

A Methodology to Quantify Surface Mar

Arun Kumar Sikder
GE India Technology Center Pvt. Ltd.

Vaidyanath Ramakrishnan
Sabic Innovative Plastics

Moitreyee Sinha
GE Corporate

Vicki Watkins
GE Global Research Center

Matthew Marks and Stephen Shuler
Sabic Innovative Plastics

ABSTRACT

Understanding scratch and mar damage performance of materials is important in the automotive industry. Hence there is need to develop a suitable method to quantify them and relate back to product performance. This paper elucidates a method to quantitatively evaluate mar defects. The method involves marring the surface of a sample with a crockmeter and the damaged surface characterized using a two-camera optical imaging system. These results were then correlated with visual survey results and a transfer function was generated using Design expert DX6net. In the validation stage, a set of newly marred samples were investigated to generate both visual rank and mar index using the transfer functions. Excellent agreement between mar index and visual survey rank reconfirmed the method's effectiveness. Mar performance of different materials (black and high gloss) can be compared using this technique on a 0-100 scale. This method can also be used to characterize polycarbonate glazing surfaces. Mar quantification tool is robust, quantitative, measures visual perception and free from human bias.

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INTRODUCTION

Mar and scratch damages are critical issues for automobile manufacturers because a number of factors including carwash and showroom wiping can produce such damages on a regular basis. These defects not only deteriorate surface aesthetics but also accelerate the surface degradation process leading to product failure faster than predicted. Different types of surface defects are shown in [Figure 1](#). Quantification and fundamental understanding is not only a key to product differentiation but also to positioning new grades. Development of new materials or modifying an existing grade needs to be accompanied by enhancement in accuracy and reproducibility in measuring techniques. There are several test methods that are practiced in industry but

most often it fail to predict the true visibility of mar on a surface.

Often we fail to differentiate mar damage with scratch damage and hence ignore the difference of their performance measurement separately. Although several test methods are available to characterize mar and scratch performance of polymer and coated glazing surfaces, standardized quantitative methods do not exist [[1](#), [2](#), [3](#), [4](#)]. [Table 1](#) shows the pros and cons of various test methods. Mar and scratch resistance is most often characterized using appearance metrics. While this subjective evaluation may be acceptable for differentiating performance in coating systems with similar damage mechanism, it is unrealistic to expect repeatable test results that correlate to customer expectations when comparing materials that have different damage

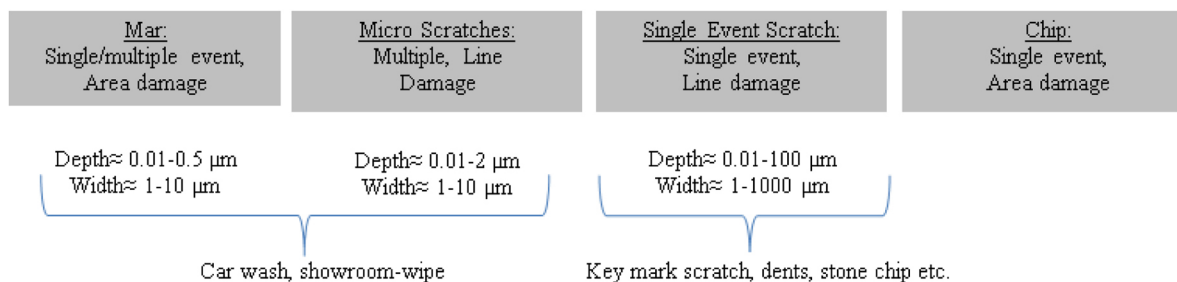


Figure 1. Differentiation of various types of surface defects and their physical dimensions.

Table. Summarizes various mar testing methods used by OEMs and their pros and cons.

Test methods	How to make judgment	Advantage	Disadvantage
- Taber testing - Crockmeter - Carwash - Falling and oscillating sand	Mass loss, cycles to failure, visual inspection, gloss measurements, gray scale changes etc.	Mimics field damage, have customers confidence, easy to perform etc.	Evaluation is either subjective or inaccurate measure of visual perception, poor robustness, provide ratings not quantitative measurements etc.

mechanisms. Rangarajan et al. reported development of a method for optically evaluating scratch visibility and later visual quality (VQ) models developed by Sinha et al. [5, 6] which addresses quantification of single scratches. Mar (which is area damage), changes the gloss and color on a surface. Often surface appearance is evaluated using a gloss meter. A major drawback in gloss measurement lies in its incapability to capture color contrasts and saturation of damage with higher severity. Also, measurement of gloss loss to characterize mar performance for low and high gloss material surfaces often produces ambiguous results. These measurements also fail to accurately capture visual perception. On the other hand, visual survey alone cannot produce reproducible and accurate differentiation on degree of marring and generate discrete and relative rating.

Scratch test methods that are currently used by the automotive industry rely on either subjective visual evaluation or the load at the onset of fracture. As mentioned earlier, some thermoplastic materials may not fracture under current test conditions and in those that do, the scratch may become quite visible even before the onset of fracture. Consequently, test methods that focus on the load at fracture will not necessarily correlate to the customer's perception of scratch performance in these systems. At present there is no proper quantitative method to characterize mar on the polymer surface. In order to overcome these issues in mar characterization, a new method is being developed, which can give quantitative evaluation of surface damage like mar. It is essential to develop a quantitative tool to evaluate mar visibility on polymer surface, which can capture maximum human perception on surface mar.

