EFFECT OF GEOMETRICAL SIZE AND NUMBER OF CORE ON BENDING BEHAVIOUR OF WEB-CORE SANDWICH STRUCTURE

NUR KHALEEDA BINTI ROMLI

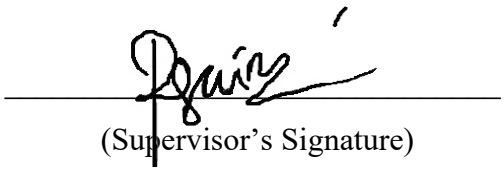
DOCTOR OF PHILOSOPHY

UNIVERSITI MALAYSIA PAHANG
AL-SULTAN ABDULLAH

اونيۏرسيتى مليسيا فهڠ السلطان عبد الله
UNIVERSITI MALAYSIA PAHANG
AL-SULTAN ABDULLAH

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy.



(Supervisor's Signature)

Full Name : Associate Professor Ts Dr Mohd Ruzaimi bin Mat Rejab

Position : Associate Professor

Date :

(Co-supervisor's Signature)

Full Name : Professor Dr Mahadzir bin Ishak @ Mohamed

Position : Professor

Date :

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang Al-Sultan Abdullah or any other institutions.

(Student's Signature)

Full Name : NUR KHALEEDA BINTI ROMLI

ID Number : PMD 18001

Date :

EFFECT OF GEOMETRICAL SIZE AND NUMBER OF CORE ON BENDING BEHAVIOUR OF WEB-CORE SANDWICH STRUCTURE

NUR KHALEEDA BINTI ROMLI

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Doctor of Philosophy

Faculty of Mechanical and Automotive Engineering Technology

UNIVERSITI MALAYSIA PAHANG AL-SULTAN ABDULLAH

OCTOBER 2023

ACKNOWLEDGEMENTS

"In the name of Allah, the most Gracious and the most Merciful"

I would like to convey my sincere gratitude to my main supervisor, Associate Professor Ts.Dr. Mohd Ruzaimi bin Mat Rejab, co-supervisor, Professor Dr. Mahadzir bin Ishak, and field supervisor, Associate Professor Dr. Jiang Xiaoxia, and lecturers from Structure Performance Materials Engineering (SUPREME) for their immense ideas, invaluable guidance, continuous encouragement, and consistent support in making this reasearch possible. Their guidance helped me in the time of research and writing of this thesis. I could not have imagined having better advisors and mentors for my Ph.D. study.

Besides my advisors, I would like to thank the rest of my thesis panels, Professors for their insightful comments and encouragement. Throughout answering the hard questions and comments from them, it encouraged me to widen my research from previous perspectives.

I want to express my appreciation to all staff members of Faculty of Mechanical & Automotive Engineering Technology (FTKMA), Universiti Malaysia Pahang and School of Mechanical Engineering, Ningxia University for guiding me in accomplishing this research.

I would also like to thank Dr Ir Jamiluddin, for providing me with the knowledge and skills needed to undertake this research. Your passion for the subject matter and your commitment to your students have been an inspiration to me. To my postgraduate friends, thank you for being my companions on this journey. Your support, encouragement, and camaraderie have made the long hours of research and writing much more bearable. I will always cherish the memories we have shared.

Besides that, I would like to thank the Ministry of Higher Education, Universiti Malaysia Pahang, and Ningxia University for supporting my research study with research grants, RDU 1603108 and Ningxia High School Scientific Research Project (Excellent Young Teacher Fund Project, NGY2017016.

My special appreciation to my husband Rizalman bin Mamat, parents and family members who gave moral support spiritually and understanding throughout my journey as a Ph.D student at Universiti Malaysia Pahang. Finally, to my lovely daughter Sofea binti Rizalman, I am so grateful for the new changes in my life. Your presence always cherishes and understands me in every situation.

