

Experimental Analysis of GFRP butt-joint under Leak Test

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ABSTRACT

A FRP butt-joint was developed between two adherends of aluminum and steel pipes of outside diameter 25.4 mm, inside diameter 22 mm and length 175 mm each. The joint was formed by pasting glass fiber patches, cut out from sheet, with controlled quantity of epoxy and hardener matrix at $\pm 10^\circ$ angle. Two varieties of specimens were formed patch on gap type and overlapped type. It was cured to form the joint with GFRP sleeve. To characterize the joint, it was subjected to leak test through a leak test fixture on dead weight pressure gauge tester. During leak test, it was observed that pressure at which leakage takes place through FRP joint increases with the number of layers of Glass fiber. It is because when number of layer of Glass Fiber increases, increased thickness of fiber bears more pressure and more compact FRP joint is formed which can undertake more pressure. Due to overlapping of fibers rather than taking gaps between them, no space is open in any layer for oil to leak out of it, also the layer is more compact. Thus Overlap-GFRP takes more pressure than that of Gap-GFRP.

Keywords- FRP Joint, adherends, GFRP, leak test, Overlap-GFRP, Gap-GFRP.

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I. INTRODUCTION

Polymer composites are an important class of composite material in which a polymer is reinforced by stiff and high strength fibers. The reinforcing fiber or fabric provides strength and stiffness to the composite, whereas matrix gives rigidity and environmental resistance. The properties strongly depend on the way the fibers are laid in the composites. The important thing to remember about composites is that fiber carries the load and its strength is greatest along the axis of the fiber. The joining method used in a piping system can often determine the success or detriment of the system over its years of use, thus making it one of the more important factors in the engineering design of the system. Syed Altaf Hussain et al. [1] work deals with the study and development of a surface roughness prediction model for the machining of GFRP tubes using Response

Surface Methodology (RSM). Mohamed Almahakeriet al.[2] has worked on longitudinal Bending and Failure of GFRP Pipes Buried in dense sand under relative ground movement with the ever persistent challenges often faced with corrosion, relative rigidity, and other issues characteristic to steel pipes, the need to explore the use of new pipeline materials, such as glass fiber-reinforced polymers (GFRP). Mathieu Robert and Brahim Benmokrane [3] worked on behaviour of GFRP Reinforcing bars subjected to extreme temperatures. M. S. Ahmadi [4] did an experimental study on mechanical properties of GFRP braid pultruded composite rods. Kumar et al. and Kumar and Kumar [5, 6] developed FRP T-joints made between two components by winding a wetted tow made of high strength and high stiffness glass fibers. The strength of the T-joint was determined under four loading conditions: (i) tensile, (ii) in-plane bending, (iii) bending under a transverse load, and

(iv) torsion-cum-bending. The strength of the FRP-joint between mild steel pipes was found to be comparable to the strength of a welded joint. Ramkumar et al. [7] developed a GFRP butt joint between two pipes by wrapping a wetted glass fabric and letting it to get cured. They found the joint to be strong against flexural loads but weak under tensile loads. Ladhwe et al. [8] formed GFRP butt joint between similar materials, aluminum and was characterized under tensile and flexural loading. Ladhwe et al. [9] developed butt joint between the pipes of dissimilar materials, aluminum and steel using carbon fiber roving. The joint was tested experimentally under tensile and flexural loading. The experimental results were interpreted on the basis of numerical analysis carried out using ANSYS. The objective of the present study was to develop and characterize a butt joint using glass fiber reinforced polymer (GFRP). To develop a GFRP butt joint, one aluminum pipe and one steel pipe were used (O.D \approx 25.4 mm, I.D \approx 22 mm and having length of 175 mm). The joint was formed by pasting wetted patches of glass fiber with epoxy and allowed it to get cured to form a joint. Figure 1 gives its schematic representation of specimen.

