Research on the forming of an asymmetric cylindrical part by two-sided hydromechanical deep drawing method

Junfeng Lin[†]
School of Materials Science and Engineering, Harbin Institute of Technology, Harbin, Heilongjiang 150001, China
[†]E-mail: jflin@hit.edu.cn
www.hit.edu.cn

Bohan Lin
College of Aerospace and Civil Engineering, Harbin Engineering University, Harbin, Heilongjiang 150001, China
E-mail: 2640206575@qq.com
www.hrbeu.edu.cn

Sule Feng
Research Institute of Shanghai Academy of Spaceflight Technology, Shanghai 201600, China

Sheet hydroforming has become an effective method in the material manufacturing fields because of its many advantages. A new metal forming method of drawing with two-sided pressure was investigated in this paper, in order to deal with the problem of the defects in asymmetric cylindrical part processing. This method exerts liquid pressure on the upper sheet surface coordinating with the counter pressure. The upper pressure can offset the pre-bulging which is suited for forming complex shape parts such as cylindrical and semi-ball cup. The results showed that pressure increased, and the single drawing ratio 2.2 was achieved by drawing with two-sided pressure compared with 1.9 in traditional forming.

Keywords: Hydro mechanical; Cylindrical part; Deep drawing; Sheet hydroforming.

1. Introduction

With the development of aerospace and automotive industry, domestic and foreign industry highly demands for structural lightweight, precision composite and combined forming[1]. Sheet hydroforming technology is an advanced metal flexible manufacturing technology which liquid is used as transmission media to form the parts[2]. it has some advantages such as short manufacturing cycle, low deformation, formed parts has high precision and good surface quality[3].

To deal with the problem of the defects in cylindrical cup processing, a new metal forming technology of drawing with two-sided pressure was investigated in this paper, the new forming technology can offset the pre-bulging which lead to rupture[4],and have many

[†]Work partially supported by National Natural Science Foundation of China (item number: 52375319).

Y. Zhang and M. Ma (eds.), *Proceedings of the 7th International Conference on Advanced High Strength Steel and Press Hardening (ICHSU 2024)*, Atlantis Highlights in Materials Science and Technology 3,
https://doi.org/10.2991/978-94-6463-581-2_13

advantages such as: (1) two-sided pressure changes the force distribution in forming which increases the deformation;(2) two-sided pressure reduces the radial stress and prevent premature rupture which ensuring higher limiting drawing ratios; (3) two-sided liquid helps in reducing friction and results in a more uniform part thickness distribution;(4) Significant saving processes, reducing costs and improving production efficiency[5].

2. Theoretical analysis

In this paper, an asymmetric cylindrical part of 5A06 aluminum alloy was investigated, shown in Fig1, the thickness 1mm，Yield strength 135Mpa,Tensile strength333Mpa was measured is experiment.

Drawing two-sided with two-sided pressure is one of the sheet hydroforming technology which exerts liquid pressure on the upper sheet surface coordinating with the counter pressure. Another oil-in was designed in drawing die to achieve the upper pressure.

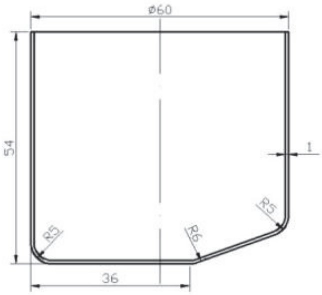


Fig. 1. Asymmetric cylindrical part

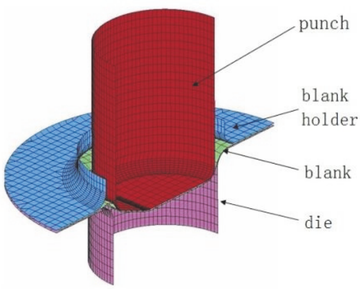


Fig. 2. Numerical simulation model

3. Numerical simulation

The process was simulated using the software Dynaform5.7 and the explicit finite element solver LS-DYNA, the explicit element solver model was shown in Figure 2. The punch, blank holder, blank and die were modeled as rigid tools. The material model of 5A06 was used to define the flow characteristics of the blank material. Half of the part was used in simulation as the symmetrical structure. The gap between blank holder and die 1.1mm, the punch speed 500mm/s were used in simulation.

