VIEEW™
A Quantum Leap in Surface Defect Evaluation for Automotive Materials Applications

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Introduction

The human eye, coupled with the subjective judgment of a material inspector, determine the surface quality levels that are acceptable in raw materials and finished goods. Where the quantification of a large number of surface defects is beyond perceptual and cognitive capabilities, pictorial references are employed for general comparison to allow a classification of the severity of a sample's defects. This technique has admirably compensated for our visual limitations, but has come at the cost of questionable repeatability and includes the psycho-physiological biases of the observer.

While this methodology has sufficed throughout the history of industrialization, revolutionary advances in imaging technology have originated precision tools for minimizing subjective, human influences and for automating inspection procedures. The VIEEW™ digital image analyzer, developed by Atlas Electric Devices Company, is a leading-edge integration of these modern technologies. It is capable of capturing digital images of samples under various lighting schemes optimized for the sample surface, of digitally processing the images to highlight and enhance surface defects, and of measuring and counting defects such that each sample is defined by a comprehensive statistical profile. This process may also be applied to graded reference samples and stored on disk, ultimately allowing a classification of test samples by automatic, statistical comparison to the reference data.

Figure 1 – VIEEW™ System

Optical Imaging System - Hardware Considerations

Lighting of a sample is of critical importance in optical imaging. Light source spectrum and angle of incidence are key factors in determining what can be optically detected. The VIEEW™ system incorporates two different illumination methods: diffuse, chromatic (color) lighting for the detection of variations in chromatic contrast; and direct lighting to measure variations in geometric reflection (gloss) and its textural characteristics.

Diffuse Illumination

To accurately measure variations in chromaticity, or color difference, the sample should be illuminated by a diffuse chromatic source where each color component (Red, Green and Blue) may be independently adjusted to maximize surface contrast. Optimal light diffusion is obtained by mounting the light source(s) inside an integrating sphere (a spherical cavity); the interior walls of which are treated with a high-reflectance coating to maximize scattering, as shown in Figure 2.

