Experimental Study on the Influence of Isostatic Pressure Support on Single Point Incremental Forming Force

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Experimental Study on the Influence of Isostatic Pressure Support on Single Point Incremental Forming Force

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Abstract. The hydraulic support is introduced into the single point incremental forming technology to obtain a new single point incremental forming technique with an isostatic pressure flexible support. Thereby, the forming process instability and the defects of the part due to the suspension of the sheet are eliminated. The isostatic pressing system are designed and developed to experimentally study the force in the forming process. The experimental results show that the horizontal forces Fx and Fy in forming process of the new technology have a certain increase compared with the force of the traditional single point incremental forming, but the increase is not large. However, the axial force Fz changes relatively large. As the isostatic pressure increases, the axial force increases.

1. Introduction

The idea of "layered manufacturing" in rapid prototype technology to sheet metal processing was formed into single point incremental forming (SPIF). The complex target components could formed quickly without the special die [1]. However, Due to the limited bearing capacity of the plate in SPIF, the forming parts was prone to instability, wrinkle, fracture and the other defects. It is found that the forming defect is closely related to the change of forming force [2].

Jyhwen [3] proposed a prediction model of effective forming force based on the experimental measurement result of forming force. Bansal et al. [4] proposed a new method for predicting the forming force size based on the experiment of forming force, which is more accurate than the previous prediction of forming force. Li et al. [5] researched the effect of ultrasonic vibration on the forming force based on the design of ultrasonic forming equipment, the results show that ultrasonic vibration could effectively reduce the forming force and improve the surface quality of the forming process. In Duflou's work, the position of the forming was preheated by laser, and then the progressive forming process was carried out, the parts have obvious effects on increasing the maximum forming Angle, improving the forming precision and reducing the forming force [6]. The effects of thickness, step down, tool head diameter and forming angle on the defects such as square cone drum and material heap extrusion were studied by Hussain et al [7], the above defects were well controlled through reasonable selection of process parameters.

In this study, the isostatic pressure support technology was introduced into the single point incremental forming process to improve the quality of formed parts. The sheet metal was subjected to

isostatic pressure in forming process, which formed a new hydraulic support single point incremental forming technology.

2. Hydraulic support single pint incremental forming principle

The isostatic pressing flexible support single pint incremental forming principle is shown in Fig. 1. In the figure, 1 is the tool head, 2 is the initial sheet, 3 is the forming sheet, 4 is the sealing ring, 5 is the pressure gauge, 6 is the two-position two-port reversing valve, 7 is the relief valve, 8 is the check valve, 9 is the hydraulic pump. The hydraulic pump is driven by a motor to draw the hydraulic oil out of the tank. The hydraulic oil is pumped into a closed fixture. The hydraulic oil then returns to the oil tank along the return port, so that the sheet continues to be subjected to constant isostatic pressure during the forming process. The function of the relief valve is to regulate the isostatic pressure. The result is displayed by the pressure gauge. On the basis of the traditional single point incremental forming technology, hydraulic support is added to the bottom of the sheet. This allows the sheet to be not only subjected to the pressing action of the tool head but also to the bottom-up support provided by the hydraulic pressure. This new technology can improve the uniformity of wall thickness and the forming quality.

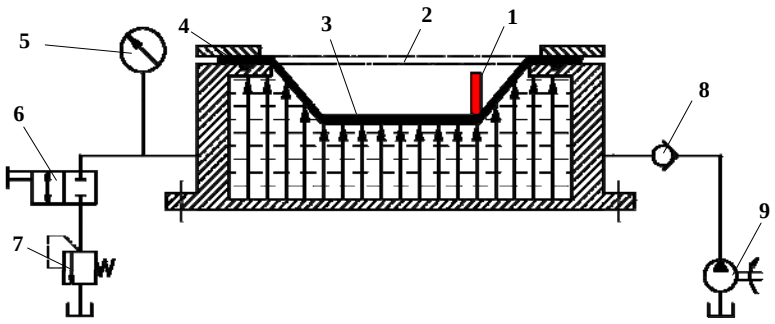

Figure 1. Principle of hydraulic support single point incremental forming technology

The tool head material was made of tungsten high speed steel of the grade X210CrW12. Its hardness is 62 HRC, which has the advantages of high hardness, high wear resistance and high heat resistance. The L-HM46 lubricant was selected as the experimental lubricant. The formed material was selected from AL1060 aluminum alloy with a thickness of 1 mm and a size of 140 mm × 140 mm. It has good ductility and plasticity and can satisfy conventional plastic forming.

