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BOLT ADHESIVE JOINT

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Abstract—-*Traditional joints have low load bearing capacity and high weight. So to reduce the weight of structures and enhance the load bearing capacity of joint, composite joints can be used. Traditional joints such as weld, spot, rivet, etc. are used for connecting various Automotive, Aerospace, etc. parts. To enhance strength of already existing joints without changing existing design can be achieved by use of industrial adhesives. So instead of only using adhesively bonded joint it can become advantageous to use hybrid joint. In this thesis, 6 different samples will be tested by UTM machine and these same samples will be simulated by using FEA. For carrying out experimental validation tensile tests will be performed on UTM to evaluate the joint strength and failure modes for different joining techniques. Same failure modes were occurred in static structural analysis by FEA. Then the Result and Conclusion will be stated.*

Keywords—*Hybrid Joint, Adhesive & bolted joints, UTM, FEA.*

INTRODUCTION

Most of the researchers have studied either adhesive or bolted joints. We decided to study on bolt adhesive hybrid joint. An adhesive, also known as glueor paste, is any nonmetallic substance applied to one surface, or both surfaces, of two separate items that binds them together and resists their separation. The use of adhesives offers many advantages over binding techniques such, mechanical fastening, thermal bonding, etc. These include the ability to bind different materials together, to distribute stress more efficiently across the joint, the cost effectiveness of an easily mechanized process, an improvement in aesthetic design, and increased design flexibility. Disadvantages of adhesive use include decreased stability at high temperatures, relative weakness in bonding large objects with a small bonding surface area, and greater difficulty in separating objects during testing. When designing joints that will use adhesives as a bonding agent, engineers must take the expected loads and required performance levels into account as fracture and failure of the bonded joint is possible under certain circumstances. Factors such as excessive strain or loading, fatigue, or the introduction of solvents can dissolve or weaken the adhesive leading to potential failure of the joint. Adhesives are extremely common throughout many products from vehicle and aircraft interiors to packaging applications but advances have allowed adhesives to be used in a structural capacity. Their high strength allows adhesives to bond metallic together with the joint often proving stronger than the components being bonded. When developing lightweight thermoset components such as carbon composites, adhesives are used to bond the different ply layers together and therefore play an extremely important part in determining the relative strength of the product and its performance characteristics.

LITERATURE REVIEW

ShashikantDashore[1]: Adhesive and Bolt joint technology is demanding research area now days. To reduce the weight of structures and enhance the load bearing capacity of joint with respect to the traditional joint composite joints can be used. New methodology for testing the hybrid joint is setup and the results are being validated with the Numerical analysis. The experiment are conducted by using the Taguchi function, 3 Level and 7 Factor i.e. Bolt size, Clearance bolt, Bolt tightening torque, Adhesive type, Adhesive thickness, overlapping length and Material of joint are used. Total of 27 such joint samples is tested as per ASTM D5968 standard to obtain the strength of Hybrid joint and Load distribution. The load distribution on the hybrid joints are evaluated by the tensile test where the joint strength is calculated from the ultimate limit of material. ANOVA is used to evaluate the contribution by each factor and best combination is found. Best combination achieved from the ANOVA is A3B3C2D1E3F2G2; the confirmation test was performed and compared with the best combination results. The test results are also validated with the Numerical analysis using Finite Element analysis. The results obtained from the FE analysis are in good agreement with the experimental result.

T. L. Yogesh[2]: three different joints, namely adhesive bonding, mechanical fastening and hybrid joining were considered for the assembly of variable substrates. Two different types of adhesives, namely high modulus acrylic adhesive and low modulus rubber adhesive, were selected for the study. Tensile tests were performed to evaluate the joint strength and failure modes for different joining techniques. Adhesive bonding was found suitable for the acrylic type adhesive. Bolting had no significant effect on the joint strength in the hybrid joints for the acrylic type adhesive. For the rubber type adhesive, the hybrid joint shows better performance compared to other types of joints. For rubber type adhesive, bolting in the hybrid joint significantly improved the load carrying ability of the joint. Composite materials have high strength to weight ratio when compared to conventional materials such as steel, aluminum, etc. Hence, the

