Science Talks 6 (2023) 100170

Contents lists available at ScienceDirect

Science Talks

journal homepage: www.elsevier.es/sctalk

The energy-absorbing characteristics of two-dimensional periodic self-reinforced polypropylene (SRPP) sandwich panel

Quanjin Ma [a,b,*], M.R.M. Rejab [a,b,*]

[a] Structural Performance Materials Engineering (SUPREME) Focus Group, Faculty of Mechanical & Automotive Engineering Technology, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia
[b] School of Mechanical Engineering, Ningxia University, 750021 Yinchuan, China

ARTICLE INFO

Keywords:
Sandwich panel
Two-dimensional periodic core
Honeycomb core
Star core
Quasi-static loading
Failure behaviour
Energy-absorbing characteristics

ABSTRACT

This paper is used the slotting technique to manufacture the self-reinforced polypropylene (SRPP) sandwich structure. The crashworthiness characteristics of the sandwich structures were measured as a function of relative density. In this research, particular focus is placed on examining the energy-absorbing characteristics of sandwich structures with honeycomb and star cores. It was concluded that the SRPP sandwich panel of star core with a length of 60 mm provided the best energy-absorbing characteristics. Moreover, it was shown that the height of the core structure of 30 mm was more stable than the core structure of 60 mm height. In addition, it was indicated that the failure behaviour was highly sensitive to the relative density of the core structure. Furthermore, the SRPP sandwich structure could potentially be used as an alternative lightweight material for recyclable structures.

Video to this article can be found online at https://doi.org/10.1016/j.sctalk.2023.100170.

Figures and tables

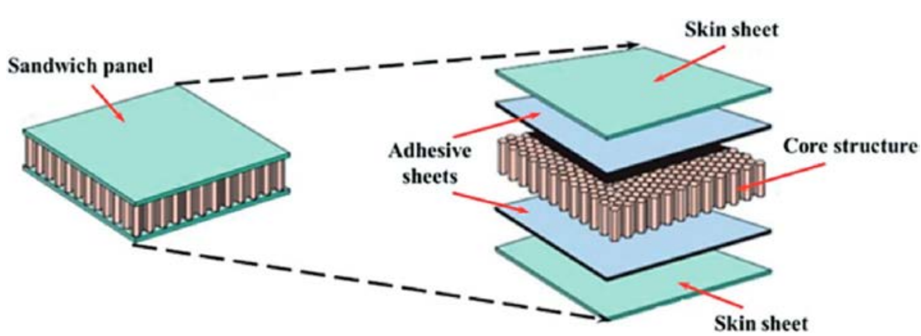

Fig. 1. Schematic diagram of sandwich structure with honeycomb core [1,2].

Abbreviations: SRPP, Self-reinforced polypropylene; PP, Polypropylene; ST, Star core; HC, Honeycomb core; SP, Sandwich panel; EA, Energy absorption; SEA, Specific energy absorption.

* Corresponding authors.
E-mail addresses: neromaquanjin@gmail.com (Q. Ma), ruzaimi@ump.edu.my (M.R.M. Rejab).

http://dx.doi.org/10.1016/j.sctalk.2023.100170
Received 31 December 2022; Received in revised form 19 February 2023; Accepted 20 February 2023

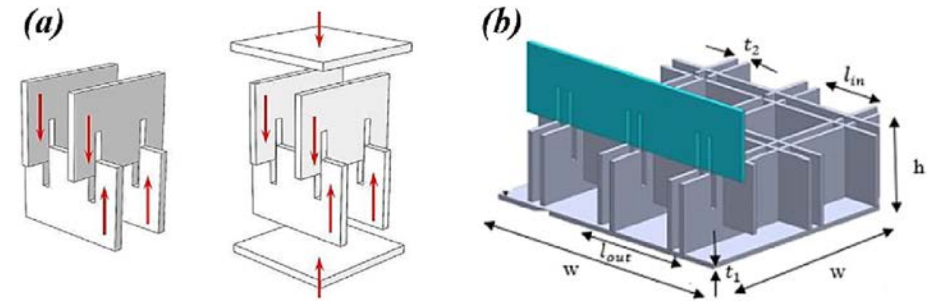

Fig. 2. Schematic diagram of the slotting technique used in sandwich structure: (a) single honeycomb core [3]; (b) interlocking core [9].

