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TITLE : Curing Polyester Resins on Demand

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ABSTRACT

An European consortium of 4 companies and 2 institutes has successfully completed a 30 months European Research project to develop a vacuum assisted infusion lamination with microwaves for polyester resins with a separation of impregnation and curing of the resin in mind. The motivation for the work was the limitations of the state of the art of vacuum assisted infusion technology:

- Large parts impregnated and curing at room temperature like hull of sport boats (Fig.1).
- Very strict curing conditions are required to impregnation and curing.
- Compromise between the properties of resin impregnation and curing time.

Figure 1: Hull of sport boat are produced with vacuum assisted infusion

The project covered material part, microwave part and part of technical realisation. These three parts were clasped by a sustainable analysis of the material and the process. In the material part a polyester resin was modified with special developed agents to enhance the microwave absorption and to increase the onset temperature for cross-linking without changing the other properties. For this propose a new dosing unit to prepare the resin was developed and built-up. On the basis of this material a microwave system was developed which heated the sample reproducible and controllable. This microwave system was portable and mounted on a portal and a robot system to develop the process and to

produce composite parts. The curing time and the styrene emission could be reduced drastically.

PROJECT OBJECTIVES

The general object of the project was the separation of the form filling process and the curing process of large polyester parts. For triggering the cross-linking of the resin microwaves were used. In the project the following objectives were posed and reached:

- Formulation of resins with regard to the injection step.
- Functionalisation of the resin for microwave-energy absorption.
- Reduction of the curing time.
- Development of a microwave antenna for the robot.
- Improvement of degree of polymerisation.

The objectives of the project lead to the following improvements:

- Obvious **advancement of the working conditions**, with regard to the processing temperature in the production plant.
- **Concentration reductions of emissions** to nearly zero.
- **Reduction of raw-materials in use** due to better impregnation of the fibres and therefore **better potential for light-weight structures** with higher fibre content.
- **Easier shape filling of complex parts**.
- **Reliable material properties**.

PROJECT RESULTS

The following results are achieved in the project:

A **resin was formulated with regard to the injection step**. The viscosity was low and the potlife long, so that the filling process could be done practically without any time limitations. Special developed hardener systems perform an adjustable triggering temperature for curing with microwaves.

The **resin was functionalised for microwave-energy absorption**. Polyester resins are low lossy materials. A special agent was developed to enhance the microwave absorption drastically without changing the other properties like mechanical stiffness, water absorption etc.

The **curing time of the resin was reduced** from days to hours. Only a triggering of the curing with microwaves was necessary.

A portal crane was designed for the preparation of the **automated process technology**. The temperature of the resin was measured to control the microwave power. This ensures a homogenous heating of the resin and therefore a homogenous cross-linking. These microwave system was integrated to a robot and the principle is proofed in a much larger system. Furthermore several **microwave antennas** were **developed** for the **integration on the robot** (Fig. 1). In particular a light weight antenna system was developed. This enables of complex shapes of the sample and can used for smaller robots.

