# A Review Paper on Effects of Vibration on Mechanical Properties and Defect of Similar and Dissimilar Weld Joints in TIG Welding

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## Abstract

TIG welding is very commonly used method in production engineering for joining metal parts. There are so many process parameters which affect the quality of weld joints. This process is widely used for welding of various metals and alloys like different grades of SS (stainless steel), Titanium, Aluminium, etc. Welding has been applied to various industries in particular, construction, automotive, aerospace and microelectronics etc. However there are many methods for welding the work pieces and one of the methods among these is vibratory welding. It has the advantages of less investment, more convenient operation, less pollution and shorter manufacturing period. 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. Mechanical properties of the welds prepared under vibratory conditions are dependent on the structural changes of the welds. Many articles describe the benefits of vibration during welding on mechanical properties of weldments. Present work will emphasize on the effect of mechanical vibration on inner defect, and mechanical property of dissimilar and similar metal joints in TIG welding. As a result, this review will provide the improvement in mechanical properties and reduction in defects of weld joints by applying mechanical vibrations during the tungsten inert gas welding process of joining. The reduction in defect of welded joints can be measured with help non-destructive testing methods such as Penetrant Testing.
**Keywords: Tungsten Inert Gas (TIG) welding, dissimilar joints, penetrant testing, Mechanical vibration, Welding defects, Ultimate tensile strength**

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## I. INTRODUCTION

Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used, though some welds, known as autogenous welds, do not require it. A constant current welding power supply produces electrical energy, which is conducted across the arc through a column of highly ionized gas and metal vapors known as a plasma. GTAW is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminum, magnesium, and copper alloys. The process grants the operator greater control over the weld than competing processes such as shielded metal arc welding and gas metal arc welding, allowing for stronger, higher quality welds. However, GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques. A related process, plasma arc welding, uses a slightly different welding torch to create a more focused welding arc and as a result is often automated. The TIG welding process uses a non-consumable tungsten electrode that delivers the current to the welding arc. The tungsten and weld puddle are protected and cooled with an inert gas, typically argon. TIG welding is similar to oxy-acetylene welding in that you use a filler material for build-up or reinforcement. The equipment required for the gas tungsten arc welding (or TIG welding) operation includes a welding torch utilizing a non-consumable tungsten electrode, a constant-current welding power supply, and a shielding gas source.

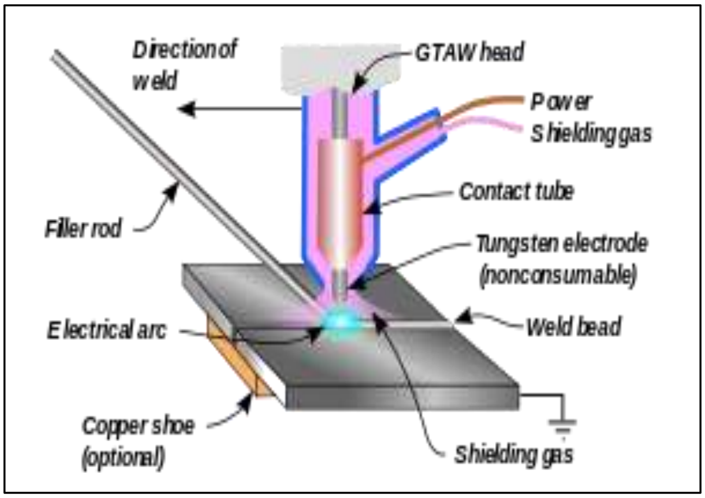


Fig. 1: TIG welding process

Gas tungsten arc welding is most commonly used to weld stainless steel and nonferrous materials, such as aluminum and magnesium, but it can be applied to nearly all metals, with a notable exception being zinc and its alloys. Its applications involving carbon steels are limited not because of process restrictions, but because of the existence of more economical steel welding techniques, such as gas metal arc welding and shielded metal arc welding. Furthermore, GTAW can be performed in a variety of other-than-flat positions, depending on the skill of the welder and the materials being welded.

