Combined Electron post-curing and surface functionalization of fiber - reinforced thermoset parts as an effective coating pre-treatment process

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Abstract

SMC-components are increasingly being used as molding compounds for exterior vehicle parts in the automotive industry to replace sheet metal parts. In order to provide the desired color the SMC-parts are usually coated in-line with the body. As an alternative to conventional in-mold-coating or primer application SMC-molded parts were modified by electron treatment prior to a subsequent coating process in order to perform a Class A surface quality. The procedure resulted in a barrier-layer by post-curing parallel with surface hydrophilization by generation of carboxylic acid groups. An initial assessment of suitable facility parameters gave the intention that the novel technology will be in-line compatible. The proof of technology for 3D parts is in progress.

1. Introduction

Surface defects of compression molded SMC-components are a great challenge to subsequent coating processes and often give rise to surface defects [1]. So far time consuming and cost-intensive cleaning, sealing and priming steps are necessary in order to obtain Class A surface. The aim was to use the capability of high-energy electrons to induce curing reactions of residual double bonds to overcome these problems in future [2].

In our project reasons of coating problems and their influence on surface properties were studied by thermal analysis [3]. In addition, the electron treatment of molded parts was investigated concerning post-curing and surface functionalization. Finally initial calculations with regard to suitable facility parameters were done.

2. Materials

Low profile SMC-components (SMC5/automotive, SMC2/MAN) were used which were industrially manufactured by Polytec GmbH Gochsheim.

Moldings

Test plates (2/4 mm thickness) were compression molded using a chromium plated tool: mold temperature: 139 °C male part of cavity/ 140 °C cavity, molding pressure: 140 bar, mold closing time: 12 s

DSC-measurements

Non-isothermal DSC-measurements (DSC-Phoenix/ Netzsch: heating rate 10 K/min) were proceeded to detect the reactivity of SMC-sheets and SMC-molded plates.

TGA-measurements

Thermo-gravimetrical analyses were performed using a TGA Q 5000 of TA Instruments in a nitrogen atmosphere.

Electron accelerator ELV-2

Electron treatments were performed using an electron accelerator ELV-2 (Budker Institute of Nuclear Physics) under air atmosphere at the Leibniz-Institut für Polymerforschung Dresden e.V.

Contact angle measurements

The measurements were carried out by using an OCA 20 instrument (Data physics) using water as test liquid.

Topography measurements

The surface topography was studied by confocal imaging using the chromatic white-light sensor MicroGlider® (Fries Research&Technology, Germany).

3. Results

As shown in Figure 1, the curing state of molded SMC-plates hardly depends on the molding time. Even an inefficient extension of the processing time did not result in the formation of a completely cured SMC-component.

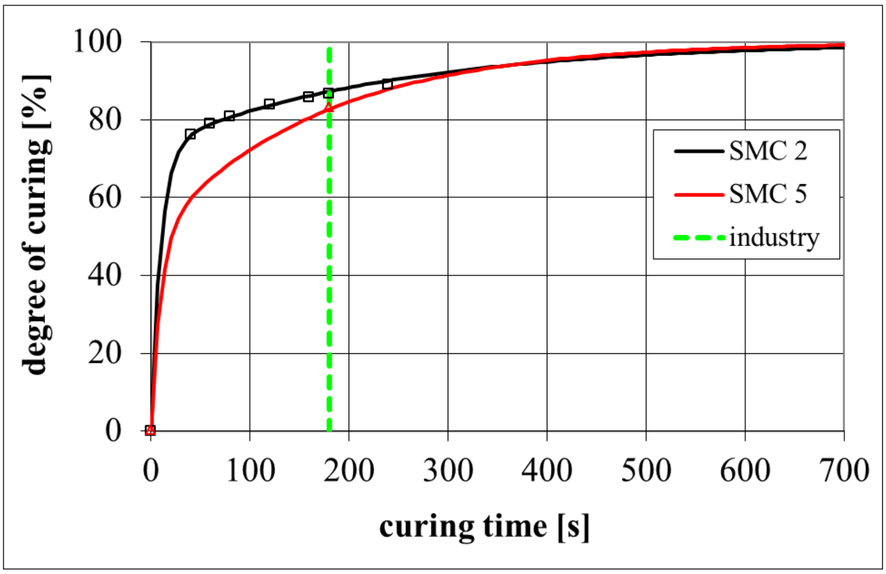

Figure 1. Curing state of industrially molded SMC-plates.

Additionally, TGA-measurements by using a temperature-time profile compareable to the several steps of in-line coating process showed the outgassing of low molecular substances at a level of about 0.8 weight-%. The majority amount of substance was identified as styrene.

To overcome these drawbacks two appoaches based on electron treatment were tested:

- High energy electron bulk treatment by using 1.5 MeV electrons.
- Low energy electron edge modification by using 0.6 or 0.15 MeV electrons.

As can be seen in Table 1 the high energy electron treatment resulted in a completely cured bulk phase of molded SMC 2 test plates parallel with a decrease of surface contact angle. Prior to the coating process the surface is more hydrophilic. Beside these effects also a slighly smoother surface was detected after the treatment operation.

	Reactivity [%]	**Contact angle [°]**	**Surface roughness [%]**
Prepreg	100	-	
After molding	8.8	100	100
100 kGy	0	80	37
120 kGy	0	73	62
140 kGy	0	69	90

Table 1. Thermal and surface properties of SMC 2 test plates after high energy electron treatment.

