A MAJOR PROJECT REPORT
On

DYNAMIC SHEAR STRENGHT CHARACTERIZATION OF ADHESIVE LAP JOINT UNDER DYNAMIC COMPRESSION USING SPLIT HOPKINSON PRESSURE BAR (SHPB) ON AL-6063 T6 ALLOY

Submitted in Partial fulfillment of the requirement
For the Degree Of
MASTER OF TECHNOLOGY
(PRODUCTION ENGINEERING)

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2012-2014

CERTIFICATE

Date:-__________

This is to certify that dissertation entitled **“Dynamic shear strength characterization of adhesive lap joint under dynamic compression using Split Hopkinson Pressure Bar (SHPB) on Al-6063 T6 alloy”** by **Mr. SUBODH KUMAR,** is the requirement of the partial fulfillment for the award of Degree of **Master of Technology (M. Tech.)** in **Production Engineering** at **Delhi Technological University**. This work was completed under my supervision and guidance. He has completed his work with utmost sincerity and diligence. The work embodied in this project has not been submitted for the award of any other degree to the best of my knowledge.

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ABSTRACT

The use of adhesive joints is continuously increasing in automotive, aerospace and structural applications as compared to the bolted joints because of their low cost, manufacturing flexibility and performance. An important feature of any vehicle structure is its behavior during high loading rates so it is important to understand the dynamic behavior of adhesive joints under impact loading.

Al 6063 T6 specimen geometry was made to evaluate the static and dynamic shear strength of the adhesive lap joints. The spectro analysis of specimen was done and weight percentage of the composition was obtained. The dynamic compression experiments were performed by using Split Hopkinson Pressure Bar (SHPB) setup. The static shear strength was evaluated and its variation with adhesive thickness was studied. The result indicates that the static shear strength decreases with increase in adhesive thickness. The specimens were loaded dynamically on the SHPB setup and the dynamic shear strength was evaluated by varying adhesive thickness, adhesive bonded area and pressure. The results indicate that the dynamic shear strength increases up to an optimum area thereafter it decreases. While with increase in adhesive thickness, the dynamic shear strength decreases. With increase in pressure the dynamic shear strength increases.

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Chapter 1

Introduction

Adhesive joints are extensively used in automotive and aerospace industries. The mechanical structures must have sufficient strength against high loading rates and large dynamic deformations. Strain rate play a vital role in determining the mechanical properties of adhesive joint. Therefore for estimating the strength of adhesive joints it is important to study the impact deformation behavior of adhesive joints subjected to impact loading. For evaluation of dynamic response at high strain rate, Split Hopkinson Pressure Bar (SHPB) at the department of Applied Mechanics, IIT Delhi was utilized.

The main reason of adaptation by industry and increasing popularity of the adhesive bonded lap joints is that they are easy to implement, cost-effective, manufacturing flexibility and lesser stress-concentration as compared to bolted joints. Variety of loads act in a structural joint in different applications due to which the understanding and determination of the dynamic strength of adhesive bonded lap joints has a large scope for researcher.

The purpose of the this work to study adhesive joints, was subjected to a dynamic and static loading. Some researcher has conducted experiments on determining the static and dynamic shear strength of adhesive lap joint by varying the parameter like thickness of adhesion, overlap length of adhesion, and load.

1.1 Literature review

In 1913, Hopkinson (1914) developed a new technique for determining the peak pressure attained during impact or shock load. The most significant addition came to Hopkinson in **1949** [1], when Kolsky modified the original version of design. Kolsky method or design quickly gains popularity for testing the material at high strain rate from **10^2 to 10^4 s^{-1}** [1]. It is widely called as the **Split Hopkinson Pressure Bar (SHPB)**. Its name derived from John Hopkinson and his son Bertram Hopkinson. **John Hopkinson (1872)** [2] conducted Rupture tests on iron wire by impact of drop weight. **Bertram Hopkinson (1914)** [3] invented a pressure bar which could measure pressure by explosives and high speed impacts. **Davis (1948)** [4] introduced parallel plate condenser microphones to measure the movement of the bar loaded by detonation. **Kolsky** was the first to use this mechanism to measure stress strain response of a specimen. He made use of two bars and sandwiched a thin specimen in between the bars (Thus the name split Hopkinson). It is important to keep size of specimen thin so as to negate the inertia effects. **Krafft (1954**) [5] used strain gauges in place of condenser microphones. He also used a striker bar in place of explosive detonator which gave a trapezoidal shaped pulse. **Lindholm (1964)** [6] used most of the previous improvements and presented an updated version of the kolsky bar.

Srivastava et al. [7] used split Hopkinson pressure bar technique in compression to evaluate the dynamic shear strength of adhesive lap joints at high loading rates. The specimens were loaded dynamically at four different loading rate, and the transmitted load through the joint was obtained .The behavior of epoxy adhesive under dynamic loading was investigated. During the dynamic loading equilibrium conditions of the specimen were verified and strength was determined from the peak transmitted load. The results of the experiment clearly indicate that adhesive lap joints when subjected to impact loading can transmit significantly higher loads.

Adamvalli et al. [8] used split Hopkinson pressure bar setup and determine the strength of single lap joint using titanium adherents and Araldite adhesive at two different loading rates and four different temperatures in compression. The experimental results obtained shows that the strength of adhesive lap joint increases with loading rate and decreases with increase in temperature. They also observed that the dynamic strength of adhesive lap joint is more than the quasi-static strength for a given temperature and loading rate.

Goda et al. [9] investigated the effects of the strain rate sensitivity on the behavior of epoxy resin structural adhesive under compression for strength of tubular lap joint on Split Hopkinson pressure bar apparatus. The shear stress distribution at the adhesive interface of tubular lap adhesive joints under impact loading was studied. The results indicate that the shear strength increased for the adhesive thickness layer of about 0.2 mm and decreased thereafter.

Sen et al. [10] investigated the effect of overlap area of the specimen on the estimation of the dynamic strength of an adhesive bonded single lap joint using a Kolsky bar. An experimental method was utilized to obtain the shear strain distribution on the adhesive length at the time of failure. The effect of overlap length and width on strain was also studied.

Chen et al. [11] conducted experiments on mild steel specimen by using split Hopkinson pressure bar apparatus with and without pulse shaper. The results of the experiments indicate that to achieve dynamic equilibrium and constant strain rates pulse shaping is essentially required.

F.Delvare et al. [18] conducted experiment on the building materials such as concrete and some geomaterials which resists accidental event such as shock .The approach accepted in this paper can be used to interpret the dynamic bending on quasi-brittle material specimens. In this paper a method is developed specifically for the purpose gives accurate and reliable results.

Sohan Lal Raykhere et al.[19]conducted his experiment evaluation of the shear strength of adhesive joints prepared using four different commercial adhesive Araldite 2014,Araldite 2011,Epibond 1590 and A/B Locite 324.Joints were prepared with two different adherent combinations; aluminium-aluminium and aluminium-glass fiber reinforced plastics. They found that dynamic strength was always higher than the static strength for all adhesive and among all the adhesive Epibond 1590 A/B exhibited the highest rate sensitivity whereas Locite 324 show lowest rate sensitivity.

1.2 Motivation & Objectives

Cost-effectiveness, lesser stress-concentration and manufacturing flexibility is the main concern in the automotive and aerospace industries has increased in recent years. So study of the dynamic behavior of the adhesive joints under impact loading is increasing. Till date on the on the dynamic shear strength of adhesive lap joint a very limited work has been done. So the main concern of our work is to evaluate the dynamic shear strength of the adhesive joint and its variation with different parameters and comparison of dynamic shear strength and static shear strength with respect to adhesive thickness of the joint. Split Hopkinson Pressure Bar (SHPB) is used for determining the dynamic shear strength.

The main objectives of this study are as follows:

1) To prepare lap joint specimen of Al-6063 T6 for static and dynamic test.
2) To study the variation of dynamic shear strength with the variation of adhesive bonded area adhesive thickness and strain rate.
3) Comparison of static and dynamic shear strength with respect to adhesive thickness.

Chapter 2

Experimental Setup & Description

The experimental setup consists following components

1. High speed data acquisition system
2. Control chamber
3. Compressor and storage cylinder
4. Velocity probes
5. Projectile
6. Incident and transmitted bars
7. Barrel

2.1 Description of the experimental setup

LOADING DEVICE

A cylindrical bar is used as a striker (projectile) in this loading device in SHPB setup. To accelerate the projectile compressed air is used which impact the incident bar. The striking velocity is measured optically or magnetically. The projectile speed can be changed by changing the pressure of the gas in chamber. The duration of the loading is proportional to the projectile length. The dimensions of the projectile are

Diameter of projectile = 19 mm

Length of the projectile = 300 mm

HIGH SPEED DATA ACQUISITION SYSTEM

High speed data acquisition systems consists two types of channel one is digital channel and another one is analog channel. Data is recorded by the digital channel with the help of optical sensors. By using this data we can calculate the velocity of the projectile. The analog channels are used to record the strain signal from the strain gauges mounted on the two bars. Using these channels we obtain the data of incident, reflected and transmitted strain pulse in the bars. The strain gauges are connected in half bridge configuration. The strain gauges and optical sensors are shown in fig 2.1.