The simulation process was carried out by using different upper pressures in order to optimize the drawn cup thickness(counter pressure 30Mpa), as is shown in Figure 3. Then on the basis of first step changes the two-sided pressure to find the optional pressure value in Figure 4.

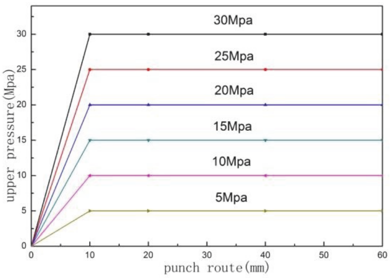


Fig. 3. Upper pressure load path

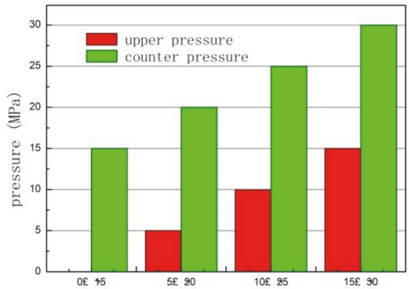
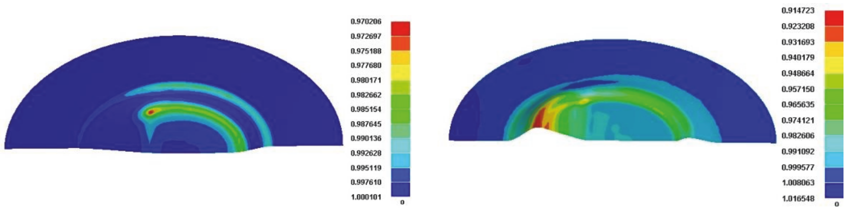


Fig. 4. Two-sided pressure load path

4. Results and discussion

4.1. *Upper pressure influence on thickness distribution*

Figure 5 compared the simulation results of upper pressure effect and no upper pressure effect. It can be seen that, a bulge forms in the unsupported blank region which lead thickness. And upper pressure can optimizing the bulge height which reduces the possibility of blank rupture due to bulging.



(a)Pre-bulging induces thinning (b)Upper pressure offsets bulging

Fig. 5. Upper pressure influence on forming

Figure 6 shows the cup thickness in different upper pressures, it can be seen that, when counter pressure 30Mpa, upper pressure 5Mpa (the pressure different 25Mpa), the minimum thickness was 0.80mm.

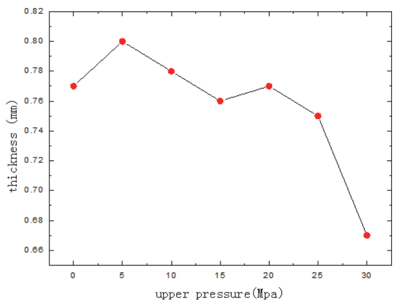
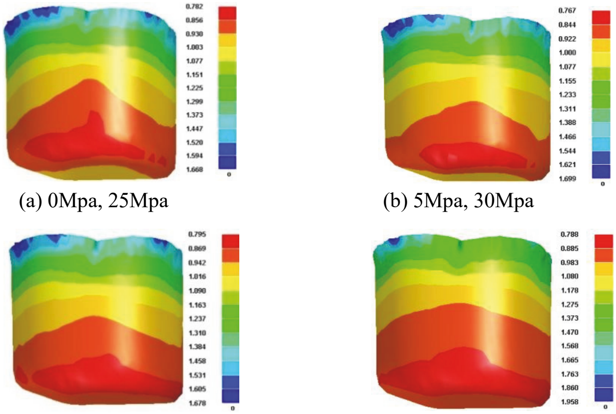


Fig. 6. Minimum wall thickness curve under different pressures

4.2. *Two-sided pressure influence on thickness distribution*

Figure 7 shows the thickness distribution under different two-sided pressures. It can be seen that cup thickness became uniform as two-sided pressure increased, when upper pressure 0Mpa,counter pressure 25Mpa, the minimum thickness 0.77, thinning rate 23% and the thickness different 0.93mm. when upper pressure 10Mpa, counter pressure 35Mpa, the minimum thickness 0.8mm, thinning rate 20% and the thickness different 0.88mm.



