High strain rates effect on the dynamic properties of E-glass/jute using SHPB

Muhamad Shahirul Mat Jusoh[1,2], Mohd Yazid Yahya[1,*], Haris Ahmad Israr Ahmad[1], Meor Syazalee Meor Sha[2]

[1]Centre for Composite, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

[2]Department of Polymer Composite, Kolej Kemahiran Tinggi MARA Masjid Tanah, 78300, Masjid Tanah, Melaka, Malaysia

[*]Corresponding e-mail: yazidyahya@utm.my

Keywords: SHPB; Hybrid; Composite

ABSTRACT – Presently, the application of natural fibres widely gains attention from academia and industries as an alternative material in the composite system. The introduction of the hybrid composite using natural and synthetic fibres is extensively investigated on the static mechanical properties. However, the investigation on the high strain-rates effect is less reported due to the difficulty of the experimental set-up as well as the limitation of dynamic testing apparatus. The split Hopkinson pressure bar (SHPB) was utilised in this present study to characterise the dynamic mechanical properties of the hybrid composite between E-glass with jute fibres at three different strain rates - 755, 1363, and 2214 s^{-1}. Results showed that the tested specimens were significantly influenced by the value of strain rates applied. The E-glass/jute specimen exhibited the strain-rate dependent behaviour, whereby the higher dynamic mechanical properties were recorded when the higher strain rates were imposed. The difference between maximum dynamic stress was 12.1 and 23.9% when the strain rates were increased from 755 to 1363 s^{-1} and 1363 to 2214 s^{-1}. In terms of compressive strain, the maximum compressive strain was recorded when the lower strain rates were imposed during testing.

1. INTRODUCTION

The strain-rate effect is widely recognised as a crucial factor influencing the mechanical properties of material [1]. However, there are little studies focusing on understanding the correlation between the factor and the sensitivity of the polymers, particularly in terms of the relevant mechanical properties. Natural fibres of pultruded jute and kenaf reinforced composites were investigated experimentally using SHPB at strain rates of 1021, 1150, and 1340 s^{-1}. It was found that the higher dynamic compression properties were recorded when the higher strain rates were imposed on the tested specimens [2]. Strain rate effects of the composite materials are highly correlated with materials hardening factors. The factors are highly influenced by the types of materials used, manufacturing process, surficial adhesion between fibre and matrix, fibre architecture, loading direction, and the range of applied strain rates when tested on the hybrid composite of carbon/glass at strain rates of 200, 600, and 1000 s^{-1} [3]. Natural fibre of hemp, glass, and hybrid composite of hemp/glass reinforcced vinyl ester were characterised using SHPB. It was found that the hemp/glass composite recorded intermediate dynamic properties between the glass and hemp laminates [4]. The SHPB test was applied on the rice husk/linear low-density PE with the strain rates of 650, 900, and 1100 s^{-1}, and the higher dynamic compression strength and modulus were recorded when the higher strain rates were applied [5]. The objectives of the present work are to investigate the influence of the different high strain rates on the stress-strain curves of E-glass/jute hybrid composite using the SHPB testing apparatus.

2. METHODOLOGY

Hybrid composite of E-glass/jute toughened epoxy was prepared using the vacuum infusion process. The dynamic compressive test was conducted at the strain rates of 755, 1363, and 2214 s^{-1} using the SHPB apparatus. Basically, the SHPB equipment consists of a gun barrel, a striker bar, an incident bar, and a transmitter bar which maintain the elasticity during the test as shown in Figure 1.

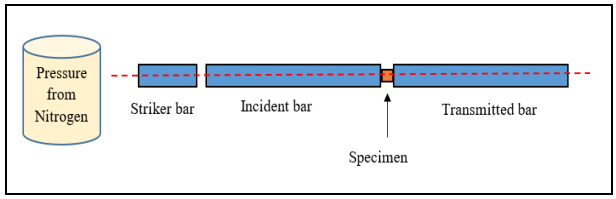

Figure 1 Schematic of SHPB

Initially, the generated pressure from the nitrogen tank was transferred to the striker bar and the applied pressure would accelerate the striker bar and collide with the incident bars. As a result of the collision, the compression wave was generated and travelled down along the incident bar and known as incident wave (ε_i). Meanwhile, at the specimen interface, the wave was partially transmitted into the specimen and referred to as the transmitted wave (ε_t). The remaining wave was reflected and known as reflected wave (ε_r) due to the impedance mismatch between the incident bar and the specimen.

