Investigation into Innovative Fabrication of Fiber Metal Laminated Pipe and Application

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Abstract. Fiber reinforced metal laminated tube (FMLT) is a kind of multi-layer super-hybrid material which is cured at a fixed pressure and temperature after alternately laying metal laminated tube and fiber composite material. The development of GLARE composite pipe hydroforming technology and performance testing is of great significance to the development of aviation industry and automotive industry in terms of lightweight and safety.

1. Introduction
For a long time, aircraft and automobile manufacturers have been looking for a new material with high specific strength, good fatigue performance and corrosion resistance. The birth of GLARE composite pipe has solved many problems, and now scientists have been researching it successively. Based on the research of fibre metal laminates, Tao Jie used Yan Huigeng's graphic method to determine the matching pipes for fibre metal reinforced pipes. Through Lame's formula, Tao Jie gives the minimum internal pressure required for expansion by assuming that the expansion nozzle is in a plane stress state. KUL CAN obtains the optimum pressure curve through dynaform during the expansion process, and gives that the best forming condition is that the feed speed of the axis is 8mm/s. Based on Dai Qiwei's KUL CAN, the preparation and formability of Ti/CF/PEEK/Ti composite layer tube were studied. It was pointed out that the critical bulging value of the composite crown was 7.9 MPa, and the strength of the inner layer titanium tube was lower than that of the outer layer titanium tube. The deep drawing experiments of the Ti/CF/PEEK/Ti GLARE composite pipe were carried out, and the deep drawing performance was obtained. In addition, KUL CAN also carried out the deep drawing performance of the Ti/CF/PEEK/Ti GLARE composite pipe. The energy absorption experiment of LARE tube under axial compression was carried out. The main purpose of this study is to further study the hydraulic forming technology of GLARE composite pipe and to further study the physical objects.

2. Current Situation of Development

2.1. Research Background and Significance
Lightweight is the development trend of aerospace, high-speed railway, automobile and other transport machinery manufacturing industry. Thin-walled, integral and lightweight structure is an
important measure to realize lightweight products. The first ten-year action plan of the Chinese government to implement the "Made in China 2025" strategy clearly emphasizes and points out that green manufacturing, aerospace equipment and new energy vehicles are key areas for development. In addition, COP15, the World Climate Conference held in Copenhagen, Denmark in 2009, advocated a green low-carbon lifestyle and enterprise production and consumption. For green manufacturing, one of the important measures is lightweight components. At the same time, various countries and regions are stricter and stricter in terms of environmental protection, safety and corrosion resistance of the automobile industry, which greatly promotes the automobile manufacturers all over the world to actively develop some environmentally friendly automobile products. According to statistics, the automobile manufactured by lightweight design has reduced about 2% compared with the previous steel manufacturing.\(^1\)

Under this background, tube hydroforming and its derivative technology have gained wide attention and development in the field of aviation, aerospace and automobile manufacturing all over the world. This technology is one of the key technologies to realize lightweight structural manufacturing proposed in the late 1970s. It was first used in large-scale engineering practice by Germany in the 1990s. In the field of automobile manufacturing, its industrial chain covers liquid-filled forming equipment, liquid-filled forming pipes, liquid-filled forming parts and related inspection and testing equipment. In Japan, Europe, America, Korea and other countries and regions, a relatively independent and complete supplier system has been formed. The parts produced are designed for chassis, body and exhaust system of automobiles. And many other fields.

Pipe hydroforming technology has also made extensive development in aerospace industry. In the field of aircraft, rocket and engine manufacturing, the requirement of lightweight is more urgent. The integral complex thin-walled structural parts suitable for tube hydroforming technology are widely used in the above fields, so this technology has attracted much attention. In 2004, the Wright Foundation of the United States made the hydroforming technology one of the key developing forming technologies. In view of the current situation in China, the technology has also been funded by the National Natural Science Foundation, the National Science and Technology Support Plan and the National Key Basic Research Development Plan. The development prospects are broad\(^2\).

