

Appearance of a Class A Surface Orange Peel and Brilliance

Abstract

Color and appearance are essential quality parameters of coatings. Especially the paint finish of an automobile is expected to be brilliant, smooth and uniform. The visual perception is depending on the observer, illumination and viewing conditions as well as on material and product properties. In order to measure waviness objectively instrumental measurement is performed with the wave-scan. The following article reviews visual perception of waviness and brilliance and explains the measurement principle of the wave-scan. Different practical examples are showing possibilities of data interpretation.

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1 Visual Perception of Class A Surface Appearance

We evaluate a surface by focusing our eye on a reflected image of a light source or on the surface itself. When we focus on the reflected image of a light source, the image forming quality is evaluated – i.e. the capability of a surface to reflect objects. The light source can appear brilliant or dull (gloss). When reflecting an edge the dark area can appear lighter (haze) and the edge can be blurred or distinct (DOI). (Fig. 1)

When we focus our eyes on the surface, we gain additional information about structure size and form. We see these structures as a wavy pattern of light and dark areas. This waviness is often referred to as orange peel or flow/leveling defects. (Fig. 2)

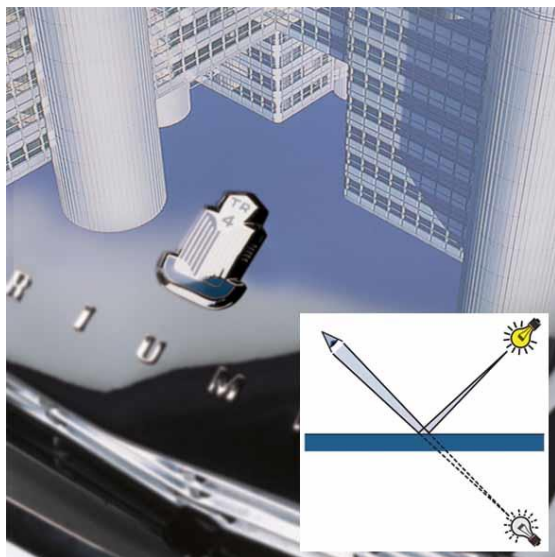


Fig. 1: Focus on reflected image

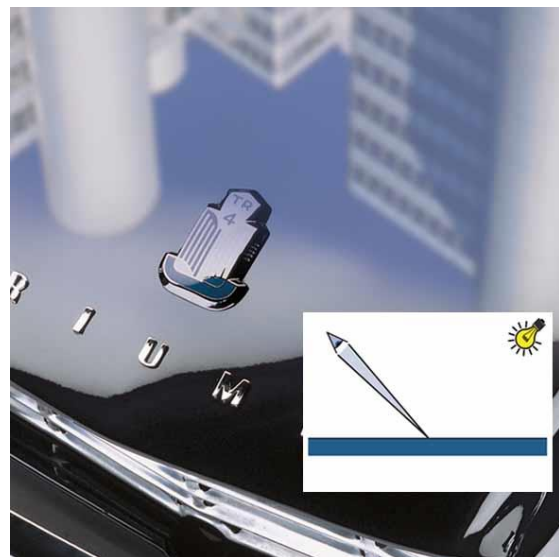


Fig. 2: Focus on surface

Both evaluation types are individually weighted and contribute to the total appearance perception.

Appearance				
Focus on Surface		Focus on Reflected Image		
Waviness, Orange Peel		Image Forming Quality		
Longwave	Shortwave	DOI	Gloss	Haze

In order to guarantee reliable and practical quality assurance, it is necessary to define appearance with objective and measurable criteria. Accurate characterization of appearance does not only help to control quality but also supports to optimize the manufacturing process and thus leads to an improved quality of the product.

The total appearance and the visibility of structures depend on the structure size, the observing distance and the image forming quality.

2 Waviness and Structure Size

The waviness of automotive paints is in a range of approx. 0.1 to 30 mm lateral wavelength. These phenomena are often visually evaluated and subjective terms like degree of orange peel or texture are used as descriptions. Orange peel can be seen on high gloss surfaces as a wavy pattern of light and dark areas. Depending on the slope of the structure element the light is reflected in various directions (Fig. 3). Only the elements reflecting the light in the direction of our eyes are perceived as light areas.

