OPTIMIZATION OF THE OPERATIONAL PARAMETERS FOR JOINING OF DISSIMILAR POLYMER USING ULTRASONIC WELDING

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ABSTRACT

In the present scenario of developing plastic utility in engineering applications, demand for reliable and faster joining processes has increased. There are number of advantages for ultrasonic plastic welding, including greater efficiency and speed, longer tool life, higher accuracy and no filler or flux needed to be used. Ultrasonic welding of thermoplastic is one of those joining methods which is based on application of high- frequency vibratory energy in that work pieces are held together under pressure without melting. Ultrasonic welding of thermoplastic composites has become an important process in industry because of its relatively low cost and high quality resultant joints. The experiments are conducted on three parameters using response surface method (RSM). The method is designed in software package MINITAB-14 and the percentage contribution of each parameter is calculated by ANNOVA which will be compared to the actual test specimens for optimality and competence of mathematical model. Literature review has been done on the effect of Different Parameter and its Effect on The Strength of The joint of Metal Sheet So Trying and investigate about the effect of different parameter on the strength of dissimilar thermoplastic polymer material.

Keyword: - *Ultrasonic, welding joint ,Tensile Strength*

1. Introduction

Ultrasonic plastic welding is the joining or reforming of thermoplastics through the utilize of heat generated from highfrequency mechanical motion. It is accomplished by converting high-frequency electrical energy into high-frequency mechanical motion. That mechanical motion, along with applied force, generate frictional heat at the plastic components' mating surfaces (joint area) so the plastic material getting melt and form a molecular bond between the parts[22]

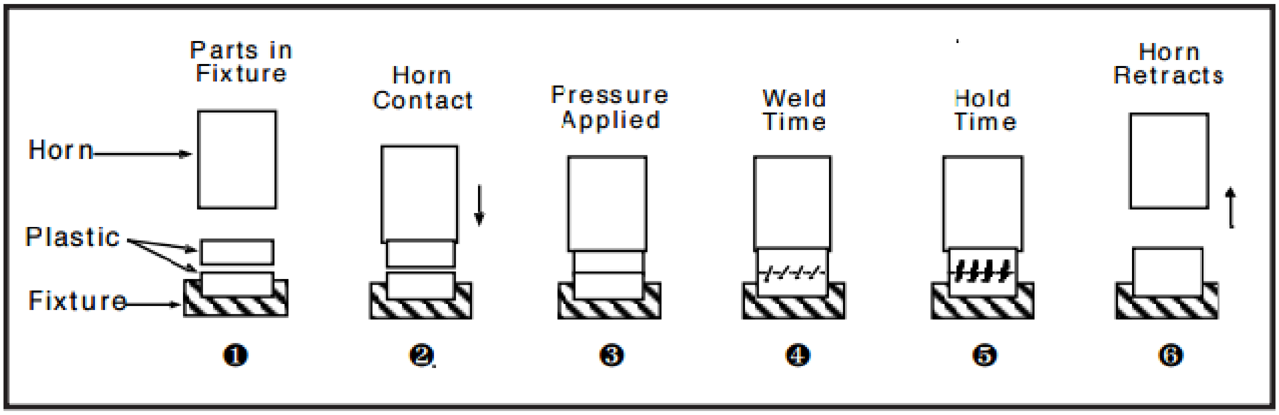


Figure1.1- Ultrasonic welding, (1)Parts in Fixture, (2) Horn Contact, (3) Pressure Applied ,(4) Weld Time, (5) Hold Time ,(6) Horn Retracts [22]

1.1 Basic Principal

The basic principle of ultrasonic assembly involves conversion of high-frequency electrical energy to high-frequency mechanical energy in the form of reciprocating vertical motion, which, when applied to a thermoplastic, can generate frictional heat at the plastic/plastic or plastic/metal interface as shown in figure 1.1. In ultrasonic welding, this frictional heat melts the plastic, allowing the two surfaces to fuse together; in ultrasonic staking, forming or insertion, the controlled flow of the molten plastic is used to capture or retain another component in place (staking) or encapsulate a metal insert.[17]

1.2 Near-Field / Far-Field Welding

Near-field welding refers to welding a joint located 1/4 inch(6 mm) or less from the area of horn contact; while far-field welding refers to welding a joint located more that 1/4 inch (6 mm) from the horn contact area. The greater the distance from the point of horn contact to the joint, the more difficult it will be for the vibration to travel through the material, and for the welding process to take place.[17]

