Modeling and Optimization of Ultrasonic Welding Process for Low Density Polymer: A Review

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Abstract-- The purpose of this research is to determine the effect of various weld and machine parameters on ultrasonic weld strength. In this we are going to use thermosetting material named epoxy which is one of the low density polymers. By considering three main parameters that is amplitude, pressure and weld time we are going to conduct the experiment. After doing the welding, we will check the tensile strength of the welded pieces by using UTM. (Universal testing machine).Further with the help of MINITAB software we will optimize the number of experiments.

Keywords-- *Amplitude, Weld Time, Pressure, Tensile strength.*

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1. Introduction

Ultrasonic plastic welding is the joining or reforming of thermoplastic and thermosetting materials 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. Thus welding is done. It is locally applied to workpieces being held together under pressure to create a solid-state weld. In ultrasonic welding, there are no connective bolts, nails, soldering materials, or adhesives necessary to bind the materials together.

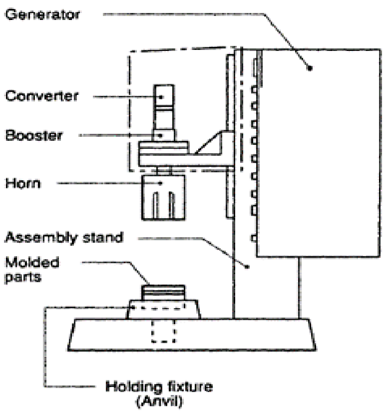

Fig1: Schematic illustration of Ultrasonic machine

2. Processing and equipment

Ultrasonic welding process consists of four stages as follows:

1.) Approach time: - In this, the tool will move towards the workpiece. 2.) Weld time: - In this, the tool will take time for welding. 3.) Hold time: - In this, the tool will apply pressure on workpiece. 4.) Shake off time: - In this, the tool will move back to its initial position. The generator used in USM produces 20KHz frequency which is converted into mechanical vibrations with the help of Transducer/converter.

3. Applications

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. 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.

4. Welding parameters

The three main parameters in Ultrasonic welding are amplitude, pressure and weld time. In order to produce good quality weld the above parameters must be controlled properly.

5. Literature Review

A. Ultrasonic welding of micro plastic parts
(W. Michaeli, , et al.2014.)
Due to the ongoing miniaturization in many industrial branches plastics are increasingly applied in Microsystems Technology. To guarantee the functionality of the system suitable joining processes must be applied to join separate components. Most of the welding processes commonly used for series production are not suitable for welding micro parts made from plastics, since either the mechanical or the thermal load of the joining partners during the welding process are too high. Only laser transmission welding and ultrasonic welding are applicable for welding complex micro components. Since with ultrasonic welding a certain frictional load of the components cannot be avoided totally with standard welding equipment, specially adapted machinery has to be used as it could be shown at the Institute of Plastics Processing (IKV) at RWTH Aachen University. While micro parts with two-dimensional weld seams have already been successfully welded in previous investigations, recent research deals with the ultrasonic welding of micro parts with more complex three-dimensional weld seam geometry. It could be shown that for appropriate welding parameters this can be accomplished, whereby the mechanical load of the parts has to be kept as small as possible.[1]

B. The Increasing Of Weld Strength By Parameters Optimization Of Ultrasonic Welding For Composite Material Based On Aluminum Using Design Of Experiments.
(Marius Pop-Calimanu, Traian Fleser, 2013)
Ultrasonic welding is a solid-state welding process in which similar or dissimilar work pieces are jointed by the application of high frequency vibratory energy, where the work pieces are held together under pressure without melting. The problem faced by researchers and industry which have deals with ultrasonic welding process is poor strength of the weld, due to improper selection of welding parameters. Therefore, we are usually interested to determine which variables process affects the response. A stage is to optimize, this means that we can determine the region in the important factors that lead to the best possible response. In this paper, welding parameters, like welding time, welding pressure and amplitude of the vibration are taken into account during the realization of ultrasonic welded joints of Al/20%SiC composite material under disks form, whose thickness are 1 mm. This work focuses on the development of an effective methodology to determine the optimum conditions for welding, that maximize the strength of joints produced by ultrasonic welding. Here we have investigated the effect of process variables and energy input on joints formation between Al/20%SiC composite material disks, and a report on the optimum welding conditions. A suitable experimental design, based on 2k factorial design was designed and executed for conducting trials. These designs have a greatly simplified analysis.[2]

