Double Shear Testing of Adhesives

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***Abstract*—This lab aims to calculate the shear strength of two different adhesive materials bonded with aluminum and determine if the mode of failure is cohesive or adhesive. The shear strength of the Loctite Hysol EA E-90Fl and the Cyanoacrylate were 6.62 ± 1.09 MPa and 1.19 ± 0.442 MPa respectively. These results illustrate that the epoxy adhesive material is a more effective and reliable material to bond to aluminum due to it being able to withstand higher tensile loads than the superglue. The 95% confidence interval for these results are for the epoxy, and for the superglue. These values are relatively close to the official shear strength values of these materials illustrating the accuracy of the lab. Although these values are more accurate relative to the official values, they are not very precise due to the large uncertainty values that were calculated by using RSS and 95% Confidence Interval analyses.**

***Index Terms*— Adhesive, confidence interval, shear area, shear strength**

I. INTRODUCTION

The lab aims to test 2 aluminum specimens with different adhesive materials under tension using an Instron 5967 Universal Testing Machine. The specimens will fail and then the lab will measure the adhesive contact area using ImageJ, and then it will develop a statistical analysis of the shear strength for the superglue and epoxy specimens using a 95% Confidence Interval.

This lab studies the failure of adhesive joints due to shear failure. These adhesives bond together with a different material and the strength of that adhesive joint can be measured by designing a double lap-shear specimen. A double lap-shear geometry is used to make the loading of the specimen easier and more consistent along all parts of the specimen. This produces a shear stress that is parallel to the contact areas of the 2 specimens. Since adhesive failure precedes the failure of the material, once the adhesive joints break, the lab will determine which type of failure (adhesive or cohesive) and then will determine the shear strength by using the following equation and free-body diagram:

$$\tau = \frac{P}{2A} \tag{1}$$

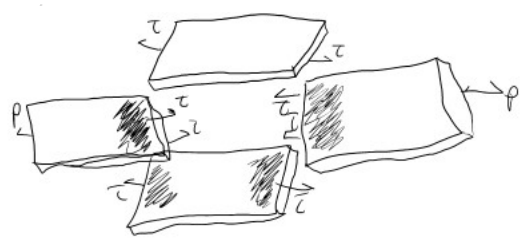

Fig. 1 This is the free-body diagram for the double-lap shear specimen illustrating the tensile forces and the shear forces..

Where P is the tensile force applied by the UTM, and A is the area for which the adhesive separated from the aluminum. Once the specimens fail, this lab will utilize ImageJ to determine the sheer area of the specimen, then the shear strength. If the glue is on both sides of the specimen, then it is cohesive failure, if it is on one side only after failure it is adhesive failure. The ultimate shear stress is when the adhesive material cannot resist the shear tension and it fails.

Once this lab measures the shear strength, mode of failure, shear area, and extraneous factors of failure it will use all of the data to determine the uncertainty in the force and the shear strength. It will conduct a 95% Confidence Interval on the data to determine the reliability and precision of the shear area calculation from the ImageJ software.

II. PROCEDURE

Materials

The materials that were used to conduct this lab were as follows: Instron 5967 Universal Testing Machine (UTM) with 30KN Load Cell, 8 rectangular strips of aluminum, calipers, micrometers, camera, ImageJ software, Cyanoacrylate (superglue), and Loctite Hysol EA E-90Fl epoxy.

Experimental Procedure

The first step of the lab was to assemble the aluminum specimens that would be placed under shear. Two double-lap specimens were produced, one with superglue, and the other with epoxy. To prepare the specimens for adhesive bonding the strips were polished, sanded, and cleaned with alcohol. The adhesives were applied to the aluminum strips and the strips were configured unevenly to the middle aluminum specimen to ensure failure on one side (one side was 2/3rd length and other side was 1/3rd length which is where the adhesive will fail first). The completed specimen should represent this figure below:

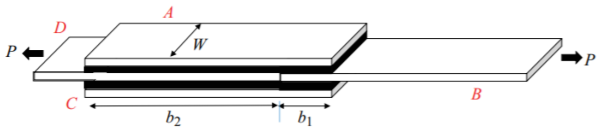

Fig. 2 Is a pictorial representation of the double-lap configuration where the outer strips are offset by 1/3 from the center [1].

The second step was the placement of the aluminum specimens in the UTS machine under tension at a rate of 7mm/min until failure occurred.

The third step was the analysis of the failure surfaces by using the ImageJ software on the computer. The software was used to measure the shear area of the glue by setting a scale via a ruler, outlining the contact areas, and then go to analyze to measure the area of the failure.

