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Parametric Effect Of Ultrasonic Plastic Welding On Tensile Strength For ABS, Acrylic And Polycarbonate Materials.

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ABSTRACT:

Engineering thermoplastics have found wide applications in automotive, aerospace, electronics, medical, and other domestic appliance industries. Therefore the joining of the thermoplastics has become an important manufacturing operation. In near field ultrasonic plastic welding the distance between the horn and the weld interface is less than 6mm.The near field ultrasonic plastic welding of polycarbonate, acraylic and ABS material are studied. The taguchi method is used for experiment analysis. We study the different parameter which is affected on the weld tensile strength. There are mainly two parameters which is affected on the weld tensile strength one is pressure and other is weld time.We analysis of weld tensile strength for above two parameters. During this analysis use 20kHz frequency for ultrasonic welding machine.

1.0 Introduction:

Engineering plastics which belong to the broad family of polymers are those materials which posses high strength, high toughness, flame retard ant characteristic, good rigidity and durability. These combined with other attractive features such as excellent insulation properties, corrosion resistance and light weight make them a very useful material in many industries, namely, automotive, aerospace, electronics, medical, and other domestic appliance industries. Increased use of engineering plastics has occurred in several industries; hence joining of these materials becomes an important manufacturing operation. The techniques available for joining plastics are (1) mechanical joining (screws, rivets, pin fasteners, and retaining rings (2) adhesive bonding and (3) welding. Mechanical joining offers an advantage in that the joints are not permanent. But the insertation of a foreign material through a mounting hole gives rise to stress concentrations. Mechanical fasteners also increase the overall weight of the structure. Adhesive bonding is a process where an adhesive, e.g. Epoxy is placed between the parts and allowed to cure with time. This produces a joint of adequate strength. Although adhesive bonding offers good strength in shear, its tensile, bending, and peeling strength are low. If the joint is not design properly there is also the problem of stress concentration. The welding of plastics offer distance advantages in terms of weight savings and with good joints designs and

proper process control it provides excellent joint strength [1].
There are a number of processes for welding thermoplastics. Hot gas, hot plate, resistance implant, and induction implant require an external heating source. Ultrasonic welding friction welding, and vibration welding rely on the heat generated by the mechanical movement within or between the parts [1].

2.0 Experimental Procedures:

The experiments were conducted on ultrasonic plastic welding machine. The welding is conducted on three different material abs, polycarbonate and acrylic. In ultrasonic welding, ultrasonic vibrations created a friction-like relative motion between two surfaces that are held under pressure. The power is supplied to the piezoelectric base transducer. The transducer produces the vibration. This vibration is transfer to the booster.

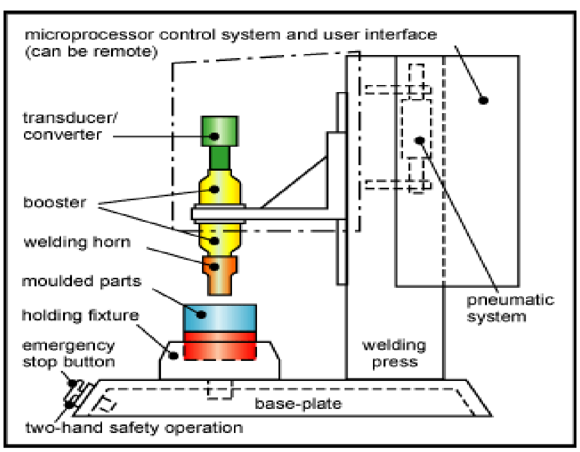

Fig.1 Ultrasonic plastic welding machine

In booster booster this vibration signal is amplified as par requirement. This amplified signal is transfer to the horn. In the horn this signal is converted into mechanicalvibration. This mechanical vibration is used to produce the friction between the adjusting layers.

3.0 Ultrasonic plastic welding:

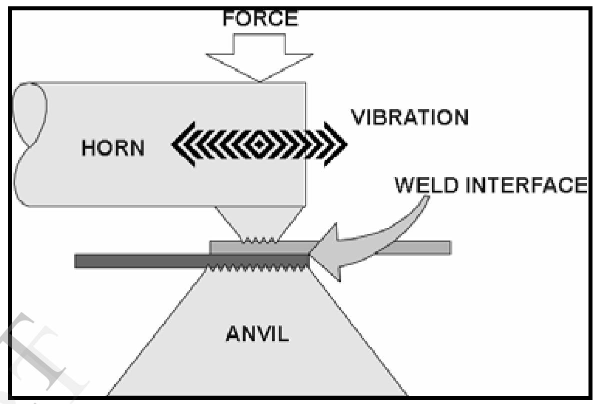

Figure 1.3 Ultrasonic plastic welding processes

Ultrasonic plastic welding is the joining or reforming of thermoplastics through the use of heat generated from high-frequency mechanical motion. It is accomplished by converting high-frequency electrical energy into high-frequency mechanical motion. That mechanical motion, along with applied force, creates frictional heat at the plastic components' mating surfaces (joint area) so the plastic material will melt and form a molecular bond between the parts. Plastics assembly is a fast, clean, efficient, and repeatable process that consumes very little energy. No solvents, adhesives, mechanical fasteners or other consumables are required and, or other consumables are required, and finished assemblies are strong and clean.