1.3 Components

- A press to put the two parts to be assembled under pressure
- A nest or anvil where the parts are placed and allowing the high frequency vibration to be directed to the interfaces
- An ultrasonic stack composed of a converter or piezoelectric transducer, an optional booster and a sonotrode (US: Horn). All three elements of the stack are specifically tuned to resonate at the same exact ultrasonic frequency (Typically 20, 30, 35 or 40 kHz)
- Converter: Converts the electrical signal into a mechanical vibration
- Booster: Modifies the amplitude of the vibration. It is also used in standard systems to clamp the stack in the press.
- Sonotrode: Applies the mechanical vibration to the parts to be welded.
- An electronic ultrasonic generator (US: Power supply) delivering a high power AC signal with frequency matching the resonance frequency of the stack.
- A controller controlling the movement of the press and the delivery of the ultrasonic energy.[19]

1.4 Thermoplastics

When classified by chemical structure, there are two generally recognized classes of plastic materials: Thermosets, having cross-linked molecular chains and Thermoplastics, which are made up of linear molecular chains. There are two types of thermoplastic polymers: Crystalline and Amorphous.[17]

1.4.1 Crystalline Polymers

Crystallinity is indication of amount of crystalline region in polymer with respect to amorphous content. So while selecting polymer for required Application its crystallinity plays foremost role. When polymers extruded through the spinneret, the molecules orient themselves in the direction of the extruded melt.

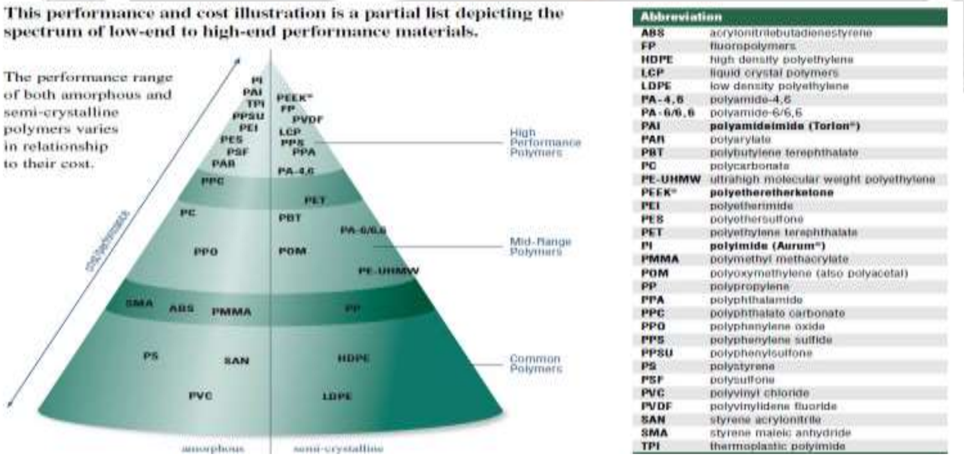
- Have a relatively sharp melting point.
- Have an ordered arrangement of molecule chains.
- Generally require higher temperatures to flow well when compared to Amorphous.
- Reinforcement with fibers increases the load-bearing capabilities considerably.
- Shrink more than Amorphous, causing a greater tendency for war page.
- Fiber reinforcement significantly decreases war page.
- Usually produce opaque parts due to their molecular structure.[17]

1.4.2 Amorphous Polymers

A parameter of particular interest in synthetic polymer manufacturing is the glass transition temperature (Tg), at which amorphous polymers undergo a transition from a rubbery, viscous liquid, to a brittle, glassy amorphous solid on cooling.

- Have no true melting point and soften gradually.
- Have a random orientation of molecules; chains can lie in any direction.
- Do not flow as easily in a mould as Crystalline Polymers.
- Shrink less than Crystalline Polymers.
- Generally yield transparent, water-clear parts.[17]