## II. EQUIPMENT USED IN TIG WELDING

### A. *Welding Torch:*

GTAW welding torches are designed for either automatic or manual operation and are equipped with cooling systems using air or water. The automatic and manual torches are similar in construction, but the manual torch has a handle while the automatic torch normally comes with a mounting rack. The angle between the centerline of the handle and the centerline of the tungsten electrode, known as the head angle, can be varied on some manual torches according to the preference of the operator. Air cooling systems are most often used for low-current operations (up to about 200 A), while water cooling is required for high-current welding (up to about 600 A). The torches are connected with cables to the power supply and with hoses to the shielding gas source and where used, the water supply.

### B. *Power Supply:*

Gas tungsten arc welding uses a constant current power source, meaning that the current (and thus the heat) remains relatively constant, even if the arc distance and voltage change. This is important because most applications of GTAW are manual or semiautomatic, requiring that an operator hold the torch. Maintaining a suitably steady arc distance is difficult if a constant voltage power source is used instead, since it can cause dramatic heat variations and make welding more difficult. Alternating current, commonly used when welding aluminum and magnesium manually or semi-automatically, combines the two direct currents by making the electrode and base material alternate between positive and negative charge. This causes the electron flow to switch directions constantly, preventing the tungsten electrode from overheating while maintaining the heat in the base material.

### C. *Electrode:*

The electrode used in GTAW is made of tungsten or a tungsten alloy, because tungsten has the highest melting temperature among pure metals, at 3,422 °C (6,192 °F). As a result, the electrode is not consumed during welding, though some erosion (called burn-off) can occur. Electrodes can have either a clean finish or a ground finish—clean finish electrodes have been chemically cleaned, while ground finish electrodes have been ground to a uniform size and have a polished surface, making them optimal for heat conduction. The diameter of the electrode can vary between 0.5 and 6.4 millimeters (0.02 and 0.25 in), and their length can range from 75 to 610 millimeters (3.0 to 24.0 in).

### D. *Shielded Gas:*

As with other welding processes such as gas metal arc welding, shielding gases are necessary in GTAW to protect the welding area from atmospheric gases such as nitrogen and oxygen, which can cause fusion defects, porosity, and weld metal embrittlement if they come in contact with the electrode, the arc, or the welding metal. The gas also transfers heat from the tungsten electrode to the metal, and it helps start and maintain a stable arc. The selection of a shielding gas depends on several factors, including the type of material being welded, joint design, and desired final weld appearance. Argon is the most commonly used shielding gas for GTAW, since it helps prevent defects due to a varying arc length. When used with alternating current, argon shielding results in high weld quality and good appearance. Another common shielding gas, helium, is most often used to increase the weld penetration in a joint, to increase the welding speed, and to weld metals with high heat conductivity, such as copper and aluminum. A significant disadvantage is the difficulty of striking an arc with helium gas, and the decreased weld quality associated with a varying arc length. Argon-helium mixtures are also frequently utilized in GTAW, since they can increase control of the heat input while maintaining the benefits of using argon. Normally, the mixtures are made with primarily helium (often about 75% or higher) and a balance of argon.

## III. LITERATURE REVIEW

In 2014, P. Sakthivel and P. Sivakumar [1], the microstructure of the steel is refined by heat treatment resulting de-crystallization, homogenization of segmentation and elimination of Harmful gases. However welding such possibilities (or) rather limited since welded component cannot be solution annealed and tempered. The vibration welding from vibration is increased microstructure improve, complete fusion structure and hardness increasing comparison of without vibration welding. Study have revealed vibration during welding was increased depth of penetration component fusion of penetrate metal is also health's in the stress reliving. Especially the study of effect of vibration on stainless steel welding is a new area since, the welding of stainless steel possess a great change.

In 2011, K. Balasubramaniam, S. Raghavendran and V. Balusamy [2], studied the effect of vibration on grain structure has been investigated and found that:

1) The non-vibrated specimen both super austenitic stainless steel and pure Nickel were composed of coarse grains.
2) Grains were disturbed and smaller grains were formed when the vibration is in the frequency range of 500Hz for super austenitic stainless steel and 100Hz in case of pure nickel. The structural refinement of both super austenitic stainless steel and pure nickel were achieved by the imposition of vibratory treatment during GTAW process.

