The effect of ultrasonic vibration on the springback of incremental sheet forming

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ABSTRACT. In this study, aiming at the springback problem, ultrasonic vibration was applied to incremental sheet forming to assist the sheet forming. The springback distribution of ultrasonic vibration and no ultrasonic vibration was compared. The influence of the application of ultrasonic vibration on the springback of the sheet metal formed was analyzed; and also by adjusting the power of the ultrasonic generator to adjust the amplitude of the ultrasonic vibration, the effect of the ultrasonic amplitude on the springback is studied. Experimental data shows that the effect of ultrasonic vibration on each forming stage is different during the forming process. Therefore, it is necessary to select the best amplitude to assist the sheet forming process to achieve the effect of restraining springback.

1. Preference
Incremental sheet forming technology is a new type of sheet metal forming technology that introduces the idea of layered manufacturing. No molds are required in the production process. Flexible manufacturing can be realized, shortening the development speed of products, reducing development costs, and stamping and other large quantities. The traditional sheet forming methods complement each other and promote the further development of sheet forming technology[1][2]. However, the sheet formed by the incremental sheet forming technology has factors such as bending effect, springback and pillow effect, which affect the forming accuracy of the sheet[3]. When the external load is removed from the sheet, the internal stress of the formed part is redistributed to form a springback that seriously affects the accuracy of the formed part. It is necessary to investigate the springback problem in detail. At present, most of the research on the forming accuracy of incremental sheet forming technology is from a macro perspective. The three main influencing factors of bending effect, springback and pillow effect are considered as a whole for research, and the precise processing of different stages of the sheet cannot be achieved. This research explores the springback problem of asymptotically formed sheets. In the process of investigation, ultrasonic assisted forming is applied to the sheet forming process, and the numerical detection and analysis of springback at different stages are refined, and ultrasonic vibration and the impact of its amplitude on springback.
2. Experimental environment

2.1 Ultrasonic vibration assisted asymptotic forming experimental platform

Based on the existing experimental platform for progressive forming, an ultrasonic vibration assisted asymptotic forming experimental device as shown in Figure 1 was built. The device mainly includes an incremental sheet forming machine, an ultrasonic generator, and a vibration system. The vibration system is composed of an ultrasonic transducer and an amplitude transformer; its working process is that the ultrasonic generator converts AC power into high-frequency electrical signals to the transducer. The transducer converts the high-frequency electrical signal into mechanical vibration, and then the amplitude of the transducer is amplified by the amplitude transformer, and finally the mechanical vibration is transmitted to the forming tools[4][5]. The device adjusts the amplitude of ultrasonic vibration by selecting different tool diameters, ultrasonic generating power and other parameters. According to the existing hardware environment, the forming tools diameter is 5mm, and the maximum amplitude can reach 15.9μm within the rated power of 100W.

2.2 Detection system

The springback detection system mainly includes: high-speed profile measuring instrument, controller, PC and other equipment. The data acquisition process is that the PC sends instructions to the controller, and the controller controls the sensor to collect data. The collected data is finally transmitted back to the PC for processing.

The metal plate used in the experiment is a 5052 aluminum plate with a thickness of 2mm. The diameter of the forming tool is 5mm. The truncated cone part is formed according to the trajectory shown in Figure 2. The interlayer cutting method is to feed the part obliquely, and the feed speed is 800mm/min. The specific parameters of the experiment are shown in Table 1.

Table 1. Incremental sheet forming test parameters

| Serial number | Feed between layers /mm | power /% | amplitude /μm |
|---------------|-------------------------|--------|---------------|
| 1             | 0.3                     | 0      | 0             |
| 2             | 0.3                     | 70     | 6.3           |
| 3             | 0.3                     | 99     | 15.9          |

The method of measuring springback in this research is different from other measurement methods[6][7][8], the line laser measurement method is used to carry out the detection research on the part that has a greater impact on the springback of the formed part, and the detection of springback is divided into The following stages:

The first stage: Before raising the tools-the springback data measurement of raising the tools.
The second stage: Raise the tools-release the springback data measurement of the blank holder.
From the first stage, the springback value after the forming tools is raised can be obtained from the second stage. From the second stage, the rebound amount from raising the forming indenter to releasing the blank holder is obtained. From the springback value of the first two stages, the implied springback amount of the third stage can be obtained, that is, the springback value after the forming tool is not raised to the release of the blank holder, and the springback amount in the third stage represents it is the final springback. Through the analysis of the two detection stages and the third stage, a more detailed understanding of springback is helpful to determine the amount of springback compensation more accurately, to compensate for springback more accurately, and to achieve a high level of progressive forming technology. Precision machining. Furthermore, this study also explored the springback of the formed parts at different stages (as shown in Figure 3). This stage can be roughly divided into the sidewall forming stage (AB), the bottom forming stage (BC) and the pillow effect stage (CD).

