INFLUENCE OF TRANSVERSE VIBRATIONS ON THE FATIGUE LIFE OF ALUMINUM ALLOY WELD CONNECTIONS

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ABSTRACT

Welding is a commonly used method to join a wide variety of materials. Formation of residual stresses can't be avoidable in the welded structures. Uneven heating cycles are the main cause for the formation of residual stresses. Non-uniform heating cycles in the welding affect the service life of welded connections. In this, an investigation is made to understand the fatigue life of aluminum weldments under transverse vibrations. It is observed that the ultimate tensile strength of aluminum weldments got increased with the increase in vibration amplitude. It is also found that there is 12 percentage of improvement in fatigue life of weldments when compared with normal weld condition.

KEYWORDS: Vibrations, Fatigue Life, Amplitude, Frequency & Acceleration

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INTRODUCTION

1. PREFACE

Aluminum alloys have many more advantages, including corrosion resistance, acceptable formability and weldability. Because of these advantages, Aluminum has been universally used in the marine, automotive and construction industries. Welding is a common method to join a wide variety of materials. During the welding process, specimen is subjected to heating. Because of the localized heating specimen is subjected to thermal expansion. In general, with the change in temperature materials tend to shrink or expand. When the material at the weld bead solidifies, it pulls the adjacent material to maintain the bond. So that it causes to develop welding residual stresses. Residual stresses may be of either tensile or compressive. The service life of structures is increased due to compressive residual stresses. Tensile residual stresses cause the service life to decrease. Tensile residual stresses need to be reduced or relieved from the structure.

There are several ways to decrease tensile residual stresses i.e., design considerations, preheating, shot peening, natural ageing, sequence of welding and post welding heat treatment. Most of these methods are time consuming and costlier. There is another alternative way to decrease residual stresses that is vibratory stress relief. Most of the researchers concluded that vibratory stress relief has a positive effect on reducing the residual stresses

Intermetallic compounds (IMC's) quantity, size and distribution of AA5083-H321 aluminum alloy weldments during GMAW under harmonic vibrations were also characterized. Along with this, the weldments microstructure was also investigated, with different sources like the Scanning electron microscope, optical

microscopy, XRD and thermal analysis. Murakami's static method was conducted to know the inclusion rate. The results obtained with the harmonic vibrations during welding process shows the decreased grain size at fusion zone about 50 μm , grain size significantly reduced when compared with the specimens welded without the application of vibrations [Reza Tamasgavabari et al.,]. Effects of local and global vibrational effect on steel plates during welding were investigated. Improvement in mechanical properties like micro-hardness, tensile strength and metallurgical behavior of steel plates were noticed with the application of vibrations [Ehud Ingram et al.,].

Similarly Xichang Liang et al., evaluated the quality of the butt-welded connection with the inclusion of vibrations in CO₂ arc welding. With the results, the improved mechanical properties and reduction in residual stress and distortion were identified. The weldments microstructure was observed and identified that the improved results are due to the refined grain structure. Refined grain structure mechanism was achieved because of the reduction in growth rate and an increase in the rate of nucleation. Pravin Kumar Singh et al., Studied the vibrational welding effect on properties of butt-welded joints. A novel technique of vibratory welding was developed which is having the capacity to transfer excitations of 300Hz vibrating frequency to the weld pool during fusion state during the Shielded metal arc welding process (SMAW). Response surface methodology and Taguchi's methods were used to optimize the vibration process parameters are welding speed, frequency and current. Hardness and tensile strength process parameters were analyzed with optimization techniques. Regression equations were generated for both hardness and tensile strength with RSM. The harmonic vibrations effect with a vibrational frequency which is below the range of resonant on Aluminum alloy (AA-5083-H321) mechanical properties were analyzed [Reza Tamasgavabari et al.,]. Material characterization was also studied with the optical microscope and also found surface fractures by using an optical microscope. the test result shows that with the vibrations, tensile strength is increased from 6% to 16.3% and there is no change significantly in hardness.

Effect of micro-vibrations of high frequency along with laser on the microstructure and mechanical properties of 316L steel were investigated [Zhang Wei et al.,]. The weld tail morphology was evaluated to describe the stability of the hole and it is identified that joint microstructure and properties were greatly affected by acceleration and Frequency. It was observed that better ultimate tensile strength and hardness were achieved when the specimens are vibrated with higher frequency. Similarly Peer Woizeschke et al., Studied the laser welding process for deep penetration on aluminum alloys weldments along with vibrations. In this research, the approach of transferability was investigated for a long time casting process to the short time laser welding process for with vibrational frequencies of 4 kHz during deep penetration. The obtained grain size by the application of the procedure of circular intercept on each weld micrograph is determined at the cross-section Centre.

