

Natural fiber based adhesive butt joints as a replacement to gas welded butt joints for thin tubes: An experimental study

Anubhav Mishra¹, Suruchi Singh², Rajeev Kumar^{3*} and Arun Mital⁴

^{1,2}M.Tech Student, Department of Mechanical Engineering, Institute of Engineering & Technology, Lucknow, Uttar Pradesh, India -226021

^{3*}Professor, Department of Mechanical Engineering, Institute of Engineering & Technology, Lucknow, Uttar Pradesh, India -226021

⁴Associate Professor, Department of Mechanical Engineering, Institute of Engineering & Technology, Lucknow, Uttar Pradesh, India -226021

Email: anubhavmishra.er@gmail.com, suruchimech04@gmail.com, rajeev.kumar@ietlucknow.ac.in and arun.mittal@ietlucknow.ac.in

Abstract- In this investigation, adhesive based butt joints were made between two mild steel tubular rods of 1.5 mm thickness and between mild steel and aluminium tubular rods of 1.6 mm wall thickness by winding a single sleeve of woven jute fiber. The sleeve was wetted with a suitable epoxy resin before it was wound. In few hours the winding cures to give a strong joint. The strength of the butt joint was determined for two loading conditions; axial tension and under 3-point bending. The strength of woven jute fiber butt joints was then compared with the strength of similar tubular rods joined with help of gas welding. It was observed that the strength of composite butt joints between dissimilar materials, aluminium and mild steel tubular rods, was higher in bending than butt joint between mild steel to mild steel tubular rods while the later was stronger in tension.

Keywords: Woven jute fiber, similar and dissimilar materials, epoxy resin, butt joints, adhesive joint.

1. Introduction

In product fabrication, structural and pipeline applications joining of two materials plays a very important role. There are various types of joining techniques available they can be broadly classified as (i) welding, brazing and soldering (ii) stitching (iii) adhesive bonding (iv) tying components together (v) fasteners- joining through screwing, bolting and riveting (vi) joining used by magnetic attraction. All the joining techniques have their own advantages and disadvantages. In most cases it has been often found that joints are the weakest link. Welding is the most common joining techniques in industrial applications however; the major constraint of welding is that it can only join similar materials. Further, though welding joins the steel parts effectively but it has its own limitations like subjecting components to high temperatures with associated problems such as scaling, distortion, crack in heat affected zone (HAZ) or weldment. Stitching is generally preferred for joining components like leather, fabric etc. Adhesive bonding can join dissimilar materials but it is not good in tension. Tying components has its disadvantages such as breakage of tow and outward impression of knots.



Fasteners perform very well in many applications but it is costly and decreases the strength of components.

J M Lees [1] used GFRP (Glass reinforced fiber polymer) for tubular pipe sections of small diameter bonded by adhesives and checked the performance of joint under combination of high tensile axial load and under low pressure. Jiao et al [2] studied the strength of CFRP (Carbon fiber reinforced polymer) and butt welded joint of very high strength steel tube. Two coaxial steel tubes were joined by CFRP and welding and their load capacity was observed under tension on different specimens. De Moraes et al [3] carried out the investigation of strength of stainless steel pipes joined using two epoxy adhesives. Experimental test on single lap and butt joints carried out along with adherent and napkin ring tests. Result shows that tensile and shear strength of both the epoxy adhesive were similar and failure could be predicted by maximum shear strain criteria using FE Analyses. Mertiny & Ellyin [4] used a novel adhesive insertion method for joining composite pipes and studied their performance. Related damage behaviour of prototype size pipe joined by above method was also considered. Griffin et al [5] used a theoretical model to find out the strain in adhesively bonded joints of pipes. Delamination was the main mode of failure in this study. Pedro Glvez et al [6] developed a finite element model of a bus steel structures in order to obtain the forces that work on the reference node from the obtained force values, the value and type of stress at the reference node were calculated. A new carbon fiber reinforced polymer (CFRP) node was developed replacing the existing welded joint by steel – CFRP adhesive joints. This new adhesive joint showed strength values higher than 30% of the strain values along with minimizing the fatigue problems. Kumar et al [7] in their study developed T-joint between two tubular rods using glass based FRP. The GFRP was wounded diagonally, straight and circularly over the joining area to create the T-joint configuration. The strength of these joints was checked under four loading (i) tensile (ii) in-plane bending (iii) bending under transverse loading and (iv) torsion cum bending. The strength of FRP joints were compared to the strength of welded T-joints developed using similar sized rods. Further, the strength of T-joint between dissimilar tubular rods were developed and tested and compared.

