

SPRINGBACK OF FDSC MPF FOR CYLINDRICAL SURFACES

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Abstract: In this paper, Force-Displacement Separated Control Multi-Point Forming technology (FDSC MPF), a new technology of sheet metal forming is proposed. Through controlling displacement by upper die and controlling force by lower die, the technology realizes the separated controlling of displacement and forming force through the forming process. Through numerical simulation and forming experiment, the discrepancy of the springback between FDSC MPF and MPF are studied. The springback regulars of FDSC MPF are studied as the cylindrical radius and the forming force changed. The results show that in the same condition, the springback of FDSC MPF is much less than that of MPF, the springback decreases with the increase of forming force and the decrease of cylindrical radius.

1. INTRODUCTION

Multi-point forming technology(MPF) [1,2] is to divide the traditional die into many regularly arranged, height adjustable matrixes according to the needed 3D surface through controlling the axial location(Figure 1).

Various researches have been carried out about MPF. Ji et al [3] compared the MPF and die forming of thin sheet, the results showed that sheet forming was easy to wrinkle, so blankholder technology must be used in both MPF and traditional die forming. Se Yun Hwang et al [4] researched multi-press forming using thick plates, and developed a displacement adjustment algorithm for practical application, which proved to be an effective way to compensate springback in the shipbuilding industry. David E. Hardt et al [5] developed multivariable run-by-run control methods with application to a sheet metal forming process, and the experimental results showed the validity of the method. Hua and Hu [6] developed a No-Pair Dies forming technology. The top of the matrixes were movable heads instead of hemisphere heads, which could made satisfactory surface. Zhang and Cai [7] proposed

compensation algorithm for springback in MPF, which could effectively control the error of the springback in MPF.

As mentioned above, many new methods or improvements such as deformation compensation have been developed for MPF. However, the method by controlling the material constraints to reduce springback of the blank is not involved. In this paper, Force-Displacement Separated Control Multi-Point Forming technology (FDSC MPF), a new technology of multi-point forming is proposed (Figure 2). Through controlling displacement by upper die and controlling force by lower die, the technology realizes the separated controlling of displacement and forming force through the forming process. In this technology, the sheet deformation mode is changed from local normal constraint and overall deformation to overall normal constraint and local forming in order. The stress state of the forming sheet is improved effectively, and had many advantages such as a simple and stable control, no need of blankholder, restrain wrinkles, small amount of rebound, etc.

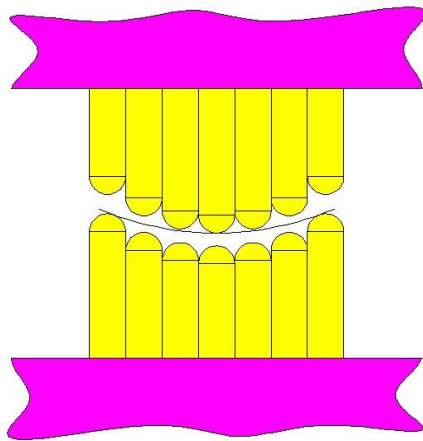


Fig. 1: Traditional MPF

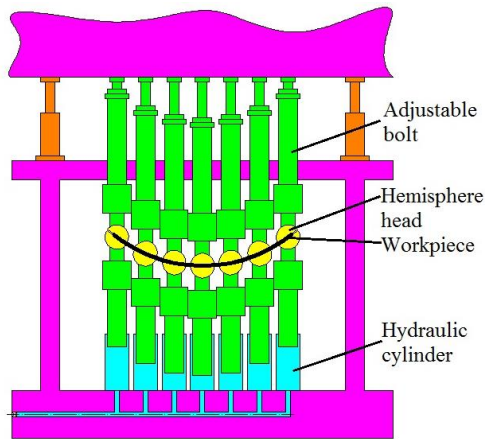


Fig. 2:FDSC MPF

In this paper, the springback of FDSC MPF is compared with MPF. The springback regular of cylindrical FDSC MPF is studied as the cylindrical radius and forming force changed. Experiments and simulation of MPF are made as the radius changed, and the geometric compensation method is adopted to get the target surface.

