Bayer MaterialScience

Plastic Glazing - Scratch and Abrasion Tests

IGPG Meeting in Hamburg

2011-06-14

Polycarbonates

Overview re Scratch and Abrasion Tests

Three different test kinds and their potential to assess real wear performance

Common used Abrasion Tests for Glass

- Taber Abrasion
- Oscillating Sand
- Sand Trickling (Falling Sand)

Derived from Real Abrasion Situations in a Vehicle Life

- Car Wash
- Wiper Resistance
- Sand Blast

Further Abrasion or Single Scratch Methods

- Scrub Resistance
- Scratch Test

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based on this methods it is difficult to select suitable rigid plastics for glazing due to

- missing correlation to real wear and
- high standard deviation in the case of Taber
- no finished part testing possible for Taber and Oscillating Sand

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based on this methods it is difficult to select suitable rigid plastics for glazing due to

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Derived from Real Abrasion Situations in a Vehicle Life

- Car Wash
- Wiper Resistance
- Sand Blast

based on this methods suitable rigid plastics systems can be selected for glazing due to

- close approximation to real wear conditions

Further Abrasion or Single Scratch Methods

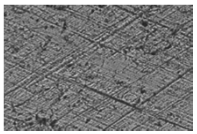
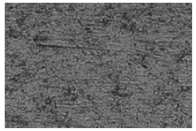
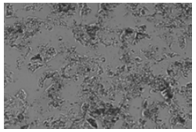
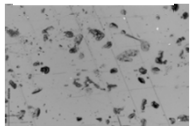
- Scrub Resistance

several kinds using different abrasives like steel wool, sponges, felt, brushes, paper etc. exists, but no one comes closer to real wear than a modification using commercial rubber blades

- Scratch Test

several kinds like pencil hardness, Erichsen scratch tester, nano indentation etc. exists, but since it is difficult to quantify the effect of a single scratch on the drivers vision these test do not help qualifying a tested material

Overview re Scratch and Abrasion Tests for rigid plastic glazing

	Taber Abrasion	Oscillating Sand	Sand Trickling	Car Wash	Wiper Resistance	Sand Blast
standardized	+	+	+	+	⚡ / ?	⚡ / ?
finished part testing	⚡	⚡	+	+	+ / ?	+
correlation to reality	⚡ 	⚡ 	⚡ / ? 	+ 	+ 	? 
other features	⚡ low repeat- & repro-ducibility at least for plastics	⚡ no precision statement	⚡ / ? reference sample needed	+ correlation to outdoor use proven	? precision not yet investigated	? precision not yet investigated

Options for plastic glazing

Options to ensure the selection of suitable surface protection systems for plastic glazing regarding abrasion:

OPTION 1

keep the Taber test for glass and plastic glazing

- despite the fact that it is not suited to assess abrasion resistance of plastics and
- despite the fact that it is far away from real wear for vehicles

OPTION 2

keep the Taber test for glass and **substitute it for plastics** with a common abrasion test

- that at least leads to the same selection than a realistic test does like sand trickling test

OPTION 3

keep the Taber test for glass and **substitute it for plastics** with a realistic test

- that is standardized like the car wash test

OPTION 4

keep the Taber test for glass and **substitute it for plastics** with more than one realistic test to check different / all kinds of wear situations

- e.g. car wash for all glazing locations and
- additionally a wiper test for glazing locations with a wiper system

OPTION 5

keep the Taber test for glass and **substitute it for plastics** with one realistic test and one common abrasion test

- that at least leads to the same selection like sand trickling test
- in order to use only standardized tests