The fourth step was to determine the dominating failure mechanism whether it be cohesive, adhesive, or mixed mode failure.

Lastly, record and upload the max load each specimen endured and the average shear area online for everyone to access.

III. Results

The load at which the Loctite Hysol EA E-90Fl epoxy adhesive failed was 8785 ± 1000 N, and the shear area was 662.87 ± 53.48 mm^2. The load at which the Cyanoacrylate adhesive failed was 1348 ± 300 N, and the shear area was 562 ± 17.82 mm^2. The aluminum plates are 19 ± 0.05mm wide, 1.6 ± 0.0001mm thick, and 100 ±0.05 mm long.

IV. Discussion

This lab aims to study the mode of failure and shear strength of two double-lap aluminum specimens with different adhesive materials. The mode of failure will be determined by analyzing the adhesive material on the failure surface. Additionally different factors that influence the shear strength will be investigated.

The shear strength of the Loctite Hysol EA E-90Fl epoxy is calculated from equation (1) and is 6.62 ± 1.09 MPa and the shear strength of the Cyanoacrylate is also calculated from equation (1) and is 1.19 ± 0.442 MPa. These results illustrate that the Loctite Hysol EA E-90Fl epoxy has a higher shear strength and was a more effective adhesive agent for the aluminum material. Once factor that can contribute to this is the fact that the epoxy has a particle size of roughly 47 µm and the superglue has a particle size of about 300 µm [4]. Shear strength is directly affected by the size of the particle, the smaller the particle the higher the shear strength [4]. This is due to the fact that the epoxy particles can settle into the impurities and voids of the aluminum strip deeper than the superglue, so it has a tighter bond and stronger friction force.

The magnitude of uncertainty in the force and area are profound and this can be attributed to mechanical defects in the aluminum, improper application of the adhesive, or other factors that would cause this inconsistency.

The mode of failure for the Loctite Hysol EA E-90Fl epoxy specimen can be determined from the pictures below:

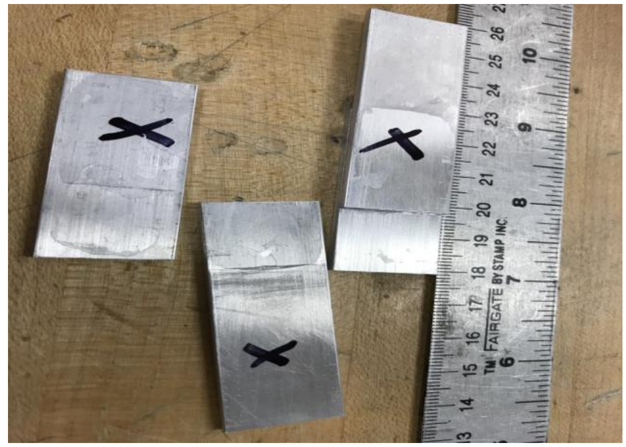

Fig. 3 This is a picture of the CA adhesive contact areas after failure.

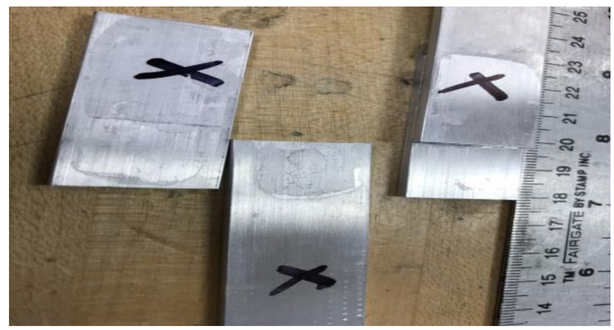

Fig. 4 This is another picture of the CA adhesive contact area for the other side of the specimen.

From these pictures one can determine that the mode of failure for the CA adhesive was adhesive failure. This is due to the fact that the adhesive is bonded to only one side of the aluminum and isn't split in half between the two contact areas. Adhesive failure means that bond strength between the CA and the aluminum is less than the cohesive strength of the CA. Factors that could influence the results to be adhesive failure include the time taken to let the CA adhesive dry fully, and how properly the CA was applied to the aluminum strips.