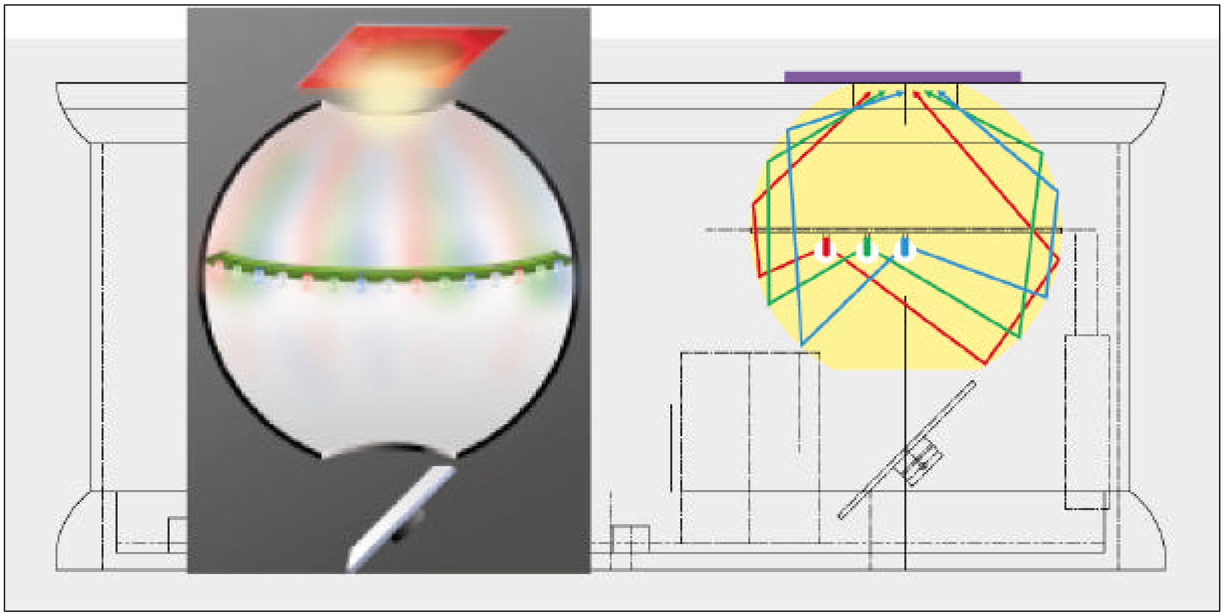

Figure 2 – Diffuse Illumination

Direct Illumination

The most accurate measurement of the reflectance, or gloss, of a surface is made when light strikes the sample normal to its plane at an incident angle of 0°. Light striking an optically smooth surface under these conditions will be reflected back at 0°, but light striking a textured surface will be reflected at angles other than zero; and, in effect, will be lost to the detector of the camera which is viewing the sample at a 0° angle. See Figure 3. This results in very smooth surfaces appearing as a uniform color and irregularities being revealed as significantly darker areas; or in the case of scratches, as distinctly dark lines. An example is shown in Figure 4.

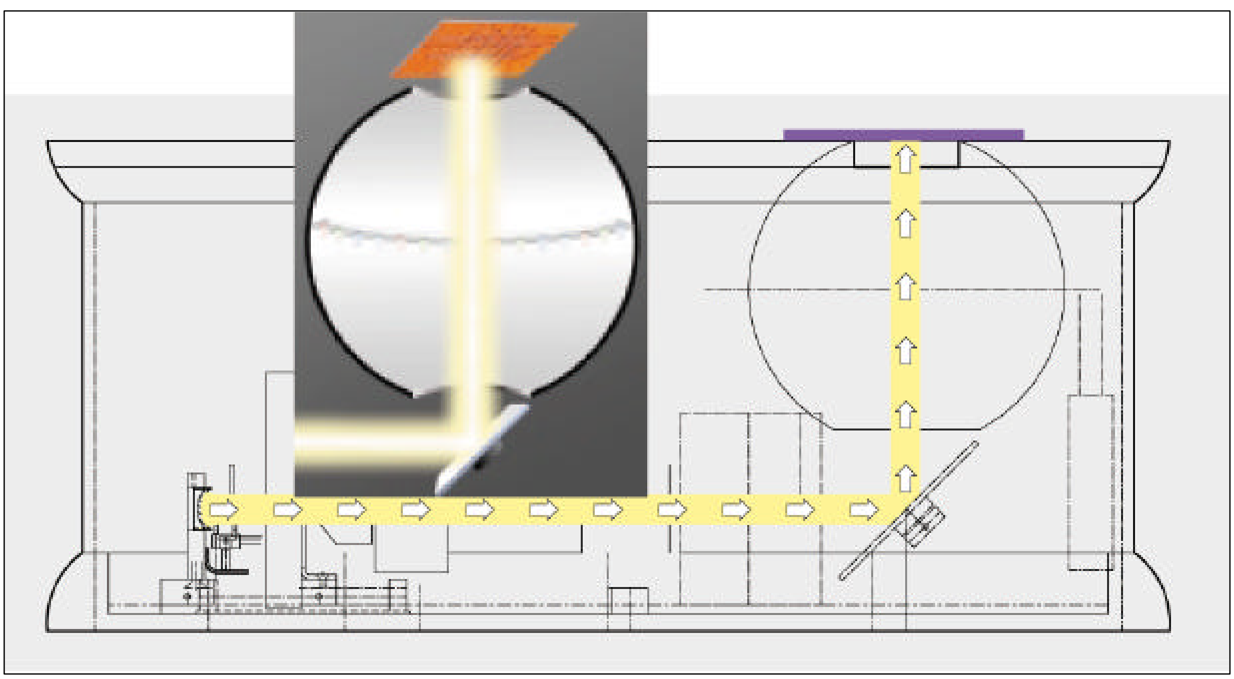

Figure 3 – Direct Illumination

DIRECT ILLUMINATION DIFFUSE ILLUMINATION DIFFUSE + DIRECT ILLUMINATION

Figure 4 – Effects of Differing Illumination Sources

Direct illumination provides additional advantages with coated samples where degradation is limited primarily to a clear top coat layer. In this topology, light is reflected only from the surface of the clear coating and not from the deeper pigmentation layer, which is of no interest when the defects are produced by marring, light abrasion or chemical and environmental exposure of the exterior layer.

