Journal of Materials, Processing and Design (2019) 3: 1-9
Clausius Scientific Press, Canada
DOI: 10.23977/jmpd.2019.31001
ISSN 2516-0923

Study on Multi Process Forming Process of Aluminum Alloy Flat Flange

Zhiyuan Guo[a, *]

School of Mechanical Engineering, Tianjin University of Technology and Education, Tianjin 300222, China

[a]15762185532@163.com

*Corresponding author: 15762185532@163.com

Keywords: hydrodynamic deep drawing, Rigid and Soft Combination, numerical analysis, Forming process

Abstract: Taking the plane flange drawing part as an example, the traditional forming process is mostly rigid drop forming in the early stage and artificial knock shaping in the later stage, so the qualified rate of the part is low in the forming process. It has a long production cycle, costs a lot of energy and other material resources, and the manufacturing cost is high. The application of the forming technology based on the combination of rigid and flexible in the forming process of such parts can effectively solve the problems existing in the traditional forming process of such parts, and effectively improve the surface quality of parts. By using DYNAFORM finite element analysis software to analyze the forming process of parts, we can accurately analyze the advantages and disadvantages of traditional rigid drop forming and rigid flexible combination forming process. Through the combination of rigid and flexible forming process, adjusting the pressure of flexible medium on parts and the size of blank holder gap in the forming process can solve the technical problems such as the rupture of flat flange drawing parts in the deformation stage, excessive local thinning and the surface quality of parts after forming not up to standard.

1. Introduction

In recent years, with the rapid development of China's aerospace industry, in order to meet the requirements of aircraft design, to make better use of its space structure and improve the degree of product lightweight, the design of parts used in aerospace vehicles is becoming more and more personalized, which makes the parts show the complexity of the shape in the design. It is very difficult to use the traditional stamping forming process to produce parts. It is difficult to meet the requirements of parts production due to its high cost and product qualification rate [1-2]. The multi process forming process of rigid flexible combination is a forming process which combines the traditional stamping process with the advanced liquid filling forming. It is characterized by replacing the rigid die with the flexible medium, reducing the contact between the sheet metal and the die, reducing the friction in the forming process, promoting the sheet metal flow, reducing the local thinning of the parts, and greatly improving the forming feasibility of the parts. The traditional stamping process is used to close the die rigidly to solve the problem of local small features of parts [3-5].

Aluminum alloy material has physical properties such as high strength, strong toughness, low density and chemical properties such as corrosion resistance, so it is widely used in aerospace, automotive parts lightweight and other fields, but aluminum alloy has poor plasticity and low yield strength in the forming process, which makes aluminum alloy poor formability [6-9].

With the development of modern industry, the technology of hydroforming is becoming more and more mature through a lot of practice, especially in the forming of sheet and tube parts, such as in the forming of complex structural parts in aerospace vehicles [10]. Its working principle is to use the flexible medium such as emulsion, hydraulic oil, water and so on to replace the die in the rigid forming process, and to use the flexible medium to transfer the pressure to make the advanced technology of part forming. Compared with the traditional rigid stamping method, the liquid filled deep drawing technology has many outstanding highlights, which can ensure the surface quality of parts, meet the requirements of forming accuracy of parts, reduce the spring back of parts after forming, reduce the forming process of parts, etc. [11-12]. The forming method combining liquid filling forming with traditional forming process is conducive to the more integrated forming of parts, and the local forming and shaping of parts by traditional forming process make the parts more optimized [13-14]. Now, the forming process analysis of aerospace parts is studied as an example.

2. Dimensions and Materials of Parts

2.1 Overall dimension of parts

In this paper, the overall dimensions of multi process forming parts are 200 mm long, 100 mm wide, 25 mm high and 1.5 mm thick, as shown in Figure 1. One side of the part is inclined section, the other side is spherical end with radius of 30. There are two small features in the plane flange area. Because the forming height of the part is different, the defects of traditional deep drawing are local wrinkling of small features, and the spherical end is too thin and easy to crack.

