Digital Manufacturing

Joint strength and numerical modelling of laser welding for CFRP/Steel and resistance spot welding for CFRP/Aluminum

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Abstract

An advanced numerical analyzing model was developed to reproduce the thermal and mechanical phenomena during directly joining CFRP (carbon fiber reinforced resin material) and metals (high-strength steel plate, aluminum alloy) using the laser or electric resistance joule heat as heat sources. Based on analyzed results, the temperature distribution on the joining interface, the melting region and decomposition region of CFRP were quantified, which cannot be observed experimentally. The bonding mechanism was elucidated. It was found that controlling the joining interface temperature to the range between the melting and decomposition temperatures of CFRP is a necessary condition for joining CFRP and metals. The wider of this temperature range zone, the higher the strength of the joints. Through more detailed research, we clarified the correlation between laser welding conditions (laser power) and CFRP/Steel joint strength, and resistance spot welding current (Joule heat) and CFRP/Aluminum joint strength.

Background & Results

At manufacturing sites, digital control and visualization are essential to improve productivity and ensure product quality. DT (digital twin) and DX (digital transformation) are paid great attentions as digital systems.

Firstly, a DT of resistance spot welding of CFRP/Aluminum was developed, which quantified and visualized the temperature field, weld dimensions, and tensile shear strength. The welding conditions with changes in dimensions of CFRP plates and aluminum plates used at production sites can be given using this DT system. It is expected that this DT system will propose optimized welding conditions and predict associated results in real time.

In order to put the research results of laser welding of CFRP/Steel into practical use, it is necessary to accumulate experimental and analytical datasets and build prediction technology using ML (machine learning) algorithm.

Significance of the research and Future perspective

To save energy and reduce CO_2 emissions of vehicles, how to reduce the weight of automobile bodies is also necessary besides to improve engine efficiency and battery performance. Therefore, it is essential to design vehicle body using multi-materials and join/assembly various parts made of lightweight materials such as composite resin (CFRP), light metals (aluminum, magnesium, etc.) and high-strength steel. In this study, we focused on resistance spot welding technology for joining CFRP/Aluminum and laser welding technology for joining CFRP/Steel. Through clarifying the joining mechanism, it can be known interface temperature distribution governs the joint strength and the size of joining zone. Through numerical simulations, guidelines for optimizing welding conditions can be proposed. Furthermore, through developing a digital system such as DT/DX, the research achievement can make great contribution to realize the GX (green transformation).

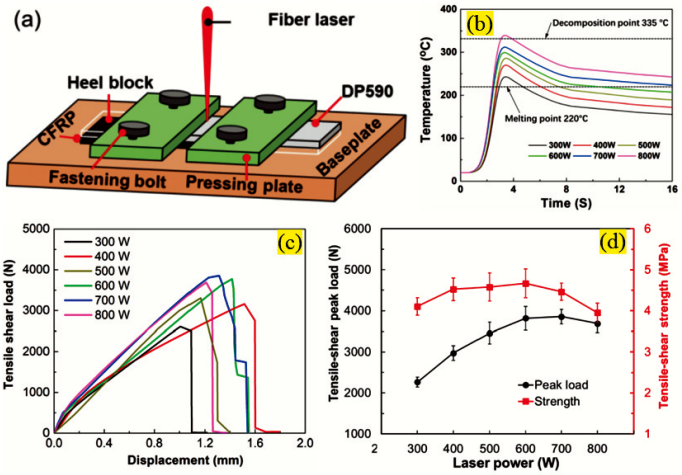

Fig.1: (a) CFRP/Steel laser welding setup, (b) Interface temperature history, (c) Force-displacement curve in tensile-shear test, (d) Joint Strength

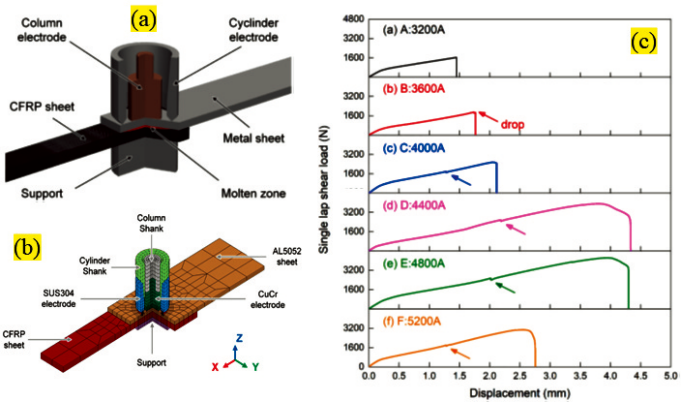

Fig.2: (a) CFRP/Aluminum resistance spot welding, (b) Finite element modelling, (c) Force-displacement curves in tensile-shear tests

Manufacturing technologies

Patent	
Treatise	Xia, Hongbo; Ma, Ninshu et al. Influence of laser welding power on steel/CFRP lap joint fracture behaviors. Composite Structures. 2022, 285 (115247), 1-12. doi: 10.1016/j.compstruct.2022.115247 Ren, Sendong; Ma, Ninshu et al. Numerical analysis on coaxial one-side resistance spot welding of Al5052 and CFRP dissimilar materials. Materials and Design. 2020, 188 (108442), 1-14. doi: 10.1016/j.matdes.2019.108442
URL	http://www.jwri.osaka-u.ac.jp/en/research/research03_1.html
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