1.4.3 The Performance And Cost Illustration



Abbreviation	
ABS	acrylonitrilebutadienestyrene
FP	fluoropolymers
HDPE	high density polyethylene
LCP	liquid crystal polymers
LDPE	low density polyethylene
PA-4,6	polyamide-4,6
PA-6/6,6	polyamide-6/6,6
PAI	**polyamideimide (Torlon®)**
PAR	polyarylate
PBT	polybutylene terephthalate
PC	polycarbonate
PE-UHMW	ultrahigh molecular weight polyethylene
PEEK*	**polyetheretherketone**
PEI	polyetherimide
PES	polyethersulfone
PET	polyethylene terephthalate
PI	**polyimide (Aurum®)**
PMMA	polymethyl methacrylate
POM	polyoxymethylene (also polyacetal)
PP	polypropylene
PPA	polyphthalamide
PPC	polyphthalate carbonate
PPO	polyphenylene oxide
PPS	polyphenylene sulfide
PPSU	polyphenylsulfone
PS	polystyrene
PSF	polysulfone
PVC	polyvinyl chloride
PVDF	polyvinylidene fluoride
SAN	styrene acrylonitrile
SMA	styrene maleic anhydride
TPI	thermoplastic polyimide

Figure 1.2 Performance And Cost Illustration [17]

1.5 HDPE (HIGH DENSITY POLYETHYLENE)

High-density polyethylene (HDPE) or polyethylene high-density (PEHD) is a polyethylene thermoplastic made from petroleum. It is sometimes called "alkathene" or "polythene" when used for pipes. With a high strength-to-density ratio, HDPE is used in the production of plastic bottles, corrosion-resistant piping, geo-membranes, and plastic lumber. Property of hdpe as shown in table 1.5.1[24]

1.5.1 Properties

Table no 1.5.1

Physical Property	Value
Tensile strength	0.20-0.40 N/mm^2
Notched impact strength	No break Kj/m^2
Thermal coefficient of expansion	100-220 x 10^{-6}
Max. Continued Used temp.	65^0C (149 ^{0}F)
Melting point	$120^{\ 0}$ -180 ^{0}C (320 ^{0}F)
Density	0.93-0.97 g/cm^3

1.6 Polypropylene

Polypropylene (PP), also known as polypropene, is a thermoplastic polymer used in a wide variety of applications including packaging and labelling, textiles (e.g., ropes, thermal underwear and carpets), stationery, plastic parts and reusable containers of various types, laboratory equipment, loudspeakers, automotive components, and polymer banknotes. An addition polymer made from the monomer propylene, it is rugged and unusually resistant to many chemical solvents, bases and acids. Property of pp as shown in table 1.6.1[24]

1.6.1 Properties

Table no 1.6.1

Physical Property	Value
Tensile strength	0.95 – 1.30 N/mm^2
Notched impact strength	3.0-30.0 Kj/m^2
Thermal coefficient of expansion	100-150 x 10^{-6}
Max. Continued Used temp.	80^0C (176 ^{0}F)
Melting point	160^0C (320 ^{0}F)
Density	0.905 g/cm^3

1.7 Application of ultrasonic in thermoplastic

The applications of ultrasonic welding are extensive and are found in many industries including electrical and computer, automotive and aerospace, medical, and packaging. Whether two items can be ultrasonically welded is determined by their thickness. If they are too thick this process will not join them. This is the main obstacle in the welding of metals. However, wires, microcircuit connections, sheet metal, foils, ribbons and meshes are often joined using ultrasonic welding. Ultrasonic welding is a very popular technique for bonding thermoplastics. It is fast and easily automated with weld times often below one second and there is no ventilation system required to remove heat or exhaust. This type of welding is often used to build assemblies that are too small, too complex, or too delicate for more common welding techniques.

(1) Extensively used in the appliance industry for assembling, toys, pumps, particulate-filled soap dispensers, and packing. ex. mecasonic uk ltd

(2) Automotive applications include all-plastic automotive bumper, headlight, taillight, instrument panel assemblies, gasoline reservoirs, dash-and-trim components, air conditioning and heater ducts etc.

(3) Manufacturing of the automotive air intake manifold. The manifold is made in two or three injection moulded parts and linear vibration welding is used to assemble the final manifold.