(a) 0Mpa, 25Mpa (b) 5Mpa, 30Mpa

(c) 10Mpa, 35Mpa (d) 15Mpa,40Mpa

Fig. 7. Thickness distribution under different pressures

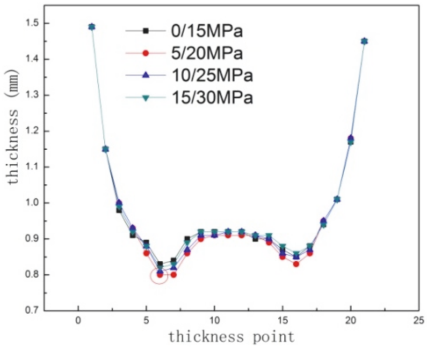


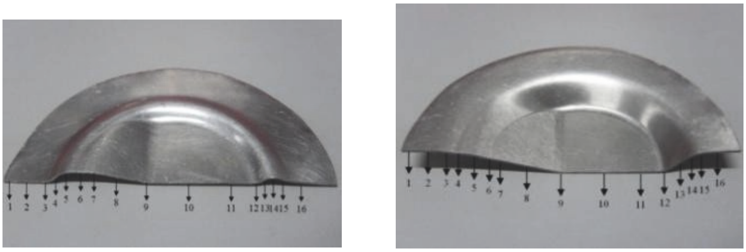
Fig.8. Thickness distribution curve under different pressure

The thickness distribution was shown in Fig 8 under different pressures. It can be seen that the serious thickness decreases at the punch radius. As the pressure increased, the thickness become uniform because of the liquid lubrication effect.

5. Experimental Research

The drawing die was divided into five parts: upper die, lower die, punch, hydraulic pump and sealing circle. Lower die was filled with oil which produced counter pressure. Upper die was designed to realize upper pressure. Sealing circle and sealing ring were designed to realized static seal and dynamic seal.

In conventional hydromechanical deep drawing, high counter pressure results in rupture due to bulge which is shown in Figure 9 (a), in the present die set, upper pressure can optimize the bulge and make thickness distribution uniform. As is shown in Fig. 9(b).



(a) None upper pressure (b) Existence upper pressure

Fig. 9. Upper pressure influence on forming

Sixteen points were selected in the formed parts to compare the thickness distribution. Fig 10 shows the thickness distribution. It can be seen that with upper pressure, the thickness distribution became more uniform than with no upper pressure.

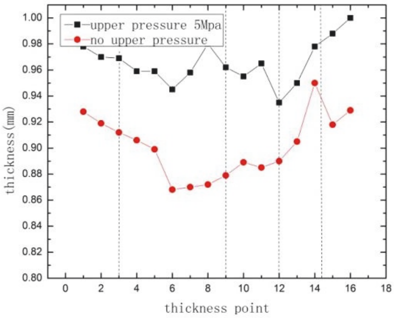


Fig. 10. Comparison of thickness distribution

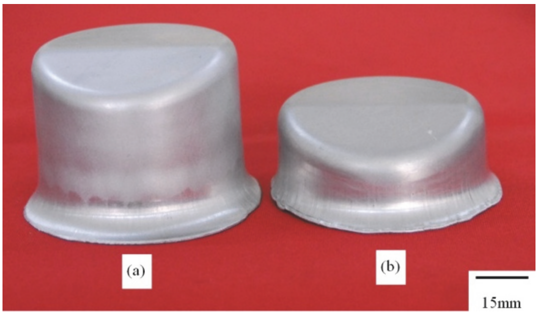
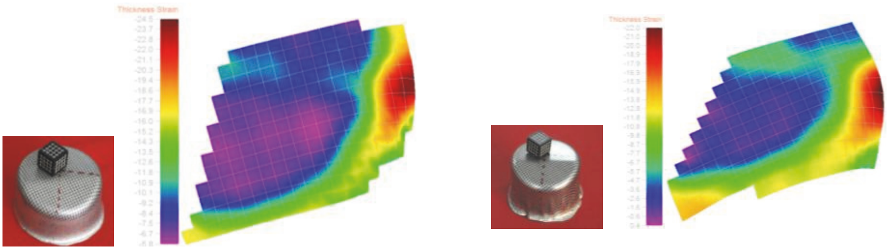