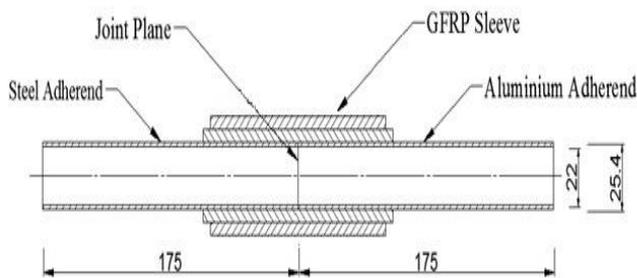


Figure 1 Schematic representations of specimen (Multiple Layers)

2. Experimental Technique

2.1 Materials

Commercially available aluminum and steel pipes were used as the adherends in this study, whose properties were: aluminum- modulus=69 GPa, Poisson's ratio=0.33, yield stress=152MPa and steel- modulus=210 GPa, Poisson's ratio=0.30, yield stress = 330 MPa. Aluminum and steel adherends were 25.4 mm outside diameter, 22.0 mm inside diameter and 175 mm length. The unidirectional glass fiber used was of 473 gsm and was purchased from Owens Corning India Limited, Raigad, India. The epoxy resin employed was Dobeckot 520F (100 parts by weight) with hardener Beck 758 (9 parts by weight) which cured the resin at room temperature. The mixture of epoxy and hardener has processing time of 25-30 minutes and it gets cured in 25-30 hours at room temperature.

2.2 Preparation of specimen

Step by step procedure for the development of the specimen :

1. Cut the Aluminum and Steel pipe into the required lengths.

2. Hold them face to face onto a spindle of specially designed set up shown in Figure 2. Make the surface of the pipe a bit rough on which the fiber is going to be stuck so that fibers get a better grip.
3. Now cut the fiber into the required size and inclination $\pm 10^\circ$ angle.
4. Cut Breather, Extra epoxy removal bag, Vacuum bag into the required size.
5. Make holes on epoxy removal bag in proper pattern.
6. Fix the vacuum bag onto the compressor pump's pipe mouth.
7. Stick double sided tape on pipe and vacuum bag.
8. Prepare solution according to the amount required and using appropriate proportion of Epoxy and Hardener.
9. Now using a brush spread the solution on the rough part of pipe.
10. Stick the fiber on the pipe properly considering the inclination and number of layers to be made.
11. After pasting the fiber, put on the extra epoxy removal bag on the fiber patches.
12. Next put the breather on it, so that it absorbs the extra epoxy.
13. Put on the vacuum bag on it and make sure no passage for air is left.
14. Start on the compressor and keep it on for 45 minutes, so that all the extra epoxy is removed.
15. Turn off the compressor and remove the vacuum bag.
16. Keep the specimen in the above leftover condition for 24 hours.
17. After it, remove the breather and extra epoxy removal bag from the specimen.
18. Next, put it into oven for post curing process at 80°C and keep it for 5 hours shown in Figure 3. As the temperature increases so does the molecular activity and polymerization becomes complete with ester molecules, cross linking and then forming strong matrix.
19. Remove the specimen and let it get cooled to room temperature.
20. Now the specimen is ready for taking test shown in Figure 4.



Fig 2 Specimen setup (Vacuum bagging process)



Figure 3 Interior of Oven



Figure 4 Photograph of the GFRP butt-joint

2.3 Dead Weight Pressure Gauge Testers

For checking leakages at the joint in the specimen, a dead weight pressure gauge tester was used using lubricant oil. A working of tester was based on calibration method that uses a piston cylinder on which a dead load was placed to make equilibrium with an applied pressure underneath the piston. The instrument, used for leak detection, was manufactured by the RAVIKA instruments, Delhi. The maximum pressure that can be measured by tester was 300 bar. Figure 5 shows the experimental set-up of the dead weight pressure gauge tester.