Results of coated SMC 2 test-plates subsequent to an edge modification are collected in Table 2. 0.6 MeV electrons and a dose of 80 kGy led to a high quality Class A adhesion of the final coating. By using 0.15 MeV electrons and a dose of 200 kGy the adhesion of the coating is not acceptable in all required parameters yet.

Dose/ Energy	**Adhesion (DBL 5416)**	**Weathering/ constant climate 240 h**		**Weathering/ constant climate 740 h**		**Cold-check cycle test 3 cycles**	**Vapor jet test**
[kGy]	cross-cut	cross-cut	degree of blistering	cross-cut	degree of blistering	cross-cut	cross-cut
80 / 0.6	1	1	0/S0	0	0/S0	1	1
200 / 0.15	2 - 3	2	1/S1	3 - 4	4/S3	2 - 3	3

Table 2. Coating quality after low energy edge electron-treatment (green spaces are accepted Class A).

A few months ago a validation project to proof the 3D-compatibility of the above described results has started. An initial calculation of the throughput is presented in Figure 2. Especially low energy electrons enable a high throughput at low beam power.

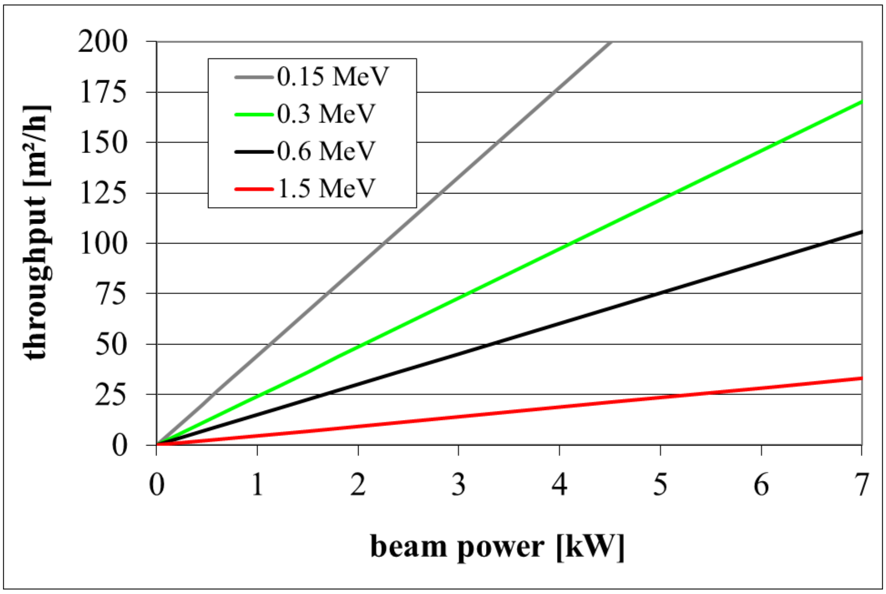

Figure 2. Facility concept: Throughput depending on beam power.

Another important parameter for in-line use is the cycle time. It was calculated (Figure 3) that low energy electrons combine low cycle time and low beam power. Particularly advantageous for practical use is an electron energy lower than 300 keV.

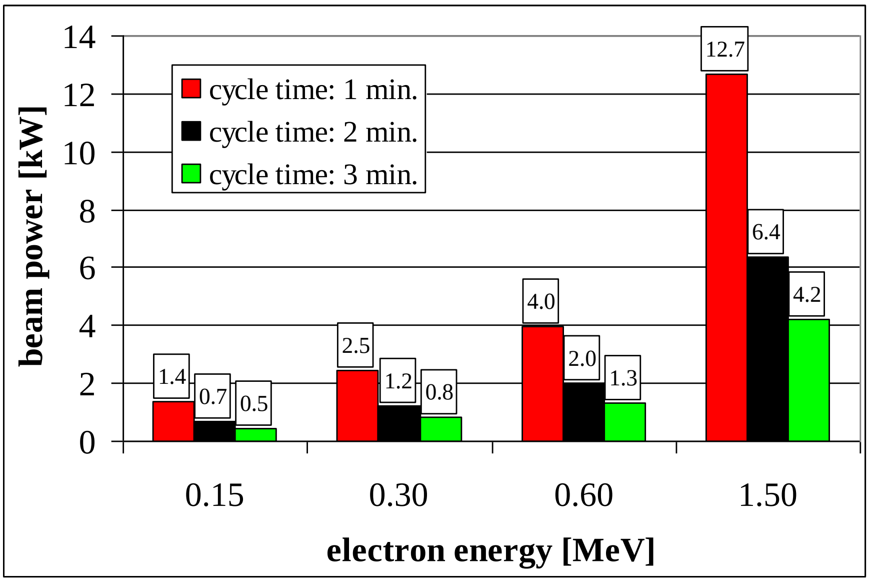

Figure 3. Facility concept: Cycle time for a total component surface of 1 m^2.

4. Conclusions

Post-curing reactions and weight loss/emissions were evaluated as the main two reasons for coating defects of SMC-components. Electron bulk treatment and edge modification are two successful approaches to overcome the coating process drawbacks in the state of the art in a more efficient way. Initial calculations for a facility concept seem to confirm the in-line practicability of this novel technology. The proof of technology for 3D parts is in progress.

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