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Design of a fibrous composite preform for wind turbine rotor blades

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ABSTRACT

The present work addresses the different factors and challenges one must cope with in the design process of a composite preform used for the load-carrying main laminate of a wind turbine rotor blade. The design process is split up into different key elements, each of which are presented and discussed separately. The key elements are all interconnected, which complicate the design process and involves an iterative procedure. The aim is to provide an overview of the process that governs the design of composite preforms for wind turbine blades. The survey can be used as an information source on composite preform manufacturing. Basic knowledge on wind turbine blade technology and composites is assumed.

1. Introduction

Fibre reinforced composites are the natural material selection for wind turbine rotor blades due to their large strength and stiffness to weight ratio compared with conventional structural materials [1,2]. During the recent decade, the rotor blade size development has increased rapidly, as illustrated in Fig. 1. In turn, much effort has been put on the improvement of the mechanical properties of these composite materials in order to reduce the blade weight by materials savings.

The processed composite in the blade consists of resin encapsulated fibres arranged in a preform. A composite preform is defined as the unconsolidated assemblage of dry fibres, yarns, and/or fabrics [3]. Edwards [4] presents a general overview on the present composite technology including preforms. The design of a composite preform is by far a trivial task, and involves many different engineering aspects. In the following, the design process for a composite preform used in the load-carrying main laminate of a wind turbine rotor blade, is outlined. The location of the main laminate in a blade is shown in Fig. 2.

A simplified interaction scheme showing the key elements regarding the preform design process, is presented in Fig. 3.

In order to design a suitable preform, one must be aware of all the elements mentioned in Fig. 3, and it is noted that the elements in the design process are interconnected in a non-coherent manner. For instance, choosing a certain filament diameter affects mechanical and processing properties, and in order for the preform to be certified for blade use there might be restrictions on the allowable fibre diameter. Therefore, the scheme presented in Fig. 3 is iterative, and requires control of all the different elements. The preform must also be designed according to a number of business and regulation requirements, e.g. cost and a certain required strength (safety). The general requirements for future composites used in wind turbine blades are, [5]: enhanced mechanical properties (especially stiffness and fatigue), improved processing time, lower (or at least similar) cost as conventional fabrics, and improved reliability. In turn, a given preform must be designed to meet these requirements.

In the following survey, each of the key elements presented in Fig. 3 are introduced and discussed in relation to preforms for wind turbine blades. The survey is limited to an introduction and discussion of the key elements, and should be considered as an information source on preform design for wind turbine blades. The structure of the survey is that each key element is presented separately following the progress in Fig. 3. For each key element, the common factors in blade manufacturing are outlined, and the most widely used is passed onto the next key element. For instance, choosing the basic fibre material forms the basis for a presentation of the next key element, namely the filament. Using this format, the preform design process is gradually outlined following Fig. 3.

2. Material

The traditional baseline material selection for fibres used in wind turbine rotor blades is glass, which has been used since the

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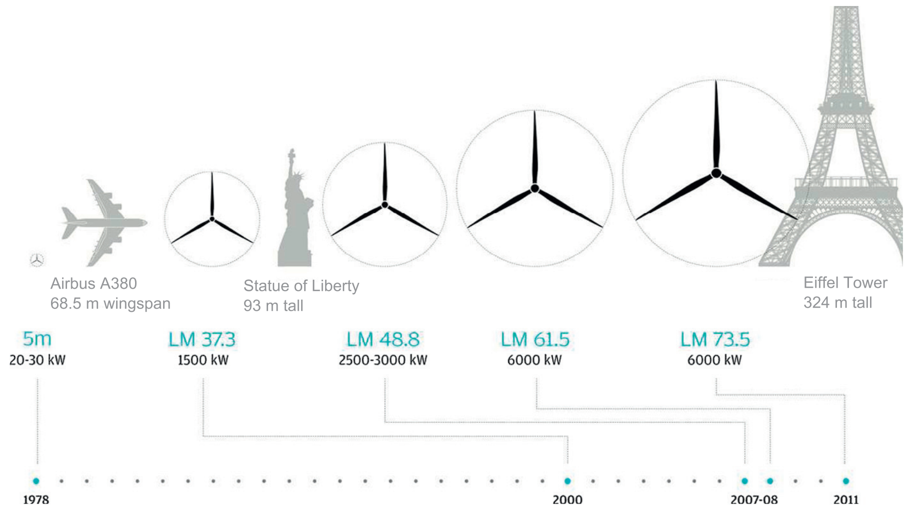

