Critical Study on Scratch Resistance Test Methods

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Abstract

A number of international test methods have been advanced in various industries – electronics, optical, automotive and others – to evaluate the scratch resistance (abrasive wear) of thin film UV-curable coatings on polymeric substrates, displays and qualify coatings suppliers. Some of these wear tests do not provide valid inferences with real life experiences and pose a conundrum on the proper evaluation of different coatings performance on thermoplastic and transparent substrates.

This paper will address different scratch resistance tests – focusing on abrasion wear, – the Taber® Abraser, Norman Tool "RCA", Pencil Hardness and Steel Wool Wear tests on Polycarbonate (PC) and Poly Methyl Methacrylate (PMMA) optical clear, thermoplastic sheet materials with two sample UV curable coatings, under 15 μm in dry film thickness.

Conclusions and recommendations on the practical selection and use of various wear tests to ascertain the abrasion resistance of UV-curable thin film coatings will be discussed.

Introduction

How do we evaluate the abrasion resistant properties of UV-curable thin film coatings?

Which ASTM or other International abrasion test provides quick, accurate and relevant test results that correlate well with field use and experience?

How does one assess and select the best abrasion resistant UV-curable thin film coatings for new products?

How should companies report data with the various abrasion resistant test methods widely employed?

Does higher functionality and cross-linked density (without Nano-particles,) necessarily ensures superior mechanical and wear properties on polymeric substrates with acrylate based UV-cured, thin film coatings?

Answers to the aforementioned five questions is the primary purpose of this paper.

Protective thin film UV curable top coats are applied onto thermoplastic materials to enhance the appearance, protect the article's surface and improve among other properties, the wear resistance capabilities of the substrate material.

A products' uniform appearance is one of the most important characteristics and it depends not only upon surface conditions (coating, morphology, waviness, orange peel, etc.) but also upon the reflected image's focusing quality. All products will eventually wear and scratches will alter a product's appearance and affect durability; leading to premature failure. For example, most (coated) electronic tactile displays fail due to scratches caused by sharp objects and high load, rather than repetitive or constant loading.

Wear occurs between contacting surfaces and is defined as damage done to a surface - loss of material, - caused on the interface of two contacting bodies when subjected to relative motion, under load. There are many different wear mechanisms that can cause material removal known as adhesion, abrasion, fatigue, erosion, cavitation and corrosion wear. Wear is a complex phenomenon that depends on materials (hardness, surface morphology,) environment, and just as importantly, on normal load and motion conditions (sliding speed, time,) among others.

Abrasion is the process of marring, scratching and wearing away any part of a material by rubbing against another surface. The Archard(3) wear equation (1), is a simple model used to describe this sliding abrasion wear, based upon the theory of asperity contact:

$$Q = KWL/H \quad (1)$$

Where:

Q = is the total volume of wear material removed

W = is a normal load

L = is a sliding distance

K = dimensionless constant (indicates severity of wear)

H = is the hardness of the softest of the contacting surfaces.

Surfaces of interacting materials in relative motion, is the study of tribology and the frictional force resisting the movement does not depend on the contact area, but simply on the gravitational (vertical) force. Every smooth surface is “rough” at the very micro level. At the contact point between two surfaces, materials only touch over small “peaks”, called asperities. They support the load and deform (both elastically and plastically) to reach static equilibrium.

Plastics as viscoelastic materials and do not always conform to the classical laws of friction, because of the large plastic deformation that occurs at the tips of the asperities; thus, it is difficult to predict linear relationships between constant pressure, sliding speed and coefficient of friction.

Mar abrasion is the permanent deformation of a surface without breaking the surface.

Sliding (or scratch) abrasion is a surface deformation process; caused by indentation due to the displacement or removal of material under load, over a period of time by another harder object. Scratches, typically they can be seen as lines.

The terms wear, abrasion, mar and scratch resistance are used interchangeably in industry, but as we have seen based on the above definitions, they are indeed different.

Hardness is a material’s (surface) ability to resist plastic deformation, by impact or sliding.