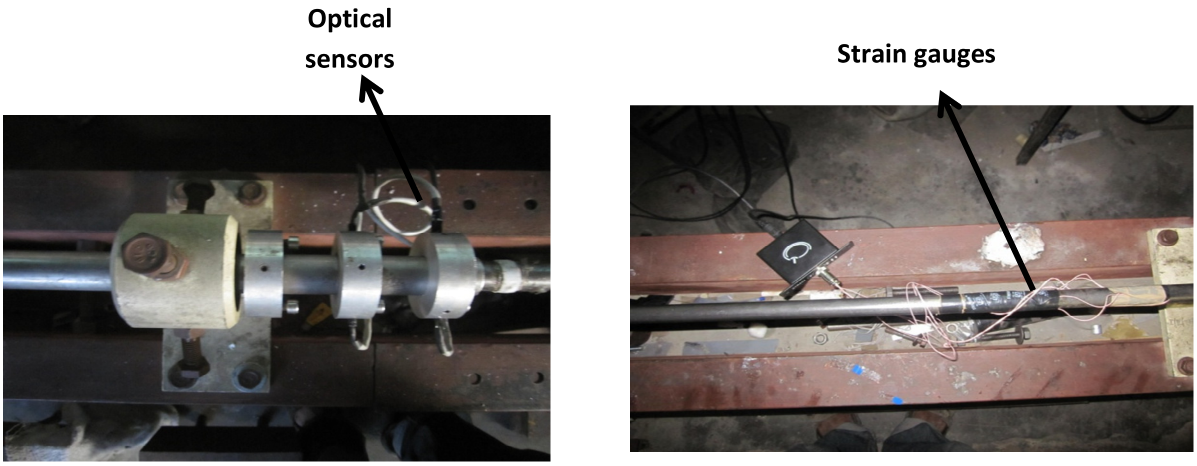


Fig 2.1- Pictures of optical sensors and strain gauges respectively.

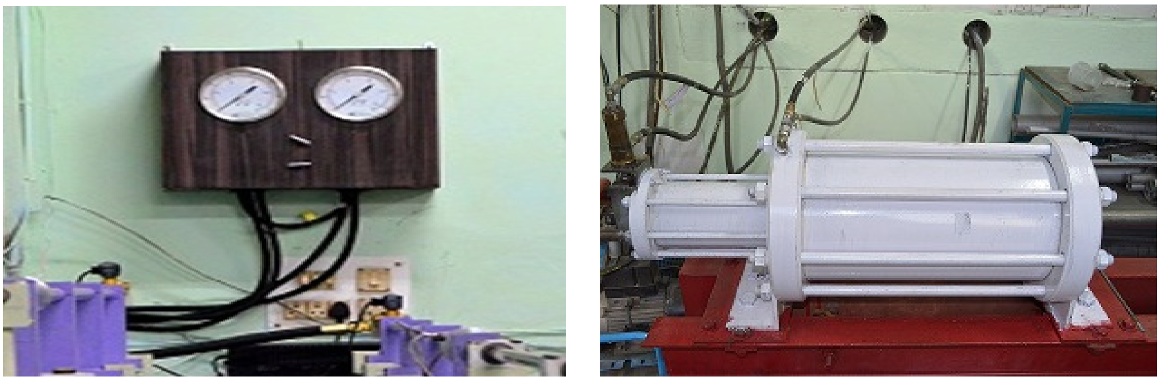
COMPRESSOR AND STORAGE CYLINDER

In the current experimental setup, the compressor is used to fill the air inside the storage cylinder. The compressed air from the cylinder is used to create pressure inside the gas chamber. Both the equipmentis shown in Fig 2.2.

(a) (b)

Fig 2.2- Pictures of the (a) compressor (b) storage cylinder.

LAUNCHING MECHANISM



(a) (b)

Fig 2.3- Pictures of the (a) control panel (b) pressure chamber.

The launching mechanism consists of a chamber which is filled with compressed air from the storage cylinder. It consists of a main chamber and two other chambers before it. The launch pressure is built inside the main chamber. The projectile moves inside a barrel before hitting the incident bar. The velocity is measured with the help of optical sensors mounted on the mouth of the steel barrel, and the high speed data acquisition system. These components can be seen in the Fig 2.3 and Fig 2.4.

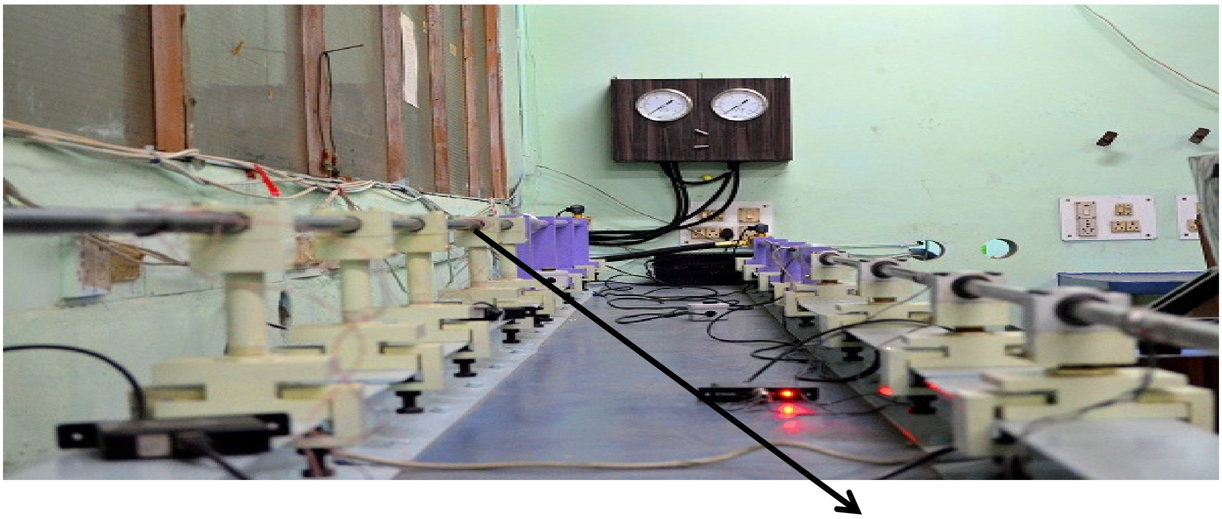


Fig 2.4 -Picture of the barrel.

BARS

Two bars are used in SHPB, one incident bar and the other transmission bar. As the projectile comes and hits the incident bar it generates a compressive stress wave in the incident bar. The strain measurement on the bars is performed with the help of strain gauges in half Wheatstone bridge configuration. The specimen is placed between the two bars. To reduce the effects of inter facial friction lubrication is used on the specimen surface and on the bar ends. A momentum trap is also kept after the transmission bar to stop the transmission bar after impact. The bars are made of Aluminium 6063 T6. The properties of Aluminium 6063 T6 are shown in table 2.1. The diameter of the bars is 19mm.

Properties	Metric values
Density	2700 Kg/m^3
Modulus of elasticity	69Gpa
Yield strength	214 Mpa

Table 2.1 Properties of Aluminium 6063 T6.

In a table 2.2spectro analysis of Al6063 T6 was conducted and composition details are shown below

Al(%)	Si(%)	Cu(%)	Mg(%)	Fe(%)	Zn(%)	Ni(%)	Mn(%)	Cr(%)	V(%)
98.69	0.489	0.0176	0.5171	0.1834	0.0088	0.0016	0.051	0.0054	0.0037
Ti(%)	Bi(%)	Pb(%)	Sn(%)						
0.0132	0.0016	0.0006	≤0.0010						

Table 2.2 Spectro Analysis of Al6063 T6

2.2 Working of MHSPB A

During dynamic experiments, the following assumptions were made:

a) The wave propagates without any dispersion.

b) The wave propagation is assumed to be one-dimensional.