ABSTRAK

Struktur terapit berkimpalan laser mempunyai ciri nisbah kekakuan terhadap berat yang begitu tinggi, di mana secara tipikal diaplikasikan di dalam pembuatan struktur kapal. Masalah lenturan pada struktur terapit semakin meningkat yang disebabkan oleh beban yang berat dan sering dibangkitkan dalam industri kapal. Walau bagaimanapun, daripada perkembangan kajian terhadap struktur terapit dengan perbezaan geometri dan bilangan teras, ia masih belum jelas dan secara menyeluruh. Oleh itu, kajian yang terperinci mengenai struktur terapit bersama teknologi kimpalan, bahan struktur yang ringan dan kuat amat diperlukan. Tujuan utama kajian ini adalah untuk mengkaji kesan saiz geometri dan bilangan teras ke atas beban tiga titik pada struktur terapit teras web berkimpalan laser. Struktur terapit teras web berkimpalan laser telah diperbuat dari kepingan keluli bergalvani dan disambungkan dengan menggunakan mesin kimpal fiber. Tambahan pula, struktur terapit tersebut telah dibina dengan perbezaan dari segi ketebalan kepingan teras, jarak antara dua kepingan teras dan bilangan teras. Selain itu, terdapat dua jenis struktur terapit yang telah dibina, antaranya adalah dengan sokongan busa dan tanpa sokongan busa. busa *polyvinyl chloride* (PVC) telah dipilih untuk digunakan pada struktur terapit. Di samping itu, analisa unsur terhingga dimodelkan dengan berdasarkan kemuluran yang berasakan terikan untuk meramal kelakuan lenturan ke atas struktur terapit dengan perbezaan geometri dan bilangan teras. Namun begitu, oleh kerana data eksperimen yang terhad, data dari tinjauan literatur telah diambil dan digunakan sebagai input bahan konstitutif pada model di dalam Abaqus/Standard. Ujian tegangan telah dijalankan ke atas sampel tegangan keluli bergalvani dan menghasilkan keputusan tegangan alah bersamaan 324.522 MPa. Berdasarkan pemerhatian, kegagalan pada dua jenis struktur terapit adalah sama, di mana terdapat lenturan pada kedua-dua jenis struktur tersebut. Walaupun, lenturan telah berlaku pada kedua-dua jenis struktur terapit, penjelasan mengenai kelakuan lenturan telah diterangkan pada sudut yang berbeza. Kegagalan struktur terapit teras web tanpa busa berkimpalan laser telah berlaku disebabkan oleh tiada kekangan pada kedua-dua belah hujung struktur untuk sokongan ketika beban tiga titik dijalankan ke atas struktur. Tambahan pula, busa PVC telah digunakan untuk meningkatkan ketegaran and kekuatan lenturan. Penggunaan busa PVC pada struktur terapit bekimpalan laser telah meningkat sebanyak 90% pada kekuatan struktur. Keputusan analisis unsur terhingga-ketaksempurnaan telah disahkan dengan keputusan eksperimen, di mana persetujuan telah dicapai dengan ralat peratusan dalam 5.834%. Berdasarkan perbandingan prestasi lenturan melalui ujian beban tiga titik, kesaan saiz geometri dan bilangan teras ke atas struktur terapit teras web berkimpalan laser sangat bermanfaat untuk meningkatkan kekuatan lenturan, dan menyebabkan daya serapan tenaga bertambah juga. Walaubagaimanapun, kekuatan struktur boleh terjejas akibat kegagalan yang biasa berlaku dalam sistem terapit seperti nyah ikatan, masalah ikatan antara dua permukaan dan juga pada sambungan kimpalan. Selain itu, kekuatan struktur terapit telah terkesan dari peningkatan bilangan teras dan menyebabkan ketegaran struktur semakin kukuh and kuat. Di samping itu, kesan jarak antara dua kepingan dan ketebalan teras telah dikaji, di mana jarak yang lebih besar dan kepingan teras yang lebih tebal akan meningkatkan kestabilan dan kekakuan pada struktur terapit tersebut.

ABSTRACT

Laser-welded sandwich structure is a promising solution due to the high stiffness-to-weight ratio, which is typically applied in the structure of shipbuilding. According to engineering demands, bending of the sandwich structure is frequently raised in the shipbuilding industry due to heavy loads. However, structural improvement with variant geometries and number of cores have not been clearly studied. Therefore, a detailed study of the sandwich structure with the technology of joining, strong and lightweight material is required. The primary aim of this research study is to investigate the effect of geometrical size and core number on the three-point bending performance of a web-core laser-welded sandwich structure. A Web-core laser-welded sandwich structure was manufactured using galvanised steel. In addition, the sandwich structure was fabricated with different web plate thicknesses, spacing distances, and number of cores. Besides that, two types of web-core sandwich structure were fabricated; with foam and without foam. Polyvinyl chloride (PVC) foam was chosen to be installed in the web-core sandwich structure. Furthermore, a finite element analysis was modelled with strain-based ductility to predict the bending behaviour of the web-core sandwich structure by different spacing distances and core numbers. Nevertheless, data from the literature review was extracted due to limited experimental data and applied to formulate the constitutive material in the Abaqus/Standard model. A tensile test was conducted on galvanised steel specimen and found that yield stress was initiated at 324.522 MPa. Based on the observation, failure of the two types of sandwich structures were found to be similar, where bending was initiated due to the bending of the sandwich structure. Although bending was established in both types of sandwich structure, the discussion was stated in different ways. The failure of the web-core laser-welded sandwich structure without foam was due to no constraint acted at the end-sides to support the structure during the three-point bending loading. Moreover, PVC foam was substituted to increase rigidity and bending strength of the web-core laser-welded sandwich structure. The substitution of the PVC foam was increased up to 90% on the structural strength. The FEA-Imperfection result was validated in the experimental result, where good agreement was achieved, in which the percentage error of the comparison was about 5.834%. Owing to the comparison of bending performances in the three-point bending load, the effect of geometrical size and number of cores on the web-core laser welded sandwich structure was beneficial to increase bending strength, where energy absorption would also be higher. However, the strength of bending would reduce because of the common failures in the sandwich structure system, such as debonding due to interface bonding and welding joint problems. Besides that, the strength of the sandwich structure was affected by an increasing number of cores, where rigidity of the sandwich structure was increased and stronger. In addition, the effect of variant spacing distances was also studied, and it was found that the larger space distance and thicker web plate thickness would increase the stability and stiffness of the sandwich structure, respectively.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

