INDIAN INSTITUTE OF TECHNOLOGY,ROPAR

DEVELOPMENT ENGINEERING PROJECT (CP-301)

ON

“Analysis of tensile shear strength in Weld bonded Single lap joints ”

Submitted by

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Introduction

In terms of mechanical fastening, bonding of metals is increasingly important.The joint between metals can be temporary and it can be permanent.With respect to permanent joints, welding and riveting comes first in mind.For lap joints we can do resistance spot welding.In automotive industry some parts of vehicle joins together with resistance spot welding.Besides resistance spot welding, Adhesive bonding has its own importance.The applications of adhesive bonding are found in the assembly of many products like aircrafts, cars, trucks and office furniture.In electrical and electronic industry, adhesives are used in variety of ways.Due to uniform distribution of stresses, adhesive bonding makes life easier.But what if materials joined by both methods of joining i.e, resistance spot welding and adhesive bonding?So such joining technique is known as weld bonding.We will discuss types of weld bonding(In flow and Weld through techniques) and our study will be on weld through technique.

So in our project our main goal will be to analyze the tensile shear strength of singly weld bonded lap joints of mild steel(made from weld through technique) and compare tensile shear strength with resistance spot welded lap joints and adhesive bonded lap joints.In our study we will compare the bond strength among three techniques that are Resistance spot welding, adhesive bonding and weld bonding.Also varying different process parameters will result in different strength of weld joints. We will go through the whole procedure to make weld bonded lap joints .We will have a small discussion on applications of weld bonding and its advantages over resistance spot welding and adhesive bon

2. THEORY RELATED TO PROJECT

2.1 Resistance spot welding and adhesive bonding

Adhesive bonding and resistance spot welding represent two fundamental techniques in modern manufacturing, each offering distinct advantages and applications in joining materials. While adhesive bonding relies on the molecular interaction between materials to create a strong bond, resistance spot welding utilizes localized heat and pressure to fuse metals together. Both methods have been extensively employed across various industries, from automotive and aerospace to electronics and construction, due to their ability to produce durable and reliable joints.

Basically resistance spot welding is a process in which faying surfaces are joined at one or more sports due to the heat generated by resistance to the flow of electric current through the work pieces that are held together(see fig. 1).The contacting surfaces in the region of current flowing are heated by high amount of current o form a weld nugget.The size of weld nugget primarily depends on welding time and welding current.

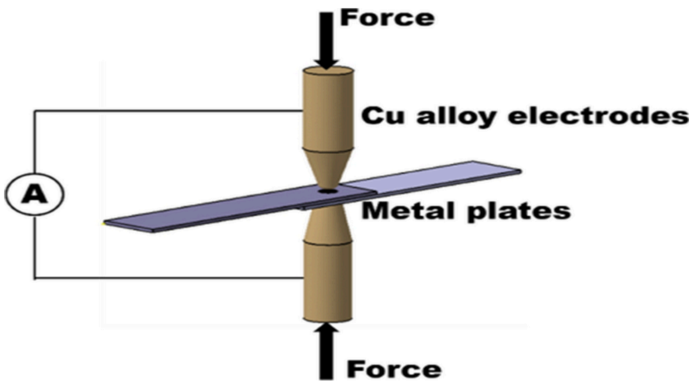


Fig. - 1

Adhesive bonding Is the process of joining materials using an adhesive, a substance capable of holding such material together by surface attachment. AdhesiveBonding uses an intermediate layer to join the substrate. The intermediate layer can be glass epoxies and polymers depending on substrate material. (see Fig. 2)

Fig. - 2

2.2 *What is Weld bonding ?*

When We combine resistance spot Welding with adhesive bonding The resulting Bond has more strength and such bonds are known as Weld Bonds.Weld-bonding technology represents an innovative hybrid joining approach, incorporating both resistance spot-welding and adhesive bonding. By integrating adhesive bonding into the process, corrosion is prevented at the inner surface of spot welded joints, and stress concentration around the spot welds is minimized. Consequently, weld-bonded structures exhibit a tensile-shear strength surpassing that of conventional spot-welded joints.The main advantages of weld bonding are- Combining the advantages of both adhesively bonded and spot-welded joints, hybrid joints offer:

1. Stress concentration reduction within spot-welded regions-

2. Enhanced overall strength and energy absorption capacity during destruction.

3. Improved corrosion resistance of spot-welded joints.

4. Reduction of component vibrations through the implementation of hybrid joints.

We will see the increment in tensile shear strength of weld bonded single lap joints than tensile shear strength of resistance spot welded lap joints and adhesive bonded joints in later sections.

2.3 Types of Weld Bonding - a) In-flow technique

b) Weld through technique

In the realm of adhesive bonding, two innovative techniques have emerged to address specific challenges and enhance the effectiveness of joining processes: weld through and flow in. These techniques represent significant advancements in the field, offering tailored solutions for bonding applications in various industries.