(4) Widely used in making high quality joints in polyethylene (PE) gas distribution pipes.[18]

1.7 Advantages

- Fast, economical and easily automated.
- Mass production, up to 60 parts per minute is possible.
- Increased flexibility and versatility.
- Possibility to join large structures.
- Used in health care industries due to clean welds.
- Produce the high strength joints consistently.[17]

1.8 Disadvantages

- Large joints (>250 x 300 mm) cannot be welded in a single operation.
- Specifically designed joints are required.
- Ultrasonic vibrations can damage electric components.
- Tooling costs for fixtures are high.[17]

1.9 CARD (Computer Aided Resonator Design)

Computer Aided Resonator Design (CARD) is software that applies quantitative techniques to the design of ultrasonic resonators (horns, boosters, and transducers) that vibrate in a longitudinal mode. CARD provides assistance in the design of resonators having low-to moderate complexity. With CARD, alternative resonator designs can be quickly evaluated without machining and testing. The effects of proposed resonator modifications can be easily determined. CARD is especially useful for designing low-stress resonators, resonators with a specified gain, and resonators with a specified node location. CARD automatically tunes the horn to the desired frequency by adjusting the resonator dimensions. The adjustable dimensions include the length, thickness or diameter, and location of a transition radius. In addition, CARD can automatically adjust the gain and minimize the stress. CARD calculates numerous acoustic parameters, including tuned length, tuned frequency, gain, node location, maximum stress, stored energy, loss, overall quality factor (Q), and weight. When calculating the stress, CARD considers the effect of stress concentrations at radii and slot ends. CARD graphically displays the calculated amplitude, stress, and strain loss distributions at each point along the length of the resonator. The resonator shape can be graphically displayed to verify its correctness. The resonator can be composed of multiple, userdefined materials. The resonator can have a cavity in the face and can have studs, wrench flats, and spanner wrench holes. CARD allows up to 10 different user-defined materials and ultrasonic equipment configurations. These defaults can be saved to disk. CARD is very easy to learn and use, so that even those with minimum computer experience should have little difficulty. All user input is from menus; there are no commands to memorize. From any menu within CARD, a single key press will change between metric and English units. Extensive hypertext help is available for each menu option. Also included with the help is a glossary of over 300 acoustic terms. (Note: although CARD is very easy to use, the user must have some understanding of resonator design in order to evaluate the computer-generated output.) Except for flatted-cylindrical horns (above), CARD cannot be used for resonators whose cross-sectional shape changes along the length of the resonator. Thus, for example, if a resonator has a rectangular cross section, then this cross-sectional shape must continue along the entire resonator length. Although the cross-sectional shape cannot change, the cross sectional dimensions can be adjusted as desired. Note that certain non symmetric entities (e.g., wrench flats and spanner holes) are permitted. CARD cannot be used on bar horns with risers on the back.[25]

2. LITERATURE SURVEY

2.1 Problem Identification

In the industries and manufacturing ultrasonic welding is widely used in the joining of the plastic materials and the dissimilar materials by the welding joint. the ultrasonic welding is used in the welding joint using the predefined ranges, which can led to the poor weld strength, which leads to poor quality of work piece. the predefined ranges does not necessarily relate to the optimal parameter values. If the parameters value are not optimal and defined then weld strength is compromised and which can lead to material failure.

2.2 Review of literature

Rashiqah Rashli[1]: we studied the journal and we think that ultrasonic weld joint defect and determination of effective parameter for plastic material. They take weld time, weld pressure, hold time, welding speed and amplitude as parameter. optimization of effective parameters of ultrasonic welding for plastic materials for manufacturing products had been successfully well-known by using trial and error method and Taguchi method. It can be seen from these both methods, Taguchi optimization method perform better and optimization to compare to the trial and error method. it is sufficient in terms of its low cost and more speedy. The parameter was preferred base on material quality, ultrasonic weld design and its thickness and welding configurations.

Khyati vyas[2] : we studied the journal and we think that on Glass Fiber reinforced plastic composite, plastic is used as medium which form network with glass fiber Strength of ultrasonically weld Glass Fiber reinforced plastic depends on parameters like pressure, weld time, thickness ratio, and amplitude. In this paper a summary of ultrasonic welding method, joining of GFRP, and effective parameters. From the literature survey, they found that hardly any attempt was made to join glass fiber reinforced thermosetting plastic using welding techniques because thermosetting polymers cannot be heated once it is cured. Therefore, an investigation on effect of joining glass fiber reinforced thermosetting plastic composite with thermoplastic as intermediate layer using ultrasonic welding method can be accepted.

M. Roopa Rani & R. Rudramoorthy[3] : we studied the journal and we think that The tensile strength of joint using the different horn profile, they using the finite element analysis using simulation for the ABS sheet material and aluminums horn material .in this paper Power of USW machine, frequency, material of sheet, field, weld time, hold time, weld pressure, collapse as input parameter and measure the Modeled and experimental temperatures for different horn profiles.