REFERENCES

Abdulridha, M., & Jilabi, A. (2022). Effect of fibre laser welding parameters on the microstructure and weld geometry of commercially pure titanium. *Archives of Materials Science and Engineering, 117*(1), 34-41.

Allahyari, P., Silani, M., Yaghoubi, V., Milovanovic, P., Schmidt, F. N., Busse, B., & Qwamizadeh, M. (2023). On the fracture behavior of cortical bone microstructure: The effects of morphology and material characteristics of bone structural components. *Journal of the Mechanical Behavior of Biomedical Materials, 137*, 105530. doi:https://doi.org/10.1016/j.jmbbm.2022.105530

Almusallam, A. (2001). Effect of degree of corrosion on the properties of reinforcing steel bars. *Construction Building Materials, 15*(8), 361-368.

Aparecida Diniz, C., Brighenti Bortoluzzi, D., Luiz Junho Pereira, J., Simões da Cunha Junior, S., & Ferreira Gomes, G. (2022). On the influence of manufacturing parameters on buckling and modal properties of sandwich composite structures. *Structures, 46*, 664-680. doi:https://doi.org/10.1016/j.istruc.2022.10.059

Arslan, K., & Gunes, R. (2018). *"Experimental damage evaluation of honeycomb sandwich structures with Al/B4C FGM face plates under high velocity impact loads". Composite Structures, 202*, 304-312. doi:https://doi.org/10.1016/j.compstruct.2018.01.087

Avachat, S., & Zhou, M. (2015). Response of submerged metallic sandwich structures to underwater impulsive loads. *Journal of Mechanics of Materials and Structures, 10*(1), 17-41.

Azimi, A. e. a. (2012). Metallurgical analysis of pimples and their influence on the properties of hot dip galvanized steel sheet. *Engineering Failure Analysis, 26*, 81-88.

Bao, L., Miura, Y., & Kemmochi, K. (2018). Improving bending characteristics of FRP sandwich structures with reinforcement webs. *Advanced Composite Materials, 27*(2), 221-233.

Belouettar, S., et al. (2009). Experimental investigation of static and fatigue behaviour of composites honeycomb materials using four point bending tests. *Composite Structures, 87*(3), 265-273.

Bouhamed, A., Mars, J., Jrad, H., Ben Said, L., Wali, M., Dammak, F., & Torchani, A. (2022). Identification of fully coupled non-associated-Ductile damage constitutive equations for thin sheet metal applications: Numerical feasibility and experimental validation. *Thin-Walled Structures, 176*, 109365. doi:https://doi.org/10.1016/j.tws.2022.109365

Cernescu, A., & Romanoff, J. (2015). "Bending deflection of sandwich beams considering local effect of concentrated force". *Composite Structures, 134*, 169-175. doi:https://doi.org/10.1016/j.compstruct.2015.08.074

Cho, J.-H., & Na, S.-J. (2006). Implementation of real-time multiple reflection and Fresnel absorption of laser beam in keyhole. *Journal of Physics D: Applied Physics, 39*(24), 5372.

Chowdhury, S., Nirsanametla, Y., Muralidhar, M., Bag, S., Paul, C. P., & Bindra, K. S. (2020). "Identification of modes of welding using parametric studies during ytterbium fiber laser welding". *Journal of Manufacturing Processes, 57*, 748-761.

doi:https://doi.org/10.1016/j.jmapro.2020.07.038

Colombo, I. G., & Colombo, M. (2018). Analytical and numerical prediction of the bending behaviour of textile reinforced concrete sandwich beams. *Journal of Building Engineering, 17*, 183-195. doi:https://doi.org/10.1016/j.jobe.2018.02.012

da Silva, G. S., Kosteski, L. E., & Iturrioz, I. (2020). Analysis of the failure process by using the Lattice Discrete Element Method in the Abaqus environment. *Theoretical and Applied Fracture Mechanics, 107*, 102563. doi:https://doi.org/10.1016/j.tafmec.2020.102563

Deng, Jeschke, Jakeria, White, Hirth, Eiden, . . . Cole. (2023). Synergistically and sustainably performed inhibitors for galvanised steel against aqueous corrosion. *Corrosion Science, 213*, 110984.

