A Review on Effect of Vibration Welding of Different Materials in Various Welding Processes

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Abstract **- This paper deals with the effect of vibratory welding technique in various welding process like TIG welding, shield metal arc welding (SMAW), friction stir welding, ultrasonic welding. It also involves in using this vibratory welding technique in joining different materials like dissimilar metals, joining composites and in joining plastics. In vibratory welding, work piece vibrates in the whole welding process and it mainly effects the welding solidification to improve the quality. Vibration facilitates the release of dissolved gases and the resulting weld beads greatly exhibit reduced porosity. There exists residual stress near the bead because of locally given heat. These residual stresses decrease the fatigue life of the joint. The vibration technique has been used to avoid these residual stresses. The increase in mechanical properties is attributed to, as the weld pool solidifies, grains are not only limited in size but also dendrites are broken before they grow large in size. The above mechanism is responsible for the improvement in hardness of weld bead and in the heat affected zone (HAZ) with vibratory welding technique compared to without vibration during welding. Lot of research work has been done in describing the benefits of vibration during welding in various welding processes, joining of composites, dissimilar metals, plastics and enhancement of material properties of weld joints. In this paper, these effects are reviewed and discussed to provide a better understanding of the processes Understanding of these processes and application of the procedures offer extensive scope for significant cost savings in design and fabrication of welded products.**

Keywords: ***effect of vibration weld in various process, micro hardness, mechanical properties, process parameters, residual stress, vibration weld microstructure.***

I. INTRODUCTION

Welding is a manufacturing technique widely used in industry for fabricating products with complex shapes in very simple processing runs. Mechanical vibration has been used to improve microstructure and mechanical properties of weldments by way of grain refinement and this practice has been used by researchers. In the case of welding under vibratory conditions, work pieces are held rigidly on a vibratory table and the table is rigidly coupled to the vibration exciter which generates vibrations at different frequencies of oscillation and transmits them to the table and work pieces which in turn vibrate at different frequencies of oscillation. The molten metal solidifies under these vibratory conditions. Fluidity is one of the most important factors in welding processes. It is defined variously as the distance covered by quality liquid metal in a channel of fixed geometry before solidifying. That is the ability of a melt to flow and fill very narrow spaces, in a gap between welding grooves [1].From the available literature, it has been demonstrated these sonic or ultrasonic vibrations of mechanical origin can be effective in increasing fluidity by as much as a factor of three. A number of examples can be found in the literature where external forces have been applied to induce fluid flow during solidification in order to refine grain size hence improve mechanical properties. These methods include rotation of the work pieces, mechanical vibration and electromagnetic stirring.

In earlier studies, Campbell [2] noticed grain refinement to occur and mechanical properties improved in weldments due to the application of vibration during welding. Production of high strength structural materials is mainly based upon developing a product in which the grain size is as small as possible. A coarse grained structure may result in a variety of surface defects in alloys used in rolled or extruded form, while the size of defects such as micro porosity may reduce as a result of fine grain structures since the solidification of smaller grains will allow the mould to fill more completely and avoid unfavorable micro and macro- porosity thereby producing sound castings. Grain refinement also, remains a very

 DOI : 10.18231/2454-9150.2018.0018

ISSN : 2454-9150 Vol-03, Issue-10, Jan 2018

important means for improving the physical and mechanical properties of welded joints.

II. LITERATURE REVIEW

S. Fouladi, M. Abbasi [3] et al. studied that, different methods have been applied to improve the mechanical properties of joint manufactured by friction stir welding (FSW). One is addition of second phase particles into the stir zone to reinforce the joint and to constitute a particle reinforced metal matrix composite. The problem with regard to this method is non-homogenous distribution of particles during FSW. In the current research, friction stir vibration welding (FSVW) process is applied for welding. The joining work pieces of Al5052 alloy are vibrated normal to the weld line during FSW while SiO2 particles are incorporated into the weld. Microstructure and mechanical properties of welds are compared with those made by conventional FSW. Vibration decreases the grain size in the weld region and increases the homogeneity of particles distribution. Strength, hardness and ductility of FSV welded specimens are higher than FS welded specimens. Application of FSVW as an “easy to apply” friction stir welding method to improve the mechanical properties of joint included second phase particles is recommended.

