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Effect of Multiwall Carbon Nanotubes on Tensile Strength of Cross Lap Joint

Vikram H. Londhe[1], Laxmikant D. Joshi[2]
[1]*Principal, Mechanical Engineering Department, New satara College of Engineering & management (Polytechnic) Pandharpur*
[2]*Assistant Professor, SVERI College of Engineering, Pandharpur*

Abstract: This paper compares the tensile strength of an adhesively bonded single cross lap joint with and without the addition of multiwall carbon nanotubes (MWCNT) in the adhesive. Tensile strength analysis of adhesively bonded cross lap joint is done by applying pulling load which produces tensile stress at overlap between two substrates which joined together by using adhesive. Cross lap joint were created using Al-Al substrates. Five tests were performed on Al-Al substrates with and without the addition of MWCNT in the adhesive for each specimen. MWCNT filler particles increase the toughness and strength of epoxy resin when compared to epoxy resin that does not contain MWCNT. MWCNT fill epoxy resin increases toughness and resists crack formation, increasing the interface strength between two substrates.
Keywords: Cross Lap Joint, MWCNT, Epoxy Resin

I. INTRODUCTION

Due to enhanced mechanical properties adhesively bonded lap joints are widely used in aerospace and automobile industries .these joints have better interface strength. Araldite, locktite, etc adhesives can be used to prepare adhesive lap joint. Use of various adhesive depends upon properties of adhesive and working condition. Exceptional mechanical properties of carbon nanotubes (CNTs) enhance them to use as reinforcing nanofillers in composite materials. The results indicate improved mechanical properties through selective use of CNT and processing conditions. The accuracy of the results of strength tests of adhesive bonds will depend on the conditions under which the bonding process is carried out. The bonding conditions shall be prescribed by the manufacturer of the adhesive. Al-Al substrates with and without addition of MWCNT in adhesive is prepared as per ASTM standard and strength analysis of single lap joint is carried out on universal testing machine

II. EXPERIMENTS

A. Substrate Material

In this experiment we have used cross lap joint which is made up of aluminum substrate. The length of substrate 1 and substrate 2 is 102.4 mm each. Thickness of adhesive layer is 1 mm and thickness of substrates is 3 mm width of substrate is 10 mm. We have selected material as Aluminium copper alloy 5251 as it is having good strength and good ductility. It is also known for work hardening rapidly and is readily wieldable; it also possesses high corrosion resistance.

B. Adhesive and Filler Material

Araldite AW 106, Hardener HV 953 is used as epoxy resin. Araldite AW 106 resin/Hardener HV 953U epoxy adhesive is a multi-purpose viscous material that is suitable for bonding a variety of materials like metal, ceramic, and wood etc.

Araldite AW 106 resin/Hardener HV 953U epoxy adhesive cures at temperatures from 68ºF (20ºC) to 356ºF (180ºC) with no release of volatile constituents.

Multi-walled nanotubes (MWCNTs) consist of multiple rolled layers (concentric tubes) of graphene. The interlayer distance in multi-walled nanotubes is close to the distance between graphene layers in graphite, approximately 3.4 Å.For this testing MWCNT used with specifications:

Carbon purity: min.95%.
Number of walls: 3-15
Outer diameter: 5-20 nm;
Inner diameter: 2-6 nm;
Length: 1-10 um;
Apparent density: 0.15-0.35 g/cm3
Loose agglomerate size: 0.1-3mm

Cross lap joint is prepared as per ASTM standard in which first substrates of aluminum were cut into size 102.4 X 10 X 3,Before bonding process Al substrate were properly cleaned with acetone and then dried for some time, Araldite AW 106 (50%) and Hardener HV 953 (50%) by weight were used as epoxy resin, Now this mixture is used as adhesive glue to join two Al substrate together with 10 mm overlap area. Overlap area is common area between two substrate where adhesive is applied. MWCNTs 3% and 5% by weight were added in araldite by sonication process. To prepare nanocomoposite with epoxy resin,CNTs were ultrasonicated for 1 hour in ethanol (0.1mg/ml) and then for another hour after the addition of epoxy. The ethanol was then removed by heating the mixture to 70 ºC while stirring followed by evaporation under high vaccum at 50 ºC for 24 hour. The above epoxy resin is applied on the surface of Al substrate with uniform layer of 1 mm.

