HEATING CARBON/THERMOPLASTIC FIBRE HYBRID NONWOVENS USING MICROWAVES TO PRODUCE ORGANO SHEETS

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Abstract

Carbon fibre reinforced composites have become a technical necessity in large sectors of the industry. Especially the aviation and the renewable energy sector are in need of carbon fibre reinforced composites. In addition the automotive industry is increasingly using composites in order to reduce the weight of their vehicles. An alternative to classical thermoset composites are thermoplastic matrix systems. The viscosity of molten thermoplastic material is distinctly higher than the viscosity of duroplastic material. Therefore reinforcing fibres are being mixed with thermoplastic matrix fibres using textile processes to reduce the melt flow paths. These fibre mixtures are then processed into textiles. To produce a composite part out of these textiles, also called prepregs, they have to be heated and consolidated. The cycle time of this process is determined by the heating and cooling of the material. The advantage of microwave heating is the volumetric heating of the material, where the energy of the electromagnetic radiation is converted into thermal energy inside the material. By using microwave ovens the process times can be shortened and the use of energy and therefore the production costs of composites can be decreased.

1. Introduction

The Thermoplastic fibre reinforced composits are mainly reinforced with carbon or glass fibres [1]. These fibres are embedded in a thermoplastic matrix system. Most of the thermoplastics used as matrix systems are Polypropylene (PP), Polyamide (PA) as well as Polyphenylensulfid (PPS) and Polyetheretherketon (PEEK) [2]. As other fibre reinforced composites, they offer high strengths at low weigt. It is also possible to use a large variety of different textiles for reinforcemet phase of the composite. Possible structures are fabrics, non-crimp fabrics and nonwovens [3]. The use of thermoplastic fibre reiniforced composites allows reproducible results at short cycle times. Short cycle times are necessary for a large scale production. Therfore thermoplastic fibre reinforced composites are gaining the interest of the industry. [4]

There are multiple processes available to produce thermoplastic fibre reiniforced composites, also called organo sheets. Figure 1 displays an overview on possible production processes. It is possible to

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use prepregs as an indirect processing route. The direct processing route indicated with the dotte lines. Reiniforcement textile and matrix are combined directly before consolidation. [3]