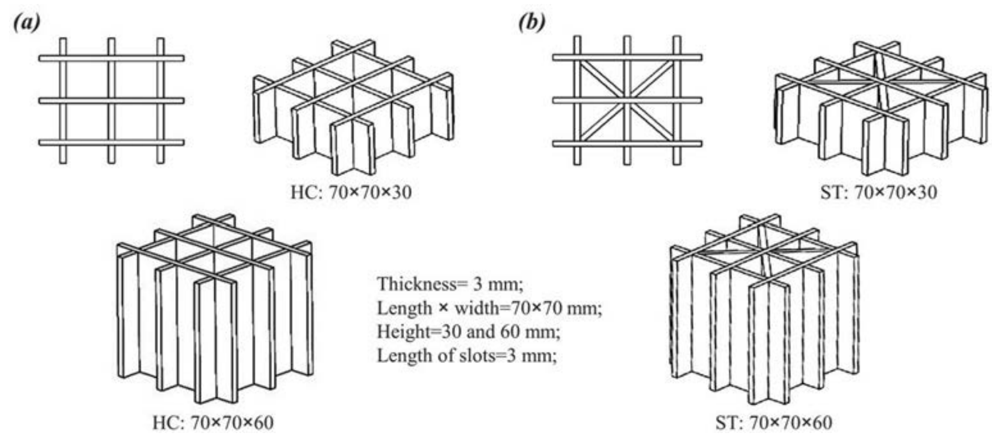

Fig. 3. Structural dimension of two core designs: (a) honeycomb core; (b) star core.

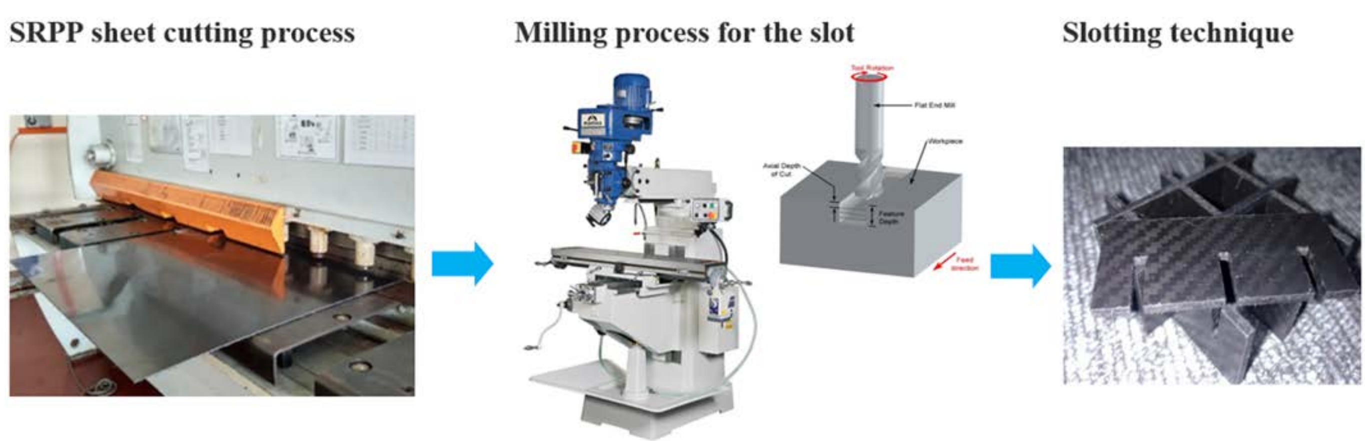

Fig. 4. Fabrication procedure of SRPP sheet for SRPP honeycomb sandwich panel.

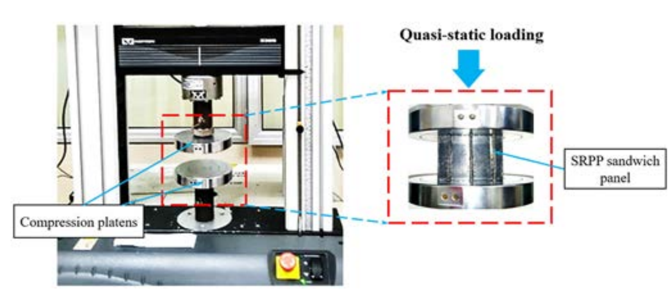

Fig. 5. Experimental setup of SRPP honeycomb sandwich panels under quasi-static loading [4–6].