S.Elangovan[4] : we studied the journal and we think that In ultrasonic welding, high frequency vibrations are joint with pressure to join two materials simultaneously rapid and strongly, without generating heat. During ultrasonic welding of sheet metal, normal and shear forces act on the work piece to be welded and the weld interface. These papers also include a model for the temperature supply during welding and stress supply in the horn and welded joints are presented. With the information, the forces that work at the interface it is feasible to control weld strength and keep away from horn welding. The presented limited element model is able to predict the interface temperature and stress distribution during welding and there influences in the workpiece, horn and anvil. This paper is also included the impact of clamp forces, objects thickness and coefficient of friction throughout heat generation at the weld interface.

Fernandez[5] : we studied the journal and we think that the visual and microscope method for analysis the part. They are also investigating the impact of the shape of the energy director on the performance of the weld. This paper is represents an experimental reading on the influence of several configurations of energy directors in the quality and the mechanical performance of the weld. The effect of the path of the energy director with respect to the load path was investigated. Attention was paid to the effect of the size and distribution of multiple energy directors. Influence of the energy director on the strength and the quality of the weld was investigate from two different point of view, the influence of the orientation of the energy director and impact of the several energy directors.

K. Palanikumar & J. Paulo Davim[6]: we studied the journal and we think that a mathematical model has been developed to determine the tool wear on the machining of Glass Fiber Reinforced Polymer (GFRP) composite using decay analysis, and analysis of variance in order to study the main and interface effective machining parameters, like cutting feed, speed, depth of cut and the work piece fiber approach angle. The capability of the developed model is verified by using co-factor of determination and residual investigation. This model can be successfully used to predict the wear on tool machining Glass Fiber Reinforced Polymer components in the range of variables studied. They using the carbide coated tool which composition is Co 6.0%; composite carbide 8.0%.the tool wear increases with increase of cutting speed. The higher cutting speed was found to cause a large deformation of glass fiber and severe tool wear and hence the cutting speed has been set low, and it is vary in between75 and 175 m/min. The depth of cut play a small operation in composite machining process compare to cutting speed and feed. but the higher depth of cut cause a harmful impact on surface quality in GFRP machining and it also lead to more tool wear and low limits of depth of cut are selected for the this study. The increase in feed rate increased the heat produce and hence, tool wear, which resulted in the higher tool wear .The raise in feed rate also raise the chatter and it produces incomplete machining at a quicker traverse, which leads to more tool wear.

Jiromaru Tujino & Tetsugi Ueoka[7] : we studied the journal and we think that the different parameter like Weld time, clamping force, thickness of plate, width, amplitude and measure the strength of the weld joint. Ultrasonic spot welding using two vibration systems of 15 kHz and 27 kHz cross at a 90̊ angle are studied. They conclude that the welding plate specimens of aluminum, aluminum alloy, copper and steel plate specimens between 0.5mm to 2.0mm thickness and 100mm to 200mm width were successfully welded continuous with nearly uniform welding strength along the specimen width by spot lapped welding, using the ultrasonic welding components with two vibration system cross at a 90̊ angle and by controlling the vibration modes of the plate specimens by clamping the specimen at adequate positions by metal vices with sufficient mass for reflection or suppression of the upper and lower specimen vibrations.

Farid Haddadi[8] : we studied the journal and we think that the process parameters weld time, clamping force, thickness, temperature of weld for measuring the strength of welded joint using modeling and structure analyses. Author takes aluminum and steel for joint. Rectangular shape of 100mm length and 25mm width to be welded at 25mm over lapped position. Conclude that similar aluminum welding was seen to give 3.0 kN strength with a fracture (nugget pullout) mode under optimal state but in a considerable short weld time compared to different aluminum to steel joint. The same maximum weld strength and Fracture mechanism (nugget pullout) of similar aluminum welds was observed when aluminum was welded to un-coated steel. In the case of aluminum to un-coated steel welding, the formation of micro bonds occurred on the early stages of the welding and spread rapidly across the faying surface with increase in weld time. This followed by interdiffusion resulting in the nucleation of intermetallic islands.