In the present study, an adhesive based joint using natural fiber is used for butt joining of similar and dissimilar metals pipes. The parts were joined by using woven jute mat sleeve which was impregnated with an epoxy resin before winding. Strength of these joints were then experimentally determined and compared with the strength of two mild steel tubular rods butt joined with gas welding.

2. Materials and methods

This segment describes the material used, specimen preparation and various testing procedures used in this study.

2.1 Material for reinforcement

The use of natural fibres are increasing day by day because of their easily availability and lesser cost as compare to synthetic fibres. In the present work, woven jute fiber mat was used as reinforcing material. Jute is created from plants which are classified in the family of malvacease. It is one of the most common and widely used and easily available natural fibres after cotton fiber. It is 100% biodegradable, recyclable and thus environmentally friendly. Jute has tensile strength in the range of 393-773 MPa, Young's modulus 26.50 GPa, elongation at break 1.50-1.80 and density 1.30 g/cm³ [8]. Jute also offers many advantageous like good insulating properties and lower thermal conductivity and it regains moisture at

moderate level. In addition, jute has ability to merge with natural and synthetic fibres and it also accepts cellulosic dye classes.

2.2 Materials for specimen

Two non-galvanized Mild Steel pipes of 24.5 mm diameter and 1.5 mm wall thickness and 120 mm in length were used for making specimens with similar materials while for joining dissimilar materials similar steel pipes along with aluminium pipes of 24.5 mm diameter and 1.6 mm wall thickness and 120 mm length were used. Figure 1 shows the schematic diagram of butt joint between two tubular rods.

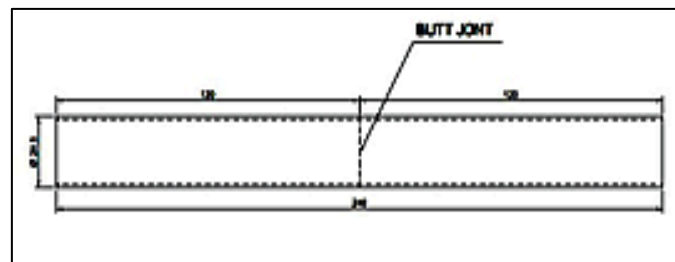


Fig 1: Schematic drawing of butt joint between pipes

2.3 Resin

Standard epoxy resin (Araldite AW 106) was used with hardener (HV 953 IN) for joining the specimens. Resin and hardener were mixed in the ratio of 5:3 and it took 3-4 hrs for curing at room temperature.

2.4 Specimen fabrication

In this study, two types of specimens were prepared. Butt joint between two similar materials using two mild steel pipes and joint between two dissimilar materials using mild steel and aluminium pipes.

To prepare the specimen with similar materials, the surfaces of each mild steel pipes of length 120 mm, diameter 24.5 mm and thickness 1.5 mm were prepared manually roughen by emery paper (grade 180) and then cleaned and degreased with acetone for proper bonding. These pipes were then clamped onto a specially fabricated fixture to ensure straightness and alignment of specimen while the joint is created. The mild steel pipes were clamped on the fixture for joining and proper alignment during the joint fabrication. Figure 2 shows the mounting fixture along with a specimen mounted over it.

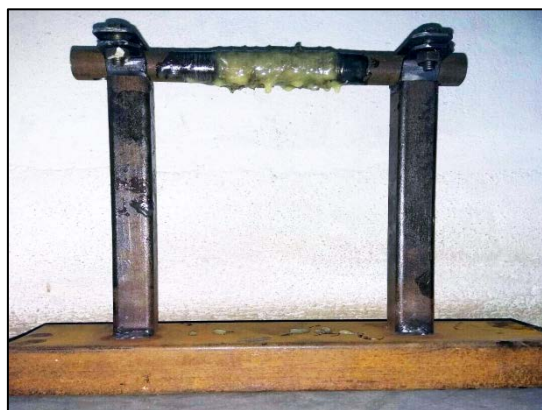


Fig 2: Clamping fixture for preparing the specimen

The epoxy paste that was prepared by combining resin with hardener was applied on the surface of mild steel pipes and after applying paste, woven jute fiber sleeve was wrapped around the surface of pipe over a span length of 80 mm. Specimen was left on the fixture for 3-4 hours for curing at room temperature. After the curing, the specimens were removed from the fixture. In a similar manner, total six specimens were prepared. Figure 3 shows the specimens prepared with mild steel pipes.



