SURFACE QUALITY CHARACTERISATION OF COMPOSITE COMPONENTS FOR AEROSPACE APPLICATIONS

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Keywords: Out of autoclave processing, surface properties, surface analysis, process and surface appearance relationship

Abstract
This study focuses on benchmarking Class-A surface finish of composite components processed through vacuum assisted resin transfer moulding (VARTM) for use in the aerospace sector. The surface quality baselines have been established for tooling, as-moulded composite part, part with primer coating and part with top coating. The Class-A surface quality is characterised by roughness and waviness measurements, using a contact stylus profilimeter (Taylor Hobson Surtronic S100) and the laser optical profile device (BYK Wave-scan dual).

1. Introduction

Surface appearance of a composite component depends on the complex interaction of incident light, surface roughness, surface waviness and human perception. Aesthetics of visible surface greatly influence the perceived product quality. Composite manufacturers often allocate great deal of resources to ensure their products with consistent and compatible surface quality. Human eye would be the most sophiciated instrument to evaluate surface quality, under the standardized viewing conditions[1]. In reality, visual surface evaluation has its limitation due to uncertainties in viewing conditions and human perceptions. Hence, the objective measurement of surface quality has been developed through the interdisciplinary work of physics, psychology and physiology[2]. For a wide range of materials and applications, Hunter was the first in 1937 to classify surface gloss into six types with the corresponding defined reflectance functions and instruments for measurement [3]. The principal of gloss measurement is based on measuring the specular and diffuse components of the reflected light, as being specified in the standards ASTM D523, ASTM E430 and ASTM E2387.

The exterior surfaces of aeroplanes, cars and yatches, are often coated with high gloss paint. For these applications, the objective measurement has been based on the optical simulation of human eye's focus both on the the reflected image and on the geometric surface itself [4]. When focus is on the

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reflected image, the measurement is distinctness-of-image (DOI)[5-7]. Visually DOI is the degree of distortion in the specular reflection of an image on a glossy surface. When focus is on the paint surface, the measurement is waviness or orange peel[8-10]. The previous studies showed the correlation of instrument measured waviness and the perceived surface appearance[11-14]. These studies demonstrated that waviness measurement was a meaningful approach to minitor the underlying factors that influenced surface quality. These previous studies were delicated to automaotive applications.

This study investigates the surface quality of composite parts by the out-of-autoclave process. The composite components are intended for the aero-engine nacelle application. In comparison to cosmetic automotive applications, exterior composite parts in aerospace have to meet multiple performance criteria, including lightning protection, bird-strike & hailstone resistance and extreme load cases during service. These design considerations influence surface characteristics of composite parts. In addition, the VARTM process plays a significant role on surface quality. Furthermore, the paint specification in the aerospace sector differs significantly to automotive applications, which influences the ability to hide print-through defects.

2. Materials and Methodology

Flat panel with Omega stiffener is an idealised subcompoent structure to a typical aero-engine nacelle design. The subcomponent was manufactured through the vacuum assisted resin infusion process, as illustrated in Figure 1. The aerospace graded resin RTM-6 was infused at 120ºC with the triaxial NCF preform. The infused component was cured at 180ºC.

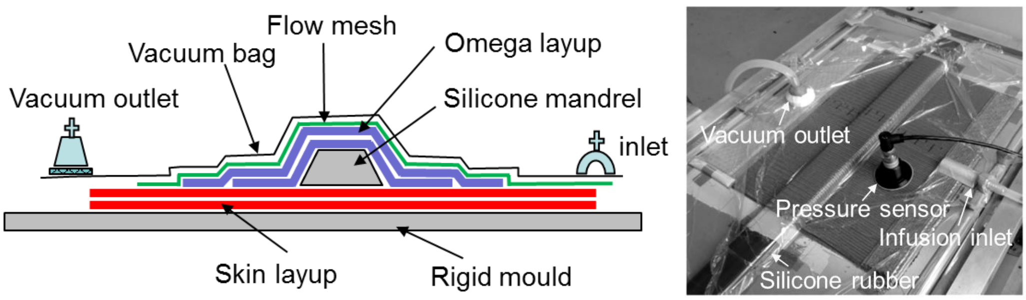

Figure 1. Sketch (Left) and actual setup (Right) of vacuum assisted resin transfer moulding for manufacturing the nacelle sub-component.