Test TABER ABRASION

Standards and Regulation

- ASTM D 1044
- ISO 3537
- ECE R43
- ANSI Z26.1

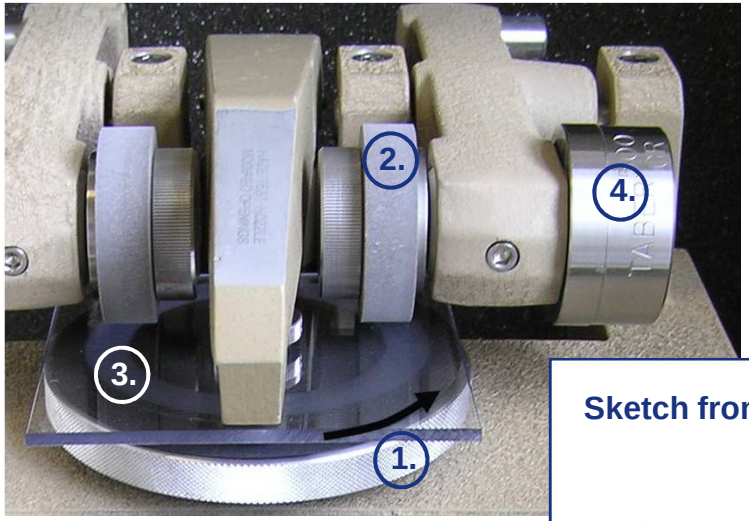
Settings

- see test setup on the right side
- number of cycles 100, 500 and 1000
- specific conditions (like wheel specification, refacing procedure and surface cleaning) depending on the applied standard

Correlation to Real Use

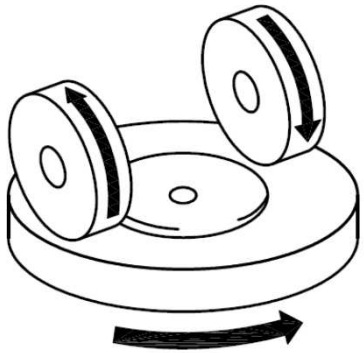
Neither the tested abrasion nor the test plaques have a known correlation!

Test Setup and Procedure



1. **rotating specimen holder**
2. **abrasive wheel CS 10F (hard particles in a resilient binder)**
3. **abraded track on the test plaque**
4. **500g load**

Sketch from ISO 3537



Test TABER ABRASION

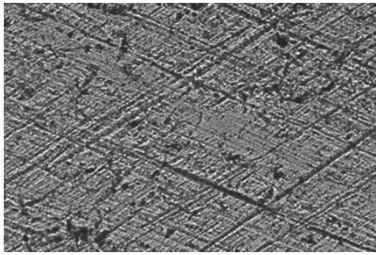
Pros and Cons

- standardized
- used since decades for glass without issues during real usage

- correlation to real wear unknown / not existing
- can only be measured on test pieces not on actual glazing parts
- repeatability & reproducibility in case of coated plastics limited
- single source with not shared specifications for decisive abrasion wheels
- correlation of hurdles to safety requirements?

Microscope Image of the Abrasive Action

typical Taber cross scratch pattern



Typical Values for Different Sample

	Taber Abrasion Test
	CS 10F wheels (Gen IV); 1000 Cycles
	Δ haze [%] *
Laminated automotive glass	**0,5 - 1,5**
Siloxane based wet coats on PC	**2 - 7**
UV curable head lamp lense coatings on PC	**5 - 7**
Uncoated plastics	**30 - 40**

* typical values usually obtained with this kind of coating

Test OSCILLATING SAND

Standards and Regulation

- ASTM F 735

Settings

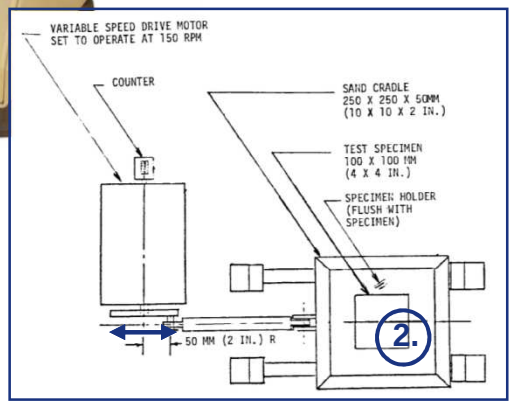
- see test setup on the right side
- 300 strokes per minute of reciprocating motion of approx. 100-mm travel
- quartz silica sand graded 4/10
- specimens having both sides substantially plane and parallel

Correlation to Real Use

Neither the tested abrasion nor the test plaques have a known correlation!

