Nonwovens and laminates based on recycled IMS carbon fibres

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Abstract:

During recycling of carbon fibre waste, there is currently no separation according to the type of carbon fibre (CF), as this is associated with increased effort and costs. The project “IMS nonwoven” has investigated whether the mono-material recycling of 100 % IMS carbon fibre waste (IMS = intermediate modulus) retains the higher strength and stiffness of IMS fibres compared to standard HT carbon fibres (HT = high tenacity) and thus result in nonwovens and laminates with increased mechanical properties. The results confirm this assumption. Therefore, a separation of carbon fibre waste should be considered in the future and investigated in depth.

Introduction:

The market for carbon fibre reinforced plastics is growing continuously, and therefore the emerging amount of carbon fibre waste as well. Carbon fibre waste is currently not separated according to fibre type, as this is connected with increased effort and costs. Consequently, unspecific mixtures of, e. g. standard HT CF and cost-intensive IMS CF, are recycled. The specific technical properties of different types of carbon fibres are lost.

The project objectives are:

- material development of mono-material IMS CF nonwovens by adapting common manufacturing processes
- proof of increased mechanical properties of IMS CF nonwovens and thermoset laminates made from them in comparison with analogous semi-finished products based on HT CF

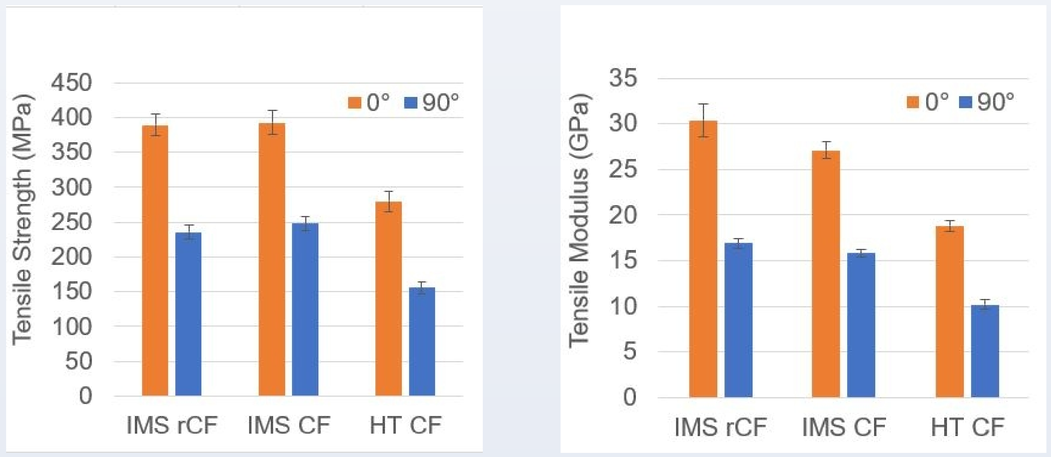

Figure 1: Tensile test results for the laminates (FVC: 25 %) made of carded nonwovens (area weight for single nonwoven layer 300 g/m², fibre length 90 mm)

Experimental and Results:

The processability of nonwovens made of 100 % IMS CF was initially investigated and verified using common technologies by varying manufacturing parameters. Some steps of the manufacturing line are shown in Figure 2. Nonwovens were successfully produced with variations of:

- fibre type (IMS primary fibre, IMS pyrolyzed fibre and HT primary fibre as reference),
- fibre length (60 mm and 90 mm),
- grammage (100 g/m² and 300 g/m³) and
- manufacturing technology (Airlay, carded).

The qualities of the nonwovens were determined by measurements of the fibre orientiations (inline), area weight and maximum tensile forces. In general, the results with the carded nonwovens were slightly better, because the fluctuations in area weight were marginally lower. Regardless of the type of fibre, this technology is therefore preferable to airlay technology. Furthermore, input-output analyzes and examinations of the mean fibre length were carried out. An increased loss of material or fibre breakage due to the brittleness of IMS fibres was not observed. Overall, a manufacturability of nonwovens made of 100 % IMS CF could be demonstrated.