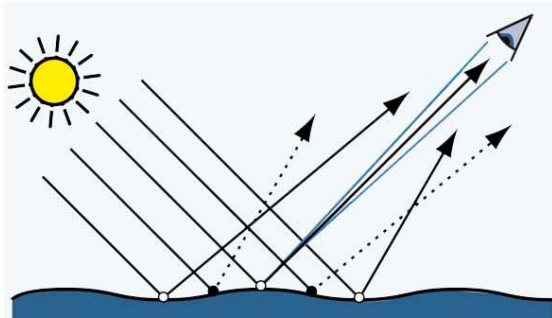


Fig. 3: Visual perception of orange peel

Visibility of structures is dependent on the observing distance. The greater the distance, the smaller objects will appear. Structures with a size of 10 - 30 mm can best be seen at a distance of approx. 3 m. Fine structures in a range of 0.1 - 1 mm can only be recognized at a close distance. (Fig. 4)

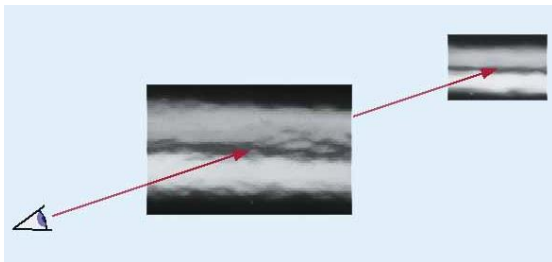


Fig. 4: Appearance changes with observing distance

The resolvable structure size is also dependent on the observing distance. Very fine structures that are below the human eye's resolution (smaller than 0.1 mm) can no longer be recognized as a light / dark pattern, even at a close distance. The result is a reduction of the image forming quality (IFQ). At three-meter distance, structures between 1 - 3 mm can hardly be resolved as a waviness but influence the appearance (Fig. 5)

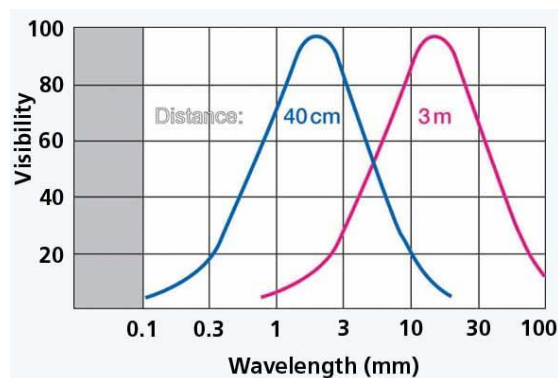


Fig. 5: Resolution of the human eye

3 Image Forming Quality (IFQ)

The higher contrast and sharpness of a reflected object, e.g., the edges of black and white lines, the better the image forming quality will be. Fine structures disturb the reflected image, consequently edges become blurry and are no longer sharp.

Image Forming Quality at a close distance: Distinctness of Image (DOI)

DOI can also be described with terms like brilliance, sharpness or clarity. The DOI is diminished by very fine structures close to the human eye resolution (smaller than 0.3 mm). (Fig. 6)

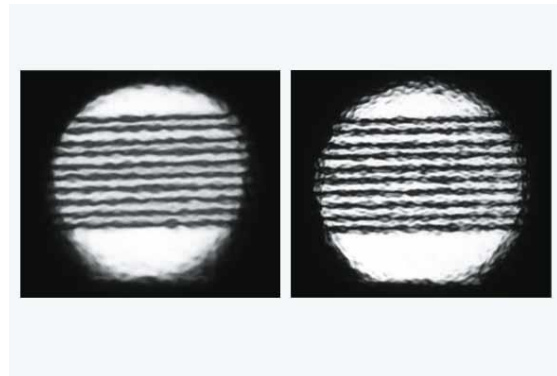


Fig. 6: Brilliance – DOI

Image Forming Quality at a far distance: Wet Look

At a distance of three meters, the image forming quality is mainly influenced by structures between 1 - 3 mm. This effect is also referred to as Wet Look.