Test Setup and Procedure

Sketch from ASTM F 735



1. sand cradle with sample holder moving to and fro
2. test sample completely cover with sand (1kg)

Test OSCILLATING SAND

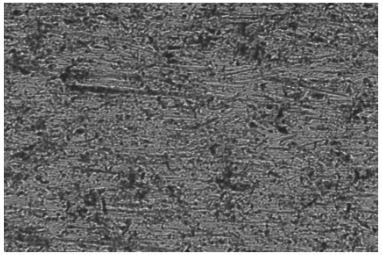
Pros and Cons

- standardized (national standard)

- correlation to real wear unknown / not existing
- can only be measured on test pieces not on actual glazing parts
- number of strokes to be decided
- according to ASTM „no justifiable statement can be made on the precision of the procedure“
- up to now not used to assess safety glazing

Microscope Image of the Abrasive Action

combination of scratches and surface erosion



Typical Values for Different Sample

	Oscillating Sand Test
	1kg sand; 40 double strokes
	Δ haze [%]*
Laminated automotive glass	**< 1**
Siloxane based wet coats on PC	**3 - 6**
UV curable head lamp lense coatings on PC	**5 - 11**
Uncoated plastics	**ca. 35**

* typical values usually obtained with this kind of coating

Test SAND TRICKLING (Falling Sand)

Standards and Regulation

- DIN 52348
  (ASTM D 968 uses a similar setup)

Settings

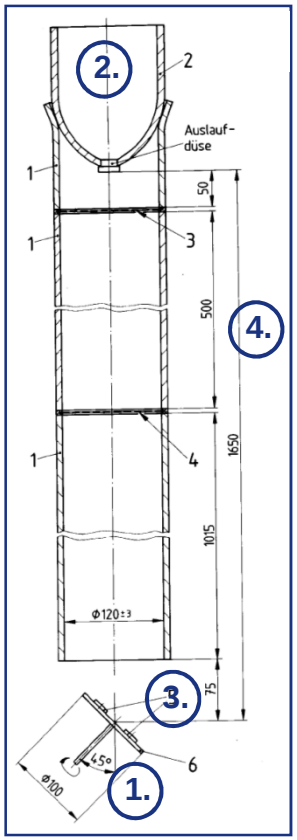
- see test setup on the right side
- natural silica sand (grain fraction 0,5/0,71 mm)
- two reference samples with know base values are part of each test series

Correlation to Real Use

The tested abrasion has no obvious correlation while it is possible to use real parts for the test!

Test Setup and Procedure

1. **rotating specimen holder (at an angle of 45° to the vertical)**
2. **reservoir with 3kg sand**
3. **part or test sample**
4. **down pipe 1,65m long**



Sketch from DIN 52348

Test SAND TRICKLING (Falling Sand)

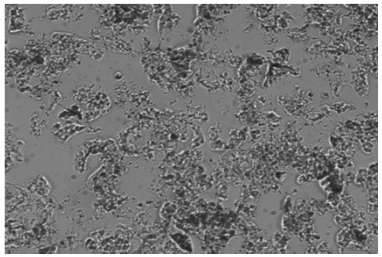
Pros and Cons

- standardized (national standard)
- testing of samples cut out of actual glazing parts possible

- correlation to real wear not known
- distinction between different systems not possible
- test result correction using reference samples necessary (see DIN 52348)
- up to now not used to assess safety glazing

Microscope Image of the Abrasive Action

impact based wear / surface erosion



Typical Values for Different Sample

	Trickling Sand Test
	3kg sand; height of fall 1650mm
	Δ haze [%] *
Laminated automotive glass	**3,5 - 5,0**
Siloxane based wet coats on PC	**3,5 - 6,0**
UV curable head lamp lense coatings on PC	**5,0 - 7,0**
Uncoated plastics	**ca. 40**

