SURFACE VEHICLE RECOMMENDED PRACTICE

J2661™ MAR023

Issued 2011-05
Stabilized 2023-03

Superseding J2661 MAY2011

Optical Imaging Evaluation of Impact Damage Resistance Testing on Exterior Finishes

RATIONALE

SAE J2261 provides technical background information of potential relevance to the development of additional SDPs. As such, it is not dynamic in nature, but retains relevance. Updates are not likely to be required in the near term.

STABILIZED NOTICE

This document has been declared “STABILIZED” by SAE Textile and Flexible Plastics Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

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1. SCOPE

This SAE Recommended Practice covers a procedure for evaluating plastic and multiple-layer coatings exposed to gravelometer testing (as defined in SAE J400) with an optical imaging and analysis system. The intent of the procedure is to detect, count and characterize instances of damage in the coated surface that fracture the top coat layer or penetrate through multiple layers of the coating system. It may be possible to extend this methodology of coating damage evaluation to specimens that have undergone test procedures or exposures that produce similar, discrete damage sites in the coating system. If so applied, evaluation results must be interpreted with respect to the limitations and intent implied by the original evaluation procedure and its associated rating system, if applicable.

1.1 Applicability

This method may be applied to the evaluation of surface damage on plastic and coated surfaces caused by means other than gravelometer testing; provided that the specimen substrate is not significantly deformed to a degree that would prevent all surface damage sites from remaining in a single focal plane capable of being adequately resolved by the image capturing device.

1.2 Application

This SAE Recommended Practice covers a procedure for evaluating plastic and multiple-layer coatings exposed to gravelometer testing (as defined in SAE J400) with an optical imaging and analysis system. The intent of the procedure is to detect, count and characterize instances of damage in the coated surface that fracture the top coat layer or penetrate through multiple layers of the coating system. It may be possible to extend this methodology of coating damage evaluation to specimens that have undergone test procedures or exposures that produce similar, discrete damage sites in the coating system. If so applied, evaluation results must be interpreted with respect to the limitations and intent implied by the original evaluation procedure and its associated rating system, if applicable.

2. REFERENCES

2.1 Related Publications

The following publications are listed for information purposes only and are not a required part of this SAE Technical Report.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J400 Test for Chip Resistance of Surface Coatings

2.1.2 ISO Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ISO 21227-2[1] Paints and varnishes – Evaluation of defects on coated surfaces using optical imaging – Part 2: Evaluation of multi-impact stone chipping test

3. SUMMARY OF METHOD

Tested specimens are digitally captured under predetermined (software controlled) Illumination geometries. The images are then processed to highlight the damage sites. Subsequent processing may be applied to separate out the damage sites layer-by-layer on specimens having multi-layer coatings. The damage sites are then automatically measured and analyzed geometrically (by a software program) to derive statistical characteristics. The ratio of the damaged area to the total evaluated area on the sample specimen is measured and recorded as a percentage. If desired and within the capability of the analysis program, other quantitative variables may be determined. This data is then saved to disk.

The procedure above may also be applied to reference specimens, ultimately allowing a rating of the test specimens by comparing their statistical data with those of the numerically ranked reference specimens. The reference samples shall be as similar as possible to the samples to be tested, as far as material formulation, structure, finish and contrast of the individual layers (in coating systems) are concerned; therefore they shall be made using real resources and systems subject to strict quality control.

During the evaluation procedure, optimal specimen illumination and image processing conditions are established and their software settings shall be savable to disk. This allows them to be recalled, ensuring stable and reproducible evaluation conditions specimen-to-specimen, especially critical if the evaluation procedure is interrupted or conducted over multiple sessions.

[1] To be published.

4. EQUIPMENT

4.1 Optical Imaging System

4.1.1 Hardware

The hardware shall include an image capturing device, fixed-geometry illumination source or sources, and a means for performing the capture of specimen surface images in the absence of ambient light**.** Illumination source and imaging control shall be provided by computer software to allow accurate reproducibility of the image capture conditions.

4.1.1.1 Image Capture Device

This component shall include a charge coupled device (CCD, or CCD chip) providing an imaging resolution of 10 pixels/mm and the capability to record 8 bit/pixel grayscale (256 shade) images. The viewing lens shall be fixed-focal length type with a fixed aperture to ensure identical image capture magnification and prevent variations in the detection resolution. A vibration damping mounting shall be included to ensure optimal image clarity.