Ziad.Sh.Al.Sarraf [4] et al studied that in a lateral-drive ultrasonic metal spot welding device, he modelled a spot welding horn using finite element analysis (FEA) and its vibration behavior is characterized experimentally to ensure ultrasonic energy is delivered effectively to the weld coupon. The welding stack and fixtures are then designed and mounted on a test machine to allow series of experiments to be conducted for various welding and ultrasonic parameters. It has been observed that vibration amplitude, clamping force and, in some circumstances, material arrangement order has a significant effect on weld strength. Al-Al welds are stronger than Cu-Cu welds and weld strength in both cases tends to increase the clamping force within the range of forces examined. In case of welding dissimilar metals, slightly stronger welds are obtained when the Aluminum layer is placed on top and in direct contact with the ultrasonic horn .It has been observed that when the clamping force exceeds above 500 N weld strength was decreased.

Pravinkumarsingh, D.Patel, S.B.prasad[5] et al proposed that, in shield metal arc welding (SMAW) a vibratory setup has been designed to stir the molten weld pool before it solidifies during operation. Mechanical vibration having resonance frequency of 300 Hz and amplitude of 0.5 mm was transferred to the molten weld pool of 6 mm thick mild steel butt welded joints during the welding operation. The welding operation was conducted at various ranges of frequencies (250Hz, 100Hz and 80Hz), welding current (90,100 and 110 amp), welding speed (8,10,12 cm/min). The auxiliary vibrations induced into the weld pool resulted in increased micro hardness of the weld metal which indicates the orientation of the crystal and refinement of grains took place, it also increased the tensile properties of the weld joint. Taguchi’s analysis technique has been applied to optimize the process parameters and it has been observed that yield strength of the weld joint is maximum when current is at 110 amp, welding speed at 8cm/min and the induced vibration frequency is at 250 Hz. It was also observed that when applied frequency of the vibration increases its yield strength also increases. When the welding current is high and the welding speed is low then the metal deposition rate increases, the mentioned condition of the weld geometry lead to enhancement of the tensile property of the welded structure.

P. Govinadarao ,P. Srinivasarao, A. Gopalakrishna and Sarkar M.M.M[6] et al proposed that, During the welding of metals along with mechanical vibrations, uniform finer grain structures can be produced. This increases the toughness and hardness of the metals, because of solidification effects at the weld pool surface. As the weld pool solidifies, grains are not only limited in size, but dendrites growing perpendicular to the fusion line are restricted. While the process is going on, dendrites can be broken up before they grow to become large in size. Hence, the microstructure of the weld metal is improved during the solidification process. In this work, a dynamic solidification technology is employed, by applying mechanical vibrations during the ‘Arc welding’ process. Analyses have been carried out for mild steel pieces having 5 mm. of thick butt joints. The results obtained from the current study pointed out that the butt welded joints fabricated with vibratory condition are found to possess relatively high hardness, without any considerable loss in its ductility.

***Marius Pop-Calimanu, TraianFleser[7]* et** al studied that, In ultrasonic welding both similar or dissimilar metals or composites can also be welded by the application of high frequency vibratory energy without melting. In the present work he improved the strength of the joint by optimizing the process parameters like amplitude of vibration, welding time, welding pressure during the realization of ultrasonic welded joints of Al/20%SiC composite material under disks form, whose thickness are 1 mm. The process parameters are optimized by using Pareto optimal technique. It has been observed that the maximum strength of the joint is observed at welding pressure of 1.4 bar, welding time of 1.2 secand amplitude of sonotrode of 85%.The optimal parameters for minimum strength of the joint is welding pressure of 1.4bar, welding time of 2 sec, and amplitude of sonotrode of 85%.

A.Benatar and A.Mokhtarzadeh[8] et al studied that, Ultrasonic welding and vibration welding are commonly used to weld Thermoplastic Polyolefin (TPO) which is widely used

 DOI : 10.18231/2454-9150.2018.0018

in automotive interior applications instrument panels, doors and Centre console. This work included design of experiments (DOE) to evaluate ultrasonic and vibration welding of a TPO. In the present work ultrasonic welding and vibration welding are done on American welding society (AWS) standard test samples of butt joint geometry. It has been observed that in ultrasonic welding amplitude was the most dominant factor in affecting the weld strength than the time and weld pressure, and the maximum achievable weld strength using the ultrasonic welding is 40**%** of the base metal. Vibration welding results indicated that amplitude was the most dominant factor in affecting the weld strength and high weld pressure resulted in lower weld strength. The maximum achievable weld strength using vibration **welding** was **66 %** of the base material strength. From this work it has been came to know that vibration welding is more dominant than ultrasonic welding in attaining a strong weld joint and better micro structural and mechanical properties.