Weld through adhesive bonding involves the application of adhesive materials that can withstand the intense heat generated during welding processes. This technique allows for the simultaneous bonding and welding of components, eliminating the need for separate bonding and welding operations. By seamlessly integrating adhesive bonding with welding, welding through techniques offer improved efficiency, reduced assembly time, and enhanced structural integrity in joined assemblies. In this technique first we Join the two specimens through adhesive joining and then we do resistance spot welding. The Conductivity of the epoxy plays a crucial role in this. If the epoxy is non conducting then we have to make it conducting by adding some filler material in it.

Flow in technique, on the other hand, focuses on optimizing the adhesive application process to ensure complete coverage and uniform distribution between mating surfaces. Through controlled application methods and precise rheological properties of adhesive materials, flow-in techniques facilitate the seamless flow and penetration of adhesives into intricate joint geometries.

This results in enhanced bonding strength, reduced voids, and improved resistance to environmental factors such as moisture and temperature variations. In this technique first we join the two specimens using resistance spot welding and then we make the recipe flow through the gap between the two specimens.

See fig. -3 to see the difference between these two techniques.

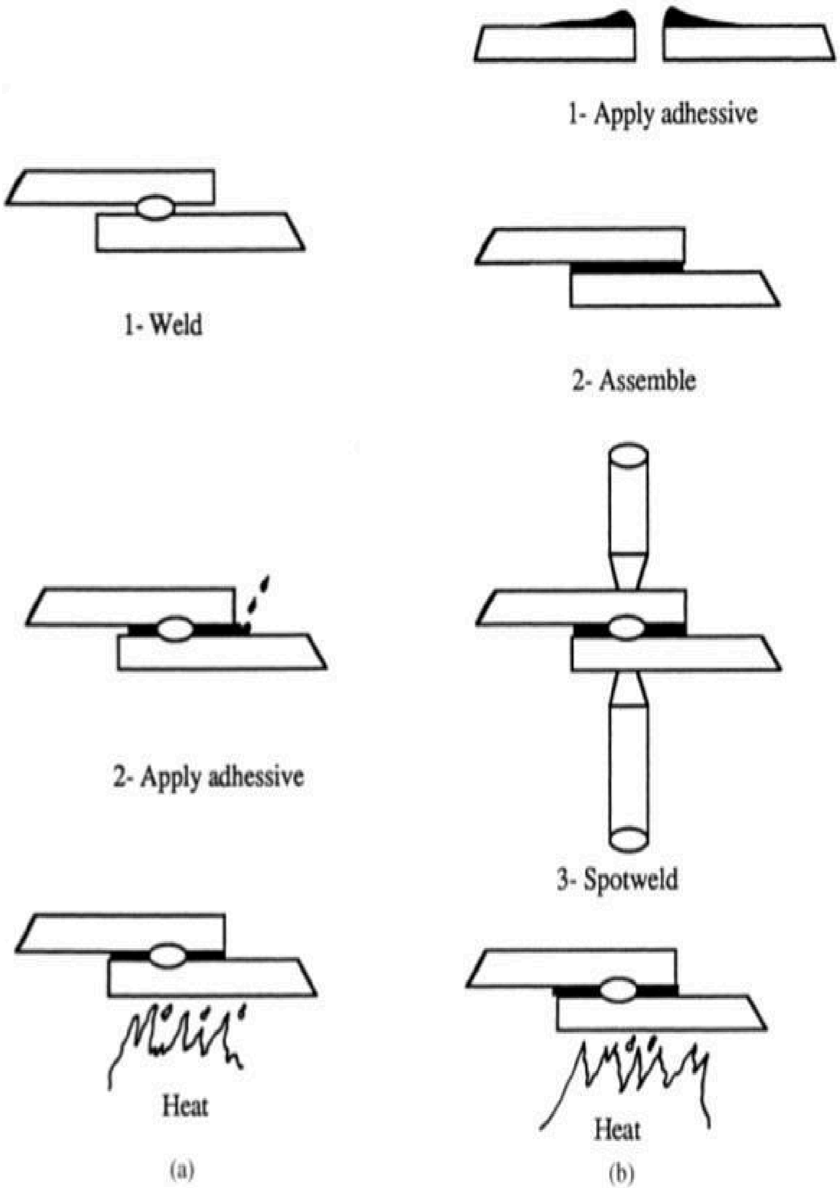


Fig. - 3

Our whole study will be on singly lap joints made from weld through technique.

2.4 Applications of Weld bonding

1. Automotive Industry: In automotive manufacturing, weld bonding is used to join dissimilar materials such as steel and aluminum, providing high-strength and lightweight structures. It enhances vehicle structural integrity and crashworthiness.

2. Aerospace Sector: Weld bonding is employed in the aerospace industry for assembling components where weight reduction is critical. It ensures reliable bonding of lightweight materials like carbon fiber composites while maintaining structural integrity under extreme conditions.

3. Marine Engineering: In shipbuilding and marine engineering, weld bonding is utilized to join metal panels and structures, providing superior strength and corrosion resistance in maritime environments.

4. Construction: Weld bonding finds applications in construction for bonding steel and concrete elements, improving the structural integrity of buildings and bridges. It enhances load-bearing capacity and reduces the risk of corrosion-induced structural failures.

5. Rail Transportation: In the rail transportation sector, weld bonding is employed for joining rail tracks and structural components, enhancing the durability and safety of railway infrastructure.

