OPTIMISATION OF A PYROLYSIS PROCESS FOR RECYCLING OF CFRP´S

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Keywords: *recycling, carbon fiber, pyrolysis, TGA, surface modification, fiber-matrix- interface*

1 Introduction

Carbon fiber reinforced polymers (CFRPs) were first used in aerospace applications in the early 1970´s. They posses high specific modulus and strength and excellent fatigue behaviour and, therefore, have become indispensable as structural material in lightweight applications. Today they are widely used in aircraft and sporting good industry and also other industries like windenergy and automotive industry are expected to start using CFRPs in the near future.

A problem not yet solved satisfactorily is the question of recycling the fiber reinforced composites. Today disposal of production waste and end-of-life-parts is done by landfilling or incineration. This is possible due to the relatively low amount of production waste and the fact that most CFRP-parts produced so far are still in operation. However, it has to be mentioned that the cost for disposal of CFRP-waste is ~200€/t.

The first bigger series production of CFRP parts for aircraft (vertical and horizontal stabilizer, flaps, landing gear doors) took place in the early 1980´s. In the next years a lot of these parts have to be disposed because the airplanes have reached the end of their operational life. Also the amount of production waste will increase as the demand on CFRPs and the amount of CFRP-parts produced is growing rapidly. Due to these facts the development of practical recycling routes for CFRP is important.

Besides future problems with disposal of CFRP, waste recycling can also have an economic benefit. Carbon fibers are, with a price of ~20$/kg, a valuable raw material. Although the production capacity is growing constantly it is exceeded by the demand from industries. Recycling offers the possibility to provide cheap carbon fibers for non-aircraft applications.

Different approaches for recycling of composites have been investigated by other researchers. An overview about the these works can be found in an article recently published by Pickering [1]. Most of the investigations described there consider only the recovery of fibers. It is important to keep in mind that recycling includes a second step, which is the reuse of the recovered fibers in composites. This second step is essential to close the loop for carbon fibers and their composites. In order to achieve this, it is necessary to provide good properties of the recycled fibers and a good compatibility to different matrices.

The results of the characterization of fibers from experiments in a very simple pyrolysis plant were presented earlier and also the properties of composites with recycled fibers were analysed [2]. It was shown that the properties of the recovered carbon fibers are strongly depending on the process conditions.

During pyrolysis the epoxy-macromolecules are transferred into smaller molecules at temperatures above 350°C in an oven. These smaller molecules evaporate from the material and, due to their high calorific value, can be used as energy source for the process. Together with the fibers an amount of pyrolytic carbon bonded to the fiber surface remains in the oven. The amount of pyrolytic carbon influences the mechanical properties of the reclaimed fibers and strongly depends on the process parameters as oven atmosphere, temperature, heating rate and others. Consequently, it is possible to influence the fiber properties by these parameters, but this also shows that process optimization is required to obtain optimum properties of the recovered fibers to fit the demands for the application in new composite parts.

2 Experimental

2.1 TGA

In this work the influence of different process parameters on the pyrolysis of CFRP-prepreg-waste generated during aircraft production is investigated by TGA experiments. First the epoxy resin was extracted from the prepreg and pyrolysed at different temperatures in nitrogen and synthetic air atmosphere, respectively. It was found that an oxidative treatment is required to remove the matrix without residues of pyrolytic carbon. By comparing the decomposition and oxidation temperatures of the epoxy with those of the carbon fibers it was possible to define a temperature range, where the pyrolytic carbon can be completely oxidized while the carbon fibers remain undamaged.

Using the results from these experiments further optimization of the pyrolysis parameters was performed by TGA-experiments with uncured prepreg-samples.

2.2 Fiber characterisation

The recovered fibers were investigated by Raman-spectroscopy and SEM. The amount of organic residues and pyrolytic carbon on the fiber surface was determined by further TGA experiments.

2.3 Upscaling

In a test run it was demonstrated that the process parameters determined in lab-scale experiments can be directly transferred to an industrial process. The fibers recovered from the test run were characterised by single fiber tensile tests, measurements of the electrical properties, Raman spectroscopy and SEM. It was shown that the fiber properties are on the level of new carbon fibers and therefore should be appropriate for the production of new composites.

2.4 Testing of composites

Finally new composites were produced with the recovered fibres and their mechanical and electrical properties were measured. The neat recycled fibers already exhibit a high potential that can be further increased by a surface treatment such as the application of a new sizing.

The new composites are showing a high potential to fit the requirements for automotive applications. By production and testing of prototype parts it was shown that the reclaimed fibers fit the demands for automotive industries.

References

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