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Evaluation of pipe stub flange behaviour during hydrostatic pressure testing

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1 INTRODUCTION

1.1 Glass fibre reinforced plastic materials in engineering fields

Glass fibre reinforced plastic materials (GRP) can be defined as combined materials that consist of reinforcing glass fibres embedded in a compatible matrix system. The reinforcements are strong glass fibres such as C-Glass, E-Glass, D-Glass and S/R-Glass. They may be in the form of continuous fibres or chopped fibres. The matrix system is a polymer such as polyester resin, vinyl ester resins, rubber, etc. Fibre reinforced plastic materials have excellent structural qualities when compared to conventional materials, for example steel and concrete, ceramic, etc. This motivated an extensive use of GRP materials in various fields. The advantages of fibre reinforced plastic materials are:

- high strength to weight ratio and fatigue endurance;
- high resistance to corrosion and chemical attack;
- the manufacturing of the composite material and the structure can be done at the same time;

However, they also have some disadvantages, which need to be taken into consideration:

- they are prone to environmental degradation, such as due to high temperature, alkali attack and ultraviolet radiation exposure;
- they are subject to shrinkage or spring back.
- they may have inconsistent material properties, especially when the hand lay up process is used.

Glass fibre reinforced plastic materials are no longer used only in weight sensitive applications such as naval and aircraft. They are being used widely in various fields including building, transportation systems, water treatment installations, electrochemical facilities, etc.

Fibre reinforced plastic materials offer a diversity of design options to obtain specific properties. A variety of materials may be fabricated depending on the patterns, properties and proportions of the different constituents within the construction. As a result, a good understanding of the arrangement of the different constituent (reinforcements and matrix) as well as the mechanical behaviour of the actual product is required for effective use.

1.2 GRP stub flange in piping systems

In the design and manufacturing of pipe stub flanges made up of fibre reinforced plastic materials, adherence to codes and standards is essential because standardization reduces manufacturing costs, installation inconvenience, and provides safety. However, in practice manufacturers also develop their own guidelines based on experience. These specifications cover various engineering methods and empirical approaches due to the complexity of fibre reinforced plastic materials. Since the specifications allow a certain amount of flexibility in the design, manufacturing, and testing methods, a better understanding of stress and strain fields within loaded pipe flanges is required to optimize joint reliability.

1.3 Failure of pipe stub flange

Pipe joints are susceptible to two types of failure mechanisms as shown in figure 1.1, material failure and leakage [(4)]. Material failure is related to bolt and flange failure while leakage is associated with gasket failure. Material failures are caused either by incorrect flange design or by inappropriate bolt material selection; whereas leakage often occurs when the joint has inadequate preload, normally caused by incorrect bolt torque magnitude. Incorrect bolt torque magnitude is due to various factors such as inappropriate bolt torque sequence, inappropriate material selection of gasket and fasteners, excessive thread friction that cause bolt twisting instead of stretching in tension to tighten the joint, the use of non calibrated tools, etc. Therefore, the test specimens were analyzed in two main stages as described below:

- A finite element analysis using MSC Patran/Nastran was performed to predict the strain and stress distribution fields within the flange laminates. This allowed the identification of regions subjected to highest stress concentrations. These regions were used for strain gauge locations.
- Hydrostatic testing designed according to BS 5480:1990 and ASTM F 37 specifications was conducted on test specimens to cause leakage and material failure. Experimental test results were analyzed and compared to the numerical results.

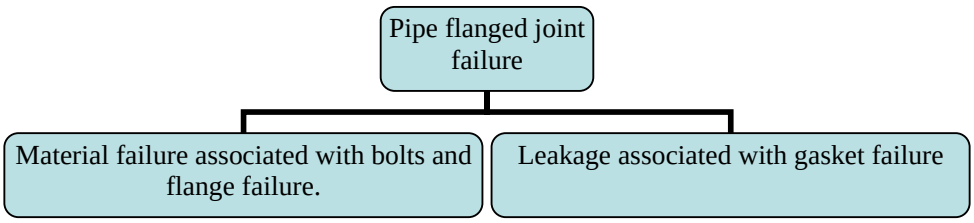


Figure 1.1: Failure analysis of the pipe flange

1.4 Project objectives

The objectives of this project are:

- to get a better understanding of the strain and stress distributions within the stub flange;
- to determine how the design and manufacturing methodology affect the stress and strain distributions within the stub flange;
- to provide guidelines for design and manufacturing to avoid premature failure