Research on liquid impact forming technology of double-layered tubes

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Abstract. A double-layered tube is widely used and developed in various fields because of its perfect comprehensive performance and design. With the advent of the era of a double-layered tube, the requirements for double layered tube forming quality, manufacturing cost and forming efficiency are getting higher, so forming methods of a double-layered tube are emerged in an endless stream, the forming methods of a double-layered tube have a great potential in the future. The liquid impact forming technology is a combination of stamping technology and hydroforming technology. Forming a double-layered tube has huge advantages in production cost, quality and efficiency.

1. Introduction

The double-layered tube has developed ten years in tube field since 1991. Due to its corrosion resistance, higher bearing capacity and lower cost, it has a rapid development in tube field. Compared with traditional single tube, a double-layered tube has the comprehensive advantages of materials. With the physical, chemical, mechanical, and other properties of metallic materials, a double-layered tube combines property of intensity, stiffness, corrosion resistance, heat exchange. In addition, it also combines the metal material and the optimized material performance, thus saving noble material and reducing raw material cost. Therefore, a double-layered tube makes a great progress in R & D technology, production quantity, production scale, manufacturing scale and marketing team building[1].

In earlier times, a double-layered tube was impacted by production quality and cost. There is no advanced production mode and processing technology will influence forming quality and cost. At the same time, the production cost affects the business market, thus preventing the further development of a double-layered tube. In earlier, a double-layered tube has various forming methods, which could be divided into the compound between solid and solid, and compound between solid and liquid state. In earlier, a double-layered tube forming methods include aeroform method, welding forming method, centrifugal thermites forming method, centrifugal casting method, rolling forming method, and drawing forming method[2-4]. Their disadvantages and advantages are following:

Aeroform method: it can cause compound forming to various metal materials with a high efficient forming and close tightly. But this kind of forming method has a certain risk.

Welding forming method: combined closely, non-easy falling out, but it needs multi-step forming process, so the forming is tedious and high cost.

Centrifugal thermites forming method: combined closely, simple process. But chemical reaction be generated due to it requires to mix aluminum powder and other powders. So the alumina will be caused by chemical reaction, which have an influence on welding function.

Centrifugal casting method: after forming, the internal tube is fine and high purity. The forming process is simple. But, its casting surface is rough and easy to generate segregation.

Rolling forming method: friction, energy consumption and driving power are low. However, it will lead to the inner tube become thin, in severe cases, it will cause inner tube cracking, even harden the process.

Drawing forming method: under the effect of pultrusion die and draw bar, expands or reduces tube stock's radius so that the inner tube can perfectly combine the outer tube. Its process is simple and forming efficiency is high. But its adhesive strength is lower. Under the high temperature environment, the forming compound is easy to generate layers.

When makes double-layered tubes into various shapes, the traditional forming process [5] generally divides the tubes into two or more than two sheets, then begins to stamping one by one according to the forming shape you requires, to weld those forming sheets into a whole in the end. Therefore, the traditional forming methods can't obtain the completed closed section, it need weld into a whole, thus causing lower intensity, stiffness of a double-layered tube and poor reliability. In addition, welding could waste material so that lower utilization of metal materials and increase high cost. In order to consider the utilization of materials, cost and the forming quality and efficiency, introduces advanced forming technology of a double-layered tube. That is liquid impact forming technology of a double-layered tube. It takes hydroforming technology as the core, assisting with stamping technology.

2. Hydroforming of double-layered tube

2.1 Fundamental principle

Double-layered tube forming by liquid impact forming is based on its by hydroforming, which is belong to cold forming without additive material and subtractive material, using the elasto-plastic properties of materials to make the inner and outer tubes have counter-acting force, thus causing the inner and outer tubes combine closely [6-7]. The compound stage of hydroforming of a double-layered tube could be divided into three continuous processes.

To begin with, deformation stage of inner tube. To nest the inner and outer tubes which have been matched in size, due to they exist interval between inner and outer tubes, firstly make a liquid pressure to inner tube which will begin to expand and deform along the radius after receiving the pressure of liquid. Until the inner tube radius expands to touch the outer tube, which means the interval has been eliminated and does not generate the contact pressure between inner and outer tubes.