In addition to the development of new technologies, the search for new materials is also an inevitable requirement for the development of aircraft with better performance. Compared with other materials, the plasticity of traditional metal materials is better and easier to be processed and moulded, but the corrosion resistance is relatively poor. Fiber reinforced resin matrix composites have high specific modulus, specific strength, corrosion resistance and fatigue properties, but have poor impact damage resistance and ductility, and are vulnerable to humidity. The water aging is affected by the environment. Considering that these two materials have their own advantages, a new type of composite material with colloidal connection structure, fiber reinforced metal laminates, emerged as the times require. “Figure 1” shows the application of GLARE composite laminated tubes in various fields.
3. Development status

Fiber reinforced metal laminates can be divided into the following generations according to the material of fiber reinforced matrix: aramid reinforced aluminium laminates (ARALL), glass reinforced aluminium laminates (GLARE) and glass reinforced aluminium laminates (GLARE) in the first generation and in the third generation. Carbon fiber-titanium alloy laminates (CARE) and graphite fiber-titanium alloy laminates (TiGr) are the fourth generation.

Fiber reinforced metal laminated tube (FRMT) is a kind of interlaminar superhybrid material which is cured at a fixed pressure and temperature after alternately laying metal laminated tube and fiber composite material.

Among them, the composite laminated tube formed by similar manufacturing process of second generation GLARE fiber reinforced metal laminates has good impact resistance, which can be used for aircraft crashworthiness structure, aircraft landing buffer structure, automobile body crashworthiness device, air transmission material protection and so on; at the same time, because of its excellent corrosion resistance. It can be widely used in chemical industry. The development of GLARE laminated tube hydroforming technology and performance testing is of great significance to the development of aviation industry and automotive industry in terms of lightweight and safety.

In this paper, the formability and liquid filling formability of the fibre metal laminated tube are studied as an example. The structure is shown in the following “figure 2”.

![Figure 2. Structural sketch of GLARE layered tube](image)

The manufacturing technology of Grail tube is mainly liquid-filled forming, which has developed rapidly in recent years.

After the pre-treatment (deburring, elbowing and oiling) of the tube, the tube is usually placed in a pre-set cavity die, and the tube is deformed by controlling the axial feed (lateral thrust) and internal pressure. Finally, the technology of the given shape is obtained[3]. “Figure 3” shows the process schematic diagram of hydroforming pipe.

![Figure 3. Process schematic diagram of hydroforming pipe](image)

Because the material is formed under the action of real-time controllable uniform fluid surface force, and the axial thrust force can continuously push the appropriate material into the deformation area, thus greatly improving the forming limit of the tube hydroforming and the precision of the
part clamping. Because water (or emulsified liquid) is used as force transfer medium in industrial production and test, and hydraulic proportional servo control technology is applied, forming pressure and lateral thrust can also be precisely controlled by real-time servo, and real-time pressure holding treatment is carried out according to specific conditions, thus the quality of formed parts can be accurately controlled. Pipe hydroforming technology is suitable for the production of any plastic thin-walled metal materials, including stainless steel, carbon steel, copper alloy, aluminum alloy, magnesium alloy and titanium alloy. Pipe filling parts are widely used in advanced manufacturing fields such as automobiles, aerospace, military nuclear power and so on. Twist beams, towing arms, front and back frames, energy absorbing boxes, etc. in automobile manufacturing are typical application cases, such as fuel conduits, heat dissipating vanes, tee tubes, small radius elbows, etc.

3.1. Development Status of Hydraulic Expansion Joint

Generally, the methods of manufacturing laminated pipes include hot extrusion, explosive cladding (forming), coil welding (welding), centrifugal casting, cold drawing and hydraulic bulging, etc.\(^4\). Compared with other technologies for manufacturing composite laminated pipes, hydraulic expansion has the advantages of low cost and good formability. The manufacturing process of common composite pipes is listed in “Table 1”.

| Forming method | Forming characteristics | Combinatio n method |
|----------------|-------------------------|---------------------|
| Hot extrusion  | It is suitable for alloy metal composite with low plasticity and poor workability; small deformation resistance and high surface roughness of composite pipe. | Mechanical combination |
| Explosive forming | It can realize the compounding between various metals and has high efficiency. The thickness of the covering metal can be large or small, and the interface is tightly combined; the explosion site is dangerous and the technical requirements are high. | Mechanical combination |
| Welding method | It can be used to manufacture composite steel pipes for natural gas transportation with a diameter of more than 300mm; the production process is complicated and the production cost is high. | Metallurgica l combination |
| Diffusion bonding | The material combination is more diversified, the quality is good, the cost is slightly higher; the production process is complicated, the equipment investment is large, and the production efficiency is low. | Metallurgica l combination |
| Drawing method | The production process is simple and the cost is low; the interface is non-diffusion connection, the temperature is high and easy to stratify, and the application temperature is low. | Mechanical combination |

The expansion joint of the composite pipe refers to the plastic deformation after the inner pipe is convex, and the outer pipe is elastically deformed. When the internal pressure is unloaded, the rebound amount of the outer tube is greater than the rebound amount of the inner tube. Finally, the residual contact stress at the interface stroke causes the two layers of tubes to mechanically bond, as shown in the following figure. As a plastic forming method, the expansion-molded composite
layer tube can greatly improve the material utilization efficiency and has high forming precision. In addition, the hydraulic expansion joint pipe is used, the expansion joint force is uniform, and can be calculated according to the set parameters and mechanical properties of the two metal pipes, the wall thickness distribution is uniform, and the inner surface quality of the pipe is high.\cite{5} “Figure 4” is a expansion joint schematic.