In 2016, N.B. Patel, Dr. P.S Jain, M.R. Patel [3], has shown effect of various parameters like Welding current, Voltage, welding speed, welding amplitude, Welding Frequency of arc welding for mild steel and ferrous alloys on Tensile strength, Yield strength and Hardness. Welding current is most significant factor on Tensile strength but the frequency of vibrations has also major impact according to recent studies. By using the different method of vibration during welding stress relieving can be done and mechanical properties can be increased. It can be used in option of Post Weld Heat Treatment to relieve stress. Industrial pipe joints, Offshore structures, Petro-chemical tanks defects can be studied and research for vibration effects.

In 2015, Munish Kainth, Deepak Gupta [4], in this paper, summarized the effect of vibration during welding on microstructure and mechanical properties of weldments. 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.

In 2015, Munish Kainth, Deepak Gupta, Vivek Sharma [5], In this study, auxiliary vibrations are induced with SMAW for improving the mechanical properties of the base material and the weld metal. The small grain structure is attained due to the effect of vibration. During manual butt weld joints, uniform long dendrites are formed which show that a uniform solidification process took place with uniform dendrites. Due to auxiliary mechanical vibrations, long dendrites break and form a new nucleation sites and a non-uniform solidification process took place. The oscillatory conditions modify and/or change the grain nucleation and grain growth that are influenced under welding conditions. Thus the higher the cooling rate, the more the nuclei coming into play and the smaller the grain size. Finer grain size benefits the mechanical properties. Following are the findings of this research work:

1) Tensile strength of the material AISI 1018 during vibration welding is 18.25 % more as compared to the tensile strength of same material during SMAW.
2) Elongation of the specimen is 39.34 % more during vibration welding than SMAW.
3) C1 specimen can bear 29.17 % more force as compared to A1.
4) Reduction in area is approximately 50 % more in sample C1 as compared to sample A1.

In 2017, G. Vamsi Durga Mohan, K.S. Rao, P. Srinivasa Rao [6], The effect of various parameters such as voltage, current, frequency in altering the mechanical properties such as hardness, tensile strength, impact strength, flexural strength have been studied under vibratory welding process. Hence the proposed methodology facilitates the effective use of vibratory welding in order to increase the mechanical properties of the material in small scale industries where heat treatment can't be affordable.

This paper consolidated the improvements in mechanical properties from the past literature available using Vibratory welding technique. Vibratory welding is a promising method in eliminating the disadvantages experienced by the traditional welding like residual stress due to the electrical energy input which induces vibrations by varying the input parameters voltage, current, amplitude and frequency. It is also a better alternative to the heat treatments available to increase the strength, with no special tools and less cost during time of welding itself. The very advantages of vibratory welding are that it gives effective penetration of the molten metal to each corner of the joint that is chosen.

In 2016, Pravin Kumar Singh, D. Patel, Shashi B. Prasad [7], In the present article, the effect of inducing auxiliary vibration into the weld pool during welding has been investigated and the work has been aimed to understand the fundamental role of vibration in controlling the weld pool microstructure and mechanical properties.

This study discussed the application of vibrator welding technique during the SMAW process of butt welded joint. From the analysis of the results, following can be concluded:

1) It has been shown in this work that vibration applied into the weld pool can be successfully enhanced the mechanical properties of welded joints. Thus the present research attempt provided an alternative for grain refinement of weldments.
2) The Yield Strength increased by 27% and tensile strength of the welded joint increased by 23% due to transformation of 300 Hz of vibration into the weld-pool when it was in liquid state. The ductility of welded joint also improved. The total percentage of elongation gets twice by using the vibrations.
3) The auxiliary vibrations induced into the weld pool resulted in increased micro hardness of the weld metal which indicates the orientation of the new crystals and refinement of grains took place.
4) The grain refinement has been found in the welded structures which were welded during vibratory conditions. Microstructure studies of the welded joints have revealed that due to auxiliary stirring of the weld pool using a vibratory tip, steeper thermal gradients are established that lead to a condition where grain coarsening is relatively less.