III. EXPERIMENTAL ANALYSIS OF CROSS LAP JOINT:

A. Tensile strength analysis of cross lap joint with Araldite AW 106:

Single lap joint substrate orientation is not suitable for tensile testing hence cross lap joint is prepared. Fixture is design and manufactured to fix aluminum substrate of lap joint in it. This fixture is mounted between two jaws of UTM which pulls the aluminum substrate in axial direction and tensile stress is occur at overlap area. In this testing Universal Testing machine is interfaced with computer which shows results of load Vs. displacement, load Vs. time, displacement Vs. time etc.

1) Manufacturing of Cross Lap Joint

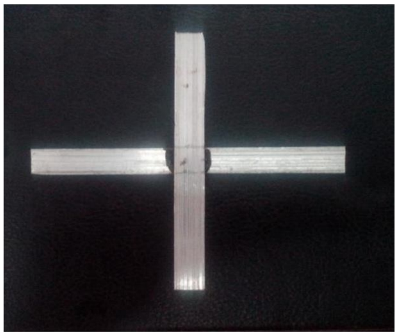

Fig. 1 Cross Lap Joint prepared using Araldite AW 106 as adhesive

As per ASTM standard single lap joint is prepared using aluminum substrates. Two aluminum substrates were cut into size (102.4 X 25.4 X 3) mm. Before bonding process Al substrate were properly cleaned with acetone and then dried for some time.

Araldite AW 106 (50%) and Hardener HV 953 (50%) by weight were used as epoxy resin. Now this mixture is used as adhesive glue to join two Al substrate together with 10 mm overlap area at the center as shown in figure. The above epoxy resin is applied on the surface of Al substrate with uniform layer of 1 mm.

2) Fixture for Holding lap Joint

Fig. 2 Fixture for clamping of Cross lap joint in Universal Testing Machine

Fig. 3 Fixture for clamping of Cross lap joint in Universal Testing Machine

Lap joint cannot directly clamp in jaws of universal testing machine hence fixture is required. To clamp single lap joint in universal testing machine fixture is design and manufactured. Holes are made in fixture and at the substrates of lap joint and clamping pins are used to fix lap joint in fixture.

3) Tensile Testing of single lap:

Fig. 4 Cross lap joint tensile testing

In fig.4 it is shown that single lap joint specimen is properly fixed in fixture, two jaws of UTM pulls the two substrate in opposite direction axially for tensile testing, stress at the joint and force carrying capacity is directly displayed on computer, specimen after tensile testing, it can be easily seen the specimen both substrates were totally separated from joint junction, result of this test is displayed on computer and it is given below.
The process is carried out for cross lap joint without addition of MWCNTs in araldite AW 106 similarly samples are prepared for cross lap joint with addition of MWCNTs in araldite AW 106.

4) Result and Test Parameters
Gauge Length-102.4 mm
Width – 10 mm
Thickness- 3 mm
Area of C/S- 100.00 mm2

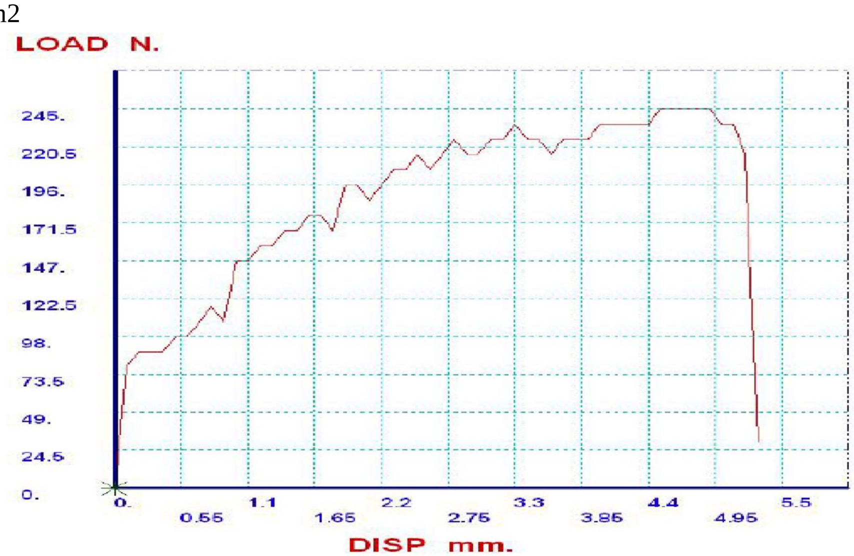

Fig. 5 Load Vs. Displacement for cross lap joint Specimen-1 without MWCNTs in Araldite AW106