Little, R (1975) discussed the methods to analyze the data related to fatigue, methods to design the fatigue experiments and test program planning methods. Procedure for determining the sample size, stress level selection and average fatigue life determination were discussed by Lipson and Lipson, (1973)

Most of the researchers focused on the effect of vibrations on the residual stresses and hardness, tensile strength. In this, the effect of transverse vibrations on the fatigue life of non-ferrous alloys has been focused on the analysis.

2. EXPERIMENTATION

Aluminum 5052 alloy specimens are considered for the analysis. It consists of 2.2 to 2.8% Mg. double V butt joints of 300mm length and 120 mm width and 5 mm thick plates are considered for the experimentation. These double V-butt joints

are clamped directly on the vibrating table. Vibromotor is used to vibrate the table during welding. Vibrations of the vibromotor are transverse and these are transferred to the vibrating table. Amplitude, acceleration and frequency of the table are varied by changing the voltage input through dimmer stat. Lower bound and upper bound of voltage is 50V and 230V respectively. After welding, 19 tensile test experimental sets are prepared as per ASTM E8. Double-acting Instron 8801 hydraulic system is used to test ultimate tensile strength. Specimens during welding are shown in figure 1. The ultimate tensile strength of specimen welded at 160V vibration input is 224Mpa and for the no vibration welding condition is 190Mpa. It is observed that ultimate tensile strength is increasing from 0 to 160V and decreasing in between 160 to 230V vibration condition.

Figure 1: Aluminum alloy Specimens while Welding

3. EXPERIMENTAL RESULTS

Based on the ultimate tensile strength of the aluminum alloy, fatigue tests have conducted. 3 stress level chosen for conducting the fatigue test. First one is 90% Ultimate tensile strength, the second one is 70% ultimate tensile strength and the third one is 50%ultimate tensile strength. Fatigue life is calculated based on the tensile test results. Normal welding and welding at 160V considered for fatigue life testing. Table.1 and figure 2 shows the life cycles of aluminum at different stress levels. The fatigue life of the specimen is increased with vibration.

Table 1: Fatigue Life of normal and with Vibration Condition at Different Stress Ranges

S. No	with Normal Condition (0V Vibration)		With 160V Vibration	
	Stress (Mpa)	Life (No.of cycles)	Stress (Mpa)	Life (No.of cycles)
1	171	25389	196	29006
2	133	81610	152	84130
3	95	107344	109	118590

Figure 2: Fatigue Life of Aluminum alloy Specimens at Different Vibration Condition

4. CONCLUSIONS

The following conclusions were made after analyzing the fatigue life of Aluminum 5052 alloy weldments

- Improvement in the ultimate tensile strength observed for the with vibrating conditions compared to normal condition.
- Fatigue life is more for the specimen welded with vibration condition than normal condition.
- The Fatigue life of aluminum specimens is 12.% more than the normal condition.

REFERENCES

1. Munsu, A. S. M. Y., Waddell, A. J., & Walker, C. A. (2001). *The influence of vibratory treatment on the fatigue life of welds: A comparison with thermal stress relief*. *Strain*, 37(4), 141-149.
2. Lipson, C., and Lipson, C., *Statistical design and analysis of engineering experiments*, 1973.
3. Ezech, J. C, Ibearugbulem, Owus M & Ebirim, Stanley I, "fundamental natural frequency for isotopic rectangular plate simply supported on three edges with one edge free of support (sssf plate)", *IMPACT: International Journal of Research in Engineering & Technology (IMPACT: IJRET)*, Vol. 2, Issue 2, pp. 67-74
4. Little, R. E., *Manual on statistical planning and analysis for fatigue experiments*: ASTM International, (1975).
5. Achutha, M., Sridhara, B., and Budan, D. A., "Fatigue life estimation of hybrid aluminium matrix composites," *International journal on design and manufacturing technologies*, vol. 2, no. 1, pp. 14-21, (2008).
6. Tamasgavabari, R., Ebrahimi, A. R., Abbasi, S. M., & Yazdipour, A. R. (2020). *Effect of harmonic vibration during gas metal arc welding of AA-5083 aluminum alloy on the formation and distribution of intermetallic compounds*. *Journal of Manufacturing Processes*, 49, 413-422.
7. Jamal Nawaser& Mohammad Amin Rashidifar, "Evaluation of Harmful vibrations caused By sea Waves on Patients with Critical Conditions for Transport by marine Vessels", *BEST: International Journal of Management*,

Information Technology and Engineering (BEST: IJMITE), Vol. 4, Issue 1, pp. 31-48