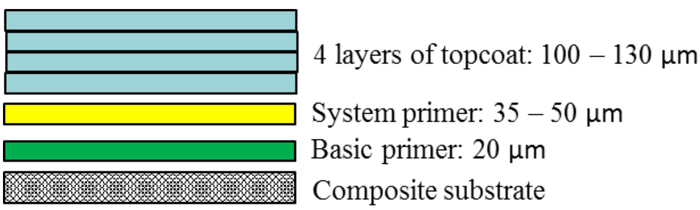

Figure 2. Typical painting scheme for composite aero-structure

The composite structure underwent the painting process as shown in Figure 2. Class-A surface quality needs to be controlled at the various production stages that imprint various features onto composite surface. We propose to adopt a holistic and practical approach to characterise the surface texture. Figure 3 plots the correlation of surface roughness and longwave at the corresponding manufacturing stage. Such approach has been applied in the automotive industry, including Audi[15]. Roughness was

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measured by Taylor Hobson Surtronic S128 with a stylus pickup diameter 10 µm. The measurement data was processed in Mountains Map Premium 7.2, with the Standard filter Gausian ISO 16610-61, cut-off 0.8 mm. The roughness parameters were specified by ISO4287. 20 measurements were performed for each surface area of interest. Longwave was measured by BYK Wave-scan Dual, with 10 cm scan length. In order to measure the medium gloss composite surface, the algorithm for correction was active, while plausibility control was inactive. The measurement procedure was performed according to Airbus Manual M2435 External painting quality criteria.

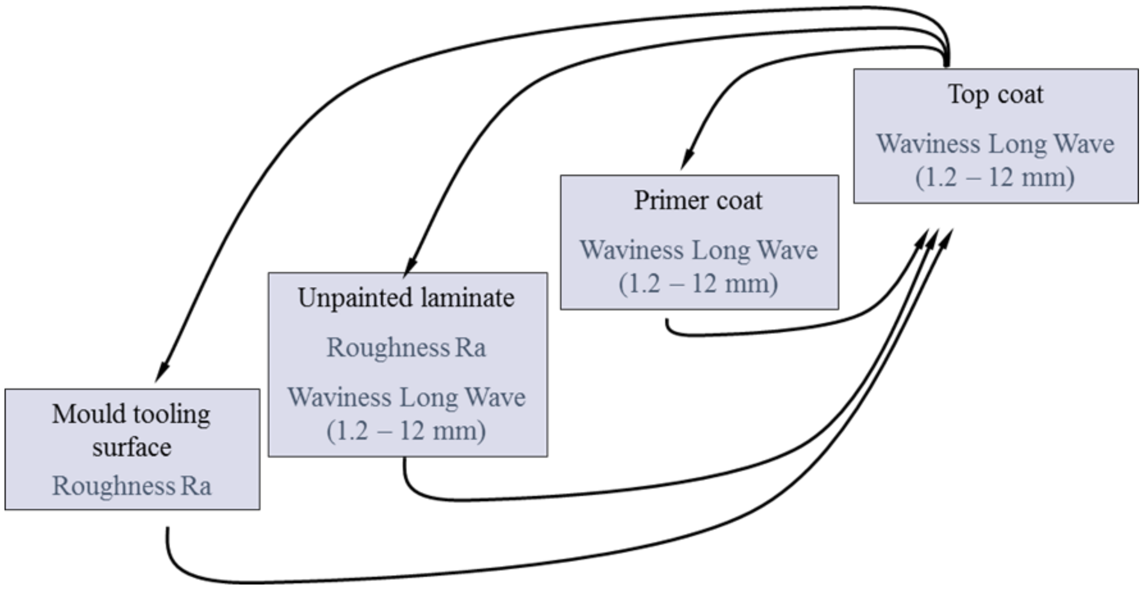

Figure 3. Cross-correlation of composite manufacture and surface quality measurements by roughness Ra and waviness Long Wave (1.2 – 12 mm).