The Atlas VIEEW™ system incorporates both of these illumination schemes, independently or in combination, to allow the most comprehensive detection of surface defects.

Software Analysis of a Digital Image – Binary and Grayscale Images

In computerized, surface defect analysis, two categories predominate: defect characterization and surface texture properties. The former category includes defect size, shape and distribution while the latter entails a determination of the change in surface appearance. Analysis software exploits two different image types to perform these characterizations: binary (or 2-bit black and white) images and grayscale images.

Binary Image Analysis

Binary images are created by processing the original 256-shade grayscale photo with a thresholding filter which reduces the image to black and white pixels. A variety of different thresholding techniques are used to allow the image to retain optimal defect information while eliminating those pixels of the unaffected areas. The analysis program then applies special analysis algorithms to the defects of each sample and records defect quantities and the geometric parameters of each in an associated statistical file.

The spatial formations (distribution over the surface) of the defects are also of importance since spatial characteristics can be related to physical and mechanical properties of the sample as well as to material processing. Typical examples in coatings applications are: Corrosion (rust) analysis, delamination analysis, pitting or popping analysis, crack analysis, chipping analysis/impact resistance, etc. See Figure 5.

Grayscale Image Analysis

Grayscale images are used in their original grayscale form. In some cases, image preprocessing may be applied, equally to all the samples, to highlight defect information. Sample images are then analyzed for surface texture and variations in shade that do not submit to geometrical definition. Since the original grayscale (or equally preprocessed) images are analyzed, this method provides objective results comparable to visual perception techniques.