3. RESULTS AND DISCUSSION

As shown in Figure 2, the stress-strain characteristics of E-glass/jute composite had been dominated by the strain rate effect. The higher the strain rates imposed, the higher the maximum stress exhibited by the tested specimens. The E-glass/jute composite recorded the maximum compressive stress of 230, 202, and 175 MPa at the strain rates of 2214, 1363, and 755 s^{-1}, respectively. Similar findings were also reported by the previous literatures [2], [5]–[8] and the increment is attributed by the strengthening effect of the material towards the strain rate applied as suggested by Omar et al. [7]. Conversely, the dynamic failure strain decreases with the increasing strain rates. At the fixed dynamic stress of 150 MPa, the maximum dynamic strains were approximately 0.053, 0.037, and 0.021 with the applied strain rates of 755, 1363, and 2214 s^{-1}, respectively. This suggests that the rapid crack propagation and fibre's failure occurred within a very short time which caused the total failure of the specimens, as stipulated in previous literatures [1].

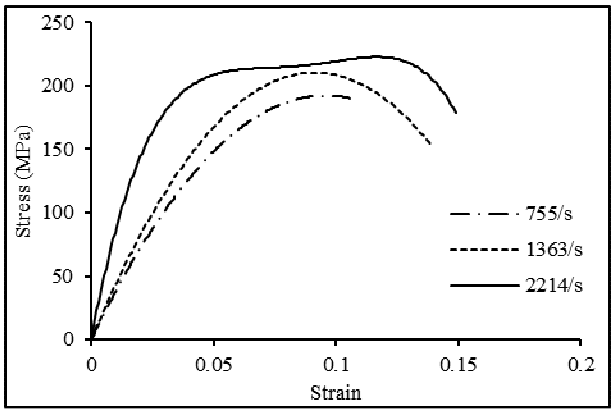

Figure 2 Stress-strain curves of E-glass/jute

4. CONCLUSION

This study explored the high strain rates effect on the dynamic mechanical properties of hybrid composite between E-glass and jute fibres reinforced epoxy at the strain rates of 755, 1363, and 2214 s^{-1}. It was found that the dynamic properties were dependent on the applied strain rates. Thus, when the strain rates increase the dynamic stress increases. However, the dynamic strain recorded the contrary pattern.

ACKNOWLEDGEMENT

Authors would like to thank to Kolej Kemahiran Tinggi MARA (KKTM) Masjid Tanah, Melaka for providing research fund to support this study and has made this work possible.

REFERENCES

[1] Z. Song, Z. Wang, H. Ma, and H. Xuan, "Mechanical behavior and failure mode of woven carbon/epoxy laminate composites under dynamic compressive loading," *Compos. Part B Eng.*, vol. 60, pp. 531–536, 2014.

[2] M. Firdaus, H. Akil, Z. Arifin, A. A. M. Mazuki, and T. Yokoyama, "Dynamic properties of pultruded natural fibre reinforced composites using split Hopkinson pressure bar technique," *Mater. Des,* vol. 31, pp. 4209–4218, 2010.

[3] P. Zhu, J. Lu, Q. Ji, and Z. Cheng, "Experimental study of in-plane mechanical performance of carbon/glass hybrid woven composite at different strain rates," *Int. J. Crashworthiness*, pp. 1–13, 2016.

[4] D. Kim, W., Argento, A., Lee, E., Flanigan, C., Houston, "High strain-rate behavior of natural fiber-reinforced polymer composites.," *J. Compos. Mater.*, vol. 46, pp. 1056–1065, 2011.

[5] N. S. Abdul Wahab, M. F. Omar, H. Md Akil, Z. A. Ahmad, and N. N. Zulkepli, "Effect of surface modification on rice husk (Rh)/linear low density polyethylene (LLDPE) composites under various loading rates," *Mater. Sci. Forum*, vol. 840, pp. 3–7, 2016.

[6] H. Akil, Z. Arifin, M. Firdaus, O. Hui, and D. Hui, "Measurement on the dynamic properties of nanosilica/polypropylene composite using split Hopkinson pressure bar technique," *Composite Material Research Laboratory, University of New Orleans*. pp. 1–3, 2010.

[7] M. F. Omar, H. M. Akil, and Z. A. Ahmad, "Measurement and prediction of compressive properties of polymers at high strain rate loading," *Mater. Des.*, vol. 32, pp. 4207–4215, 2011.

[8] N. S. Suharty, H. Ismail, K. Diharjo, D. S. Handayani, and M. Firdaus, "Effect of kenaf fiber as a reinforcement on the tensile, flexural strength and impact toughness properties of recycled polypropylene/halloysite composites," in *5th International Conference on Recent Advances in Materials, Minerals and Environment (RAMM) & 2nd International Postgraduate Conference on Materials, Mineral and Polymer (MAMIP)*, 2016, vol. 19, pp. 253–258.