C. Determination of Ultrasonic Welding Optimal Parameters for Thermoplastic Material of Manufacturing Products.
(Rashiqah Rashli, Elmi Abu Bakar, , et al.2012)
Ultrasonic welding had been widely used in various anufacturing industries such as aviation, medical, electronic device and many more. It offers a continued safe operation, faster and also low cost as it able to join weld part less than one second and also simple to maintain the tooling devices. Though ultrasonic welding brings a lot of advantages in assembly especially in thermoplastic material of manufacturing product, it also has a dominant problem to be deal with. The problem in ultrasonic welding is poor weld quality due to improper selection of ultrasonic welding parameters especially in near field configuration. Thus, an optimal combination of parameters is crucial in order to produce good quality weld assembly for this configuration. In this paper, ultrasonic welding process, ultrasonic weld joint defects and determination of optimal parameters for thermoplastic material had been discussed thoroughly.[3]

D. OPTIMIZATION OF ULTRASONIC WELDING PROCESS USING IMPERIALIST COMPETITIVE ALGORITHM.
(SEYED AANAN ADNANI SALEHI, HOSSEIN TOWSYFYAN, et al2014.)
In this paper Imperialist Competitive Algorithm (ICA) is applied to determine the optimum welding conditions that maximize the strength of joints produced by ultrasonic welding. Imperialist Competitive Algorithm is inspired by imperialistic competition mechanism and has shown some advantages such as simplicity, accuracy, and time saving in comparison with evolutionary algorithms. A case study from literature is presented to show the effectiveness of the proposed algorithm. In this regard, the imperialist competitive algorithm is utilized to predict weld strength by incorporating process parameters such as pressure, weld time and amplitude in ultrasonic welding process. The numerical results reveal that ICA can find optimum welding

condition with higher accuracy in less computational time when compared to conventional Genetic Algorithm (GA).[4]

E. "FAILURE ANALYSIS OF A 30KHZ ULTRASONIC WELDING TRANSDUCER"
(CHRISTOPHER PAUL HAMPTON, 2014)

Ultrasonic welding is used across variety of industries to join together thermoplastic materials. During ultrasonic welding, high frequency mechanical vibrations and compressive pressure are applied to the plastic materials. This creates intermolecular friction within the plastic which raises the temperature high enough to reach the melting point. During high volume production in manufacturing environments, the ultrasonic welding system component which fails most often is the transducer, which is responsible for creating the vibration. The transducer converts electrical energy into mechanical energy by means of a polarized piezoelectric PZT (lead zirconate titanate) polycrystalline ceramic material using high frequency voltage. The transducer is composed of round PZT disks attached to a titanium machined body by means of a central bolt.The bolt creates compressive pre-stress which prevents any tensile stresses within the brittle crystals during vibration and ensures perfect coupling between all components. The piezoelectric PZT crystals behave according to linear coupled electrical and mechanical equations. The transducer assembly is vibrated near the parallel resonant frequency to maximize efficiency and amplitude output.[5]

F. Process optimization: Ultrasonic welding of coextruded polymer film.
(David A. Grewell, Major Professor Michael Kessler, D. R. Raman.2013)