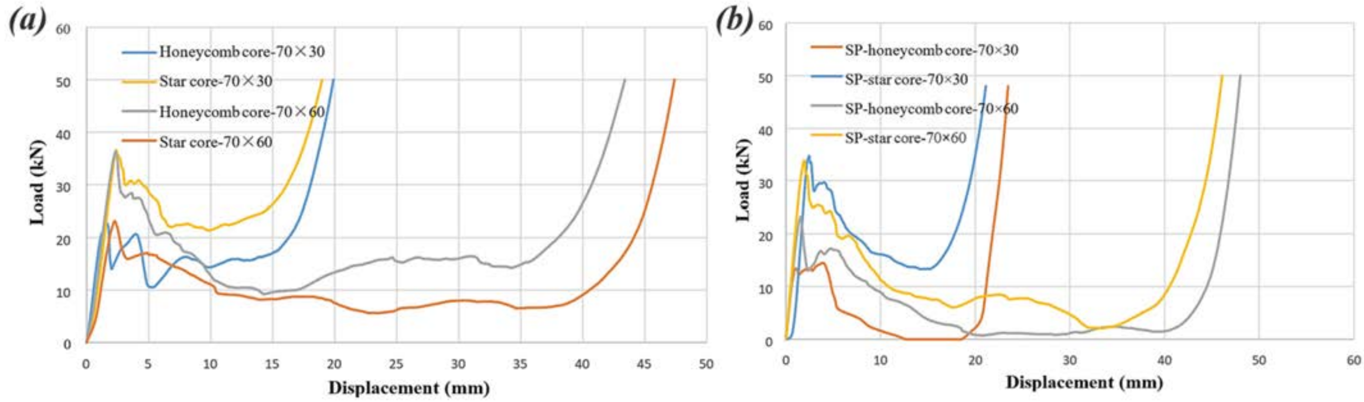

Fig. 6. Load versus displacement curves of SRPP honeycomb core and sandwich panel: (a) core structure; (b) sandwich panel.

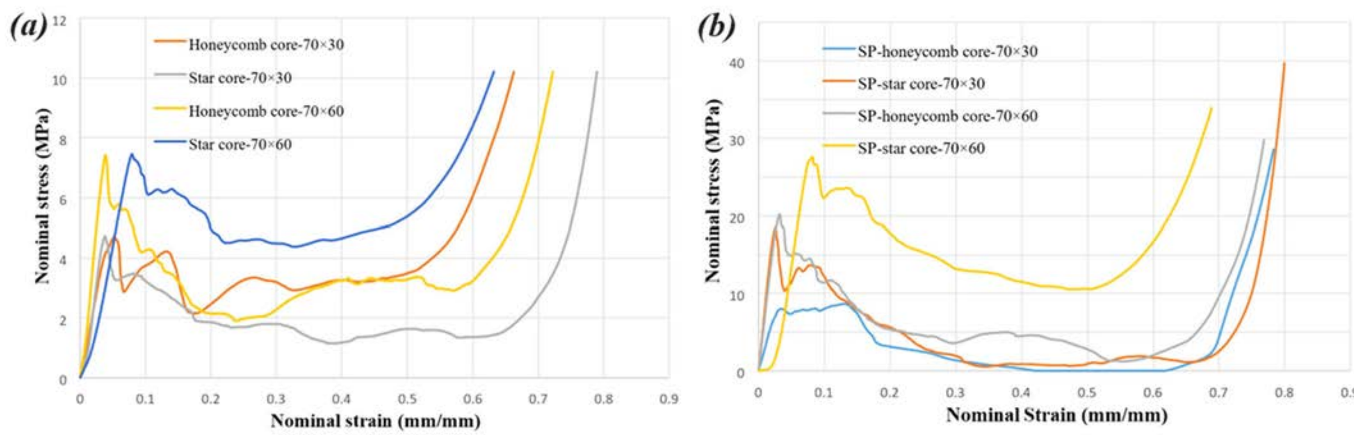

Fig. 7. Nominal stress versus nominal strain curves of SRPP honeycomb core and sandwich panel: (a) core structure; (b) sandwich panel.