J.Kalpana, P.Srinivasarao, P.Govindarao[9] et al studied that in joining dissimilar metals the weld strength is greatly affected by vibratory welding .In this work he joined dissimilar metals like mild steel and stainless steel by TIG (Tungsten Inert Gas) welding with aid of vibrations. In this study mechanical vibrations were given by two metal engravers to the specimens. The vibrations were given at frequencies of 600Hz, 800Hz, and 1000 Hz. Finally, the effect of mechanical vibrations with the variation of vibration parameters is studied on the hardness at the weld bead and heat effected zone (HAZ) of welded joints. Hardness of welded joints is increased with respect to increase **in** frequency along the weld bead and heat affected zone (HAZ). This is due to the fragmentation of long dendrites into small dendrites and better filler metal distribution, which leads to fine grain structure, is attained at the weld bead region. Thus the strength of dissimilar weld joints can be increased by vibratory weld joining.

Jaskirat Singh, Gaurav Kumar, Narayan Garg[10] et al studied that ,a dynamic solidification technology is employed, by applying mechanical vibrations during the solidification in SMAW process. Studies using 10 mm thick stainless steel (AISI202) butt joints. Low and high heat input (**high current and low current**) combinations were used to study the effect of mechanical vibrations on small sized and large sized fusion zone respectively. The results from the present study indicate that the weld joints fabricated with vibratory condition were found to possess relatively high yield strength (YS) and high ultimate tensile strength (UTS), without any appreciable loss in the ductility. Metallographic studies conducted show that weld metals under vibratory condition possessed relatively finer microstructure and hence high micro hardness, owing to dendrite fragmentation. The **high** heat input with **low current was 90-110 Amp** and **low heat** input with high was given by 130-160Amp. From the results obtained it has been observed that high current vibratory welding with low heat input has achieved high yield and ultimate tensile strength than the low current vibratory welding.

S. G. Arul Selvan, R. Rajasekar, M. Kalidass, M. Selwin[11] et al studied that, polymers or polymer composites can be welded through either vibration or ultrasonic welding, both the processes have its own benefits and drawbacks. This papers deals with the use of the above welding methods at appropriate situation corresponding to its applications, benefits and drawbacks. Vibration welding provides a good quality welding for parts which are flat and small for most cases. Agglomeration in case of Nano composites and fiber delamination are some of the drawbacks of vibration welding but strong welding is achieved with this type of welding compared to the other welding techniques. Ultrasonic welding provides a defect free welding to a maximum extend and can be used for welding small areas but requires surface preparation, such as adding artificial or man-made asperities with the help of molding. This welding technique is suitable for mass production since it involves a very less operating time but higher installation cost. Fiber delamination and agglomeration in Nano composites are avoided to some extent with this type of welding technique. This technique can be effectively used for spot welding of thin structures.

Karanbir SinghGagandeep Singh, Fateh Pal Singh[12] et al studied that , microwaves are the part of electromagnetic spectrum ranging from frequency of 300GHz to 300Mhz and wavelength of 1mm to 1 m respectively. In this work microwave energy has been used to join dissimilar materials. In microwave selective heating takes place and the heat is generated inside the material rather than on the surface like in conventional methods which leads to volumetric heating of material and inverted heating profile is generated. Because of this selective and localized heating heat affected zone HAZ is very small and defects during processing get reduced. Here the vibrating energy of the microwaves is used to generate heat for joining. Due to the selective heating nature of microwave radiations this technique can be used in the felid heat sensitive materials and equipment's those material, which are difficult to join with conventional methods, can be joint with microwave joining with altering of inherent properties.