The purpose of this research is to determine the effect of various welds and machine parameters on ultrasonic weld strength. Specifically, welds with six different triple-layer coextruded polyethylene and metalized polypropylene films were examined. These materials were welded in separate experimental studies using a bench top weld system and a high production volume packaging machine. The first study investigated the effect of a range of weld forces, energies, and amplitudes in a lap joint geometry using a bench top ultrasonic plunge welding system. Weld strength was determined by measuring resistance to tearing and peel and shear strength. It was observed that low energy and low weld force had a significant effect on shear strength welds for all materials. High peel strength was observed at relatively high weld forces and energies, and high tear resistance was observed at relatively high forces, high amplitudes, and mid-range energy levels. The second study determined the suitability for the same materials to be sealed as bags for packaging applications in a vertical "form fill seal" machine. This machine was equipped with an ultrasonic end seal jaw. The machine factors tested in this study include energy, amplitude, and production rate (the rate at which bags are created/welded) to determine the effect on peel strength. It was observed that low energy and amplitude correlated with high strength for the top weld (top of bag) of one material and low production rate resulted in high strength for the top weld of two materials as well as the bottom weld for two materials. Data for the sixth material was inconclusive.[6]

G. "ULTRASONIC WELDING OF ADVANCED THERMOPLASTIC COMPOSITES: AN INVESTIGATION ON ENERGY DIRECTING SURFACES".
(I. Fernandez, D. Stavrov, et al.2011)

Research on different energy directing surfaces for ultrasonic welding of advanced thermoplastic composites was performed. Special attention was paid to the influence of the orientation of the energy directors with respect to the load direction and to multiple energy directors' configurations. The experimental results show that the welding parameters are the important factors for the strength of the welded joint. which may increase or decrease the strength of the welding joint so we can say that the combination of the parameters is necessary for the maximum strength of the ultrasonic weld.[7]

H. Determination of Ultrasonic Welding Optimal Parameters for Thermoplastic Material of Manufacturing Products.
(Rashiqah Rashlia, Elmi Abu Bakarb, et al.2000)

Ultrasonic welding had been widely used in various manufacturing industries such as aviation, medical, electronic device and many more. It offers a continued safe operation, faster and also low cost as it able to join weld part less than one second and also simple to maintain the tooling devices. Though ultrasonic welding brings a lot of advantages in assembly especially in thermoplastic material of manufacturing product, it also has a dominant problem to be deal with. The problem in ultrasonic welding is poor weld quality due to improper selection of ultrasonic welding parameters especially in near field configuration. Thus, an optimal combination of parameters is crucial in order to produce good quality weld assembly for this configuration. In this paper, ultrasonic welding process, ultrasonic weld joint defects and determination of optimal parameters for thermoplastic material had been discussed thoroughly.[8]

I.A Review on Ultrasonic Welding of Glass Fiber Reinforced Plastic.
(Khyati H. Vyas, Prof. Akash B. Pandey, et al.2011.)

The "composite material" is composed of a discrete reinforcement & distributed in a continuous phase of matrix.

In Glass Fiber reinforced plastic (GFRP) composite, plastic is used as matrix which form network with glass fiber. Glass fiber composites are strong and stiff being light in weight increases strength to weight and stiffness to weight ratios. Plastic composites can joined by mechanical fastening, adhesive bonding and welding. Mechanical fastening, adhesive bonding combined with pre-treatment and welding, therefore, have been applied for joining. Ultrasonic welding has received significant attention during past few years due to their suitable applications in comparison to conventional fusion welding techniques. Strength of ultrasonically welded GFRP depends on process parameters like pressure, weld time, thickness ratio, and amplitude. This paper presents an overview of ultrasonic welding process, joining of GFRP, and process parameters.[9]

J. “ULTRASONIC WELDING OF THERMOPLASTIC WORKPIECES”.

(Thomas B, Sager, et al.2001)

