The Influence of Blanking Process by Superimposing Ultrasonic Vibrations

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Abstract - The application of ultrasonic vibrations superimposed on wire drawing, deep drawing, upsetting and rolling has been developed in the literature. No attempts have ever been made to develop the application of the ultrasonic vibration to blanking process. This paper reports an investigation into the effects of the superimposed ultrasonic vibrations of the punch during the blanking process by experimental design and response surface methodology. The effects of the ultrasonic vibration on the punch load and edge profile are systematically studied. The results show ultrasonic vibration can decrease the punch load and improve the quality of edge profile.

Keywords – ultrasonic vibrations, blanking, response surface methodology.

I. INTRODUCTION

Blanking is one of the most frequently used processes in metal forming process. The shearing process develops between a punch and a die and leads to the total rupture of the sheet. The quality of the blanking product is affected not only by the mechanical properties but also by the ductile fracture process in shearing band between the punch and the die. Few experimental and numerical analyses have been reported in the literatures by superimposing ultrasonic vibrations on the wire drawing, deep drawing, upsetting and rolling processes. It is well known that the forming force, the flow stress and the friction between the die and the sheet could been reduced by the applications of ultrasonic vibrations [1,2].

Response surface Methodology (R.S.M.) is a collection of statistical and mathematical techniques as is useful for developing, improving and optimizing processes [3]. It also has importance and applications in the design, development and formulation of new products, as well as in the improvement of exiting product design [4]. It is a good tool to explore the relationship between input variables and the performance measure or quality characteristics of the product or process [5].

In this report, blanking process by superimposing ultrasonic vibrations is studied by experimental design and R.S.M. The objective of the proposed study is to analyze, in the case of thin Al-1015 sheets, the influence of parameters such as various blanking angles, blanking speed and clearances on the characteristic features of the punch load and edge profile, as illustrated in Fig. 1.

II. EXPERIMENTAL APPARATUS

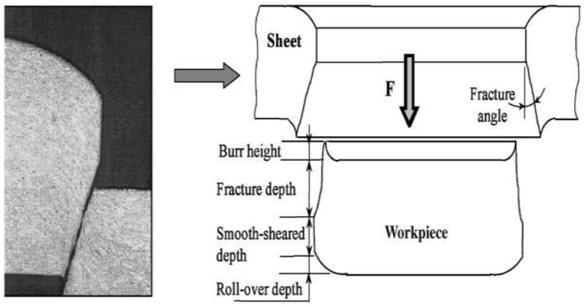


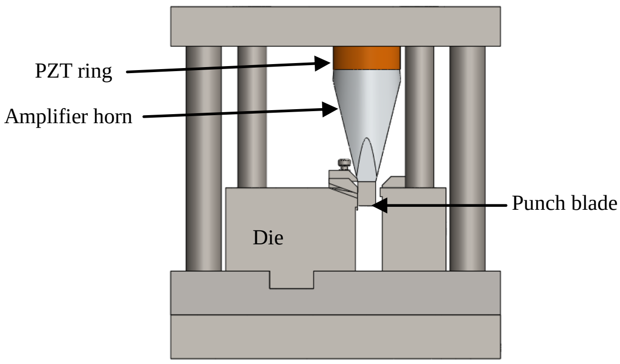
Fig. 1 Characteristic features of edge profile.

Fig. 2(a) shows the schematic illustrations of the newly developed tool set. The punch screwed to amplifier horn was excited by a piezoelectric transducer ring driven by an ultrasonic generator. The applied amplitude, which could set with the generator performance, was between 1.7 and 5 μm at the resonance frequency of 18.3 kHz. The ultrasonic vibrations must not influence the measuring equipment, actuators and machine elements or assembly groups of the machine. The blanking force was measured with a prestressed piezoelectric load cell mounted on the upper die. Displacements are measured by a linear encoder. All recorded signals were acquired by InstruNet signal acquisition hardware and software for data processing. As schematically illustrated in Fig. 2(b), the blade sharpness is quantified by the clean corner and the clearance is the distance between the blade edge and the bottom die edge. For convenience, in this paper the blanking angle is defined as the complementary angle of blade travel direction with respect to the sheet plane.