The volume of removed material in abrasive wear is proportional to the work done by frictional forces, sliding distance and indentation hardness (1); thus, it is apparent that the abrasive wear would decrease with increased hardness of the coated substrate. Thus, even the pencil hardness test has been used in industry as a test method to verify the scratch resistance properties of thin film coatings.

One of the most critical features for a good laboratory test is that findings and conclusions correlate well with the product’s actual use, in predicting real life failure modes; which can only be verified by field testing. Furthermore, for a test to be useful in an industrial laboratory or QC setting, it is must be simple to execute, reproducible, carried out quickly, traceable to International Standards and of course, be economical.

Comparative Wear Test Methods for Thin Film Protective Coatings

Rotary Steel Wool Test

This test method describes a uniform procedure for evaluating the abrasion resistance of thin-film coatings following the controlled movement under load of a standardized steel wool pad (abrasive media) over the surface of transparent plastics. Severe abrasion is caused by subjecting the coated surface to a number of cycles, under specified, normal load conditions. This method can also provide a ranking of the scratch resistance of transparent thermoplastic materials and different formulations.

The test method involves rotating a 31.8 mm (1.25 in) square steel wool pad No 0000 (super fine, with a fiber width of ~0.03 mm; equivalent to 300-600 sandpaper) under load at 165.4 kPa (24 psi) or higher at 60 +/- 2 rpm. The weighted pad is usually rotated 25 times at about 1 rps to clearly show comparative wear performance. The Steel Wool Test apparatus used is shown in Figure 1.

Figure 1

The Rotary Steel Wool Tester with a constant angular velocity (ω), experiences both varied tangential velocities (ωr) and centripetal acceleration ($\omega^2 r$) components (i.e. the centripetal force) that impacts thin film coatings, dramatically. A circular wear pattern is obtained. See Figure 2. The qualification of the coating's abrasion resistance is established either i) by the visual comparison of the test samples to the abrasion of a reference sample, ii) by checking the transparency difference of the coated substrate before and after test or iii) by measuring the percent change in haze, as per ASTM D-1003 (Test for Haze and Luminous Transmittance of Transparent Plastics) before and after test.

Figure 2 - Worn Rotary Steel Wool tested samples

Simple visual classification criteria can be established with a scale from 1 – 5. Criteria 1 shall mean that the surface shows no evidence of damage, whereas, 5 shall mean that the surface shows severe damage under load. Inspection distance is no less than 300mm with a 1000 lux light source.

Samples are properly cleaned with alcohol (or dishwashing soap - aryl or alkyl sulfonate types) and conditioned at room temperature (23 ºC +/- 3 ºC) for no less than 24 hours prior to testing, to minimize any changes in properties due to the effects of temperature and relative humidity. A standard laboratory atmosphere of 23 °C +/- 1 ºC (73.4 °F) and relative humidity of 50% +/- 5% as per ASTM D-618-95, should be used.

The preparation of the standardized steel wool pad (by the same manufacturer,) by folding and with proper fiber orientation is critical for measurement. Cut a strip of (0000) steel wool, approximately 31.8 mm x 130 mm, 6.35 mm thick (1.25" x 5.1" long, .25" thick.) First, fold both ends of the long side in to touch, and then fold one half under the other by assuring that fibers are aligned the long way. The steel wool pad should be free of fibers or burrs. Attach it with a double sided 3M pressure sensitive tape 4 cm2 per pad. The steel wool pad must be first conditioned by placing a glass test sample under the steel wool abrasion tester. Condition pads for 250 cycles.

A ranking for optically clear coated materials can be attained by reporting the rotary Steel Wool Ratio (SWR) with the same formulations on different substrates.

It is calculated as the ratio of the haze difference between initial and final conditions of the coated test sample divided by the uncoated substrate, as follows:

$SWR = \Delta Coat / \Delta Sub$ (2)

Where:

Δ Coat = final haze value of test coated sample – minus initial haze value of same test sample

Δ Sub = Final haze of uncoated substrate material – initial haze of the substrate at the same test conditions as coated sample.