* typical values usually obtained with this kind of coating

Test CAR WASH

Standards and Regulation

- ISO 20566

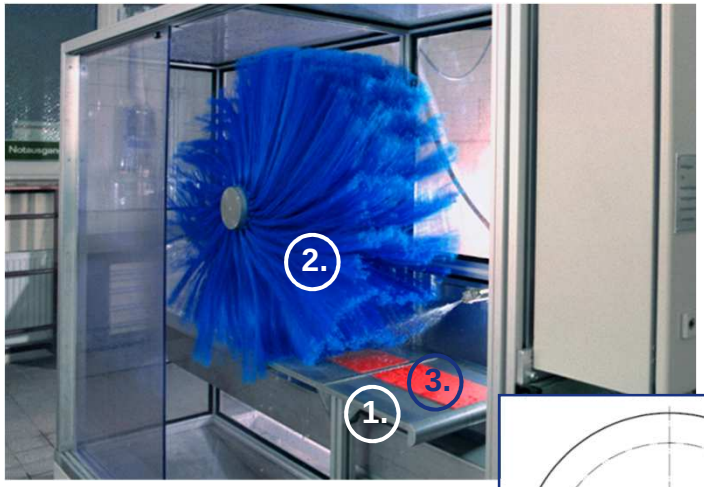
Settings

- see test setup on the right side
- gloss or haze determination after 10 washing operations (double strokes) with
- a penetration depth of the bristle of 100mm using
- quartz powder as artificial dirt

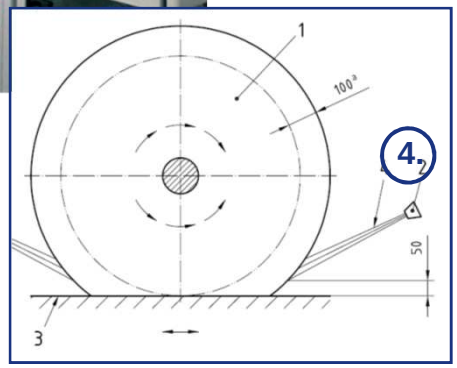
Correlation to Real Use

Tested abrasion is realistic and can be performed on finished / actual glazing parts!

Test Setup and Procedure



Sketch from ISO 20566



1. **sample holder moving back and forth**
2. **rotating brush using x-shaped, spliced PE bristles**
3. **test sample**
4. **“1,5g quartz powder per 1l tap water” sprayed with 2,2 l/min at 300 kPa**

Test CAR WASH

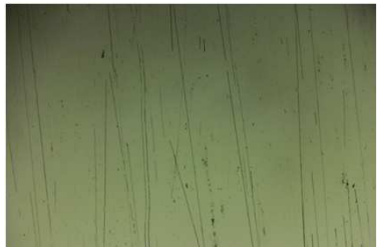
Pros and Cons

- standardized (international standard)
- test is used to assess paint coatings in the automotive industry
- realistic test since it is a minimized setup used to clean cars
- correlation to outdoor use proven

- up to now not used to assess safety glazing

Microscope Image of the Abrasive Action

single scratches on the surface



Typical Values for Different Sample

	Car Wash Test
	10 double strokes; 1.5g sand per 1l water
	Δ haze [%]*
Laminated automotive glass	**< 0,5**
Siloxane based wet coats on PC	**0,5 - 1,1**
UV curable head lamp lense coatings on PC	**2 - 6 ****
Uncoated plastics	**10 - 15**

* typical values usually obtained with this kind of coating
** depending on the type of UV curable coating