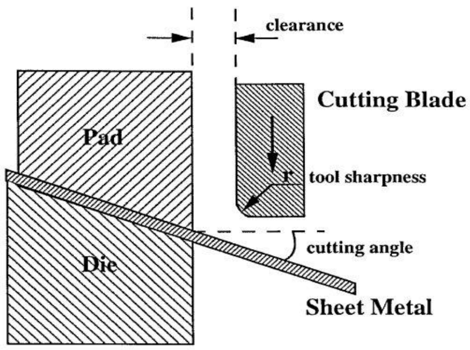
The 5kN servo press was driven by an AC servomotor through a mechanical link, and ram position could be changed via PLC control. The position accuracy and the maximum speed of the ram were 0.05 mm and 40 mm/s, respectively. Since the speed of the press decreases near the bottom dead centre, the average forming speed is employed. The materials used here is Al-1015 with thickness of 1 mm. The blanking experiments were conducted under a non-lubricated conditions.

III. THE INTRODUCTION OF R.S.M.

To acquire a systematic method to replace the conventional trial and error, R.S.M. was employed to approximate the model of forming process over a particular region of interest. The R.S.M. comprises regression surface fitting to obtain approximate response, design of experiments to obtain a minimum variance of the responses, and optimization using the approximated response. It is a good tool to explore the relationship between the input variables and the performance. R.S.M. was employed to construct a model about the forming process over a particular region of interest. R.S.M. can map the true unknown response surface over a particular region of interest. The response surface can be approximated with a suitably fitted response surface, and an engineer can predict the changes of response variable in advance that will result from any readjustment. The Box-Behnken, one method of R.S.M., which is the most popular class of second-order design, is introduced in this paper.



(a)



(b)

Fig. 2 (a) Schematic illustrations of tool set
(b) Blanking parameters evaluated in the experiments.

The response surface method is a statistical and mathematical method which gives an effective and practical means for design optimization. It is well suited when a function y depends on multiple design variables (x_i) and is known in some points of the feasible domain. Then a polynomial approximation of $y = f(x_i)$ is generally defined to express the function on the basis of observation data. The general expression of the response surface method has the following form:

$$y = \beta_0 + \sum_{i=1}^{n} \beta_i x_i + \sum_{i=1}^{n} \beta_{ii} x_i^2 + \sum \beta_{ij(i\langle j)} x_i x_j \qquad (1)$$

IV. RESULTS AND DISCUSSION

A. The R.S.M. Analysis of Blanking Process with Ultrasonic Vibrations

From practical point of view, the size of burr height is often the most important quality parameter. For this reason, this report only discusses the characteristics of the zone. The punch was superposed by ultrasonic vibrations during the blanking process. The interest of the following studies lies in the possibility of determining the working parameters which should be applied to the process. The feasible domain is defined by the three design variables influencing the blanking process, namely the blanking speed (x_1) which varies from 0.1 mm/s to 20mm/s, the clearance (x_2) which varies from 5% to 15% of the thickness of the sheets and the blanking angle (x_3) which varies from 0° to 20°.

The evolutions of the burr height occurring in the blanking process are plotted in Fig. 3. It is constructed according to the polynomial approximation based on Eq.(1) and the corresponding fitted model is as follows:

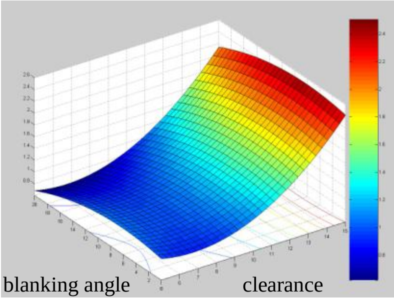
$$\begin{aligned} y &= 0.514 - 0.041x_1 + 0.039x_2 + 0.081x_3 - 0.002x_1x_2 \\ &- 0.005x_2x_3 + 0.002x_1^2 + 0.007x_2^2 - 0.003x_3^2 \end{aligned} \qquad (2)$$

When the blanking speed is selected, for instance, 0.1 mm/s, the change of the blanking angle has less effect on the burr height, as shown in Fig. 3(a). This means that the clearance has a great influence on burr height. It can be seen that it is important to decrease the clearance if the burr height have to be reduced. For the same clearance (10%), Fig. 3(b) showed the burr height was influenced by both the blanking angle and the blanking speed. The deviation of the burr height is not remarkable and can be directed to the desired place through varying the working variable in the blanking process. When the blanking angle is constant, change of the working variables the clearance and blanking speed is an effective way to decrease the burr height, as shown in Fig. 3(c). It showed that burr height was deeply influenced by both the clearance and the blanking speed.