The aforementioned formula may also be used with a benchmark coating (as standard,) to replace the substrate's denominator and assess relative abrasion performance between different coating formulations on the same substrate material. All haze measurements in accordance with ASTM- D 1003.

$SWR = \Delta Coat / \Delta Std$ (3)

Where:

Δ Coat = final haze value of test coated sample – minus initial haze value of same test sample

Δ Std = Final haze of standard coating – initial haze of standard coating.

The Rotary Steel wool test is applicable to:

- Rank optically clear coatings; same dry-film thickness on same substrate material
- Rank different optically clear materials; same coating (same dry-film thickness) on different substrates.
- Rank competitive coatings Vs. benchmark coating of same thickness

The Steel Wool Tester is one of the few abrasion tests that the test loads can be large >345 kPa and can simulate "real-life" damage. If the most prevalent mode of failure is scratching, the use of steel wool as an abrasive medium is well suited to quickly generate scratches on the surface of a material in curvilinear motion.

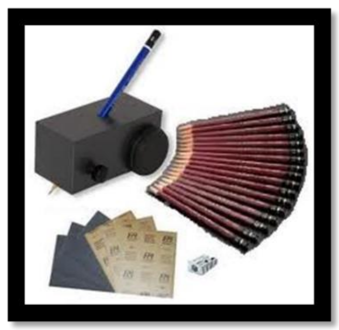
Precision – No statement concerning precision of this test method can be made for thin-film coated substrates at this time, until a round robin inter-laboratory evaluation study is completed for this method.

Repeatability – Two test results by operators within a lab using the same apparatus and test panels should be considered suspect if the differ by more than r = 3.5 x 1.45 = 5.07 (where 3.5 represents 99% of measurements for a normal distribution.)

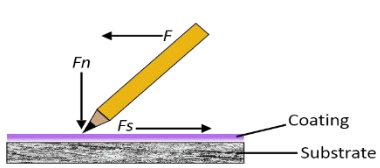
Bias – No accepted standard material was found for determining bias.

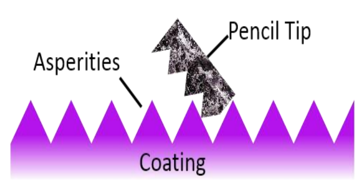
Pencil Hardness Test Method - (ASTM D-3363)

This test method describes a simple and rapid evaluation of a coated material's resistance (film's hardness) to scratch effects due to the sliding of pencils of various hardness (6B to >6H), under load, over the surface of a coated substrate, for approximately 10 to 12 mm (1/2"). The pencil hardness is reported as the hardest pencil that does not scratch or gouge the surface of the coated substrate and is a measure of surface's ability to resist plastic deformation. It indicates abrasive wear; the process by which a hard material plows a groove into the surface of a softer material, thereby resulting in the removal of material from the softer surface.



The ASTM D-3363-05 method (Standard Test Method for Film Hardness by Pencil Test) has suspect precision, repeatability and reproducibility and warns users to standardize pencil leads (from the same pencil manufacturer), making consistent measurements in industry impossible. The ASTM test method does not define pencils or normal load of the pencils onto the coated substrate. In industry, most companies use a pencil hardness test similar to the Wolf-Wilburn method where the pencils are mounted onto a device @ 45 degrees and constant load of 750 g or 1000 g (based on JIS K-5400,) ensuring the least amount of operator error. Plastic samples must be conditioned prior to test, as per ASTM 618-00.





Fs= µ x Fn (gravitational, normal force)
µ= coefficient of friction

Friction due to the movement of asperities on a coated material's surface in contact with the harder pencil lead material causes friction. Calibrated wood pencils of different hardness from 9B (soft) to 9H (hard) are supposed to be used from the same pencil manufacturer. The difference in pencil hardness is determined by the amount of graphite, clay and wax. For example, a 6B pencil has 85% graphite, 10% clay and 5% wax whereas, a mid-hardness pencil such as HB has 68%

graphite, 27% clay and 5 % wax. However, there is a substantial difference in pencil hardness between pencil manufacturers, as shown on Table 1.