Yingna Zhao, Xiongfeng Zeng, Guiquin Hou, Wenli Zhang[13] investigated the joining of Al203 ceramics using Nano metric Si powder as an interlayer material. Slurry of Nano-Si powder mixed with alcohol is placed as a sandwich between the butt joint of 95-Al2O3. Taking into account the thermal loses the joint is embedded in the compacted aluminum oxide, more over the Al2O3 ceramic annulus above the joint provide the extra pressure to encourage adhesion. The

 DOI : 10.18231/2454-9150.2018.0018

interface reaction of Al with Si and inter diffusion of atomic species enhances the quality of joints. The consistency of microstructure and micro hardness near the sandwich layer of joint material benefit for high temperature, high wear and corrosion resistant material applications.

G. Jandali*and* ***P. K. Mallick[14]*** et al studied that, the lap shear strength of vibratory welded joints of glass(GF) and carbon fiber(CF)-reinforced polypropylene(PP) and polyamide(PA)-6 matrix composites were greatly affected by the process parameters like clamping pressure, vibration time, vibration direction, and holding time. Weld strength at elevated temperatures was also investigated. The results showed that the combination of clamping pressure and vibration time had a significant effect on the lap shear strength. Holding time also influenced lap shear strength, but the effect of vibration direction was not significant. In addition to lap shear specimens, ring specimens were designed and tested to determine the cross tension strength of these composites under tensile stress normal to the weld plane. From the experimental results it was found that clamping pressure and vibration time are the most influencing parameters of lap shear strength, and it was found that carbon fiber reinforced polyamide(CFPA) matrix have higher lap shear strength than other fiber matrix composites like GFPA,GFPP,CFPP at clamping pressure of 1MPa and vibration time of 4 seconds.

MacDonald, J., Bates, P., and Liang, [15] et al studied that, the purpose of this study was to determine the adequacy of butt and T-shape welds in predicting the burst strength of realistic nylon 66 parts. This study assessed the effects and interactions of vibration welding process parameters using a central composite design of experiment on selected part geometries. The results confirm that butt welded plaques exhibit higher weld strengths under tensile load than T-welded plaques and simple cup-plaque parts. These latter two welds were typically 50% weaker than butt welds. A comparison of weld strengths suggests that the lab-scale T-joint geometry more closely models more complex vibration welded parts.

K.Pal,VinayPanwar, Sven Friedrich and Michael Gehde[16] et al studied that, Vibration welding technique has been used to study the weld zone of thermoplastic polymers using Acrylo Nitrile-Butadiene- styrene(ABS- amorphous), polycarbonate (PC), PMMA(poly- methyl- methacrylate-amorphous),and PBT(semi crystalline). Polymers were welded using alike components and combinations of semi crystalline polymer with different amorphous polymers. Mechanical testing of welded polymers has proved that the tensile strength, elongation at break, and deformation was highest for PC-PC weld and least for ABS-ABS weld, when alike polymers were welded. However, welding of semi crystalline and amorphous polymer shows enormous reduction in its tensile strength as well as other tensile properties. Also, the tensile fracture of PBT with other amorphous polymers always occurred at weld zone which was not always in case of alike polymer welds. The weld strength of these polymers was observed to be dependent on the mechanical interlocking among the layers and not on interfacial bonding. This phenomenon may be due to the difference in glass transition temperatures of semi crystalline and amorphous polymers. XRD, FESEM and AFM have been used in this study to observe the morphology of welded surfaces.

Vijayaram[17]et al., investigated the effect of mechanical vibration on the properties, microstructure and fractography of titanium carbide (TiC) particulate-reinforced LM6 alloy composite casting. The composites were fabricated by vibration molding sand casting technique at frequencies of 10.2, 12 and 15 Hz. Results showed that the impact strength and hardness of the composites increased with an increase in frequency of vibration and increasing titanium carbide Particulate reinforcement in the LM6 alloy matrix composite. Increase in tensile strength was also observed at the frequency of 10.2 Hz when compared with the gravity-die casting without vibration. In other similar study TiC particulate reinforced LM6 alloy matrix composites were fabricated by different particulate weight fraction of titanium dioxide and microstructure studies were conducted to determine effect on mechanical properties of the. Results showed that mechanical properties improved significantly when mold was vibrated during solidification compared to gravity castings without vibration.