4.1.1.2 Illumination Sources

Typical geometries shall include provisions for selecting the desired source and the ability to adjust its illumination intensity. Geometries shown to be suitable for this purpose are direct illumination (to allow capturing of specular reflection characteristics) and diffuse illumination (to allow capturing of chromatic reflection).

Direct illumination is capable of illuminating the specimen surface at a 0 degree incident angle. In plastic specimens, this allows optimal detection of surface irregularities. In coated specimens it allows detection of specimen topcoat (clearcoat) damage without influence from reflections originating in pigmented sub layers. (Direct illumination reflects from the surface of the clear topcoat layer and provides image information only from that layer.)

Diffuse illumination provides a means for highlighting (optimizing contrast) between pigmented coating layers to facilitate their differentiation in the specimen image damage sites (a capability critical for detecting and analyzing such defects extending through multiple coating layers). For advanced analysis on a layer-by-layer basis, the application of direct and diffuse illumination sources may be combined to allow comprehensive characterization of specimen surface damage.

Since the influence of variable ambient lighting would render the specimen illumination unreliable and irreproducible, the image capture shall be performed in a dark box or similar light-proof enclosure housing the illumination sources and image capture device.

4.1.1.3 Illumination Source Calibration

Prior to conducting an evaluation, the spectral characteristics of the illumination sources shall be verified to a traceable source. An appropriate spectral measuring device shall be mounted to acquire its readings in the same plane and at the same distance from the illumination source(s) as that of the test specimen surface during an image capture procedure. As well, the illumination intensity across the region viewed by the capture device shall exhibit a verifiable uniformity no greater than ±5%. Imaging system manufacturers typically include a methodology for verifying these functional characteristics of the illumination sources.

4.1.1.4 Specimen Indexing Capability

If the region of interest (ROI) to be evaluated on the sample surface exceeds the viewing region of the image capture device, a means shall be provided for reliably indexing (incrementally moving) the specimen so that sequential image captures may be performed; such that the entire ROI is captured in segments (multiple images). This may be achieved with movable fixturing to which the test specimen is fastened and its positional adjustment within the capture region performed either manually by the operator or automatically via software program control driving servo indexing motors. The fixturing shall be anchored to the system so that its incremental movements are precise, consistently repeatable and preventive of image overlap. To accommodate such an indexing device, the image processing software shall include a routine for stitching partial, segmented specimen images into a single image.

4.1.2 Software

The software program shall provide an operator interface allowing control of the system illumination sources, the image capturing device and the specimen indexing fixture (where applicable). It may also provide features that allow image processing for optimization of specimen image appearance and surface defect clarity and contrast. For defect analysis, the software shall provide a means for differentiation and automated detection of the grayscale values exhibited by damage sites in polymer surface images, as well as the various exposed layers within damage sites of a coated-specimen image. The software shall also be capable of geometrically defining (measuring) such damage regions with regard to surface area and of automatically counting their instances of occurrences throughout the image. All such setup and analysis settings shall be recordable in a configuration file so that interrupted or subsequent evaluations may be performed under the exact same conditions (i.e., under the same illumination, grayscale image processing/enhancement and analysis schemes).

4.1.2.1 Illumination Control

For the illumination geometries, controls shall be provided to allow a selection between direct and diffuse sources. Additional controls shall be included to allow precise and repeatable adjustment of the source illumination intensity.

4.1.2.2 Image Capture Device Control

A means shall be provided in the software program for remote activation of the capture device to ensure a vibration-free capture.

4.1.2.3 Specimen Indexing Control

Where applicable, the software shall allow remote control of the motorized indexing fixture for the acquisition of multiple specimen images. If a non-motorized fixture is in use, it is allowable to have the operator adjust its position by hand if the fixture meets the requirements specified in 4.1.1.

4.1.2.4 Image Processing and Analysis

The software shall include an automated function for executing a thresholding procedure on the specimen image. This causes pixels within a selected grayscale range to change to black. The function of this is to segregate the pixels that represent surface irregularities (damage sites) in plastic surface images from the background (or undamaged region), or the exposed surface of a coating layer within a damage site from the other layers in that site and from the background. These pixel groups may then be geometrically characterized (damage area quantified and their frequency within the image enumerated), as well as quantified and characterized (where applicable) on a layer-by-layer basis throughout a coating system via a threshold-based particle size analysis. Examples of a captured specimen image (Figure 1) and damage pixels segregated by thresholding (Figure 2) are shown below. (The images of Figure 2 have been inverted for presentation clarity.) The software shall provide an adjustable algorithm for executing these functions automatically; the user settings for which may be saved to disk in a configuration file. Once established on an initial test specimen, the recorded routine can be executed repeatedly on all subsequent specimens of the test sample lot. After a specimen image is analyzed, its statistical data shall be recorded in an associated file and saved to disk.