![Figure 4. Expansion joint schematic](image)

3.2. Research status of fiber reinforced metal layer tube at home and abroad

3.2.1. Status of foreign research

In the early 1970s, Fokker discovered the effect of metal thickness on the cementitious laminate in the bonding structure between the laminates. It was unexpectedly found that the fracture toughness of the thin plate can be improved by cementation and the fatigue crack propagation can be suppressed.\cite{6}. Based on the above phenomenon, the University of Delft in the Netherlands developed in cooperation with Fokker to add a reinforcing base (single aramid fiber) to an aluminum alloy metal laminate to obtain a composite-fiber reinforced metal laminate (ARALL) having a novel structure. Since then, Delft University has systematically studied fatigue performance, durability, processing properties, fracture toughness, impact damage, structural design, etc., and laid a precedent for fiber reinforced metal laminate research.\cite{7}.

In 1987, the second generation of fiber reinforced metal laminates, which is the main technical idea used in this experiment, was the glass fiber-aluminum laminate (glare). Compared with the first generation of fiber reinforced metal laminates, glare laminates have the advantages of higher fatigue properties, notch strength and compressive strength. Airbus became the first person to eat crabs. The company first applied glare laminates and its technology to the A340 and A330 fuselage sections. After more than 100,000 flight tests, no damage was found. Boeing will then Glare laminates are used in the cabin floor of the 777 and 757. The first large-scale application of the glare laminate is in the upper fuselage skin, fairing, fairing, vertical and horizontal tail, upper fuselage siding and upper double cabin A380 side panel.”Figure 5” shows the vault of the barrel portion of the fuselage made of glare. According to statistics, the upper body of the A380 has a total area of about 470 square meters and a total of 27 glare laminates.\cite{8} The longest part is 11 meters and the weight is reduced by about 800 kilograms.

![Figure 5. A380 fuselage dome made with glare laminate](image)

The third-generation fiber reinforced metal laminate is a carbon fiber reinforced aluminum
alloy laminate, but due to the large difference between the galvanic sequence of carbon and aluminum, it is prone to electrical corrosion that is common in life. To solve this problem, a solution for filling a barrier layer between the carbon fiber layer and the aluminum alloy laminate has appeared, but the use of the barrier layer increases the difficulty in preparing the carall laminate. For these various reasons, carbon fiber reinforced aluminum alloy laminates have not been able to achieve large-scale applications in actual production and life.

The main research of glare laminate mechanics focuses on both shear properties and anisotropy.

The glare laminates are directional and exhibit anisotropy along the direction of the different fiber arrangements. In general, due to the high modulus of elasticity of the fibers, the tensile strength of the unidirectionally arranged glare laminate in the fiber arrangement direction is much higher than that of the aluminum alloy sheet, but the lateral tensile strength is low. If the fiber layer is selected as the prepreg, the horizontal and vertical drawing strengths are guaranteed.

Hale et al. first studied the related effects of the orientation direction of glass fiber prepreg on the tensile properties of GLARE laminates. Donnellan et al. studied the effect of temperature on the tensile properties of ARALL laminates by operating at varying ambient temperatures. The results show that low temperature and normal temperature have no effect on the tensile properties of various types of ARALL laminates. However, when the temperature is raised to 120 °C, the tensile strength of ARALL-1, -2, -3 ARALL laminates will be. The above phenomenon occurs for the ARALL-4 type to reach 170 °C or higher.

Liu Cheng et al. used the short beam method to study the shear behavior between the plate and the plate of the galre laminate. The results show that when the span-thickness ratio is 8, the sample undergoes pure shear failure, i.e., near the neutral layer. Interlayer peeling delamination. The apparent interlaminar shear strength values obtained by this method can characterize the layers of the composite laminate. Shear performance. When the span-thickness ratio is 5, the shear test is the squeeze-shear failure mode, and when the span-thickness ratio reaches 10, the failure mode is the bending effect. “Table 2” lists the glare laminate shear performance.