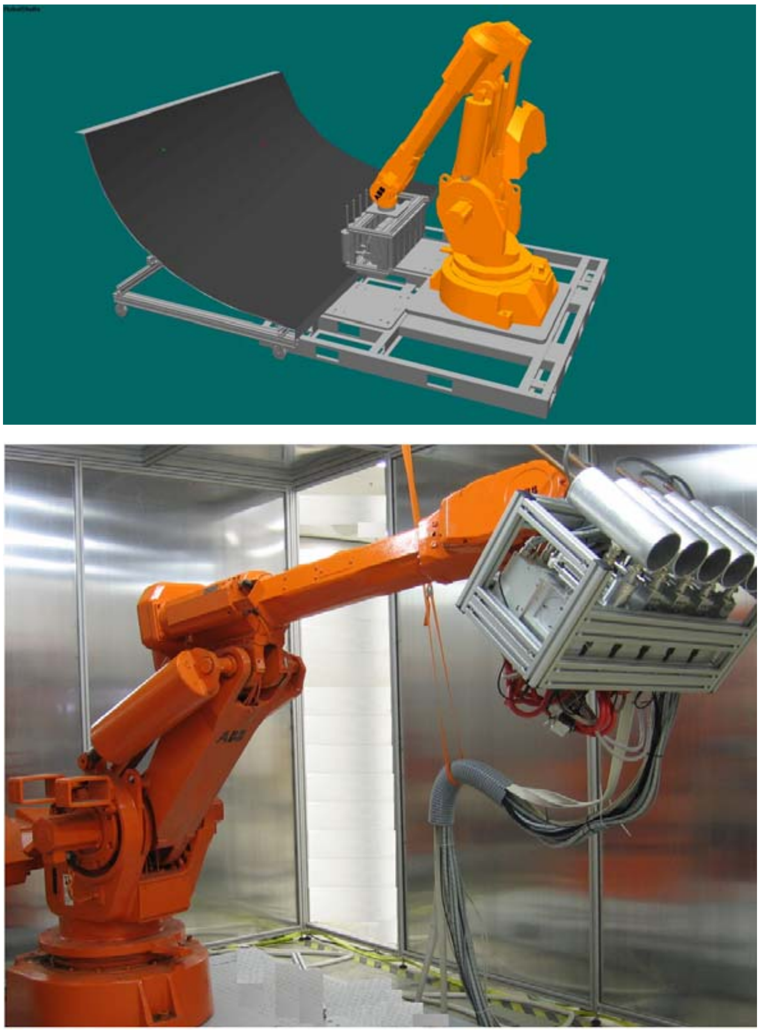

Figure 1: Microwave system mounted on a robot.

The **degree of polymerisation** of microwave cross-linked resin is **nearly 100%**. That is a strong improvement of degree of polymerisation. In Fig. 2 the degree of polymerisation was measured with Differential Scanning Calorimetry (DSC). The absence of heat flow in the microwave cured samples attested a nearly 100% degree of polymerisation.

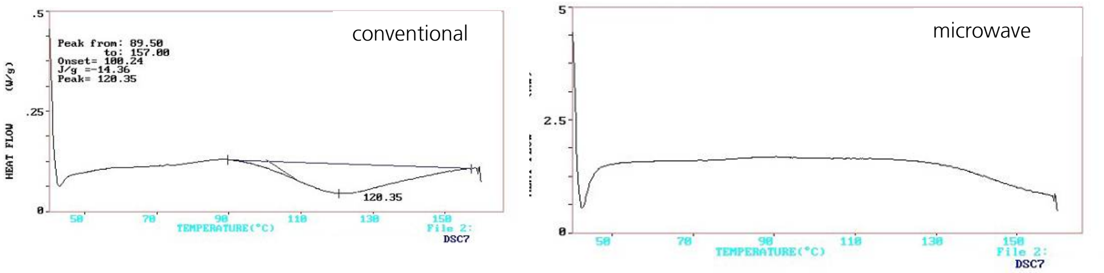

Figure 2: Comparison of the DSC measurements between conventional and microwave cured samples

Within the sustainable analysis a balance of the **styrene emissions** was performed. The microwave cured resin evaporates only approximately 10% of the styrene amount compared with a conventional cured polyester part due to the nearly 100% degree of polymerisation without thermal post curing. Therefore the emissions of the styrene were reduced by approximately 90% (Tab. 1).

Conventional Heating		**Microwave Heating**	
Infusion	Demolding	Infusion	Demolding
1.05 mg / m^3	7.8 mg / m^3	0.93 mg / m^3	0.60 mg / m^3

Table 1: Comparison of Styrene emissions

A **dosing unit for the resin** for the process was developed. The machine is designed for pumping, dosing and mixing the 3 materials (resin, catalyst & microwave agent) together. The catalyst and the microwave agent are pre-mixed before being mixed to the resin so as to reach a homogenous mixing.

Figure 3: Dosing unit

Conclusion

In the project a scaleable microwave system was developed for homogenous heating and therefore curing of large part areas. Only the combination of the new resin and the microwave system with a temperature control ensured a homogenous processing of the part.

The potential benefits of the new process are:

- Fundamental change of resin infusion process by separating the filling and the curing process, the reaction does not start during the filling.
- Reduction of curing time from days to hours (volumetric heating).
- Reduction of styrene emission and manual work.
- Increase of the degree of polymerization to nearly 100% with microwave curing, without the need of post-curing at high temperature

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