Fig. 11. Comparison of formed part

Figure 11 compared the formed parts of two-sided pressure drawing and conventional deep drawing. It can be seen that, the drawing ratio was 1.7 in conventional deep drawing, however using upper pressure the drawing ratio can increase to 2.2, with 30% increased.



(a)Upper 0Mpa, lower 10Mpa (b)Upper 10Mpa, lower 20Mpa

Fig. 12. Typical zone thickness distribution

The ASAME strain test analysis software was used to analysis the typical regional strain, as is shown in Figure12. When upper pressure 0Mpa, counter pressure 10Mpa, the maximum thickness strain at corner -24.5%, at bevel face -3.6%, as the two-sided pressure increased, the absolute value of thickness strain decreased at the same time.

Thickness distribution under different pressures were measured and drawled into curves (Figure 13), it can be seen that, when upper pressure 0Mpa, counter pressure 10Mpa, the formed cup minimum thickness 0.68mm, as the upper pressure increased, the minimum thickness increased. When upper pressure 5Mpa, counter pressure 15Mpa, the minimum thickness 0.74mm, when upper pressure increased to 10Mpa, counter pressure increased to 20Mpa， the minimum thickness increased to 0.77mm. As a result, two-sided pressure can obviously prevent rupture, improve uniform thickness and finally improve the production quality.

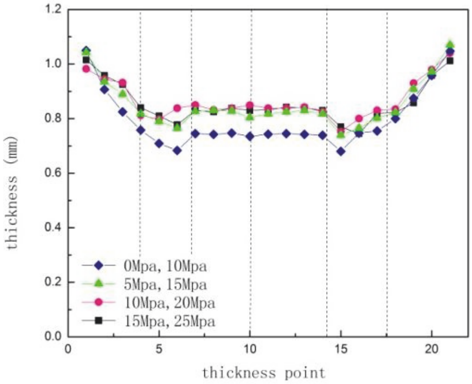


Fig. 13. Section thickness distribution curve under different pressures

6. Conclusions

In this paper, theoretical analysis, numerical simulation and experimental studies were used in deep drawing with two-sided pressure, the results showed that: The variation of the pressure in the die cavity affects the forming process significantly, upper pressure plays a positive role in offsetting bulge and prevent rupture in deep drawing; Drawing with two-sided pressure can improve the stress distribution in deformation zone, which decrease the thickness, and can effectively improve the forming limit;When upper pressure 10Mpa, counter pressure 20Mpa, blank gap 1.1mm, a asymmetric cylindrical part with drawing ratio 2.2 can be formed.

References

1. Siegert K, Haussermann M, Losch R, Rieger R.*Journal of Material Processing Technology*, 98,251. (2000).
2. Cui,X.L.,Wang,X.S.,Yuan,S.J. *Journal of Materials Processing Technology*. 214,pp.1341–1351. (2014).
3. Feifei Zhang, Xifeng Li,Yongchao Xu , Jun Chen, Jieshi Chen , Gang Liu, Shijian Yuan. *Journal of Materials Processing Technology*. 221,pp.13–20. (2015).
4. Lihui Lang,Joachim Danckert, Karl Brian Nielsen , Xibin Zhou *Journal of Materials Processing Technology*. 167,pp.191–200.(2005).
5. T.Khandeparkar, M.Liewald. *Journal of Materials Processing Technology*, pp.246-254.(2008).