



Adhesion Strength of Thick Coatings on Rigid Substrate Cross-Sectional Interfaces via Scratch Test Method

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. A method is defined to measure the adhesion of thick, rigid coatings in terms of resistance to delamination induced by a scratch normal to the coating-substrate interface. The Coating Delamination Resistance (CDR) is reported as load applied to the scratch Indenter. Thermal spray coating on aluminum cylinder bore surfaces is used as an example to explain methodology in this document.

1.2 Applicability. This method applies to thick rigid coatings ($> 20 \mu\text{m}$, metallic, ceramic, cermet materials etc.) on rigid substrate.

Examples: Thermal/cold sprayed coatings, electroplated coatings (Nikasil), anodized coatings, etc.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

ASTM E3

ISO 17025

2.2 GM Standards/Specifications.

GMW17934 (ID)

(ID) = This document is limited to internal use within General Motors and shall not be accessed outside this company. Contact the GM Lead Engineer for further instructions.

3 Resources

3.1 Facilities.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.1.1 Load measurement on Anton Paar Micro Scratch Tester. Scratch Indenter must be inspected prior to use for correct geometry by optical microscope or SEM if drop test or scratch on master sample raises concern. The test facilities and equipment shall have a valid calibration label through certified maintenance service providers on yearly basis.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

Pull off test (GMW17934).

3.2 Equipment.

3.2.1 Scratch Tester. Anton Paar Micro Scratch Tester, with rotational stage for curved specimen, Figure 1.

3.2.2 Scratch Indenter. Type: Rockwell, Anton Paar Part Serial number: K-123:

- Material: Diamond.
- Radius: $50 \mu\text{m}$.

3.2.3 Compressed Air Duster.

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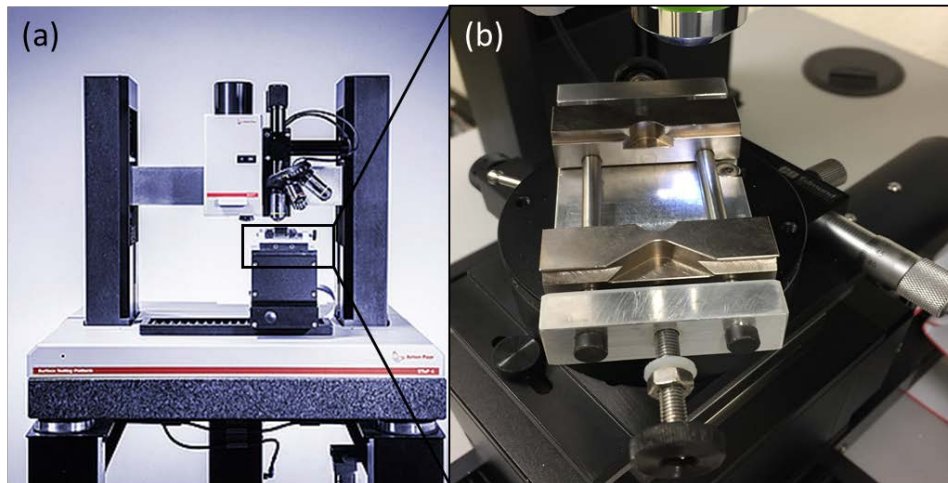
3.2.4 Band Saw.

3.2.5 Metallurgical Abrasive Saw, water cooled.

3.2.6 Diamond Saw with Carbide Blade, water cooled.

3.2.7 Cold Mount Resin.

3.2.8 Metallurgical Sample Polisher.



(a) Anton Paar micro scratch tester unit with rotational stage.

(b) Rotational stage (magnified image).

Figure 1: Anton Paar Micro Scratch Tester Unit

3.3 Test Vehicle/Test Piece. Parts with thick rigid coatings.

3.4 Test Time.

Calendar time: 2 d

Test time: 3 h

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills. Staff training and assessment of competence per ISO 17025 Section 5.

4 Procedure

4.1 Preparation.

4.1.1 Summary of Method.

- Sample preparation per 4.1.2.
- Select procedure.
 - Pass/fail method (4.3.1.1).
 - Adhesion strength method (4.3.1.2).
- Set up scratch test per 4.2.4.
- Perform scratch test per 4.3.1.
- Evaluate scratch test results per 5.2.
- Report the results per Appendix B.