application fields for composites are continuously expanding from high tech to common engineering applications. Recently, traditional materials such as steel or metal alloys have been widely used in conjunction with the innovative ones called fiber reinforced polymers in order to obtain hybrid structures. The joints between these materials often represent the weak point of structures. This is why a key challenge is to realize the structural joints able to bear elevated loads. To increase the effectiveness and efficiency, many prehistoric as well as modern devices require the assembly of several components, often involving dissimilar materials. By combining multiple materials, the resulting structure acquires useful features of each constituent, often making the whole greater than of the parts. Joining allows us to fabricate efficient, lightweight, and open structures with tailored properties and performance matched to the intended use. There are three different types of techniques for joining between a composite and metal. They are classified as(a) adhesive bonding, (b) mechanical fastening, and (c) hybrid joining.
Adhesive bonding requires no holes to be drilled which eliminates the stress concentration and provides uniform stress distribution at the joint. Certain brittle or damage prone adherends are difficult to drill and hence mechanical fasteners cannot be used. However, these joints are very sensitive to the environment and have poor heat resistant properties. Kwon et all suggested that difficult because of its catastrophic mode of failure.

P. D. Yadav[3]: Joint design in the composite structures is a very important consideration because improper design may lead to overweight or defective structures. The joining of composite materials has traditionally been achieved by mechanical fastening or adhesive bonding in this technique the important idea how we can get high ability to load transfer hence composite materials can be two or more than two materials in similar or dissimilar materials the purpose of composite is to get high properties of materials and to improve the ability of load transfer. Adhesive bonding does not require holes and distributes the load over a larger area than mechanical joints; however, adhesive bonding joints are very sensitive to the surface treatment of the material, service temperature, humidity and other environmental conditions. Hybrid joint is a process that makes use of two different joining techniques. They, in principle, bring together the advantages of two different techniques. In hybrid joining two or more joining operations are carried out either simultaneously or sequentially, leading to enhanced properties of the joint. Hybrid joining is used in the assembly of modern light weight automotive and commercial vehicle structures. Combining adhesive bonding with mechanical joining can offer advantages in terms of process ability and load bearing capacity. Any number of papers can easily be found about mechanical joints that use bolts, rivets, or pins. These papers consider various approaches, including Design of Experiments methodology and the 3-dimensional finite element method and/or test. In the present study, the influence of the base material, bolt geometry, and adhesive on tensile shear strength was assessed.

Haider Al-Zubaidy[4]:the efficiency of the application of adhesively-bonded CFRP materials to rehabilitate and/or strengthen steel structures is completely dependent on the bond between the CFRP composites and the steel. As the repaired and/or upgraded structural elements are likely to be exposed to impact tensile loads during service, this necessitates the importance of understanding the bond strength between CFRP materials and steel under dynamic loadings. This paper presents the experimental procedure, the equipment and the test results for double strap joints at four speeds of loading to highlight the effect of loading rate on the bond strength. Two different CFRP layouts with various bond lengths were examined. It was found that the loading rate has significant influence on bond strength and failure modes, although it has little influence on the effective bond length.