3. EXPERIMENTAL METHODOLOGY

In our study we took sheets of mild steel having dimensions 70 mm x 30 mm x 0.9mm.(see fig. -4)

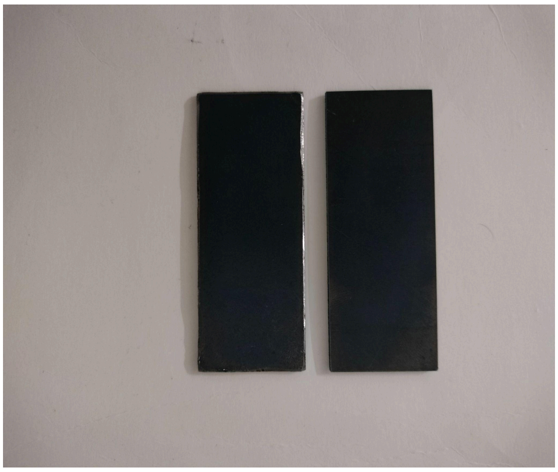


Fig. - 4

The material properties are - Yield strength = 250 MPa and Tensile strength = 440 MPa

3.1 Experiment for resistance spot welding

First we did an experiment for Resistance spot welding.Following are the welding parameters-

Avg. Current value = 5-6KA , Contact surface diameter of electrode = 5mm , Welding Time = Around 1 second(or less than a second).

We took Rectangular mild steel sheets(see Fig. c) .To make the edges of the sheet smooth we did grinding and after that we placed one sheet on top of another to make a lap joint. Remember the overlapping area between sheets was **25mm x 30mm**.Then we placed the sample between the two electrodes of the Resistance spot welding machine. Current will flow between the two electrodes for seconds and a bond between two metal sheets will form(see fig. 5).

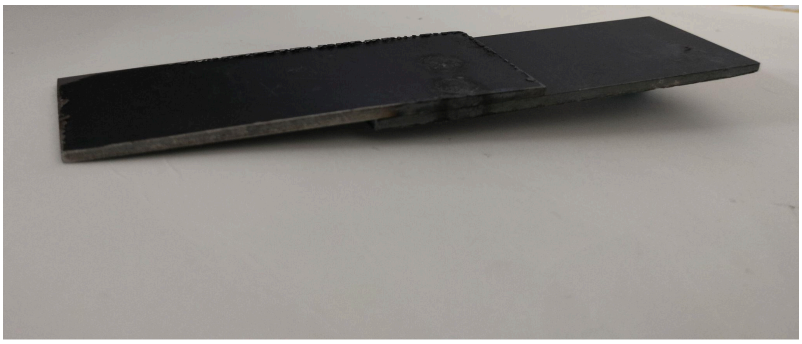


Fig - 5

After this we conducted a UTM test for Resistance spot welded samples (see fig. 6) and found the results (discussed in later sections- Results and discussions)

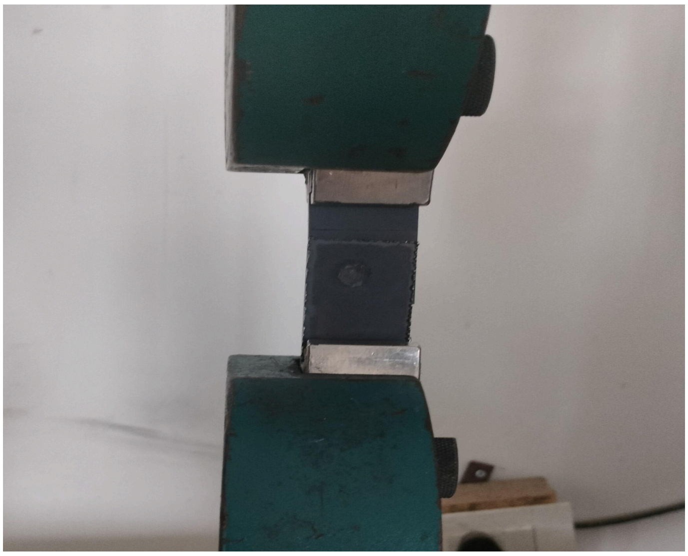


Fig. - 6 - UTM test for resistance spot welded sample

After getting results for spot welded joints, we moved to adhesive bonded lap joints.

3.2 Experiment for Adhesive bonding

We used **epoxy adhesive araldite(resin and hardener in equal amount during whole experiment)** as an adhesive to join metal sheets in lap joint.Firstly we took resin and hardener in equal volume and mix them properly.After this we apply mixture on overlapping area of sheets and join them.We placed sample at a safe place and left for 4 hours at temperature 299 K - 300.15 K .This 4 hours are basically curing time for sample.

After this, We conducted a UTM Test for an adhesive bonded sample and found results.(discussed in a later section - Results and discussions).

Take a note that our Adhesive is **non - conducting hence for weld bonding we will use filler metal so that current can pass through adhesive**.

3.3 How we approached Weld bonding?

So we mentioned earlier that we will make lap joint samples using weld through technique.Because the adhesive that we took was non-conducting in nature, we added filler metal(Aluminium powder) so that current can pass through metal sheets.