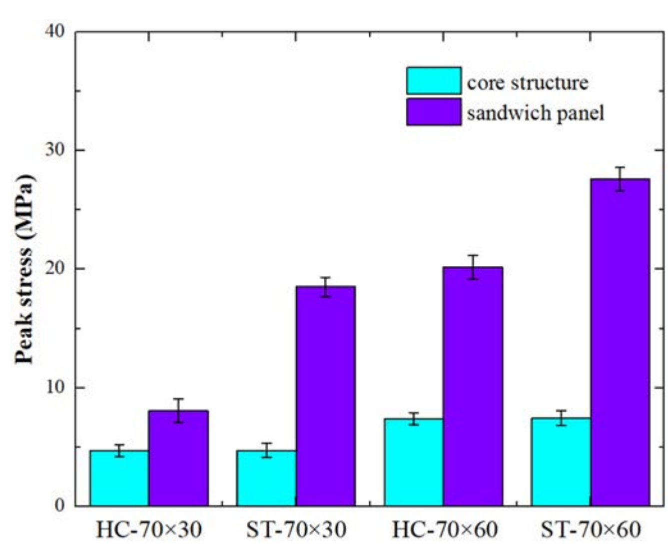

Fig. 8. Peak stress on SRPP core and sandwich panel with honeycomb and star cores [7].

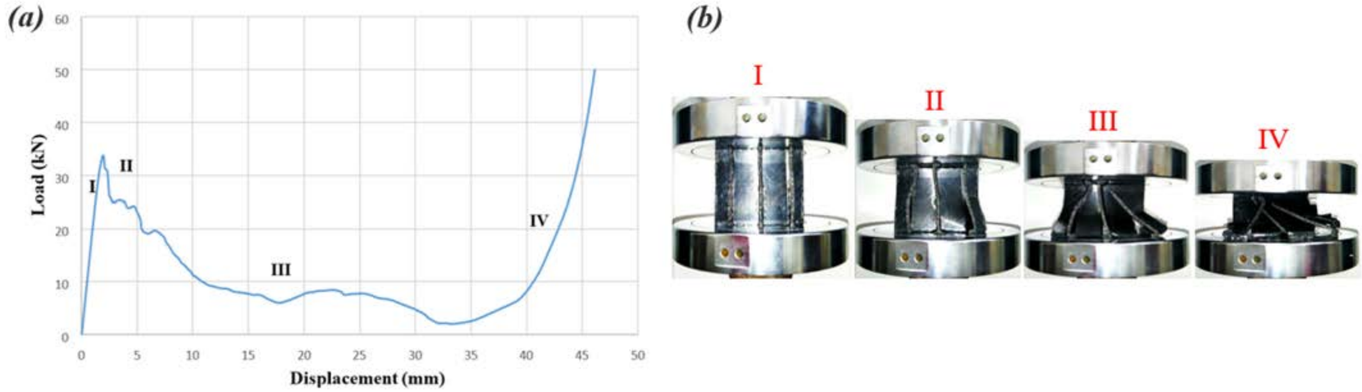

Fig. 9. (a) load versus displacement curve of SRPP honeycomb core; (b) failure behaviour of the core structure under quasi-static loading.

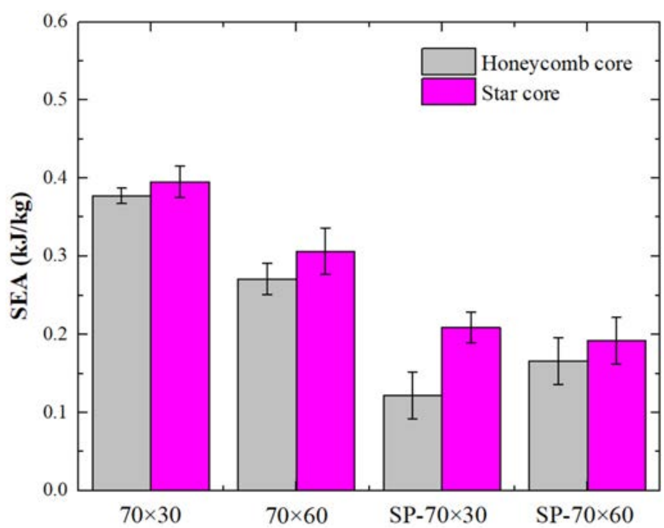

Fig. 10. Specific energy absorption of SRPP core structure and sandwich panel with honeycomb and star cores [8].

