UNIVERSITI TEKNOLOGI MARA

DAMAGE TOLERANCE OF NANOSILICA FILLED BASALT FRP – AL FOAM SANDWICH PANEL

NURUL EMI NOR AIN BINTI MOHAMMAD

Thesis submitted in fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Mechanical Engineering)

College of Engineering

June 2022

ABSTRACT

Sandwich panel composite consists of face sheets and foam core. Conventional sandwich panels that are made of thermoplastic foam or honeycomb have very low damage resistance, damage tolerance and interfacial adhesion strength in-between face sheets and core. In this study, aluminium (Al) foam is introduced and used as core material of the sandwich panel to improve the damage resistance and tolerance properties. Basalt and glass fibre reinforced polymer (FRP) composites were used as face sheet. These FRP were modified with 5, 13 and 25wt% of nanosilica to enhance the impact and damage tolerance of FRP – Al foam sandwich panel. The increase in environmental concern, as well as materials sustainability awareness, has positively attracted industries to use mineral-based fibre, such as basalt, in in various applications such as for building construction, marine, automotive, sports and aircrafts industries. In this study, three different nano silica contents (5 wt%, 13wt% and 25 wt%) were mixed with epoxy matrix and impregnated onto the basalt fibre using hand-layup method. The face sheet and foam core were bonded together using nano silica epoxy paste to improve the adhesion strength property. Density and burnt off tests were conducted to determine the physical properties of FRP composites and FRP-Al foam sandwich panel. Damage resistance and damage tolerance properties were measured using impact test and compression after impact (CAI) test. In addition, the flexural and interlaminar shear strength tests were also conducted to determine the mechanical properties such as elastic flexural modulus, flexural strength and interlaminar shear strength of the FRP composites and sandwich panel. The fractured samples were observed using optical microscopy and scanning electron microscopy (SEM) for the evaluation of damage mechanisms. The incorporation of nanosilica into FRP composites enhanced the mechanical and impact properties of the sandwich panel. It was found that sandwich panel that was made of closed cell Al foam core, basalt fibre FRP face sheets and 25wt% nanosilica, denoted as CCBF25, exhibited the highest damage resistance and tolerance properties when compared to the other sandwich panel systems. The results showed that the addition of 25wt% nanosilica in closed cell Al-Basalt sandwich panel improved the impact strength, compression after impact strength, compressive strength, flexural strength and interlaminar shear strength by 140%, 16%, 38%, 215% and 9%, respectively, when compared to unmodified sandwich panel. It was also discovered that the addition of 25wt% nanosilica in Basalt and Glass FRP composites, Open Cell and Closed Cell Al foams-FRP sandwich panels, denoted as BF25, GF25, OCBF25, OCGF25, CCBF25 and CCGF25, displayed improvement in damage tolerance properties of 90%, 87%, 65%, 54%, 47% and 37%, respectively, when compared to the unmodified systems. These results showed that nanosilica filled aluminium foam sandwich panels are very promising advanced lightweight high-strength materials that could be used in a wide range of modern mechanical elements and structures.

ACKNOWLEDGEMENT

Firstly, I wish to thank Allah for giving me the opportunity to embark on my PhD and for completing this long and challenging journey successfully. My gratitude and thanks go to my supervisor, Assoc Prof Dr. Aidah Jumahat, for her patience, motivation, enthusiasm and immense knowledge. Her guidance has helped me at all times during the research and writing of this thesis.

I am extremely grateful to my dear late Mama and Papa, Halijah Ngah and Mohammad Ngah, for their love, prayers, care and sacrifices for educating and preparing me for my future. This piece of victory is dedicated to both of you. Alhamdulilah. I am very thankful to my loving husband, Afifuddin Ahmad and sons, Umar Alkhalif Afifi and Uthman Affan Afifi for their love, understanding, prayers and continuous support to complete this research work. Also, I would like to express my thanks to my siblings, Norazlina, Shilla, Alif, Amir, nieces and nephews, Ellissa, Safiya, Fahim, Fateh and Faiq for their support, love and valuable prayers.

My appreciation goes to all the technical staff in the Faculty of Mechanical Engineering for the facilities and assistance during my laboratory work. Special thanks to my colleagues and friends, Ir. Nuraini, Dr. Najibah, Dr. Ummu Raihanah, Dr. Napisah, Dr. Azean and Dr. Norleha for helping me with this project.

TABLE OF CONTENTS