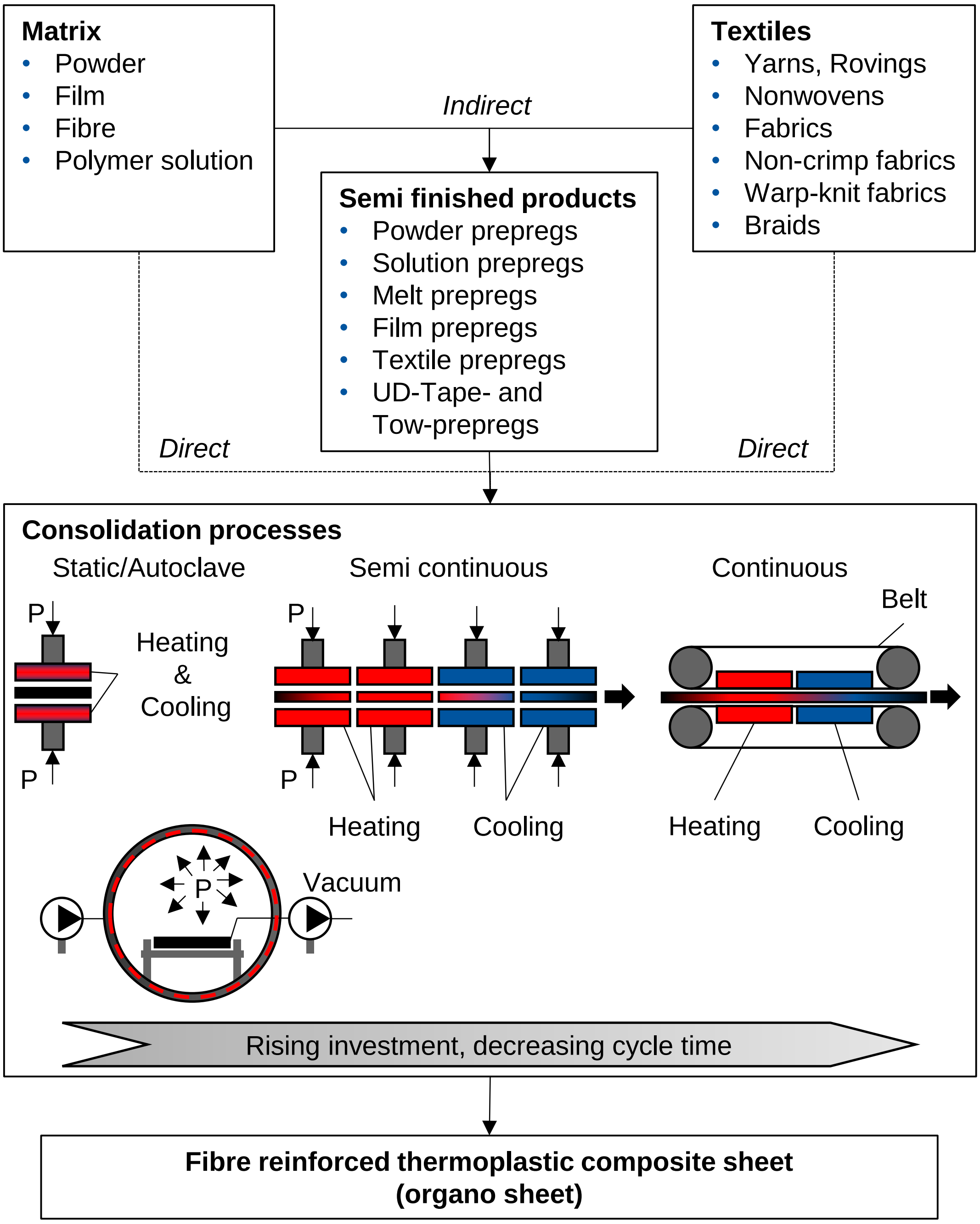

Figure 1. Propduction processes for fibre reinforced thermoplastic composite sheets [3]

The focus on this paper is based on the heating technology used for melting the thermoplastic matrix. Most commonly used heating methods are contact heating, Infrared heating and the use of hot air [2]. An alternative heating technology is based microwaves. Microwave technology becomes increasingly important in industry and research. Higher material depths can be reached compared to conventional heating technology [5]. The most wide spread industrial application of microwave heating technology is the drying of materials [6].

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2. Experimental

The material used is a textile prepreg consisting of thermoplastic and carbon fribres. The hybrid nonwoven has been produced using an Airlay-technology. The carbon fibres used are recycled non-crimp fabrics. The fibres have been mixed with PA-fibres. The nonwoven has been mechanically needed in order to increase the compactness of the nonwoven. The area weight of the CF-PA nonwoven is 390 g/m^2.

The nonwovens have been cut into 50 by 50 mm samples for the heating experiments. The edges of the samples have been wrapped in aluminium tape from tesa SE, Hamburg, Germany in order to prevent short circuits on the edges of the samples. The preparation of the samples is shown in figure 2.

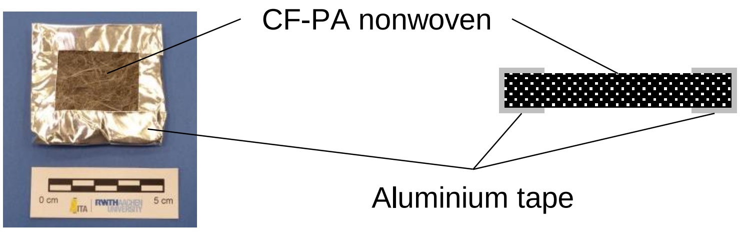

Figure 2. Sample preparation with aluminium tape (left: top view; right: schematic cross section)

The microwave oven used for heating the samples is a M 621 S from Miele & Cie. KG, Gütersloh, Germany. The microwave is modified with an external generator in order to contiously control the power of the magnetron. The generator FMG2000 has been build by the project partner, the company Fricke und Mallah Microwave Technology GmbH, Peine, Germany. This allows the documentation of the experiments using an infrared camera. The camera used is a SC640 from FLIR Systems, Inc., Wilsonville, OR, USA. The samples have been placed on a quartz glass plate. The quartz glass has to be used because it does not interact with the microwaves. The top of the microwave oven is covered only with a metal mesh. The ventilation system has been installed to vent any fumes of melting polymer. See figure 3 for setup.

