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Effect of welding parameters on joint strength in Microwave hybrid Welding of Monel -400 Metal Sheets -An AIML approach

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ABSTRACT

Microwave welding is a potential method for welding high-temperature materials such as Monel-400 metal sheets. This article discusses parameter optimization in microwave hybrid welding for improving joint quality. Experimental data on joint strength was captured with power level, welding time, and temperature as factors. A Random Forest Regressor model, an AI-ML technique, was employed to fit the experimental data to predict joint strength. Power level and welding time were found through experiments to have significant influences on joint strength, with temperature in second place. These outcomes are of great significance for optimizing welding parameters and improving the reliability of microwave weld processes for Monel-400 metal sheets.

Keywords - *Inconel metal sheets, Joint strength, Microwave welding, Parameter optimization.*

1. INTRODUCTION

Microwave welding is a latest advancement that holds promise to be applied for the joining of high-temperature alloys such as Inconel metal sheets in various industries such as aerospace, auto, and energy. Microwave welding differs from conventional welding methods in that it deals advantages like rapid heating, reduced distortion, and improved control over process of heating. Optimal joint performance and quality can be attained through optimal parameter selection for variables such as power level, welding time, and temperature. Inconel alloys have also been studied for joining applications. There has been considerable research on Microwave Hybrid Heating (MHH) for the welding of high-performance alloys such as Inconel in recent years. A survey of the literature indicates a number of studies carried out for investigating the potential of MHH for welding Inconel, more specifically Inconel 718 and Inconel 625[1-10].

Bansal et al. [1] were capable of MHH welding Inconel 718 plates by a power applicator of 900 W with a nickel powder layer as an interlayer. The tensile strength of the joint was 400 MPa with ductility of 6%. Inconel 718 butt welding of MHH with Inconel 718 filler powder was possible with no joint interface cracks [2]. Again Bansal et al. [3] showed the welding of Inconel 718 with MHH using Inconel 718 powder. Badiger et al. [4-5] joined Inconel-625 successfully utilizing nickel-based powder as an interfacial material in MHH. Badiger et al. [6] maximized process parameters affecting the performance of MHH for Inconel-625 joining through a design of experiment approach. Observed that addition of fine filler powder, silicon carbide susceptor, and graphite separator increased the tensile strength of the joint. Another identical researcher [7] investigated the effect of input power on the tensile and flexural strength of the joints fabricated by MHH of Inconel-625 plates using nickel-based powder as interface material. Samples grown with 600 W possessed finer grain structure and exhibited 9% and 11% increased tensile and flexural strengths, correspondingly, in comparison to the samples grown with 900 W. These investigations as a whole demonstrate the promise of MHH as a viable technique for joining Inconel alloys, providing process parameter, mechanical property, and microstructural feature information of the joints. Nickel, copper, stainless-steel, and Inconel are some of the most commonly used materials in microwave hybrid heated joining (MHJ), where metal solubility plays a critical role in the achievement of strong joints. Nickel is frequently the preferred material for brazing a stainless steel part due to its favorable characteristics. The paper is based on the parameter optimization procedure of microwave welding to determine joint quality and performance for Monel 400 sheets using AL and ML approach. It is the purpose of the study to explore the influence of welding parameters like power level, temperature and duration on joint strength and determine the best parameter ranges for obtaining maximum joint strength. Experimental data are employed to simulate the welding process and forecast joint strength.

2. METHODOLOGY

Monel 400 sheets were welded in microwave welding fixture with nickel powder used as brazing material. The microwave welding fixture utilized frequency of 2.45GHz, power level up to 1.2kW and temperature of up to 1350°C. Experimental data for analysis was obtained from open literature [1-7] as well as experimental results carried out in laboratory environment for different power levels, temperature and time. The performance was measured by using a Random Forest Regressor, a stable machine learning algorithm for regression problems. The data were separated into training and testing sets to assess the method generalizability. The model performance was validated by MSE, The lower MSE the better the model performance.

3. RESULTS AND DISCUSSION

The Random Forest Regressor trained reached mean squared error of 0.33, which represents a satisfactory level of accuracy in joint strength prediction. Analysis of feature importance (Fig. 1) was performed to establish the parameters that most significantly predict joint strength. The most significant parameter found was power level, with 42% contribution to the overall predictive potential. Next to power level, welding time was the most influential factor in predicting joint strength, with a 40% importance. Temperature emerged as the third most important parameter, with a 38% contribution. The experimental results revealed that joint strength rose with power, welding time and temperature to some optimum values above which increased power, time and temperature resulted in decreased joint strength. Temperature and time had little influence on joint strength in comparison to the level of power of welding. Optimum joint strength within the range of 370MPa was reported for power level of 1.05kW, temperature 1200°C and time 1235 seconds (Fig.2).