3. Results and discussions

The threshold values for the parameters in Figure 3 were first substantiated through a series of shopfloor measurements from the Aircelle production line. The visual impression of the typical surfaces are shown in Figure 4. The measured values of roughness and longwave are compared, in Table 1, with the existing automotive standardized values[15]. The measurements of longwave and shortwave were plotted versus the orange peel parameter Tension in Figure 5. The parameter Tension is specified by Airbus Manual M2435. Longwave has a closer correlation with Tension than shortwave. As the current nacelle structures are based on the pregreg autoclave technology, this study continues in progress to quantify the threshold values for the out-of-autoclave process. A full factorial analysis will be performed and the design of experiments (DoE) include factors of tooling roughness, surface print-through features, and surface defects. The baseline values of Ra and Long Wave will be correlated with the averaged subjective assessments based on four experienced quality control supervisors in the Aircelle paint shop. The surface measurements are then used to guide the process parameters to achieve Class-A surface finish.

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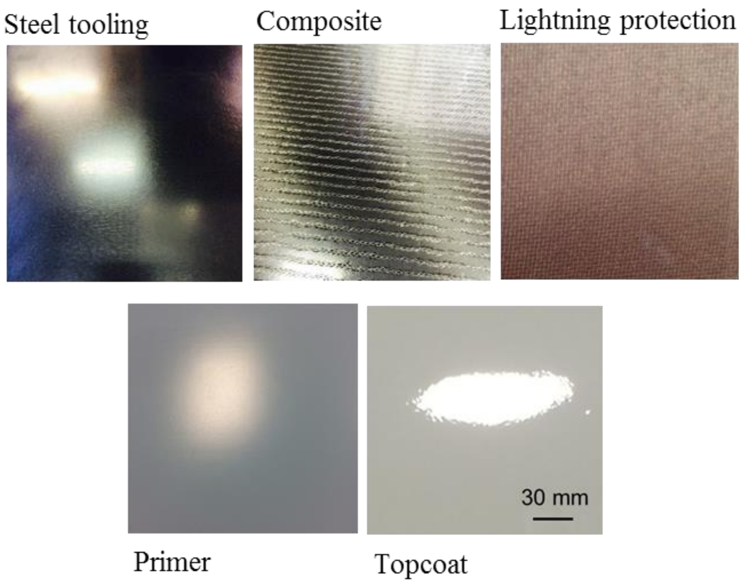

Figure 4. Visual impression of surface textures at the relevant composite manufacturing stages.

Table 1. Comparison of surface quality threshold values between automotive and aerospace industry.

Industry application	*Roughness – Ra* (µm)	*Longwave - LW* Composite	*Longwave - LW* Primer	*Longwave - LW* Topcoat
Automotive - Audi	0.2	40	20	10
Aerospace - Aircelle	0.6	52	26	13

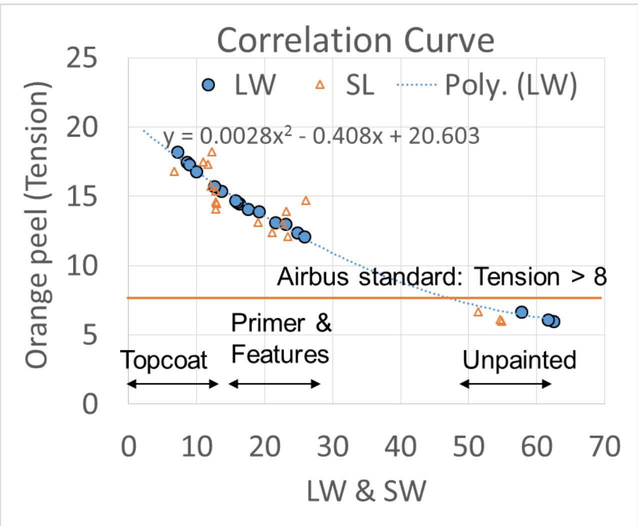

Figure 5. Plot of orange peel as parameter Tension vs the waviness spectrum parameters of longwave and shortwave.

4. Conclusions

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This study established a holistic approach of objective surface evaluation for composite aero-structure application. The criteria to achieve aerospace Class-A surface is comparable to that in the automotive industry. Futher work is required to apply the established criteria to optimise the out-of-autoclave process paramters.

Acknowledgments

The work was funded by the Department of Business, Innovation and Skills – United Kingdom, through the Advanced Manufacturing Supply Chain Initiative Project 510929.

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