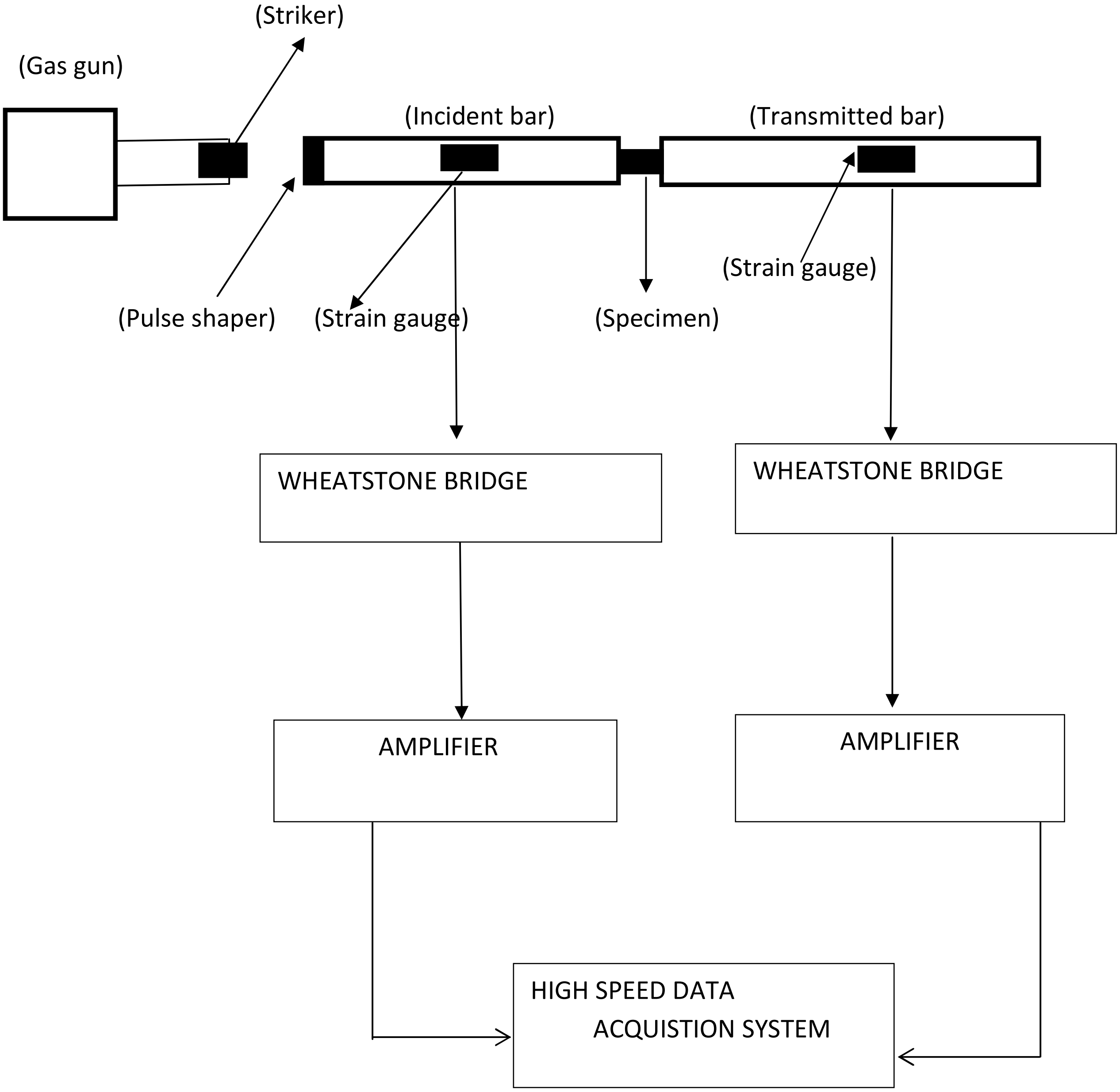


Fig2.5-Schematic diagram of Kolsky compression bar.

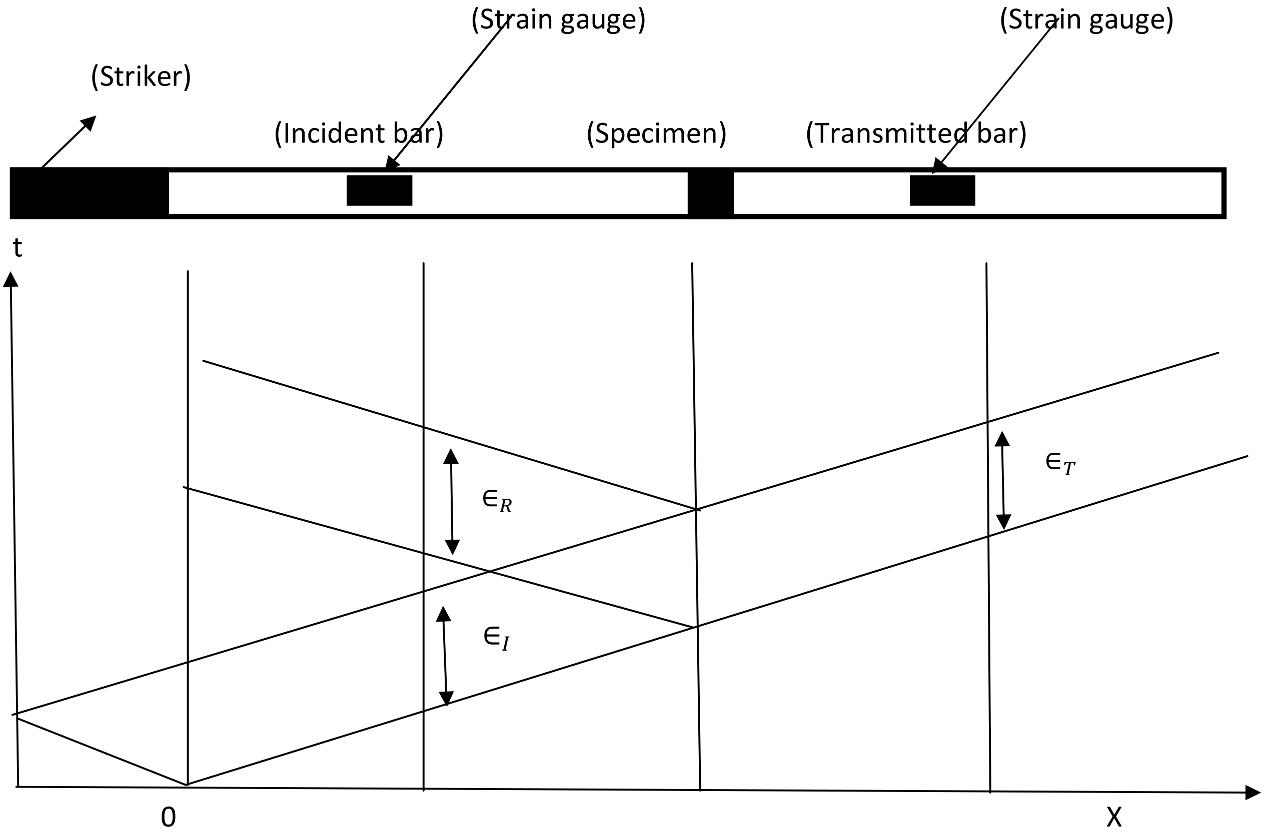


Fig 2.6- X-t diagram of stress wave propagation.

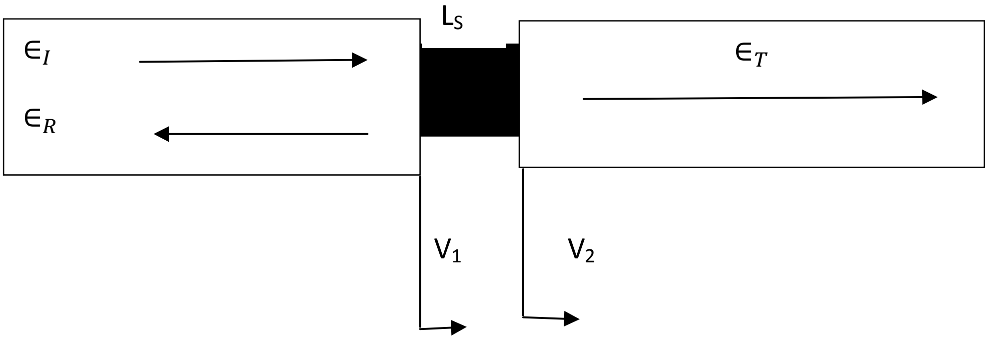


Fig 2.7-Testing section of Kolsky bar.

The original Hopkinson device (with only one cylindrical bar) was modified by Kolsky [1] (two bars) for indirect strain measurements on both sides of the specimen. The "classical" Split Hopkinson Pressure Bar system is composed of two axial bars (incident bar and transmitter bar) and a striker bar launched by a gas gun. As shown in Fig 2.5 the specimen is put between the two main bars. The impact between the striker bar and the incident bar generates a compressive stress wave. The movements of the wave are shown in Fig 2.6. The main characteristic of Hopkinson type experiments is to perform indirect strain measurements, strains are measured on the bars (and not directly on the specimen). Gauges give the values of incident ($\in_I$), reflected ($\in_R$) and transmitted ($\in_T$) strain waves in the bars. [13].