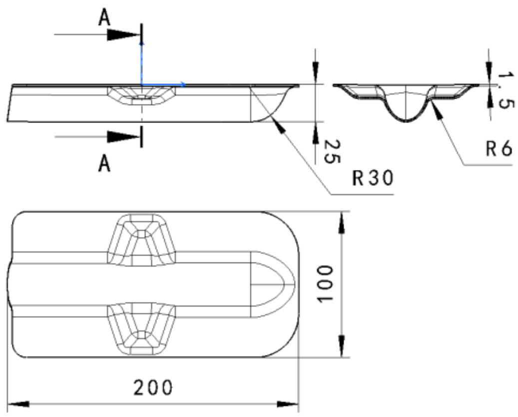


Figure. 1 Overall dimension of parts

2.2 Part material

The material used for the parts is aluminum alloy 2024-O, which is an aluminum copper magnesium alloy. The material has excellent mechanical and pressure processing properties, and can be strengthened by heat treatment process. This material can produce a lot of complex products, especially in the aerospace vehicle parts manufacturing application is very common. The aluminum alloy can show different properties under different heat treatment conditions, and its tensile strength and toughness can be effectively improved after solution treatment and normal temperature aging. The mechanical properties of the material are obtained through uniaxial tensile test, as shown in Table 1:

Table 1 mechanical property parameters of 2024 aluminum alloy

Material Science	Yield strength/MPa	tensile strength /MPa	Average elongation%	Elongation at break%
2024	65	169	14.7	18
Poisson's ratio μ	Thickness anisotropy coefficient R	Hardening hardening index n	Hardening hardening system k	Modulus of elasticity E/Gpa
0.31	0.515	0.212	297.5	72

3. Establishment of Finite Elementmodel

The three-dimensional model of the part is established by CATIA software. Because of the defects of the traditional forming process, the part can not meet the process requirements, so the two sequence forming process is adopted. Establish the finite element analysis digital analog tool as shown in Figure 2 and figure 3, and save each digital analog as a file of. IGS format. The initial blank size of the part is shown in Figure 4, with a length of 250mm, a width of 133mm and a thickness of 1.5mm. The finite element analysis software of this part is DYNAFORM 5.9.3. The model is imported into the software and meshed.

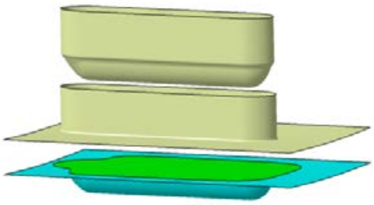


Figure. 2 Finite element model of first order forming

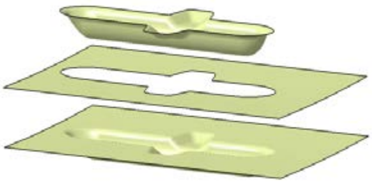


Figure. 3 Finite element model of second order forming

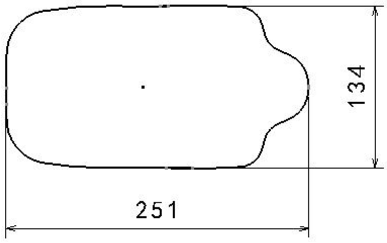


Figure. 4 Blank size

4. Numerical Simulation Analysis of Part Forming

DYNAFORM, a process analysis software, is a simulation analysis software developed by ETA and LSTC for plate and tube forming, die design, etc. so far, the software has been widely used in plate and tube forming process analysis. The solver used in the software can simulate the problems existing in the process of forming parts quickly and truly for LS- DYNA. It can not only provide the basis for optimizing the part forming in the later stage, but also shorten the time of die test and save the cost. The postprocessor of the software can display the stress and strain state in the forming process of the part, and then judge the feasibility of the forming process plan of the part.

4.1 Traditional rigid drawing technology

The numerical analysis of traditional one-step drawing process is shown in Figure 5. The flange area of the part is wrinkled, and the thinning at the bottom fillet has exceeded the fracture elongation of the material, resulting in fracture. This is because the drawing ratio of the rigid drawing is smaller than that of the liquid filled drawing, and there is no friction between the die and the sheet metal, so the thinning rate of the part is larger and the part breaks.