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Table No. 01 Tensile testing of single lap joint without adding MWCNTs in Araldite AW 106:

Overlap (mm)	Thickness(mm)	Width (mm)	Force max.P(N)	Tensile strength Nmm2	Average value tensile strength of 5 specimens(N/mm2)
10	3	25.4	245	2.45	2.85
10	3	25.4	258	2.54	
10	3	25.4	176.4	1.76	
10	3	25.4	578.2	5.78	
10	3	25.4	176.4	1.76	

B. Tensile testing of single lap joint with adding 3 % MWCNTs in Araldite AW 106

Similar to shear strength analysis for this testing uniform mixture of araldite AW 106 and 3% MWCNTs is prepared for bonding cross lap joint. Preparation method is same as explain in 3.5.2

After preparation of Nano composite with araldite AW 106,it is used as epoxy resin to join lap joint as per ASTM procedure and testing were carried out as per ASTM standard.

Test Parameters-
Gauge Length-102.4 mm
Width – 10 mm
Thickness- 3 mm
Area of C/S- 100.00 mm2

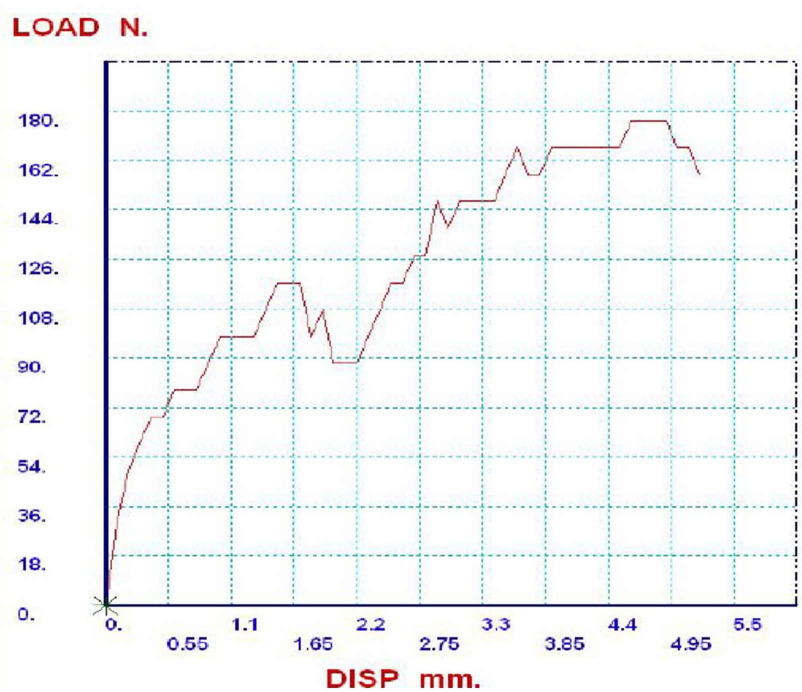

Fig. 6 Load Vs. Displacement for cross lap joint Specimen-1

Above fig.6 shows load Vs. displacement for Cross lap joint specimen-1 which is made from Aluminum material and Araldite AW 106 adhesive.10 mm overlap is placed at joint area. Maximum force taken by this specimen is 176.4N and it can be observed in above graph and results. In the similar way 5 specimens were checked and their results are as below.

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Table No. 02 Result Load Vs. Displacement for cross lap joint Specimen-1

Overlap (mm)	Thickness(mm)	Width (mm)	Force max.P(N)	Tensile strength N/mm2	Average value tensile strength of 5 specimens(N/mm2)
10	3	25.4	176.4	1.76	3.5
10	3	25.4	282	2.84	
10	3	25.4	266	2.646	
10	3	25.4	784	7.84	
10	3	25.4	668	6.68	

C. *Tensile testing of single lap joint with 5% addition of MWCNTs in araldite AW 106*

The process is carried out for single lap joint with 5% addition of MWCNTs in araldite AW 106 similarly samples are prepared for single lap joint with addition of 5% MWCNTs in araldite AW 106. After preparation of Nano composite with araldite AW 106, it is used as epoxy resin to join lap joint as per ASTM procedure and testing was carried out as per ASTM standard.