3. Experimental research

3.1. Experimental equipment and materials

The Qinchuan MVC510 vertical CNC machine tool was used as the experimental platform to build the experimental device. The experimental device consists of three parts: a forming device, a hydraulic device and a measuring device, as shown in Fig. 2. The forming device consists of a tool head and the container fixture. The hydraulic device comprises a pressure gauge, a relief valve, a check valve, a hydraulic pump, a fuel tank and the like. The measuring device includes KISTLER 9257B three-way load cell, charge amplifier, Beijing popper and terminal computer.

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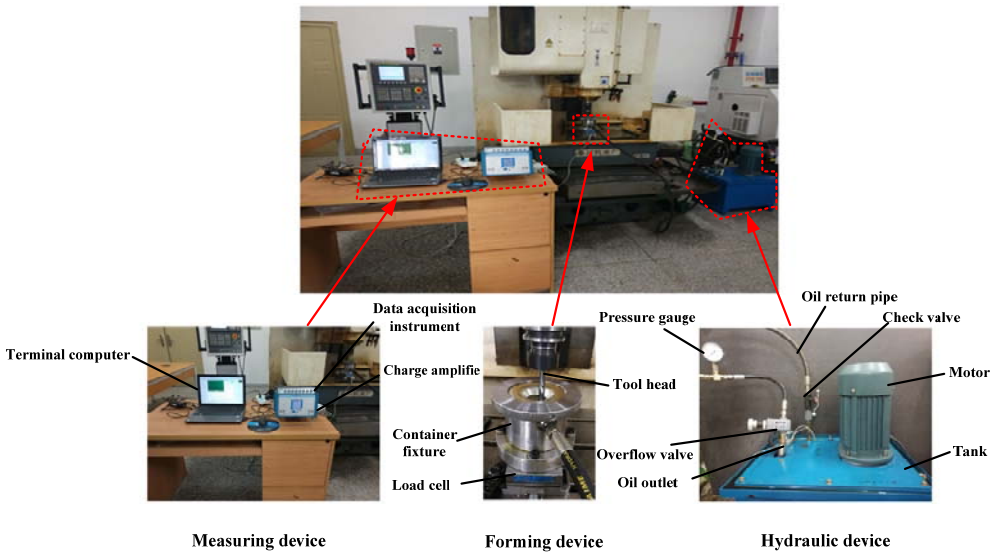

Figure 2. The experimental device

3.2. Experimental results and analysis

The process parameters were selected as follows: tool head diameter 10 mm, layer spacing 1 mm, forming angle 45 °, spindle speed 700 r/min, feed rate 550 r/min. When the process parameters were kept unchanged, the supporting isostatic pressure was changed. The variations of Fx and Fy and Fz under different isostatic pressure parameters was obtained, as shown in Fig. 3 and Fig. 4 and Fig. 5.

It can be seen from Fig. 3 and Fig. 4, under the same conditions, as the isostatic pressure increased, Fx and Fy also increased. When the isostatic pressure increased, the sheet not only overcame the deformation resistance of the material but also overcame the supporting force exerted by the isostatic pressure. At that time, more deformation energy was required to cause plastic deformation, so Fx and Fy also increased. However, since the isostatic pressure direction is vertical and does not coincide with the X and Y directions, the increase of Fx and Fy is not large.