When a compressive wave propagates along the bar axis due to the impact load applied at its end, the material is pushed forward because of axial kinetic energy and pushed sideways or in radial direction because of Poisson's effects. The material acceleration in the radial directions in turn causes inertia-induced stress in the axial direction. These two dimensional effects result in wave dispersion when propagating along the bars. The effects of dispersion accumulate as the waves propagate over distance, and become more significant when bar diameter increases. So diameter of the specimen should be small. To reduce the friction effects grease is applied on the incident and transmitted bar. To get constant strain rate and to achieve stress equilibrium we make the use of pulse shaper. Pulse shaper is even more important if the material is highly strain rate sensitive. [14, 15, 16]

The material and diameter of the striker and the bar are the same. The stress intensity in the bar is given by [4],

$$\sigma_1 = \frac{1}{2}\rho_B C_B V_{ST} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.1)$$

And the strain intensity in the bar is given by

$$\in_1 = \frac{1}{2}\frac{V_{ST}}{C_B} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.2)$$

Where

V_{ST}= Striking velocity

C_B= Wave velocity in bar

ρ_B= Density of bar

σ_1= Stress in the bar

$\in_1$ = Strain in the bar

The calculation below is based on the assumption that the waves move without dispersion. It means that that the pulses recorded by the strain gauges represent those at the ends of the bar which is in contact with the specimen. The next assumption which we take is 1D wave propagation in the bar.

Now,

$$T = \frac{2L}{C_{ST}} \quad \text{………………………………………………………….(2.3)}$$

$$V_1 = C_B(\varepsilon_I - \varepsilon_R) \quad \text{…………………….………………….(2.4)}$$

$$V_2 = C_B\varepsilon_T \quad \text{…………………………………………………..(2.5)}$$

Where,

T = Loading duration

C_{ST} = Elastic wave speed of the striker material.

$\in_I$ = Strain values in the incident wave

$\in_T$= Strain values in the transmitted wave

$\in_R$= Strain values in the reflected wave

V_1 and V2 can be seen in Fig 2.7 shows the velocity of two bars at the end points towards specimen. The specimen gets compressed with the strain rate of

$$\dot{\epsilon}=\frac{V_1-V_2}{L_S}=\frac{C_B}{L_S}(\epsilon_I-\epsilon_R-\epsilon_T)\text{.............................}(2.6)$$

Integrating the above equation we get,

$$\epsilon=\int_0^t \dot{\epsilon}\ \mathrm{dt}=\frac{C_B}{L_S}\int_0^t(\epsilon_I-\epsilon_R-\epsilon_T)\mathrm{dt}\ \text{.........................}(2.7)$$

Where,

L_S= Initial length of the specimen.

The stresses at both ends of the specimen are given by the following equations,

$$\sigma_1=\frac{A_B}{A_S}E_B(\varepsilon_I+\varepsilon_R)\text{.................................}(2.8)$$

$$\sigma_2=\frac{A_B}{A_S}.E_B\varepsilon_T\ \text{...}\ (2.9)$$

Where,

A_B= Cross section area of the bar

A_S= Cross section area of specimen

E_B= Young's modulus of the bar material

As the specimen is considered stress equilibrated i.e. the specimen deforms nearly uniformly over its volume [4] therefore, we can say that

σ_1=σ_2 or

We can say that

$\varepsilon_I+\varepsilon_R=\varepsilon_T$.. (2.10)

Equation (7) can be simplified with the help of equation (10) we get,

$$\dot{\in}=-2\frac{C_B}{L_S}\in_R \text{...} (2.11)$$

$$\in= -\frac{2C_B}{L_S}\int_0^t \in_R \, dt \text{.................................} \quad (2.12)$$

$$\sigma = \frac{A_B}{A_S} E_B \in_T \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots .. (2.13)$$

Equation (12) and (13) gives the final equation as to how we get the engineering stress and strain values. In the above equations the compression values are taken positive and the tensile values are taken negative [17, 18].

Chapter 3

Experimental Results & Discussions

3.1 DESIGN OF THE STATIC SPECIMEN

The specimen material used in static compression testing is Aluminium- 6063 T6. The properties are given in the table 3.1 .

Specimen dimensions are :

Diameter = 16mm

Length = 114mm

Overlap length = 15 mm.

Fig 3.1 shows the two parts of the cylindrical Aluminium-6063 T6 specimen used in the experiment.

Properties	Metric values
Density	2700 kg/m^3
Modulus of Elasticity	69 Gpa

Table 3.1 Properties of Aluminium-6063 T6.

Fig 3.1-Aluminium-6063 T6 specimen for static test.

3.2 ADHESIVE

Two component epoxy adhesive used is **Araldite AV 138M** with **Hardener HV 998**. Araldite AV 138M with Hardener HV 998 is a room temperature curing paste adhesive of high strength. When it is fully cured the adhesive will have excellent performance and has high chemical resistance. It is suitable for bonding a wide variety of metals, ceramics, glass, rubbers and other materials also in telecommunication and aerospace applications.

PROPERTIES

a) Excellent adhesion to many different materials.

b) Great strength, toughness and resilience.

c) Excellent resistance to chemical attack and moisture.

d) Outstanding electrical insulating properties.

PRETREATMENT

The strength and durability of a bonded joint are dependent on proper treatment of the surfaces to be bonded. At the very least, joint surfaces should be cleaned with a good degreasing agent such as acetone or other proprietary agents in order to remove all traces of oil, grease and dirt. The strongest and most durable joints are obtained by either mechanically abrading or chemically etching the degreased surfaces. Resin and hardener should be mixed until they form a homogeneous mixture.

Mix ratio	**Parts by weight**	**Parts by volume**
Araldite AV138M	100	100
Hardener HV 998	40	40

3.3 DESIGN OF DYNAMIC SPECIMEN

The specimen material used in static dynamic compression testing is Aluminum-6063 T6. Specimen dimensions are :

Diameter = 16mm

Fig 3.2 shows the two parts of the cylindrical Aluminium-6063 T6 specimen used in the experiment. L_S is the overlap length of the adhesive.

Fig-3.2-Aluminium-6063 T6 specimen for dynamic compression test.

3.3.1 SPECIMEN PREPARATION

A layer of adhesive was applied on one part of the specimen and second part of the specimen was put on the first part and then the specimen was kept idle for 24 hrs for curing.

3.4 EXPERIMENTAL RESULTS

3.4.1 STATIC COMPRESSION TEST

A static compression test was performed on INSTRON UTM machine at a cross head speed of 0.1 mm/min. Fig 3.3 shows the adhesive joint specimen under compression on INSTRON UTM machine. First experiments were performed for adhesive thickness of 0.31 mm and second experiment was performed on adhesive thickness of 0.42 mm. In both the experiments the bonded shear area was 240 mm^2 was taken.

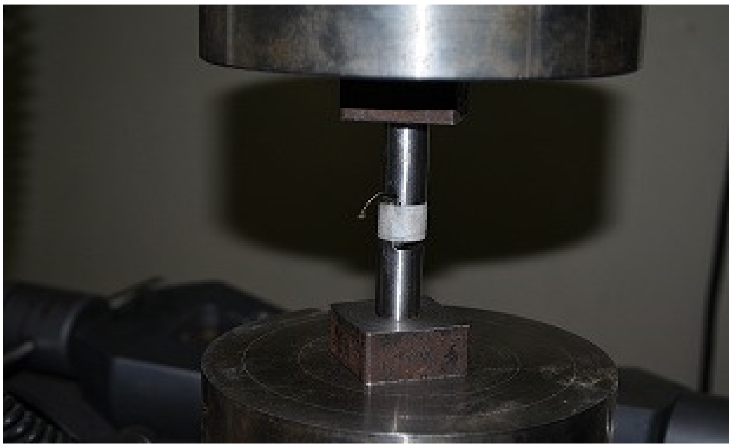


Fig 3.3- Adhesive specimen in compression during static test.

For static compressive experiments:

$$\text{Shear strength of joint} = P_M / A_b \ldots\ldots\ldots\ldots\ldots(3.1)$$

Where

P_M = maximum breaking load for the joint.

A_b = bonded shear area of the adhesive lap joint.

Fig 3.4 shows the adhesive failure of the joint after post-test examination. It was observed that the failure takes place at the interface of the adhesive and the material surface.

