry on part quality was investigated and stress distributions of worksheet and tools are analyzed through simulations.

2. CHARACTERISTICS OF ROTARY BLANKING

2.1. Comparison of Cutting Area

Cutting areas were compared through experiments aimed at understanding the differences between rotary blanking and conventional blanking. The results are shown in Figure 2, in which (a) is the cutting area produced by conventional blanking and (b) is the one produced by rotary blanking. DP500 was used as the material of both worksheets (Hoffmann et al., 2007). The characteristic of rotary blanking were obtained by comparing the parts produced by two blanking processes. In rotary blanking, a relatively large contusion was present at the top of cutting area. The contusion was a distinguishing mark that occurred at the front and rear of the part cut by rotary blanking. In contrast, the cutting area by conventional blanking was almost perpendicular contrastively.

2.2. Punch Geometry

To reduce contusion, a new advanced punch was designed by Schmidt (Schmidt, 2004). Figure 3 shows (a) a normal punch and (b) the advanced punch. The undercut which has a 12° angle of inclination is shown in Figure 3(b). Schmidt derived this suggestion by considering the relationship between the angle of undercut and the thickness of worksheet using a formula. When using the advanced punch, a cutting area that was similar to the part deformed by conventional