Test WIPER RESISTANCE

Standards and Regulation

- new or a modification of ISO 11998 (scrub resistance) needed

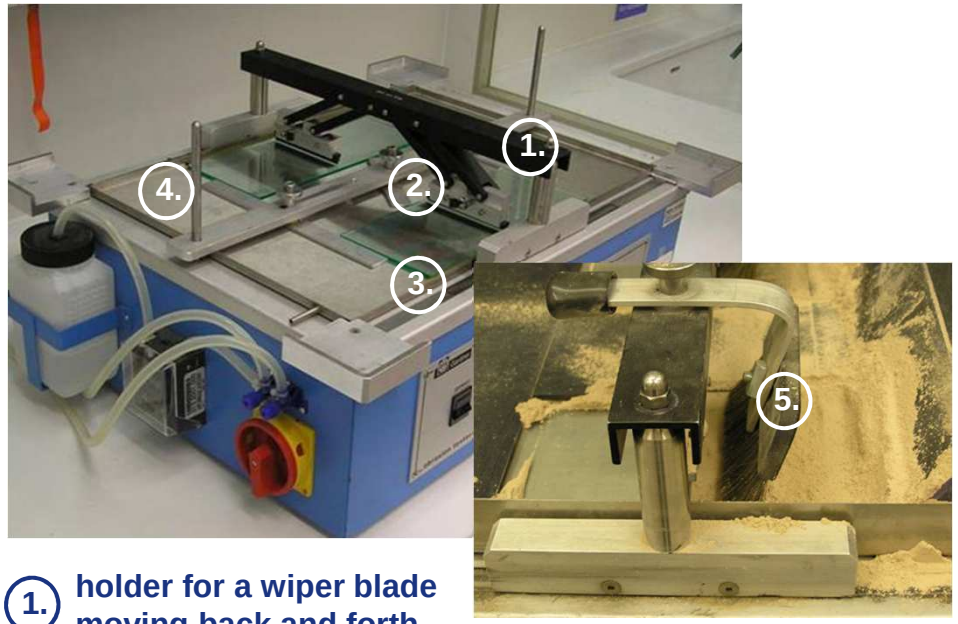
Settings

- to be defined e.g.:
- wiper blade with 20 g/cm load and 14 cm/s speed
- 5000 double strokes using sand according to ISO 12103

Correlation to Real Use

Tested abrasion is realistic and can be performed on actual glazing parts!

Test Setup and Procedure



1. **holder for a wiper blade moving back and forth**
2. **commercially available wiper blade**
3. **fixed test sample**
4. **basin for testing under wet conditions / with dirt or**
5. **brush to recover the sample with dirt**

Test WIPER RESISTANCE

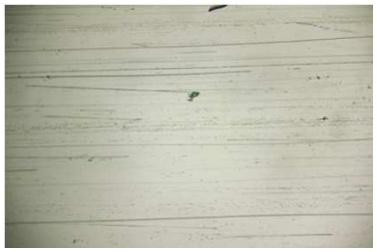
Pros and Cons

- realistic test since it is a minimized setup of a actual glass wiper
- correlation to outdoor

- not standardized (possible via modifying ISO 11998)
- detailed test conditions to be defined (dry, wet with or without dirt)
- real conditions might vary depending on the used wiper system

Microscope Image of the Abrasive Action

scratches & chatter marks on the surface



Typical Values for Different Sample

	Wiper Resistance Test
	5000 double strokes; dry with dirt
	Δ haze [%] *
Laminated automotive glass	**ca. 3**
Siloxane based wet coats on PC	**ca. 3 ****
UV curable head lamp lense coatings on PC	**ca. 4,5**
Uncoated plastics	**ca. 13,5**

* typical values usually obtained with this kind of coating
** depending on the type of siloxane coating

Test SAND BLAST

Standards and Regulation

- new or a modification of the sand spray test described in ECE R112 (used to assess head lamp lenses covers) needed

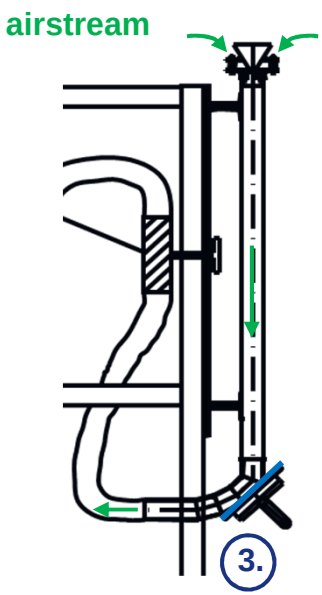
Settings

- see test setup on the right side
- amount of sand, flow rate and angle of incidence are decisive parameters
- sand with grit size 200 - 250 µm

Correlation to Real Use

Test is intended to simulate abrasion behavior of particles like sand in the airstream or sand drift and can be performed on real parts.