MaofengFu[5]: This paper presents a study on the static and fatigue performance of adhesive/bolted (hybrid) joints in a structural reaction injection molded composite. Joint design in composite materials has been a concern and also, the focus of numerous studies in the past. Most of the publications in this area have dealt with either adhesive or bolted joints in laminated continuous "ber composites. Studies on hybrid joints combining adhesive with bolts are very few. Sawa and his coworkers have considered hybrid butt joints in which two hollow cylinders are fastened by a bolt and a nut with an initial clamping force after being joined by an adhesive. The external load was either tensile normal to the adhesive layer or torsional, and, in both cases, they observed an increase in joint strength relative to the adhesive joints alone. Recently, with increasing interest in random "ber composites for automotive applications, attention is being paid to joint design with sheet molding compound (SMC) composites and structural reaction injection molded (SRIM) composites. Mallick and his co-authors have published several papers on bolted lap joints as well as adhesive lap joints in SMC and SRIM composites. In an attempt to improve the joint strength of such composites, a hybrid of adhesive and bolted joints has also been explored. In Ref., Satish Kumar and Mallick have reported the experimental work on the static behavior of hybrid adhesive/ bolted joints in polyurethane}SRIM composites. Static tests were conducted with 25.4-mm wide/3.53-mm thick SRIM specimens, 6.35-mm diameter steel bolts and 19-mm diameter round SAE Grade 8 steel washers. An epoxy adhesive was used for these joints and the adhesive thickness was 0.762 mm. The bolt was centrally located in the 25.4-mm_25.4-mm overlap area. In these tests, hybrid joints failed at a higher load than the bolted joints and with the proper clamping torque (between 3.39 and 5.08Nm) reached the same failure load as the adhesive joints. Furthermore, unlike the adhesive joints, hybrid joints failed in two steps, "rst by initiation of "ber tear (akin to de lamination in laminated continuous "ber composites) at one of the lap ends and then by tensile failure across the bolt hole. This led to a slightly higher overall elongation at failure for specimens with the hybrid joints. Later, static tests with 50- mm wide specimens have shown similar, but perhaps less dramatic results. In fatigue tests with 50-mm wide specimens, the hybrid joints with 19-mm diameter round SAE Grade 8 steel washers, on an average, survived longer fatigue cycles than adhesive joints at high-load levels, but they did not show any improved results at lower loads.

OBJECTIVES

Traditional joints such as weld, spot, rivet, etc. are used for connecting various Automotive, Aerospace, etc. parts. To enhance strength of already existing joints without changing existing design can be achieved by use of industrial adhesives. In this project , modeling of hybrid joint in CAD software is done and analyzing it for induced structural stresses and deformation in Ansys software. Tensile tests were performed to evaluate the joint strength and failure modes for different joining techniques.