Applicable International Standards:

ISO/DIS 15184:1996, JIS K-5400, JIS K-5600, ECCA T4-1, BS-3900-E19, SNV 37113, SIS 184187, MIL STD C-27 227, EN 13523-4.

Taber® Wear Test (ASTM D1044)

The Taber Abraser (ASTM D1044 "Test for Resistance of Transparent Plastics to Abrasion" and ASTM D4060-10 "Standard Method for Abrasion Resistance of Organic Coatings by the Taber Abraser" is a widely used method for determining the abrasive wear resistance of coated substrates. The Taber Abraser tests a sample (100 mm x 100mm) mounted on a rotating turntable subject to the wearing action of two abrasive wheels weighted with a specific load (@550 g or 1000 g) for a certain number of cycles. The wheels are driven by the rotating test sample about a horizontal axis. One abrading wheel rubs the test sample outwards towards the periphery while the other inwards towards the center. The resulting circular abrasion marks form a pattern of crossed arcs over an area ~ 30 cm2. The wheels traverse a complete circle on the test sample's surface. ASTM G-195-13a describes the "Standard Guide for Conducting Wear Tests Using a Rotary Platform Abraser".)

The abrasion resistance is calculated by measuring the % change in haze with a haze-meter (an integrating sphere photometer) as specified in ASTM D-1003 "Test for Haze and Luminous Transmittance of Transparent Plastics" or ASTM E-430 and ISO 13803.

Haze of a specimen is defined as the percentage of transmitted light, which in passing through the specimen, deviates more than 2.5^0 from the incident beam by forward scattering.

For thin film coatings the wear Index (calculated as the difference of weights of test specimens before and after abrasion divided by the number of cycles) cannot be calculated. Taber wheels are comprised of silicon or aluminum oxide abrasive particles in a clay binder. These Taber® abradants are designed to break down; these loose metalloid particles, create a three-body abrasive wear form between the contacting surfaces and thus, accelerate the abrasive wear on the coated substrate.

Applicable International Standards:

ANSI INCITS 322, AS/NZS 1580.403.2, ASTM D5146, BS3900, DIN 52 347, DIN 53 754, ISO 9352, JIS k5600:5:8, JIS K6735, JIS K7204

"RCA" Abrader Test (ASTM F-2357)

This test method describes a procedure for measuring the abrasion wear resistance of protective coatings on membrane switches and in many industrial applications is extended to measure the legend strength on many substrates other than printed or coated polyester, polycarbonate and/or silicone rubber, as specified in ASTM F2357-10 "Standard Test Method for determining the Abrasion Resistance of Inks and Coatings on Membrane Switches using Norman Tool "RCA" Abrader".

The Norman Tool Abrader known as the "RCA" Abrasion Wear Tester, is a point of contact abrasion tester capable of testing flat or curved samples, by the continuous paper movement under controlled loading conditions over the test specimen. The purpose of the test is to reach the wear limit, defined as the number of cycles needed until complete removal of the coating from the substrate happens (or until an underlying layer of different color may be seen) under weights of 55 g, 175 g or 275 g. The abrading material is paper 17.5 mm wide or polyester tape 6.35 mm wide in a roll form threaded thru the machine and kept by the wind-up shaft in tension.

The paper abrasive material must be new and not allowed to age or absorb moisture; otherwise it becomes less abrasive. Fresh paper rolls from Norman Tool must be used for consistency and repeatability.

Experimental

A. **Coatings**: Two UV-curable coatings, at two different thicknesses, were tested on PC and PMMA substrates with the aforementioned tests.

Coating formulation one (C1,) was based on a multi-functional acrylate (25% wt.) with a thixotropic modifier (3% wt.) with low viscosity and slow recovery, at ultra- low shear rates. The photo-initiator and additives in solvents were selected to increase the crosslinking density and glass transition temperature, trying to positive influence optical clear coating's resistance to abrasion wear.