4 Objective Measurement of Waviness with wave-scan

The wave-scan simulates our visual perception. Like our eyes, the instrument optically scans the wavy light / dark pattern. A laser point light source illuminates the specimen at a 60° angle and a detector measures the reflected light intensity at the equal but opposite angle. The orange peel meter is rolled across the surface and measures point by point the optical profile of the surface across a defined distance. The wave-scan analyzes the structures according to their size. In order to simulate the human eye's resolution at various distances, the measurement signal is divided into several ranges using mathematical filter functions (Fig. 7):

Scale	Wavelength
Wa	0.1 – 0.3 mm
Wb	0.3 – 1 mm
Wc	1 – 3 mm
Wd	3 – 10 mm
We	10 – 30 mm
SW	0.3 – 1.2 mm
LW	1.2 – 12 mm

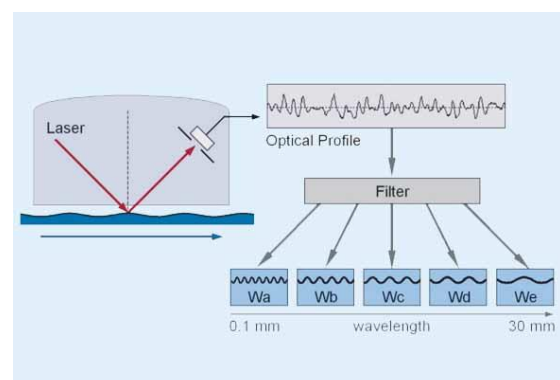


Fig. 7: wave-scan measurement principle

5 Objective Measurement of Image Forming Quality

5.1 Limitations of gloss measurement

A glossmeter measures the specular reflection which is reflected at the equal but opposite angle of illumination. The light intensity is registered over a small range of the reflection angle. On flat surfaces, the incident light is directly reflected in the main direction of reflection and completely measured by the detector. On curved samples the reflected light beam is more or less scattered in directions outside of the detector range (Fig. 8). Thus, the measured gloss values cannot be compared to those of flat surfaces. Additionally, the measurements are not very repeatable due to the curvature influence.

In addition, gloss readings are dependent on the refractive index of the coating material. Figure 9 shows a 1K and 2K system. Visually, no gloss differences can be recognized. Yet, the measurement results show a gloss difference as the two paint systems have different refractive indices. As a consequence, traditional gloss measurement cannot be used to compare the gloss of different materials.

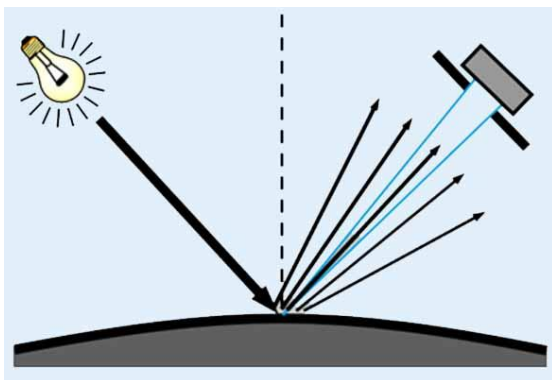


Fig. 8: Gloss measurement on curved surface

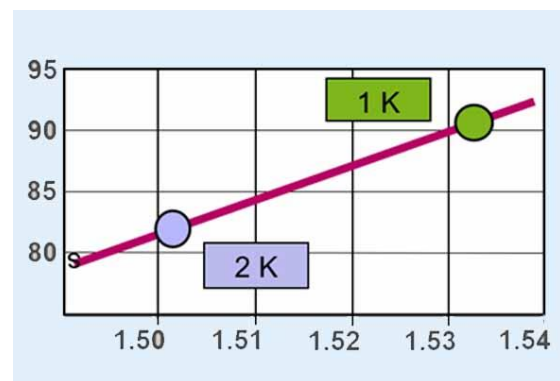


Fig. 9: Refractive index versus 20° Gloss

5.2 Objective measurement of Image Forming Quality with wave-scan

Structures smaller than 0.1 mm influence our visual perception, therefore the wave-scan uses a CCD camera to measure the diffused light caused by these fine structures. A green LED illuminates the surface at 20°. A CCD camera analyzes the reflected image of the light source's aperture (Fig. 10). If there are no fine-micro textures, all light will be detected within the image of the aperture (= max). Otherwise, light will be detected outside (= scatter value). The ratio of these two components is expressed in a new value: "Dullness" (structure < 0.1). Dullness measurement is independent of the refractive index (Fig. 11) and the curvature of the surface as it is not an absolute, but relative measurement.