METHODOLOGY

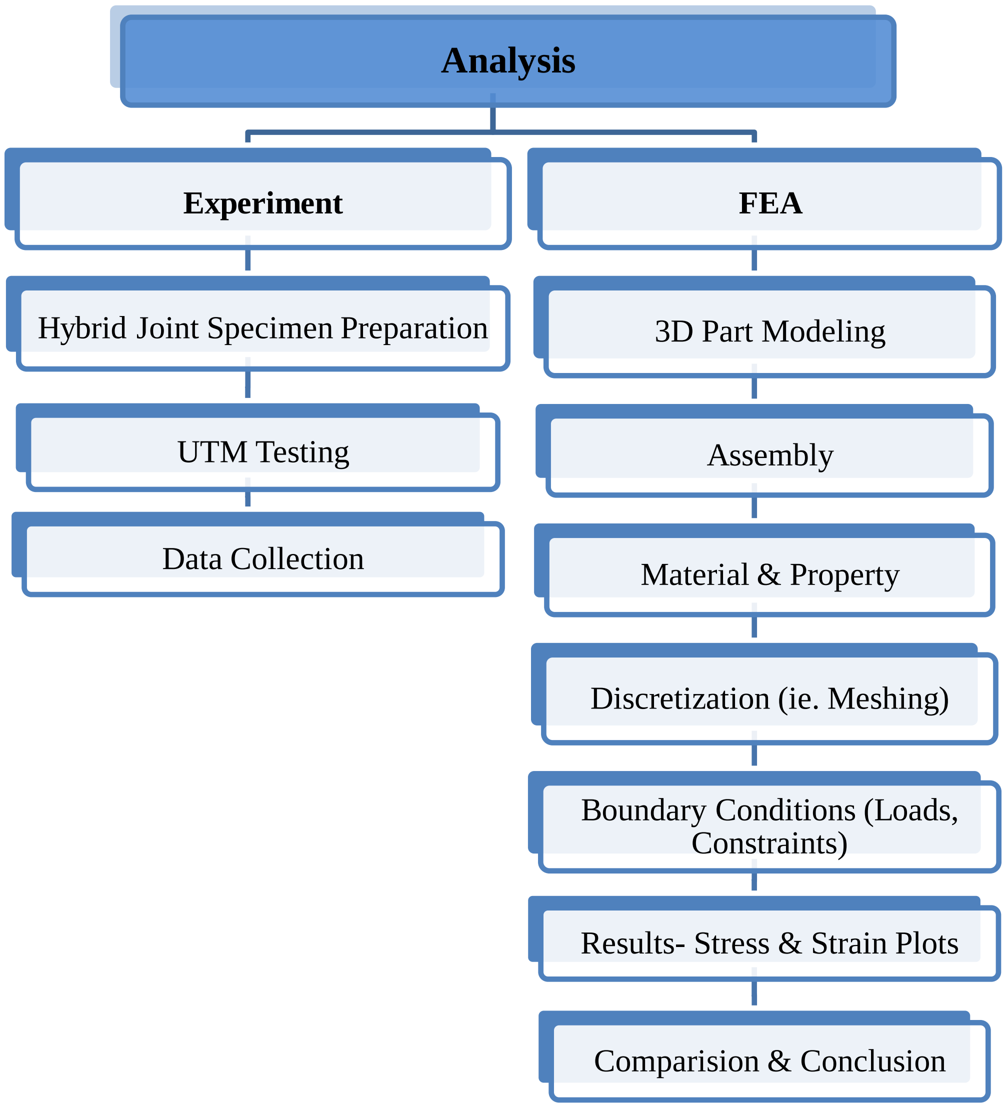


Fig.No.1 Flowchart for the Methodology

STATIC ANALYSIS

For bolt adhesive joints mild steel sheets were used in test. Araldite Epoxy Resin is used as Adhesive. Factors which affect the joint- 1. Adherent material combination
2. Type of adhesive used.

1. Material Properties:
Steel

Modulus of Elasticity	: 200GPa
Poisson's ratio	: 0.30
Density	: 7.85e-6 kg/mm3
Yield Strength	: 520 Mpa

Araldite Epoxy Resin(Adhesive)

Modulus of Elasticity	: 3100 MPa
Poisson's ratio	: 0.42
Density	: 1.15 gm/cc3
Yield Strength	: 83 MPa

2. Plate Dimensions	: 150*50*2 mm
3. Overlapping length	: 50 & 70 mm
4. Adhesive thickness	: 1 mm
5. Adhesive Area	: 2500 mm2 &
	: 3500 mm2

Finite Element Analysis:

Models of plates with bolted & hybrid joints are done by using CAD package CATIA V5 as per following;

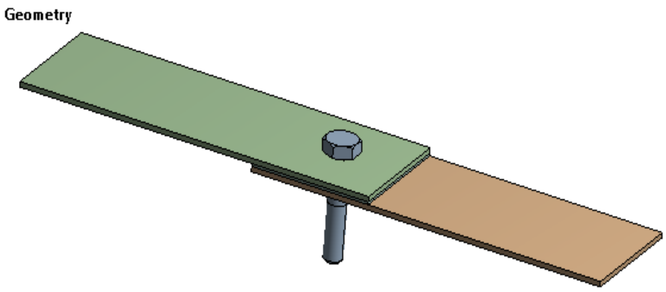
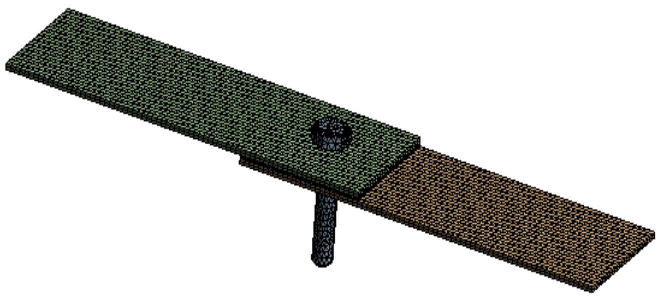