Test Setup and Procedure



1. **sample holder (angle 45° to the airstream)**
2. **funnel with 3,5g sand trickling into the pipe / air-stream**
3. **test sample (in an airstream of 35m/s flow rate with well mixed in sand particles)**
4. **vacuum exhauster generating airstream (flow rate detection after particle filter)**

Test SAND BLAST

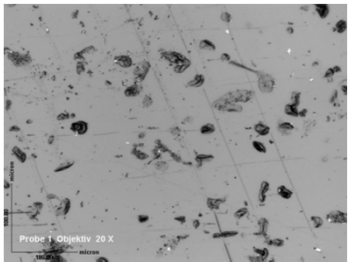
Pros and Cons

- intended to simulate abrasion of drifting sand during driving (compared to other tests here a high relative speed with low contact force of an abrasive particle against a sample is tested)

- not standardized (compared to ECE R112 sand spray test here a sand airstream is used instead of a water jet with sand)
- up to now not used to assess safety glazing

Microscope Image of the Abrasive Action

impact based wear / surface erosion



Typical Values for Different Sample

	Sand blast test
	3,5g sand; 35m/s flow rate; 45°angle
	Δ haze [%] *
Laminated automotive glass	**ca. 2**
Siloxane based wet coats on PC	**ca. 3**
UV curable head lamp lense coatings on PC	**4 - 8 ****
Uncoated plastics	**ca. 15**

* typical values usually obtained with this kind of coating
** depending on the type of UV curable coating

Taber abrasion vs. real wear

Comparison of two different coating systems on polycarbonate

Siloxane based wet coat

Nano-composite based wet coats

based on Taber the wrong system is selected due to missing correlation to real wear

Taber abrasion vs. real wear

Sun et al. in *Tribology Letters,* Vol. 13, **2002**, 49 (Eastern Michigan University with a coauthor from Exatec)

4. Conclusion

In conclusion, the Taber test is a useful test method in many applications and industries. However, in interpreting the results, attention must be paid to insure that the abrasion condition of the Taber test matches the real application condition of the tested material. We have shown that, due to its crossed-scratch abrasion pattern, the Taber test is an unsuitable test to characterize the abrasion characteristics of automotive windows. Furthermore, when it is used to test layered materials, damages, such as delamination and chipping, occur occasionally, and the standard deviation will be larger than for solid materials.

Figure 5. CCD image of the ExatecPlus surface after the Taber test showing severe damage at intersections of scratches.

Severe damage occasionally happening due to

- cross-scratch abrasion and
- some times applying relatively high forces due to size and shape distribution of the hard particle embedded in the rubber of the wheels

both not realistic in this application since "…the scratch resistance of windows in their real application, where the windows mostly suffer from abrasion in one direction by small to medium forces, …"

Precision of the oscillating sand method

ASTM F 735 version 1994

Designation: F 735 – 94 (Reapproved 2001)

Standard Test Method for Abrasion Resistance of Transparent Plastics and Coatings Using the Oscillating Sand Method[1]

11. Precision and Bias

11.1 *Precision*—A round robin has been completed. However, only five (5) laboratories, rather than six (6) per Practice E 691 were used, because no others were found to exist. Data is currently under evaluation and a precision statement will be formulated.

11.2 *Bias*—No justifiable statement can be made on the bias of the procedure in Test Method F 735 for measuring abrasion, because there is no standard material.

ASTM F 735 version 2006

11. Precision and Bias

11.1 *Precision*—No justifiable statement can be made on the precision of the procedure in Test Method F 735 for measuring abrasion, because no standard material has been designated.

11.2 *Bias*—No justifiable statement can be made on the bias of the procedure in Test Method F 735 for measuring abrasion, because no standard material has been designated.