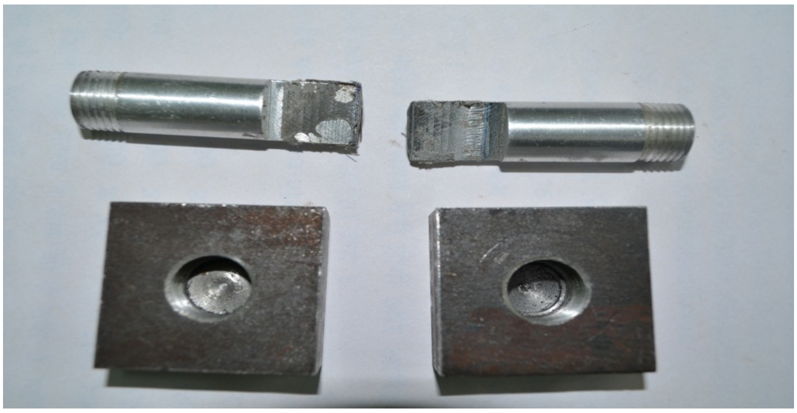


Fig 3.4-Adhesive failure of the joint in static compression test and specimen holder.

Specimen Holder

Specimen holder is made of mild steel ,which is used as a holding device to hold the specimen vertically straight during the static compression test.

EXPERIMENT NO	ADHESIVE THICKNESS (mm)	BREAKING LOAD (N)	STATIC SHEAR STRENGTH (Mpa)
1	0.31	479	1.99
2	0.43	236	0.98

Table3.2 Variation of the static shear strength and maximum load with adhesive thickness.

Fig 3.5 shows the variation of load with time for adhesive thickness 0.43mm.

Table3.2 shows clearly that the static shear strength decreases with the adhesive thickness i.e. lesser the adhesive thickness more will be the static shear strength.

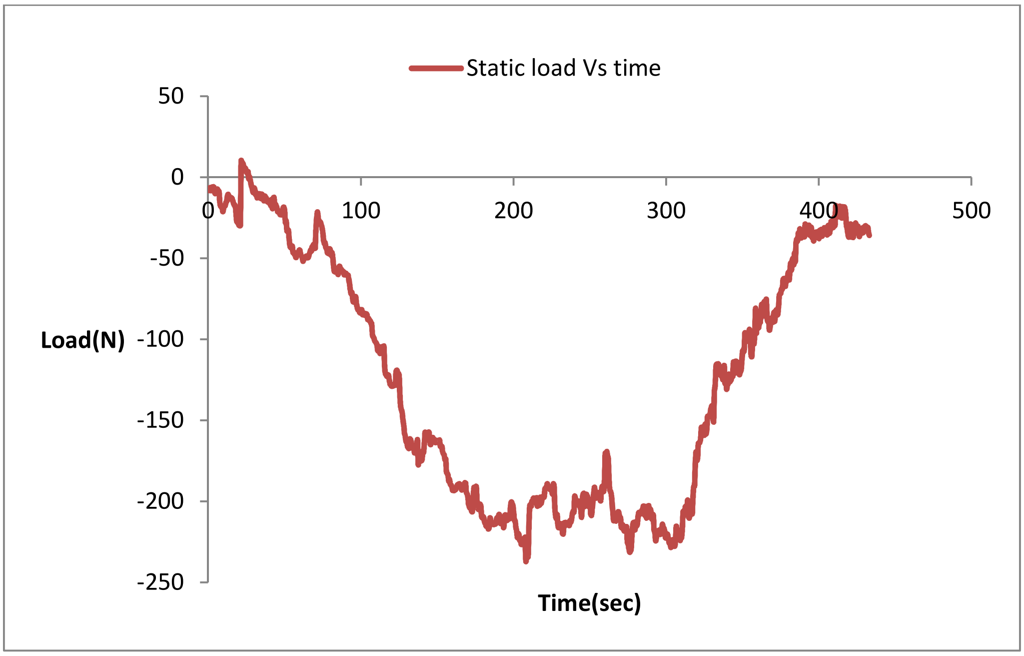


Fig 3.5 Variation of static load Vs time.

3.4.2 DYNAMIC COMPRESSION TEST

Dynamic compression tests were performed on the adhesive lap joint specimen by varying the adhesive area, adhesive thickness of the joint specimen and the strain rate. Fig 3.6 shows the adhesive bonded lap joint specimen sandwiched between incident and transmitted bars.

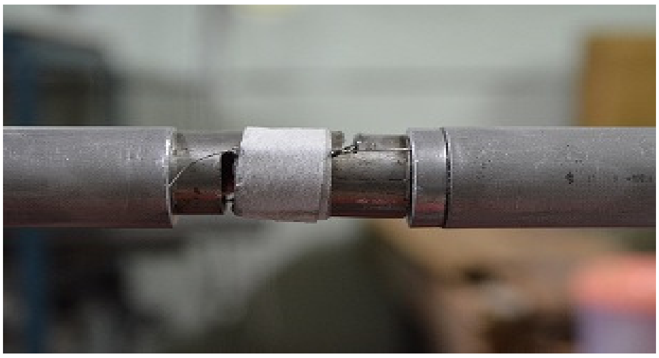


Fig 3.6-Aluminium-6063 specimen sandwiched between the two bars.

Fig 3.7- Failure of adhesive in lap joint specimen during dynamic test.

Post-test examination of the adhesive joint in the dynamic experiments showed interfacial failure as shown in fig 3.7.

Fig 3.8 shows a strain profile of adhesive lap joint specimen in dynamic compression test. As shown an incident wave which loads the joint, some part of which is transmitted through the joint and remaining part is reflected back. When the wave is transmitted, adhesive joint breaks, and stop the transmitted wave to pass through the joint to the transmission bar, resulting a smaller transmitted wave signal which can be seen in fig(3.8). With the help of incident, reflected and transmitted signal, the incident and transmitted load at the two face can be evaluated.

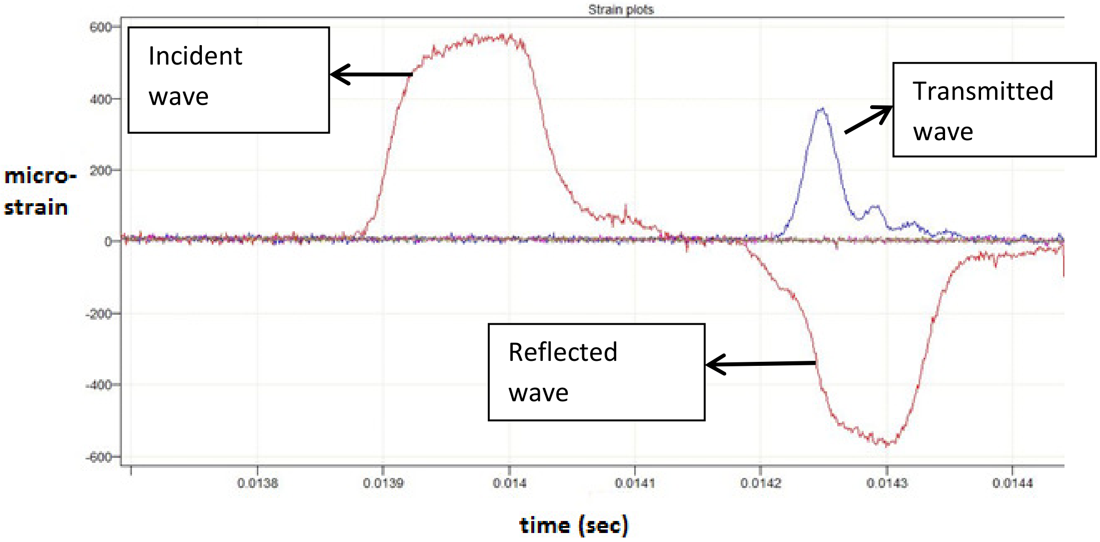


Fig 3.8- Strain history of adhesive lap joint specimen during dynamic compression test.

The applied loads at each face of the specimen in dynamic compression test can be calculated by:

$$P_1\,(t) = A_b E_b \{\,\varepsilon_i\,(t) + \varepsilon_r\,(t)\}................(3.2)$$

$$P_2\,(t) = A_b E_b \varepsilon_t\,(t)........................(3.3)$$

Where

P_1 = load at the incident bar end of the specimen.

P_2 = load at the transmitted bar end of the specimen.

A_b = cross-sectional area of the bars.

E_b = Young's modulus of the bar material.

The dynamic shear strength of the adhesive joint is given by:

Dynamic Shear strength of joint = $P_2\,(t)_{max}/\,A_{ls}$...........(3.4)

Where

$P_2\,(t)_{max}$ = maximum transmitted load through the adhesive lap joint.

A_{ls} = bonded area of the adhesive joint

3.4.2.1 DYNAMIC SHEAR STRENGTH VS ADHESIVE AREA

To get the variation of dynamic shear strength with different adhesive area, three experiments were done. For the first experiment specimen having diameter 16 mm, overlap length (L_S) = 15 mm and bonded shear area =240 mm^2 at a pressure of 1.5 bar pressure. Fig 3.9 shows the variation of force P_2 with respect to time. Dynamic shear strength was calculated by using maximum transmitted load P_2.By using equation (3.4) the Maximum dynamic shear strength was obtained as 3.27 MPa.