Fig.No.2 CATIA model of 50mm with Adhesive

Mesh



Statistics	
Nodes	58861
Elements	13937

Fig.No.3 Meshing of 50mm with Adhesive

Boundary condition

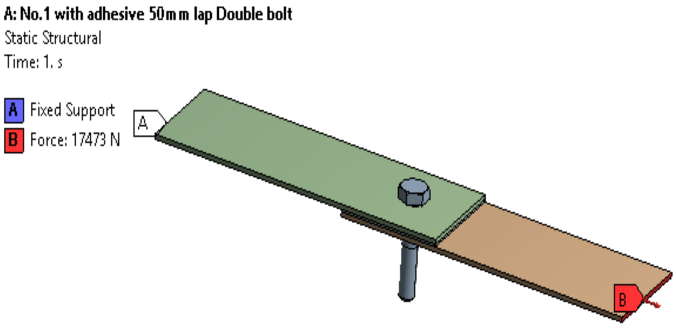


Fig.No.4 Boundary condition of 50mm with Adhesive

Total deformation

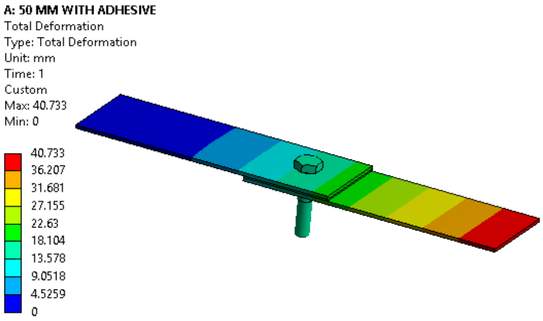


Fig.No.5 Total deformation of 50mm with Adhesive

Equivalent stress

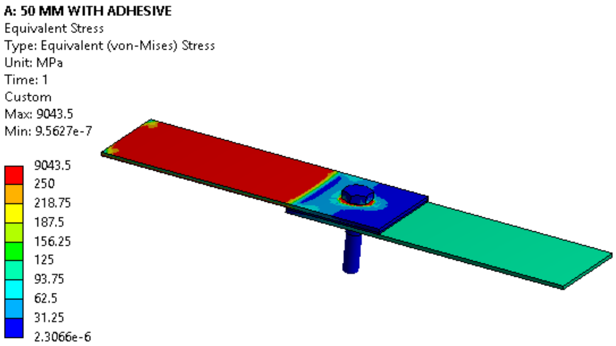
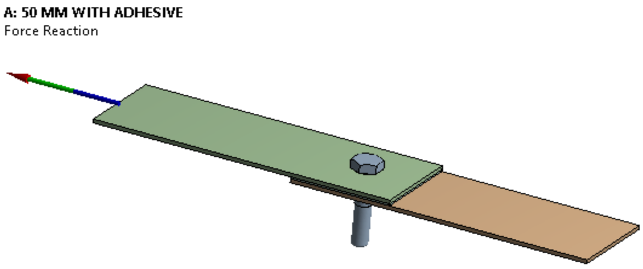


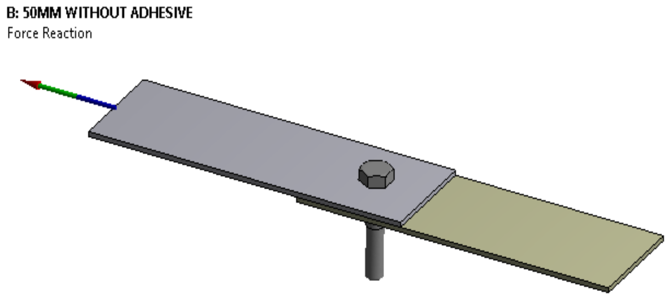
Fig.No.6 Equivalent stress of 50mm with Adhesive

Force reaction



Maximum Value Over Time	
X Axis	-2.5874e-005 N
Y Axis	-11379 N
Z Axis	-3.7176e-005 N
Total	11379 N

Fig.No.7 Force Reaction for 50mm with Adhesive



Maximum Value Over Time	
X Axis	-1.4555e-005 N
Y Axis	-8927.8 N
Z Axis	5.4463e-006 N
Total	8927.8 N