Deng, Jeschke, Murdoch, Hirth, Eiden, Gorges, . . . Cole. (2022). In-depth insights of inhibitory behaviour of 2-amino-4-methylthiazole towards galvanised steel in neutral NaCl solution. *Corrosion Science, 199*, 110206.

Deng, Zhou, Li, Wang, Wei, & Jia. (2022). Dynamic response and failure mechanism of S-shaped CFRP foldcore sandwich structure under low-velocity impact. *Thin-Walled Structures, 173*, 109007.

Engelbrecht-Wiggans, A. E., & Forster, A. L. (2023). Analysis of strain correction procedures for single fiber tensile testing. *Composites Part A: Applied Science and Manufacturing, 167*, 107411. doi:https://doi.org/10.1016/j.compositesa.2022.107411

Guo, S., Zou, J., Xu, J., Wu, Q., & Xiao, R. (2021). Multi-stage keyhole evolution in fiber laser welding: An experimental study and theoretical analysis. *Results in Physics, 31*, 104943. doi:https://doi.org/10.1016/j.rinp.2021.104943

Gupta, S., Singh, D., Yadav, A., Jain, S., & Pratap, B. (2020). A comparative study of 5083 aluminium alloy and 316L stainless steel for shipbuilding material. *Materials Today: Proceedings, 28*, 2358-2363. doi:https://doi.org/10.1016/j.matpr.2020.04.641

Hao, Z., Chen, H., Jin, X., Yu, X., & Liu, Z. (2022). Direct observation of keyhole with an innovative layer-by-layer imaging method during deep penetration laser welding. *Optics & Laser Technology, 152*, 108142. doi:https://doi.org/10.1016/j.optlastec.2022.108142

Hashemzadeh, M., Garbatov, Y., & Guedes Soares, C. (2022). Hybrid-laser welding-induced distortions and residual stresses analysis of large-scale stiffener panel. *Ocean Engineering, 245*, 110411. doi:https://doi.org/10.1016/j.oceaneng.2021.110411

He, & Hu. (2008). A study on composite honeycomb sandwich panel structure. *Materials & Design, 29*(3), 709-713. doi:https://doi.org/10.1016/j.matdes.2007.03.003

Hornbacher, A. (2019). Galvanised vs Stainless Steel Cost, Strength and Weight Differences Retrieved from https://www.wenzelmetalspinning.com/galvanized-steel-vs-stainless.html

Jelovica, J., Romanoff, J., Ehlers, S., & Aromaa, J. (2013). Ultimate strength of corroded web-core sandwich beams. *Marine Structures, 31*, 1-14. doi:https://doi.org/10.1016/j.marstruc.2012.12.001

Jen, Y.-M., & Chang, L.-Y. (2008). Evaluating bending fatigue strength of aluminum honeycomb sandwich beams using local parameters. *International Journal of Fatigue, 30*(6), 1103-

1114. doi:https://doi.org/10.1016/j.ijfatigue.2007.08.006

Jiang, Ji, Rejab, Zhang, Ishak, & Zhu. (2017). *Geometrical parameters influence on the stiffness of steel sandwich plates with web-core.* Paper presented at the IOP Conference Series: Materials Science and Engineering.

Jiang, Zhu, Qiao, Wu, Li, & Chen. (2014). The strength of laser welded web-core steel sandwich plates. *Applied Mechanics and Materials, 551*, 42-46.

Jing, L., Liu, K., Su, X., & Guo, X. (2021). Experimental and numerical study of square sandwich panels with layered-gradient foam cores to air-blast loading. *Thin-Walled Structures, 161*, 107445.

Kampker, A., Bergweiler, G., Hollah, A., Lichtenth™ler, K., & Leimbrink, S. (2019). "Design and testing of the different interfaces in a 3D printed welding jig". *Procedia CIRP, 81*, 45-50. doi:https://doi.org/10.1016/j.procir.2019.03.009

Karttunen, A. T., Kanerva, M., Frank, D., Romanoff, J., Remes, H., Jelovica, J., . . . Sarlin, E. (2017). Fatigue strength of laser-welded foam-filled steel sandwich beams. *Materials & Design, 115*, 64-72. doi:https://doi.org/10.1016/j.matdes.2016.11.039

Kim, J. W. (2013). A study on an efficient prediction of welding deformation for T-joint laser welding of sandwich panel PART I : Proposal of a heat source model. *International Journal of Naval Architecture and Ocean Engineering, 5*(3), 348-363. doi:https://doi.org/10.2478/IJNAOE-2013-0138

Kim, J. W., Jang, B. S., Kim, Y. T., & Chun, K. S. (2013). A study on an efficient prediction of welding deformation for T-joint laser welding of sandwich panel PART I : Proposal of a heat source model. *International Journal of Naval Architecture and Ocean Engineering, 5*(3), 348-363. doi:https://doi.org/10.2478/IJNAOE-2013-0138

Kolsters, & Wennhage. (2009). Optimisation of laser-welded sandwich panels with multiple design constraints. *Marine Structures, 22*(2), 154-171. doi:https://doi.org/10.1016/j.marstruc.2008.09.002

Kolsters, H., & Zenkert, D. (2006a). "Buckling of laser-welded sandwich panels. Part 1: Elastic buckling parallel to the webs". *Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment, 220*(2), 67-79.