The mode of failure for the epoxy adhesive can be determined by analyzing the picture below:

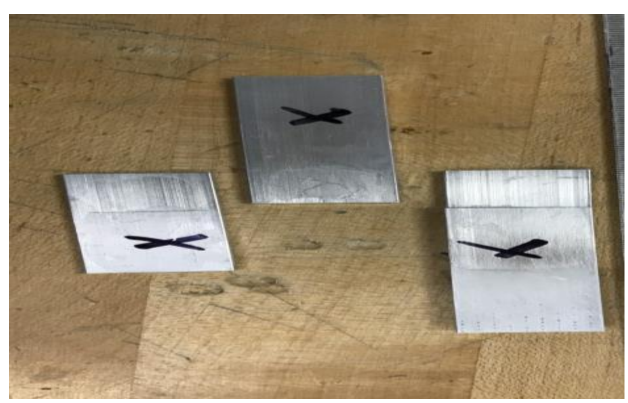

Fig. 4 This is a side view of the epoxy adhesive's contact area after failure.

From Figure 4 one can infer that the mode of failure for the epoxy adhesive is also adhesive failure. The cohesive strength of the epoxy is stronger than the adhesive strength of the epoxy and the aluminum. Factors that could influence this result can be the time allotted to allow the epoxy to dry thoroughly, the amount of pressure applied to the epoxy and the aluminum strips, and how even the application of epoxy was to the surface of the aluminum.

The shear strength determined from the lab for the superglue is extremely similar to the official shear strength reported online for it being bonded with super glue. The value from the lab is 11% higher than the value reported online indicating that our lab produced accurate results [2]. As for the epoxy material, the value is 17% less than the official value reported online [3]. The differences in these results can be attributed to a variety of factors. For the epoxy there could have been structural defects in the aluminum such as a greater number of voids, larger grain sizes, uncertainty in ImageJ, or the shape of the aluminum particles was smaller. All of these factors would lead to a smaller shear strength value. Factors from lab that could increase the value of the shear strength for the superglue is most likely either an undercalculation of the shear area of the contact area using ImageJ, or the uncertainty of the scale and ImageJ in general producing a smaller area which would result in a larger shear strength value.

A. Summation specimens under tension and failure

This lab developed and calculated the shear strength of two different adhesive materials bonded to aluminum in a double-lap configuration. The shear area and tensile load was used to calculate the shear strength, and the shear area was calculated by using the ImageJ software to analyze the pictures of the specimens after failure. The Loctite Hysol EA E-90Fl had a higher shear strength and thus should be used to bond aluminum strips together if they are going to be subjected to tensile forces since they can withstand much more load than the superglue adhesive material. Both of the adhesive materials have an adhesive failure mode since the material was only on one side of the bonded surfaces meaning that their adhesive strength is much lower than the cohesive strength.

Different factors can affect the shear strength such as the grain size of the material, the viscosity, the particle shape, and the application of the adhesive material. Limitations of this lab include the inconsistency of ImageJ due to its large uncertainty value, which illustrates that it shouldn't be used to accurately measure the shear area. Another limitation of the lab is the fact that this is only uniaxial tension. A better understanding of the mode of failure and shear strength would be obtained if it was analyzed in three dimensions. Finally, the impurities and defects of the aluminum strip would impact the validity of the results. If there were structural defects in the aluminum strips, then it would produce inaccurate shear strength values.

Future research for shear strength of these adhesives need to analyze the cohesive strength of the adhesives to ensure safety if they are being bonded on a variety of materials. Analyzing how temperature and pressure affect the properties of the two materials and how this can impact the value of shear strength.

Overall, these results are important because they allow us to analytically choose the better adhesive material and to develop a safe range for which it can be utilized. It also opens the door for how it can be improved and how to resolve or mitigate a lot of the limitations stated before.

APPENDIX

I. **Table I: Values for Uncertainties**

Measurement	Value	Uncertainty
Calipers (mm)	0.5338	± 0.0001
Micrometer (mm)	0.5338	± 0.001
Load (N)	8785	± 0.5%
w (mm)	19	±0.001
t (mm)	1.6	±0.001
L (mm)	100	±0.05
A (mm^2)	562	± 17.85
Shear Strength (MPa)	1.19	± 0.442
Ruler (mm)	2.0	± 0.05

The uncertainty of the calipers, micrometer, and ruler are given by dividing the smallest increment it can measure by 2. The uncertainty of the load is given by the Instron manual and is 0.5% of the applied load. The uncertainty of the shear strength is given by 2 different methods. The first is by conducting a 95% confidence interval on the class data and determining the variance. The other method is by using the following equation with a single class periods data to compute the variance:

$$U_\tau = \sqrt{\left(U_P \frac{\partial \tau}{\partial P}\right)^2 + \left(U_A \frac{\partial \tau}{\partial A}\right)^2} \quad (2)$$

Using this method yields an uncertainty of 0.179 which is much lower than the other method.

The uncertainty of the shear area is calculated by conducting a 95% confidence interval on the data provided and determining how consistent and reliable it is.

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