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Failure assessment of aluminum liner based filament-wound hybrid riser subjected to internal hydrostatic pressure

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ABSTRACT

The present study describes the burst behavior of aluminum liner based prototype filament-wound hybrid riser under internal hydrostatic pressure. The main objective of present study is to developed an internal pressure test rig set-up for filament-wound hybrid riser and investigate the failure modes of filament-wound hybrid riser under internal hydrostatic burst pressure loading. The prototype filament-wound hybrid riser used for burst test consists of an internal aluminum liner and outer composite layer. The carbon-epoxy composites as part of the filament-wound hybrid risers were manufactured with [±55^o] lay-up pattern with total composite layer thickness of 1.6 mm using a CNC filament-winding machine. The burst test was monitored by video camera which helps to analyze the failure mechanism of the fractured filament-wound hybrid riser. The Fiber Bragg Grating (FBG) sensor was used to monitor and record the strain changes during burst test of prototype filament-wound hybrid riser. This study shows good improvements in burst strength of filament-wound hybrid riser compared to the monolithic metallic riser. Since, strain measurement using FBG sensors has been testified as a reliable method, we aim to further understand in detail using this technique.

Keywords: Composites, Filament-wound , Hybrid Riser, Burst test, FBG, Strain

1. INTRODUCTION

There is a growing interest to move from metallic riser to composite riser due to the numerous potential advantages. One of the most significant advantage is that composite material have higher strength to weight ratio compared to metallic materials and can be exploited advantageously to replace metallic riser for deep water applications. Another potential advantage is that the bursting pressure of a composite pipe with adequate thickness exceeds that of a metallic pipe. However, the present understanding of the failure mode and fracture behavior of the filament-wound hybrid riser is inadequate.

A number of codes and standards govern the design of marine riser or pipe, so the conformity with recommended practice & standards is required to design standard pipe with suitable safety factor for specific field use. According to our knowledge, only DNV (Det Norske Veritas, DNV-RP-F202, Recommended Practice Composite Risers 2010) has developed a dedicated recommended practice for composite (fiber reinforced plastics) risers . Most of the codes follow similar guidelines for practice. There is a significant amount of literature available on burst test on metallic riser and composite riser [1-5]. Various approaches adopted by researchers in order to achieve best performance of end fittings during test are available in literature [2, 6-9]. A similar background literature and well-established design practices are not available for filament-wound hybrid riser risers. Therefore, there is a need to investigate, evaluate and analyze the filament-wound hybrid riser failure modes.

There are a many strain measurement technique available, such as strain gauging, thermal scanning, shearography and digital image correlation (DIC) etc. However, these techniques are difficult to implement in high pressure testing environment with given limited working space. In difficult situations Fiber Bragg Grating (FBG) sensor are found very useful for local and global health monitoring [10]. Many researcher have successfully tested this technique for aluminum and composite materials [10, 11].

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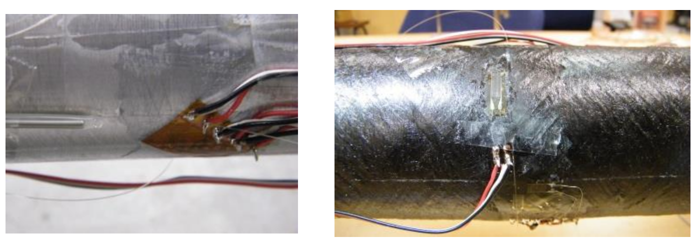
Due to feasibility and cost limitation concerns, the experiment is conducted with reduced scale of riser structures. The aluminum liner based prototype filament-wound hybrid riser were manufactured for internal pressure testing and an in-house facility has been developed for burst testing.

2. TEST SETUP AND PROCEDURE

The test rig to conduct burst experiments is shown in Figure 1a. The in-house developed set-up consists of an air driven hydraulic pump to apply internal pressure. The pump is connected to the pressure valve by hose and fittings, which are rated at 15,000 PSI. To ensure safe working environment a strong test bench was used. The specimens were kept inside this test bench during testing. The tests were conducted according to ASTM 1599 standard and burst pressure of the risers was evaluated. FBG sensors are mounted over a hoop direction of pipe as shown in Figure 1b. The actual burst of a filament-wound hybrid riser, pressurized internally at a rate of 800 psi/min. The burst tests were conducted in both aluminum and filament-wound hybrid riser.