In 2015, Tong WEN, Shi-yao LIU, Shi CHEN, Lan-tao LIU, Chen YANG [8], showed that with the application of vibration, microstructure of the AZ31 TIG welding joints is markedly refined. Average diameters of the grains within the joints decrease from 49.4 μm (welded without vibration) to 27.3−34 μm (welded with varying vibration conditions). Meanwhile, the amount of the second phase β within the fusion zone decreases slightly, and the micro hardness of the joints, macroscopic tensile strength and elongation of the weldments increase. The degree of microstructure refining increases with increasing the amplitude of vibration. Corresponding to the microstructure, mechanical properties of the welded samples reach the largest at welding groove angle of 20° under V-vib due to the highest cooling rate. The effect of vibration on the microstructure and mechanical performances of weld joints is more obvious for thick plate. As a whole, the influence of vibration on microstructure and mechanical properties of weld joints is intrinsically related to the thermal condition and solidification behavior of the molten metal. It is affected by the wave energy transferring in the molten pool and depends on the processing and geometric parameters such as vibration amplitude, vibration direction, thickness and groove angles of the sheets.

In 2013, A. Mostafapour, V. Gholizadeh [9], in this study, the effect of mechanical vibrations applied to the molten weld pool on the mechanical properties of AISI 304 L steel was investigated. For this purpose, after the work pieces were welded under different welding frequencies, amplitudes and speeds, test samples were prepared from them for the tensile and impact tests and for the observation of microstructures resulting from welding. Based on the results obtained from these tests, the following conclusions could be made:

1) The welding speed has a significant influence on the strength of the weld. At less-than-normal speeds, more heat is transferred into the work piece, and consequently, the width of the HAZ zone increases as well; this lowers the strength of the weld region. The opposite happens at higher-than-normal welding speeds. In such a case, less heat is transferred into the work piece and a smaller portion of the workpiece gets melted, and as a result, the degree of weld diffusion will also be lower. Under this condition, the two pieces of the part are not properly attached, and the overall strength will be lowered.
2) In general, applying a vibration frequency during the welding operation improves the mechanical properties. By increasing the frequency from zero to a value below the natural frequency of the set, the mechanical properties increase. Although, at the natural frequency of the setup, these mechanical properties diminish, but these lower values are themselves better than those achieved without the application of any frequency. Also, at frequencies higher than the natural frequency, the considered mechanical properties increase again and reach their maximum values at the some point.
3) In the no-vibration case in which the vibration amplitude is zero, the ultimate tensile stress, relative elongation percentage, and impact energy have their lowest values. At the vibration amplitude of 7 μm, these parameters reach their maximum values, and with further increase of amplitude, they start to decrease.
4) By examining the microstructure of the weld metal, it was observed that the finest sizes of dendrites are obtained through the application of vibrations with the frequency of 350 Hz and amplitude of 7 μm, and at the welding speed of 8 cm/min.
5) In the best case scenario, in which the welding was performed under vibrations with the frequency of 350 Hz and amplitude of 7 μmand by applying a welding speed of 8 cm/min, it was observed that the values of ultimate tensile stress, relative elongation percentage, and impact energy increase by 29.5, 32.5, and 54.16 %, respectively, compared to those in the no-vibration case.

In 2017, Pravin Kumar Singh, D. Patel, Shashi B. Prasad [10], in the current work as shown that application of vibration into the weld-pools successfully enhances the mechanical properties of weld joints. Thus the present research attempt provided an alternative for grain refinement of weldments.

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. Cooling behavior of vibratory welding shows the faster heat transfer as compare to the conventional process.

The Yield Strength increased by 78% and tensile strength of the welded joint increased by 80% due to transformation of 300 Hz of vibration into the weld pool when it was in liquid state. The ductility of welded joint also improved. The total percentage of elongation gets twice by using the vibrations.

## IV. CONCLUSION

After studying above literature review it may be concluded that there is a positive effect of mechanical vibrations on joining of various similar or dissimilar metals during TIG welding. This positive effect can be observed as the improvement in mechanical properties like ultimate tensile strength (UTS) and Hardness are increased at a particular frequency of vibration, further it can be observed that the micro grain structure of the aluminium alloy has improved at a particular frequency of vibration.

Hence an experiment can be conducted on TIG welding of various other similar and dissimilar metal joints to check the effect of mechanical vibration on their properties and casting defect. Also there has been very few studies and experiment in this field. To check the effect of vibrations on casting defect, non-destructive testing methods like Penetrant test can be used.

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