Mantra Prasad Satpathy[9] : we studied the journal and we think on the vibration amplitude, weld pressure and weld time this three input parameter for study, they measuring the weld strength of joinit for the aluminum and brass sheet of 0.3mm thickness material using the full factorial, non-linear second order regression model between the responses and predictors. A variety of weld quality levels, such as “under weld”, “good weld” and “over weld” have also been defined by performing micro structural analysis. they conclude that base on its main effects results, the most influencing parameter on the response is the vibration amplitude as it occupy rank 1 followed by weld time and weld pressure. An amplitude of 68 mm, weld pressure of 0.3 MPA and weld time of 0.8 Sec are the optimum inputs to get excellent weld using this method. Further the Florescent Magnetic Particle Inspection (FMPI) data are used to develop a mathematical model using nonlinear regression equation and the ANOVA has also been performed to analyze the accuracy of the model with the experimental value. This model can also explain the variation in Florescent Magnetic Particle Inspection (FMPI) up to 91.62%.

A. Dipal M. Patel[10] : we studied the journal and we think on proper concentration of ultrasonic energy across work piece surface during welding, geometry of sonotrode act as critical part. This point involves the design of sonotrode material and shape and also amplitude and frequency of the vibration. In this paper is representing on design of various type of sonotrode like conical, stepped and exponential for ultrasonic plastic welding. First, the theoretical dimensions of different shaped sonotrode are calculated and compare with the dimension obtain through commercial horn design software Computer Aided Resonator Design (CARD). The magnification factors available for both situations for sonotrode shapes have been compared. The discussion part of study work intended of the joint the strength of Acrylic and Polycarbonate are under different welding parameter. A stepped shape sonotrode generates high amplitude and it will have high vibration stress. Stress circulation results show that for ultrasonic plastic welding, conical shaped sonotrode and exponential shaped sonotrode are better than any other shape of a sonotrode. Same as the computerized calculation for exponential shape of sonotrode is easy three different type of shape. Also the sonotrode of exponential sonotrode has superior amplitude than the conical sonotrode. It is hardly used in system where machining cost is justified due to complexity in machining. While the calculation for conical sonotrode shape is difficult. Sonotrode manufacturing is very easy and also has similar amplitude.

3. WORKING METHODOLOGY

3.1 Design of Experiment

For relation of variable and parameter which effect the process and response of practical, DOE is used. A set of experiments, which factors and varied systematically that involves by DOE. It’s help for identify good condition of parameters. This techniques gives best design alternatives when applied to experimental design. It’s covered all already selected ranges. It’s introduced by R. A. Fisher.

3.2 Response Surface Method

Response surface methodology (RSM) is used for empirical model building collection of mathematical and statistical technique. By watchful design of the experiments, the main objective is to optimize the response factor (output variable) which is predisposed by several independent factors (input variables). An experiment is a sequence

of tests, called runs, in which changes are prepared in the input variables in order to recognize the reasons for changes in the output response. The often used second-order designs are the 3k factorial, central composite, and the Box-Belinken designs.
The DOE table will be generated in Minitabl4 using Box behnken Method of RSM

3.3 Selection of factors and Their Levels

(1) Variables Related to Welding Setup
Amplitude, frequency, pressure and weld time are the major variables affecting the performance of ultrasonic welding. The ultrasonic machine available has fixed single frequency generator so far the problem definition frequency is fixed at 20 KHz. The amplitude, pressure and weld time will be varied to take observations for finding out those conditions under which optimum output can be obtained for this frequency. So pressure, amplitude and weld time are selected as control parameters (factors) and frequency will be our cofounding parameter. Suitable levels of amplitude, pressure and weld time will be selected with screening trials.

(2) Variables Related to Welding Part
The type of material, its thickness and surface roughness are major work related variables affecting ultrasonic welding. The work material selected is HDPE and PP. three different thickness of pp sheets will be considered for welding. The shape and size of HDPE will be fixed.
The control variables selected for the experiment therefore are:

l. Weld pressure
2. Amplitude
3. Weld time
4. Thickness Ratio

A Response Surface Methodology with three levels of each for four control parameters of these parameters will be selected to carry out experimentation in order to capture nonlinearity.
The values selected for low. medium and high level for each of the control parameters are as shown in table 3.5

Table 1: PARAMETERS AND LEVELS OF PROCESS VARIABLES

PROCESS PARAMETERS	LEVEL 1	LEVEL 2	LEVEL 3
Weld pressure(bar)	3	4	5
Weld time(sec)	3	4	5
Amplitude (%)	70%	80%	90%
Thickness ratio	0.5	1	1.5

Three factors are selected for four factors which shows predefined ranges value. The test are conducted on UNIVERSAL TESTING MACHINE at Machine centre

3.4 Experimental Result and Analysis

The DOE table is generated in the MINITAB14 using box behnken design for RSM. And then after the all parameters are taken and tested on Universal Tensile Machine. And observations are made below.