Kolsters, H., & Zenkert, D. (2006b). Buckling of laser-welded sandwich panels. Part 2: elastic buckling normal to the webs. *Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment, 220*(2), 81-94.

Kortenoeven, J., Boon, B., & de Bruijn, A. (2008). "Application of sandwich panels in design and building of dredging ships". *Journal of Ship Production, 24*(3), 125-134.

Kostic, S., Miljojkovic, J., Simunovic, G., Vukelic, D., & Tadic, B. (2022). Uncertainty in the determination of elastic modulus by tensile testing. *Engineering Science and Technology, an International Journal, 25*, 100998. doi:https://doi.org/10.1016/j.jestch.2021.05.002

Kozak, J. (2006). Problems of strength modelling of steel sandwich panels under in-plane load. *Polish Maritime Research*, 9-12.

Kujala, P., & Klanac, A. J. B. T. i. p. b. i. p. t. (2005). Steel sandwich panels in marine applications. *56*(4), 305-314.

Kumar, C., Das, M., Paul, C. P., & Singh, B. (2017). Experimental investigation and metallographic characterization of fiber laser beam welding of Ti-6Al-4V alloy using response surface method. *Optics and Lasers in Engineering, 95*, 52-68. doi:https://doi.org/10.1016/j.optlaseng.2017.03.013

Li, H., Hu, Y., Fu, X., Zheng, X., Liu, H., & Tao, J. (2016a). Effect of adhesive quantity on failure behavior and mechanical properties of fiber metal laminates based on the aluminum–lithium alloy. *Composite Structures, 152*, 687-692. doi:https://doi.org/10.1016/j.compstruct.2016.05.098

Li, H., Hu, Y., Fu, X., Zheng, X., Liu, H., & Tao, J. (2016b). "Effect of adhesive quantity on failure behavior and mechanical properties of fiber metal laminates based on the aluminum–lithium alloy". *Composite Structures, 152*, 687-692. doi:https://doi.org/10.1016/j.compstruct.2016.05.098

Li, S., Georgiadis, D. G., Kim, D. K., & Samuelides, M. S. (2022). A comparison of geometric imperfection models for collapse analysis of ship-type stiffened plated grillages. *Engineering Structures, 250*, 113480. doi:https://doi.org/10.1016/j.engstruct.2021.113480

Liu, Ke, Sha, Wu, Wang, & Wang. (2022). Dynamic response of laser-welded corrugated sandwich panels subjected to plane blast wave. *International Journal of Impact Engineering, 164*, 104203. doi:https://doi.org/10.1016/j.ijimpeng.2022.104203

Liu, Mi, Yan, Wang, & Jiang. (2017). Correlation of high power laser welding parameters with real weld geometry and microstructure. *Optics & Laser Technology, 94*, 59-67. doi:https://doi.org/10.1016/j.optlastec.2017.03.004

Liu, & Soares. (2023). Recent developments in ship collision analysis and challenges to an accidental limit state design method. *Ocean Engineering, 270*, 113636.

Luong, D. D., Pinisetty, D., & Gupta, N. (2013). Compressive properties of closed-cell polyvinyl chloride foams at low and high strain rates: Experimental investigation and critical review of state of the art. *Composites Part B: Engineering, 44*(1), 403-416.

Manojkumar, Pranav, Premchand, Lokeshkumar, & Rameshbabu. (2022). Development of surface-modified galvanised steel as an immobilised photocatalyst for textile wastewater treatment. *Inorganic Chemistry Communications, 145*, 110056.

Mei, L., Chen, G., Yan, D., Xie, D., Ge, X., & Zhang, M. (2015). Impact of inter-sheet gaps on laser overlap welding performance for galvanised steel. *Journal of Materials Processing Technology, 226*, 157-168. doi:https://doi.org/10.1016/j.jmatprotec.2015.07.020

Melchers, R. (2010). Statistical characterization of surfaces of corroded steel plates. *Marine Structures, 23*(3), 274-287.