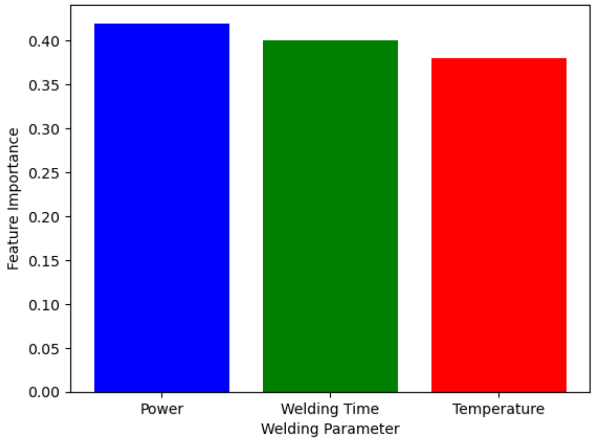
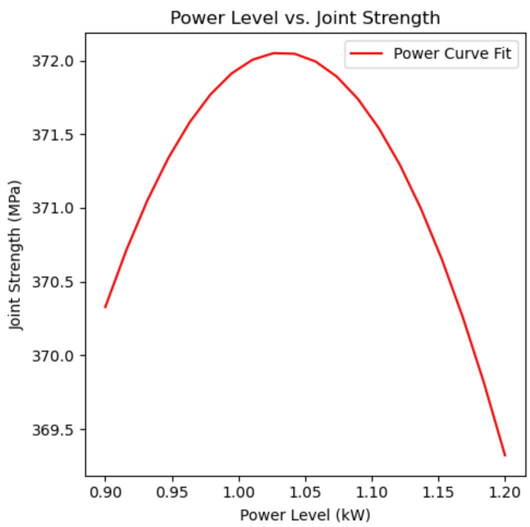


Fig. 1 Feature Importance for Joint strength



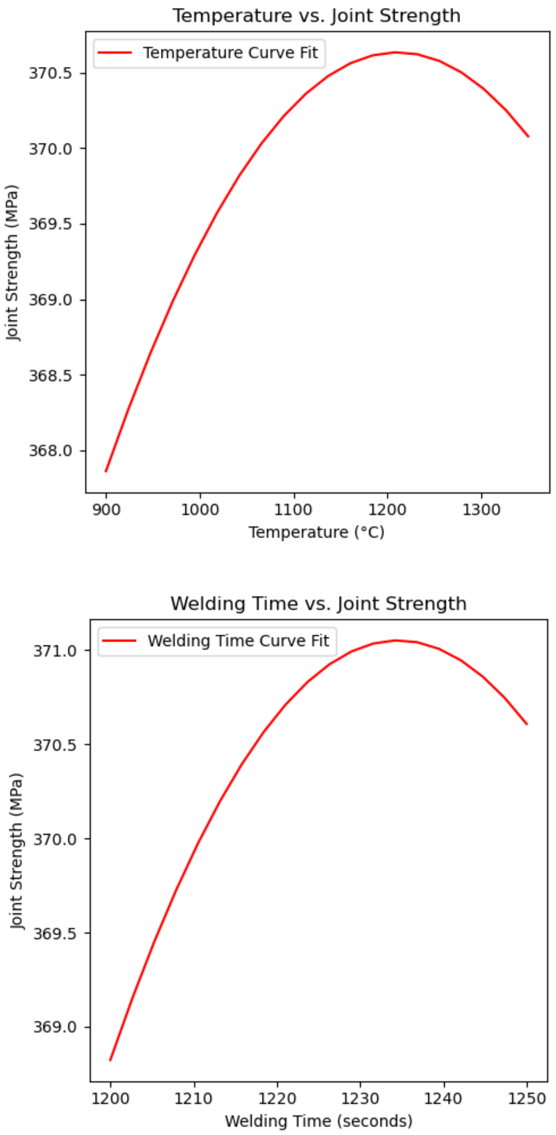


Fig. 2 Impact of process factors on joint strength

Outside these ideal process conditions joint strength was found to reduce due to degradation material properties of the joint. High temperature can result in thermal degradation, oxidation, or even melting of the joint interface High exposure to excessive heat, will lead to unwanted changes in the material structure and diminishing joint integrity. Longer time intervals might also raise the probability of defects like porosity or cracks, further reducing joint strength. The predominance of all three welding parameters in governing joint strength highlights the need to have control of these parameters within optimum levels in order to produce quality welds. The trends observed in parameter impacts are consistent with previous studies of microwave welding of similar materials, confirming the reliability of the AI ML method.

4. CONCLUSION

In our work, we conducted a combined strength analysis of Monel-400 using both predictive modeling and experimental data in microwave hybrid heated joining processes. The findings gave us valuable information on the influencing factors on joint strength and provided guidelines for process optimization.

•The mean squared error of the Random Forest Regressor model was 0.33, and it suggests reasonably good accuracy in joint strength estimation. Feature importance analysis showed that power level, welding time, and temperature were the key factors.

•Highest values for power level, welding time, and temperature were established to produce maximum joint strength.

• While each parameter contributed to joint strength, power level contributed most to this, underlining the importance of controlling power in order to create high-quality joints.

•Above these optimum values, process parameter increases led to declining joint strength, highlighting the necessity for stringent control of process conditions.

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