$$\frac{\text{Scatter value}}{\text{Max}} = \text{dullness}$$

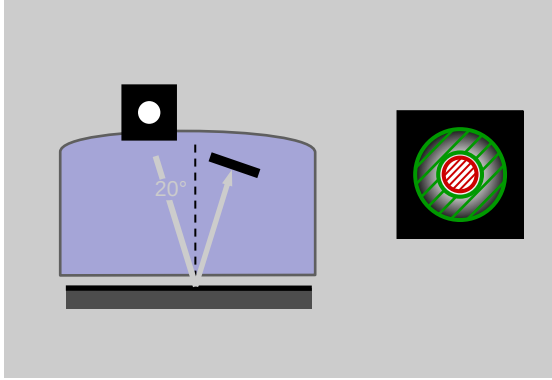


Fig. 10: Measurement principle - Dullness

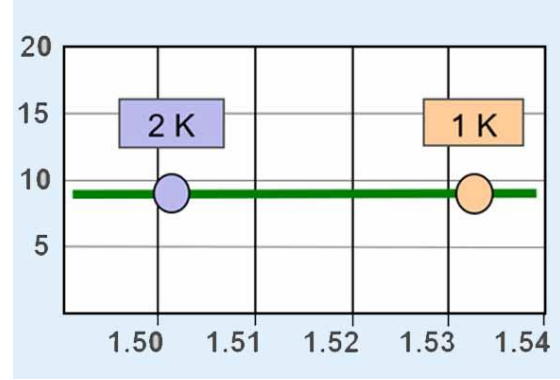


Fig. 11: Refractive index versus Dullness

6 wave-scan Scales

6.1 Structure spectrum

The values of dullness and W_a to W_e form a so-called “structure spectrum”. This allows a detailed analysis of the appearance of a Class A surface and its influencing factors, being material and / or application parameters. (Fig. 12)

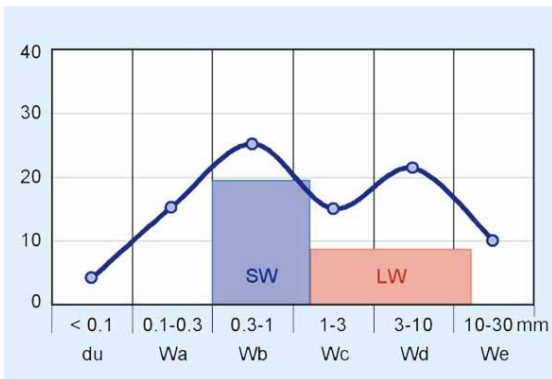


Fig. 12: wave-scan structure spectrum

6.2 Customer specific wave-scan scales

The detailed information of the structure spectrum as well as LW and SW became the basis to correlate customer specific appearance perceptions resulting in a variety of scales. In addition, visual perception studies were done and correlated with wave-scan measurement data as well as the obsolete Hunter Dorigon measurement data to correlate with the DOI as described in ASTM E430.

DOI	Function of du, Wa and Wb, Correlation to ASTM E430,
Rating:	Orange Peel based on ACT panels
Tension-Scales:	Leveling
GM-Tension	GM Specification
P-Tension	Honda Specification
H-Tension	Honda Specification
Ford Scales:	
Luster	A measurement for Gloss
Sharpness	A measurement for DOI
Orange Peel	A measurement for Leveling
Combined	An overall rating
Daimler Chrysler Scales:	
Gloss DCA	A measurement for Gloss
Dorigon DCA	A measurement for DOI
Orange Peel DCA	A measurement for Leveling
Overall DCA	An overall rating
BMW Scales:	
N1 Note 1 m	A ranking note for 1m observation
N3 Note 3 m	A ranking note for 3m observation
FIAT	
FAM	Fiat Appearance Matrix
ACY	Accuracy
Hyundai	
CF Comb Ford	Combined Value (LU,SH,OP)
PAQ	Perceived Appearance Quality
ISUZU	
GD ISUZU value	Isuzu Appearance Scale
JLR	
JLR_OP	JLR Orange Peel Scale
Nissan	
NID	Overall Appearance Scale
Piaggio	
SBI	Scooter Balance Indicator
Wcd	Combined value for Orange Peel
Subaru	
FGD	An overall rating