Coating formulation two (C2) was based on a multi-functional acrylate (11% wt.), an aliphatic urethane acrylate (11% wt.), a di-functional diluent monomer (2% wt.) and additives, to ensure a low viscosity for spray and dip processing.

The solvent system used included slow, medium, and fast evaporating solvents - lower alcohols and ketones - to facilitate mixing of the components and allow the efficient and uniform spray application, thus improving flow and leveling onto the substrates.

Coatings	Material	Dry-Film Thickness	Designated
Coating 1	PC	7 µm	C1,1,1
Coating 1	PC	13 µm	C1,1,2
Coating 1	PMMA	7 µm	C1,2,1
Coating 1	PMMA	13 µm	C1,2,2
Coating 2	PC	7 µm	C2,1,1
Coating 2	PC	13 µm	C2,1,2
Coating 2	PMMA	7 µm	C2,2,1
Coating 2	PMMA	13 µm	C2,2,2

B. Materials Tested:

Polycarbonate (PC) – Lexan 9034 from SABIC Innovative Plastics IP BV.

Poly Methyl Methacrylate (PMMA) – Optix from Plaskolite, Inc.

Material Properties			PC – Lexan 9034		PMMA –OPTIX	
Properties	Test Method	Unit	Mfg (a)	PCI Labs	Mfg (a)	PCI Labs
Initial Haze	ASTM D1003	%	<1	0.18	2	0.1
Taber @ 100 cycles	ASTM D1044	% haze	10	34.9 (500 g)	24.2	37.61 (500 g)
Pencil Hardness	ASTM D3363		NR	3B	NR	H
Sheet Thickness	Micrometer	mm	1.5	1.5	1.5	1.5
Rockwell Hardness (M scale)	ASTM D785		70		95	

(a) Data from Manufacturer's Product Data Sheets

C. Equipment:

The following equipment were used in the tests described below:

1. UV- Curing System: Fusion UV – Light Hammer 6 Bench Top Unit, with 6" H Lamps
2. Radiometer: EIT – UV Power Pack & Uvicure Plus II
3. Oven Curing : Precision Scientific Recirculating Oven (150 °C)
4. Dip Station: Minarik - Mark 2000 Series Motor Speed Controller
5. Spray System: DeViLBiss – Compact Automatic I – CMAI-1310 HVLP Gun, 1.0 mm tip

6. Haze Measurement: Hunter Lab - ColorQuest II Spectrophotometer
7. Taber® Test: Taber 5155 Abraser w/ Taber® wheels
8. RCA Test: Norman Tool – Model No 7-IBB
9. Steel Wool Test: PCI Labs – Scratch Tester 288
10. Pencil Test: Mitsu Bishi – Hi UNI Pencils
11. Thickness Test: Filmetrics – F20 Thin Film Analyzer
12. Thickness Test: Micrometrics - Tooke Gauge OG 204

D. Process Conditions:

Spray System: fully automatic w/ 38 L pressure fluid tank w/ fluid, spray fan and air-atomization controls.

Convection Oven (w/ air circulation): 3 minutes @ 30 °C

UV: 460 mJ/cm^2 (1.36 W/cm2) @ 7.6 m/min (25 fpm) – with UV Fusion - H lamps

QC: Cross-Cut Adhesion Check - ISO Class: 0 / ASTM Class: 5B - (ISO 2409, ASTM-D3002)