4.1.2 Testing Specimen Preparation (Example: Aluminum Cylinder Bore).

4.1.2.1 Section the engine block at bottom of water jacket to separate bore package, Figure 2 (a).

4.1.2.2 Separate each bore with a saw cut through interbore (siamese) interface, Figure 2 (b).

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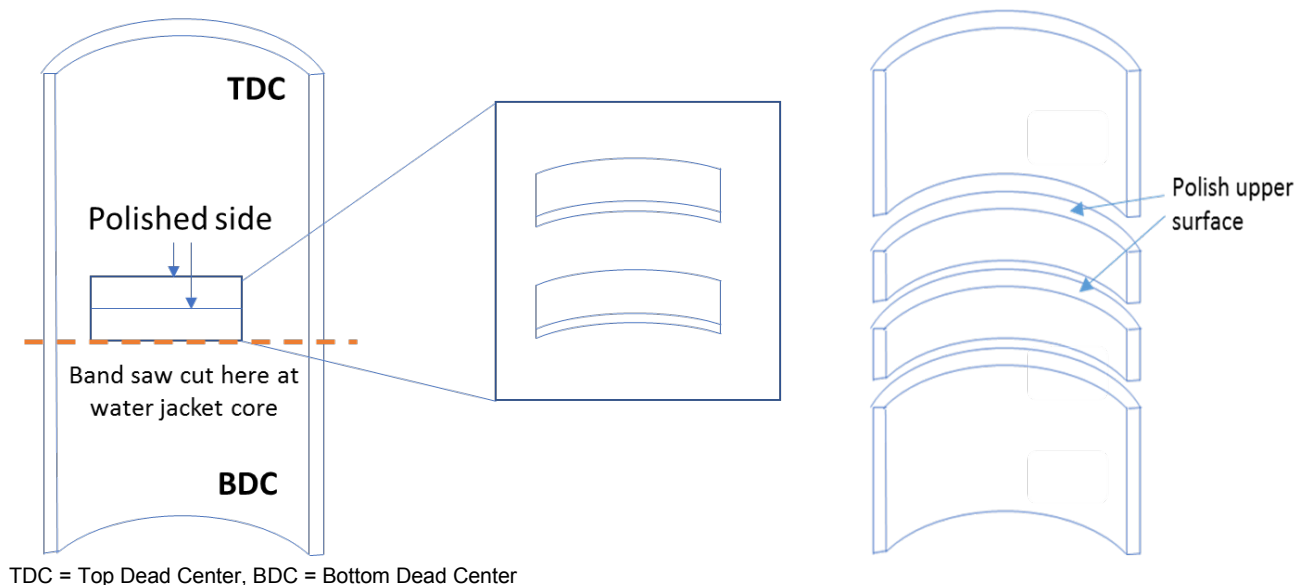
4.1.2.3 Identify bores by part number, block serial and bore position, and mark angular position, Figure 2 (c).



- Sectioning and labelling of 4-cylinder engine block.
- Lines represent band saw cuts for boring.
- Labelling nomenclature of cylinder number and angle.

Figure 2: Testing Specimen Preparation

4.1.2.4 Excise 2 or more 25 mm x 6 mm transverse sections, Figure 3. A water-cooled circular saw blade must be fed by top feeding.



TDC = Top Dead Center, BDC = Bottom Dead Center

Figure 3: Transverse Mounting Sections from Quartered Engine Bore Sample

4.1.2.5 Prepare metallurgical cold mounts per ASTM E3.

4.2 Conditions.

4.2.1 **Environmental Conditions.** Lab air.

4.2.2 **Test Conditions.** Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.2.3 **Specimen Documentation.** Capture 3 contiguous images including the sample interface before and after scratch test at 200x and at 800x magnification to compare crack width and length after scratching, Figure 4. Pic-0 position where the scratch track traverses the coating may be skipped for 800x magnification.