So initially, we took two sheets and joined them using adhesive, but this time we added some filler metal.The complete description is below-

We took adhesive plus filler metal mixture approximate 1 gram , in which metal amount was 25% and remaining was adhesive.We applied this mixture to sheets and made lap joint.The overlapping area was same as in adhesive bonding alone.We had no idea whether current will pass or not.We was just guessing that current will pass.

But current did not pass through the sample.probably adhesive was more in amount, but not sure.Same job was done again but this time we made a mixture of approximate 0.7 grams, and metal percentage was again 20%.so we can say the ratio of metal amount to adhesive amount was same in both cases.

This time current passes through sample and resistance spot welding was done.if ratio of metal to adhesive was same in both cases then why current passes through one sample only?

The difference in current passing through the two samples, despite both having the same adhesive-to-metal ratio, can be attributed to the total resistance within each sample.

In the sample with 1 gram of adhesive plus metal mixture, the total resistance might be higher due to the greater amount of material present.The overlapping area was same in both cases and 1 gram sample will have more material so the corresponding bond width will be more.As we know the resistance is directly proportional to length.hence, more length means more resistance.so this can be a reason.(see fig. -7)

In contrast, the sample with 0.5 grams of adhesive plus metal mixture has less material, resulting in lower overall resistance. This lower resistance allows the current to pass through the sample more easily during resistance spot welding.

Therefore, the difference in current passing through the two samples can be explained by the total resistance, which is influenced by the quantity of material present in each sample.

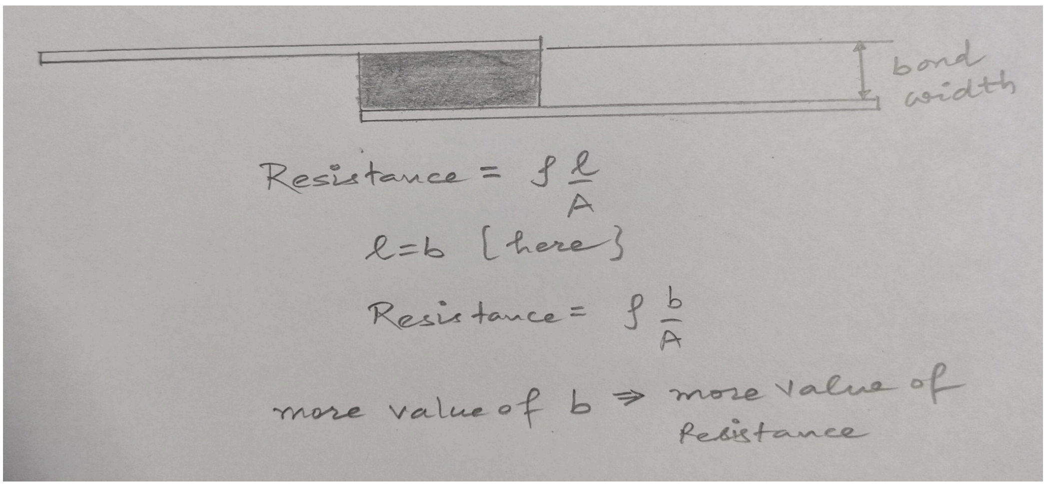


Fig. - 7

Below are the images(see fig. - 8) of samples having adhesive plus metal(at 20%) mixture between 0.9 grams and 1 gram(approximate)-

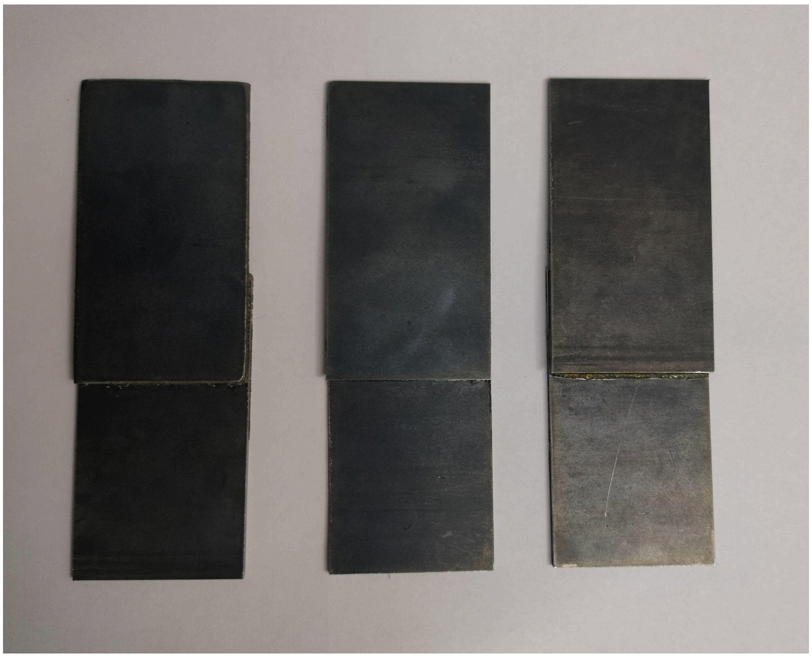


Fig. - 8

Fig. - 9

Figure -9 shows the image of a sample having 0.7 grams mixture total with 20% metal.We can clearly see the round patch on upper sheet.We also notice that some amount of adhesive damaged.During spot welding the adhesive around the spot welded zone gets liquify and flows out of sample as we can see in figure -9.

