坯表面积增大，有利于在较小的液体压力下实现毛坯紧贴冲头加大盒形件内壁与冲头之间的摩擦力，减小已变形的盒形件的底部和角部的变形。成形过程中的液体压强对成形效果影响较大，如果液体压强太小会造成起皱，而压强过大则会造成侧壁拉裂。

本论文，在我的导师宋玉泉教授的发明专利“精冲模架”的基础上，依据几种不同的液压拉深工艺，增设了盒形件液压拉深的工装和模具。此装置的特点是：无需液压和气压源，便能施加背压和压边力的气液结合弹力结构，而且弹力的大小及弹力变化的陡度或平稳度均可调。因此，具有结构简单、造价低和使用寿命长的优点，可在单动液压机上实现液压拉深，这也证实了“精冲模架”专利的创新性和科学性。

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ABSTRACT

Keywords: Deep Drawing, Hydroforming Deep Drawing, HDD, Sheet Metal Forming, FEM Simulation, LS-DYNA

Deep drawing is one of the most used and a very important sheet metal forming process. Deep drawing is widely used in the forming of cylinder cups, ladder-shaped cups, conical cups, rectangular cups, auto-body panel and the other irregular shapes thin-walled works, etc. Now, many researches have been done to study the deep drawing process of cylinder cups and conical cups etc. TLDR(Technological Limiting Drawing Ratio) has been developed to assistant the determination of stages needed in traditional deep drawing process. However, wrinkle and crack often occurr during the traditional process for the using of rigid tools. Trial and error is used to avoid the defaults. Controling the blank holder force, adjusting the input parameters such as lubricate and changing the microstructure on the sheet metal surface, reworking the tools, all these are needed during the tial and error process, which prolonging the lead time and increasing the cost.

Hydroforming deep drawing (HDD) was first brought forward in 1955. In this process the rigid tool is replaced by flexible tools. There are friction-holding effect and friction-reducing effect during the hydroforming deep drawing process. These effects can improve the LDR, improve the quality of the surfaces. we can get more uniform thickness through this process than the traditional deep drawing process. Furthermore, it can reduce the cost of the manufacture of the mold, decrease the lead time, for that we can avoid the difficulties brought by the manufacture of anisomerous and complex-shaped mould.

To most of the hydroforming deep drawing process, researchers only introduce the advantages in the forming of cylinder cups. But there are fewer

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researches on the non-axisymmetric parts. Those most used in industry product are rectangular cups, auto-body panel and other non-axisymmetric parts. The research on the deep drawing process and the analysis on forming of rectangular box and auto-body panel will help to instructing the production and the working-out of work process. Now, researchers have some knowleges about the mechanism of deformation such as the characteristic of deformation, stress state etc. Howerver, there is no formula like that of axisymmetric shell has been proposed for the LDR of rectangular box. To the forming of rectangular box by traditional deep drawing process, researchers have found the rule for the effect of BHF on forming product, and proposed the new control methods for BHF and new equipments. Researchers proposed to apply neural network and expert system in the choice of parameters in the deep drawing process. But until now, there is no special research on the forming of rectangular box using hydroforming deep drawing process.

In terms of mechanics, sheet forming process is a complicate process including geometrical non-linear (large displacement, large deformation), physical non-linear (elastoplasticity, elastic viscous plasticity, anisotropy), contact problem, and friction problem. Along with the application and development of the computer science and the development of FEM simulation, sheet metal forming process can be simulated by FEM code. Hydromechanical deep drawing without draw die, which was proposed by Aalborg University in Danmark, is a new HDD process. The researchers of Aalborg University have done some experiments and analysis about this process on cylinder cups, which show that LDR can be increased by using this process. There is no lower ring in this method, so it is not needed to consider the flow of the liquid and the pressure changing at the flange area. For the simple boundary condition, exact FEM simulation on this process can be carried out. In this thesis, explicit dynamic code LS-DYNA is used to simulate the process of both traditional deep drawing and HDD. To verify the correctness of the material and other parameters, the balnk and tools used in this thesis are NUMISHEET’93

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benchmark geometries. The simulation results under the BHF of 19.6KN, 10.4KN and 5.3KN is consistent with the experiments directed by Joachim Danckert. HDD is compared with traditional deep drawing process, the results show that more uniform thickness can be achieved by using HDD process than traditional deep drawing process in the forming of rectangular box. However, if don't properly set the curve for the hydraulic pressure, a few of the simulation results also show that wrinkle would occurr at the corner between the flange and the side when forming by this method. The reason is that there is greater resistance at the corner in traditional deep drawing process, hydrodynamic deep drawing and hydromechanical deep drawing processes. In these processes the shoulder of the die has great resistance in normal direction, the punch force will make the deformation of the blank of that area. While there is no die in hydromechanical deep drawing without draw die, the force which imposed to the corner is provided by the pressure of the liquid. However, if the pressure is too great, the material in the straight edge will not flow so easy, which result in the fracture in the sidewall.

The product quality is affected by a few of processing parameters in HDD process. The product quality is determined by the speed of punch, blank geometry and BHF etc. which is the same as that in traditional deep drawing process. Furthermore, it is affected by the hydraulic pressure, the clearance between the punch and the blank, the clearance between the punch and the inside track of the upper ring, yet. To discuss the effects of these parameters on the product quality, the author make a great of FEM simulations. The result of the simulations show that if the height is high enough, that is the interval between punch and blank, the prebulge is like a shallow deep drawing, and the later deep drawing process is like a reversal deep drawing process. So, the direction of the flow of the metal material in the punch descend stage is opposite to that of prebulge, which is help to cleaning up the residual stress. After prebulge, the surface area of the blank near the punch is enlarged, which is propitious to increase the friction between wall of the forming parts and the

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punch under less hydraulic pressure, thus diminishes the deformation of the deformed parts such as bottom and cornor of the rectangular parts. The hydraulic pressure has great affect on the quality of the products. If the pressure is too low, wrinkles will occur, while fractures will occurr, if the pressure is too high.

According to a few processes of HDD, the author designed dies for the HDD of rectangular box, based on the patent of Pro. Song's, named Fine Blanking Die Sets. The sets have some characteristics: First, it has no need of hydraulic and pneumatic forces for the BHF. Furthermore, the changing of the forces can be adjusted easily. We can see that the sets have the merits of having simple structure, low cost and long life-span. Also, it works on single action hydraulic press for the HDD process. We can see that the Fine Blanking Die Sets patent is innovative and scientific.

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