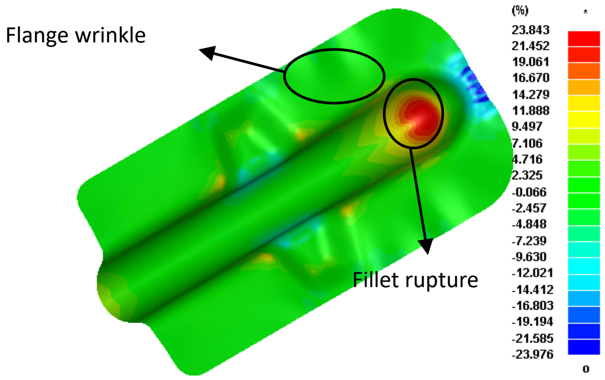
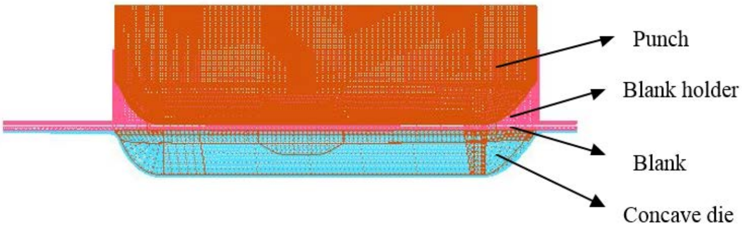


Figure. 5 Numerical analysis of rigid drawing

4.2 Establish simulation model



(a) First order numerical analysis model

(b) Two order numerical analysis model

Figure. 6 Numerical analysis model

Using the sheet metal forming module in DYNAFORM, the thickness is set to 1.5mm. In the established model, all tools are regarded as rigid bodies and mesh. The structural material type is 36× and the plate material is 4-node BT shell element. The three-dimensional digital analog grid is divided. The numerical analysis model is shown in Figure 6.

4.3 Establishment of boundary conditions for first order forming

(1) Friction coefficient

The friction force between the blank and the tool is an important factor that affects the flow of the blank, and it is also the root of the part forming. In the part forming process, because of the overflow of liquid, it is easy for the relative sliding between the blank and the tool, so the friction coefficient of the blank holder and the lower die is set as 0.08, and there is no relative sliding between the upper die and the plate of the tool, so the friction coefficient of the punch is 0.125.

(2) Pressure loading curve of liquid chamber

When the workpiece is filled with liquid, the relationship between the pressure of the liquid chamber and the time directly determines the final forming effect of the workpiece. According to the sequence and structural characteristics of the part in the deformation process, the best pressure change curve of the liquid chamber is obtained as shown in Figure 7.

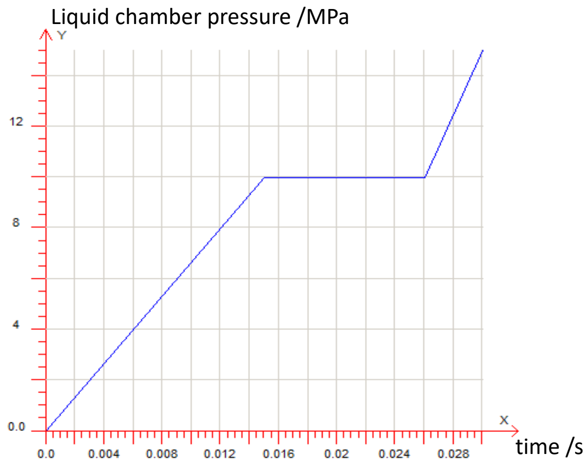


Figure. 7 Pressure loading curve of liquid chamber

The downward displacement of the upper die is 27 mm, and the part is expanded reversely by the pressure of the liquid chamber in the early stage of forming, so as to gather materials. If the reverse expansion pressure is too large, the parts will wrinkle in the later stage. If the reverse expansion pressure is too small, the blank will contact with the fillet at the inlet of the die during the forming process, and the friction will be reduced and blocked, so that the flow of the blank will be blocked, and the effect of friction retention will not be achieved. In the later stage, the pressure of the liquid chamber is continuously increased to ensure that the parts are close to the die surface before the final forming.