2. NUMERICAL SIMULATION AND EXPERIMENTAL PROCEDURE OF FDSC MPF

An FE process model was built by ABAQUS (Figure 3). ABAQUS/Explicit was used in forming process, and ABAQUS/Standard was used to simulate springback. The simulation results can be transformed easily between ABAQUS/Standard and ABAQUS/Explicit.

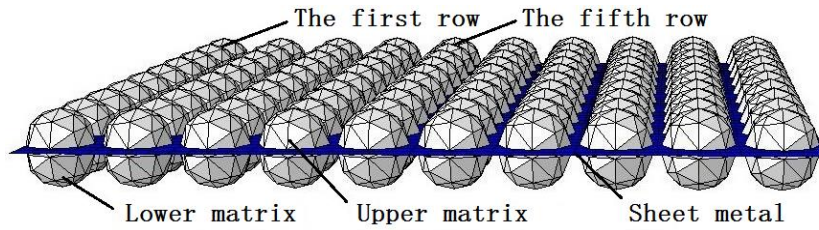


Fig. 3: Numerical simulation model

The model was consist of $200\text{mm} \times 200\text{mm}$ workpiece with the thick of 2mm, 100 upper hemisphere heads and 100 lower hemisphere heads all with the radius of 9mm. The distance between hemisphere heads was 20mm arranged by 10×10 (Figure 3). The material of the workpiece was 1060 aluminum alloy. The contact type between the workpiece and hemisphere was surface to surface, and the element type of the sheet metal was S4R with the size of 5mm. During the forming process, the upper matrixes moved down to suppress the workpiece step by step, the lower matrixes apply constant pressure to the workpiece.

The experimental equipment was made up of hydraulic press, hydraulic station, console and FDSC MPF mould (Figure 4). The displacement of the mould was controlled by upper die, and the forming force was controlled by lower die through hydraulic cylinder. The parameters of the mould were exactly the same as the numerical simulation.

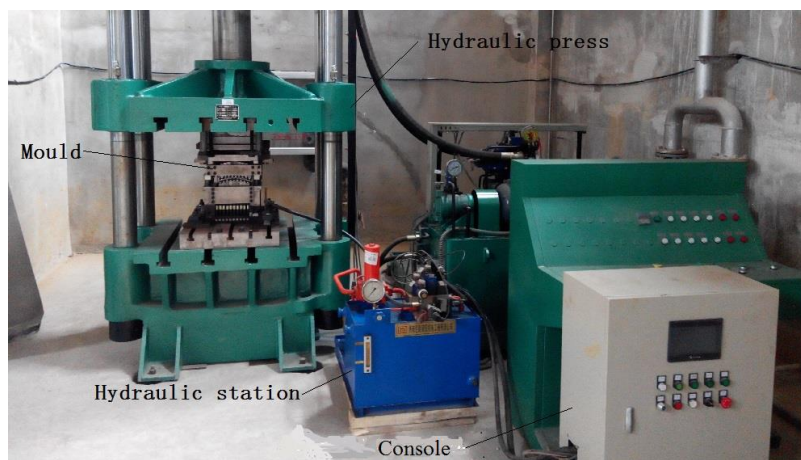


Fig. 4: Experimental equipment

3. REPRESENTATION METHOD OF SPRINGBACK

Plastic deformation and elastic deformation are included in metal deformation. Springback produces as plastic deformation preserves and elastic deformation disappears. The ordinate of any point in the workpiece changes from y to y' after springback (Figure 5). Its slope is defined as the coefficient of restitution C , namely:

$$C = \frac{y'(s)}{y(s)} \quad (1)$$

The difference between y and y' is defined as springback distance D , namely:

