INDUSTRIAL COMPOSITE CURING WITH THE 2.45 GHZ HEPHAISTOS SYSTEM

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The HEPHAISTOS system integrates advantageously the basic processing steps as tooling, tempering of the resin and lay up, the impregnation of the fibers, pre-forming techniques as well as finally the process curing of the composite structures. Composites for aerospace applications in prepreg and wet technology have been successfully fabricated and investigated for quality and certification issues. Features of the system, as well results on the material investigations are presented. The use of microwaves shows new approaches on the process interaction for the fiber materials, precursors, resin systems, lay-up preparation etc. with direct consequences on the adjustable material properties. The highest potential for cost reduction for CFRP (carbon fiber reinforced plastics) is to be found on the manufacturing process which implies substantial long time and high energy consumption, as well as a low degree of automation. The situation for the developing industrial CFRP processing business has to be carefully considered in view of its realistic market impact, e.g. by analyzing future manufacturing options as well as the weight savings for aircraft fuselage structures. The obtained studies show clearly the need to focus on the single process steps to optimize for future industrial CFRP production. For increasing the penetration of composites on the market, technological progress on several issues is essential. In conclusion, novel autoclave-free systems with innovative microwave heating techniques for CFRP processing are under special consideration of industrial oven system manufacturers and end users.

SYSTEM DEVELOPMENT

The developed microwave pilot system [1] is named after Hephaistos, who is the builder and craftsman for the Greek gods, being also responsible since the past for oven and transportation technologies. The name HEPHAISTOS (**H**igh **E**lectromagnetic **P**ower **H**eating **A**utoclaveless **I**njected **ST**ructures **O**ven **S**ystem) stands as well for the technological concept of this microwave approach.
The most notable effect processing CFRP materials with microwaves is their volumetric heating, offering the opportunity of very high heating rates. In comparison to conventional heating where the heat transfer is diffusive and depends on the thermal conductivity of the material, the microwave field penetrates the material and acts as an instantaneous heat source at each point of the sample. The CFRP can be selectively heated, keeping the oven environment cool.

Spatial temperature homogeneity is crucial for qualified material properties. The samples must be exposed therefore to excellent homogeneous field distributions. This is essential, as the carbon fibers imply a very high microwave reflectivity and the tendency for arcing and breakdowns at loose ends in areas of inhomogeneous microwave patterns.

This problem is very severe and one of the major phenomena, that made microwaves not applicable yet for CFRP processing. A specific multimode applicator development aims to tackle these problems.
Monomode applicators involve only controllable field properties in small specific applicator regions, whereas multimode ovens promise, especially for frequencies higher than 2.45 GHz, the possibility for low field fluctuations in larger regions. Simulations and experiments have shown, that achieving high quality homogeneous field distributions over most of an applicator volume is not trivial, even at frequencies in the millimeter-wave regime (30 GHz) [2].

Distinctive physical and technological advantages of microwave heating applied in the HEPHAISTOS system are:

- Volumetric heating of composite materials: The microwaves penetrate instantaneously the materials and generate locally a specific heating content.

- Reduction of cycle times: Due to the volumetric Heating, the heating rates with a structure can be strongly increased gaining for a higher throughput of products.

- Selective Heating: Microwaves only heat the composite structure, the oven and components "keep cool".

- Energy savings: Only the lightweight structure is directly heated. The oven will not be cooled actively, which results in reduction of cycle times as well.

- Rapid control of the process: Due to the instantaneous and volumetric heating within the composite structure processes can be applied, which are impossible in conventional ovens due to their inertia on temperature changes especially if local overheating occurs for exothermal reactions.

- Upscale: The HEPHAISTOS-technology can be applied for large structures.

- Automation: The fabrication process as well as control and sensoring can be adjusted very advantageously with the HEPHAISTOS-technology, such that overall optimizations of the process chain can be gained.

- Reduced hardware-costs of the heating system: Due to the use of standard industrial 2.45 GHz components, an industrial HEPHAISTOS-system is much more convenient than autoclave systems.

AUTOCLAVELESS CFRP SYNTHESIS

A preferred approach is the wet or injection technology, where resin is drawn into a dry lay up of carbon fiber weaves. The produced parts show good surface detail and accuracy. The need for shipping and storing refrigerated prepreg is removed as well. The simple set up with a 1 bar vacuum bag reduces drastically the overall technological demands. Infiltration technology can be a very cost-effective non-autoclave process, where high performance CFRP parts can be fabricated in nearly arbitrary shapes using simple process management in a not pressurized environment.

To inject resin into dry carbon weave, the resin as well as the lay up has to be preheated, to keep the resins viscosity low. After the injection phase, the curing cycle can immediately start. The complete process is automated with the HEPHAISTOS system. A continuous monitoring and control for the cure cycles of composite materials is permitted.

For the near future, additional potentials concerning the process control (reduction of cycle times) and the material properties of fabricated structures will be opened up due to optimized process steps and resin systems.

The technological demonstration could be finished successfully. Currently the scale up for production facilities and their technical specifications are worked out. A big system HEPHAISTOS-CA2 working under industrial guidelines is under development.

LITERATURE

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