The heat produced (I^2 x R x T) during resistance spot welding was the main cause of damaging some amount of adhesive.

So we came to know that material should not be more as it provides more resistance.Therefore we made samples of 0.1gram and 0.3 grams at different metal percentages.

First we made samples of 0.1 gram, 0.3 gram and 0.4 gram at 20% metal(20% metal means amount of filler metal is 20% of total mixture weight).Because we took material mixture in very small amount , the bond width was also less than that of earlier samples(0.7g and 1g samples)

Mixtures were prepared firstly and then applied on overlapping area of sheet. The sample remains untouched for more than 4 hours.Because the curing time of adhesive is 4 hours minimum.Curing time is basically the time taken by adhesive to solidify.

Then resistance spot welding was done on samples and we see that 0.1g and 0.3g samples were breaks.Basically The adhesive between sheets was completely damaged(see fig. - 10), before the weld nugget forms(through resistance spot welding) and both sheets bond breaks.In case of 0.7 gram mixture sample(at 20% filler metal),small amount of adhesive get damage but because the amount of adhesive was more and weld nugget forms completely due to presence of more amount of filler metal .(it is important to note that the welding time was always the same in all cases, approximately 1 second or less than a second).

FIg. - 10 (sample of 0.3grams mixture with 20% filler metal)

Similar behavior was observed for 0.1 gram mixture sample at 20% of filler metal and 15% of metal.(see fig. - 11)

Fig. - 11

Now ,We change the metal percentages from 20% to 25% in our sample 0.1gram and 0.3 gram.We see that adhesive gets damaged again but this time due to presence of more filler metal, weld nugget forms and it avoids the breaking of sample in between.below are the images of samples,

The sample shown above of all sample is of 0.3g at 35 percent filler metal.The middle one is of 0.3g at 30 % filler metal and last one sample is of 0.3g at 25% filler metal.(see fig. - 12)

Fig. - 12

After this we did same experiment for 0.1g mixture samples at 25% and 30% of filler metal.Below the images of samples,(see fig. - 13)

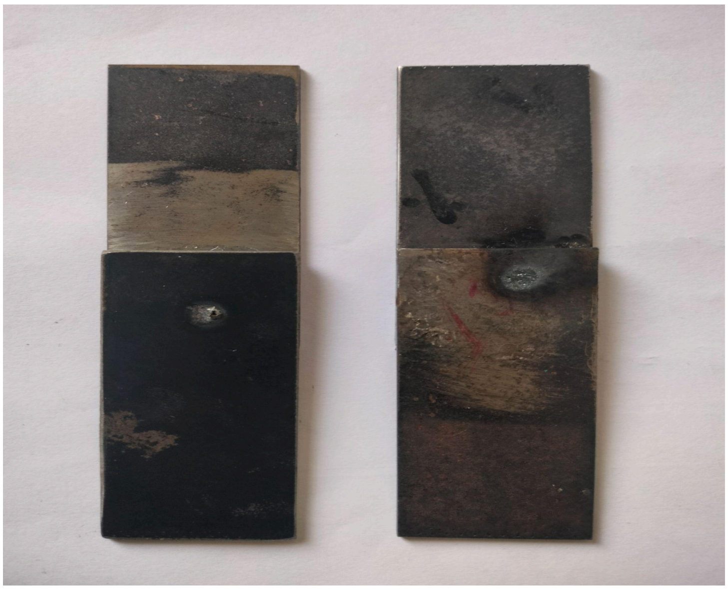


Fig. - 13

The left one sample in above image is of 0.1g at 25% of metal and right one sample is of 0.1 g at 30% filler metal.

After resistance spot welding we did a UTM test for samples to analyze their tensile shear strength.

4. Result and Discussions

Here are UTM test results of samples:

Speed = 1 mm/min

4.1 Results for Adhesive bonding

Sample 1 :- Only Adhesive used

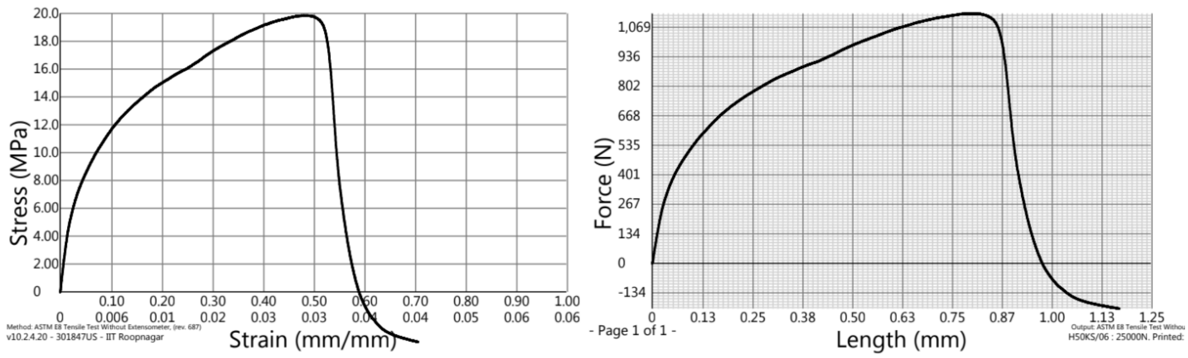
As we discussed earlier we made lap joints through adhesive bonding and Conducted UTM Test for sample.