Mohammadi, H., Ziaei-Rad, S., & Dayyani, I. (2015). An equivalent model for trapezoidal corrugated cores based on homogenization method. *Composite Structures, 131*, 160-170. doi:https://doi.org/10.1016/j.compstruct.2015.04.048

Nilsson, P., Al-Emrani, M., & Atashipour, S. R. (2017). Transverse shear stiffness of corrugated core steel sandwich panels with dual weld lines. *Thin-Walled Structures, 117*, 98-112. doi:https://doi.org/10.1016/j.tws.2017.04.008

Ogawa, Y., Horita, T., Iwatani, N., Kadoi, K., Shiozawa, D., & Sakagami, T. (2022). Evaluation

of fatigue strength based on dissipated energy for laser welds. *Infrared Physics & Technology*, 104288. doi:https://doi.org/10.1016/j.infrared.2022.104288

Ordieres, J., Rodríguez, E., Bayón, A., Caixas, J., Barbensi, A., & Guglielmi, P. (2019). "Improvement of manufacturing jigs design for reduction of welding distortion in Vacuum Vessel PS1 through finite element analysis". *Fusion Engineering and Design, 146*, 2168-2171. doi:https://doi.org/10.1016/j.fusengdes.2019.03.141

Punzel, E., Hugger, F., Dinkelbach, T., & Bürger, A. (2020). Influence of power distribution on weld seam quality and geometry in laser beam welding of aluminum alloys. *Procedia CIRP, 94*, 601-604. doi:https://doi.org/10.1016/j.procir.2020.09.086

Rejab, & Cantwell. (2013). The mechanical behaviour of corrugated-core sandwich panels. *Composites Part B: Engineering, 47*, 267-277.

Rejab, M. R. M., & Cantwell, W. J. (2013). "The mechanical behaviour of corrugated-core sandwich panels". *Composites Part B: Engineering, 47*, 267-277. doi:https://doi.org/10.1016/j.compositesb.2012.10.031

Ren, P., Tao, Q., Yin, L., Ma, Y., Wu, J., Zhao, W., . . . Zhao, Z. (2020a). High-velocity impact response of metallic sandwich structures with PVC foam core. *International Journal of Impact Engineering, 144*, 103657. doi:https://doi.org/10.1016/j.ijimpeng.2020.103657

Ren, P., Tao, Q., Yin, L., Ma, Y., Wu, J., Zhao, W., . . . Zhao, Z. (2020b). "High-velocity impact response of metallic sandwich structures with PVC foam core". *International Journal of Impact Engineering, 144*, 103657. doi:https://doi.org/10.1016/j.ijimpeng.2020.103657

Rizov. (2005). Indentation study of foam core sandwich composite panels. *Composite Structures, 69*(1), 95-102. doi:https://doi.org/10.1016/j.compstruct.2004.05.013

Rizov. (2006). Non-linear indentation behavior of foam core sandwich composite materials—A 2D approach. *Computational Materials Science, 35*(2), 107-115. doi:https://doi.org/10.1016/j.commatsci.2005.02.009

Romanoff et al. (2007). Laser-welded web-core sandwich plates under patch loading. *Marine Structures, 20*(1), 25-48. doi:https://doi.org/10.1016/j.marstruc.2007.04.001

Romanoff, J. (2014). "Periodic and homogenized bending response of faceplates of filled web-core sandwich beams". *Composite Structures, 113*, 83-88. doi:https://doi.org/10.1016/j.compstruct.2014.03.001

Romanoff, J., Jelovica, J., Reddy, J. N., & Remes, H. (2021). "Post-buckling of web-core sandwich plates based on classical continuum mechanics: success and needs for non-classical formulations". *Meccanica, 56*(6), 1287-1302. doi:10.1007/s11012-020-01174-6

Romanoff, J., Remes, H., Socha, G., Jutila, M., & Varsta, P. (2007). "The stiffness of laser stake welded T-joints in web-core sandwich structures". *Thin-Walled Structures, 45*(4), 453-462. doi:https://doi.org/10.1016/j.tws.2007.03.008

Romanoff, J., & Varsta, P. (2006). Bending response of web-core sandwich beams. *Composite Structures, 73*(4), 478-487. doi:https://doi.org/10.1016/j.compstruct.2005.02.018

Romanoff, J., & Varsta, P. (2007a). Bending response of web-core sandwich plates. *Composite Structures, 81*(2), 292-302. doi:https://doi.org/10.1016/j.compstruct.2006.08.021

Romanoff, J., & Varsta, P. (2007b). "Bending response of web-core sandwich plates". *Composite Structures, 81*(2), 292-302. doi:https://doi.org/10.1016/j.compstruct.2006.08.021

Romli, N. K., Xiaoxia, J., Sofie, S. M., & Rejab, M. R. M. (2020). Three-point bending response of Laser-Welded Sandwich Structure with varying number of core and span length. *IOP Conference Series: Materials Science and Engineering, 788*(1), 012011. doi:10.1088/1757-899X/788/1/012011

Rubino, V., Deshpande, V. S., & Fleck, N. A. (2009). The dynamic response of clamped rectangular Y-frame and corrugated core sandwich plates. *European Journal of Mechanics - A/Solids, 28*(1), 14-24. doi:https://doi.org/10.1016/j.euromechsol.2008.06.001