Secondly, compound stage. With the continuously increase of liquid pressure of inner tube, inner and outer tubes start to each other extrusion. So inner and outer tubes generate contact pressure, in addition, the outer shell also begin to expand and deform along the radius. And the initial elastic deformation gradually reaches yield condition of the outer tube's inner surface, it starts to appear partly plastic deformation, and when the inner tube liquid pressure is loaded to the maximum, the plastic deformation region of the outer tube expands to the maximum.

Finally, unload stage. When liquid pressure of inner tube begins to unload, the inner and outer tubes are in the stage of unloading, and the pressure gradually decreases from the maximum value. But due to the inner tube has occurred a complete plastic deformation in the second stage, the outer tube is at the stage of elastic or partial plastic deformation, so the elastic recovery of the outer tube should be greater than the elastic recovery of the inner tube after completely unloading the liquid pressure of inner tube. Therefore, the inner and outer tube form a tight distending force, that is residual contact pressure, which can make the inner and outer tube are in the close mechanical bond state, thus forming a double-layered tube.

2.2 Device of hydroforming

The device and operation procedure of hydroforming of a double-layered tube are shown in Figure 1[8] below: firstly, put the inner and outer tubes which have been matched in size and nested into the cavity of lower die, then close the die, at the same time, the left and right metal plug moves into both ends of

the tubes until it contacts and seals both ends of the tubes, so that double-layered tubes are surrounded by the metal plugs and dies. With inner tube liquid pressure continuous increase, the metal plug at both ends of the tube do axial feed motion, in the end, remove inner tube liquid pressure after the inner tube fully fitting the outer tube and outer tube completely fitting die cavity. At the same time, take the left and right metal plug out, then a double-layered tube also can be taken out.

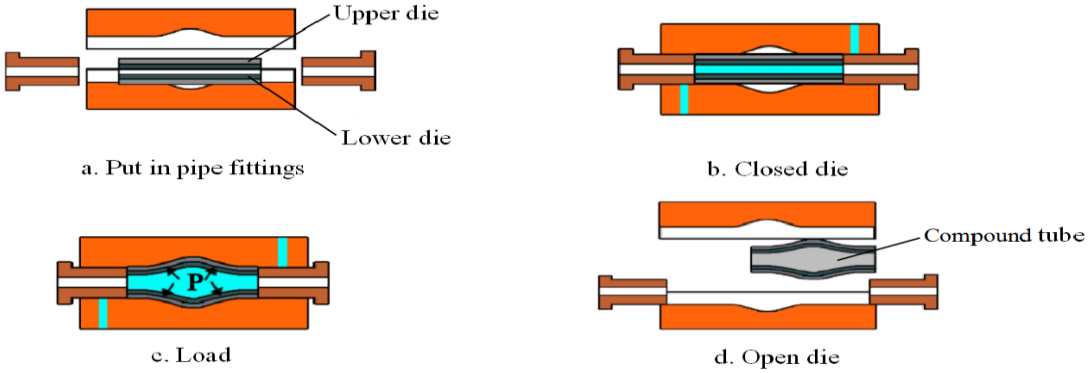

Figure 1. Sketch of double-layered tube hydroforming

2.3 Features of hydroforming

To reduce the weight: the biggest feature of hydroforming is taking the hollow material to replace solid material, so compared with welding technique, the automobile parts by using hydroforming could reduce weight of 20% to 30%. And the hollow shaft parts could reduce weight of 40% to 50%, even to 75%. Therefore, it can not only reduce the weight but also save the material [9].

To form shape at one time: in hydroforming, it just needs only primary process to form various and complicated parts, therefore, it simplifies production process and improves productivity [10].

To reduce the cost: from view of dies, the original stamping and welding forming techniques require two or more than two sheets to stamp respectively, and then to weld it, which need multi-set of forming dies. However, hydroforming technique needs only one set of die to produce forming parts, thus saving production time and costs.

To intensity and stiffness of forming parts: compared with the traditional forming process, hydroforming is to extend and spread the internal parts of fibrous structure, which does not damage the internal structure. Therefore, the internal structure performance of forming parts is enhanced, that means both intensity and stiffness of parts are improved, and forming quality is better than before.

