IMPROVEMENT OF WELD JOINT STRENGTH BY APPLYING RANDOM VIBRATIONS ALONG WITH EXTERNAL MAGNETIC FIELD

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Abstract. Welding is a metal joining process induces high residual stresses. These are strongly influencing the mechanical properties of weldment. In earlier days heat treatment and shot peening techniques were used to relieve these stresses. Due to the time consuming of these processes, in this research work we have applied random vibrations to relieve the residual stresses to improve mechanical properties. Along with that, welding arc may get affected by magnetic field during welding. This leads to arc instability which is responsible for welding defects like lack of fusion, porosity. These reduce the quality and strength of weld. To overcome this, arc spattering with external magnetic field need to be reduced. In this research work, a setup has been designed for vibration assisted welding along with external magnetic field set up to improve the mechanical properties of Mild Steel weld joints by means of hardness and ultimate tensile strength. Welding had been performed with and without these setups. After performing welding work pieces have been tested both welding conditions and results have been compared.

Keywords: Hardness; Magnetic field; Mild Steel; Ultimate tensile strength; Vibration assisted welding

1. Introduction
Welding is a permanent joining process widely used in automobile, naval & construction applications. In all types of welding techniques shielded metal arc welding is most commonly used because of its advantages like cheap and easy. In shield metal arc welding (SMAW) flux coated consumable electrodes were used, during welding the flux melts and protect the weld pool from the atmosphere. In SMAW magnetic field is induced around the workpieces, electrodes & arc. The magnetic disturbance surrounding the arc may cause arc instability which is responsible for welding defects. This obviously reduces the quality and strength of weldment. The conventional shield metal arc welding induces residual stresses which influence the mechanical properties of the weldment. The following literature survey indicates the effect of vibrations and external magnetic field on mechanical properties of the weldments.
Many researchers have analyzed the effect of vibrations on microstructure and mechanical properties of welded joints and obtained a general conclusion that vibrations are able to change the microstructure thus improving the mechanical properties of welds. Singh et al. [1] investigated the influence of vibrations on mechanical properties of butt-welded joints using dynamic solidification technology. They observed improved yield strength and ductility under vibratory conditions of the welding. Pucko et al. [2] experimentally investigated the effect of vibration on weld metal hardness and toughness. They concluded that the improvement in hardness of the weld bead depends on type of welding process, welding parameters and filler materials used and reported maximum 80% improvement in fracture toughness during multi pass welding with vibration effect. Rao et al. [3] studied the influence of mechanical vibrations on the hardness of Al5052 weldments. They conducted experiments at various input voltages (70V, 160V, 230V) of vibratory table. They observed maximum 12.36% improvement in hardness at 160V compared to without vibration. Aoki et al. [4] experimentally measured residual stresses by X-ray diffractometer and observed reduced tensile residual stresses under random vibrations compared to welding performed without vibration. Kalpana et al. [5] reviewed various techniques for improving the mechanical properties of the fusion welded joints and suggested vibratory assisted welding for improved properties compared to all other techniques. Balasubramanyam et al. [6] experimentally investigated the effect of vibrations on welding. Their results indicate 18.35% improvement in strength & 12.82% improvement in hardness compared to welding under without vibration. Jose et al. [7] studied vibration assisted welding process and their effect on quality of welds. They concluded that vibratory assisted welding helps in grain refinement and improvement in mechanical properties which in turn produce quality welds. Singh et al. [8] experimentally examined and observed 78% and 49% improvement in yield strength and elongation during welding under vibratory conditions. Sharma et al. [9] experimentally investigated the effect of magnetic field on weld quality and weld geometry. They observed that externally applied magnetic field deflects the arc and increases the bead width which in turn enriches the tensile strength. Pathak et al. [10] investigated the effect of welding current and torch angle on tensile strength of shield metal arc welded low carbon steel plates. They performed experiments with varying welding currents (95A-125A) and torch angles (65° to 85°). They reported the improvement in tensile strength from 540Mpa to 588Mpa when the torch angle varies from 65° to 85° at 120A. Senapati et al.[11] studied the effects of external magnetic field on mechanical properties and observed 9.72%, 25.98% & 43.05% improvement in tensile strength, hardness and toughness respectively with vertically applied magnetic field. Singh et al. [12] used artificial neural networks to predict the weld bead geometry as function of depth of penetration and observed decreased depth of penetration with increased magnetic field. Queiroz et al.[13] studied the effects of external magnetic field on microstructure and observed decreased primary and secondary dendrite spacings.

From the above literature review it is evident that vibration assisted welding and external magnetic field improved the mechanical properties. Till now all the researchers studied the vibration assisted welding and external magnetic field individually. In the current research work an attempt has been taken to understand the combined effect of vibration assisted welding along with external magnetic field on mechanical properties (hardness and ultimate tensile strength) of the weldment.