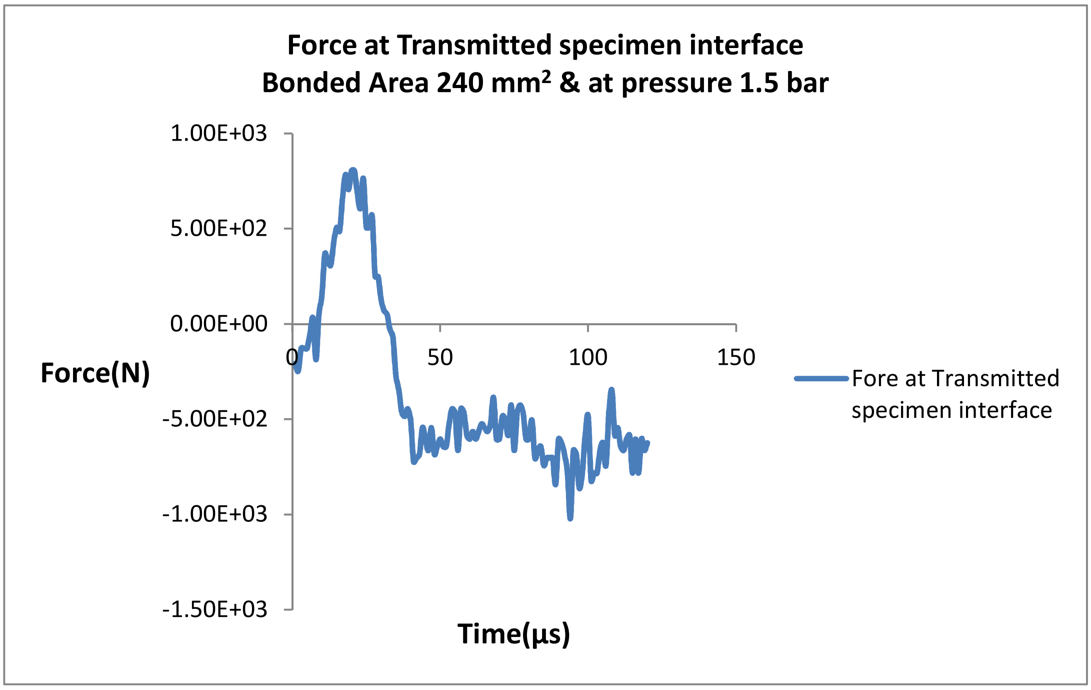


Fig 3.9- Variation of forces P_2 with respect to time for bonded shear area =240mm^2 & at pressure 1.5 bar.

In the second experiment specimen having diameter= 16 mm, overlap length (L_S) =13 mm and bonded shear area = 208 mm^2 at a pressure of 1.5 bar pressure. Fig 3.10 shows the variation of force P_2 with respect to time. Dynamic shear strength was calculated by using maximum transmitted load P_2. Maximum dynamic shear strength was obtained as 44.32 MPa.

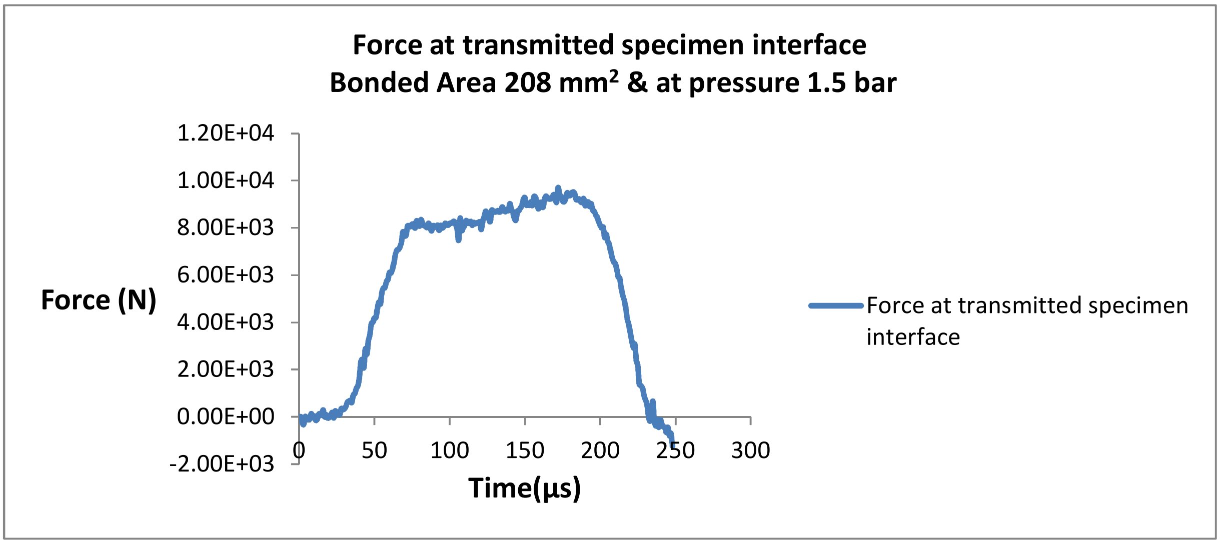


Fig 3.10- Variation of forces P_2 with respect to time for bonded shear area =208mm^2.

Third set of experiments were performed on the specimens having diameter= 16 mm, overlap length (L_S) =11 mm and bonded shear area = 176 mm^2 at a pressure of 1.5 bar pressure. Fig 3.11 shows the variation of force P_2 with respect to time. Dynamic shear strength was calculated by using maximum transmitted load P_2. Maximum dynamic shear strength was obtained as 7.7 MPa.

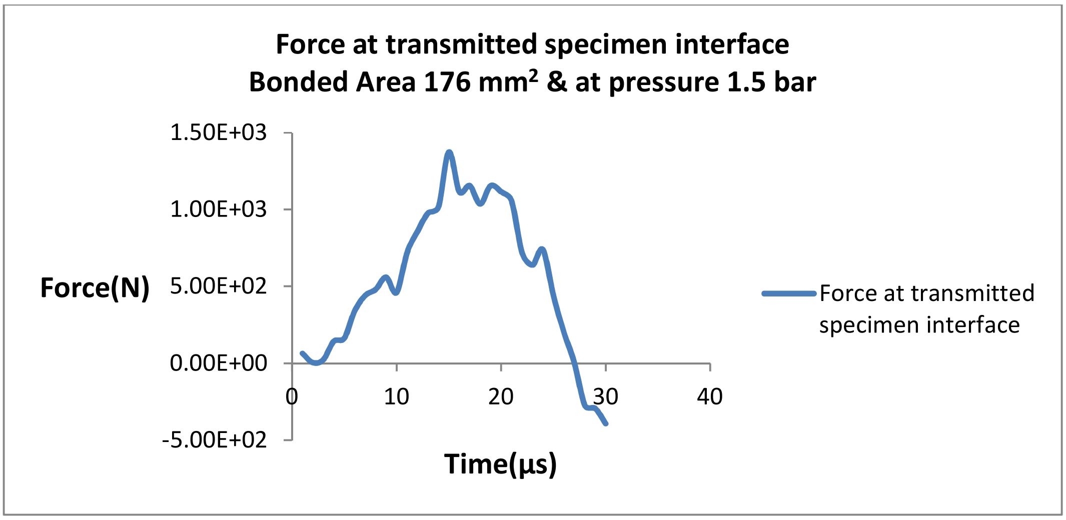


Fig 3.11-Variation of forces P_2 with time for bonded shear area =176mm^2.

EXPERIMENT	BONDED AREA OF ADHESIVE (mm^2)	L_S /W (overlap length/width)	P2 (N) (force at transmitted-specimen interface)	DYNAMIC SHEAR STRENGTH (MPa)
1	240	0.9375	785	3.27
2	208	.8125	9700	44.32
3	176	.6875	1370	7.7

.

Table 3.3 - Dynamic shear strength for different adhesive bonded area.

Table 3.3 shows the dynamic shear strength forces P2 corresponding to bonded shear area and Ls/W ratio.In the fig 3.12 variation of shear strength is shown with Ls/W where Ls and W are the bonded length and width respectively.Fig 3.12 shows that dynamic shear strength first increases upto the Ls/W ratio of 0.812 and then decreases.