Test Results & Discussion

Pencil Hardness Evaluation (*)					TABLE 1					
Manufacturers	PC	PMMA	C1,1,1 PC	C1,1,2 PC	C1,2,1 PMMA	C1,2,2 PMMA	C2,1,1 PC	C2,1,2 PC	C2,2,1 PMMA	C2,2,2 PMMA
ASTM D3363	3B	H	HB	HB	2H	4H	H	HB	>6H	>6H
Mfg 1	2B	3H	F	H	5H	5H	F	F	7H	8H
Mfg 2	2B	3H	F	F	6H	5H	HB	HB	8H	8H
Mfg 3	2B	2H	2H	3H	8H	9H	2H	2H	9H	9H
Mfg 4	3B	2H	2H	2H	7H	7H	2H	2H	8H	8H
Mfg 5	2B	3H	F	H	6H	6H	F	F	8H	9H
Mfg 6	2B	H	HB	F	6H	6H	H	H	6H	7H
Manufacturer 1	Staedtler Mars - Lumograph 100, Staedtler Mars, GmbH & Co., Germany									
Manufacturer 2	Faber-Castel - Graphite Sketch Set, Faber-Castell, Germany									
Manufacturer 3	Derwent - Graphic Arts, Acco Ltd, UK									
Manufacturer 4	Sanford - Prismacolor Premier - Sanford, LP., USA									
Manufacturer 5	Artist's Loft - Sketching Pencils (ASTM D-4236) - Thailand									
Manufacturer 6	Mitsu-Bishi - Hi Uni , Mitsu-Bishi, Japan									

(*) All Tests - other than the ASTM D3363 - were performed with a BYK Pencil Hardness Tester (Wolf-Wilburn) @ 750 g. Five (5) coated and uncoated test samples were measured by two (2) Lab technicians with two (2) sets of pencils per manufacturer. Sample size: 20 test pieces per material and coating.

Only Manufacturer 6 was found to have repeatability within one pencil unit. There is a great variation of pencil hardness between pencil manufacturers on the same coating and material. Some pencils demonstrated ability to fail coatings at 2H while passing at 3H and 5H, demonstrating a dramatic inconsistency in graphite content. Pencil hardness on thin film coatings is significantly influenced by the substrate material's Rockwell Hardness (M Scale.)

Abrasion Resistance Wear Test Results (**)				TABLE 2					
		Coatings (1)							
		C1,1,1	C1,1,2	C1,2,1	C1,2,2	C2,1,1	C2,1,2	C2,2,1	C2,2,2
Test	Units	PC 7µm	PC 13 µm	PMMA 7µm	PMMA 13 µm	PC 7µm	PC 13 µm	PMMA 7µm	PMMA 13 µm
Taber (2)	% Δ Haze	8.4	6.68	9.2	8.2	8.15	5.4	7.7	5.5
"RCA" (3)	Cycles	400	450	500	600	600	700	700	800
Pencil (4)	#	F	F	6H	6H	H	H	6H	6H
Steel Wool (5)	kPa (psi)	207 (30)	207 (30)	276 (40)	262 (38)	345 (50)	345 (50)	>345 (50)	>345 (50)
Steel Wool (6)		0.22	0.21	0.24	0.22	0.11	0.12	0.12	0.13

(1) See Designation under Materials.
(2) ASTM 1044-99, Taber Calibrase CF-10F @ 500g and100 cycles
(3) ASTM F 2357-04, Norman Tool Paper
(4) Mitsu- Bishi, Hi-Uni Pencils
(5) Rhodes American, Super Fine #0000 steel wool, 25 rotations (1rps) @ load (4 cm^2)
(6) Steel Wool Ratio – Formula (2)
(7) Temperature 21.5 °C +/- 1 ºC (70.7 °F) & Relative Humidity of 52% +/- 3%

(**) The number of coated samples tested were 30, per test, with a 90% confidence interval ($\alpha/2=0.05$).

Both the RCA and Taber wear tests are significantly influenced by coating thickness and substrate material's hardness. PMMA performed better than PC and both coatings C1 and C2 performed better @ 13µm of dry film thickness.

In the Taber Wear test the higher cross-linked coating performed better and the coating thickness had a positive effect. PC at the higher dry film thickness performed better. Temperature rise due to frictional heating with the corresponding change in the coefficient of friction has an effect on the results of this test. There is variability of test results based on Lab test process; running long cycles vs. stopping at regular intervals, cleaning the abraser media (from the coating' surface) and continuing with the test.

The "RCA" wear test is influenced by humidity and age of paper, required for testing. New paper from the same source without wax, must be used. The RCA wear test is significantly influenced by coating thickness and substrate material's hardness. PMMA performed better than PC and both coatings performed better at higher dry film thickness.