2. Experimental Details
The welding performed by traditional SMAW process faces many welding defects like porosity, arc blow, undercut, lower penetration, and generation of residual stresses. In order to overcome these defects and relieve residual stresses, vibration assisted welding along with that external magnetic field set up is used. The vibrations are generated by using eccentricity mechanism and the external magnetic field is applied with the help of solenoid. The designed set up for vibrations and external magnetic field shown in the Figure 1 & Figure 2. In the current research work mild steel is used as a workpiece material. Welding was performed on the workpieces with varying the amplitude of vibrations by altering the speed of the motor from 721 rpm to 923 rpm & by altering the external magnetic field by varying currents from 0.2 amp to 0.3 amp. In this study initially the experiments were performed...
without vibrations and external magnetic field. In second case the experiments were performed on specimens with vibrations (at 721 rpm, 823 rpm, 922 rpm) and without external magnetic field. In third case the experiments were performed on specimens with both vibrations (at 721 rpm, 823 rpm, 922 rpm) and external magnetic field (at 0.2 amp, 0.3 amp). After performing welding under three cases specimens are subjected to Brinell hardness test and the hardness number is calculated by using the equation 1. After measuring the Brinell hardness number the ultimate tensile strength is calculated by using the correlation shown in equation 2.

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\text{Brinell hardness number (BHN)} = \frac{2p}{\pi D(\sqrt{D^2 - d^2})} \quad (1)
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P = \text{Applied load}; D = \text{Diameter of indenter}; d = \text{Average diameter of indentation}
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Ultimate tensile strength = Hardness \* k \quad (2)

Where k = 3.38 to 3.55

3. Results and discussion

3.1 Brinell hardness test

The Brinell hardness test is performed on the SMAW specimens under three cases such as without vibrations and external magnetic field, with vibrations, with both vibrations and external magnetic field. The hardness of the specimens is measured on the weld bead using the equation 1. Hardness is measured by taking the average of readings at three different places on the weld bead. The pictorial representation of the welded specimens under three cases shown in the Figure 3- Figure 5. After measuring the Brinell hardness number, ultimate tensile strength is calculated by using the following correlation shown in equation 2. Table 1 & Table 2 indicates the hardness and tensile strength data under three cases.

| Conditions on which welding performed | place on which hardness measured | Avg indentation Diameter (mm) | BHN | UTS (MPa) |
|--------------------------------------|---------------------------------|-------------------------------|-----|-----------|
| Without vibration & magnetic field   | Weld bead                       | 4.6                           | 170 | 574.6     |
### Table 2. Hardness and tensile strength data under case 2 and case 3

| Conditions on which welding performed | RPM   | place on which hardness measured | Avg indentation Diameter (mm) | BHN  | UTS (MPa) |
|--------------------------------------|-------|----------------------------------|-------------------------------|------|-----------|
| With vibrations & without external magnetic field | 721 rpm | Weld bead                        | 4.2                           | 207  | 699.66    |
|                                         | 823 rpm | Weld bead                        | 3.8                           | 255  | 861.9     |
|                                         | 922 rpm | Weld bead                        | 3.4                           | 321  | 1084.9    |
| With both vibrations & external magnetic field at 0.2 amp | 721 rpm | Weld bead                        | 3.57                          | 290  | 980.2     |
|                                         | 823 rpm | Weld bead                        | 3.5                           | 302  | 1020.7    |
|                                         | 922 rpm | Weld bead                        | 3.27                          | 348  | 1176.2    |
| With both vibrations & external magnetic field at 0.3 amp | 721 rpm | Weld bead                        | 3.4                           | 321  | 1084.9    |
|                                         | 823 rpm | Weld bead                        | 3.4                           | 321  | 1084.9    |
|                                         | 922 rpm | Weld bead                        | 3.27                          | 348  | 1176.2    |

Figure 3. Without vibration and External magnetic field
Figure 4. With vibrations
Figure 5. With both vibration and External magnetic field
Figure 6. Comparison of Brinell Harness Number

Figure 6 indicates that the variation of hardness values with vibrations condition and with both vibrations and external magnetic field conditions at 0.2 amp and 0.3 amp current. Based on the results it is observed that the enrichment in hardness values with the amplitude of vibrations increase from 721rpm to 922 rpm. The results indicate that compared to conventional SMAW process vibration assisted welding and the combined vibration and magnetic field assisted welding shows improved results. The conventional SMAW induces residual stresses in the weldments, which are relieved by vibrations applied during welding and improve the mechanical properties. The applied random vibrations stir the molten weld metal pool and restricts the growth of the grains, due to that the grains do not achieve their original dendritic length. Such fragmented dendrites form new nucleation sites and produce new grains. In this way the number of grains increases continuously and reduce the size of the grains, which in turn avoid the porosity defects and voids between the grains and improve the hardness of the weldments [8]. The results also indicate the combined vibration and magnetic field assisted welding shows improved results compared vibration assisted welding. The externally applied magnetic field deflects the arc, increases the fusion zone and eliminates the arc blow defects which in turn enhance the weld quality as well as mechanical properties [11]. Vibration assisted welding shows improvement in hardness by 21.76%, 50% and maximum 88.82 % at 721 rpm, 823 rpm and 922 rpm respectively compared to conventional SMAW. Similarly, maximum 89.54% and 95.13% improvement in hardness observed for combined vibration and magnetic field assisted welding with 923 rpm at 0.2 amp and 0.3 amp respectively compared to conventional SMAW. The maximum 8.4 % improvement in hardness is reported with combined vibration and external magnetic field assisted welding compared to vibration assisted welding.
3.2 Ultimate Tensile Strength