The developed nonwovens were processed to thermosetting laminates by wet compression moulding. These laminates were then mechanically characterized using standard test methods, e.g. tensile test and 3-point bending test. The results were compared with those of analogous semi-finished products based on the HT primary carbon fibres. Depending on the manufacturing technology and the selected parameters, 20-40 % higher strengths and stiffnesses of the IMS variants were achieved. As an example, Figure 1 shows the results for a tensile test on three laminates made of carded nonwovens that only differ in the type of fibre.

Discussion and Outlook:

In summary, the results tend to show that sorting CF waste is beneficial, due to the mechanical potential of the IMS CF. The possibility of producing high-quality, mono-fraction IMS CF nonwovens would open up new areas of application for recycled fibres and make semi-finished products based on them interesting for new products. Therefore, a separation of carbon fibre waste according to types of CF can contribute to a gain in the market share of rCF, which provides an important contribution to raw material efficiency and saving of primary fibres.

Further research is needed to evaluate the findings and deepen the understanding for the comprehensive discussion of the benefits of CF waste separation in the future. Required work topics are:

- extension of the trials by:
  - fibres of different industrial producers
  - other resin systems and thermoplastics as laminate matrix
- development work in the production of nonwovens:
  - improvement of the accuracy of the aspired area weights
  - improvements in the degree of fibre orientation
  - further experimental determination of the optimal manufacturing parameters (fibre preparation, fibre length, needle geometry, puncture density)
  - investigation of the influence of sizing and fibre-matrix adhesion on the laminate parameters
- consideration of economic and ecological influencing factors (e. g. estimation of specific waste separation costs)

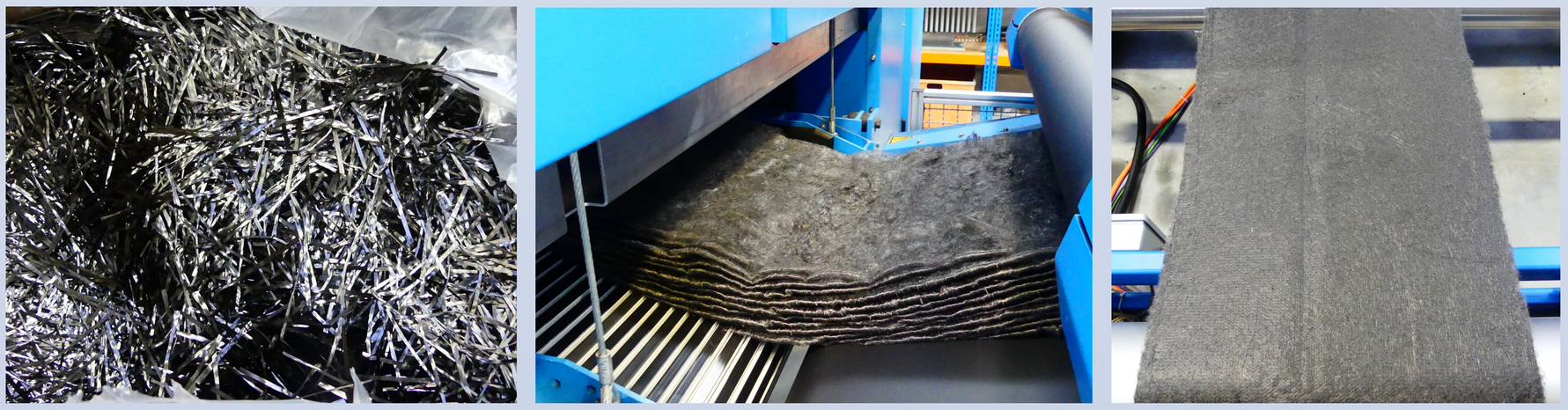

Figure 2: selected steps of nonwoven manufacturing: (left to right) cutted CF rovings → stacked fibrous web → mechanically needled nonwoven

Sources:

[1] AVK – Industrievereinigung Verstärkte Kunststoffe e.V.: Handbuch Faserverbundkunststoffe/Composites. Grundlagen · Verarbeitung · *Anwendungen. Springer Vieweg. 4. Ed. (2014), pp. 145 - 154.*

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