Rubino, V., Deshpande, V. S., & Fleck, N. A. (2010). The three-point bending of Y-frame and corrugated core sandwich beams. *International Journal of Mechanical Sciences, 52*(3), 485-494. doi:https://doi.org/10.1016/j.ijmecsci.2009.11.009

Schuh, G., Bergweiler, G., Lichtenthäler, K., Fiedler, F., & Puente Rebollo, S. d. l. (2020). "Topology Optimisation and Metal Based Additive Manufacturing of Welding Jig Elements". *Procedia CIRP, 93*, 62-67. doi:https://doi.org/10.1016/j.procir.2020.04.066

Shanthos Kumar, G., Raghukandan, K., Saravanan, S., & Sivagurumanikandan, N. (2019). Optimization of parameters to attain higher tensile strength in pulsed Nd: YAG laser welded Hastelloy C-276–Monel 400 sheets. *Infrared Physics & Technology, 100*, 1-10. doi:https://doi.org/10.1016/j.infrared.2019.05.002

Shi, G.-j., Wang, D.-y., Hu, B., & Cai, S.-J. (2022). Effect of initial geometric imperfections on dynamic ultimate strength of stiffened plate under axial compression for ship structures. *Ocean Engineering, 256*, 111448. doi:https://doi.org/10.1016/j.oceaneng.2022.111448

Sun, Y., Saafi, M., Zhou, W., Zhang, C., & Li, H. (2015). Analysis and Experiment on Bending Performance of Laser-Welded Web-Core Sandwich Plates. *Materials Today: Proceedings, 2*, S279-S288. doi:https://doi.org/10.1016/j.matpr.2015.05.038

Torkamany, M. J., Malek Ghaini, F., & Poursalehi, R. (2016). An insight to the mechanism of weld penetration in dissimilar pulsed laser welding of niobium and Ti–6Al–4V. *Optics & Laser Technology, 79*, 100-107. doi:https://doi.org/10.1016/j.optlastec.2015.11.005

Venkataraman, S. (2003). *Challenges in Comparing Numerical Solutions for Optimum Weights of Stiffened Shells* (Vol. 40).

Vijayprasad, S. (2017). Characterization of Mechanical and Physical Properties Of Polyurethane Cored Sandwich Structure. *International Journal for Research in Applied Science & Engineering Technology (IJRASET), 5*(4), 14.

Vinson, J. (2018). *"The behavior of sandwich structures of isotropic and composite materials"*: Routledge.

Wang, Cheng, Liu, & Zhang. (2020). Hydroelastic behaviours of laser-welded lightweight corrugated sandwich panels subjected to water impact: Experiments and simulations. *Thin-Walled Structures, 146*, 106452. doi:https://doi.org/10.1016/j.tws.2019.106452

Wang, & Yan. (2020). Developments of steel-concrete-steel sandwich composite structures with novel EC connectors: Members. *Journal of Constructional Steel Research, 175*, 106335. doi:https://doi.org/10.1016/j.jcsr.2020.106335

Wang, Zhou, & Yi. (2022). Buckling distortion investigation during thin plates butt welding with considering clamping influence. *CIRP Journal of Manufacturing Science and Technology, 37*, 278-290.

Wang, J., Zhou, X., & Yi, B. (2022). Buckling distortion investigation during thin plates butt welding with considering clamping influence. *CIRP Journal of Manufacturing Science and Technology, 37*, 278-290. doi:https://doi.org/10.1016/j.cirpj.2022.02.008

Williams, Griffiths, Dunlop, & Jewell. (2022). Improving the Processability of a One-Step Hydrophobic Coating for Hot-Dipped Galvanised Steel for Industrial Applications. *Coatings*, *12*(7), 895.

Wu, Qu, & Wu. (2023). Ballistic performances of the hourglass lattice sandwich structures under high-velocity fragments. *Defence Technology*.

Wu, T., Ma, Y., Xia, H., Geng, P., Niendorf, T., & Ma, N. (2022). Measurement and simulation of residual stresses in laser welded CFRP/steel lap joints. *Composite Structures, 292*, 115687. doi:https://doi.org/10.1016/j.compstruct.2022.115687

Xiaoxia, J., Liang, Z., Shangcai, F., Shuai, Z., Chunsheng, H., & Guan, W. (2016, 2016/04). *Three-Point Bending Behavior of Web-core Steel Sandwich Panel*. Paper presented at the Proceedings of the 2016 International Conference on Advanced Materials Science and Environmental Engineering.

Xue, Z., & Hutchinson, J. W. (2003). Preliminary assessment of sandwich plates subject to blast loads. *International Journal of Mechanical Sciences*, *45*(4), 687-705. doi:https://doi.org/10.1016/S0020-7403(03)00108-5

Xue, Z., & Hutchinson, J. W. (2006). "Crush dynamics of square honeycomb sandwich cores". *International Journal for Numerical Methods in Engineering*, *65*(13), 2221-2245.

