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Surface Analysis of SMC Panels

by

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Abstract

In the process of making purchasing decisions, consumers often place a high value on the appearance characteristics of a product. This is particularly true in the case of durable goods such as automobiles. Although the ability of an automobile to perform its intended function cannot be determined for some time, its exterior makes an immediate impression. While features such as color are a matter of personal taste, the fit and finish on a product convey a sense of quality that reinforces the consumer's desire to acquire the product. The automotive industry has long been sensitive to this situation and until SMC manufacturers were able to truly deliver Class-A quality body panels, composites were not specified despite their numerous other desirable features.

The ability to meet the Class-A requirement was initially a subjective impression based on the interpretation of human observers. Their reference point was usually "is it as good as steel". The desire to be able to quantify the surface quality led to the use of standard measurement equipment such as a profilometer. These were good at characterizing the intimate details of a surface but lacked the ability to display larger defects such as long term waviness. Specialized equipment was subsequently developed which used procedures to magnify out-of-plane inconsistencies. The images obtained by these methods could be used in-situ by an observer or could be digitized to mathematically describe a surface, often resulting in a single number to globally characterize a surface. These techniques often placed less emphasis on the finer details of the surface.

A new technique has been developed in recent years, the Ondulo by Visuol Technologies. As shown in Figure 1, the method uses curvature as the relevant measurement parameter [1]. Defects will induce a change in the localized curvature of a surface. By using the technique of deflectometry, more precisely phase-shifted deflectometry, surface defects can be identified. For a description of the mathematics involved in this technique, the reader is directed to Reference 2 [2]. By interacting with the various wavelengths of visible light a wide range of defects can be identified, from long waves to micro-roughness. Most importantly, this technique correlates very well with the surface quality as determined by visual observation.

Introduction.

Surface appearance, and quality, is a highly subjective interpretation. It is determined by how people see things but not everyone see the same thing in the same way. Engineers and scientists who design products and systems like to have methods that are quantifiable and produce data in terms of numbers which can be measured. Quite often a single number is not sufficient to characterize a measurement technique. In prior art, surface roughness was determined by an average deviation from a mean value but that's not how the human eye makes its determinations. Procedures that use techniques to enhance the defects for better visualization also don't correlate well with the real world as seen through the human eye. In the development of Class-A SMC, it is desirable to be able to quantify defects both in terms of number and severity. The effect of formula and process changes can be determined which lead to material optimization and robustness. In many cases, what improves one situation can make another worse. A system that can quantify a range of defects and present them in a readily identifiable format, including pictures and graphs, is a real benefit in product development.

Experimental

Various analyses of Class-A SMC molded components were conducted using the Ondulo system. The basic principle of operation is shown in Figure 2. A light grid is displayed on a screen and the reflected image from the part is captured by a camera, similar to the way an eye would operate. From this image, the local slopes and curvatures are derived. Various test panels were evaluated visually, by the Ondulo, by a Diffracto D-Sight (Figure 3) and by a Loria Surface Analyzer (Figure 4). SMCs with various low profile additives were evaluated. Panels containing typical surface defects will be shown.

Results and Discussion

A typical Ondulo contour plot is shown in Figure 5. The plot of the analyzed area is on the left and the vertical bar on the right illustrates the color pattern for the varying degrees of curvature. It also calculates a value for the standard deviation of the various curvatures on the panel, Sa or Sq value, giving the panel a single index for comparison. The curvatures associated with the different wavelengths of light can be further evaluated. The finest details are shown on the left at the shorter wavelengths and the largest details are on the right. In performing compound optimization, this type of analysis can show which areas of performance need to be improved, such as long term waviness (right map) or fiber prominence (left map), since each grouping can be analyzed separately. Figure 6 illustrates this for a low profile panel made by hand layup. The shortest waves, in this case fiber print, are the worst defect while the long waves are good. There are various methods of displaying the Ondulo images and results (Figure 7) [3]. Here we see the colored contour plot as before, a gray scale image of the part on the bottom right, a calculated contour map on the top left and a surface roughness plot in blue.