3.1 Ultrasonic plastic welding advantages:

Ultrasonic metal welding exhibits unique welding properties that include:

- Excellent electrical, mechanical, and thermal connections between similar and dissimilar metals
- Low heat buildup during the ultrasonic process (no annealing of materials).
- Compensation for normal surface variations of the material.
- Ability to clean surface oxides and contaminants prior to welding.
- Ability to weld large areas using minimal energy.
- Ability to weld thin materials to thick materials.
- Low cost per weld
- A sufficient energy input into the joining area has to be possible. Small joining areas (<1 mm ²) must be realizable.
- The reproducibility and the positioning accuracy have to be very high.
- Flash should be as small as possible in order to ensure the functionality of the micro system.

4.0 Ultrasonic plastic welding machine specification:

Parameter	Range
Model no	3000-1500
Closing force(max)	3000N
Generator	SG-22-1500
Ultrasonic output power	1.5 KW
Frequency	20 KHZ
Max stroke	100 mm
Throat depth	275 mm
Working table	465×410mm^2
Horn size	Aluminum alloy 7049, E (Mpa)=72398, Density=2850 Kg/m^3
Max pressure	10 bar
Max weld time	2.5 sec
Ultrasonic transducer capacity	9 mm
Ultrasonic booster capacity	1:2

Table 2 : Parameter of Ultrasonic plastic welding machine

5.0 Parameter Considered for Experiment:

5.1 Input Parameters:

No.	Factors	Levels	Factor Levels Values
1	WT	**4**	1, 1.5, 2.0, 2.5
2	WP	**4**	3, 4, 4.5, 5.0

Table 3: Input Parameter of Experiment.

Here,
WT = weld time (sec).
WP = weld pressure (bar).
Remaining all machine parameters are considering constant.

6.2 Output Parameters:

Here we are measuring only one output parameter which is **Tensile strength** = TS (Mpa).

6.3 Experimental Table:

Sr no	WT	WP	TS
1	1.0	3.0	28.0
2	1.0	4.0	32.0
3	1.0	4.5	35.0
4	1.0	5.0	36.2
5	1.5	3.0	30.6
6	1.5	4.0	35.3
7	1.5	4.5	38.9
8	1.5	5.0	42.3
9	2.0	3.0	34.2
10	2.0	4.0	42.8
11	2.0	4.5	44.4
12	2.0	5.0	46.7
13	2.5	3.0	40.9
14	2.5	4.0	45.8
15	2.5	4.5	48.3
16	2.5	5.0	42.6

Table 5: Experimental Table for ABS

Sr no	WT	WP	TS
1	1.0	3.0	20.3
2	1.0	4.0	25.1
3	1.0	4.5	28.3
4	1.0	5.0	30.9
5	1.5	3.0	23.0
6	1.5	4.0	28.2
7	1.5	4.5	31.4
8	1.5	5.0	34.0
9	2.0	3.0	28.3
10	2.0	4.0	31.2
11	2.0	4.5	33.9
12	2.0	5.0	39.0

13	2.5	3.0	31.9
14	2.5	4.0	40.0
15	2.5	4.5	38.3
16	2.5	5.0	36.1

Table 6: Experimental Table for Acrylic material

Sr No	WT	WP	TS
1	1.0	3.0	23.0
2	1.0	4.0	25.9
3	1.0	4.5	27.0
4	1.0	5.0	29.0
5	1.5	3.0	26.9
6	1.5	4.0	27.0
7	1.5	4.5	32.8
8	1.5	5.0	34.9
9	2.0	3.0	33.6
10	2.0	4.0	37.9
11	2.0	4.5	39.8
12	2.0	5.0	41.3
13	2.5	3.0	40.1
14	2.5	4.0	41.1
15	2.5	4.5	47.0
16	2.5	5.0	45.6

