FEATURE

Prospects of wet-laid nonwovens for organosheet-products

Angelika Endres[1,*], Steffen Schramm[1], Claus Lütke[2] and Sebastian Nendel[3]

[1] Papiertechnische Stiftung, Germany
[2] Institut für Textiltechnik, RWTH Aachen University, Germany
[3] Cetex Institut für Textil- und Verarbeitungsmaschinen gemeinnützige GmbH, Technical University Chemnitz, Germany

Using the paper process to obtain short-fiber-based reinforcements.

Rising energy and raw material prices have made lightweight components an increasingly attractive alternative, especially for vehicle and aircraft construction. Fiber-reinforced (thermo-) plastics or polymers (FRP) make it possible to meet the present requirements for resource conservation and CO_2 reduction. They are manufactured from high-performance S-glass, basalt or carbon fibers. Therefore, the amount of FRP waste from manufacturing and at end of their life will increase drastically and in particular needs to be considered for carbon fiber reinforced plastic (CFRP). Research is dominated by the quest for techniques to regain the fibers from (C)FRP waste. While dry carbon fiber waste (from cutting, stamping, etc.) is mainly treated mechanically to regain fibers, wet waste has to be recycled via pyrolysis or solvolysis. So far, only pyrolysis-based recycling is realized in industrial scale. Both options lead to fiber fractions with limited and various fiber length, mainly <60 mm. Therefore applications for those recycled fibers needs to be identified, hence, this paper focuses on the transformation of recycled fibers into a sheet material. Furthermore the fibers resulting from the pyrolysis are weaken and brittle after the high temperature treatment and tend to shortening and dusting during further processing. For this reason the wet-laid process is an appropriate route of transforming short reinforcing fibers, for example, recycled carbon fibers, in a processable raw material – a nonwoven. As mixing of the fibers takes place in aqueous solution, hereby fiber shortening is decreased and dusting is minimized as long as there is residual moisture content.

E-mail address: Angelika.Endres@ptspaper.de.
**Corresponding author.* Endres, A. (Angelika.Endres@ptspaper.de)

Wet-laid process

The manufacturing process for wetlaid-nonwovens is derived from the papermaking process. The process may be used to create webs of all types of fibers which can be dispersed in fluids. Basically the process consists of three main stages: (i) the dispersion of the fibers in water, (ii) web formation and (iii) drying/impregnation as depicted in Fig. 1.

During stock preparation short fibers (generally <30 mm) are dispersed in water, frequently together with cellulose pulp (acting as a binder) to give a dispersion with a density of 0.1–0.8 g/l. This concentration is ten times more dilute than that used for paper manufacture to assure a uniform fiber separation. Continuous web formation is achieved by the fibers being deposited onto an inclined screen. Water is then uniformly sucked off over the machine width through suction boxes located beneath the screen. Deposition of the fibers on the screen is controlled by the filtration resistance of the web that builds up during the process. The principle is highlighted in Fig. 2.

Fiber orientation can be regulated partially by adjusting the web-forming speed and the suspension rates. A randomized web is formed if the two rates are the same, whereas a difference in the rates favors the formation of a unidirectional web. As a result the materials are non-isotropic. The two resultant main directions are called 'machine direction' (MD) in flow direction and 'cross direction' (CD) orthogonally to it. The minimum requirement for 'consolidation' of the nonwoven is drying of the web by means of a suction drum or can dryer. Cohesion of the web is a result of fiber to fiber friction (entanglement) or chemical bonding by means of a binder. The binder can be precipitated on the fibers (preferably cellulose pulp) prior to web formation by coagulation in the mixing vat. Binders are, however, usually applied by

0034-3617/ http://dx.doi.org/10.1016/j.repl.2017.07.002

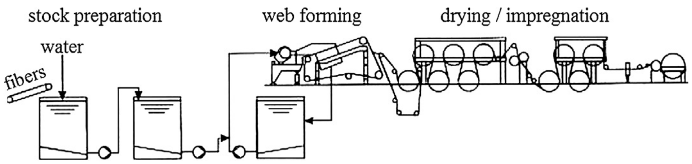

FIGURE 1

Set-up and main production stages of the wet laid process according to Pill and Afflerbach [1].

spraying, padding, foaming, screen printing, or saturation – the impregnation – prior to final drying.

The process itself and the subsequent transformation in a composite show high potentials and severe restrictions at the same time. Economic production and good processability and good surface appearance are some of the advantages. One very important advantage is the ability to mix reinforcing fibers with thermoplastic matrix fibers in 'one step'. On the other side limited fiber volume content and limited drapability are its main backdrafts.

Hence, it is makes sense to combine wet-laid nonwovens with other reinforcements, for example, airlay nonwoven or UD-tape to tailored hybrid composites. This approach was considered in several public funded research projects, which will be introduced shortly in the following paragraph.