3. Analysis of experimental results

3.1. The impact of ultrasonic vibration on springback

From the experimental data in Figure 4 and Figure 5, it can be observed that when ultrasound is applied or not during the forming stage, the springback value of the formed part in the AB section changes relatively smoothly. After the blank holder is completely released, the springback value reaches a maximum of one layer. The value of the given amount. It can be seen from Figure 4 that without applying ultrasonic vibration, as the processing depth increases, the springback of section AB shows a tortuous upward trend. From the numerical point of view, the springback value at this stage is not much different. The rebound amount is more evenly distributed. After ultrasonic vibration is applied, the rebound in the AB segment keeps increasing with the processing depth. Compared with the springback without ultrasonic application, there is a significant decrease. The application of ultrasonic-assisted forming in this area can reduce the rebound by a maximum of 15%.

![Figure 3. Workpiece inspection](image)

![Figure 4. No ultrasonic contour data and springback data](image)
In the BC section, the springback generated is the maximum value of the processing area after the forming indenter is lifted or the blank holder is released, and after ultrasonic vibration is applied to assist the forming, the springback value is more obvious than that of the forming process without springback. The increase of did not weaken the springback here to a certain extent. The reason can be analyzed from the cause of springback. Springback is a process in which the internal stress of the sheet reaches a new balance after the tools is raised or the blank holder is released. In previous studies, Zhai Weidong[9] and Cai[10] et al. studied the influence of ultrasound on the forming force of the incremental sheet forming technology, and found that the forming force increases with the increase of the feed depth. After the ultrasonic vibration is applied, the forming force in each axial direction decreases, while the forming force will reach the peak at the transition position between the area and the non-processing area. During the incremental sheet forming process, the BC section is in the transition position, and the forming force is relatively large. When the forming tools or blank holder is released, the internal stress of the sheet reaches the new equilibrium state, springback occurs at greater forming forces, so the value of springback generated at this stage is larger.

Comparing the springback distribution statistics, after applying ultrasonic vibration, the amount of springback distributed in the high springback interval is suppressed, while the proportion of the middle and low springback interval distribution increases. From the overall situation, the ultrasonic vibration has effectively suppressed the springback.

3.2. The impact of ultrasonic amplitude on springback.

During the experiment, ultrasonic vibration with two amplitudes of 6.3\(\mu\)m and 15.6\(\mu\)m was used to assist the sheet forming process. It can be seen from Figure 6 that the springback value of the 15.6\(\mu\)m ultrasonic vibration applied to the AB section of the forming part in the forming processing track is always greater than the springback value of the 6.3\(\mu\)m ultrasonic vibration applied, and at the maximum, the springback with a large amplitude it is twice the springback value of a slightly smaller amplitude. In the BC section, the springback values of both reached the peak value, especially the springback with a slightly larger ultrasonic amplitude applied. After 15.6\(\mu\)m ultrasonic vibration, the springback reached a maximum of 0.54mm, which is close to the amount given between the two layers value. In the area where the pillow effect occurs in the unprocessed area at the bottom, the springback value of this part has a large jump, but they are all distributed in a specific interval. The use of high-amplitude ultrasonic vibration is compared with low-amplitude vibration on the bottom unprocessed area of the forming. The springback suppression effect is obvious, and the springback distribution is relatively uniform.

From the analysis of each stage, after ultrasonic vibration is applied, the overall trend of springback is not changed, and it still increases with the increase of feed depth. However, applying ultrasonic vibrations of different amplitudes at different stages will give different results, and the springback effect in the BC section is not well suppressed.
3.3. Summary
In the incremental sheet forming experiment, due to the complexity and nonlinearity of the springback, the experimental conclusions obtained by changing different plates and using different hardware environments according to different experimental parameters are also different. When performing curve drawing and other related processing on the acquired data, it will be found that after ultrasonic vibration was applied, the trajectory of the forming tools is similar to that of hammered sheet metal forming. Therefore, the forming force will change slightly during the forming process, and the curve shows a jitter. On the other hand, the data points collected in the experiment are dense, and the collection of surface information is more comprehensive. In addition, debris will be generated during the processing or the internal factors of the material will cause uneven surface quality of the formed part, so the contour will be observed the curve jumps slightly according to the springback value.

The use of ultrasonic vibration to assist progressive forming has different effects on springback in different forming stages. Ultrasonic vibration with a fixed amplitude does not have an excellent suppression effect on the global springback, nor is it that the greater the amplitude of the applied vibration, the restraining effect of springback is more obvious, but ultrasonic vibrations of different amplitudes can be applied to different stages of the forming part to better restrain springback, and it can also be suppressed by selecting a more appropriate amplitude through experiments if the accuracy allows Springback. Generally speaking, the application of ultrasonic vibration can suppress the springback, but from each stage, it is necessary to find a satisfactory amplitude.

4. Conclusion
(1) Applying ultrasonic vibration assisted forming to the forming process of incremental sheet forming. From the point of view of the value distribution of springback of the forming part, the springback of the forming part can be suppressed.

(2) Ultrasonic vibration has different effects on different forming stages, and it cannot suppress the springback in all forming stages.

(3) The form of applying different amplitudes of ultrasonic vibration at different stages or determining the appropriate amplitude after accuracy evaluation should be used to assist the incremental sheet forming process to effectively suppress springback.

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