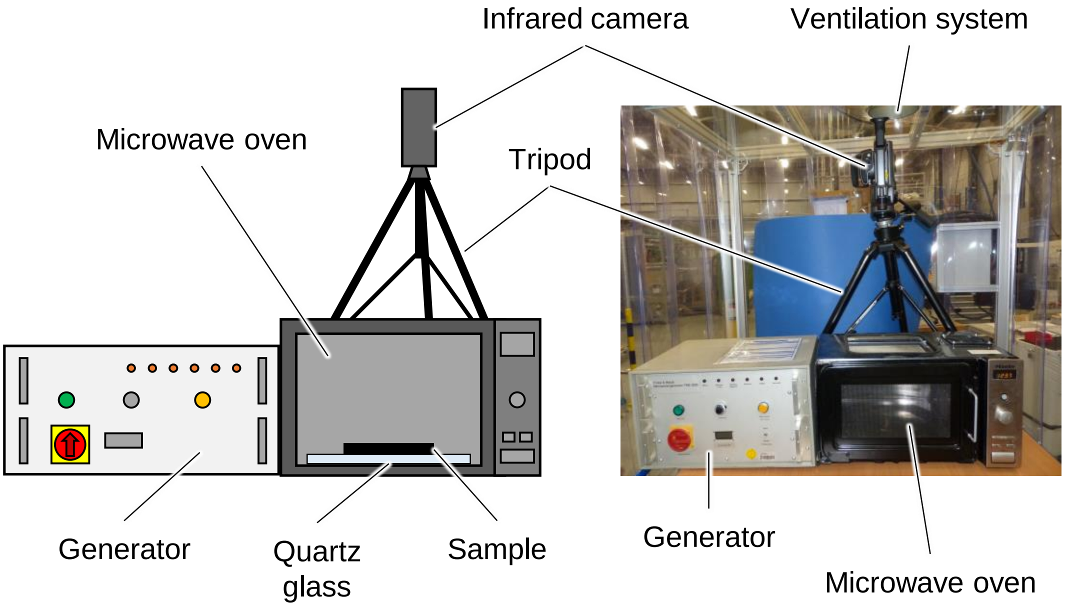

Figure 3. Setup of microwave experiments

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A schematic top view on the experiments is illustrated in figure 4. The positioning of sample inside the microwave on the quartz glass plate is shown. The measuring range of the infrared camera for temperature analysis includes the complete sample exposed to the microwaves. The parts covered in with the aluminium tape are not exposed as the tape reflects the microwaves.

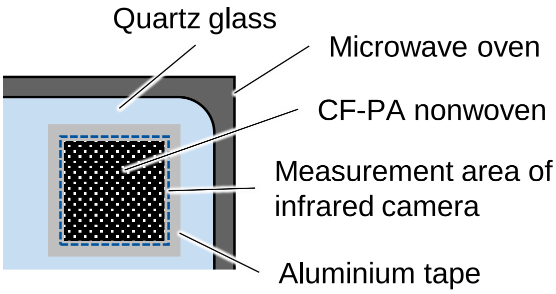

Figure 4. Schematic representation of the top view on the microwave experiments

3. Results

The CF-PA nonwovens have been tested at 250, 350, 400 and 500 W. The temperature distribution is exemplary shown in figure 5. The infrared images shown in Figure 5 are taken at 5, 30 and 60 s. At first, the temperature distribution is uneven. However the temperature continoiues to spread over the samples over time. The power was shut off after 60 s because of the previous results indicating that longer exposure times to the microwaves don't lead to a temperature increase.

