UNIVERSITI TEKNOLOGI MARA

FINITE ELEMENT METHOD (FEM) ANALYSIS ON COUPLED PROCESS OF WELDING TO FORMING AND FORMING TO WELDING

DENDI PRAJADHIANA ISHAK

PhD

June 2021

AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post-Graduate, Universiti Teknologi MARA, regulating the conduct of my study and research.

Name of Student	:	Dendi Prajadhiana Ishak
Student I.D. No.	:	2013226542
Programme	:	Doctor of Philosophy (Mechanical Engineering) – EM950
Faculty	:	College of Engineering
Thesis Title	:	Finite Element Method (FEM) Analysis on Coupled Process of Welding to Forming and Forming to Welding
Signature of Student	:	……..
Date	:	June 2021

ABSTRACT

In today's highly competitive business environment, it is crucial to have a sustainable operational that continuously strives for lower overall manufacturing cost. One strategy to have a lower overall manufacturing cost is to reduce product failure by developing the ability to predict production flaws at the earliest possible stage alongside the entire value-added stream since it can reduce expensive trial and error attempts at the real manufacturing floor. This doctoral thesis focuses on investigating major imperfection in coupled processes of Welding-to-Forming and Forming-to-Welding which are frequently found in parts production in automotive industries. Finite Element Method (FEM) - based Virtual Manufacturing (VM) approach is used to predict final dimensional change in both welding and forming processes through the utilization of specialized software Simufact.Welding and Simufact.Forming. This research is to demonstrate the accuracy in predicting final geometry in both coupled processes where the physical properties from the first process serves as the initial condition for the later process. The results will be compared to the experimental results to verify its level of accuracy in predicting the imperfection which was executed by utilizing thermo-mechanical FEM under consideration of non-linear isotropic hardening and strain rate. For verification purpose, experimental butt-joint welding was joined by means of robotic welding system (ABB IRB 2400/16) and advanced power source (KEMPPI Pro-EvolutionProMig) with mixed shielding gas 80% Ar/ 20% CO2 as well as filler wire ER70S. Experimental forming process on sheet metal was carried out using (SUNFLUID 800/2007) bending machine. Low carbon steel S235 with thickness of 2 mm is selected as material for both simulation and experiment since this type of steel is the most commonly used material in automotive spare part production due to its excellent ductility and toughness. The study shows in experimental result on coupled processes of Welding-to-Forming, that the average final displacement due to spring-back effect is 2.24 mm, while on Forming-to-Welding experimental results, the average final distortion yields the value of 1.12 mm. The FEM-based VM result, on the other hand, indicated that for the coupled processes Welding-to-Forming the error range on final displacement is found out to be 6.25% in average. In the case of coupled processes Forming-to-Welding, the error range on final distortion yields the error value of 11.61% in average. It can be concluded that coupled process Forming-to-Welding is the better coupled process compared to Welding-to-Forming since it yields a smaller average value of geometrical change. The range of error was caused by non-uniformly distributed geometrical change across the specimen after welding and forming processes. However, in both coupled processes the errors are all still within acceptable engineering level.

ACKNOWLEDGEMENT

I would like to use this first opportunity to thank The All-Mighty God, Allah SWT, The Creator and The Sustainer of the universe, for only by His permission that I could finish writing this thesis toward the completion of my PhD journey.

Mostly, I would certainly like to express my sincere gratitude to my advisor Prof Ir Dr. -Ing Ts Yupiter HP Manurung IWE/EWE/SFI CEng ImechE, for the continuous support of my Ph.D study and related research, for his patience, motivation, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better advisor and mentor for my Ph.D study. I would also like to convey my deep appreciation to Prof. Dr. Ir. Wahyu Kuntjoro for his valuable and constructive suggestions during the planning and development of this research work. I would also like to extend my thanks to the technicians and staffs of the Advanced Manufacturing Technology laboratory of the Faculty of Mechanical Engineering at UiTM Shah Alam for their help in offering me the resources in running the experiments, who gave access to the laboratory and research facilities. Without their precious support it would not be possible to conduct this research.

To all my research colleagues at the "Markaz", Computer Lab 2B, Level Six, thank you for sharing the ups and downs during the past few years we were together and for being a solid band of brotherhood.

Finally, I would like to thank my family and my BSI team for supporting me physically, mentally and spiritually throughout this journey and throughout my life in general.

I dedicate this work solely to my beloved mother for her continuous and unreserved believe in me.

TABLE OF CONTENTS