### Table 2. Glare laminate shear performance

| Shear properties | Test Direction | GLARE | GLARE | GLARE | Al |
|------------------|----------------|-------|-------|-------|----|
|                  | 4-5/4          | 4-3/2 | 4-2/1 | 2024-T3 |
| Yield shear stress/MPa | Lengthways     | 101   | 105   | 119   | 207|
|                   | Transverse     | 98    | 107   | 117   | 207|
| Shear modulus/GPa | Lengthways     | 13.67 | 15.26 | 15.77 | 28 |
|                   | Transverse     | 13.84 | 14.33 | 17.50 | 28 |

In addition to the study of basic mechanical properties, the damage of the galre laminate and its mechanics theory are also hot topics. Volume fraction theory is a classical theory that characterizes the tensile properties of galre laminates. The theoretical formula is as follows:

\[
MVF = \sum_{\text{Flass}} \frac{t_{\text{metal}}}{t_{\text{lum}}}
\]

\[
\sigma_{t,lum} = MVF \cdot \sigma_{t,mat} + a \cdot (1 - MVF) \cdot \sigma_{t,PP}
\]

\[
E_{lam} = MVF \cdot E_{mat} + a \cdot (1 - MVF) \cdot E_{PP}
\]

\[
\sigma_{0.2,lum} = [MVF + a \cdot (1 - MVF) \cdot \frac{E_{PP}}{E_{mat}}] \cdot \sigma_{0.2,mat}
\]

among them, \(t_{\text{lum}}\) is the total thickness of the laminate; \(t_{\text{metal}}\) is the thickness of a single layer of
metal; \( P_{metal} \) is the number of metal layers; \( \sigma_{1, lam}, \sigma_{1, metal}, \sigma_{1, FRP} \) Corresponding to the tensile strength of the laminate, the metal layer and the fiber layer respectively; \( E_{lam}, E_{met}, E_{FRP} \) Corresponding to the elastic modulus of the laminate, the metal layer and the fibrous layer; \( E_{0,2, lam}, E_{0,2, met} \) Is the yield strength of the laminate and the metal; \( a \) is the fiber volume fraction of the laminate in the tensile direction.

Delfe University studied the uniaxial tensile properties of GLARE1-to-GLARE-6 and other GLARE. The results show that when \( 0.45 < MVF < 0.85 \), MVF theory can give the prediction of tensile strength\(^{[12]} \).

The glare laminate also follows the industry-recognized classical laminate theory. Although the theory ignores the plastic deformation of the aluminum alloy sheet after yielding, it can reflect its main mechanical properties through some data and according to the theory. Perform relevant mechanical analysis and calculation of common clt theory before the yield behavior of the aluminum alloy, and calculate the residual stress generated by the glare laminate during the curing process, as shown in FIG. During the cooling of the glare laminate, the coefficient of thermal expansion of the aluminum alloy layer and the fibrous layer during cooling will result in residual stress between the materials, and the mechanical properties of the glare laminate will be significantly affected\(^{[13]} \). “Figure 6” uses clt theory to explain the effect of participating stress on glare laminates.

![Figure 6. uses clt theory to explain the effect of participating stress on glare laminates](image)

### 3.2.2. Status of domestic research

Based on the research of fiber reinforced metal laminates, Tao Jie used Yan Huigen’s graphic method to determine the matching of the fiber metal reinforced tube. Through the Lame formula, Tao Jie gives the minimum internal pressure required for expansion by assuming that the expansion joint is in a plane stress state. KUL CAN obtains the optimum pressure curve during the expansion process through dynaform, as shown in the figure below, and also gives the axis feed rate of 8mm/s which is most favorable for forming. Based on the theory, Dai Qijun studied the preparation and forming properties of Ti/CF/PEEK/Ti composite layer tubes. It is pointed out that the critical value of the composite crown is 7.9 MPa, and the inner titanium tube strength is required to be lower than The outer layer of titanium tube and the tube drawing of Ti/CF/PEEK/Ti tube were subjected to the deep drawing test, and the deep drawing performance was obtained. In addition, KUL CAN also carried out the axial compression energy absorption experiment on the GLARE layer tube. Its compression curve\(^{[14]} \). “Figure 7” shows the internal pressure loading curve.
3.3. Interlayer "viscous" effect test

Because semicuring has the characteristics of large tangential deformation and complicated deformation process compared with traditional cementation, in addition to considering the fluid hydroforming process in semi-cured forming in this subject, the interface has always had a normal pressure value with time. In order to better describe the viscous effect of the metal and prepreg interface in the glare laminate and the tube semi-cured, the physical simulation test shown in "Figure 8" below is designed.