2.4 Drawback of hydroforming

First, the requirements of sealing technology is strict, as for double-layered tubes, if the sealing effect of the left and right ends of inner tube is not good, the double-layered tubes can't achieve hydro-bulge. Then, the die has higher requirements, hydroforming technique need only a set of forming die to obtain the forming parts. Although it is convenient and cost saving, it has a higher requirement for forming dies. Last, a double-layered tube which is formed by hydroforming technique or other compound parts is belongs to mechanical compound. Under the high temperature, it will cause the compound parts to separate and fall off.

3. Liquid impact forming of double-layered tubes

3.1 Principle of liquid impact forming

Double-layered tubes form by liquid impact forming is to make the double-layered tubes quickly generate hydroforming. The hydro-bulge is taken as the core, assisting with radial pressure to press outer tube so that the inner tube completely fits the outer tube, and the outer tube fits the die cavity, its principle is shown in Figure 2[11]:

Firstly, to put the inner and outer tube which have been matched and nested in size into the lower die cavity of filling with liquid container, the liquid is automatically filled with inner and outer tubes, the left and right metal plug moves into both ends of the tube until it contacts and seals both ends of the inner tube. At this point, the inner and outer tube's pressure is p0=0MPa.

Secondly, to open the press machine, the upper die driven by a pressure head, begins to move downward at constant speed until the upper die contacts the outer tube, and plastic deformation is made. When the outer tube is under pressure, the inner tube does not contact or just contact with the outer tube, at this point, the pressure of inner tube is p1=0.

Finally, the pressure head leads the upper die continue to move downward, the inner tube contacts with outer tube. Under the stamping, the inner tube is squeezed by the outer tube, so that it begins to deform from elastic deformation changing into partial plastic deformation at this time. Therefore, the inner tube not only receives pressure of the outer tube, but also the liquid force P2 which squeezed by the liquid in the inner tube. After closing the upper die and lower die, keeping the pressure for a short time in order to make the inner tube completely fit the outer tube, and the outer tube fits the die cavity. Then open the press machine, let the pressure head lead the upper die to move upward, take out the metal plugs, and pull out the a double-layered tube. Therefore, the elastic recovery of the outer tube should be greater than the elastic recovery of the inner tube, so that the inner and outer tube form a pulling-out force, that is residual contact pressure, thus forming a double-layered tube.

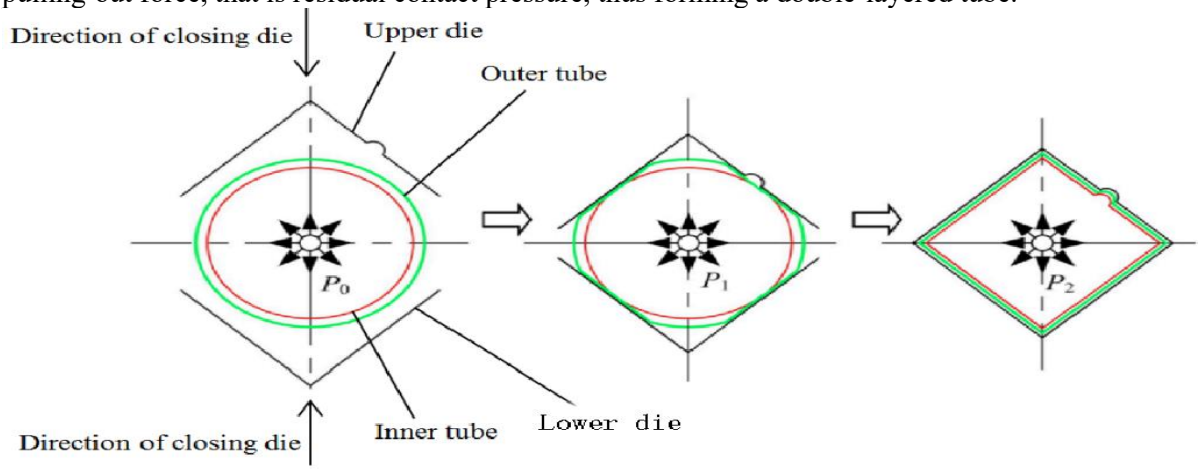

Figure 2. The bulging principle of double-layered tubes liquid impact forming

3.2 Device of liquid impact forming

Liquid impact forming of double-layered tubes which is designed as shown in Figure 3