8. Ingram, E., Golan, O., Haj-Ali, R., & Eliaz, N. (2019). *The Effect of Localized Vibration during Welding on the Microstructure and Mechanical Behavior of Steel Welds*. *Materials*, 12(16), 2553.
9. Ingram, E., Golan, O., Haj-Ali, R., & Eliaz, N. (2019). *The Effect of Localized Vibration during Welding on the Microstructure and Mechanical Behavior of Steel Welds*. *Materials*, 12(16), 2553.
10. Singh, P. K., Kumar, S. D., Patel, D., & Prasad, S. B. (2017). *Optimization of vibratory welding process parameters using response surface methodology*. *Journal of Mechanical Science and Technology*, 31(5), 2487-2495.
11. Tamasgavabari, R., Ebrahimi, A. R., Abbasi, S. M., & Yazdipour, A. R. (2018). *The effect of harmonic vibration with a frequency below the resonant range on the mechanical properties of AA-5083-H321 aluminum alloy GMAW welded parts*. *Materials Science and Engineering: A*, 736, 248-257.
12. Abdul Kadir Muhammad, Shingo Okamoto & Jae Hoon Lee, "Comparison between the One Piezoelectric Actuator and the Two Ones on Vibration Control of a Flexible Two-Link Manipulator Using Finite Element Method", *International Journal of Mechanical Engineering (IJME)*, Vol. 5, Issue 1, pp. 25-42
13. Wei, Z., Qinghua, L., Peilei, Z., Hua, Y., Xinhui, R., & Yongzhen, B. (2019). *Vibration parameters optimum of 316L steel laser welding under high frequency micro-vibration condition*. *Materials Research Express*, 6(4), 046541.
14. Woizeschke, P., Radel, T., Nicolay, P., & Vollertsen, F. (2017). *Laser deep penetration welding of an aluminum alloy with simultaneously applied vibrations*. *Lasers in Manufacturing and Materials Processing*, 4(1), 1-12.
15. Munsif, A. S. M. Y., Waddell, A. J., & Walker, C. A. (2001). *The influence of vibratory treatment on the fatigue life of welds: A comparison with thermal stress relief*. *Strain*, 37(4), 141-149.
16. Rao, P. Govinda, P. Srinivasa Rao, and A. Gopala Krishna. "A smart prediction tool for estimating the impact strength of welded joints prepared by vibratory welding process." *Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering* 231, no. 2 (2017): 343-346.
17. Rao, P. Govinda, P. Srinivasa Rao, and A. Gopala Krishna. "Mechanical properties improvement of weldments using vibratory welding system." *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture* 229, no. 5 (2015): 776-784.
18. Rao, M. Vykunta, P. Srinivasa Rao, B. Surendra Babu, and P. Govindarao. "Effect of Vibratory Weld Conditioning on Residual Stresses and Weld Joint Properties: A Review." *Journal of Manufacturing Technology Research* 8, no. 1/2 (2016).
19. Kalpana, J., P. Srinivasa Rao, and P. Govinda Rao. "Mechanical Properties Enhancement in Dissimilar Weldments Fabricated Under Vibratory Weld Conditioning." *Advanced Science, Engineering and Medicine* 9, no. 6 (2017): 493-498.
20. Rao, M. Vykunta, P. Srinivasa Rao, and B. Surendra Babu. "Effect of Vibratory Tungsten Inert Gas Welding on Tensile Strength of Aluminum 5052-H32 Alloy Weldments." *Materials Focus* 6, no. 3 (2017): 325-330.
21. Rao, M. Vykunta, P. Srinivasa Rao, and B. Surendra Babu. "Vibration Effect on the Impact Strength of Al 5052-

- H32 Weldments." Journal of Mechanical Engineering Research and Developments 40, no. 1 (2017): 311-316.*
22. Rao, P. G., Rao, P. S., & Krishna, A. G. (2015). *Evaluation of bending strength of the vibratory welded joint using regression technique. International Journal of Offshore and Polar Engineering, 25(03), 227-230.*
 23. Rao, P. Govinda, P. Srinivasa Rao, and A. Gopala Krishna. "Flexural strength improvement of welded joints prepared by vibratory welding process." *International Journal of Manufacturing, Materials, and Mechanical Engineering (IJMMME) 5, no. 4 (2015): 1-16.*
 24. N. Maurya, K. Perumal I, T. Rahangdale & N. Sanodiy, "Effect of Nanoparticles on Performance of Magneto-Rheological Fluids in Vibration Suppression" *International Journal of Mechanical Engineering (IJME), Vol. 7, Issue 5, pp. 1-10*
 25. M.VykuntaRao, P. Srinivasa Rao and B. Surendra Babu, *Effect of Transverse Vibrations on the Hardness of Aluminum 5052 H32 Alloy Weldments, International Journal of Mechanical Engineering and Technology, 10(01), 2019, pp. 327– 333.*