The useful values come out to be -   1. Ultimate stress = 19.9 MPa

2. Ultimate Force = 1130 N

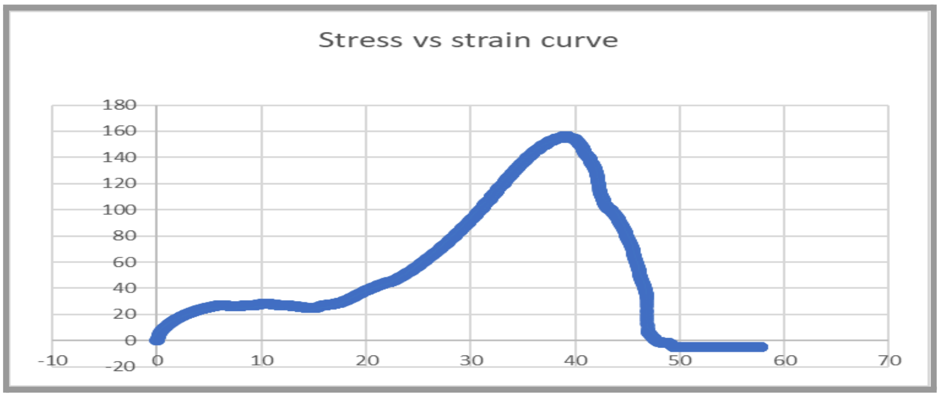
3. Break distance = 1.17 mm

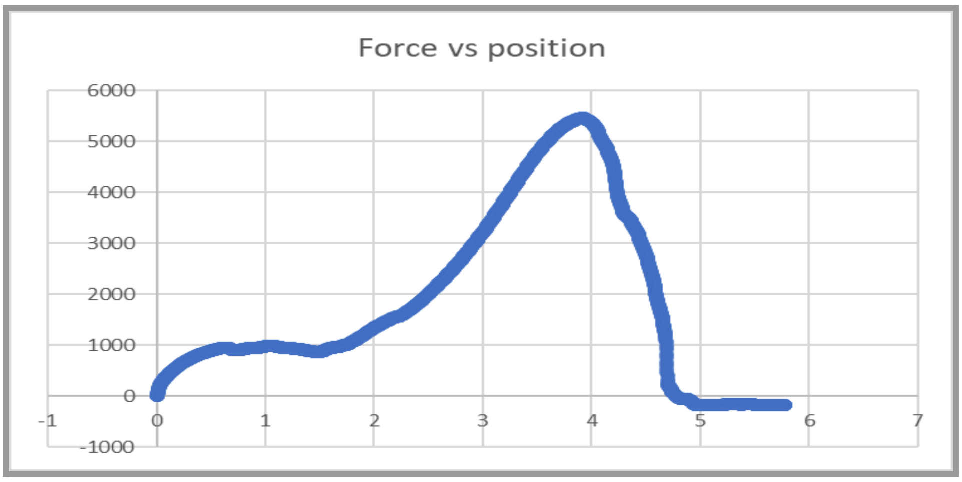
Following are the **Force vs displacement** and **stress vs strain** curve for sample.