(3) Calculation of drawing force

The drawing force of the part is divided into two parts: the common drawing force and the reaction force of the liquid chamber pressure.

$$F_D = F_1 + F_2$$

F_1—Drawing force of common drawing (KN);

F_2—Reaction force of liquid chamber pressure (KN).

F_1 It can be calculated according to the empirical formula:

$$F_1 = \pi d_p t \sigma_b K_d$$

In style

t- Sheet thickness (mm);

d_p- Diameter of drawing parts (mm);

σ_b - Tensile strength (MPa);

K_d- Coefficient related to drawing ratio and relative thickness $K_d = 0.2 \sim 1.1$.

F_2- Reaction force of liquid chamber pressure:

$$F_2 = \frac{\pi d_p^2}{4} p_{cr}$$

p_{cr}- Liquid chamber pressure.

The drawing force F_D is:

$$F_D = \pi d_p t \sigma_b K_d + \frac{\pi d_p^2}{4} p_{cr}$$

Through calculation, the drawing force is 250KN.

4.4 Analysis of simulation results

(1) Forming process analysis of first-order parts

Set the corresponding process parameters according to the boundary conditions, and get the corresponding simulation analysis results through the computer numerical analysis. The forming analysis of the parts is shown in Figure 8.

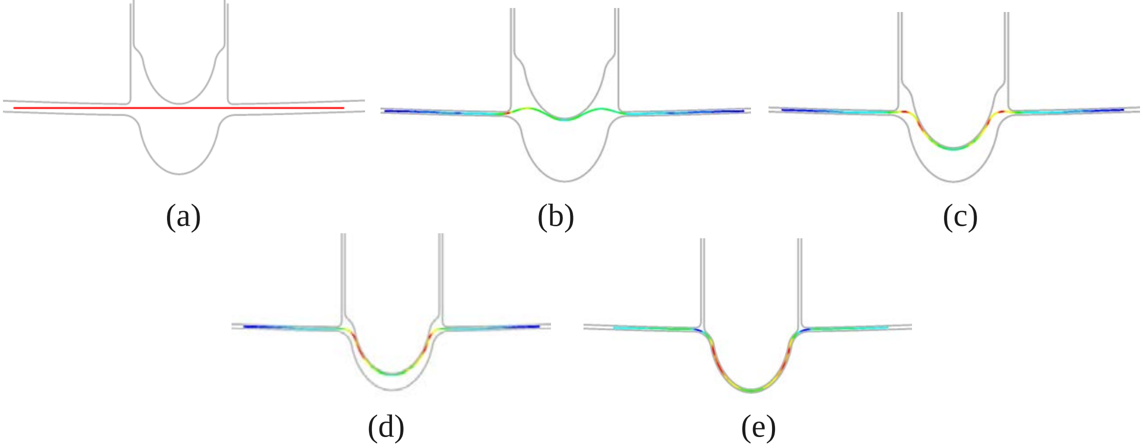


Figure. 8 Section of part forming process

It can be seen from the forming process of the part that when the punch touches the blank and forms the bottom fillet, due to the effect of the liquid chamber pressure, the sheet metal tightly adheres to the tool surface, and this part of the sheet metal will not flow. Relative to the forming of the side of the part, the sheet metal flow at the flange is needed to supplement the material, so as to reduce the thinning rate of the part and facilitate the forming of the part.

According to the analysis results, the first order forming limit diagram can be obtained as shown in Fig. 9. The first order forming has no wrinkling and fracture after adopting the liquid filled drawing process. As shown in Figure 10, the maximum thickness reduction rate of the first sequence forming of the work piece is 22.6% at the end flange, and the maximum thickness reduction position of the part appears at the bottom fillet. The maximum thickness reduction rate is 13.8%, which is less than the material fracture elongation rate of 18%. Therefore, the parts of this sequence are within the safe range.