Fig.No.8 Force Reaction for 50mm without Adhesive

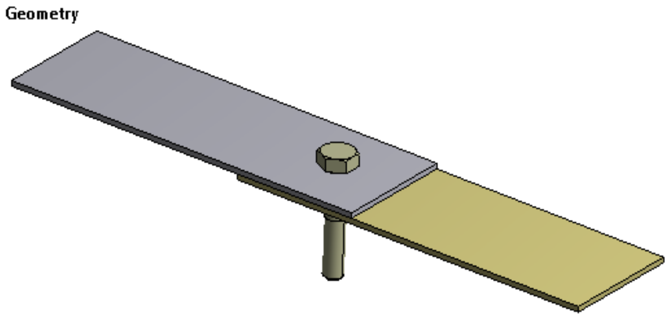
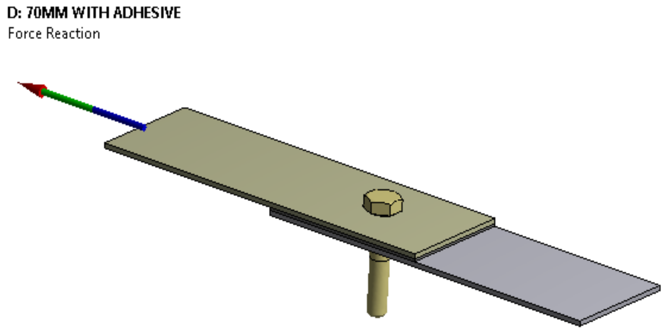


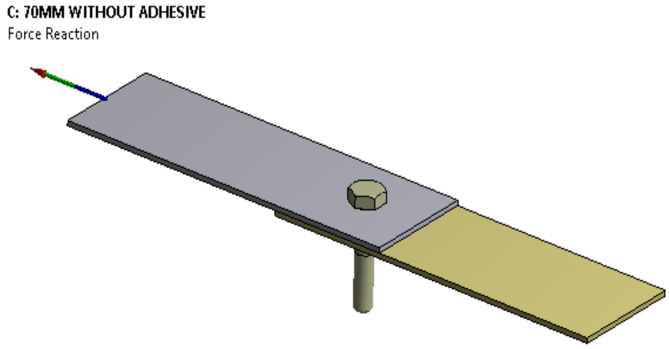
Fig.No.9 CATIA model of 70mm Bolt Adhesive

Force reaction



Maximum Value Over Time	
X Axis	5.5967e-005 N
Y Axis	-8927.8 N
Z Axis	-4.0728e-005 N
Total	8927.8 N

Fig.No.10 Force Reaction of 70mm with Adhesive



Maximum Value Over Time	
X Axis	-3.0587e-005 N
Y Axis	-8114.4 N
Z Axis	-9.681e-006 N
Total	8114.4 N

Fig.No.11 Force Reaction of 70mm without Adhesive

Geometry 50MM WITH DOUBLE BOLT WITHOUT ADHESIVE

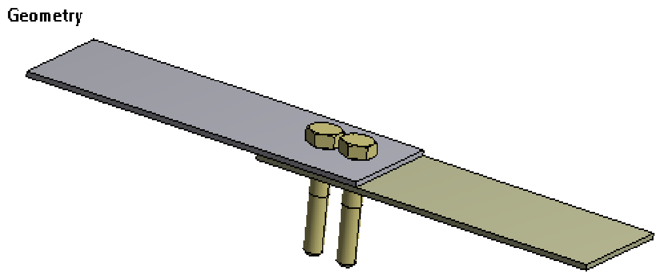
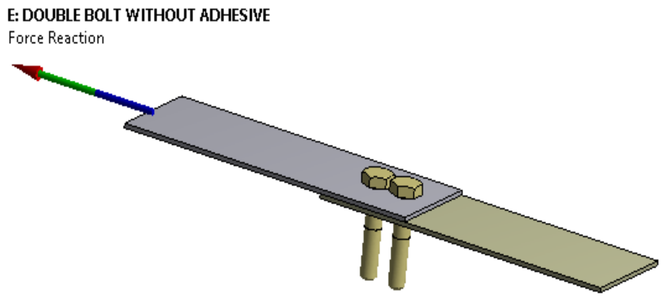


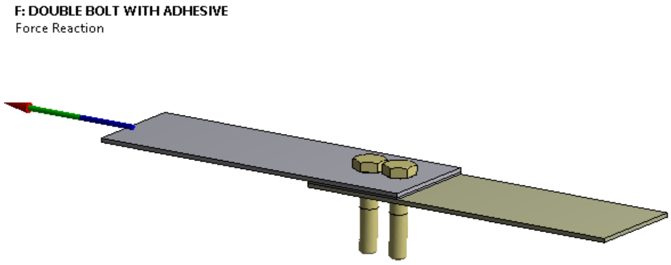
Fig. 12 CATIA model of 50mm without Bolt Adhesive