4.2 Results for Resistance spot welding

Sample 2 :- Resistance spot welded



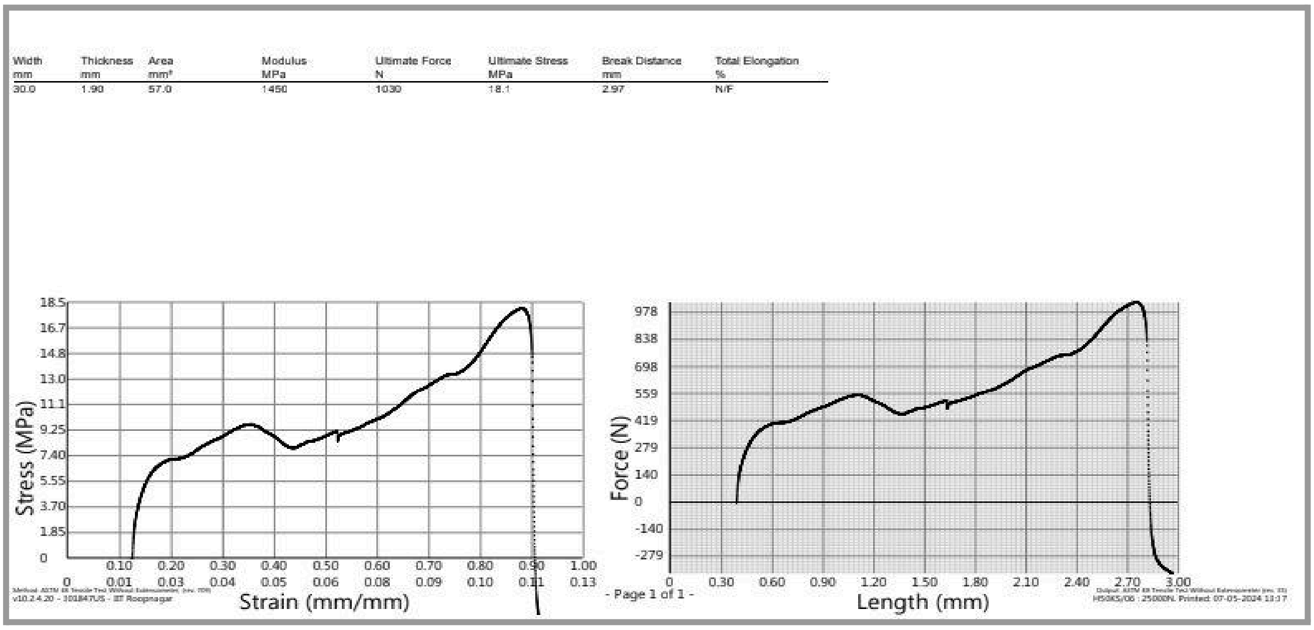


The useful values came out to be - 1. Ultimate stress = 156 MPa

2. Ultimate Force = 5460 N

4.3 Results for Weld bonding bonding

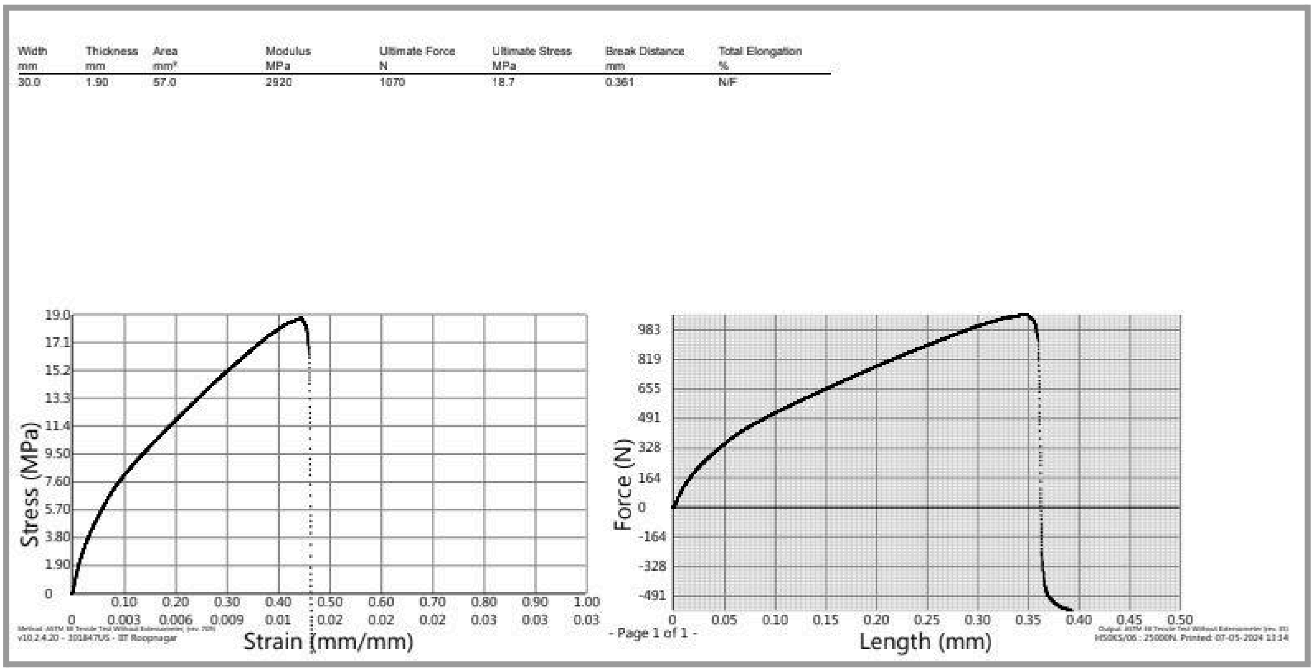
Sample 3 :- 0.3g filler material(75% Adhesive & 25% filler metal) and resistance spot welding sample



The useful values came out to be - 1. Ultimate stress = 18.1 MPa

2. Ultimate Force = 1030 N

Sample 4 :- 0.3g filler material(70% Adhesive & 30% filler metal) and resistance spot welding sample

