UNIVERSITI TEKNOLOGI MARA

FATIGUE LIFE ENHANCEMENT FOR FRICTION STIR WELDED AA6061 BUTT JOINT THROUGH HIGH FREQUENCY MECHANICAL IMPACT (HFMI) OF PNEUMATIC IMPACT TREATMENT (PIT)

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ABSTRACT

The welding and joining industry in the past few decades has witnessed a huge growth in pursuit of process optimization and design minimization due to the continued escalation of prices. A relatively typical new welding process that requires wide attention in process optimization for an ideal low defect joint and life cycle improvement is friction stir welding due to its advantage of having minimal parameters to be controlled during the process. However, despite its many advantages tensile residual stress in friction stir welded joints remains to be a significant concern due to its extensive clamping and stirring process causing a lower fatigue resistance particularly in structures subjected to fluctuating loads triggering a need for improvement by utilizing modern post-weld treatment processes. Aiming to apply the HFMI method of pneumatic impact treatment (PIT) to enhance the fatigue performance of a 6 mm thick AA6061-T651 FSW butt joint, this research consisted of three main phases. The initial phase focused on the optimization of the rotational and traverse speed based on multiple mechanical properties and quality features, which emphasized on the tensile strength, hardness and the weld quality class using the Multi-objective Taguchi Method (MTM). Furthermore, the first order model for predicting the mechanical properties and weld quality class was derived by applying Response Surface Methodology (RSM). The second phase dealt with determining the best governing process parameters of HFMI technique using a similar optimization approach for varied parameters centered on indenter diameter, air pressure and impact frequency. In the final phase, the nominal stress approach was employed to determine the fatigue class (FAT) enhancement values as well as S-N curves of HFMI/PIT treated, post weld heat treated (PHWT), as-welded and in-service HFMI/PIT treated FSW AA6061 joints. Subsequent sub-surface hardness measurements and static test evaluation with microstructure analysis was conducted to gain a better understanding of the fatigue behavior for each condition. Further analyses and measurements of the longitudinal and transverse residual stress for FSW AA6061 joints using the hole-drilling method with electronic speckle pattern interferometry (ESPI) for various conditions was conducted to establish the vicissitudes of residual stress with each as-welded and post weld treatment. It was found that the PIT treatment imparted significant amount of compressive residual stress to the FSW joint resulting in an enhanced fatigue life of FSW PIT treated condition. The FSW in-service PIT treated joints achieved marginally higher fatigue strength than the as-welded conditions although being pre-fatigued, thus giving a whole new meaning to asset integrity and management for in-service FSW aluminum alloy joints and structures.

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CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND OF RESEARCH

The welding and joining industry in the past few decades has witnessed a huge growth in pursuit of process optimization and design minimization. Surging prices economically in every fabrication and construction have driven many manufacturers and fabricators to focus on asset integrity and reliability with special attention given to structural life cycle enhancement. A relatively typical new welding process that requires wide attention in process optimization and life cycle improvement is friction stir welding (FSW).

FSW utilizes frictional heating combined with forging pressure to produce high-strength bonds with increased quality features [1]. Since the invention of FSW, it has become one of the most preferred solid-state joining processes especially for Aluminum alloy compared to the formerly used fusion welding process due to its vast number of advantages such as finer microstructure in the weld joint, less shrinkage from solidification, minimal welding defects and distortion [2]. The rapid acceptance of FSW, especially in light metal applications such as panels in ship and train structures, automotive, airplane and aerospace components is depicted in Figure 1.0 below. It is mainly due to the advantage of FSW having minimal parameters to be controlled during the process namely the tool rotation rate and tool traverse speed. Hence achieving an ideal low defect FSW joint is primarily dependent on the optimization of the governing FSW parameters. However, despite its many advantages tensile residual stress in friction stir welded joints remain to be a significant concern due to its extensive clamping and stirring process which can lead to lower fatigue resistance particularly in structures subjected to fluctuating loads such as in the transportation industry under varying load conditions where fatigue failure is an important issue. Weld failure leads to loss of lives and substantial costs each year all over the world. This triggers the need for improvement by utilizing modern post-weld treatment processes [1, 2].