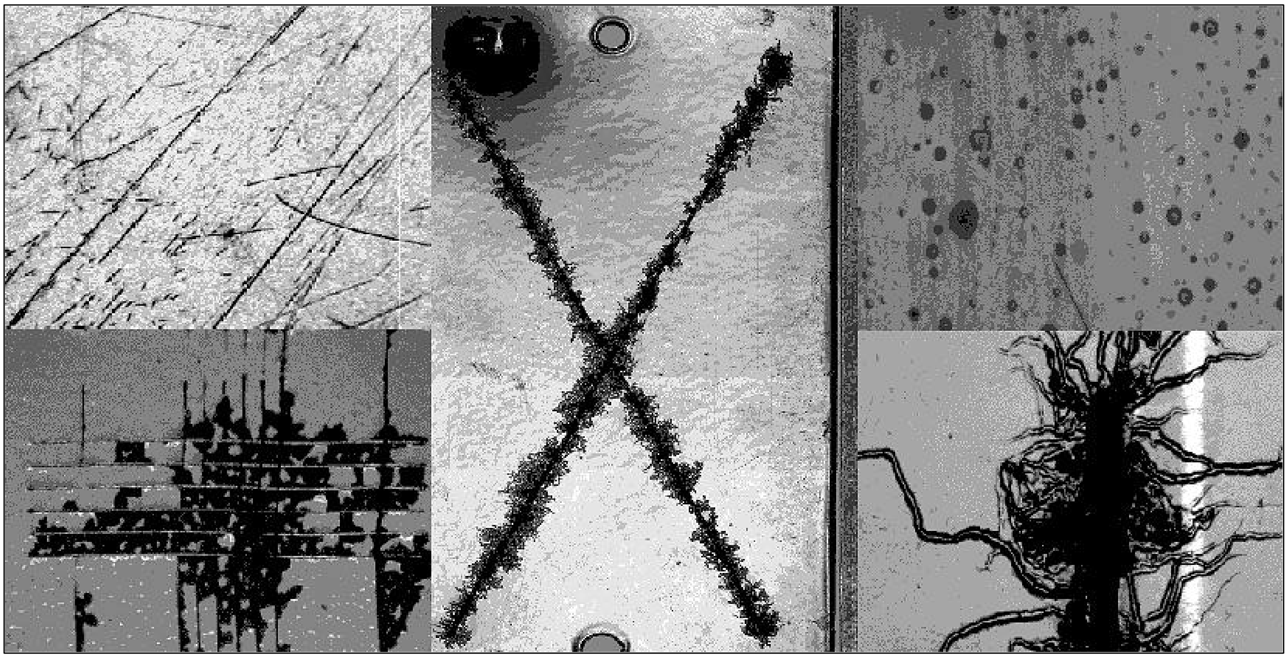

Figure 5 – Various Surface Defects Suitbale for Binary Image Analysis

Grayscale image analysis is applicable in mar analysis, scratch analysis, discoloration, micro texture analysis, pattern analysis, surface structure analysis, etc. See Figure 6.

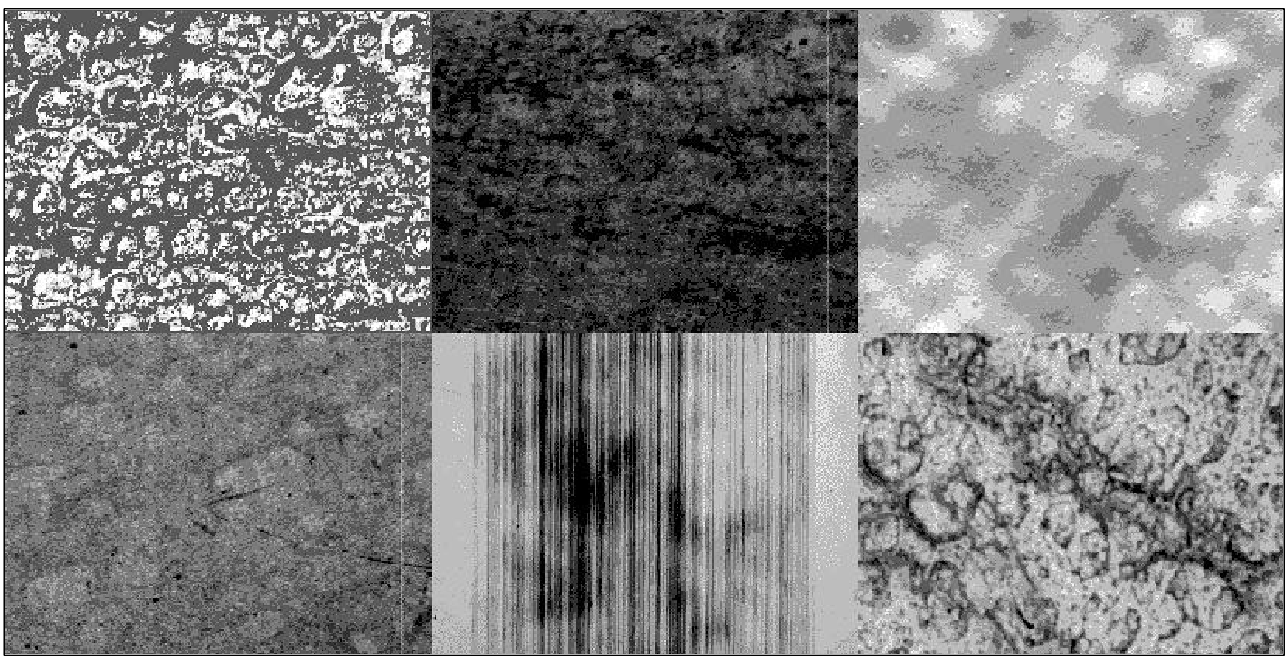

Figure 6 – Various Surface Defects Suitable for Grayscal Image Analysis

An Application Example

Analysis of Chipping Damage in a Multi-layer Coating System

Using a gravelometer, stone chips are ejected onto a group of coated samples. An image of each sample is captured and then each instance of surface damage is measured according to shape, size and other geometrical attributes to allow a rating of the samples. Additionally, the multi-layer structure of the coating must be analyzed to determine what layers have been affected in each damage instance. Traditionally, this has been measured visually, but now VIEEW™ provides a more accurate instrumental solution. Through the use of a special enhancement algorithm coupled with sophisticated illumination options, a complete analysis can be obtained by analyzing damage structures on each layer.