Force reaction



Maximum Value Over Time	
X Axis	4.2638e-006 N
Y Axis	-17473 N
Z Axis	-1.5155e-005 N
Total	17473 N

Fig. 13 Force reaction of 50mm double bolt without adhesive



Maximum Value Over Time	
X Axis	-1.2759e-005 N
Y Axis	-19463 N
Z Axis	1.3446e-006 N
Total	19463 N

Fig. 14 Force Reaction of 50mm double bolt with Adhesive

EXPERIMENTAL TESTING

The UTM (Instron 1342) is a servo hydraulic fluid-controlled machine, consists of a two column dynamically rated load frame with the capacity of load up to 100kN (dynamic), hydraulic power pack (flow rate 45 litre/minute) and 8800 Fast Track 8800 Controller test control systems is stand alone, fully digital, single axis controller with an inbuilt operating panel and display. The controller is fully portable and specifically designed for materials testing requirement. This controller has position, load and strain control capability. The softwares available with the machine are: (a) Merlin Testing Software for Tensile Test (b) da/dN Fatigue Crack Propagation Test. (c) Kic Fracture Toughness Test. (d) Jic Fracture Toughness Test.

Experimental work

Standard wedge grips are used as fixture on UTM for testing.
First specimen was placed between lower and upper gripper. Then using software and applying tear load option we are gripping specimen. Selection of test that is tensile test & giving length, width and thickness specimen. Use start test option. Proceeded test until specimen break. Verify force plot in software and print tensile test plot