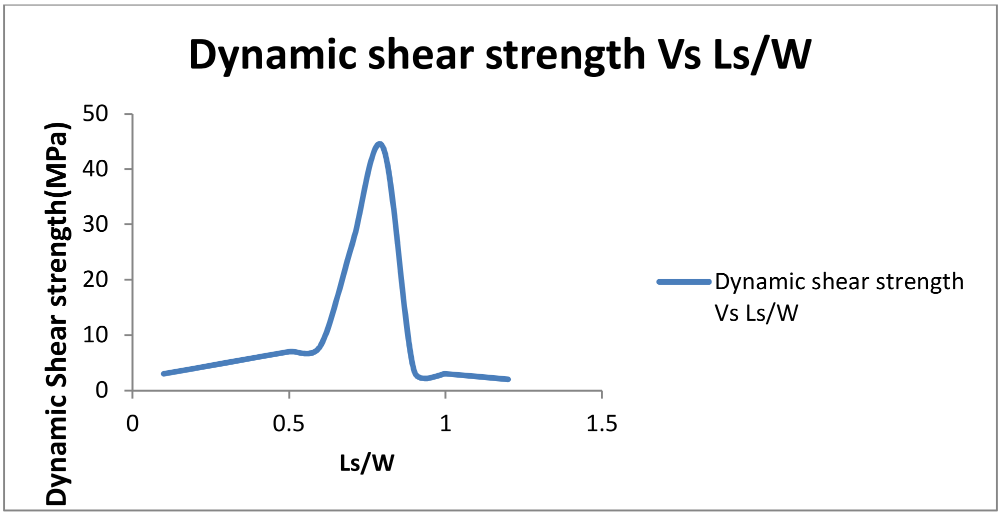


Fig 3.12- Variation of dynamic shear strength with Ls/W ratio.

3.4.2.2 DYNAMIC SHEAR STRENGTH VS ADHESIVE THICKNESS

To see the variation of dynamic shear strength with adhesive thickness,dynamic experiment is performed at a pressure of 1.5 bar. The bonded area in all the experiments were 240 mm^2. In the first experiment adhesive thickness of 0.24 mm is taken. The variation of forces P2 with respect to time is shown in fig 3.13. The maximum dynamic shear strength was obtained as 27.94Mpa.

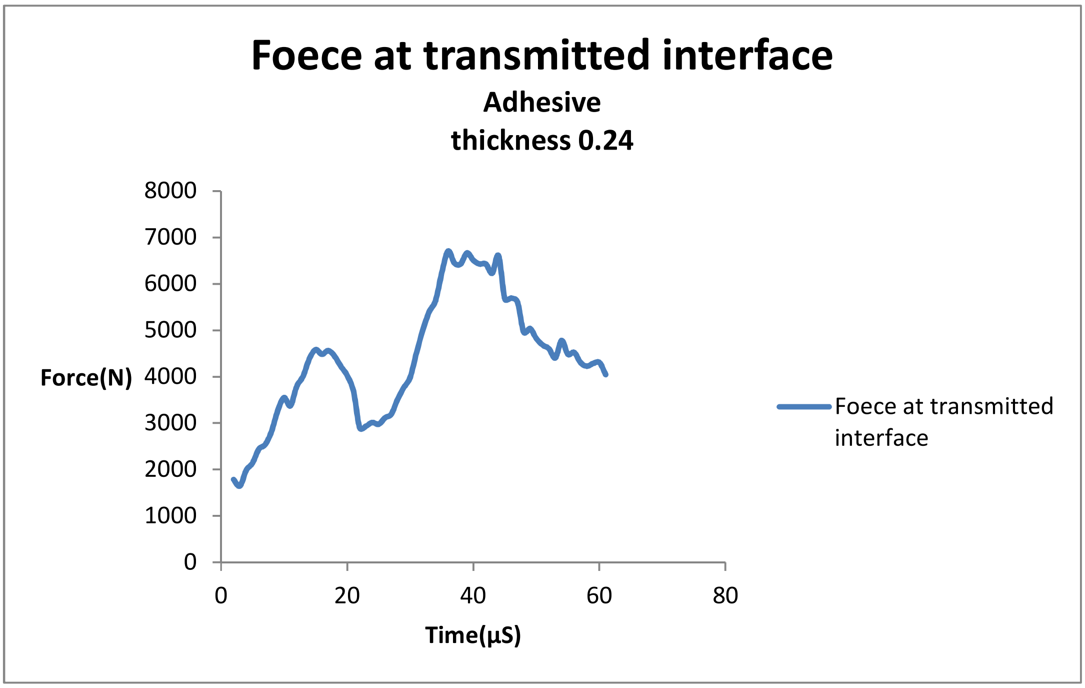


Fig 3.13- Variation of forces P_2 with respect to time for adhesive thickness =0.24mm.

In the second experiment adhesive thickness of 0.51mm is taken. The variation of forces P2 with respect to time is shown in fig 3.14. The average dynamic shear strength was estimated as 12.15 MPa.

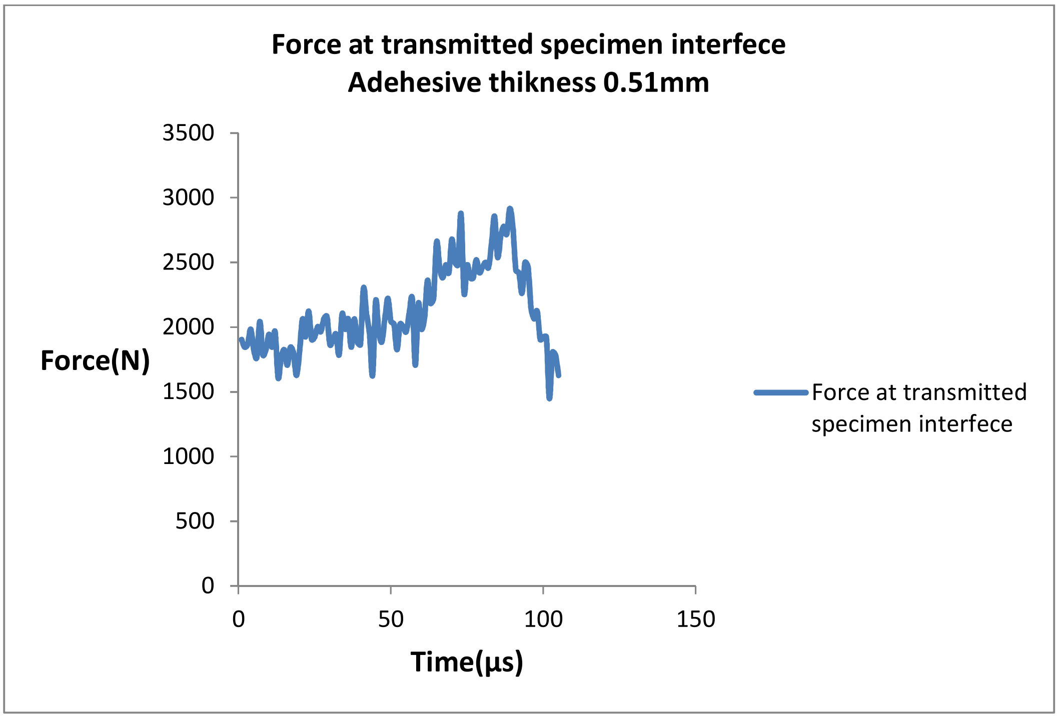


Fig 3.14- Variation of forces P_2 with respect to time for adhesive thickness =0.51 mm.

Tin the third experiment adhesive thickness of 0.83mm is taken. The variation of forces P2 with respect to time is shown in fig 3.15. The average dynamic shear strength was estimated as 10 MPa.

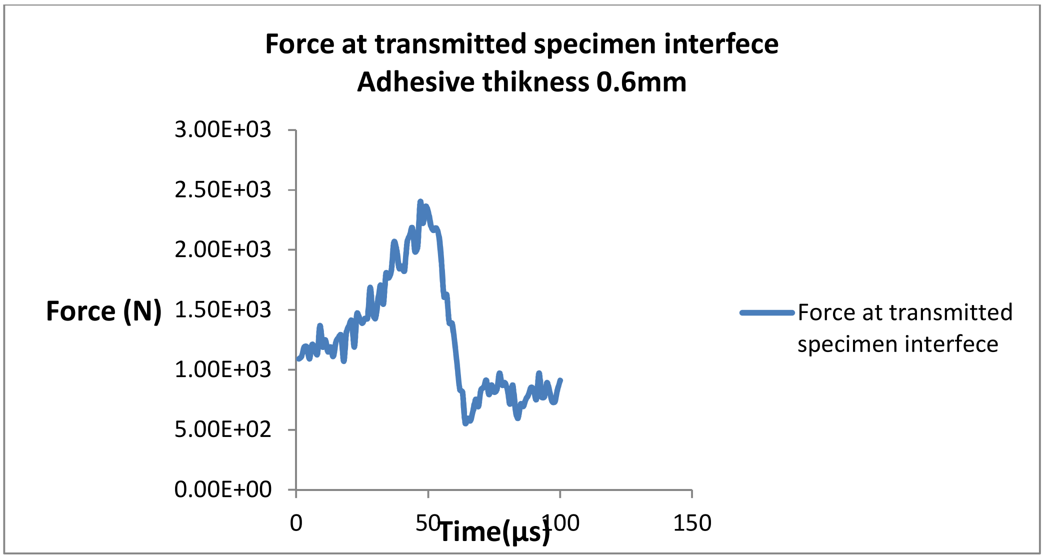


Fig 3.15- Variation of forces P_2 with respect to time for adhesive thickness =0.6 mm.

