Accepted Manuscript

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PII: S0263-8223(17)32089-5
DOI: https://doi.org/10.1016/j.compstruct.2018.07.024
Reference: COST 9941

To appear in: *Composite Structures*

Received Date: 5 July 2017
Revised Date: 10 May 2018
Accepted Date: 4 July 2018

Please cite this article as: Yuan, Z., Chen, X., Zeng, H., Wang, K., Qiu, J., Identification of the elastic constant values for numerical simulation of high velocity impact on Dyneema® woven fabrics using orthogonal experiments, *Composite Structures* (2018), doi: https://doi.org/10.1016/j.compstruct.2018.07.024

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Identification of the elastic constant values for numerical simulation of high velocity impact on Dyneema® woven fabrics using orthogonal experiments

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Abstract:

Dyneema® fibres and fabrics are widely used for ballistic protection due to its lightweight and super mechanical properties against high strain rate impact, and finite element (FE) simulation and analysis are used to study the response to the impact in parallel to the experimental-based research methods. However, elastic constants of the yarn except the Young's modulus were difficult to obtain and were basically assigned based on assumptions and approximations in the FE modelling, which caused some inaccuracies. This paper reports a study on the influence of each elastic constant of Dyneema® yarn model in modelling a single layer Dyneema® woven fabric against ballistic impact using the orthogonal experiment method. Orthogonal table L_{25} (5^6) was employed to analyse six factors (*i.e.* E_{11}, E_{33}, ν, G_{13}, G_{23}, and their interactions) with each having five levels. The ballistic modelling results were validated against the experimental results, *viz.* energy absorption, failure time of the first yarn broken and number of failed yarns. According to the orthogonal analysis, G_{13} was shown as the most significant in influencing the simulated results, with a confidence level of more than 95%, and ν was the least significant. Through the orthogonal study, the combination of levels of the elastic constants that led to a significant agreement between the FE and practical results was identified.

Key words: Dyneema® yarn; elastic constants; orthogonal experiment; ballistic impact; woven fabric

1. Introduction

Finite element method (FEM) is a widely used for prediction and analysis of materials and structures for ballistic protection. It facilitates a deep and comprehensive understanding of the material responses, and would lead to the improvement of the materials. However, developing a reliable FE model demands several inevitable steps, one of them being to define properties to the material with accuracy [1].

Ultra-high molecular-weight polyethylene (UHMWPE) yarn (*e.g.* Dyneema® and Spectra®) is one of the most widely man-made yarns for ballistic protection due to its lightweight and super mechanical properties against high strain rate impact. Finite element (FE) simulation and analysis are used to study the response to the impact in parallel to the experimental-based

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