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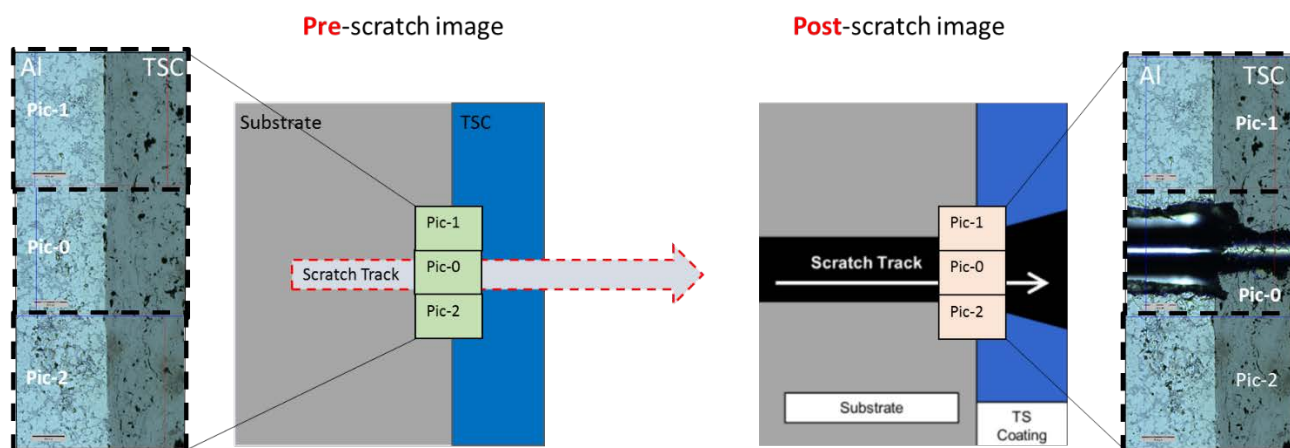


Figure 4: Locations of Contiguous Images Before and after the Scratch Test

4.2.4 Scratch Method. Follow scratch tester instructions to conduct test with the following parameters.

- **Scratch Location:** Minimum 3 mm from sample edge (avoid existing delaminated areas caused by sample preparation).
- **Scratch Starting Point:** Aluminum bore substrate, 1 mm from the interface.
- **Scratch Distance:** 2 mm (1 mm through substrate, 1 mm past coating).
- **Scratch Speed:** 1.4 mm/minute.
- **Separation of Successive Scratches:** Minimum 3 mm.
- **Scratch Mode:** Constant load.

4.2.5 Sample and the scratch indenter surfaces shall be cleaned before indent and after scratch by using compressed air duster to remove any debris on the surfaces.

4.3 Instructions.

4.3.1 Scratch Test. Follow the scratch tester instructions to conduct test.

4.3.1.1 Pass/Fail Method per Specified Load.

4.3.1.1.1 Minimum threshold load should be determined before taking this test. For example, spray bore application, the minimum threshold loads of SGE and 675T are decided by engine durability test as reported in Table A1 in Appendix A. Check the minimum threshold scratch load for different applications and use the threshold as specified.

4.3.1.1.2 Apply 6 scratches.

4.3.1.1.3 Evaluate the length of crack per 5.2.1.

4.3.1.1.4 Criteria. See Figure 5.

Pass: No delamination in any samples observed.

Fail: 1 or more instances of delamination observed.

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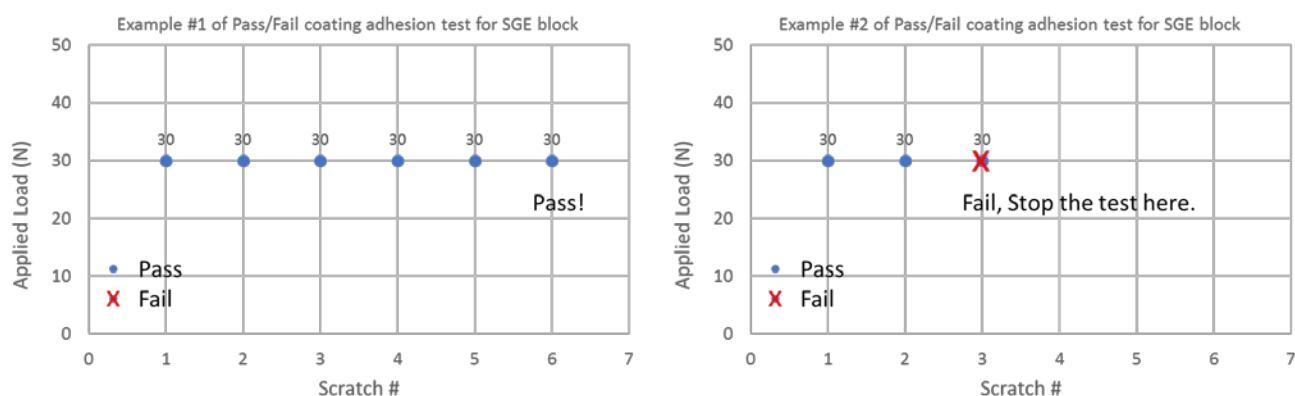


Figure 5: Examples of Pass/Fail Coating Scratch Test

4.3.1.2 Adhesion Strength Method, 100% Pass Load (PL). See the test examples in 5.2.3.

4.3.1.2.1 Determine Minimum Fail Load (MFL) per Figure 6.

- Judge pass/fail per 5.2.1.

