Numerical simulation study on active and passive hydroforming process optimization of box shaped part

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Abstract. Low qualified rate and inferior quality frequently occurring in the general deep drawing process of a certain box-shaped part, now use hydroforming to optimize forming process, in order to study the effect of hydroforming for improving the quality and formability, purposed five process schemes: general deep drawing, active hydroforming, passive hydroforming, general deep drawing combined with active hydroforming, passive combined with active hydroforming. Each process was simulated by finite element simulation and results were analysed. The results indicate the passive combined with active hydroforming is the best scheme which can obtain smallest thickness thinning and satisfactory formability, then optimized hydroforming pressure, blank holder force subsequently by adjust the simulation parameters. Research result proves that active/passive hydroforming is a new method for complex parts forming.

1. Introduction
Hydroforming is a kind of flexible forming technology, which use liquid pressure to force material formed as the shape of a die, better quality (excellent surface quality, less thinning of thickness, controllable wrinkling and smaller springback) and lower cost obtained at the same time in the process of hydroforming [1]. Sheet hydroforming process classified into two types: passive hydroforming and active hydroforming. The passive hydroforming which also called hydrodynamic deep drawing (HDD) [2], die filled with liquid as a pressure cavity in HDD process, it can significantly improve the forming limit compared with general deep drawing [3]. Active hydroforming combine deep drawing and bulging technology which use high pressure liquid to replace the punch, its forming limit generally less than HDD but it is more suitable for partial plastic forming and proved by production practice.

Recent years, many researchers study on the hydroforming process of box shaped part, Lang [4] investigated the pre-bulging effect in process of passive hydroforming of a box shaped part, the results show that pre-bulging height and pressure has important influences on the forming results, in paper [5]-[7], failure control methods investigated by numerical simulations and the general failure occurred in passive hydroforming process of box shaped part also discussed, in paper [8], the passive hydroforming process of different shaped box parts were studied by numerical simulations and discussed the influences of technology parameters for forming limit.

In this paper, the forming process of a box shaped part was simulated both by active and passive hydroforming, simulation results were analyzed, and proposed a new forming scheme which take the advantages of active and passive hydroforming.
2. Finite element simulation modelling

2.1. Box shaped part

The box shaped part as shown in figure 1, the maximum length of part is about 862mm, and the maximum width is about 231mm, maximum height of the part is 46mm, radius of the bottom is 7.95mm, eight reinforcing ribs equidistantly distributed on the flat surface of the part.

![Figure 1. 3D model of box shaped part](image1)

![Figure 2. Optimized shape of blank](image2)

2.2. Blank information

Blank geometrical shape of box shaped part as shown in figure 2, blank profile optimized by inverse calculation of numerical simulation, and 20mm allowance add on the profile, the material used for numerical simulation is 2xxx aluminium alloy, thickness of blank is 1.6mm.

2.3. Numerical simulation modelling plan of part forming process

In order to study the results of different forming process, meanwhile, confirm the most suitable forming process for box shaped part, five simulation schemes were proposed as below:

| Scheme number | Preforming       | Final forming               |
|---------------|------------------|-----------------------------|
| 1             | N/A              | General deep drawing        |
| 2             | N/A              | Passive hydroforming        |
| 3             | N/A              | Active hydroforming         |
| 4             | General deep drawing | Active hydroforming     |
| 5             | Passive hydroforming | Active hydroforming   |

2.4. Modelling of active and passive hydroforming

Active and passive modelling in numerical simulation software as shown in figure 3 and figure 4.

![Figure 3. Active hydroforming modelling](image3)

![Figure 4. Passive hydroforming modelling](image4)

3. Numerical simulation analysis

3.1. General deep drawing simulation result

In the process of general deep drawing, punch and die are rigid body, blank drawn into die while the punch moving downward during forming process, the maximum stress of blank is at the position of four corners, simulation result is shown in figure 5.

Blank serious thinning and the thinnest thickness is located in the corners of the box shaped part, the minimum thickness is 0.243mm, means fracture occurred at corners, and flange winkling seriously.
3.2. Passive hydroforming simulation result
In process of passive hydroforming, liquid cavity as a die, liquid pressure increased when punch moving downward, and blank formed under high pressure. In simulation, the pre-bulging pressure is 2MPa, maximum pressure is 50MPa, passive hydroforming simulation result in figure 6.

The thinnest thickness at the corner is 0.654mm, higher than the limit value in general deep drawing, but the corner still fractured due to thickness thinning over 30%, but no wrinkling on the flange.

3.3. Active hydroforming simulation result.
Pressurized liquid as a flexible punch in active hydroforming, at the first stage of active hydroforming, liquid deep drawing blank into die, then blank bulging and stretching by high pressure liquid at second stage. In simulation, maximum liquid pressure is 50MPa, and blank holder force changing with pressure.

Active hydroforming simulation result as below in figure 7, the thinnest thickness at the corner is 0.458mm, lower than the limit value in passive hydroforming, and small wrinkling on the flange.

3.4. General deep drawing combined with active hydroforming simulation result.
In order to avoid the fracture occurred at corners, appropriate preforming is needed, in this simulation, general deep drawing as preforming process, the depth of preformed box shaped part is 46mm, and the radius of bottom is 15mm, the simulation result of general deep drawing preforming process shown in figure 8, the thinnest thickness at corner is 1.156mm, and flange wrinkling obviously.

General deep drawing (GDD) preformed part taken into final forming by active hydroforming (AH), in active hydroforming, the rounded corners and reinforcing ribs of box shaped part are formed as the shape of the die, and the thinnest thickness at corner decreased from 1.156mm to 1.032mm, thickness thinning is 35.5%, that means fracture occurred, and wrinkling on the flange is not eliminate.
3.5. Passive hydroforming combined with active hydroforming simulation result.
Passive hydroforming (PH) as preforming process in this simulation, geometric shape of preformed part the same as the preformed part in general deep drawing, passive hydroforming simulation result shown in figure 8, the thinnest thickness at corner is 1.236mm, and no wrinkling on the flange.

The preformed part taken into final forming by active hydroforming (AH), in final process, the thinnest thickness of formed rounded corners decreased from 1.236mm to 1.171mm, the thickness thinning is about 26.8%, which is acceptable also the best result of all the simulations, and flange of box shaped part formed in good quality.

4. Simulation optimization
Active hydroforming pressure and blank holder force are optimized to obtain the best result for box shaped part, and the results as shown in figure 11.

![Figure 11. GDD and AH simulation](image1)

![Figure 12. Hydroforming part](image2)

5. Conclusion
By comparing five forming schemes for complex box shaped part and simulation results indicated that the forming scheme combination of passive and active hydroforming is the most suitable scheme for box shaped part with small rounded corners, simulation also proved the sheet hydroforming formability is higher than general deep drawing.

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