As shown in the figure above, the 3+2 GLARE layer form is used. The thickness of the aluminum plate is 3mm, the material is aluminum alloy 2024-T3, and its performance is shown in "Table 3" below; the prepreg is glass fiber WP9011(25*25), and its performance is shown in "Table 4" below:

Table 3. Mechanical properties of aluminum alloy 2024-t3

| Rolling direction | Yield stress/MPa | Tensile strength/MPa | Elongation /% | Thick anisotropy index | Hardening index n |
|------------------|------------------|----------------------|--------------|------------------------|------------------|
| 0                | 298              | 425                  | 19.2         | 0.78                   | 0.195            |
| 45               | 290              | 414                  | 16.8         | 0.82                   | 0.184            |
| 90               | 295              | 421                  | 18.3         | 1.10                   | 0.191            |
Table 4. Mechanical properties of glass fiber prepreg wp9011

|              | Tensile Strength/MPa | Tensile modulus/GPa | Compressive strength/MPa | Flexural modulus/GPa | Shear strength/MPa |
|--------------|----------------------|--------------------|--------------------------|---------------------|-------------------|
|              | 400                  | 18                 | 450                      | 19                  | 55                |

As shown in “Figure 8”, there is a 25*25mm pressure zone in the middle of the test piece, and there is a constant pressure in the normal direction to ensure that the prepreg is tightly bonded to the metal. Due to the large thickness of the aluminum plate, the amount of tensile deformation can be neglected in this experiment. Under the action of the axial force, the intermediate layer aluminum plate continuously slides in the axial direction. By performing the above experiments under different pressures (five in each group, averaging), the tensile force and sliding displacement maps are obtained as shown in “Figure 9” below.

Figure 9. Tensile-displacement curve at different pressures

It can be seen from “Figure 9” that the curve distribution law is basically the same under different pressures, that is, the slope gradually becomes smaller after linear increase, and then exponentially decays after reaching the peak value, and finally shows a linear trend; in addition, the curve peak value and the final linear segment value positively related to stress.

For any pressure, the relationship between tensile force and displacement can be expressed by the following “figure 10”:

Figure 10. Typical tensile-displacement curve
As shown in the above figure, the typical tensile-displacement curve can be divided into four parts: linear area 1, curve area 2, curve area 3, and linear area 4. The following four areas are analyzed:

(1) Linear area 1:
For the linear region 1, the main deformation mode of the cementing unit is the shear deformation in the elastic region. In this area, the cementing unit remains stable without major deformation.

(2) Curve area 2:
As the elastic shear deformation of the cementing unit becomes larger and larger, the deformation of the cementing unit exceeds the elasticity, and the deformation is permanent deformation, and the deformation amount is large. In addition, the tensile force and displacement are not linear.

(3) Curve area 3:
As the deformation gradually increases, the tensile-displacement curve tends to decline. At this time, the amount of deformation is extremely large, and it is not restored after unloading.

(4) Until the deformation to the linear region 4, the stretch-displacement curve region is stable and tends to decrease linearly.
It can be seen that when the curve reaches its apex, the interlaminar viscous effect degrades, which is conducive to subsequent forming.

4. development prospects

4.1. Technology development prospects
Composite material refers to a material composed of two or more different substances and combined in different ways. It can overcome the defects of a single material and utilize the advantages of various materials to expand the application range of materials. Due to its light weight, high strength, convenient processing, excellent elasticity, chemical resistance and weather resistance, composite materials gradually replace wood and metal alloys, and are widely used in automobiles, aerospace, construction, electrical and electronic, fitness equipment and so on. In other areas, it has grown rapidly in recent years.

As a new type of composite material, the chemical fiber reinforced metal layer tube is still in the laboratory development stage. Due to its good impact resistance, it can be used in aircraft crashworthy structures, aircraft landing buffer systems, and automobile body anti-collision devices. Airborne material protection, etc.; at the same time, due to its excellent corrosion resistance, it can be widely used in the chemical industry.

