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Effect of surface finish on the mechanical behaviour of Dacron© 360 woven

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ABSTRACT

In the present paper some experimental analyses of Dacron© 360 woven with and without surface treatment are presented to evaluate the effect of this treatment on the constitutive behaviour. This woven, widely adopted in sail manufacturing, is obtained by weaving polyethylene terephthalate (PET) yarn and it shows some peculiar features due to the manufacturing process. The experimental tensile tests, clearly show the orthotropy behaviour of the material. The effect of the treatment results in a stiffer behaviour especially along the warp and bias direction and in an increment of ultimate strength in all directions.

1. Introduction

Learning from history, it is well known that human resources have always been largely employed for the development of efficient transport machines. A 5th millennium BC painting, representing a ship under sail, is the first example of the effort to achieve this fundamental goal (Carter, 2006). Nowadays, the development of thermal engines has not relegated the sail to only recreational use. The need to limit greenhouse gas emissions has driven scientific research in re-examining sail technologies. Moreover, sail applications could play fundamental roles in developing technological solutions from many engineering research fields (materials, aerodynamics, hydrodynamics, etc.). In the early age, sails were made by means of only natural fibres like cotton or flax, the latter was the traditional fibre until it was totally replaced by cotton during the 19th century. Both of these natural fibres have similarly poor resistance to rot, UV light, and water absorption. In contrast they have different mechanical properties, flax is stronger, whereas cotton is lighter. With developments of aerodynamics understanding in the early 20th century, the sail plan form is becoming taller and flatter than before, making the natural fibres obsolete. At the same time, the development of synthetic fibres, such as polyester, drove the sail design toward modern configurations leading sail manufacturers to study a wide range of materials with different mechanical characteristics. It follows that in order to correctly design, a deep knowledge of the mechanical behaviour of the selected material is needed. In literature many papers regarding the numerical (see, e.g. Badel et al., 2008; Ingrassia, 2007; Gasser et al., 2000) and experimental studies (see, e.g. Triki et al., 2011) on cloths are available. From the other hand very few papers regarding the experimental analysis of sail cloths can be found. In this framework Dacron constitutes a fundamental reference point due to both its popularity in sail design and the surface treatment it undergoes during the manufacturing process.

Aim of the present paper is to analyze, through experimental tests, the effects of the cloth treatment on the mechanical behaviour of a commercial woven fabric of Dacron© 360. The number indicates the weight in grams of a piece of cloth whose surface is equal to one square meter. The paper is organized in many sections handling the following topics are: (1) a brief introduction to sail design; (2) geometrical analysis of the cloth with and without treatment; (3) experimental analysis by means of tensile tests (performed following international standard) to identify the treatment influence on the mechanical characteristics; (4) experimental analysis by means of cyclic tests in order to check the treatment influence with respect to time-variable load; (5) analysis of the tested specimens and discussion on the obtained results. All cloths (with and without treatment) tested in the present paper, have been produced and provided by world leading industry Dimension-Polyant (DP) GmbH.

2. Sail design

The sail is fundamentally characterized by its shape and its ability to consistently maintain that shape. The above described

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features rely mostly on the sail design (the way panels are placed together) and on the sail cloth used. In the early time, sail construction focused the attention to the development of the cloth; as a consequence, for a long time, sail design followed the vertical scheme (Fig. 1a) in order to ensure long duration thanks to double cloth thickness along panel junction. At the end of the 19th century the great Nathanael Herreshoff suggested to change into cross cut scheme in order to avoid the cotton canvas' tendency to distort under load. Following this scheme the cloth should be oriented with fill along maximum stress direction (Fig. 1b). However, this suggestion has not been adopted until 1920.

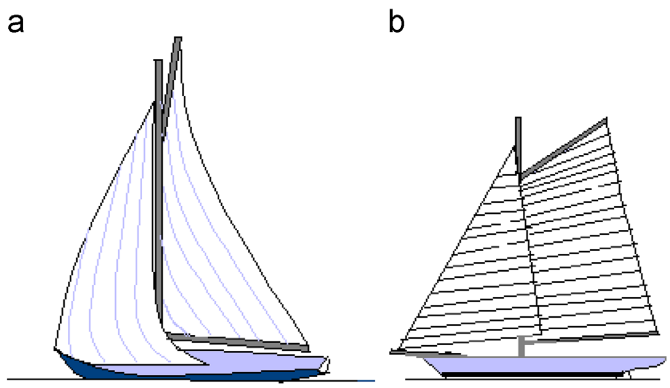

Fig. 1. (a) Vertical seam construction scheme; (b) Cross cut construction scheme.