Test Parameters-
Gauge Length-102.4 mm
Width – 10 mm
Thickness- 3 mm
Area of C/S- 100.00 mm2

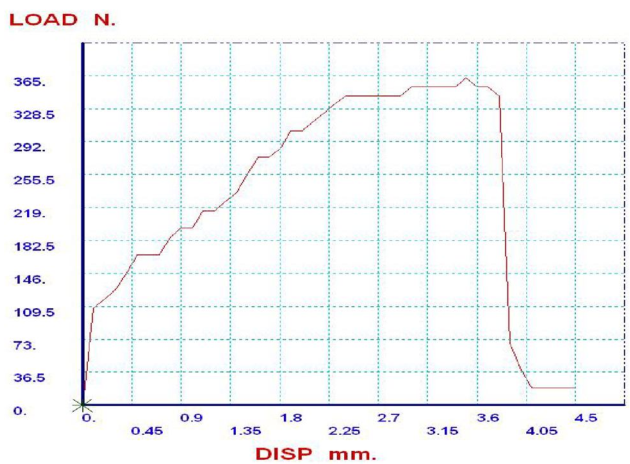

Fig.7 Load Vs. Displacement for cross lap joint Specimen-1 with 5% MWCNTs in Araldite AW106

Above fig.7 shows load vs. displacement for Cross lap joint specimen-1 which is made from Aluminum material and Araldite AW 106 adhesive.10 mm overlap is placed at joint area. Maximum force taken by this specimen is 362.6 N and it can be observed in above graph and results. In the similar way 5 specimens were checked and their results are as below.

Table No.03 Tensile strength of cross lap joint with 5% MWCNTs in Araldite AW106

Overlap (mm)	Thickness(mm)	Width (mm)	Force max.P (N)	Tensile strength N/mm2	Average value tensile strength of 5 specimens(N/mm2)
10	3	25.4	362.6	3.62	7.24
10	3	25.4	323.4	3.23	
10	3	25.4	999.6	9.99	
10	3	25.4	970.2	9.70	
10	3	25.4	970.2	9.70	

IV. RESULT AND CONCLUSION:

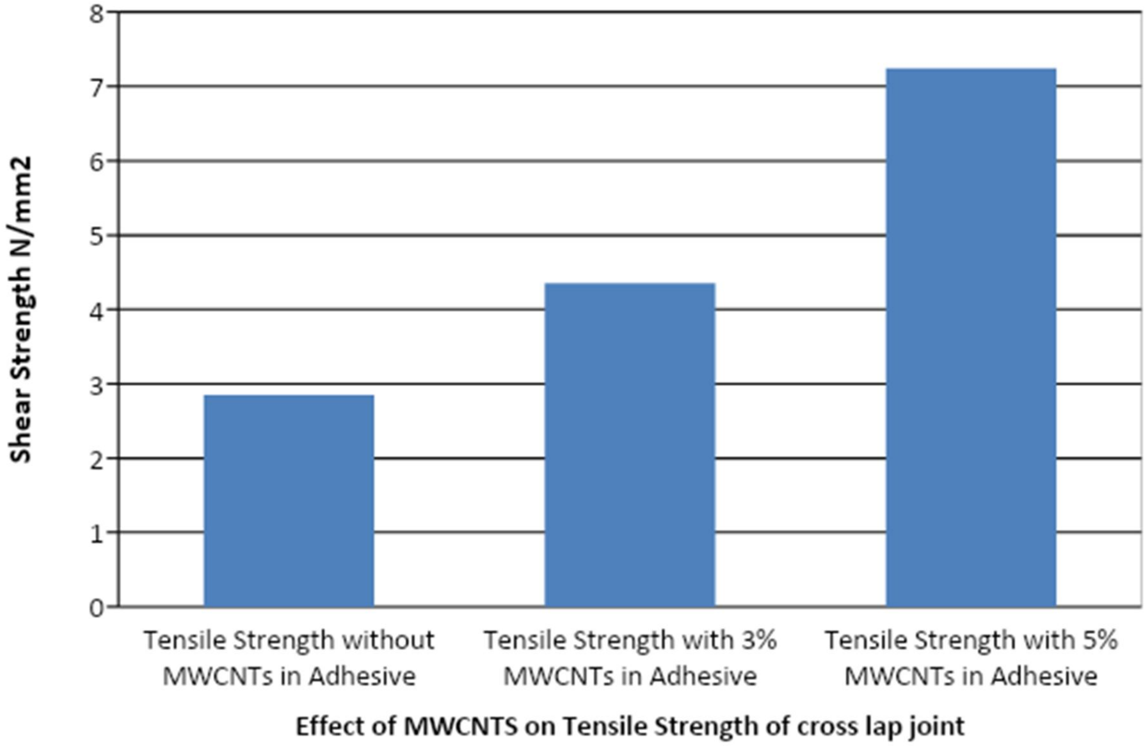

Chart-1: Graph of tensile strength Vs % MWCNTs in adhesive

From above chart no 1 it is clear that for with addition of MWCNTs in araldite strength of cross lap joint is increased as compare to without MWCNTs in araldite. Tensile strength obtained with 5% MWCNTs is greater than tensile strength obtained with 3% MWCNTs and tensile strength obtained with 3% MWCNTs is greater than tensile strength obtained without MWCNTs. The accuracy of the results of strength tests of adhesive bonds will depend on the conditions under which the bonding process is carried out.