Yamashita. (2013). Dynamic crush behavior of adhesive-bonded aluminum tubular structure—Experiment and numerical simulation. *Thin-Walled Structures, 69*, 45-53. doi:https://doi.org/10.1016/j.tws.2013.04.005

Yan, S., & Jelovica, J. (2021a). Buckling and free vibration of laser-welded web-core sandwich panels: Extreme sensitivity to variation of weld rotational stiffness. *Engineering Structures, 244*, 112737. doi:https://doi.org/10.1016/j.engstruct.2021.112737

Yan, S., & Jelovica, J. (2021b). "Buckling and free vibration of laser-welded web-core sandwich panels: Extreme sensitivity to variation of weld rotational stiffness". *Engineering Structures, 244*, 112737. doi:https://doi.org/10.1016/j.engstruct.2021.112737

Zhang, Cheng, Guo, & Dai. (2023). Toughness-improving design of lattice sandwich structures. *Materials & Design, 226*, 111600.

Zhang, Liu, Zhou, & Shi. (2023). Uniaxial compressive performance of an aramid and aluminum honeycomb sandwich structure. *Ocean Engineering, 270*, 113676. doi:https://doi.org/10.1016/j.oceaneng.2023.113676

Zhang, & Santhanagopalan, e. a. (2015). A representative-sandwich model for simultaneously coupled mechanical-electrical-thermal simulation of a lithium-ion cell under quasi-static indentation tests. *Journal of Power Sources, 298*, 309-321. doi:http://dx.doi.org/10.1016/j.jpowsour.2015.08.049

Zhang, Wang, Cai, Chen, Zhou, Liu, & Cheng. (2023). Experimental investigations into the dynamic response of sandwich panels with multi-layered corrugated cores subjected to underwater impulsive load. *Thin-Walled Structures, 191*, 111021.

Zhang, Wang, Mi, & Ouyang. (2022). In situ study on fracture behaviors of SiC/2A14Al composite joint : Co-construction of microstructure and mechanical properties via laser welding. *Composites Part B: Engineering, 238*, 109882. doi:https://doi.org/10.1016/j.compositesb.2022.109882

Zhang, Y., Gao, X., You, D., & Jiang, X. (2022). Online judgment of laser welding process based on time-frequency analyses of in-situ high-speed optical signals. *Optik, 265*, 169552. doi:https://doi.org/10.1016/j.ijleo.2022.169552

Zhang, Y., Zhang, C., Tan, L., & Li, S. (2013). Coaxial monitoring of the fibre laser lap welding of Zn-coated steel sheets using an auxiliary illuminant. *Optics & Laser Technology, 50*, 167-175. doi:https://doi.org/10.1016/j.optlastec.2013.03.001

Zhao, Li, Liu, Wang, Li, & Zhan. (2023). Stability enhancement of molten pool and keyhole for 2195 AlLi alloy using fiber-diode laser hybrid welding. *Journal of Manufacturing Processes, 85*, 724-741. doi:https://doi.org/10.1016/j.jmapro.2022.12.002

Zhao, J., Jiang, P., Geng, S., Wang, Y., & Xu, B. (2023). Effect of pulsed laser pretreatment induced pit-structure on the formation of intermetallic compounds in titanium-aluminum dissimilar welded joints. *Optics & Laser Technology, 167*, 109589. doi:https://doi.org/10.1016/j.optlastec.2023.109589

Zhong, Q., & Wang, D. (2021a). Ultimate strength behavior of laser-welded web-core sandwich plates under in-plane compression. *Ocean Engineering, 238*, 109685. doi:https://doi.org/10.1016/j.oceaneng.2021.109685

Zhong, Q., & Wang, D. (2021b). "Ultimate strength behavior of laser-welded web-core sandwich plates under in-plane compression". *Ocean Engineering, 238*, 109685. doi:https://doi.org/10.1016/j.oceaneng.2021.109685

Zhong, Q., & Wang, D. (2022). Ultimate strength characteristics and assessment of laser-welded web-core sandwich plates under combined biaxial compression and lateral pressure. *Ocean Engineering, 263*, 112324. doi:https://doi.org/10.1016/j.oceaneng.2022.112324

Zhou, X., Huang, Y., Chen, Y., & Peng, P. (2018). Laser joining of Mo and Ta sheets with Ti6Al4V or Ni filler. *Optics & Laser Technology, 106*, 487-494. doi:https://doi.org/10.1016/j.optlastec.2018.05.004

Zou, J., Zhu, B., Zhang, G., Guo, S., & Xiao, R. (2022). Power density effect on the laser beam-induced eruption of spatters in fiber laser keyhole welding. *Optics & Laser Technology, 147*, 107651. doi:https://doi.org/10.1016/j.optlastec.2021.107651