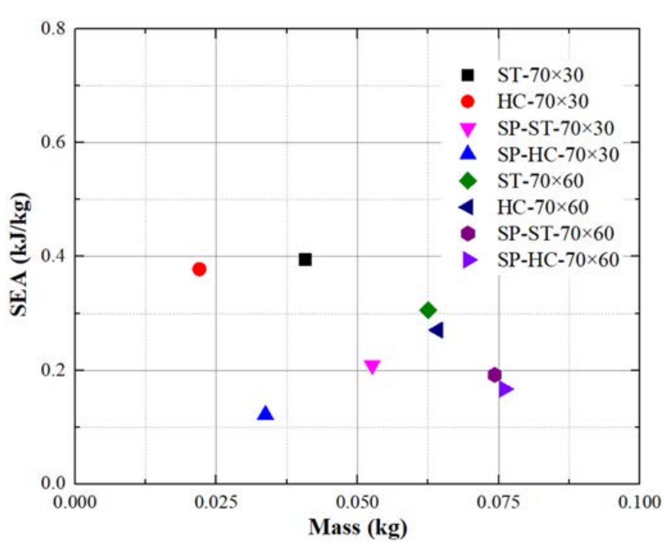

Fig. 11. Specific energy absorption per unit mass of the SRPP sandwich structures in this study.

Table 1
Mechanical properties of SRPP sheet.

Mechanical properties	SRPP
Density (kg/m^2)	920
Tensile modulus (GPa)	5
Tensile strength (MPa)	180
Notched Izod impact strength (J/m)	4750

Table 2
Mechanical properties of polypropylene (PP) adhesive film.

Mechanical properties	PP adhesive film
Density (g/ml)	0.9
Shear modulus (GPa)	60
Modulus of elasticity (MPa)	115
Yield stress (MPa)	3.8
Tensile strength (MPa)	14.1
Ultimate strain (%)	1430

Table 3
Results of the SRPP sandwich panels with honeycomb and star cores under quasi-static loading.

Labels	Mass (kg)	Peak load (kN)	Maximum nominal stress (MPa)	Energy absorption/EA (J)	Specific energy absorption/SEA (kJ/kg)
HC-70 × 30	0.02	23.02 ± 1.02	4.68 ± 0.41	7.42 ± 1.25	0.37 ± 0.12
HC-70 × 60	0.06	36.20 ± 1.53	7.39 ± 0.38	16.25 ± 2.05	0.27 ± 0.05
SP-HC-70 × 30	0.03	13.48 ± 0.55	8.04 ± 1.02	3.61 ± 1.83	0.12 ± 0.08
SP-HC-70 × 60	0.08	23.18 ± 2.17	20.13 ± 1.28	12.82 ± 2.18	0.16 ± 0.03
ST-70 × 30	0.04	36.64 ± 1.42	4.72 ± 0.54	15.67 ± 1.62	0.39 ± 0.05
ST-70 × 60	0.06	23.13 ± 0.83	7.43 ± 0.75	18.62 ± 2.01	0.31 ± 0.02
SP-ST-70 × 30	0.05	34.79 ± 2.02	18.46 ± 0.85	10.56 ± 1.44	0.21 ± 0.06
SP-ST-70 × 60	0.07	33.67 ± 1.39	27.54 ± 1.27	13.38 ± 2.23	0.19 ± 0.11

CRediT authorship contribution statement

Quanjin Ma: Writing – original draft, Investigation, Methodology, Validation. **M.R.M. Rejab:** Supervision, Writing – review & editing.

Data availability

The authors are unable or have chosen not to specify which data has been used.