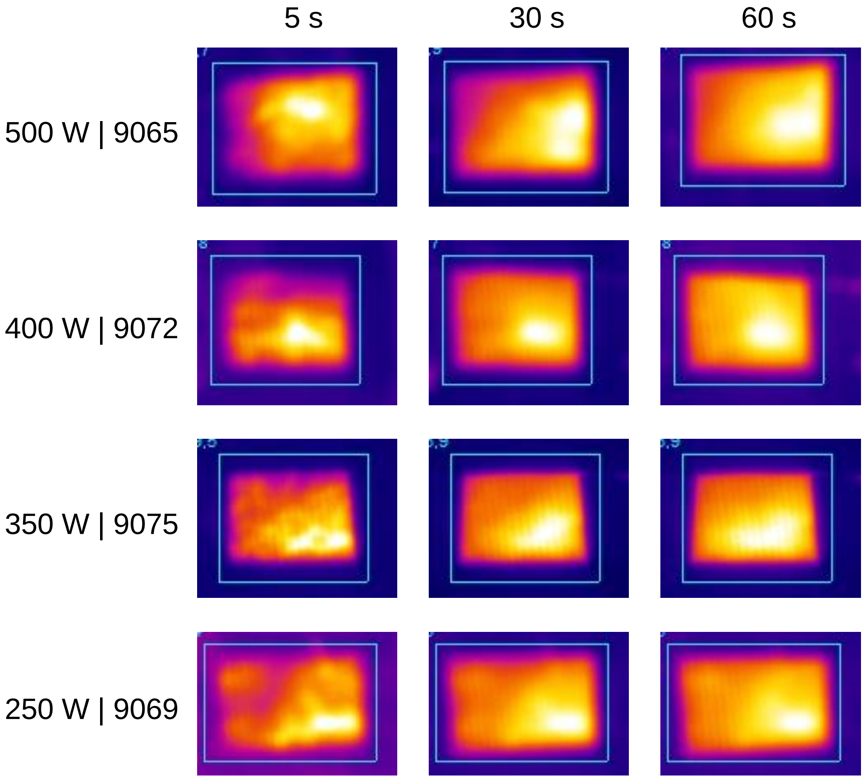

Figure 5. Temperature distribution of heating CF-PA nonwovens with microwaves

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Figure 5 also illustrates some hot spots that acuured during the heating process. The hot spots are not fixed to a ceratain position. This material beahviour can be seen at the 500 W samples. The maximum temperatures are reached within 30 s after the start of the experiment. Maximum temperatures measured with the infrared camera are 250 °C. The melting point of the Polymer has been analysed using Dynamic Scanning Calorimetry (DSC). The melting point of the PA is at 260 °C. Although the measured temperature with the infrared camera is below the melting point measured with DSC, visual inspection shows molten areas.

4. Discussion

The analysis with the infrared camera of the heating process shows the development of hot spots. The development of hot spots may be caused by the fibre distributions (wt.-%) in the tested samples. The hot spots may also have been caused by the orientation of the fibres as well. The tests were performed in a laboratory microwave with a single magnetron. The hot spots may have been caused by an inhomogeneity of the microwave field. In this case, the problems of hot spots can be overcome by reconfiguring the construction of the microwave.

The compactness and thickness of the samples has an impact on the temperature distribution and heating rates as well. The thermal conductivity is influenced by the compactness as the air inside the nonwoven acts as an isolator. Due to small a small sample size, especially the thickness, theinduced heat my be transferred to the quartz glass plate. This can explain that temperature levels after reaching the maximum.

5. Conclusion

Microwave technology can be used to heat CF-PA nowovens. High heating rates can be achieved within 30 s. The use of aluminum tape on the edges of the nonwoven samples solved the problems of short cuts occurring on the edges. Future research should include a more detailed temperature analysis. Since metallic temperature sensors can not be used inside the microwave, a fibre optic measurement system should be used. The impact of the fibre length on the heating process has to be evaluatied. With regard to actual part sizes, multiple layers and shapes of the nonwovens should also be assessed. Finally the energy consumption has to be compared to a standard heating process using an infrared oven for example.

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References

[1] C. Cherif. *Textile Werkstoffe für den Leichtbau*. Berlin, Heidelberg: Springer-Verlag, 2011.

[2] AVK–Industrievereinigung Verstärkte Kunststoffe e. V. (Hrsg.). *Handbuch Faserverbundkunststoffe / Composites*. Wiesbaden: Springer Vieweg, 2014.

[3] M. Neitzel, P. Mitschang and U. Breuer. *Handbuch Verbundwerkstoffe*. München: Hanser, 2014.

[4] E. Bürkele. *Faserverbundwerkstoffe halten sich den Spiegel vor*. Kunststoffe, 10:144-148. 2014.

[5] P. Lechner. *Untersuchungen zum mikrowellenunterstützten Aushärten von vernetzenden Harzsystemen auf Polyurethan- und Kohlenwasserstoffbasis*. Darmstadt, PhD thesis. 2012.

[6] N.N. *Fricke und Mallah Microwave Technology GmbH*. URL: http://www.microwaveheating.net, accessed 30.03.15

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