Welding of thermoplastic workpieces by ultrasonic energy using frequencies in the range from sixteen kHz to sixty kHz is well established in the art. The dissipation of ultrasonic energy causes molten thermoplastic material at the interface between the workpieces. After a predator mined time interval, usually a fraction of a second, the ultrasonic energy is stopped for causing the molten thermoplastic material to solidify and thereby provide a fusion joint between the workpieces. In order to improve the welding process, the use of projections or ridges, also known as “energy directors”, projecting from the surface of one workpiece and contacting the at surface of the other workpiece has become well established.[10]

K. “Ultrasonic Bonding Methods”.

(John W. Louks, Hudson, Wis., et al.2000)

A method of high speed bonding at least one material includes applying acoustic energy, using an acoustic horn and an anvil, to the material. The method also includes applying force to at least one of the horn and the anvil to yield a peak pressure between the horn and the anvil of at least 2.068><107 N/m2. The acoustic energy and pressure are applied for a time sufficient to create bonds in the material such that the material is sufficiently quenched before reducing the pressure. The method can include applying acoustic energy at an amplitude of vibration selected in combination With the frequency of vibration to yield an acoustic velocity of no greater than 4.72 m/s.

6. Conclusion

The experimental results will show that the welding parameters will be important factors for the strength of the welded joint which may increase or decrease the strength of the welding joint also the optimal results will be achieved. At the end of analysis with help of ANNOVA method we would see that the welding parameters i.e. Time, Amplitude and Pressure are most significant for this experiment. Also the increase in tensile strength will be seen at the end of project.[11]

7. References

[1] W. Michaeli, E. Haberstroh, W.-M. Hoffman.“Ultrasonic welding of micro plastic parts”, International journal of research in mechanical engineering-(2014)

[2] Marius Pop-Calimanu, Traian Fleser.“The Increasing Of Weld Strength By Parameters Optimization Of Ultrasonic Welding For Composite Material Based On Aluminum Using Design Of Experiments”, International journal of research in mechanical engineering and technology-(2013)

[3] Rashiqah Rashli, Elmi Abu Bakar, Shahrul Kamaruddin. “Determination of Ultrasonic Welding Optimal Parameters for Thermoplastic Material of Manufacturing Products”, International journal of emerging technology and advanced engineering-(2012)

[4] SEYED AANAN ADNANI SALEHI, HOSSEIN TOWSYFYAN, GHOLAMREZA DAVOUDI, MAJED GHAYYEM AND FARID MOSAEDI. “OPTIMIZATION OF ULTRASONIC WELDING PROCESS USING IMPERIALIST COMPETITIVE ALGORITHM”, International journal of applied engineering and technology-(2014)

[5] CHRISTOPHER PAUL HAMPTON.“FAILURE ANALYSIS OF A 30KHZ ULTRASONIC WELDING TRANSDUCER”, (JAN-FEB.2014)

[6] David A. Grewell, Major Professor Michael Kessler, D. R. Raman.“Process optimization: Ultrasonic welding of coextruded polymer film.”(2013)

[7] I. Fernandez, D. Stavrov, H.E.N. Bersee. “ULTRASONIC WELDING OF ADVANCED THERMOPLASTIC COMPOSITES: AN INVESTIGATION ON ENERGY DIRECTING SURFACES”. (2011)

[8] Rashiqah Rashlia, Elmi Abu Bakarb, Shahrul Kamaruddina. “Determination of Ultrasonic Welding Optimal Parameters for Thermoplastic Material of Manufacturing Products”. (2000)

[9] Khyati H. Vyas, Prof. Akash B. Pandey, Prof. Paawan Panchal. “A Review on Ultrasonic Welding of Glass Fiber Reinforced Plastic”. (2011)

[10] Thomas B, Sager, Newtown, conn. “ULTRASONIC WELDING OF THERMOPLASTIC WORKPIECES”. (2001)

[11] John W. Louks, Hudson, Wis.; Donald L. Pochardt, Hastings, Minn; Desmond T. Curran; Christopher P. Henderson, both of Durham, United Kingdom.“Ultrasonic Bonding Methods”. (2000)