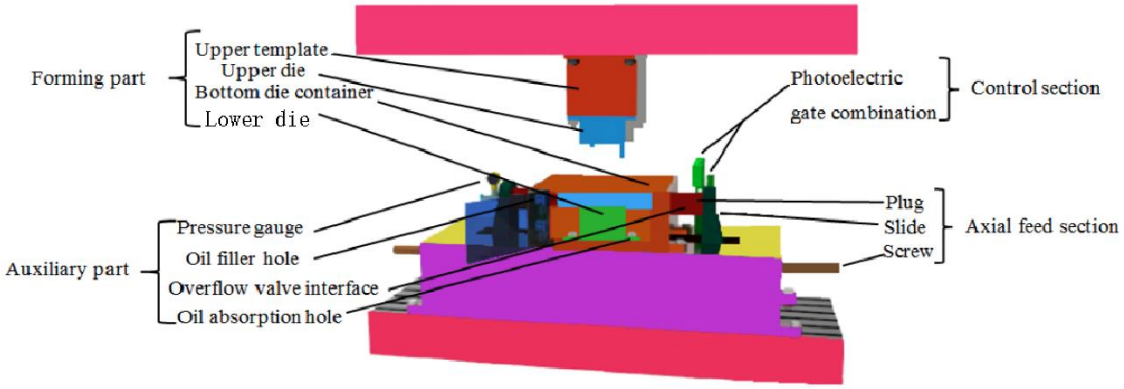

Figure 3. The double-layered tubes liquid impact hydro-bulge device

The device is divided into four parts, including forming parts, supplementary parts, control parts, and axial feed parts which complement one another, and set up liquid impact forming of double-layered tubes device. In our country, the device is advanced in forming metal tubes, which can achieve double-layered tubes compound forming by an electric motor, its forming efficiency is high and internal parts could be used repeatedly.

3.3 Features of liquid impact forming

Liquid impact forming of double-layered tubes is to fill liquid in internal tube before stamping. Then impact sealed tube by using stamping technology, thus tube spontaneously generating internal high pressure to forming. This technology has not to offer high pressure with a special internal pressure source, so it greatly saves cost and simplifies the device.

Compared with hydroforming technology, double-layered tubes form by hydroforming technology must constantly offer forming liquid in order to make the tube hydro-bulge consist with tube of die cavity. However, it forms by liquid impact forming need not constantly offer forming liquid to inner tube, using stamping technology to impact the closed tube, which could finish forming tube. It can improve the forming efficiency.

The development of liquid impact forming technology is based on hydroforming technology. It combines stamping to make the tube forming. Therefore, it owns the advantages and disadvantages of hydroforming.

4. Development trend

There are various methods of double-layered tubes forming, which could be divided mechanical compound and metallurgical compound. The mechanical compound is cold-forming, using the elastic-plastic principle of a double-layered tube to achieve tight mechanical compound of double-layered tubes. Although double-layered tubes mechanical compound is simple, available and low cost, it might cause a double-layered tube appear stratified at high temperature.

Metallurgical compound can be processed forming by cold-hot pressure. Its forming principle usually includes diffusion compound and melt compound. The diffusion compound makes use of high temperature so that the inner and outer tubes over interface generate larger plastic deformation, thus becoming diffusion compound. The melt compound is to mix the inner and outer metal tube under the situation of melting. Then it has a diffusion compound after solidification. Therefore, diffusion compound is fastness and cannot be readily separated in a high temperature. At the same time, it has a better comprehensiveness of forming tubes. However, this forming technology is complicated and has a high requirement for forming conditions.

In conclusion, if it has a high temperature requirement for a double-layered tube, metallurgical compound should be considered, if it has no a high temperature requirement, mechanical compound should be considered. With the widely use of a double-layered tube and its forming requirements constantly increase, the forming methods are still constantly improving. Therefore, the technology prospect of high quality and economical with a double-layered tube will be more wide in the future.

5. Conclusions

A double-layered tube owns the advantages of inner and outer tubes. And it has the unique advantages in price and structure, so it has been widely used in various fields. With the rapid development of a double-layered tube, it has a high requirement for a double-layered tube. The forming methods have been developed from the stamping, welding and aeroform to the advanced liquid impact forming. The technology of liquid impact forming is developed based on technology of hydroforming, its principle combine with stamping and hydroforming to make a double-layered tube forming. People's requirement for a double-layered tube has improved due to the technology development. Therefore, it is the necessary to seek more advanced double-layered tubes forming methods.

Acknowledgments

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