Acknowledgments

The authors are grateful to the Ministry of Education Malaysia: RDU190158 and Universiti Malaysia Pahang: PGRS180319 for funding this research. This research work is strongly supported by the Structural Performance Materials Engineering (SUPREME) Focus Group.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Q. Ma, M.R.M. Rejab, S. Kang, M.S. Idris, M.A.A.M. Zin, The energy-absorbing characteristics of single spherical-roof contoured-core (SRCC) cell with composite materials, Int. J. Automot. Mech. Eng. 17 (4) (2020) 8265–8273.
[2] Q. Ma, M.R.M. Rejab, J.P. Siregar, Z. Guan, A review of the recent trends on core structures and impact response of sandwich panels, J. Compos. Mater. 55 (18) (2021) 2513–2555.
[3] Q. Ma, T. Kuai, M.R.M. Rejab, N.M. Kumar, M.S. Idris, M.H. Abdullah, Effect of boundary factor and material property on single square honeycomb sandwich panel subjected to quasi-static compression loading, J. Mech. Eng. Sci. 14 (4) (2020) 7348–7360.
[4] M.R.M. Rejab, W.J. Cantwell, The mechanical behaviour of corrugated-core sandwich panels, Compos. Part B 47 (2013) 267–277.
[5] A.K. Haldar, Z.W. Guan, W.J. Cantwell, Q.Y. Wang, The compressive properties of sandwich structures based on an egg-box core design, Compos. Part B 144 (2018) 143–152.
[6] Q. Ma, M.R.M. Rejab, S.A. Hassan, M. Azeem, M.S. Saffirna, Failure behavior analysis of the Spherical-Roof Contoured Core (SRCC) under quasi-static loading: A numerical study, J. Fail. Anal. Prev. (2022) 1–9.
[7] Q. Ma, M.R.M. Rejab, M.M. Hanon, M.S. Idris, J.P. Siregar, 3D-printed Spherical-Roof Contoured-Core (SRCC) composite sandwich structures for aerospace applications, High-Performance Composite Structures, Springer, Singapore 2022, pp. 75–91.
[8] Q. Ma, M.R.M. Rejab, S.A. Hassan, H. Hu, A.P. Kumar, Potentiality of MWCNT on 3D-printed bio-inspired spherical-roof cubic core under quasi-static loading, J. Mech. Behav. Biomed. Mater. 136 (2022), 105514.
[9] S. Alsubari, M.Y.M. Zuhri, S.M. Sapuan, M.R. Ishak, Quasi-static compression behaviour of interlocking core structures made of flax fibre reinforced polylactic acid composite, J. Mater. Res. Technol. 9 (6) (2020) 12065–12070.

Further reading

[1] Q. Ma, M.R.M. Rejab, A.P. Kumar, H. Fu, N.M. Kumar, J. Tang, Effect of infill pattern, density and material type of 3D printed cubic structure under quasi-static loading, Proc. Inst. Mech. Eng. C J. Mech. Eng. Sci. 235 (19) (2021) 4254–4272.
[2] M.A. Quanjin, I.M. Sahat, M.R. Mat Rejab, S. Abu Hassan, B. Zhang, M.N. Merzuki, The energy-absorbing characteristics of filament wound hybrid carbon fiber-reinforced plastic/polylactic acid tubes with different infill pattern structures, J. Reinf. Plast. Compos. 38 (23–24) (2019) 1067–1088.
[3] M. Quanjin, M.R.M. Rejab, M.S. Idris, M.N.M. Merzuki, H. Shaoliang, Compressive properties on the spherical-roof contoured-core cell with different amounts of diamond-shaped notches, IOP Conference Series: Materials Science and Engineering, vol. 788, No. 1, IOP Publishing 2020, p. 012049.

Mr. Quanjin Ma is a Ph.D. postgraduate student at the Faculty of Mechanical and Automotive Engineering Technology (FTKMA), Universiti Malaysia Pahang, Malaysia. He has published more than 40 journals, conference articles, and 7 book chapters. He has reached h-index 17 of Google Scholar within 4 years with 771 citations. He has been appointed as the research assistant and lab demonstrator of the Structural Performance Materials Engineering (SUPREME) Focus Group, Universiti Malaysia Pahang. He has obtained two patents: Malaysia patent: PI 2018701785 and China Patent: ZL 201921360351.

Associate Prof. Ts. Dr. M.R.M. Rejab is an associate professor at the Faculty of Mechanical and Automotive Engineering Technology (FTKMA), Universiti Malaysia Pahang. He has been appointed as Director of German Academic, Collaboration Centre (GACC). His research interests are in novel lightweight structure, polymer composites, sandwich structures, polymeric foam studies, computational mechanics and finite element method, mechanical design and material testing and performance evaluation. He has published more than 100 papers in journals and conferences. He is a Professional Technologies (P.Tech), appointed by Malaysia Board of Technology (MBOT). For international recognition, he is a Chartered Engineer (C.Eng), certified by Institute of Mechanical Engineers (IMechE) UK. He is actively involved as Certified Auditor for the Malaysian Qualifications Agency (MQA) and Technology and Technical Accreditation Council (TTAC) - MBOT. He is also the member of several professional bodies such as Board of Engineers Malaysia (BEM), American Society of Mechanical Engineers (ASME), American Society for Composites (ASC), Malaysian Society for Engineering and Technology (MySET), and others.