Designation: F 735 – 06

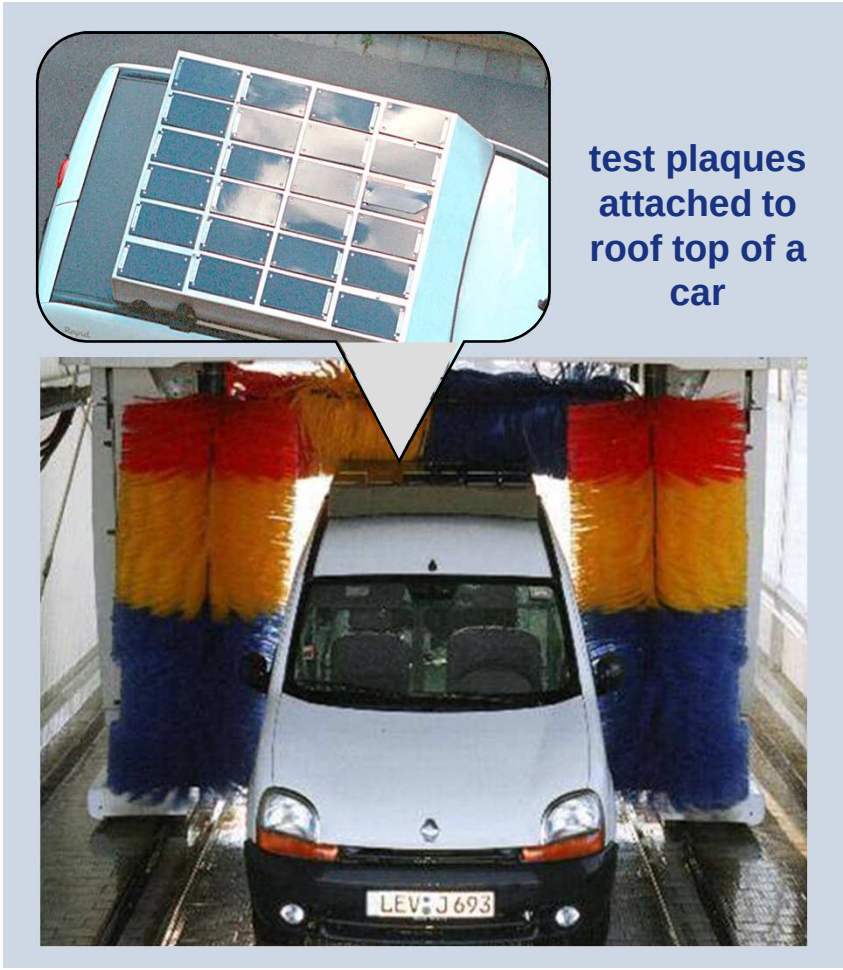
Standard Test Method for Abrasion Resistance of Transparent Plastics and Coatings Using the Oscillating Sand Method[1]

Real Test CAR WASH

- **Test scope:**
  resistance against car wash conditions

- **Test conditions:**
  - test plaques getting dirty during outdoor use in Lev & cleaned once a week in a car wash
  - X-shaped, spliced, PE bristle-containing brushes
  - no wax / cleaning agent