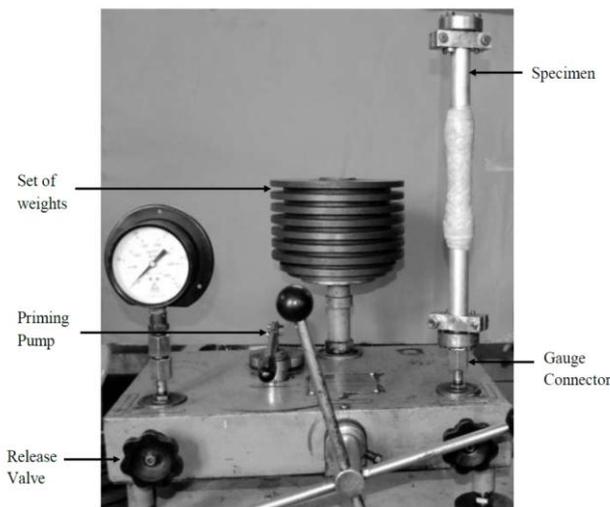


Figure 5 Experimental Set-up of dead weight pressure gauge tester

For carrying out the leak test, initially the specimen was mounted on the ‘Dead weight pressure gauge tester’ machine. The oil was pumped inside the specimen by using the inbuilt priming pump till it was completely filled with oil and air inside the system was removed. The oil used for the test was SAE-40 Grade. The pressure was increased by adding the dead weights till the leakage occurred through the GFRP butt-joint or the pressure reached which would not burst the aluminum adherend. A special attachment was designed to conduct the leak test of the butt-joint specimen on the dead weight pressure gauge tester (Figure 6). One end of the specimen was blocked and the other end was required to have a male threaded portion (M 20) so that it could be screwed on the tester. The interface was designed in such way that, it did not leak during the testing. The interface was designed for the maximum pressure of 250 bar. Beyond 250 bar, the aluminum may fail and test may be dangerous.

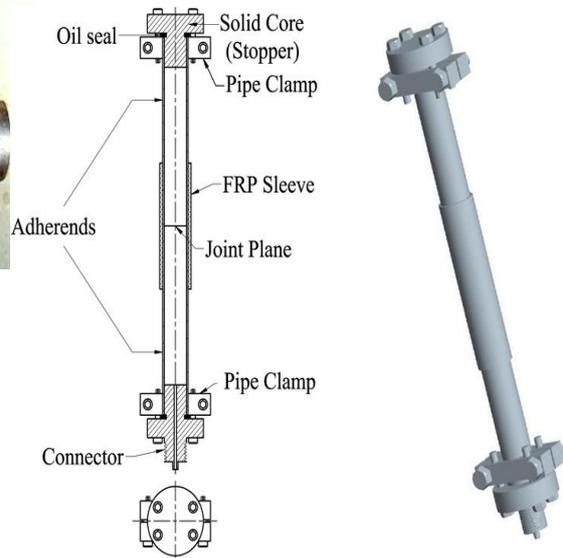


Figure 6 Sectional view of assembly for leak testing

The assembly is divided into two subassemblies. The upper subassembly blocked the upper end of the specimen while the lower end was suitably designed to be attached to the leak tester. The upper end was blocked by inserting a solid core. The flanged portion of the core was screwed to a pipe clamp attached to the external surface of the pipe using four M6 high strength screws. The pipe clamp was made of two halves of mild steel. One of them was having tapped holes, M8, and the other one clear holes. To clamp it, the two halves were screwed to the pipe, using high strength alloy steel allen screws. An oil seal made of neoprene was used between the flange and specimen end face to ensure that no oil leaks through. It is flat ring with size 15.87x27.38x3.17 mm. It is worth mentioning here that the core was made long enough in such a way that the pipe clamp did not crush the adherend tube. In the lower subassembly the core had a drilled hole of $\varnothing = 2.5$ mm so that the liquid of the tester could enter the specimen. The design of the cored portion and its flange was same as that one used on the blocked end. However, the other end of the core was machined with M20 thread so that it could be screwed to the leak tester. Another pipe clamped was employed to tighten the core to the specimen pipe with an oil seal in between. Figures 7 show

the photographs of the specimen with both subassemblies for GFRP butt joint specimens.



Figure 7 Photograph of Actual assembly of Glass Fiber

3. Results and discussion

Following are the results obtained by the experimentation of Glass-FRP specimen. We performed sets of experiments for each layers of GFRP patch and observations are listed in Table1. Graphical representation of leak test results for various types of specimens is shown in Figure 8, 9, 10 and 11. The combine results of all specimens are shown in Figure 12.