Table 7: Experimental Table for polycarbonate material

7.0 Analysis of Results and Discussions:

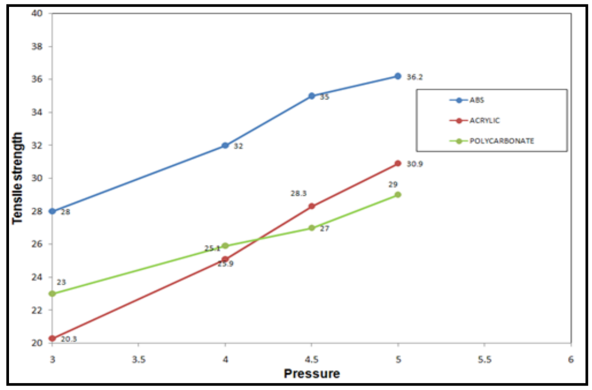

Fig: 2 Graph of pressure Vs. tensile strength at weld time 1.0sec

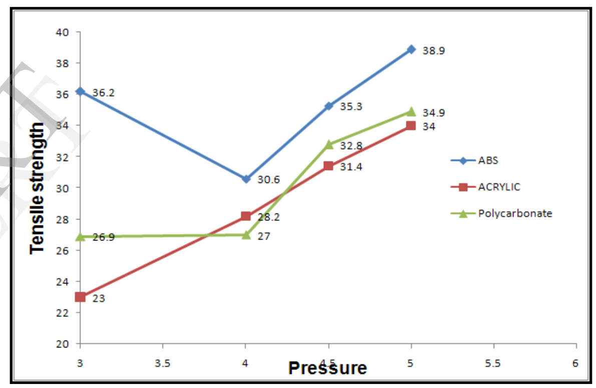

Fig: 3 Graph of pressure Vs. tensile strength at weld time 1.5sec

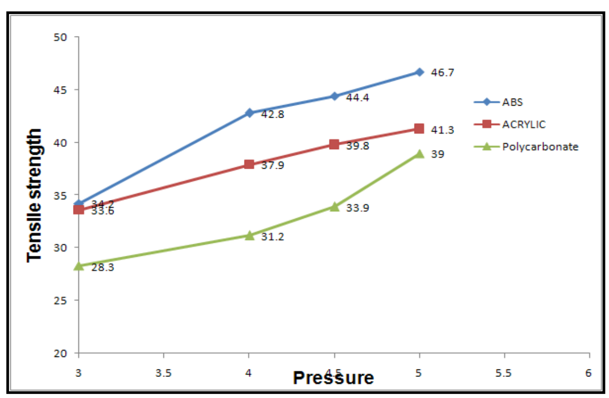

Fig: 4 Graph of pressure Vs. tensile strength at weld time 2.0 sec

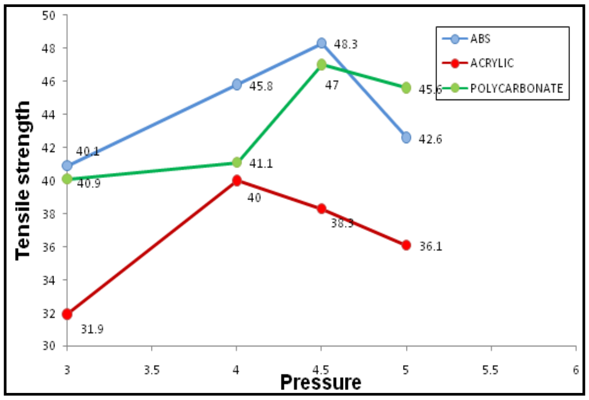

Fig: 5 Graph of pressure Vs. tensile strength at weld time 2.5 sec

(1) From the **Fig 2** in which pressure Vs tensile strength for three different materials at constant weld time 1.0 sec is indicated. It is the comparison of three different material weld strength for same weld time 1.0 sec and same pressure. We shows that the tensile weld strength of abs material is higher compare to the polycarbonate and acrylic for same condition. For abs material at pressure 3.0 bar the tensile strength is 28.0 Mpa. When pressure is increases 1 bar the tensile strength is also increases 32.0 Mpa at constant weld time 1.0 sec. if further increase of pressure 0.5 bar the tensile strength is increases at 35.0 Mpa. For acrylic material at the pressure 3.0 bar the tensile strength is 20.3 Mpa. Further increase of pressure 4.0 bar the tensile strength is also increases, but at that point the tensile strength of polycarbonate material is slightly higher as compared to the polycarbonate material. At the last point pressure 5.0 bar the tensile strength of polycarbonate material increases compared to the acrylic.

(2) From the **Fig 3** in which pressure Vs tensile strength for three different materials at constant weld time 1.5 sec is indicated. It is the comparison of three different material weld strength for same weld time 1.5 sec and same pressure. We Shows that the tensile weld strength of abs material is higher compared to the two other material for same condition. For abs material at pressure 3.0 bar the tensile strength is 30.6 Mpa. When pressure is increases 1 bar the tensile strength is also increases 35.3 bar at constant weld time 1.0 sec. If further increase of pressure 0.5 bar the tensile strength is increases at 38.9 Mpa. At the last for increase of pressure 1 bar the tensile strength is slighting increases 42.3 Mpa. For acrylic material at the pressure 1.0 bar the tensile strength is 23.0 Mpa which is

lower compared to the polycarbonate. Further increase of pressure 2.0 bar the tensile strength is also increases at 28.2 Mpa which is also lower than the polycarbonate material. At the last point pressure 5.0 bar the tensile strength of the acrylic is increases at 34 Mpa but it is lower than the polycarbonate material.