7 Typical Applications for Trouble Shooting

7.1 Influence of baking position

In general, horizontal surfaces have a better flow and leveling behavior than vertical surfaces due to the influence of gravity, i.e., resulting in lower long wave values (W_c , W_d , W_e). The shorter waves are hardly influenced by the baking position. (Fig. 13)

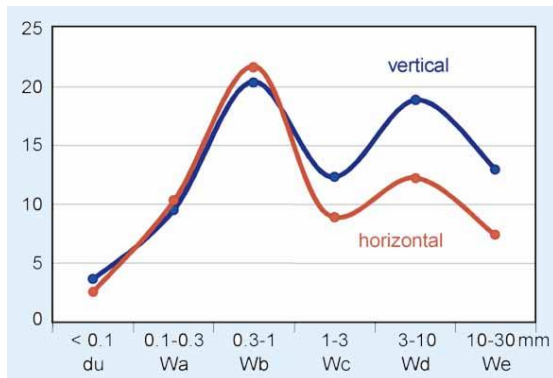


Fig. 13: Influence of Baking Position

7.2 Influence of film thickness

The structure spectrum can help optimize the appearance, e.g., in determining the optimum film thickness. In general, increasing clear coat thickness will improve flow and leveling. In figure 14 this can be seen in decreasing W_c and W_d values.

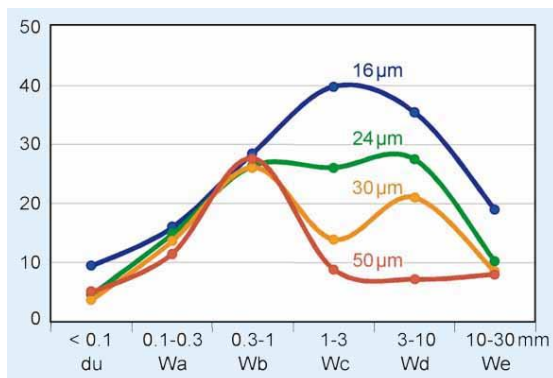


Fig. 14: Influence of Film Thickness

7.3 Substrate influence

In figure 15, the substrate influence is analyzed. The substrate roughness can telegraph through the clear coat and reduce the brilliance of the topcoat. Sample D is a laser-textured panel with a specific texture resulting in lower SW values than on standard car body steel panel.

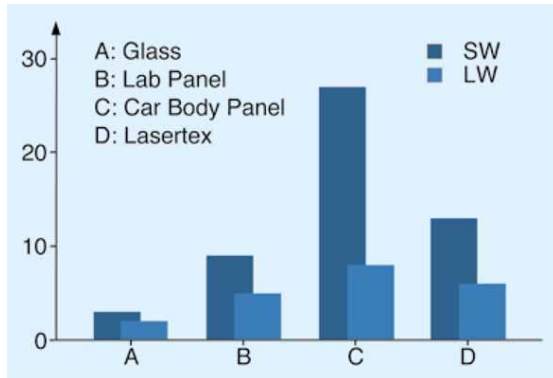


Fig. 15: Substrate Influence

8 wave-scan Measurement on High to Semi Gloss Surfaces

Appearance control is no longer limited to final topcoat inspection. The wave-scan dual, orange peel meter scans the optical profile of high gloss surfaces using a laser light source. An additional, infrared - high energy LED allows measuring the same structure spectrum (0.1 - 30 mm) on medium gloss surfaces. The dullness measurement is recorded with state-of-the-art CCD camera technology. It gives information on the image forming qualities of the surface caused by structures < 0.1mm.