Fig 3: Specimen with similar materials

Similar procedure was followed for preparation of specimens with dissimilar materials (aluminium and mild steel). In this case also total 6 specimens were prepared. In addition, total 6 specimens were also prepared by butt joining two similar mild steel pipes with help of gas welding.

3. Experimental procedure

The specimens were tested under axial tension and under three-point bending with help of a universal testing machine to determine their breaking strengths.

3.1 Tensile testing

To test the specimen under tension, two 13mm diameter holes were drilled on both the sides of tensile specimens at a distance of 95 mm from the midpoint of the joint. The specimens were mounted between the jaws of the universal testing machine with help L shaped fixtures as shown in figure 4. Axial tension force was applied at a load rate of 2.0 kN/mm. Specimens were allowed to fail and corresponding forces were recorded.

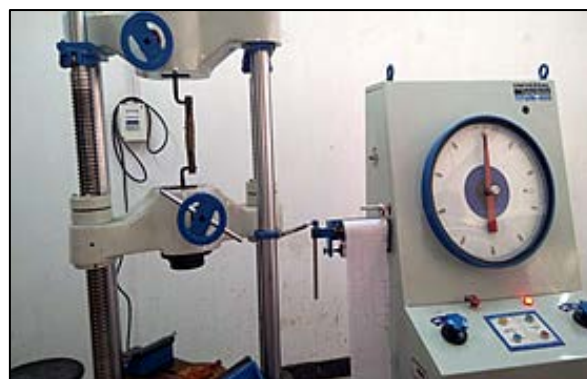


Fig 4: Tensile specimens mounted in the universal testing machine

3.2 Three-point bending

The specimens were supported over the two rollers of the three-point bend fixture of the universal testing machine and 2.0 kN/mm lateral load was applied at the midpoint of the joint as shown in figure 5. The joints were allowed to fail under lateral loading and corresponding force values were noted.



Fig 5: Specimen under three-point bending

4. Results and Discussion

Three types of specimens were fabricated for this study; mild steel to mild steel joined in butt position using woven jute mat based composite joint, mild steel to aluminium pipes joined using same method and mild steel to mild steel pipes joined using gas welding. Each specimen was tested under axial tension and three-point bending loadings.

Figure 6 displays the breaking strengths of each type of the specimens. The average breaking force under tensile test of the gas welded joints was found to be about 12.33 kN while the failure forces for composite joints for similar materials and dissimilar materials were 2.6 kN and 1.8 kN respectively. It can be observed that the breaking strength under tensile test of the mild steel to mild steel specimen joined using gas welding was much higher as compared to the breaking strengths of similar and dissimilar materials joined using jute epoxy composite. Under tension joints made between similar materials was about 30% stronger than the joints between dissimilar materials.

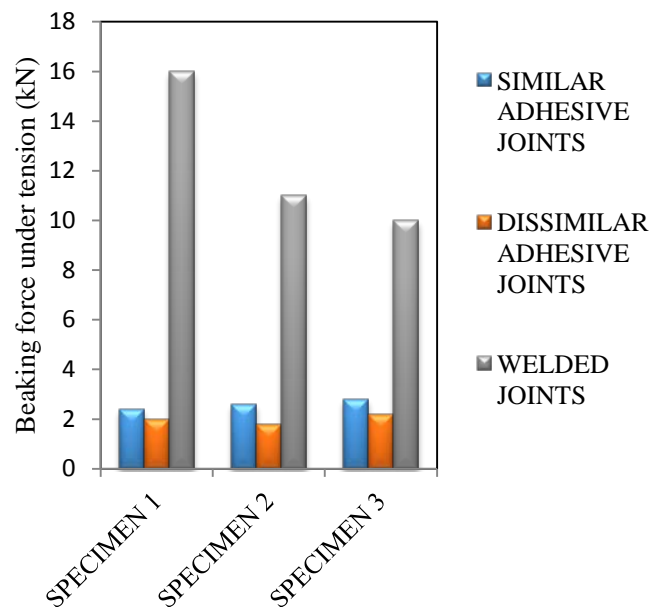


Fig 6: Breaking strengths of the specimens (Axial Tension)

In a similar way, comparison of bending strengths of the three types of the specimens can be seen from figure 7. The average breaking force under three-point bending for gas welded joints was found to be 6.53 kN while these force values for composite joint with similar material was 1.47 kN and for dissimilar materials was 1.87 kN. In this case also the breaking strength under bending test of gas welded joints was much superior to the composite joints.