(a) Test set up assembly

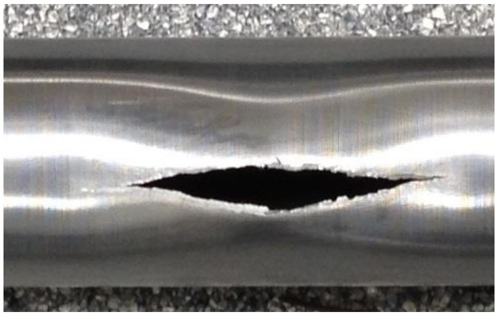


(b) FBG mounting on risers

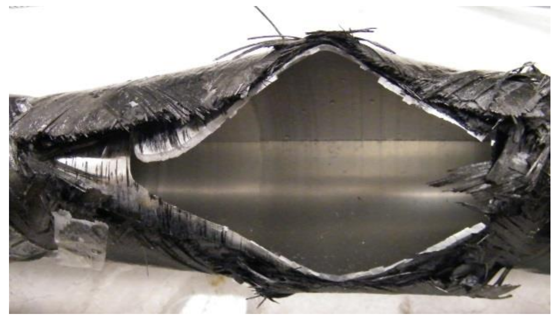
Figure **1**: In-house testing facility for conducting burst tests.

3. RESULTS AND DISCUSSION

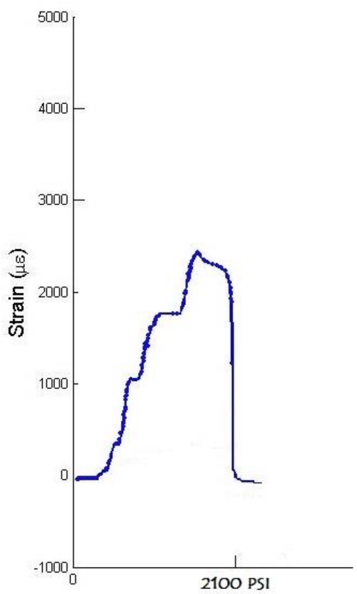
The burst tests of aluminum and filament-wound hybrid riser were successfully conducted using the in-house developed test facility. Three specimens of each aluminum and filament-wound hybrid riser were tested. The failure patterns of the riser after bursting showed good repeatability. The fractured risers after burst are shown in Figure 2a and b. It is noticed from Figure 2a and 2b that, the riser bulges around the circumference when a high internal pressure is applied and contracts in length before bursting. After bulging of the riser the strain data stopped due to delamination, debonding or failure of adhesive during internal pressure test. The strain verses average internal pressure results of the aluminum and filament-wound hybrid riser are shown in Figure 2c and 2d . The fracture due to burst is observed at the mid length of the riser. This kind of failure was commonly observed in both the aluminum and composite risers. The following causes of failure as the riser is initially pressurized until burst is explained. A closer examination of the fractured regions reveals interesting observations. The fracture surface reveals that, during bursting the crack propagates and causes a major delamination at the aluminum composite interface. Until burst, the composite layer resist effectively when subjected to higher internal pressure than virgin aluminum risers. When the internal pressure reaches critical value, the aluminum liner shows a bulging effect due to which, the composite also undergoes progressive damage phenomena such as fiber breakage, matrix cracking and fiber pull-out. Finally, filament-wound hybrid riser bursts with sudden drop in internal pressure. The aluminum riser burst at 2800PSI while the aluminum liner based prototype filament-wound hybrid riser burst at 10,100 PSI during internal hydrostatic pressure test.



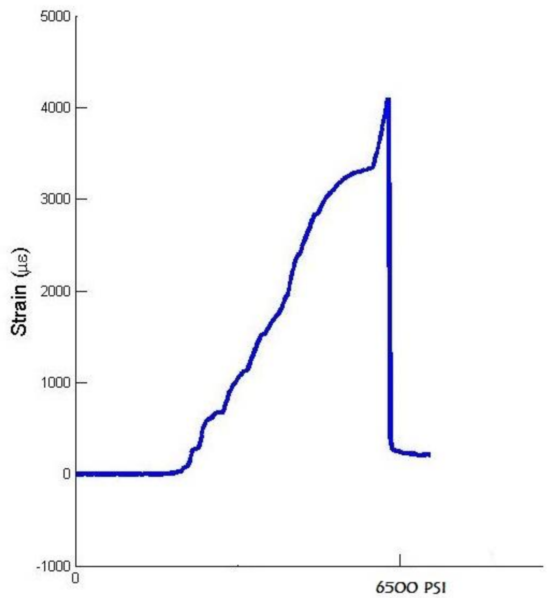
(a) Aluminum riser



(b) Filament-wound hybrid riser



(c) Strain Vs internal pressure in aluminum riser



(d) Strain Vs internal pressure in hybrid riser

Figure 2 Bursting of risers and strain measurement

4. CONCLUSION

In this study, the burst tests of aluminum and hybrid composite risers were successfully accompanied with an in-house developed test facility. The conclusions from this study are: The burst pressure of the filament-wound hybrid riser is higher than that of aluminum riser. The lightweight prototype hybrid composite riser developed in this study reveals adequate improvement in resisting burst pressure and shows promise that, a full-scale hybrid riser is indeed feasible for deepwater applications. For the high pressure application FBG sensor based strain measurement was found reliable, effective, promising and easy to use.

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