Since the Ondulo system is a new surface analysis technique, several test panels were evaluated by the Ondulo and by two classical techniques, the Diffracto and the Loria. Visual evaluation was also done as a reference. Figure 8 illustrates the output from a D-Sight analysis. Figure 9 shows a typical Loria result. Figure 10 compares the four different results of analysis of SMCs made with different low profile additives. The overall rankings are similar for the visual, Ondulo and Loria evaluations but not for the D-Sight. This is further illustrated in Figure 11 which shows a correlation plot for the Ondulo versus D-Sight and the Loria. Table 1 is a comparison of the characteristics of all four measurement techniques.

The next few figures illustrate some of the capabilities of the Ondulo system. In the development of Class-A SMC it is desirable to be able to improve the compound performance in areas that it is deficient but maintain the otherwise good features. Figure 12 on the left shows some degree of medium to long waves in red. The improved formula eliminates these waves. The result is a smoother panel with a lower Sq index and lower shrinkage. Figure 13 compares the surface of Class-A SMC with a general purpose, low shrink SMC. It is important to note that the color scales on the two plots are significantly different, being 8º maximum on the Class-A panel and 45º on the low shrink panel. The low shrink panel has considerably more and larger waviness which is usually readily visible to the naked eye on these type panels. In Figure 14 we see the low shrink panel compared with various low profile panels all shown on the same scale and now the difference becomes much more obvious. The smoothest panel, Sq of 0.95, is almost featureless. This shows the versatility of the Ondulo. It can compare materials of widely varying degrees of surface profile to show their relative quality. For materials with a high quality profile it can still delineate the fine details that distinguish a very good profile from an excellent profile. While a number of surface defects are readily apparent to the naked eye, the Ondulo captures the image in a similar fashion and can then graphically display the results in various formats. Figure 15 compares standard Class-A SMC with flexible Class-A SMC molded over bosses with ribs. The boss areas are clearly visible in the contour plots but what may not be so obvious to the unaided eye is that the bosses affect the overall surface more on the standard SMC than the flexible SMC. In the standard SMC contour plot there is more red area. In the surface roughness graphs, the flexible SMC is smooth between the bosses while the standard SMC shows more deviation from the mean profile. Figure 16 shows two common defects, blisters and a knit line. The profiles of these panels are displayed in three dimensions, highlighting the blisters and also showing the localized roughness induced by the converging flow fronts.

Conclusions

A new tool for surface analysis, the Ondulo, provides a new technique for the characterization of composite surfaces. By introducing curvature as the relevant parameter, the equipment provides a closer approximation of visual perception. Additionally, Ondulo is able to present the data in various formats to improve our ability to observe the intimate details that define a high quality surface.

References

1. Ondulo Surface Analysis, Visuol Technologies, Metz, France

2. Reda, Hsakou, "Curvature; the Relevant Crite rion for Class-A Surface Quality", JEC Composites Magazine, March 2006

3. Ondulo Surface Analysis, Visuol Technologies, Metz, France

Authors:

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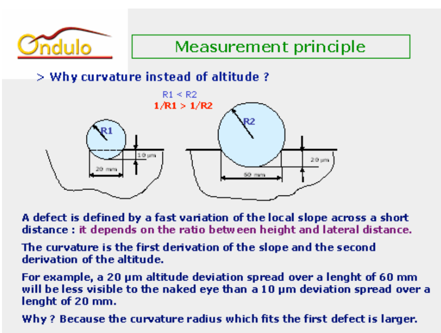

