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CHARACTERIZATION AND STATISTICAL ANALYSIS OF SINGLE FIBER STRENGTH OF FIBERS AT VARIOUS PROCESSING STAGES

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1 Introduction

For numerous applications exploiting high performance composite materials, in-service safety and reliability assessment is a key challenge for engineers. Composite material performances rest largely on the mechanical behavior of its constituents and especially on the strength of technical fibers of which it is made. Researchers since long have been working on simulation and modelling tools to understand and predict the failure behavior of composites. It is essential that the simulation or modelling tools are provided with accurate input parameters. One of the most important input parameters for composite modelling tools is the single fiber strength and its distribution; and correctly capturing fiber strength statistics and failure kinetics is crucial to the success of composite stochastic strength models.

Single fiber test (SFT) is one of the most popular way of characterizing the fiber strengths, the others being bundle fiber test and fragmentation tests. SFT too has its own limitations: complex sample preparation, misalignments, lengthy and time-consuming process and prone to errors because of major human intervention [1, 2]. The characterization of fibers through SFT is hence challenging, but it is the only unambiguous means of characterizing fiber strength data to feed into the micro-mechanical models. Despite great progress in characterization techniques, many obstacles remain to obtain accurate fiber strengths and most studies have reported the difficulty in obtaining fiber strength data which can accurately represent the entire fiber population for each application.

2 Research questions

Manual SFT has several limitations only some of which can be completely overcome. An automated SFT is hence the way forward to characterize and analyze the single fiber strength properties [3, 4]. In this work the challenges for automatic characterization of carbon and glass fibers will be addressed. Apart from this, the paper answers the very important but so far unanswered question: if the tensile strengths and Weibull parameter of fibers be identified from the raw bobbin or from the final reinforcement fabric? This work will help the modelling experts to choose the right input parameter value for the tensile strength and it will also help the textile manufacturer to understand if the manufacturing process and the process parameters (temperature, mechanical vibration, abrasion, etc.) are affecting the fiber strength distributions and to what level.

The work also explores the ideal distribution for single fiber tests. Experimental uncertainties are evaluated and provided.

3 Fiber strengths and distribution

The strength of a single fiber cannot be captured in one single average value. Single fibers normally exhibit a distribution of strengths that could be represented by using a probabilistic approach. The Weibull distribution is a good representation of the weakest link behavior of brittle single fibers [5]. Using the 2-parameter Weibull distribution assumes that fiber failure is controlled by the random distribution of a single type of defect. That being said, the classical 2-parameter Weibull distribution is not able to capture the non-linear deviation of the fiber

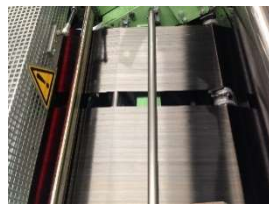
strength distribution accurately while the 3-parameter Weibull distribution would assume that the minimum strength value in the data set represents the weakest fiber in the population which is often an incorrect assumption. Hence as suggested by Berger and Jeulin's [6] and further by Joannes et. al. [3] a Truncated Weibull distribution can be an ideal choice where; a truncation limit is set. This truncation limit is a limit below which the data is not available and that it is not necessarily a deterministic value and could be considered as a continuous variable.

4 Materials and methods

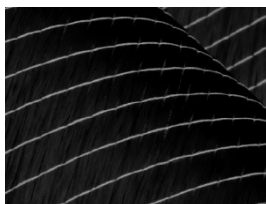
In this study we characterize carbon T700S and E-CR glass fibers in an automated SFT equipment from Dia-Stron Ltd. Carbon fibers are extracted i) from raw bobbin, 12k procured from Toray ii) from spread sheet/tape produced on a spreading machine using the 12k bobbins and iii) from the NCF produced using the manufactured spread tape on a multi-axial machine from LIBA. Similarly, glass fibers are extracted and tested at these three stages as shown for carbon fibers in Fig. 1.



a) Carbon raw bobbin



b) Carbon spread tape



c) Carbon UD NCF

Fig.1 Carbon fiber population at several processing stages

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