Development of hybrid carbon fiber reinforcements for organo-sheets ('FullCycle')

PTS (Papiertechnische Stiftung, Germany) was collaborating in the 'FullCycle'-Project (IGF-Reference 18717BG) with ITA (Institut für Textiltechnik, RWTH Aachen University, Aachen, Germany) and LCC (Chair of Carbon Composites, Technical University of Munich, Munich, Germany) to develop hybrid carbon fiber nonwoven reinforcement structures for organo-sheets. Goal of the project that started in 2015 was to combine an airlay-process and a paper-process to produce a hybrid isotropic reinforcement structure on C-fiber basis and to use the full spectrum of fibers supplied by the recycling industry. Key idea to this process is to combine a nonwoven process with strength in short fiber handling and a nonwoven process with strength in long fiber processing. Considering all available nonwoven process variants, there are many possible process combinations available. Thus, the process choices were derived from the targeted application field. Actual developments in the transportation sector show, that multi-material solutions offer the largest weight saving potential. In these solutions, metallic components are substituted by composite parts. Thus, the novel material which results from the combined – a hybrid nonwoven layer reinforced composite – is targeted to be a substitute material for metal sheets in surface applications. This choice results in the combination of a paper and an airlay nonwoven process, to create an isotropic structure leaning on isotropic metal structures. This process combination enables the layer-wise design of staple fiber reinforcements for organo-sheets. Long fibers and directed structures can be placed in layers with high expected loads, while short fibers can be added for surface design and bending flexibility. Carbon fiber waste (CFW) and short fiber sections are processed into a carbon paper. This paper can either be applied as a highly homogenous surface layer to enhance the optical and haptic perception of the product by customers. Otherwise, the paper can be supplied as a central layer to 'store' CFW pulp in a composite. Long fibers are processed by the airlay process to add strength to the composite. These long fibers are mixed with matrix fibers into a mixed nonwoven. Finally, several layers of these nonwoven are stacked and heat pressed into an organo-sheet. The mechanical performance of a hybrid reinforced PA6-organo-sheet was with round about 25 GPa tensile modulus comparable to what is known from literature [3]. Additional the integration of functions into the hybrid structure was explored. Since the CFW based structure is electro conductive but shows a certain electric resistivity, the current investigations focused on the generation of heat. By including copper wires into the organo-sheet, a voltage could be applied. Due to the isotropic structure of the material the heat generation was very uniform, which could be used for example for panel heating. Future research by the authors will focus on optimizing the multi-layer nonwoven structure. The qualitative impact of different layer setups will be investigated as well as the impact on the heat development and distribution in the nonwoven sheet. *The project was funded by the German Federation of Industrial Research Associations – AiF.*

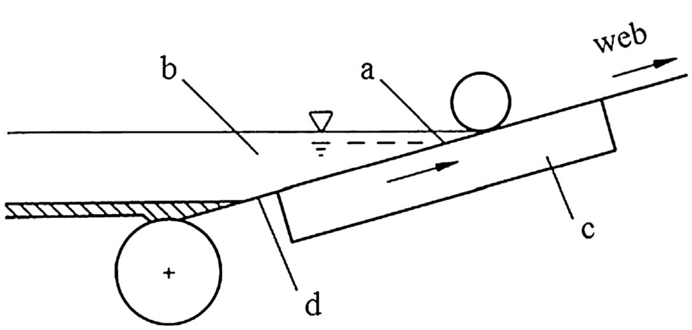

FIGURE 2

Principle of web forming on an inclined screen: **(a)** inclined screen, **(b)** suspension, **(c)** suction box, **(d)** suction-free zone; according to Fahrbach et al. [2].

Joint research project of STFI, Cetex and PTS about new lightweight materials ('HyBaVli')

The Saxon textile research institute STFI, Institute for textile and converting machines Cetex and Papiertechnische Stiftung have launched a joint research project with the acronym 'HyBaVli' (ZIM project Reg.nr. 16KN021655) to develop structural components based on high-strength, well drapable materials made from basalt fiber-reinforced thermoplastic UD tapes and hybrid basalt nonwovens. Aim is to substitute basalt for the fibers commonly used in these components. Basalt fibers are made from crushed basalt stone, preferably from a basalt of high acidity and low iron content. The raw material is washed and then melted, no additives are needed for the spinning process. Their favorable mechanical properties make basalt fibers a cost-efficient alternative to other high-performance fibers.

When developing the hybrid nonwoven, it was decided to use needle punching as dry compacting process, with basalt fibers of three different lengths (50, 80 and 110 mm) and thermo-plastic polyamide fibers (PA6, 3,3 dtex/60 mm). The basalt fibers were cut to the desired lengths at the company Fibtex GmbH in Rovings. To

Please cite this article in press as: A. Endres, et al., Reinf. Plast. (2017), http://dx.doi.org/10.1016/j.repl.2017.07.002