Figure 1. Curvature effect

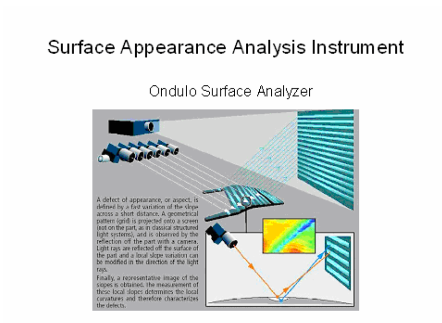

Figure 2. Ondulo principle of operation

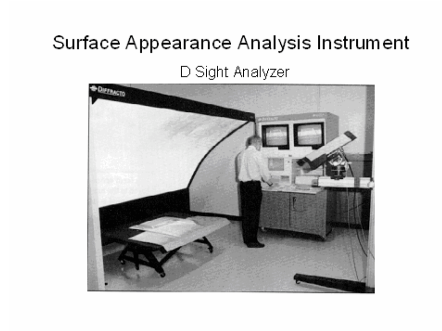

Figure 3. Diffracto D-Sight

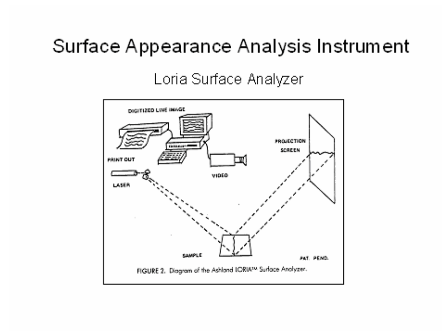

Figure 4. Loria Surface Analyzer

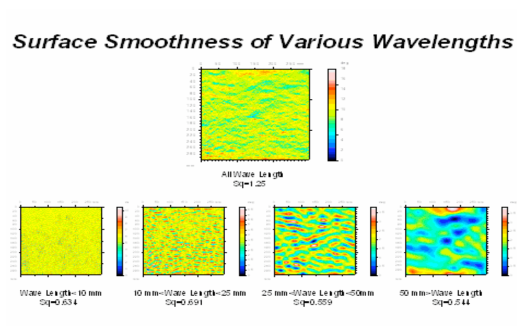

Figure 5. Ondulo contour plots

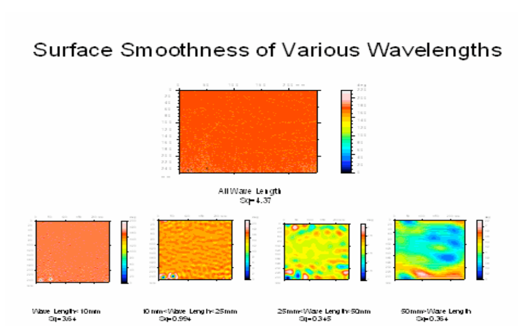

Figure 6. Hand layup panel with fiber print

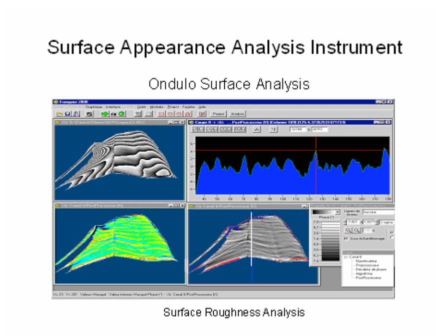

Figure 7. Various graphical outputs

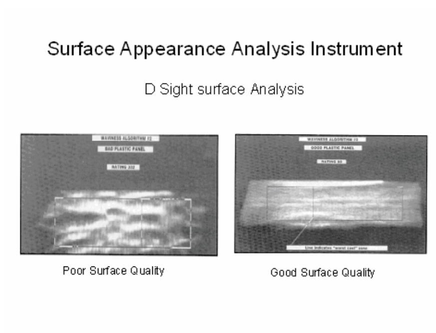

Figure 8. Diffracto D-Sight images

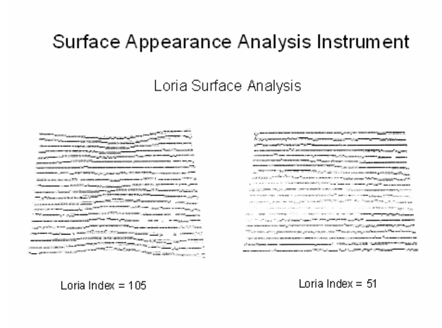

Figure 9. Loria Surface Analyzer images

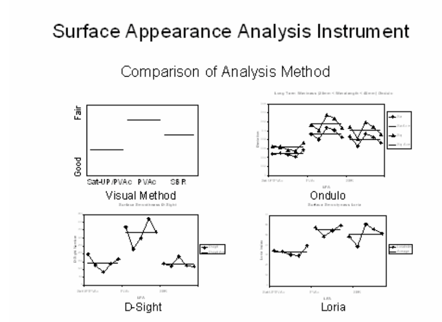

Figure 10. Comparison of evaluation methods

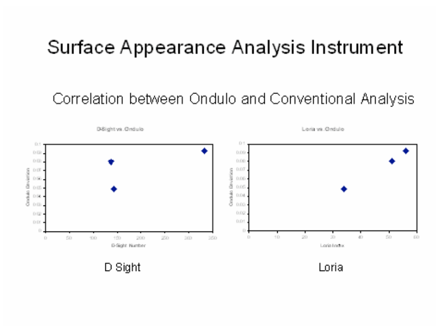

