HEPHAISTOS – Development of a Novel Automated Microwave Processing System for Carbon Reinforced Fibre Plastics (CFRP)

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In a general sense, microwave heating at 2.45 GHz and 915 MHz ISM (Industrial, Medical, Scientific) frequencies has been established as an important industrial technology since more than 50 years ago. Successful application of microwaves in industries has been reported e.g. by food processing systems, domestic ovens, rubber industry, vacuum drying etc.
Due to a strong decreasing price of carbon fibres in the next future, another application field of new laminated materials can be recognized. In addition, in the last decades considerable progress in advanced composite technology has been made. However, the full potential in the design, the manufacturing process and the application of these materials has not been realized. A specific bottleneck for wide spread application is the price/kg in comparison to aluminium, which is not yet competitive due to high fabrication costs (material costs just about 30% of the actual end price). The highest potential on cost reduction is carried by the manufacturing process which implies substantial long time and high energy consumption, as well as a low degree of automation. The most commonly used processing method of composite materials is the simultaneous application of heat and pressure in autoclave systems.

Fig.1: Upgrading a standard autoclave system at DLR Braunschweig with the HEPHAISTOS-Technology

Investigations on processing high electric conducting organic materials like reinforced carbon fibre structures with higher frequency microwaves at Forschungszentrum Karlsruhe showed a set of specific advantages solving problems in the manufacturing of these industrial high quality materials. The performed experimental work shows that the development of a specific high frequency processing technology is promising for this application [1][2].
A novel automated microwave processing system HEPHAISTOS (High Electromagnetic Power Heating Autoclave InSeT Oven System) for small and medium sized structural parts of CFRP has been developed at IHM. The current system integrates advantageously the

basic processing steps as tooling, tempering of the resin, the impregnation of the fibres as well as finally the curing of the laminate.
The main hardware contribution of the development is realized for a specific modular applicator containment providing an excellent homogeneous electromagnetic field distribution, which is applied as an upgrade tool for conventional autoclave systems. The fabrication process can be performed pressurized or at standard conditions. The process is measured remotely by infrared sensors.
Fibre reinforced composite materials are in general anisotropic materials if one considers their mechanical, thermal and electromagnetic properties[3]. The fibres are embedded in an essentially homogeneous matrix. Their material properties have to be described by tensors with respect to the orientation of the fibres. It turned out, that a precise understanding of the related electromagnetic and thermal parameters is essential for designing industrial microwave processing systems. To understand and predict the material dynamics, the exothermal heat wave propagation, hot spots etc., a precise computational approach is essential taking the time development and local curing progress as well as the fibre/matrix composition of the laminate into account. For this purpose, the THESIS3D-Code [3][4], a time dependent FDTD-code is currently upgraded by implementing the anisotropic material and field properties.
Design criteria for low cost industrial processing systems using high frequency microwaves are under current development. The current developments and results show, that a very precise process control and knowledge of the right temperature correlation determine the quality and reliability of the microwave accelerated fabrication, as well the adjustment of sealing material, vacuum tubes and tool equipment etc. for material compatibility reasons. Due to the thermal conducting properties of the injected matrix resin, volumetric deposited heat from the surfaces distributes homogeneously through the poor conducting fibre material. The gain on power savings for a “cold oven” and by increasing cycle times is obvious for curing and injection. Automation techniques for the process as well as for the preparation of the processed tools have to be carefully chosen for each step of the industrial fabrication workflow[5].

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