However, under three-point bending composite joints made for dissimilar materials has shown better strength than that of the similar materials. The strength of composite joint made between dissimilar materials was found to be about 27% higher in bending than the joint made for similar materials. While, under axial tension the strength of composite joint made for similar material has shown better strength.

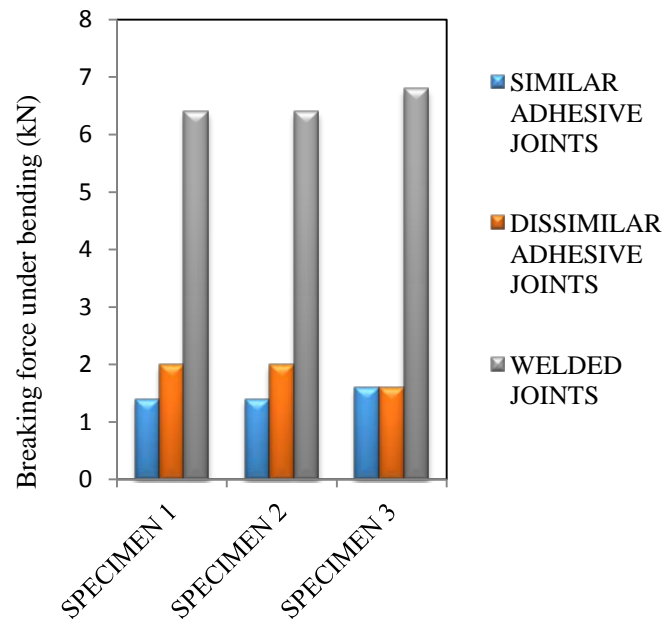


Fig 7: Breaking strength of the specimens (3-point bending)

5. Conclusion

From the above investigation it can be interpreted that the strengths of similar and dissimilar butt type adhesive joints made by natural fiber (woven jute mat) were lesser than the joints prepared with gas welding. It was expected as the breaking strengths under tensile and 3-point bending test of jute fiber which was used as reinforcement material in the present study are very less as compared to that of mild steel. Therefore, it may be concluded that such adhesive butt joint may be used where less load capacity is required. However, the results are encouraging as above conclusions are based on a preliminary study conducted. It is believed that the strength of the joints can be further increased by choosing more number of layers of reinforcing material in design or by choosing different reinforcing materials.

6. Acknowledgement

Authors would like to sincerely acknowledge Mr Virendra Mishra, Workshop Superintendent, at School of Technology, Lucknow University for providing necessary help in carrying out the experimental work in the lab.

7. References

- [1] Lees JM 2006 Behaviour of GFRP adhesive pipe joints subjected to pressure and axial loadings *Compos Appl S A* **37** 1171-1179.
- [2] Jiao H and Zhao XL 2004 CFRP strengthened butt-welded very high strength (VHS) circular steel tubes *Thin Wall Struct* **42** 963-978.
- [3] deMorais AB, Pereira AB Teixeira JP and Cavaleiro NC 2007 Strength of epoxy adhesive-bonded stainless-steel joints *Int. J. Adhes. Adhes.* **27** 679-686.
- [4] Mertiny P, and Ellyin F 2006 Joining of fiber-reinforced polymer tubes for high-pressure applications *Polym Compos* **27** 99-109.

- [5] Griffin SA, Pang SS and Yang C 1991 Strength Model of Adhesive Bonded Composite Pipe Joints Under Tension *Polymer Sc & Engg* **31** 533-538
- [6] Galvez P, Quesada A, Martinez MA, Abenojar J, Boada MJL and Diaz V 2017 Study of the behaviour of adhesive joints of steel with CFRP for its application in bus structures *Compos Eng* **129** 41-46.
- [7] Kumar P, Singh R, Kumar R 2007 Joining similar and dissimilar materials with GFRP *Int. J. Adhes. Adhes.* **27** 68-76.
- [8] Sonar T, Patil S, Deshmukh V and Acharya R 2015 Natural Fiber Reinforced Polymer Composite Material - A Review *IOSR-JMCE* 142-147.