Table1. GFRP Leak test results

Results of Leak Testing of Glass FRP				
Specimen No.	No. of layers	Patch Pattern	Leakage Pressure (bar)	Average
1	2	Gap	60 (failed)	86.667
2	2	Gap	75	
3	2	Gap	95	
4	2	Gap	90	
5	2	Overlap	85	90
6	2	Overlap	90	
7	2	Overlap	90	
8	2	Overlap	95	
9	3	Gap	100	102.5
10	3	Gap	100	
11	3	Gap	105	
12	3	Gap	105	
13	4	Gap	150	120

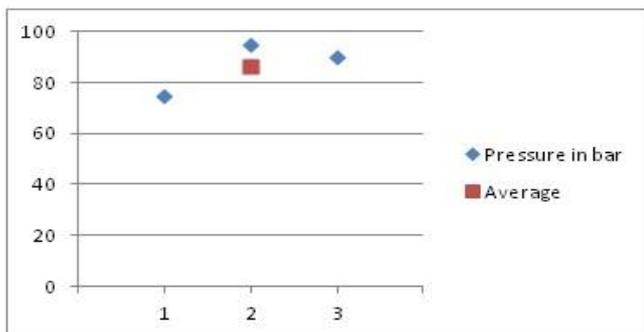


Figure 8. Two layer non overlap (gap) test result

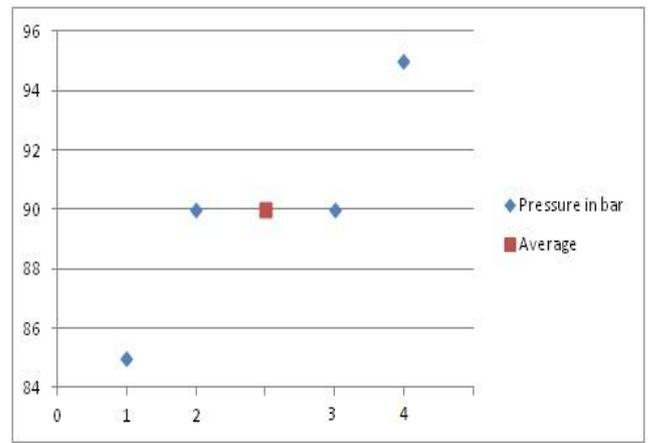


Figure 9 Two layer overlap test result

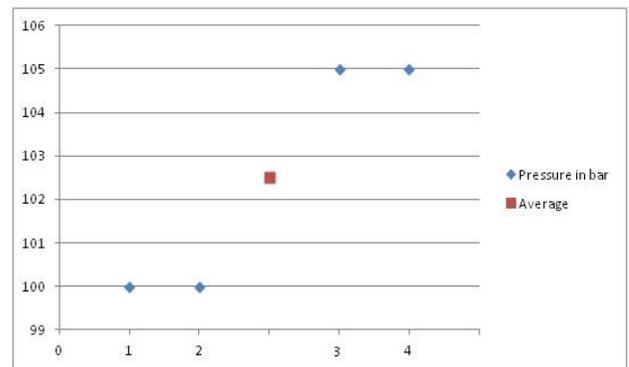


Figure 10 Three layer non overlap (gap) test result

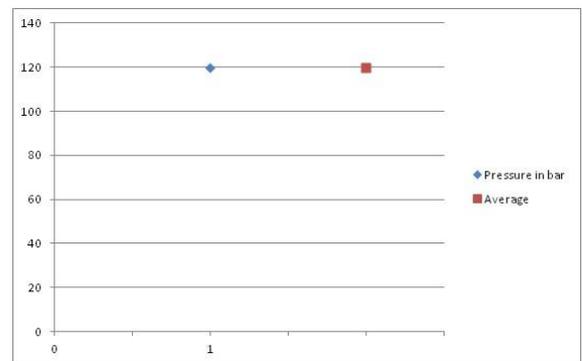


Figure 11 Four layer non overlap (gap) test result

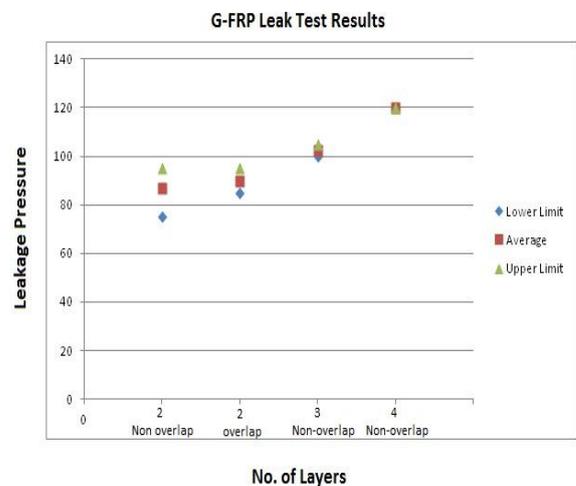


Figure 12 Graph between Number of passes of Glass fiber and Leakage pressure

4. Conclusion

G-FRP butt joint was formed between aluminum and steel pipes by sticking patches of glass fiber using epoxy and allowed it to be cured to form a joint. The GFRP patches are in alternate $+10^\circ$ and -10° angle of orientation at the butt joint. Thus, after curing FRP forms a sleeve over the metal pipes. This joint was subjected to Leak test. From the graphs, it can be inferred that:

1. The pressure at which leakage takes place through FRP joint is directly proportional to the number of layers of Glass fiber. It is because when number of layer of Glass Fiber increases, increased thickness of fiber bears more pressure and more compact FRP joint is formed which can undertake more pressure.
2. Due to overlapping of fibers rather than taking gaps between them, no space is open in any layer for oil to leak out of it, also the layer is more compact. This is probably the reason why Overlap-GFRP takes more pressure than that of Gap-GFRP.
3. These tests are conducted on Dead weight pressure gauge tester. Results are subjected to lower temperature but specimen may fail at low pressure when working temperature is high.