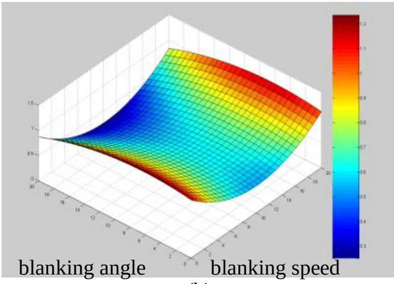
B. Effect of Ultrasonic Vibrations on Punch Load and Edge Profiles

The edge profile after blanking process with and without the ultrasonic vibrations superimposed is shown in Fig. 4 for comparison. Burr-free condition and the greater smooth-sheared depth are both clearly observed due to the effect of the ultrasonic vibration. Because of the reduction of the mean flow stress, the fracture appeared later and more slowly during application of the ultrasonic vibrations. It not only increases the plasticity of the sheet but also extends the shear zone. Burr always forms at the beginning of the rupture and is elongated during the final blanking process. By numerous vibrations between the die and the sheet, burr forms later and reduces the damage evolution in the neck zone. By this way, the elongation of burr is limited by superimposing the ultrasonic vibrations, which also show positive effect on the mean flow stress and the quality of edge profile.

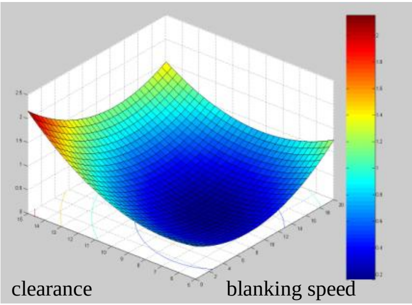
The punch force after blanking process with and without the ultrasonic vibrations superimposed is shown in Fig. 5 for comparison. The reduction of blanking load is due to continuously alternate contact and separation by superimposing ultrasonic vibrations, considerably resulted in



(a)



(b)



(c)

Fig. 3. Response surface of the burr height (a) blanking speed=0.1 mm/s(b) clearance=10 % (c) blanking angle =20°.

the decrease of friction condition between the die and the sheet.The lowest drawing force is required because the higher drawing force is, the greater the amount of wear on the tooling is, which is critical in industry where expensive tooling for complicated components cannot be replaced on a regular basis.

V. CONCLUSIONS

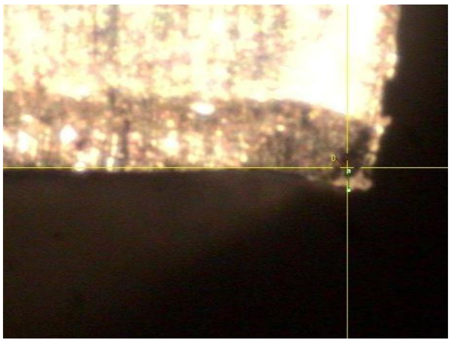
An ultrasonic vibration system is developed to analyze the formability for thin sheet at the end of blanking. Main conclusions can be drawn are:

1. It was shown that the clearance is the most influenced parameters for reducing the burr height with ultrasonic vibration. With the different levels of contributions for other working parameters, the burr height can reach the local optimizing value.

2. The approach based on the application of experimental design and response surface, provides useful information about the influence of the most important blanking parameters on the mechanical behavior of the burr height.

3. The results reveal that ultrasonic vibrations not only have positive effect on decreasing the punch load required, but also decrease the burr height.

(a)



(b)

Fig.4. The edge profile of sheet (a) without ultrasonic vibration (b) with ultrasonic vibrations.

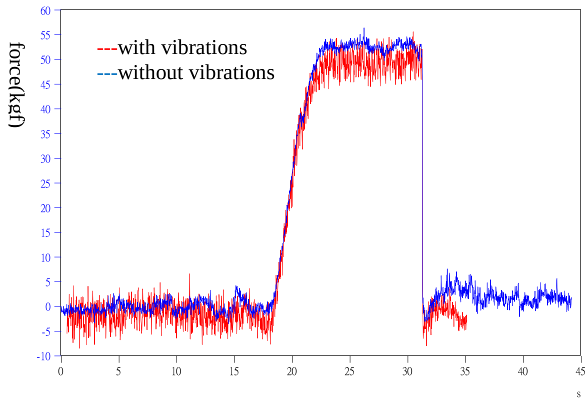


Fig.5. The comparison of punch load with and without vibrations.

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