Figure 11. Correlation graphs

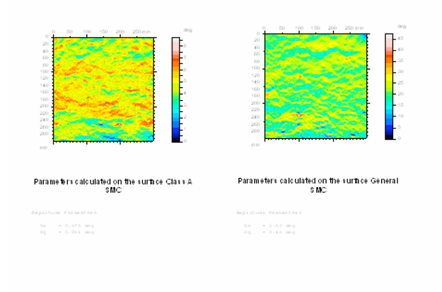

Figure 13. Low profile versus low shrink SMC

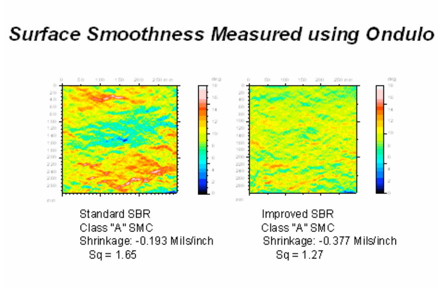

Figure 12. Improved SMC without long waves

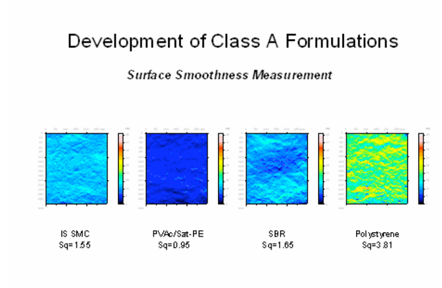

Figure 14. Comparison on same scale

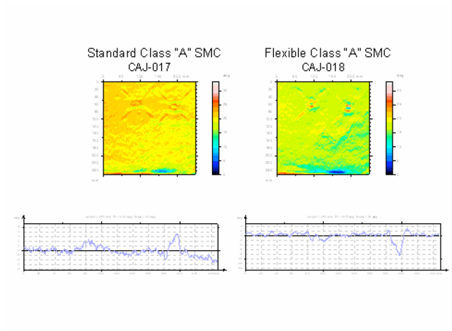

Figure 15. Standard versus flexible SMC

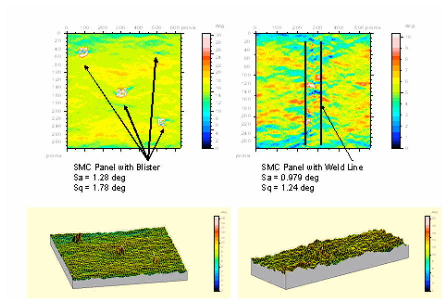

Figure 16. 3-D plots of blisters and knit lines

Surface Appearance Analysis Instrument

Comparison of Analysis Method

	Visual Method	Ondulo	D Sight	Loria
Correspondence with Visual	Good	Good	Poor	Good
Measurement in Numerical	Poor	Good	Fair	Good
Surface Roughness Measurement in Numerical	-	Good	-	-

Table 1. Comparison of surface analysis equipment