

The experimental study for FRP flange structural characteristics

M. Wang, Z.M. Huang

School of Aerospace Engineering and Mechanics, Tongji University

Abstract

In this study, the mechanical properties of an FRP flange material made of continuous glass fibers and a vinyl ester resin are characterized. Based on these properties, structural design for a series of FRP flanges is carried out. A sample FRP flange is fabricated and its performance is verified.

Introduction

Currently, an FRP flange is generally fabricated through moulding on short fiber SMC materials or hand lay-up with continuous fiber reinforcement. The mechanical property of a thus obtained flange is low and it is easy to leak. Reinforcing with continuous fibers, increasing fiber content and eliminating porosity is the only way to improve the quality of an FRP flange. The fiber content used in this project is more than 60%, with a neglected porosity.

Systematic tests for the continuous glass fiber reinforced vinyl ester resin composites under shearing, bending, compression and tension loads are carried out, which are used the design basis of new types of FRP flanges. Furthermore, a sample flange of the new type is made.

1. Material test

The experimental characterization for the FRP material includes tension, compression, bending and shear tests.

1.1 Testing samples

The composite is made of continuous glass fibres and a Vinyl Ester Resin with relatively large thickness. The raw material can be used for preparing samples for flexure, tensile, compressive and shear tests in-plane and along thickness directions respectively.

1.2 Testing procedure

The tests are performed according to different ASTM standards on the CSS electronic universal testing machine. As shown below are in accordance with the order of flex, compression, tensile and shear test.



Fig 1. FRP test

1.3 Testing results

The testing results are summarized in Table 1, in which a property followed with “-in” represents the property measured under an in-plane load, whereas that with “-out” indicates that the property is obtained under an out-of plane (i.e., along the thickness direction) load condition.

Table 1. FRP Performance Data

		flex-out	flex-in	compre-out	compre-in	tens-out	tens-in	shear-out	Shear-in
Stress(σ)	MPa	36.98	340.72	482.04	295.46	17.74	181.31	112.62	25.258
Modulus(E)	GPa	5.79	12.82	5.0225	6.6116	2.87	16.1336		

2. Flange design

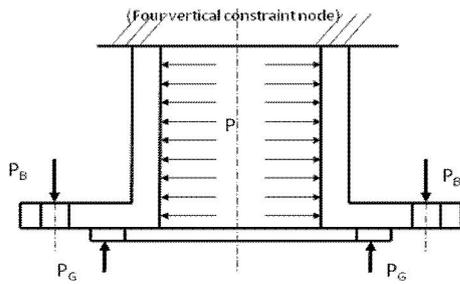


Fig 2. Force on Flange

2.1 Force analysis

There are three external forces on a flange once in operation. They are Medium pressure, Bolts reaction and Gaskets compaction force. The axial force on the flanges exerted by the pipe can be replaced by four vertical constraint nodes.

The total moment in operation is given by

$$M_R = P_D L_D + P_T L_T + P_G L_G$$

P_D , the hydrostatic axial force on flange inner diameter face; P_T , the media pressure on flange end; P_G , the gaskets compaction force.

2.2 Stresses analysis

Obtain design value of strength according to admissible stress, admissible strength and allowable elastic modulus which root in minimum mechanical properties of FRP.

Determine the flange torque the larger one

$$\text{of } \frac{M_U [\sigma]_f'}{[\sigma]_f} \text{ and } M_R.$$

2.3 Calculate

Determine the flange ring thickness, flange pipe thickness and flange pipe length by stress analysis.

Flange ring is symmetrical ring plate, which receives P_D , P_T and P_G three uniform forces. It can be seen as circular plate. So from the flange ring moment, shape modulus and FRP radial allowable stress, we can get the flange ring thickness.

Analysis stress on unit length and angle flange wall, flange pipeline thickness can be calculated. It depends on FRP allowable stress, design pressure and nominal diameter. Flange pipeline length lies on bond strength, design pressure and nominal diameter.

3. Flange fabrication

A sample FRP flange, with a nominal diameter of 200mm and a minimal pressure of 1.6MPa, has been fabricated. The obtained flange is shown in Fig. 3.



Fig 3. A new type of FRP Flange

Conclusion

Through the glass fiber reinforced plastic composite materials tension, compression, flex and shear performance test, it's evident that composite materials have different characteristics in different directions. Since the failure objects are different (resin or fiber), Impact on the material strength is significant. Characteristic is continuous fiber reinforced, high fiber volume content and minimal porosity. As the fiber fault is nonhomogeneous, the property of materials is signally affected.

References

- [1] Kitching R., Priester R., Hashemizadeh H., Soden P.D., Failure characteristics of glass -reinforced plastic pipe and pipe assembly, *Composite Structures*, v 18, n 4, 1991, p 365-377.
- [2] Pizhong Qiao, Explicit local buckling analysis and design of fiber-reinforced plastic composite structural shapes, *Composite Structures*, v 70, n 4, Oct. 2005, p 68-83.
- [3] Zhao Y., Pang S.-S., Lea R.H, Integral flange for filament wound composite pipe - fabrication and analysis, American Society of Mechanical Engineers, Pressure Vessels and Piping Division (Publication) PVP, v 375, Integrity of Structures and Components; Nondestructive Evaluations, 1998, p 75-79.