From the file data, statistical functions may be performed to ascertain such defect geometrical parameters as Mean Size and Size Standard Deviation, in addition to the basic parameters of Percent Damage and Number of Defects, and all these on a per layer basis, where applicable, within the capability of the software program.

5. SETUP AND EVALUATION PROCEDURE

5.1 Specimen Preparation Considerations

For a multi-layer coating system to be suitable for imaging analysis evaluation, there must be observable tonal contrast between the coating (or substrate) in the damage sites and the surrounding unaffected coating (or between each layer of the coating system when equipment permits individual layer detection and analysis). Without such contrast, the imaging system will be unable to differentiate between the damaged and original surfaces. As an aid to achieving this, coating systems should be formulated such that the various layers have differing tonal values or tints. When this is not possible, an alternative method may be employed where common joint spackling compound is applied to the damage sites and carefully wiped off leaving a layer of compound only in the damage sites, thus providing contrast with the surrounding undamaged surface. Use of this latter method will eliminate the possibility of distinguishing what specific coating system layer(s) has delaminated and provides only a total damaged-area result.

5.2 Calibration

Illumination source spectral and uniformity verification/calibration shall be performed according to the imaging system manufacturer's instructions. Such procedures are usually required to be performed on a regular basis. If the system is not user serviceable in this regard, ensure that the imaging system has been recently calibrated and contact the manufacturer if the system is overdue for such service.

5.3 Specimen Indexing Fixture Setup

For specimens damaged by a gravelometer, the region of interest (ROI) shall be captured by the imaging system in a single image, or in accurate multiple images to be stitched into a single image by the software program. If the dimensions of the optical capture region are less than the ROI, install an indexing fixture to allow segmented image capturing. Mount and adjust it as described in the imaging system manufacturer's instructions. If required, activate any applicable software program selections to enable the use of the indexing fixture.

5.4 Evaluation Procedure

The evaluation procedure consists of four primary tasks:

1. Image Capture
2. Image Processing
3. Image Analysis
4. Sample (image) Rating

5.4.1 Imaging and Analysis Procedure

Where applicable in the steps below, refer to the imaging system manufacturer's instructions for the specific and detailed instructions on the procedure indicated.

a. Place the specimen in its capture location on the image analyzer (or in the indexing fixture, if applicable).

b. Adjust the illumination settings for optimal image appearance.

c. Save the illumination settings in a configuration file.

d. Perform an image capture of the initial specimen.

e. Adjust the image appearance with applicable software enhancement features, if necessary for clear identification of damage site details.

f. Perform a thresholding procedure to identify and isolate defect areas. If applicable, use multiple thresholding procedures to optimize multiple layers.

g. Initiate the image analysis routine for damage site detection and characterization.

h. Save the analysis data to a file with a name reflecting the specimen designation.

i. Save the image processing and analysis setup parameters.

j. Remove the initial specimen from the image analyzer.

k. Capture subsequent specimen images for the entire test lot.

5.4.2 Presentation of Results and Specimen Rating

5.4.2.1 Reporting Results

A test report shall include the Percent Damage and Number of Defects for each specimen. Additionally it may be desirable to include defect Mean Size and size Standard Deviation for each specimen and, if the software allows, the presentation of all the aforementioned parameters on a per-layer basis for each coated specimen tested. This will allow determination of the damage share contributed by each layer, with the layer accounting for the largest share easily recognizable as the separation level. A typical test report shall include some or all of the items listed below.

a. A reference to this test method (SAE J2661).

b. Identification of the material or coating tested (manufacturer, trade name, batch number, etc.).

c. Name of imaging system manufacturer and system model number.

d. Software algorithms or analysis filters used on samples (Mfg., filter name and version).

e. Test results.

f. Any deviation from the test method procedure.

g. Date of most recent instrument calibration.

h. Date of testing.

i. Name of the tester.

5.4.2.2 Specimen Rating

To rate or rank the test specimens with respect to reference specimens or standards, perform an image capture and analysis of each reference specimen under the illumination and analysis conditions established in 5.3.1. This will provide a Percentage Damage value for each reference specimen. The statistical data of each test specimen may then be compared and matched to an equivalent reference specimen to establish a numerical rating value.

6. NOTES

6.1 Marginal Indicia

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