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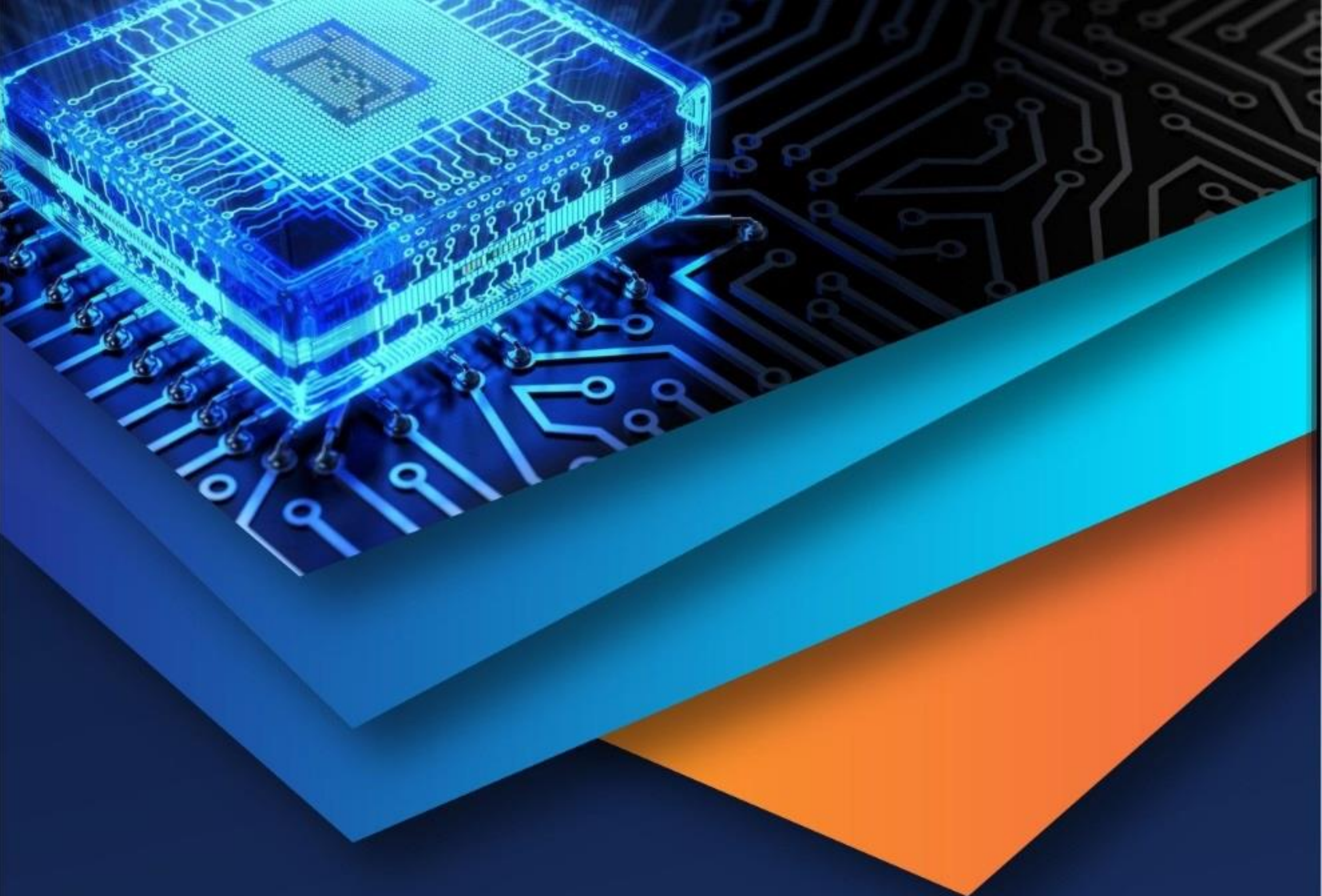

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