Experiment	Adhesive thickness (mm)	P2 (N)	Dynamic shear strength (MPa)
1	0.24	6706.75	27.94
2	0.51	2916.84	12.15
3	0.6	2400	10

Table 3.4-Dynamic shear strength for different adhesive thickness.

Table 3.4 shows the variation of dynamic shear strength and maximum transmitted load through the adhesive lap joint specimen with adhesive thickness of specimen. Fig 3.16 shows the variation of dynamic shear strength with adhesive thickness.

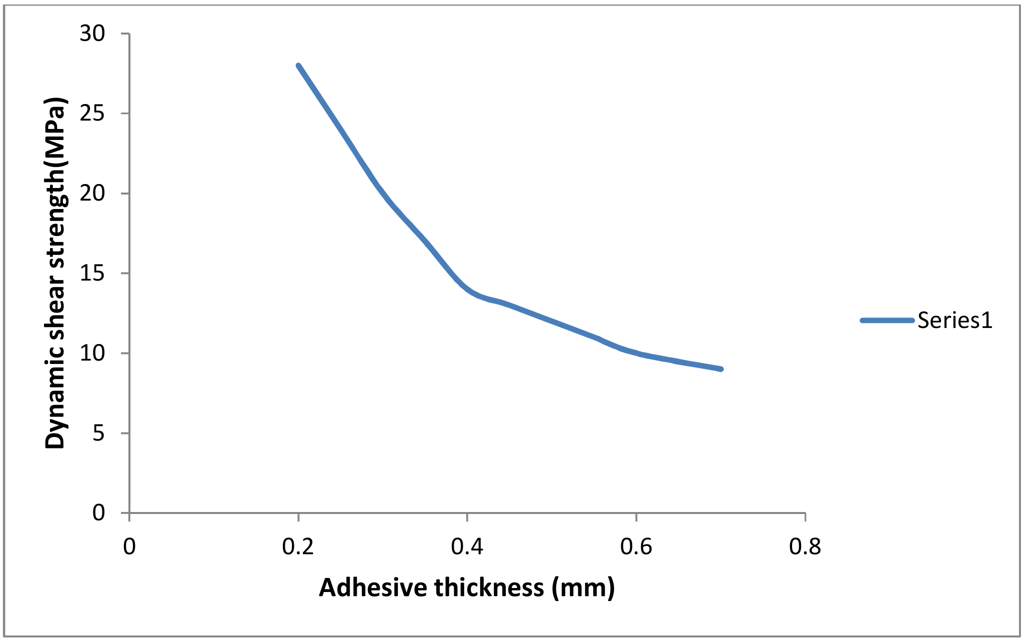


Fig 3.16-Variation of dynamic shear strength with adhesive thickness.

Fig 3.16 shows variation of shear strength that for an adhesive thickness of 0.24 mm, 0.51 mm and 0.60 mm the.e. for the same adhesive thickness the dynamic shear strength of adhesive lap joint is more as compared to static shear strength.

3.4.2.3 DYNAMIC SHEAR STRENGTH VS STRAIN RATE

A series of dynamic experiments were performed at different pressures i.e. at different strain rate. First set of three dynamic experiments were performed at a pressure of 1.5 bar. Similarly second, third and fourth set of experiments were performed at a pressure of 1.75 bar, 2 bar, 2.5bar respectively. The bonded shear area and the adhesive thickness of the the adhesive lap joint was same i.e. 240 mm^2 and 0.31 mm respectively for all the experiments. Table 3.5 shows the variation of dynamic shear strength with increase in strain rate.

EXPERIMENT	PRESSURE (BAR)	STRAIN RATE (1/S)	P2 MAXIMUM TRANSMITTED LOAD (N)	DYNAMIC SHEAR STRENGTH (MPa)
1	1.5	325	841	3.5
2	1.75	437	1140	4.75
3	2	479	2320	9.66
4	2.5	533	3321	13.8

Table 3.5 Variation of dynamic shear strength with strain rate for adhesive lap joint area 240mm^2 and thickness of adhesive 0.31mm.

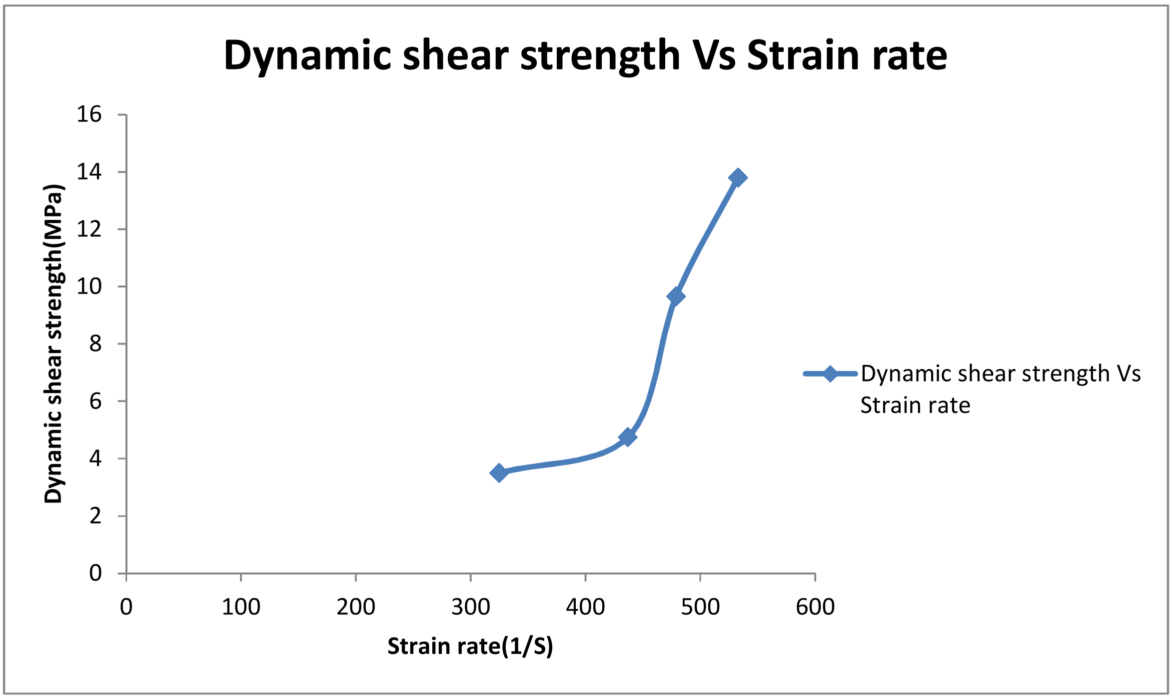


Fig 3.18 -Variation of dynamic shear strength with respect to strain rate.

Fig 3.18 shows the effect of strain rate on dynamic shear strength of adhesive lap joint. It can be observed that during impact loading adhesive joint can transmit higher loads.

Chapter 4

Conclusions & Future work

4.1 CONCLUSIONS

The motivation behind this study was to evaluate the dynamic shear strength characterization of adhesive lap joint under dynamic compression using Split Hopkinson Pressure Bar (SHPB) setup on Al-6063 T6 alloy. The behavior of adhesive lap joint under static and dynamic loading was observed. The strength was calculated by using maximum transmitted load. The dynamic compression tests are performed on Al6063 T6 alloy and dynamic shear strength is found by varying the adhesive thickness, adhesive area and applied loads. The experiments were done on four pressure value of 1.5 bar, 1.75 bar, 2 bar and 2.5 bar respectively i.e. at different strain rate. The experiments were done for three different adhesive areas viz 240, 208 and 170 mm^2 and for three adhesive thickness viz 0.24, 0.51 and 0.60 mm. From the experimental result it is found that dynamic shear strength first increases with adhesive area up to an optimum area thereafter then it start decreases but with increase in adhesive thickness dynamic shear strength decreases. It was observed that for a given adhesive thickness dynamic shear strength was more as compared to static shear strength. The results shows that the adhesive lap joint transmit higher load during impact loading.

4.2 FUTURE WORK

Due to its appreciable dynamic shear strength characteristics, adaptation of adhesive joints is increasing day by day in many fields especially aerospace, automobile and defence. But there are more work need to be done on different material like Al-7075 T6,Al-2024 T4,Al-7075 and high strength alloy steel. The effect of different types of adhesive like Araldite 2014,Araldite 2011,Epibond 1590 and A/B Locite 324 on different materials can be analyzed.

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