Plastic surfaces such as auto exteriors, body panels are subjected to light wiping damage throughout their lifetime. Even before the product leaves the showroom or factory it typically has undergone various dry and/or wet cloth cleanings. It is important to differentiate various types of defects and their quantitative characterization. Also depending on the applications we may put effort to improve one or two areas or all areas. Sometimes two types of defects are not related to each other. Improvement of scratch does not always imply that mar will improve. This mar damage is particularly offensive on a brand new vehicle or on a TV bezel where the adjacent areas are pristine. The auto exteriors' high gloss finish (60 degree gloss of 85-110) and high distinctness of image (DOI) make these mar defects (swirl marks) even more visible. Light colors (silvers and whites) and metallic flakes can hide this damage to some extent. Present study is carried out on black and glossy samples in order to study the extreme scenario.

NEED FOR A QUANTITATIVE TOOL

The industry practice is to use either gloss loss or visual inspection to qualitatively give relative ranking to various materials for assessing mar resistance. Measuring the gloss loss often fails to differentiate materials for low mar regime while in the high mar regime; the gloss measurement saturates and often fails to predict actual visual perception across broad range of materials. For example PC (polycarbonate) saturates faster than PMMA (poly methyl methacrylate). Figure 2 shows that 20 deg gloss loss saturates differently depending on the marring elements and marring cycles. Both substrates were marred with the three different

mar fabrics up to 20 cycles or to saturation. This indicates that gloss loss measurement will not be able to capture the true nature of a material surface after mar testing. Visual rating is relative, expensive and associated with human psychological error. Two painted steel systems and four thermoplastic film systems were marred with the 2 micron polishing paper for 2 cycles and evaluated by %gloss loss (20 degree). Same set of samples was ranked against a standard visual scale created internally.

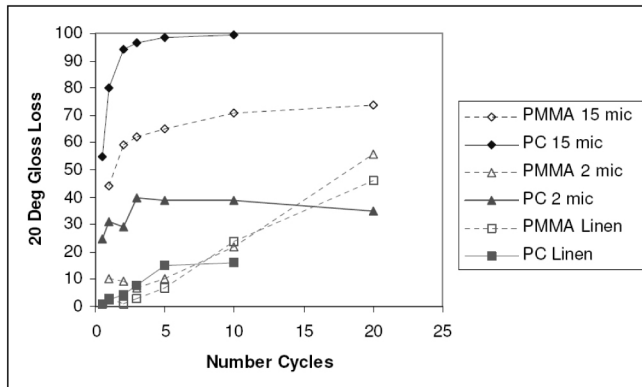


Figure 2. 20 deg gloss loss values saturate after some cycles of operation. Tests were done with 2 substrates, 3 mar fabrics, 6+ cycles. Saturation comes faster for PC than PMMA.

The samples names in these studies are coded. Figure 3 shows that the gloss loss fails to rank these samples comparably to the visual scale and the gloss differences do not scale similarly to the visual scale (Film 4 appears much worse by gloss loss than by visual scale). Clearly alternative response metrics are needed that better correlate to visual perception.

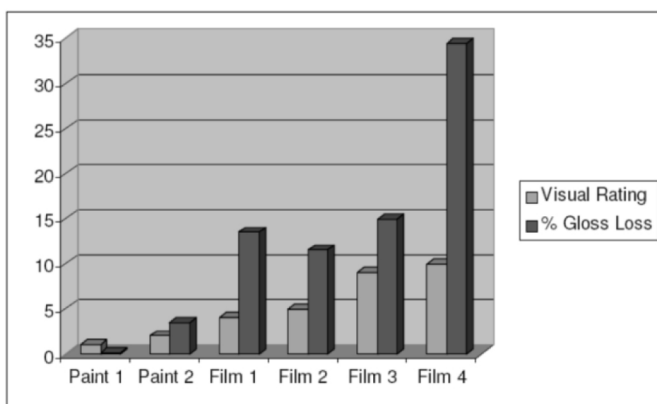


Figure 3. Gloss loss and visual rating of 2 paints and 4 thermoplastics systems and marred with 2 micron paper for 2 cycles.

OPTICAL IMAGING SYSTEM

The defects on a surface are visible to the eyes through reflected or scattered light from the object [7]. Also eyes and brain work synchronously to produce a decision on the surface quality. For example when we look at the exterior of a new car we report the intensity of color and how glossy the surface is. However, we do not mention the fact that our own image is also seen into the surface. Although the eye is an extremely sensitive and discriminating sensor, it cannot make quantitative measurements and visual inspection can vary with person and time. This subjectivity in assessment of appearance could be removed by simulating human vision through optical measurement system. If we can position two cameras and a light source appropriately we can get information regarding a surface as effectively as human can do, in addition to being more robust. This will be free of the influences of human visual and psychological responses. Human eyes are sensitive to change in color and gloss on a surface and a measure of these changes is the contrast. Eyes are also sensitive to differences in gradual change in contrast or defect with no definite pattern. In this study, contrast perceived on a marred surface, is being measured using two cameras.

When light falls on a material surface the following optical events may happen:

- Specular reflection from the first surface of the materials (related to gloss)
- Scattering (off-specular) within the material or from the defective surface (associated with diffuse reflection)
- Reflection and sometimes with diffuse transmission
- Absorption within the material (largely responsible for color) and
- Light transmission through the material, if it is more or less transparent (associated with clarity)

In this report we will be dealing with opaque materials only and hence specular and off-specular reflections are the source of information for the contrast on a surface. Human eyes capture mixed signals of both specular and off-specular, which contain information of contrast created by the defects, but cannot decouple these reflections. Eyes typically will compare the defective area with virgin area and give a decision on appearance.

Details of the 2-camera imaging system and its usefulness to capture human perception had been discussed elaborately earlier [5]. A schematic of the optical system used in this study is shown in the Fig. 4. Briefly, one camera can capture diffuse, chromatic light signal to detect color contrast (off-specular camera, OSC) and other can capture direct light signal where incident angle is same as reflected angle (specular camera, SC). Specular signal contains geometric