$$D = y - y' \quad (2)$$

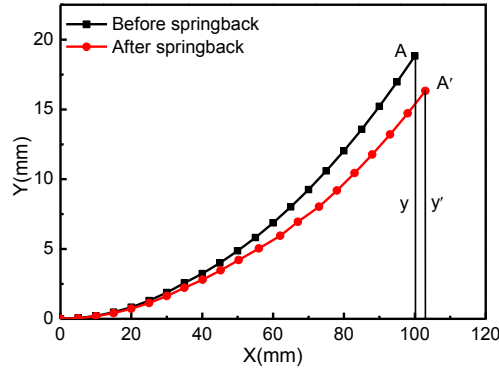


Fig. 5: Representation method of springback

The springback decreases with the increase of C and the decrease of D . C can express the springback amount of whole change trend, and D can represent the springback of sheet at different location of the workpiece.

4. THE CONTRAST OF TWO FORMING MODES

The key characteristic of FDSC MPF is the small amount of springback and and restrain wrinkle effectively. In order to verify this conclusion, the simulation results of the two forming modes were compared. The springback amount of FDSC MPF is much smaller than that of MPF, as shown in Fig.6 and Fig.7. This is because during the forming process of FDSC MPF, compressive stress is applied on the normal direction of the sheet by punches and additional tensile stress at tangential direction is produced. Thus the tangential compressive stress at the inside of sheet neutral plane is decreased, the wrinkling instability is restrained and the springback is decreased.

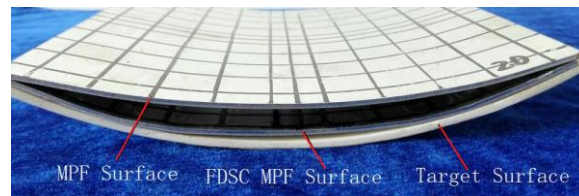


Fig. 6 Experimental results of different forming modes

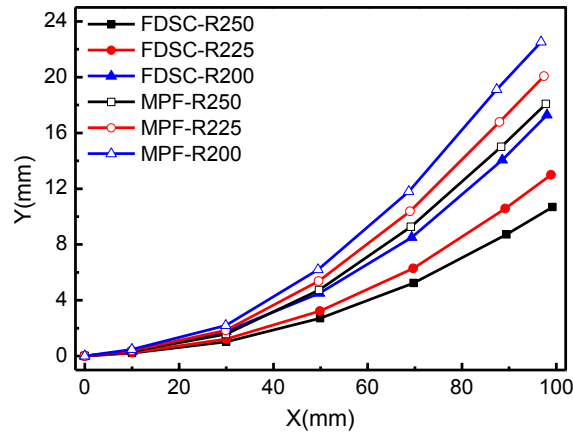


Fig. 7: Blank profile of two forming modes

5. SPRINGBACK OF THE FDSC MPF

In this section, numerical simulation and experiments were carried out to investigate the influence of cylinder radius and forming force.

5.1 Cylinder radius

ABAQUS was used to investigate the influence of cylinder radius to minimize the experimental works. Table 1 lists details of the parameters.

Table 1: The parameters settings of different radius

Material	Thickness(mm)	Forming force(N)	Cylinder radius (mm)
1060Al	2.0	1000	200、225、250

As can be seen from Fig.8, springback of workpiece increases as the cylinder radius increases. This is mainly because the greater the target curvature radius, the smaller the forming parts deformation, the smaller the plastic deformation of the proportion of the total deformation, the greater the springback.

5.2 Forming force

To investigate the influence of different forming force, experiments were carried out. Table 2 lists details of the parameters. Experimental results are shown in Fig.7.

Experimental results indicate that the springback decreases with the increasing of forming force. This is because normal stress on the surface of the workpiece and the additional tensile stress caused by the friction become larger as the forming force increased. Thus the springback bending moment become smaller, so is the springback.