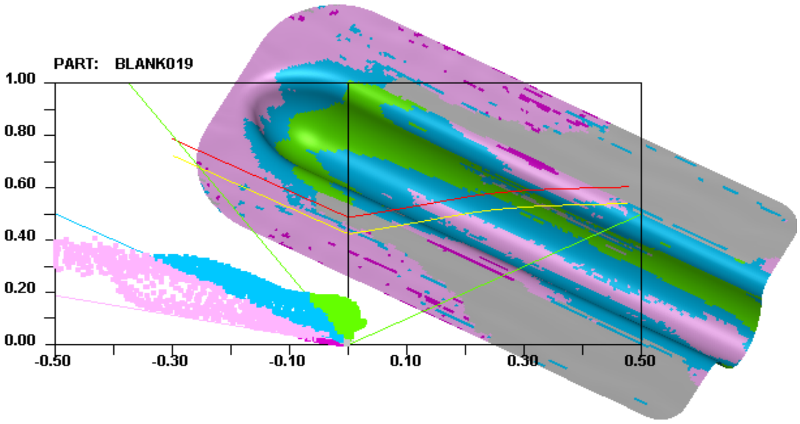


Figure. 9 Part firstly forming limit diagram (FLD)

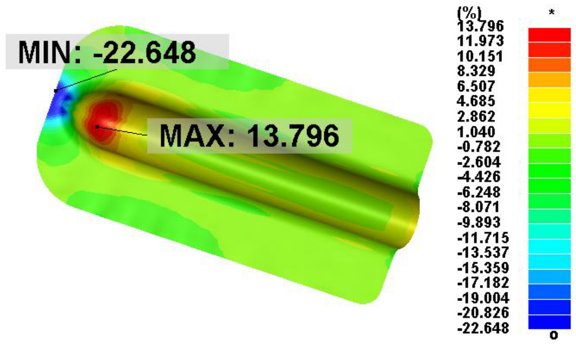


Figure. 10 Cloud chart of first order thinning rate of parts

(2) Forming process analysis of second order parts

On the basis of satisfying the conditions of the first order part forming, the second order part forming is carried out, which is a rigid die closing, forming the local features of the flange area of the part. According to the forming limit diagram of the part, as shown in Figure 11, it can be seen from the diagram that the part is free of wrinkle and fracture. The cloud chart of the second order thinning rate is shown in Figure 12. The maximum thickening is about 22.6% at the end flange, the maximum thinning is 13.85% at the end fillet, which is less than 18% of the material fracture elongation, and the small characteristic thinning rate at the plane flange is less than 8%. Through the above simulation analysis, the forming process is feasible.

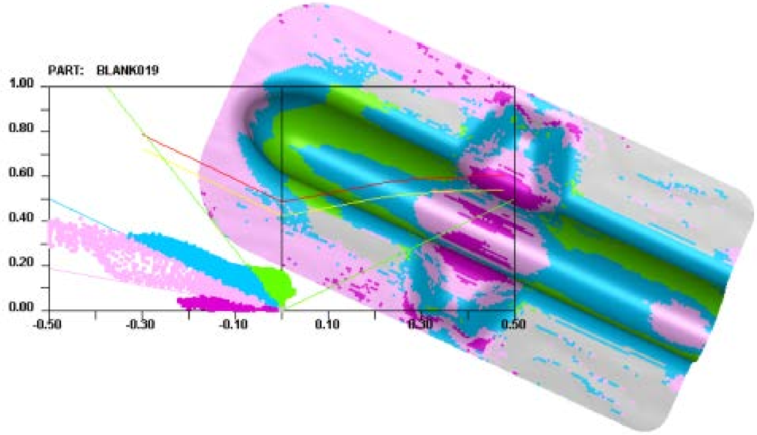


Figure. 11 Part secondary forming limit diagram (FLD)