There is a minor difference in pencil hardness with increased coating thickness in thin films. However, there was a substantial difference based upon the substrate material itself. PMMA showed much higher pencil hardness than PC, of at least 5 pencil units, with the same coating and dry-film thickness. With the Pencil hardness test, investigators must report not only the pencil maker, load, coating thickness on substrate material and but also substrate material's thickness.

Regarding the Steel Wool wear testing; the proper conditioning of the steel wool prior to the test and the manufacturer of steel wool, has an influence on the coatings' test performance and correlation of test results. The Steel Wool test verified better performance vs. higher crosslinking density. The best performer was the PC sample with the higher cross-linked coating with the lower dry-film thickness; it exhibited a SWR of 9X improvement.

For all wear tests temperature and humidity played an important role and must be reported as well as, how tested materials were conditioned.

Conclusion

Highly cross-linked, acrylate based UV-curable thin film coatings are highly resistant to abrasion wear but sacrifice flexure, are brittle and have higher shrinkage rates. The same coating with the same dry film thickness, will behave different on different substrate materials and that includes topcoats on different basecoats, used in multi-layer systems. The overall scratch resistance is improved by the increased functionality of the acrylate based resins in the UV curable coatings. The wear tests performed provide insight into how inconsistent wear test results can be within the coatings industry, when test methods and conditions vary.

Scratch Test Methods Evaluation				
Scratch Test	**Substrate Hardness (Rockwell)**	**Film Thickness**	**Crosslink Density**	**Coating Differentiator**
Taber Wear	↓	↑	↑	Average
RCA Abrader	↑	↑	↑	Average
Pencil	↑	↔	↑	Average
Rotary Steel Wool	↔	↔	↑	Better

Scratch abrasion is complex mechanical damage process; test method dependent.
The type of abrasion wear mechanisms acting on a part (in movement and force) must be carefully analyzed regarding cycling, repeatability, randomness, etc. For example, most (coated) displays fail due to scratches caused by sharp objects and large loads, rather than repetitive or constant loading.
Slip additives, fluorocarbons, solid lubricants (PTFE, etc.) with their extreme low coefficient of friction, have a positive effect on scratch wear tests. Also, adding nanoparticles into polymer coatings increases the scratch resistance of these coatings.

Different conclusions were drawn from the test data reported above, comparing the different abrasion resistance methods. However, the rotary steel wool test is a quick test that provides better correlation with abrasion wear when the actual load is not cycling or repetitive, such as those experienced by portable mobile device users and seems to provide more consistent laboratory data.

Coatings evaluations must be performed on the same material, at the same dry film thickness with the same abrasive media, properly conditioned, to demonstrate clear statistical differences for thin film UV-curable coatings and provide reliable acceptance criteria. It is unwise to make inferences about characterization of a coatings ability to withstand wear by a single value. The most effective way is to perform multiple abrasion resistance tests –under very precise and controlled environmental conditions- to evaluate a coatings ability to withstand real life, scratch abrasion conditions.

References

(1) Bunshah, R. F., “Selection and Use of Wear Tests for Coatings,” ASTM STP 769, pp. 3-15
(2) Haluska, L. A., “Wear Testing of Abrasion-Resistant Coated Plastics,” ASTM STP 769, pp. 16-27
(3) Archard, J.F., Journal of Applied Physics, Vol .24, 1952, p. 981
(4) Rabinowitz, E., “Friction and Wear of Materials”, Wiley, NY, 1965
(5) Briscoe, B.J., Tribology International, 1998, 31,121
(6) Sung L., Drzal, P., “Metrology for Characterizing Scratch Resistance of Polymer Coatings”,J. Coat. Technol. Res., 2 (8) 583-589, (2005)
(7) Swaraj P. “Surface Coatings – Science & Technology”, Wiley, NY, 1997
(8) Lowe, C., “Test Methods for UV &EB Curable Systems,” V6, Wiley, 1997

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Test Laboratory

PCI Labs is an ISO 9001:2008 registered Research and Development Company, manufacturing high performance coatings, oligomers, polymer based optical filters and test instruments in Bangor, PA.