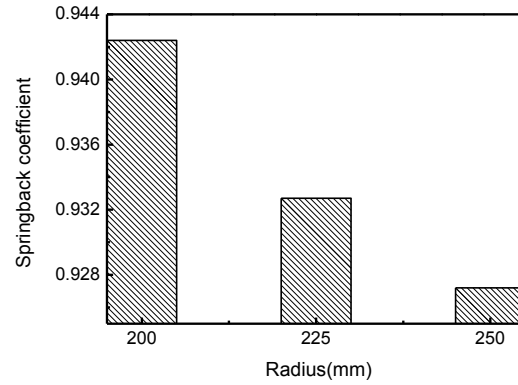


Fig. 8: The influence of different radius

Table 2: The parameters settings of different forming force

Material	Thickness(mm)	Cylinder radius (mm)	Forming force(N)
1060Al	2.0	200	750、1000、1250、1500

The springback distance of the workpiece increases with the increasing of the distance to the center of symmetry. However, the increasing trends of springback slow down when the distance from the center of symmetry is over 50mm.

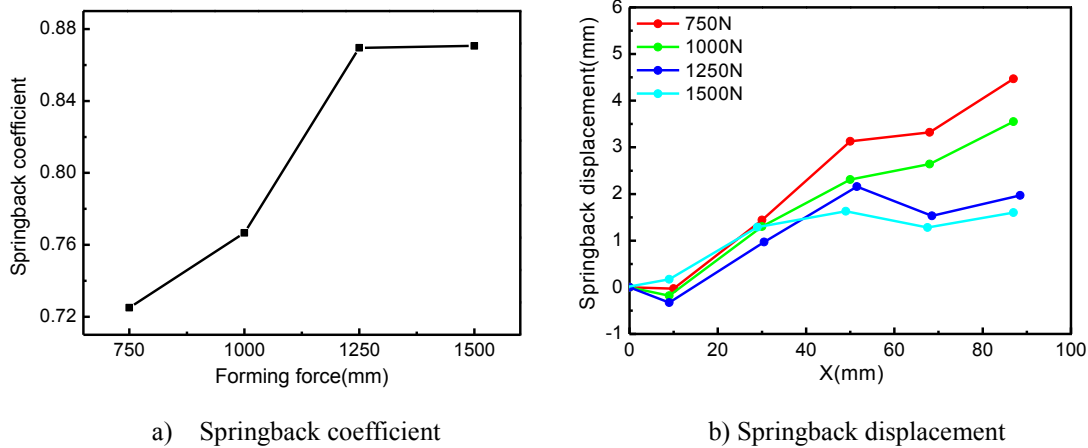


Fig. 9: The influence of forming force

Stress concentration appears at the sheet metal between the second and the third row of the matrixes, as shown in Fig.10. Plastic deformation there increases obviously and the increasing trend of springback slows down.

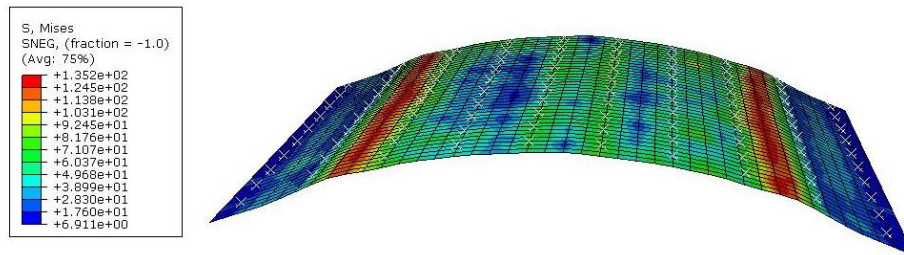


Fig. 10: Mises stress of the workpiece

6. CONCLUSION

(1) In this paper, Force-Displacement Separated Control Multi-Point Forming technology (FDSC MPF), a new technology of sheet metal forming is proposed. The technology realizes the separated controlling of displacement and forming force through the forming process.

(2) Through the contrast of two forming methods by numerical simulation and experiment, it is confirmed that the springback can be restrained effectively in FDSC MPF.

(3) The springback decreases with the increase of forming force and the decrease of cylindrical radius.

ACKNOWLEDGEMENTS

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