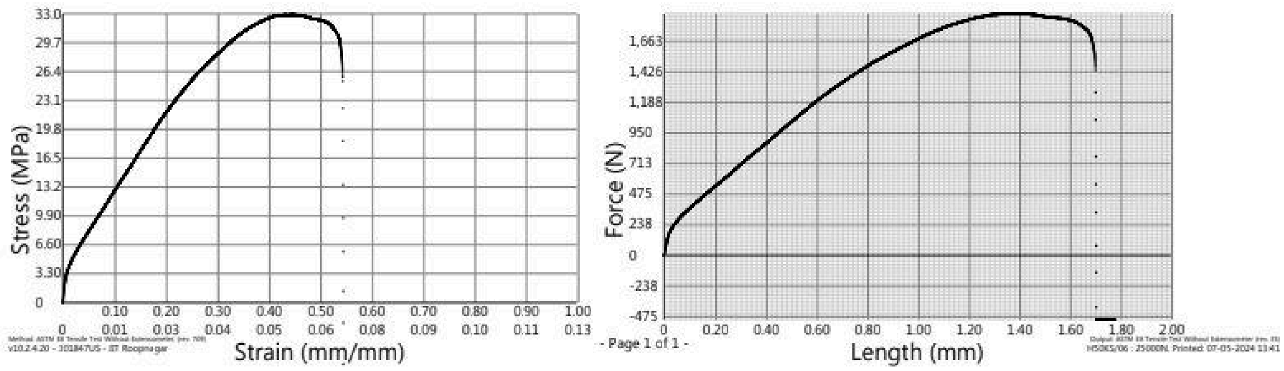


The useful values came out to be - 1. Ultimate stress = 18.7 MPa

2. Ultimate Force = 1070 N

Sample 5 :- 0.3g filler material(65% Adhesive & 35% filler metal) and resistance spot welding sample

Width mm	Thickness mm	Area mm^2	Modulus MPa	Ultimate Force N	Ultimate Stress MPa	Break Distance mm	Total Elongation %
30.0	1.90	57.0	737	1880	32.9	1.70	N/F

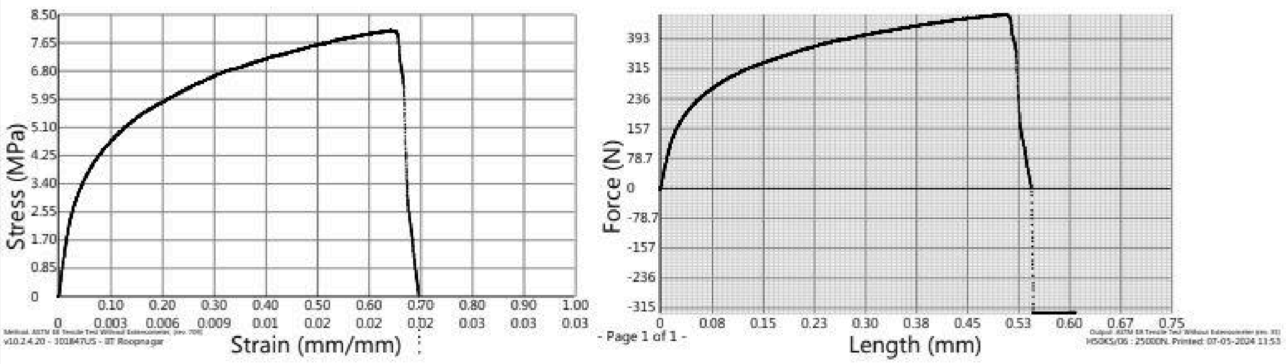


The useful values came out to be - 1. Ultimate stress = 32.9MPa

2. Ultimate Force = 1800 N

Sample 6 :- 0.1g filler material(70% Adhesive & 30% filler metal) and resistance spot welding sample

Width mm	Thickness mm	Area mm^2	Modulus MPa	Ultimate Force N	Ultimate Stress MPa	Break Distance mm	Total Elongation %
30.0	1.90	57.0	3210	458	8.03	0.527	N/F



The useful values came out to be - 1. Ultimate stress = 8.03MPa

2. Ultimate Force = 458 N

4.4 Comparison among samples

Comparison among samples 3, 4 & 5 -

In sample 3, 4 & 5 We increased filler metal percentage and found that increase in filler metal percentage increases the strength of the weld bond. This is because of as we increase the filler metal percentage it enhance the quality of resistance spot welding and there is decrease in adhesive bond strength also because there is decrease in quantity of adhesive but overall resistance spot welding strength is in dominant so increase in filler metal percentage enhance the strength the weld bond.

Comparison between samples 4 & 6 -

In samples 4 & 6 we increase filler material quantity and found that as we increase filler material, the adhesive quantity also increases by which adhesive bond strength increased and increase in adhesive quantity decrease the resistance spot welding because adhesive is a non- conductive material, it resist spot welding.but adhesive bonding dominants over spot welding so sample 4 have more tensile shear strength.

5. Conclusion

We studied two techniques of weld - bonding, namely Weld through and flow in technique.We worked on weld through technique during whole time.Basically we want to compare the tensile shear strength of lap joints made from resistance spot welding and weld bonding .From intuition we can guess because weld bonding contains features of both adhesive bonding and resistance spot welding so its strength should be increased.we made different samples of different amount of adhesive plus filler metal mixture and see how they behave on spot welding.After spot welding we did UTM test for samples and see results.basically strength should be increased as we guessed earlier but strength was not even greater than resistance spot welding samples.This happens may be due to the technique through which we were doing weld bonding.We first applied adhesive plus filler metal and then did spot welding.Because adhesive is non conductor of electricity, it always resist spot welding but due to presence of filler metal the current passed somewhat but spot welding did not have much strength as compare to spot welding alone.And the second thing is the adhesive gets damage in some amount in different samples based on amount of mixture.so the strength that adhesive bonding can provide in actual was not even that.

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