IV. Optimized parameters and enhanced properties

i) Ziad.Sh.Al.Sarraf stated that the welding parameters like clamping force and vibration amplitude of ultrasonic welding tip are optimized in certain combinations to enhance the strength of the metal joints like Al-Al,Cu-Cu,Al-Cu. welding strength increases with increase in clamping force. It has been noted that by implementing the optimal combination of 42µm amplitude and clamping force of 400N to 500N higher weld strengths are obtained.

ii) Pravin Kumar Singh, D. Patel, S.B. Prasad stated that to enhance the hardness ,yield strength, grain structure of the welded joint the molten weld pool is vibrated during solidification in SMAW with different frequencies, weld current and velocities like 80Hz,100Hz,250 Hz,90A,100mpAmp,110Amp,8,10,12(cm/sec) respectively. By using Taguchis technique it has been found that optimal combination of 250Hz,12cm/sec and 110Amp higher hardness can be achieved and by the same technique it was found that with the combo of 250Hz,110Amp and 8cm/sec higher yield strength of weld joints can be obtained.

 DOI : 10.18231/2454-9150.2018.0018

iii) S. Fouladi, M. Abbasi studied that in joining Al5052 alloy specimens with friction stir welding(FSW) and friction stir vibration welding(FSVW) the Strength and ductility of FSV-welded specimens are higher than FS welded specimens and he also concluded that corrosion resistance, Chip length of FSV-welded specimens is lower than FS welded specimens. The machining force for FSV-welded specimens is higher than that for FS welded specimens.

iv) Jaskirat Singh, Gaurav Kumar, Narayan Garg studied that the tensile, yield strength were enhanced by using vibratory welding technique in SMAW by comparing the high/low current (heat) along with the optimized vibratory parameters and found that stainless steel butt joints have high yield and tensile strength when using the high current(heat input) of 409.8,602.5 MPa respectively.

v) A. Benatar and A. Mokhtarzadeh studied the comparison of ultrasonic welding and vibration welding of Thermo Plastic Polyolyefin(TPO) and optimized the welding parameters like amplitude, weld time, and pressure and found that weld strength of the joints are 66% of the bulk strength in vibration welding where as it is 40% of the bulk strength in case of ultrasonic welding. The optimized parameters for TPO for ultrasonic welding is 40.1µm(amplitude),0.8 seconds(weld time) and 4.8 MPa weld pressure with weld strength of 8.47MPa. The optimized parameters for TPO for vibration welding is 1.25µm(amplitude),weld time of 4 seconds and a pressure of 1MPa with the welding strength of 13.94 MPa.By this the authors concluded that high weld strength is obtained by vibration welding which is better than the conventional welding.

vi) G. Jandali*and* ***P. K. Mallick*** studied and optimized the vibration welding parameters like clamping pressure, weld time to increase the lap shear strength of the weld joints in continuous-fiber reinforced thermoplastic matrix composites. In this context vibration welding is done and compared among CFPP,GFPP,GFPA,CFPP. Vibration welding parameters of combination of welding pressure and welding time of .345Mpa/8sec,1MPa/4sec,1MPa/8sec,and1.72MPa/4sec were applied to CFPP,GFPP,CFPA,GFPA and it was found that CFPA has highest lap shear strength of 20-25MPa at 1MPa/4sec followed by GFPP,GFPA and CFPP. The lowest lap shear strength was obtained at .345MPa/8sec.Thus the optimized combination of clamping pressure and vibration time is 1MPa/4sec.

III. CONCLUSION

In this paper, effect of vibration during welding on microstructure and mechanical properties of weldments was summarized, and the literature suggests appropriate welding parameters for corresponding weldings based on the type of material, application, and geometry. The process parameters of vibration welding were also optimized for various weldings like SMAW, ARC, TIG, ULTRASONIC, MICROWAVE, POLYMER, COMPOSITE, THERMOPLASTIC weldings. The process parameters were also optimized to achieve better mechanical properties like yield strength, ultimate tensile strength, lap shear strength. The outcomes of the several literatures suggest vibration during welding greatly benefits grain structure and mechanical properties of products. Dendrite fragmentation and detachment and total cooling rate have been identified as two major factors that contribute to the enhancement (refinement) of grain size of vibrated microstructures. Microstructural changes affect mechanical properties that take place during solidification of the melt. Vibration during welding has now been fully documented and accepted as one important procedure for manufacturing high quality weldments for commercial industrial use. Application of this procedure offers extensive scope for significant cost savings in design and fabrication.

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