Table 2: ANNOVA Table

Std order	Run order	Amplitude (micron)	Pressure (bar)	Weld time (second)	Thickness ratio	Strength (Mpa)
1	1	0.7	3	4	1.0	10.573
2	2	0.9	3	4	1.0	44.234
3	3	0.7	5	4	1.0	40.987
4	4	0.9	5	4	1.0	48.344
5	5	0.8	4	3	0.5	32.255
6	6	0.8	4	5	0.5	28.689
7	7	0.8	4	3	1.5	22.495
8	8	0.8	4	5	1.5	18.148
9	9	0.7	4	3	1.0	8.483
10	10	0.9	4	3	1.0	40.269
11	11	0.7	4	3	1.0	19.630
12	12	0.9	4	5	1.0	41.265
13	13	0.8	3	5	0.5	21.137
14	14	0.8	5	4	0.5	34.233
15	15	0.8	3	4	1.5	18.594
16	16	0.8	5	4	1.5	37.234
17	17	0.7	4	4	0.5	28.344
18	18	0.9	4	4	0.5	50.984
19	19	0.7	4	4	1.5	21.388
20	20	0.9	4	4	1.5	30.808
21	21	0.8	3	3	1.0	23.487
22	22	0.8	5	3	1.0	36.998
23	23	0.8	3	5	1.0	22.390
24	24	0.8	5	5	1.0	38.490
25	25	0.8	4	4	1.0	47.398
26	26	0.8	4	4	1.0	36.690
27	27	0.8	4	4	1.0	39.927

3.5 Analyze the response surface method

The analysis of variance is the most frequently applied of all statistical analyses. Analysis of variance is used extensively in many areas of research, such as education, sociology, engineering, antrohoplogy, economics, psychology, political science, as well as in industry and commerce. One reason for frequency of analysis of variance applications is their suitability for many different type of design of study.

Analysis of variance for weld strength is carried out using MINITAB software for experimental data on=btained during ultrasonic welding of HDPE and PP as listed in above chapter and table. ANOVA for weld strength is represented in table.

Table 3 Estimated Regression Coefficient for strength

Term	Coef	SE Coef	T	P
Constant	41.3417	3.124	0.000	
amplitude	10.5186	1.562	0.000	
pressure	7.9441	1.562	0.000	
weld time	0.2521	1.562	0.874	
thickness ratio	-3.9166	1.562	0.028	
amp*amp	-2.5296	2.343	0.302	
press*press	-3.4174	2.343	0.170	
wt*wt	-8.9434	2.343	0.002	
tr*tr	-7.6851	2.343	0.007	
amp*press	-6.5363	2.705	0.033	
amp*wt	-2.05050	2.705	0.373	
amp*tr	-3.3055	2.705	0.245	
press.*wt	0.7675	2.705	0.781	
press.*tr	1.3860	2.705	0.618	
wt*tr	-0.1967	2.705	0.943	

S=5.411 R-Sq=89.8% R-Sq(adj)=77.9%

Table 4: Anlaysis of variance for strength

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	14	3097.16	3097.16	221.23	7.56	0.001
Linear	4	2269.83	2269.83	567.46	19.38	0.000
Square	4	577.44	577.44	144.36	4.93	0.014
Interaction	6	249.89	249.89	41.65	1.42	0.284
Residual error	12	351.34	351.34	29.28		
Lack-of-fit	10	291.12	291.12	29.11	0.97	0.609
Pure error	2	60.23	60.23	30.11		
Total	26	3448.50				