4. More GFRP thickness should be added at junction of two pipes so that leakage occurs from end of sleeve and not the middle junction. 4 layers or above will be required for the same.

References

- [1] Syed Altaf Hussain V. Pandurangadu K. Palanikumar "Surface Roughness Analysis in Machining of GFRP Composites by Carbide Tool (K20)" European Journal of Scientific Research ISSN 1450-216X Vol.41 No.1 (2010), pp.84-98
- [2] Mohamed Almahakeri, M. ASCE¹; Amir Fam, M. ASCE²; and Ian D. Moore, M. ASCE³ "Longitudinal Bending and Failure of GFRP Pipes Buried in Dense Sand under Relative Ground Movement" 710 / Journal of composites for construction.
- [3] Mathieu Robert and Brahim Benmokrane "Behavior of GFRP Reinforcing Bars Subjected to Extreme Temperatures" DOI: 10.1061/_ASCE_CC.1943-5614.0000092
- [4] M. S. Ahmadi¹, M. S. Johari^{1*}, M. Sadighi², M. Esfandeh³ "An experimental study on mechanical properties of GFRP braid-pultruded composite rods" eXPRESS Polymer Letters Vol.3, No.9 (2009) 560-568 DOI: 10.3144/expresspolymlett.2009.70'
- [5] Kumar, P., Singh, R. K., and Kumar, R., Joining similar and dissimilar materials with GFRP. Int J Adhesion & Adhesives. **27**, 68-76 (2007).
- [6] Kumar, P., and Kumar, R., Joining of pipes using FRP - an experimental study. J Institute of Engineers (India). **89**, 16-19 (2008).
- [7] Ramkumar, J., Singhal, A. K., Singh, R. K., and Kumar, P., Butt joining of similar & dissimilar pipe material by cold joining process. Ad composite materials. **16**, 173-79 (2007).

[8] Ladhwe, R.N., Kumar, P., Singh, K.K. and Sarkar, P.K. 'Characterization of GFRP butt-joint under tensile and flexural loading.' 'Journal of Composite Material' September 4, 2014. doi: 10.1177/0021998314550220.

[9] Ladhwe, R.N., Kumar, P., Singh, K.K., Sarkar, P.K. and Ugale, V. 'Experimental study and numerical analysis of a CFRP butt-joint between the pipes of dissimilar materials.' 'The Journal of Adhesion' November 21, 2014. doi: 10.1080/00218464.2014.972502