Figure 7 indicates the variation of ultimate tensile strength with vibration assisted welding and with combined vibration and magnetic field assisted welding processes. In this study the ultimate tensile strength is calculated by using the correlation which is function of Brinell hardness number shown in equation 2. It is observed that ultimate tensile strength increases when the amplitude of vibrations increase from 721 rpm to 922 rpm. The vibration assisted welding and combined vibration and magnetic field assisted welding show improved results compared to conventional SMAW process. Maximum 89.02% improvement in ultimate tensile strength was observed with vibration assisted welding compared to traditional SMAW process. Similarly, maximum 89.95% and 96.64 % improvement in ultimate tensile strength was observed with combined vibration and magnetic field assisted welding with 922 rpm at 0.2 amp and 0.3 amp respectively. The maximum 15.23 % improvement in ultimate tensile strength is reported with combined vibration and external magnetic field assisted welding compared to vibration assisted welding.

4. Conclusions
The present investigation aimed at improving the mechanical properties like hardness and strength of the welded joints by applying random vibrations along with external magnetic field. The analysis was carried out by fabricating the experimental setups, preparing the specimens and performing the hardness test on the specimens. The bar charts are drawn between the hardness number and rpm and also between the ultimate tensile strength and rpm. Finally, the results are compared for the three cases and observed the improvement in mechanical properties.
1. Hardness of the weld joint on weld bead zone is enriched with the increase of random vibrations. The maximum 88.82%, 95.13% improvement in hardness was observed with vibration assisted welding and combined vibration and magnetic field assisted welding. The maximum 8.4 % improvement in hardness was observed with combined vibration and magnetic field assisted welding compared to vibration assisted welding.
2. Ultimate tensile strength of the weld joint on weld bead zone is improved with the increase in random vibrations. The maximum 89.02%, 96.64% improvement in UTS was observed with vibration assisted welding and combined vibration and magnetic field assisted welding. The maximum 15.23% improvement in UTS was observed with combined vibration and magnetic field assisted welding compared to vibration assisted welding.

References

[1] Sing, J, Kumar G and Garg N 2012 Influence of vibrations in arc welding over mechanical properties and microstructure of butt-welded-joints Int. J. Sci. & Technol. 2(1) 1-6.

[2] Pucko B and Gliha V 2005 Effect of vibration on weld metal hardness and toughness Sci. Technol. Weld. Join. 10(3) 335-338.

[3] Rao M V, Rao P S and Babu B S 2016 Investigate the influence of mechanical vibrations on the hardness of AlSi052 weldments Ind. J. Sci. Technol. 9 39.

[4] Aoki S, Nishimura T and Hiroi T 2005 Reduction method for residual stress of welded joint using random vibration Nucl. Eng. Des. 235(14) 1441-1445.

[5] Kalpana J, Srinivasa Rao P and Govinda Rao P 2017 A review on techniques for improving the mechanical properties of fusion welded joints Eng. Solid Mech. 5(4) 213–24.

[6] Balasubramanyam P N V, Uzwalkiran R, Kumar M N V R L and Ramgopal M 2016 Strength improvement of welded joint by using random vibrations ARPN J. Eng. Appl. Sci. 11(18) 11068–73.

[7] Jose M J, Kumar S S and Sharma A 2016 Vibration assisted welding processes and their influence on quality of welds Sci. Technol. Weld. Join. 21(4) 243–58.

[8] Singh P, Patel D and Prasad S B 2017 Investigation on the effect of vibrations on cooling behavior and mechanical properties of smaw butt welded joints UPB Sci. Bull. Ser. D Mech. Eng. 79(2) 137–46.

[9] Sharma S S, Kumar M and Ojha P K Effect of Magnetic Field on Weld Quality and Weld Geometry 53–8.

[10] Pathak D, Singh R P, Gaur S and Balu V 2020 Experimental investigation of effects of welding current and electrode angle on tensile strength of shielded metal arc welded low carbon steel plates Mater. Today Proc. 26 929–31.

[11] Senapati A and Mohanty S brata 2014 Effects of External Magnetic Field on Mechanical properties of a welded M.S metal through Metal Shield Arc Welding Int. J. Eng. Trends Technol. 10(6) 297–303.

[12] Singh R P, Gupta R C and Sarkar S C 2012 The effect of process parameters on penetration in shielded metal arc welding under magnetic field using artificial neural networks Int. J. Appl. Innovation Eng. Manage. 1(4) 12-17.

[13] Queiroz A V D, Femandes M, Silva L, Demarque R, Xavier C R and Castro J A D 2020 Effects of an external magnetic field on the microstructural and mechanical properties of the fusion zone in TIG welding. Metals 10(6) 714.