Close the loop by checking the quality of each process step

Thus, the surface quality after each paint process step can be objectively evaluated (Fig. 16). No more guessing which substrate layer is influencing the final appearance. The wave-scan dual will help you to objectively analyze appearance problems and reduce the time necessary for trouble shooting.

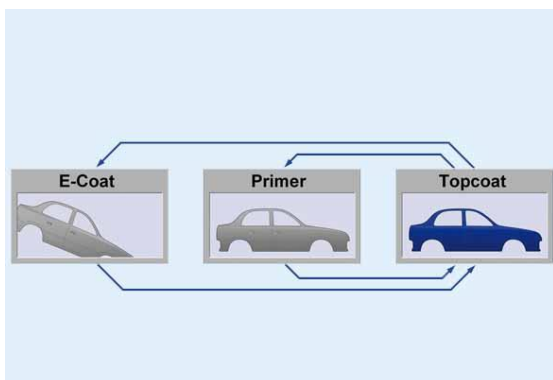


Fig. 16: Paint process steps

Example: Influence of Steel Quality on Final Appearance

Step 1: Appearance Control after E-coat

Same E-coat system was applied on rough and smooth steel. The influence of rougher steel can be seen in increased Wb and Wc-values (Fig. 17).

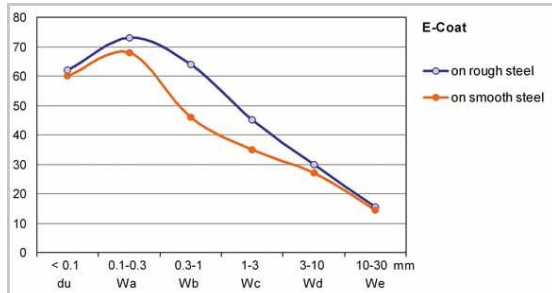


Fig. 17: Appearance Control after E-coat

Step 2: Appearance Control after Primer Surfacer

The primer surfacer was applied on both panels. The roughness of the steel quality can still be detected in increased Wb and Wc- values. This primer system could not completely cover the steel influence (Fig. 18).

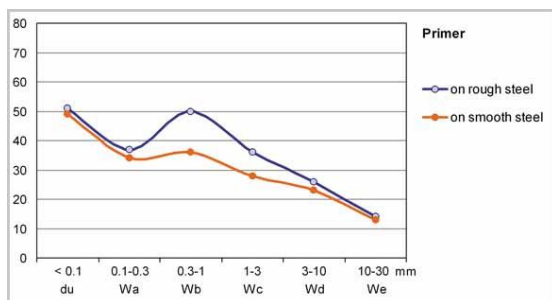


Fig. 18: Appearance Control after Primer Surfacer

Step 3: Appearance Control after Topcoat

The final appearance shows higher shortwave values on the rougher steel panel. Therefore, the smooth panel will appear more brilliant (Fig. 19).

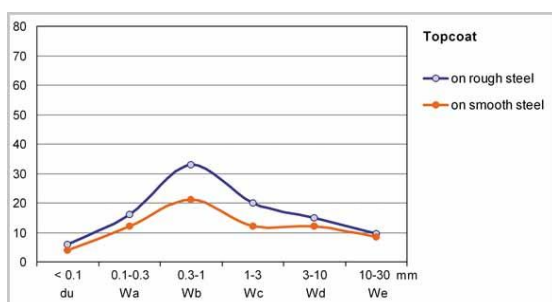


Fig. 19: Appearance Control after Topcoat

wave-scan dual – a diagnostic tool for trouble shooting and optimizing appearance

Now, you can establish appearance specifications for each paint layer to ensure the final appearance is always on target.

9 Summary

The appearance of a Class A surface can be influenced by many different parameters. To keep the quality of your product smooth and brilliant with uniformity between adjacent panels the wave-scan objectively measures waviness and distinctness of image. The measurement results are correlated to visual perception studies resulting in customer specific scales which can be used for quality control to ensure a stable process. In order to optimize appearance and improve harmony between body and add-on parts the detailed structure spectrum data will guide you in the right direction to either improve process or material properties.

10 Literature and Standards

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