4.3.1.2.2 Determine 100% Pass Load (100%PL) per Figure 7.

- 100%PL is determined as the load where no delamination occurs in 4 successive scratches.

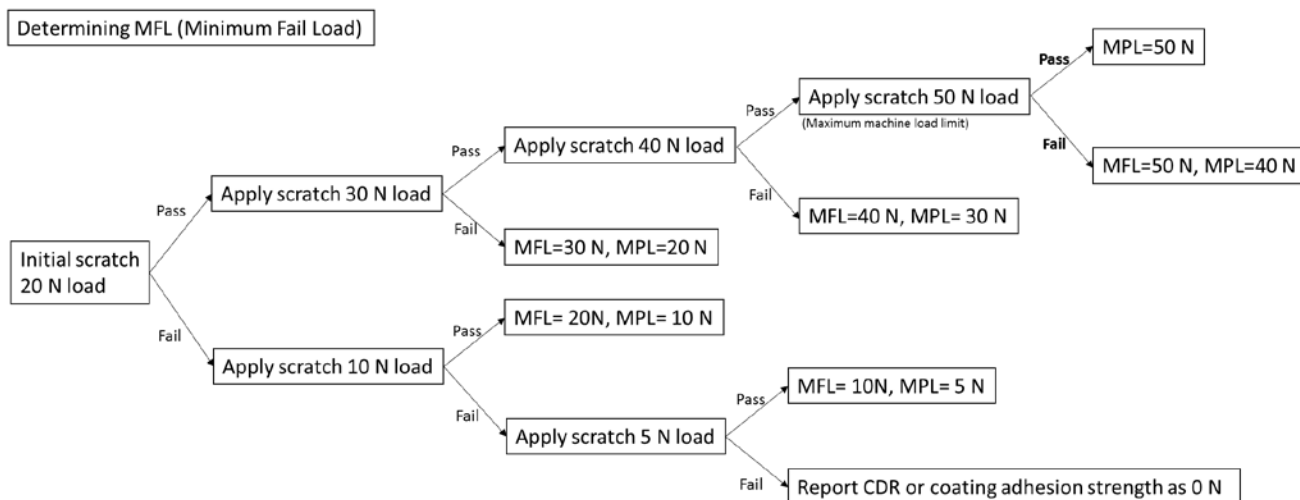


Figure 6: Determining Minimum Fail Load (MFL) And Maximum Pass Load (MPL) with 10 N Interval

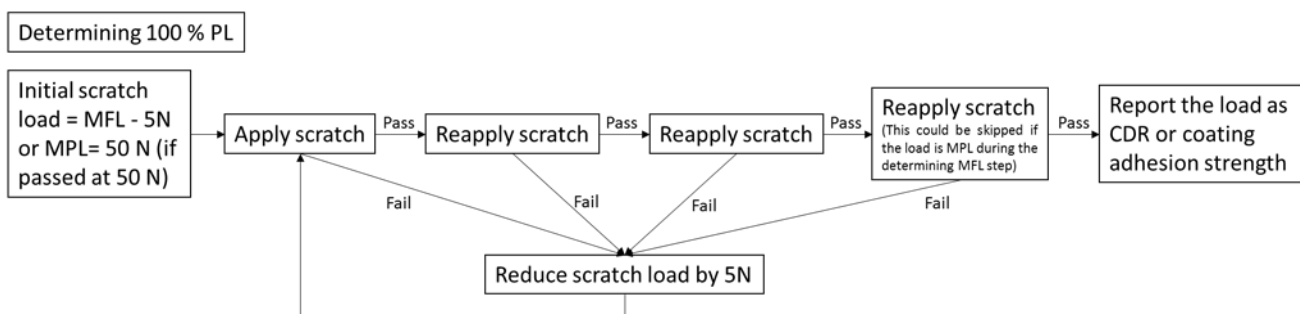


Figure 7: Determining 100% Pass Load (PL)

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