Experimental test photo

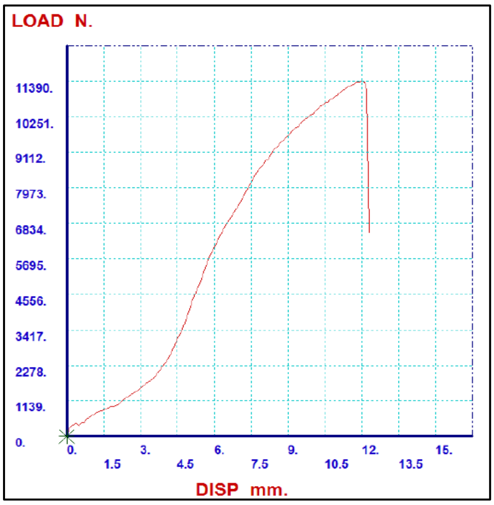


Fig.No.15 Experimental Testing result of 50mm with Adhesive

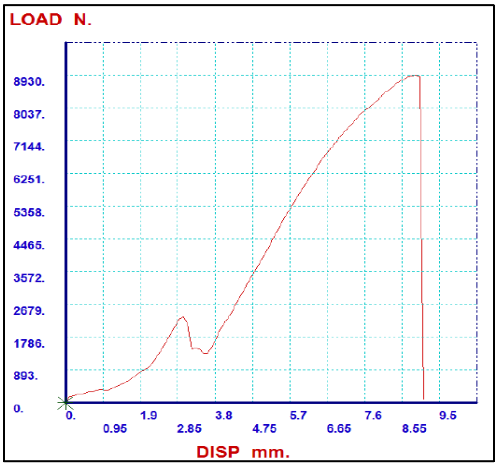


Fig.No.16 Experimental Testing result of 50mm without adhesive

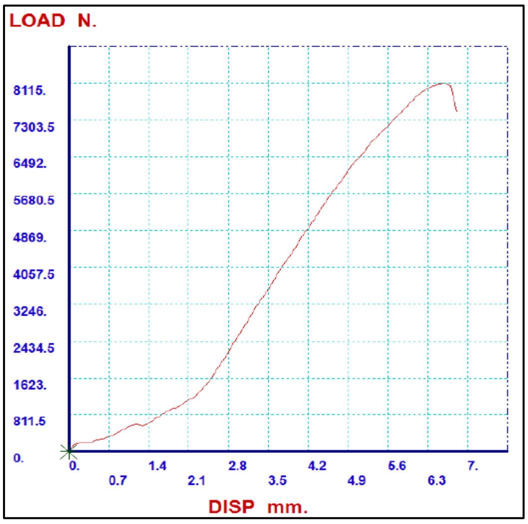


Fig.No.17 Experimental Testing Result of 70mm without Adhesive

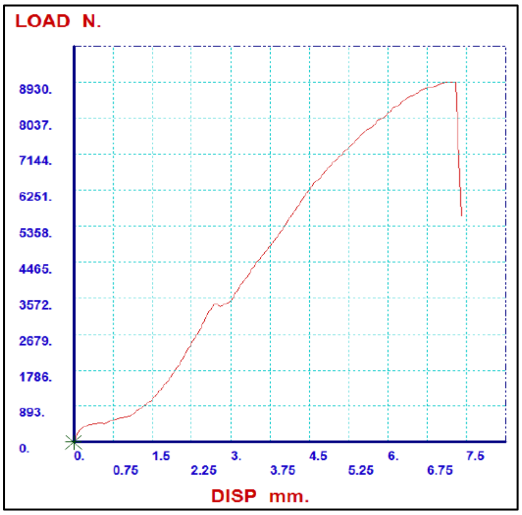


Fig.No.18 Experimental Testing Result of 70mm with Adhesive

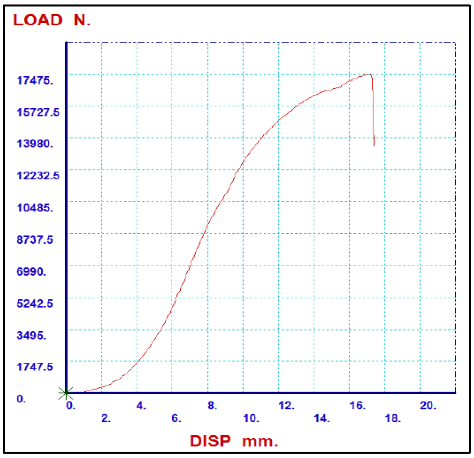


Fig. 19 Experimental Result of 50mm double bolt without adhesive

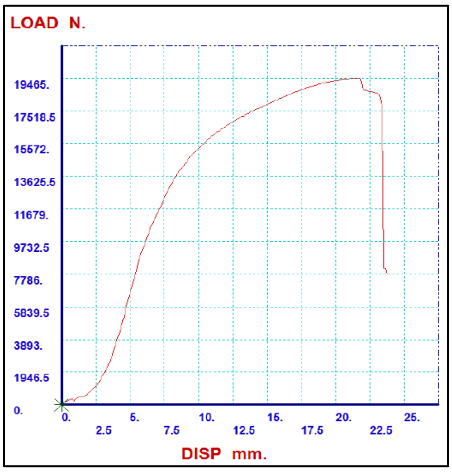


Fig. 20 Experimental Result of 50mm double bolt with adhesive

RESULTS

FEA final result

BOLT JOINTS	Total deformation (mm)	Equivalent stress (MPa)
50mm Without Adhesive	14.298	4163.8
50mm with Adhesive	40.733	9043.5
70mm without adhesive	12.926	3758.8
70mm with Adhesive	28.054	6222.6
50 mm double bolt without adhesive	27.504	6392.1
50mm double bolt with adhesive	45.528	10646

After, Experimental testing & FEA analysis results obtained are as follows:

BOLT JOINTS	**Force reaction** (N) FEA	**Force reaction** (N) Testing
50mm Without Adhesive	8927.8	8927.8
50mm with Adhesive	11379	11387.67
70mm without adhesive	8114.4	8114
70mm with Adhesive	8927.8	8927.8
50 mm double bolt without adhesive	17473	17473.4
50mm double bolt with adhesive	19463	19462.8

CONCLUSION

1. From the above results obtained after testing & analysis are same so, the validation is done. The total Reaction force for bolt joint with adhesive is more than bolt joint without adhesive
2. Force reaction of FEA and testing are in good relationship each other.
3. Due to use of adhesive in 50mm single bolt joint force reaction increase 21.54% as compare to normal bolt joint.
4. Due to use of adhesive in 70mm single bolt joint force reaction increase 9.11% as compare to normal bolt joint.
5. Due to use of adhesive in 50mm double bolt joint force reaction increase 10.22 % as compare to normal bolt joint.
6. Hybrid joints with adhesives are stronger than traditional joints.

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