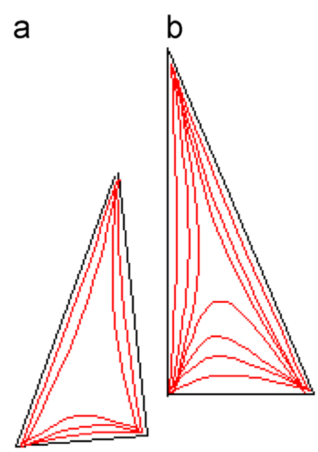

Fig. 2. Principal stress directions in upwind condition: (a) Headsail; (b) Mainsail.

The developments of the scientific knowledge in aerodynamics and in materials behaviour suggested an optimization approach (Ingrassia, 2012) to the sail construction. To this aim, i.e. to improve the sail performance, sailmakers tried to take advantage of the anisotropic cloth characteristics orienting panels along the maximum stress direction. A typical sketch of the principal stress direction for sail in upwind condition is reported in Fig. 2. The above-described approach led to different sail cuts, the most adopted of which (radial, biradial and full radial) are sketched in Fig. 3. It is fundamental to remark that sail is a 3D shape subjected to several time-variable wind and sea conditions; it follows that the principal stress directions are also time-variable. Therefore, in order to retain the designed shape and to show similar performances in all wind and sea conditions it is required that all yarn directions (warp, weft and bias, see Fig. 4) possess the necessary strength and stiffness.

Nowadays, usually adopted sail cloths are obtained by weaving synthetic fibres, the most adopted of which are: Nylon, Polyester (PET), PEN fibre (Pentex), Kevlar, Technora, Twaron, Spectra, Dyneema, Certran, Zylon (PBO), Vectran, Carbon fibre. Due to its technological characteristics and low price, PET (whose commercial name is Dacron©) is the most largely adopted material in sailcloth construction especially in the cross cut configuration. The Dacron© sailcloth is a cloth with different mechanical performances in warp and weft directions showing a relevant weakness in bias direction. In order to overcome this drawback and to improve cloth performances, manufacturing industries defined several cloth treatments also called '*finishes*'. Another approach adopted to overcome the above described feature is that of manufacturing Dacron© cloths with threads of different characteristics in weft and warp directions combined with different cloth treatment.

3. General analysis

As confirmed by DP, among the sailcloths on sale, Dacron© 360 is that widely adopted by sailmakers. This sailcloth is available with only one type of treatment, called impregnating treatment, consisting in running the cloth through a bath of a melamine resin and squeezing it. Depending on the amount of resin remaining in the cloth after squeezing process, different stiffness levels are obtained. Dacron© 360 is available only with a medium stiffness level, referred to as MTO.

From the above remarks it follows that the treatment process implies a density increment of the treated cloth with respect to the non-treated one. In order to characterize this increment (i.e. the amount of melamine resin in the treated cloth), two specimens, with the same shape and dimensions, from treated and non-

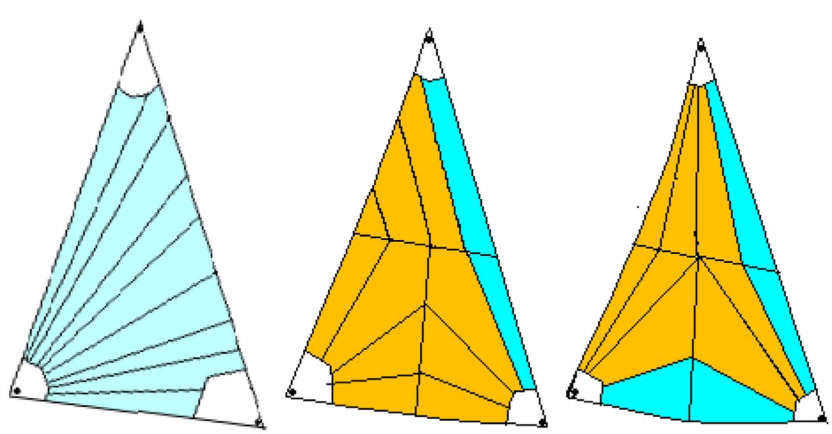

Fig. 3. From left to right: radial, biradial, full radial construction scheme.