3.6 Effect of Pressure, Amplitude, Weld time and Thickness ration in Weld Strength

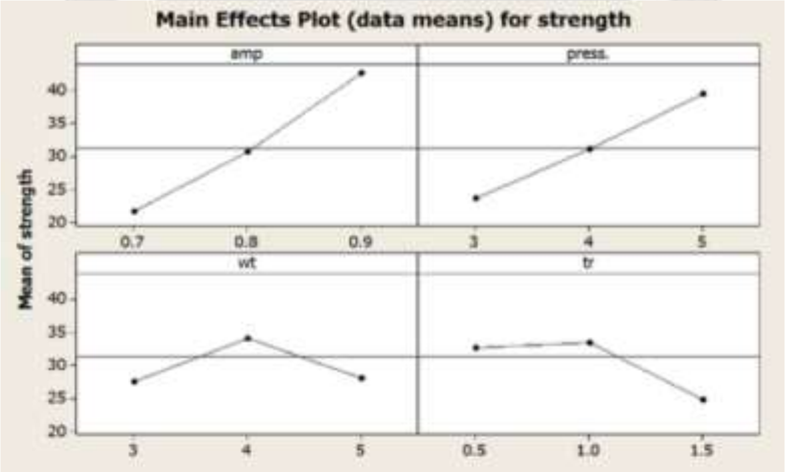


Fig 3.1: Main effect Plot: Data means for strength

Fig 3.1 shows that pressure is the most significant parameter among the remaining three parameter for strength. It was observed that with increase in thickness ratio strength decreases. The highest strength is obtained at thickness ratio 0.5 to 50.9860 Mpa.

With the increase in the weld pressure will increase the weld quality. Too low weld pressure will produce incomplete fusion of thermoplastic, while too high weld pressure gives burning parent material and resulting bad quality weld. So it is important to set exact and optimum weld pressure.

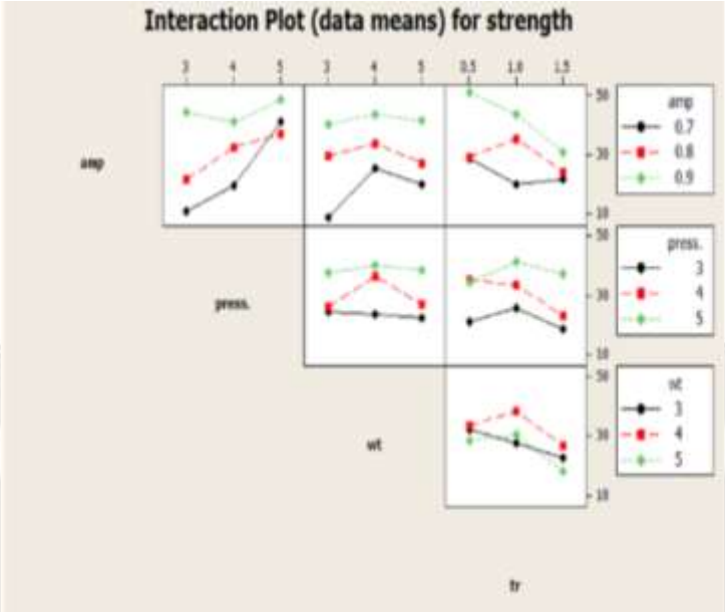


Fig 3.2 interaction plot for strength

Fig 3.2 shows the interaction effect plot at data means of strength. It shows that higher and lower side pressure, gives low strength at moderate amplitude, weld time and thickness ratio respectively. Weld strength is increased with combined effect of increase in pressure and amplitude. With increase in thickness ratio a good quality of weld is obtained with higher weld time, pressure and amplitude. Hence, strength is also obtained by the combined effect of thickness ratio with amplitude, pressure and weld time.

4. CONCLUSIONS

Sonotrode design was required for two reasons. one for bridging the gap between the transducer and part being welded and second for getting amplitude amplification. Hence. a tuned horn was designed and fabricated.The weld strength is found to increase with increase in pressure. amplitude and with weld time up to a certain point after strength start getting reduce. From the main effect graph it was found that highest strength of 50.986 Mpa is obtained by transferring ultrasonic vibrations for 4 seconds weld time. at 4 bar pressure. with 90% amplitude. for thickness ratio being 0.5. Analysis of variance for strength of the observations obtained gave 89.896 R.sq. The combined effect of all the parameters at high level. decreases weld strength. This happens so because of high energy transfer for longer time at high pressure damages the parent material. Hence. decreases overall strength of joint. Therefore. a combination of control parameter must be selected to obtain high weld strength. At mildest thickness ratio]. good weld quality is obtained. while at lower and higher thickness ratio poor quality weld is obtained. The combined effect of pressure and amplitude at constant weld time and thickness ratio. produces better weld strength at middle range of pressure and amplitude. The combined effect of pressure and weld time while keeping amplitude and thickness ratio constant. produces higher strength at high pressure for longer weld time. Though at high pressure but with minimum weld time. poor quality weld is obtained. because of less time to transfer ultrasonic energy through parts. By controlling the machine setup parameters. weld strength of joint can be improved.

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