4.2. Development prospects of the transportation market
The development potential of composite materials in the transportation market is even more important. Although composite materials are commonly used in the field of automation, composites account for only 1% of the weight of ordinary vehicles. Not to mention the proportion of fiber-reinforced metal sheet materials, it can be seen that the market development potential of fiber-reinforced metal materials is enormous. The driving force of regulations and technology has made people's optimism about the growth of composite materials become reasonable, but the adoption of composite materials is still difficult, and the market conditions in the next few years will challenge the industry. Composite materials will be used in aerospace and other industries that are in urgent need of light weight, but will still occupy a certain share in the general market.

To be like other materials, composites are the choice of people, and only the overall cost, weight and performance can be compared to the extraordinary value. Although in automotive and other fields where lightweighting is not demanding, the reason for the application of composite materials is not only its lightweight, but its main disadvantage is that the processing cost is higher than that of ordinary manufacturing materials. At this point, the decline in sales of light vehicles and
competition from other materials has become an obstacle to composite applications. “Figure 11” shows the use of Ford gt's wide range of carbon fiber materials

![Image](image1.jpg)

**Figure 11. Use of Ford gt's wide range of carbon fiber materials**

The results of the survey show that a 10% reduction in vehicle volume will result in a 7% increase in fuel economy. In addition, lightweight vehicles require less power to accelerate, so even with smaller, low-burning engines, these vehicles still have the potential to drive. Therefore, original equipment manufacturers are investing in lightweight materials to produce economical but at the same time enjoyable vehicles.

Composite materials - here is the fiber reinforced metal tube, which will be used more in automotive structural design due to its outstanding performance compared to other materials.

4.3. **Development prospects of the aerospace market**

At present, the aerospace industry is one of the main application fields of carbon fiber, which is mainly due to the high strength and lightweight properties of carbon fiber. Compared with aluminum or steel, carbon fiber can reduce weight by 20% to 40%. “Figure 12” shows the carbon fiber aviation interior.

![Image](image2.jpg)

**Figure 12. Carbon fiber aviation interior**

In the aerospace industry, it is mainly used for aircraft structural materials (about 40% of aircraft weight), so the use of carbon fiber is comprehensive. It can reduce the weight of the aircraft by 6% to 12%, which significantly reduces the fuel cost of the aircraft. In the aerospace industry, composite materials - carbon fiber was first used in the manufacture of satellite antennas and satellite supports, and because of its heat and fatigue resistance, carbon fiber has also been widely used in solid rocket engine casings and nozzles. Some aircraft tubular structures, such as the fuselage, oil pipelines, landing gear, etc., use this product to not only improve the strength, but also reduce the quality, is a good choice.

5. **Conclusions**
1. A new preparation method of metal fibre tube has been studied and successfully formed. The results show that the tube has higher specific strength, specific modulus, fatigue property and corrosion resistance than common composite materials and uniform metal components.

2. Hydroforming is a good way. For hollow variable cross-section structural parts, the traditional manufacturing process is to stamp two halves and then weld them into a whole. Hydraulic forming can form hollow structural parts with variable cross-section at one time. Compared with stamping welding process, hydroforming technology and process have the following main advantages:
   (1). Reduce quality and save materials. For hollow shaft parts, the weight can be reduced by 40%-50%.
   (2). Reduce the number of parts and moulds and reduce the cost of moulds. Hydraulic forming parts usually need only one set of dies, while stamping parts mostly need multiple sets of dies.
   (3). It can reduce the welding quantity of follow-up mechanical processing and assembly.
   (4). Improve strength and stiffness, especially fatigue strength.
   (5). Reduce production cost. According to the statistical analysis of the parts already used in hydroforming, the cost of production of hydroforming parts is 15%-20% lower than that of stamping parts on average, and the cost of die is 20%-30% lower than that of stamping parts.

3. After hydroforming, the interface property can be improved greatly. Hydraulic expansion of GLARE composite pipes refers to a mechanical connection mode which realizes expansion by residual stress caused by different deformation of inner and outer pipes before solidification. The basic principle is that the two ends of the pipe are sealed by the left and right sealing devices, and the high-pressure liquid enters the inner pipe through the sealing device, and the plastic deformation of the inner pipe occurs under the action of the fluid surface force; when the internal pressure is unloaded, the rebound of the outer pipe is greater than that of the inner pipe, and finally the residual contact stress at the interface stroke makes the two-layer pipe. Mechanical bonding occurs. As a plastic forming method, the bulging forming of composite tube can greatly improve the material utilization efficiency and the forming accuracy. In addition, the hydraulic expansion joint compound pipe has the advantages of uniform expansion force, uniform wall thickness distribution and high surface quality, which can be calculated according to the set parameters and mechanical properties of the two metal pipes.

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