(3) From the **Fig 4** in which pressure Vs tensile strength for three different materials at constant weld time 2.0 sec is indicated. It is the comparison of different material weld strength for same weld time 2.0 sec and same pressure. We show that the tensile weld strength of abs material is higher compared to the polycarbonate material at initial first point. When pressure is increases 1 bar the tensile strength is also increases 42.8 Mpa in ABS material, while in polycarbonate material the tensile strength is 31.2 Mpa which is lower than the ABS at constant weld time 2.0 sec. If further increase of pressure 0.5 bars the tensile strength is an increase at 44.4 Mpa in abs material. At the last for increase of pressure 1 bar the tensile strength is slighting increases. For acrylic material at the pressure 3.0 bar the tensile strength is 33.6. Further increase of pressure 4.0 bar the tensile strength is also increases at 37.9 Mpa, at the pressure 4.5 bar the tensile strength is also increases at 39.8 Mpa. At the last point pressure 5.0 bar the tensile strength is increases at 41.3 Mpa. For poly carbonate also when we increase the pressure gradually the tensile strength is also increase. At the last point pressure at 5.0 bar the tensile strength is suddenly increases at 39.0 Mpa. In this graph we show that the pressure effect on abs material is more effective than in polycarbonate material.

(4) From the **Fig 5** in which pressure Vs tensile strength for three different materials at constant weld time 2.5 sec is indicated. It is the comparison of three different material weld strength for same weld time 2.5 sec and same pressure. We show that the tensile weld strength of abs material is higher compared to the polycarbonate and acrylic material. For abs material at pressure 3.0 bar the tensile strength is 40.1Mpa.

When pressure is increases 1 bar the tensile strength is also increases 45.8 Mpa, at constant weld time 2.5 sec. If further increase of pressure 0.5 bars the tensile strength are increases at 48.3 Mpa. But at the last for increase of pressure 0.5 bar the tensile strength is suddenly decreases at 42. For acrylic material at the pressure 1.0 bar the tensile strength is 40.9 Mpa. Further increase of pressure 2.0 bar the tensile strength is also increases at 41.1Mpa. At the pressure 4.5 bar the tensile strength is suddenly increases 47.0 Mpa. At the last point pressure 5.0 bar the tensile strength is decreases at 45.6 Mpa. For polycarbonate also when we increase the pressure gradually the tensile strength is also increase. Here at last 2 point the tensile strength of polycarbonate material is decreases like acrylic and abs material due to overheating in the welding.

As per **ANOVA Analysis** we can find the percentage contribution of input parameters for Tensile strength for ABS, Acrylic and polycarbonate material is as shown in below **Tables.**

Sources of Variation	**Percentage Contribution (%)**
Factor – **A** Weld time	57.92
Factor – **B** Pressure	33.14
Error	8.9332
Total	100

Table 8: Percentage contribution of Process Parameter for tensile strength for abs material

Sources of Variation	**Percentage Contribution (%)**
Factor – **A** Weld time	52.10
Factor – **B** Pressure	38.49
Error	9.4073
Total	100

Table 9: Percentage contribution of Process Parameter for tensile strength for acrylic material

Sources of Variation	**Percentage Contribution (%)**
Factor – **A** Weld time	84.013
Factor – **B** Pressure	14.16

Error	1.818
Total	100

Table 10: Percentage contribution of Process Parameter for tensile strength for polycarbonate material

8.0 Conclusions:

With the above study on ultrasonic plastic welding the tensile strength conclusion of the welding can be drawn as follows:

- The weld time is most significant control factor on Tensile strength during ultrasonic plastic welding. Meanwhile the pressure is also equally significant. The recommended parametric combination for maximum tensile strength of the material.
- On the basic of the experimental results, Analysis of variance (Anova) and the effect of welding parameters on tensile strength the conclusion can be drawn for effective welding of Abs, Acrylic and polycarbonate materials by ultrasonic plastic welding processes as follows:
  (1) Increasing the weld time the tensile strength is improved.
  (2) For time based ultrasonic plastic welding machine it was confirmed that the weld time is most effective factor in comparison of pressure for same welding condition.
  (3) The other analysis we judge from our experimental work is the weld ability of the Acrlonitrile butadiene (abs), is more than the acrylic and polycarbonate material.

9.0 References:

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