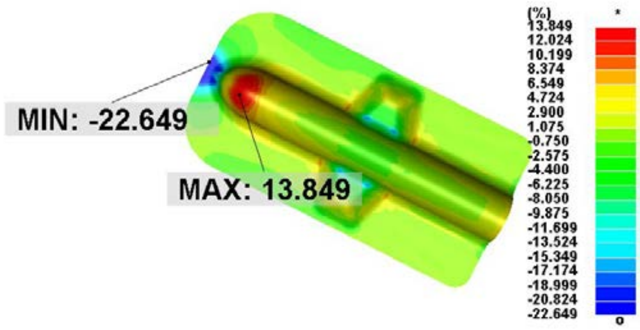


Figure. 12 Cloud chart of second order thinning rate of parts

5. Conclusion

(1) Through the above analysis, we can determine the feasibility of adopting the rigid flexible combination forming process plan for this part, and provide reference basis and guidance for the actual production and manufacturing.

(2) Adopting liquid filling forming technology can effectively avoid the defects of traditional forming technology, effectively solve the problems of wrinkling and fracture in the forming process of parts, and improve the surface quality of parts.

References

[1] Li Tao, Lang Lihui, a Dongyang. Numerical simulation of multi-stage liquid filling forming and process of complex thin-walled parts [J]. Journal of Beijing University of Aeronautics and Astronautics, 2007, 33 (7): 830-832.

[2] Lang Lihui, Wang Yongming, Xie Yasu, et al. Study on shape optimization of liquid filled forming blank for a special shaped aluminum alloy box [J]. Precision forming engineering, 2013, 5 (3): 19-23.

[3] Wang Huiting, Gao Lin, Shen Xiaohui, et al. Two way naturally pressurized aluminum alloy 2a120 liquid filled drawing [J]. Journal of Aeronautics, 2010, 31 (6): 1266-1271.

[4] XU Y C, LI F, YUAN S J. Effects of Pre-bulging on 2024 Aluminum Alloy Complex-shaped Components[J].JOM Journal of The Minerals, Metals & Materials Society, 2011, 63(5): 39-41.

[5] LANG L H, WANG Y M, XIE Y S, et al. Prebulging Effect during Sheet Hydroforming Process of Aluminum Alloy Box with Unequal Height and Flat Bottom [J]. Transactions of Nonferrous Metals Society of China, 2012,

22(2) :302-308.
[6] Chen Wei, Zhou Hongchao, Xu Xuelai, et al. Research on variable blank holder force deep drawing of box parts [J]. Forging technology, 2014, 11 (39): 20-24.
[7] Sun Hui, Ji Pingxin. Formability analysis and process research of conical drawing parts [J]. Forging equipment and manufacturing technology, 2014, 03: 63-65.
[8] Chen Xuguo, Li Jiguang, Zhang Jiegang, et al. Numerical simulation study on liquid filled drawing of 2A12 aluminum alloy flat bottom cylinder [J]. Precision forming engineering, 2015, 6: 86-91.
[9] Bagherzadeh S, Mirnia M J, Dariani B M. Numerical and experimental investigations of hydro-mechanical deep drawing process of Zaminated aluminum/steel sheets [J]. Journal of Manufacturing Processes, 2015, 18: 131-140.
[10] Wang Wei, Liu Chun, Li Dongsheng. Drawing test and finite element simulation of 2024 aluminum alloy cylinder [J]. Forging technology, 2014, 11 (11): 1-6.
[11] Bai Yunrui, Tao Jie, Guo Xunzhong, et al. Study on the formability and numerical simulation of 6061 aluminum alloy sheet [J]. Forging technology, 2013, 38 (4): 177-181.
[12] FARZAD R, SEYED J H, HASSAN M, et al. Numerical and Experimental Study of the Efficient Parameters on Hydromechanical Deep Drawing of Square Parts [J]. Journal of Materials Engineering and Performance, 2013, 22 (2): 338-344.
[13] GUO J D, ZHAO C C, CAO M Y. Process of Back Pressure Deep Drawing with Solid Granule Medium on Sheet Metal [J]. Journal of Central South University, 2014, 21 (7): 2617-2626.
[14] HUANG G M, WANG J P, CHEN T T, et al. Optimal Design for the Fluid Cavity Shape in Hydromechanical Fine Blanking [J]. International Journal of Advanced Manufacturing Technology, 2015, 78 (1-4): 153-160.