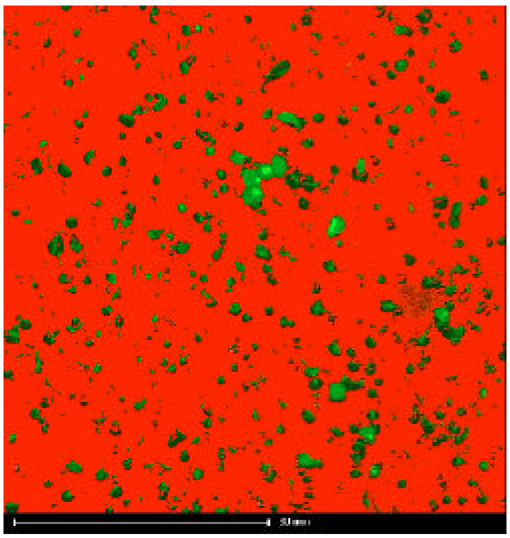

Figure 7. Chipping Damage in a Multi-layer Coating System

Step 1 - Image Capture

A sequential combination of direct and diffused illumination is used to reveal the chipping damage of each coating layer. The direct illumination reveals the damage on the top layer of clear coating. Then, a spectrally-optimized diffuse source illuminates the subsequent layers so that the damage on each can be revealed with visible distinction. See Figure 7.

Step 2 – Image Processing (Enhancement)

The captured images, revealing the damage in each layer, can be further processed to digitally separate each layer of chipping damage in a black and white image format. See Figure 8.

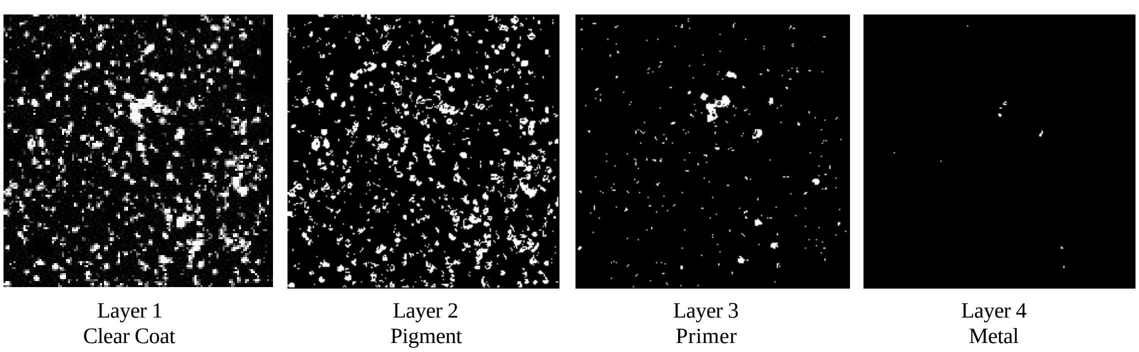

Figure 8. Chipping Damage – Each Layer Revealed

Step 3. – Image Analysis

The damage shown as black pixels is measured and analyzed geometrically to derive statistical characteristics. The calculated geometrical attributes then can be compared to industry standard classification and yield a standard rating.

Layer	% Damage	No. of Defects	Mean Size – mm^2	Size – Std Dev
1 (Clear Coat)	11.9	481	0.5	1.1
2 (Pigmented Layer)	10.3	439	0.3	0.5
3 (Primer Layer)	1.5	85	0.2	0.4
4 (Metal Substrate)	0.1	8	0.2	0.2

Conclusion

Surface defect evaluation is a science to which modern imaging and computer analysis technology may be adapted to greatly enhance its accuracy, depth of application and empirical repeatability, while minimizing or eliminating subjective human biases. Such an adaptation has been realized in the Atlas VIEEW™ digital image analyzer. It provides incomparable accuracy and repeatability in the analysis of paint, plastics, coatings and textiles surface defects.