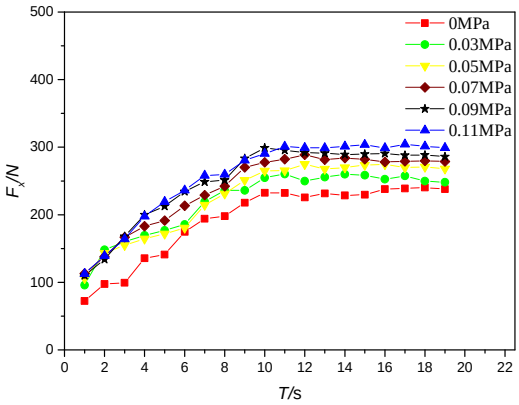

Figure 3. Comparison of different back isostatic pressure Fx

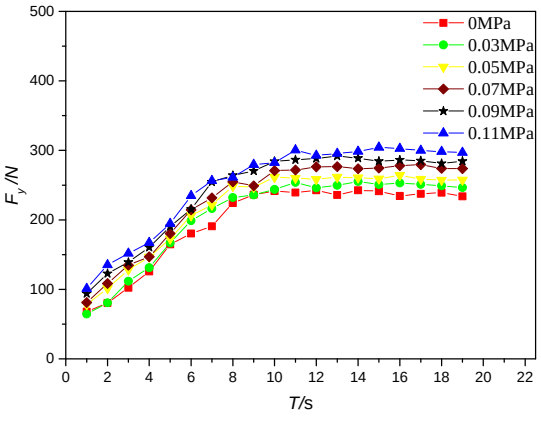

Figure 4. Comparison of different back isostatic pressure Fy

It can be seen from Fig. 5, the Fz is much larger than the axial force without the hydrostatic support, and increases as the isostatic pressure value increases. Since the isostatic pressure caused upward deformation in the initial forming process, the deformation of the sheet per unit area was relatively large. Thereby the Fz was relatively large. The accuracy errors of the molded part under different

isostatic pressures were obtained using the V-TOP high-precision blue light scanner and Geomagic Qualify 2013, as shown in Fig. 6. It can be seen that when the isostatic pressure value is 0.06 MPa, the accuracy error of the sheet geometric shape is the smallest, which is 1.24 mm.

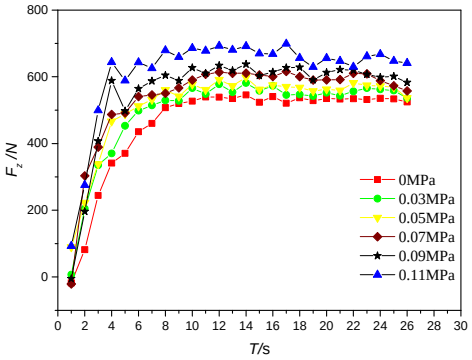

Figure 5. Comparison of different back isostatic pressure Fz

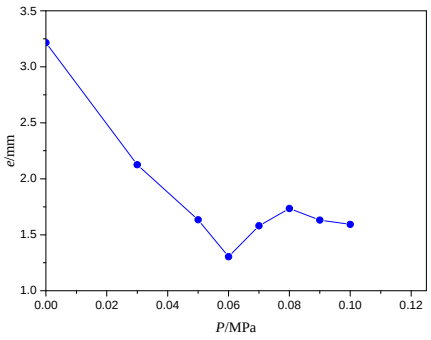

Figure 6. Springback in the curved transition zone

4. Conclusion

It can be seen from the experiments of hydraulic support single point incremental forming technology that the support isostatic pressure has a significant influence on the forming force during the forming process. As the isostatic pressure o increases, Fx, Fy and Fz continue to increase. The increase of Fx and Fy are small, and gradually increases to zero as the isostatic pressure increases. The increase of Fz is relatively large. The isostatic support single point incremental forming technology can effectively reduce the geometric error value and improve the forming quality of the part. The isostatic pressure is nonlinearly related to the accuracy. Under a certain conditions, there is a pressure extreme value that makes the part the highest precision. And the geometric error is the smallest.

Acknowledgments

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References

[1] Duflou J R, Habraken A M, Cao J, et al. Single point incremental forming: state-of-the-art and prospects [J]. International Journal of Material Forming, 2017 (2): 1-31.
[2] Ankush Bansal, Rakesh Lingam, Sateesh Kumar Yadav, N. Venkata Reddy. Prediction of forming forces in single point incremental forming [J]. Journal of Manufacturing Processes, 2017, 28:486-493.
[3] Jyhwen Wang, Mahesh Nair, Ying Zhang. An Efficient Force Prediction Strategy in Single Point Incremental Sheet Forming [J]. Procedia Manufacturing, 2016, 5: 1-9.
[4] Ankush Bansal, Rakesh Lingam, Sateesh Kumar Yadav, N. Venkata Reddy. Prediction of forming forces in single point incremental forming [J]. Journal of Manufacturing Processes, 2017, 28:486-493.
[5] Pengyang Li, Jin He, Qiang Liu, Mingshun Yang, Quandai Wang, Qilong Yuan, Yan Li. Evaluation of forming forces in ultrasonic incremental sheet metal forming [J]. Aerospace Science and Technology, 2017, 63:132-139.
[6] Duflou J R, Callebaut B, Verbert J, et al. Improved SPIF performance through dynamic local heating [J]. International Journal of Machine Tools & Manufacture, 2008, 48 (5): 543-549.
[7] Hussain G, Gao L, Hayat N. Forming Parameters and Forming Defects in Incremental Forming of an Aluminum Sheet: Correlation, Empirical Modeling, and Optimization: Part A [J]. Materials & Manufacturing Processes, 2011, 26 (12): 1546-1553.