DESING, INSTALLATION AND OPERATION OF A PILOT SCALE FIBRE SIZING LINE

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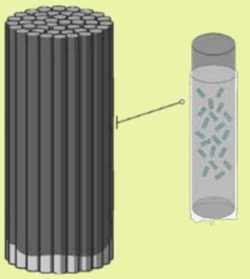
Context

Market needs in the composite sector are reaching an all-time high with the ever-growing demands in the yearly productivity. The global CF & CFRP market size is expected to be 35.5 USD billion by 2025, registering a CAGR of 12.4% during the forecast period. This market growth is attributed to the increased demand for carbon fibre from the aerospace and wind energy industries. Besides the technological aspect, there is also a thorough scientific investigation that needs to be performed to enable multifunctionality in advanced composite materials. In this work, both the optimum operation conditions and the sizing solution are being examined, to provide the best results in terms of surface morphology and mechanical properties.

Aim

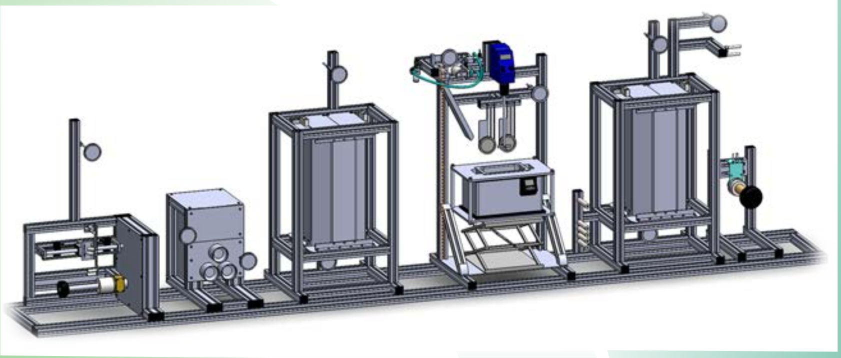
This study focuses on the design, installation and operation of a pilot scale, carbon fibre sizing line. The main goal is the production of fibres with enhanced mechanical properties and multifunctionality, through the incorporation of nanomaterials in sizing solutions.



Carbon fiber functional sizing concept

Method

In this section the main components of the pilot scale carbon fibre sizing line are presented.



Let off tension creel: the fibre spool is mounted on this compartment and its role is to feed the fibre to the de-sizing unit and provide the required tension setting in cooperation with the take-up winder (analyzed below).

De-sizer: one of the most important aspects of the sizing line is the removal of the already existing sizing at the commercial fibre. This is accomplished at the de-sizing unit, where specific temperatures are reached to remove it. The temperature range is wide and covers temperatures up to 600°C enabling the user to remove every coating that is deemed unnecessary.

Fibre sizing bath: this part is consisted of the bath rollers, sizing bath, squeeze rollers and overhead stirring system. The bath rollers guide the de-sized fibre through the sizing bath where a solution with the users' desired composition coats the fibre. The overhead steering rotor is submerged in the solution where it continuously roils to avoid its sedimentation. Subsequently, the squeeze rollers remove the excess solution from the fibre so that a uniform coating is achieved.

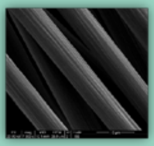
Fibre drying heater: as the fibre passes through the squeeze rollers, the drying heater evaporates the remaining solvent and slightly solidifies the coating around the fibre. The temperature of the dryer does not exceed 300°C.

Feed roller system: this section is used to pull the fibre from the let off creel. Its speed is adjusted from the user at the control panel. It is important to note that the speed is of utmost importance as the user needs to make sure that the fibre stays long enough at the de-sizer and the dryer so that each process is completed successfully.

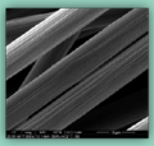
Take-up Winder: Take-up spindle winds the fibre with mechanical traverse system. The spindle is driven by a constant torque motor. High tension is not required for the fibre winding, but a specific ratio between the tension of the feed roller inlet and outlet needs to be followed. Tension is adjusted by changing the torque on the control panel.

Results

The ideal temperature for the de-sizer in combination with the operation speed needs to be investigated. Firstly, three different temperatures for the de-sizer were chosen for the complete removal of the initial commercial carbon fibre sizing (350/ 400/ 600ºC), while operation speed varied from 0.2m/min to 2m/min. Scanning Electron Microscopy (SEM) proved that 600°C was the most optimal temperature as the removal of the initial coating was nearly absolute, regardless of operation speed. In 350 and 400ºC, even on the lowest possible operation speed, the sizing was partially removed.

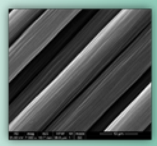


600ºC – 2min



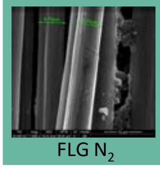
600ºC – 18sec

Optimum solid content concentration in sizing solution is also investigated at pilot scale, as it has a major impact on coating's thickness and morphology at surface. If concentration is low, sizing may not protect the fibre from safe handling, however if it is too high, it appears far too thick and no uniform distribution is achieved. Taking the previous founding into account, total solid content concentration of 1, 2.5 and 5% were put to the test. The main goal was to find which one would spread the coating more evenly throughout the entire fibre whilst maintaining its original fibre structure and not becoming a solid excess mass. 1% solid content concentration exhibited the most uniform coating and it was chosen as the best fit as proved from Scanning Electron Microscopy.

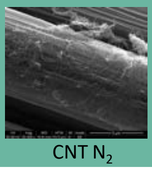


1% solids

Developing sizing solutions which are compatible with epoxy resins for carbon fiber coating where one of the main purposes of this study. Commercial sizing solution (Michelman's Hydrosize® HP2-06), with functionalized nanoparticles (carbon nanotubes - CNTs and few layer graphene - FLG) and Toray's carbon fiber FT300B 6000-40D were used. After initial assessment on lab scale, the sizing solutions that showed better affinity and mechanical behavior are those with CNTs and FLG, which were functionalized with N_2 and with a nanomaterial content of 0.1% wt in total formulation.



FLG N_2



CNT N_2

Affinity

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