Fig. 1. Size development of LM Wind Power blades during the last decades. The number LM XX denotes the blade length in metres, and the number below the associated electrical power output from the turbine.

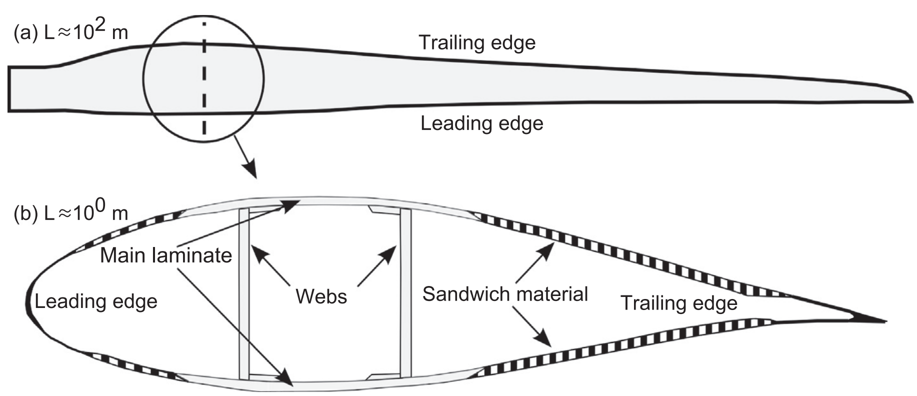

Fig. 2. Sketch of a wind turbine rotor blade along with main components. (a) Overview. (b) Cross-section.

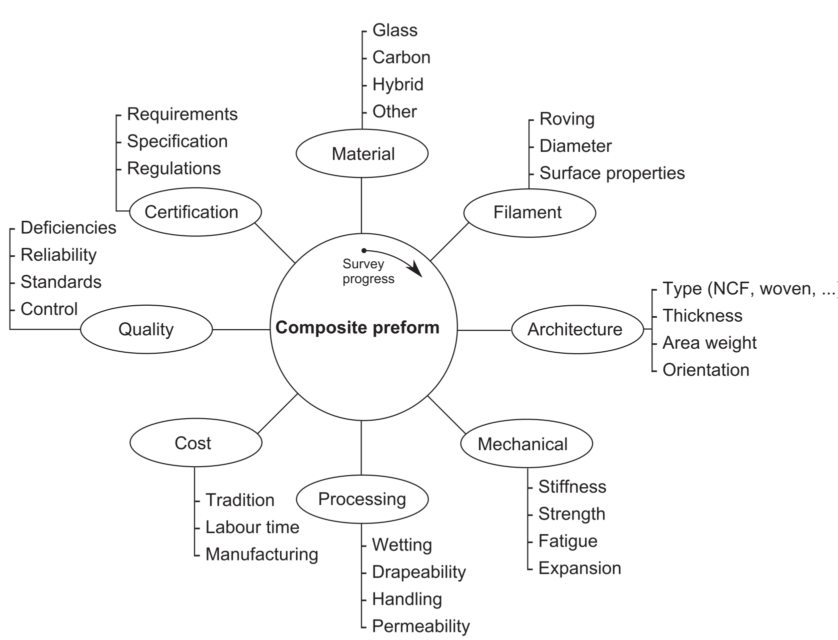

Fig. 3. Interaction scheme with key elements and associated influential factors for consideration in the design of a composite preform for wind turbine blades. The key elements are encircled by an ellipse, and selected influential factors are mentioned in connection to these.