- **Test advantage / disadvantage**
  - realistic
  - not standardized

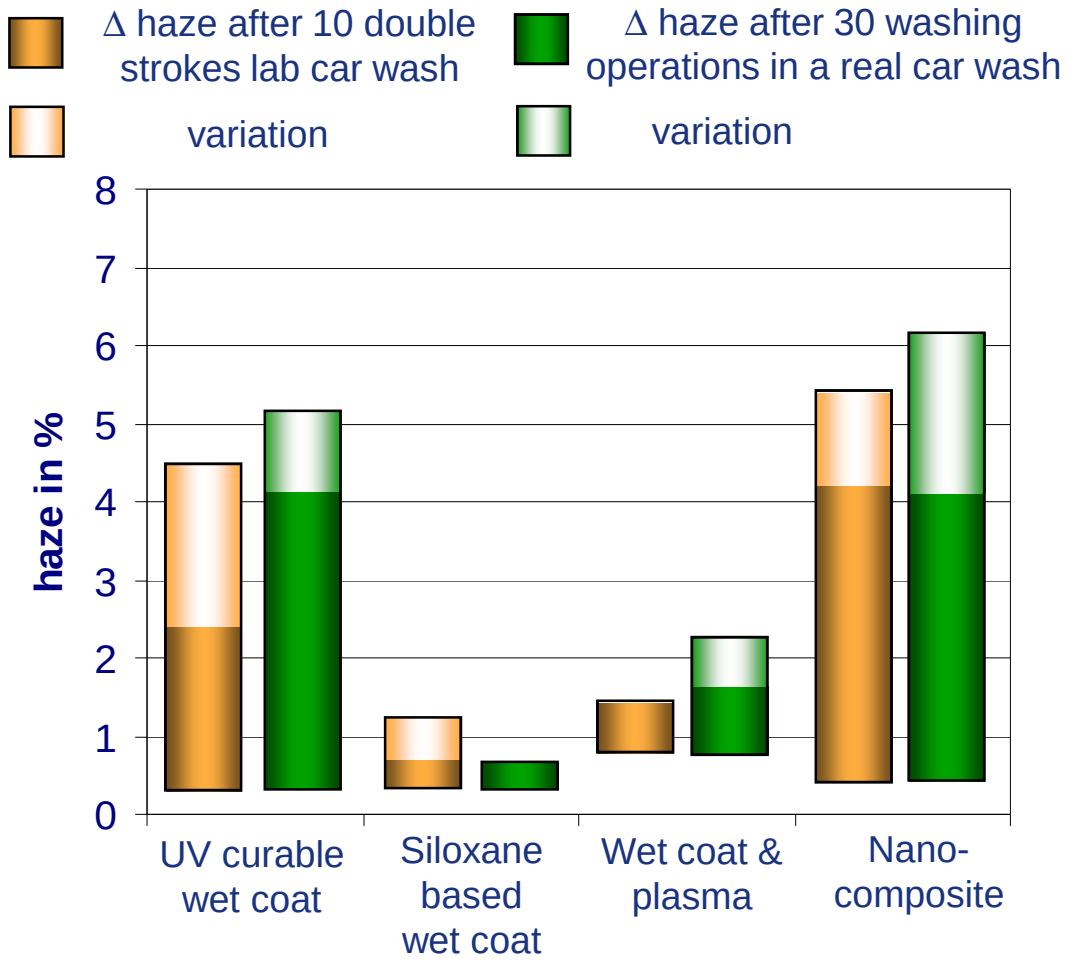


test plaques attached to roof top of a car

Comparison of real vs. laboratory car wash

- good correlation between real and laboratory car wash for coated Polycarbonate

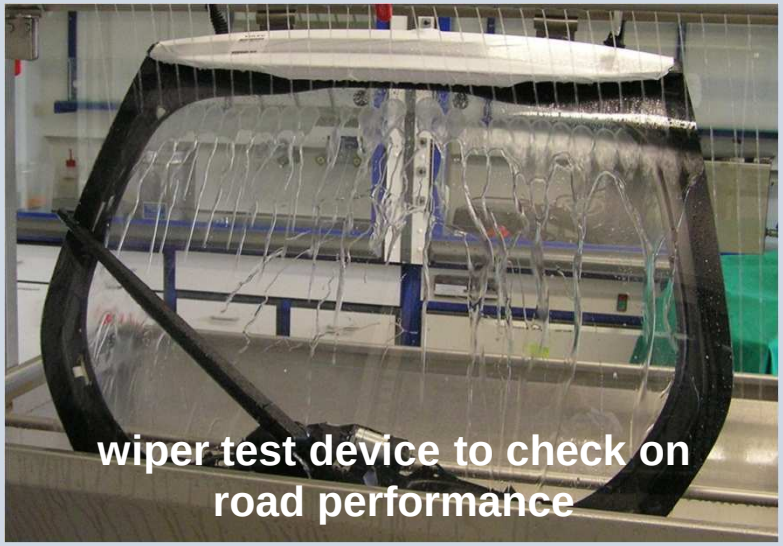
+ test according to ISO 20566 (laboratory car wash) is suitable to check real wear resistance of glazing parts against car wash conditions



Wiper resistance

Background Information:

- standardized tests verify cleaning efficiency and durability of the wiper system etc.
- BUT not the resistance of the wiped glazing part
- practical experience as base for suitable test conditions is missing
- existing plastic glazing parts with wiper systems (e.g. windscreens of police cars with special permission or vehicles which can not exceed 40km/h) “mostly” use engineering options as solution (water is automatically sprayed on the part before the wiper blade starts to move)



but first of all DUE TO missing specifications

► evaluation of influencing factors on the durability of the plastic glazing based on a laboratory wiper test

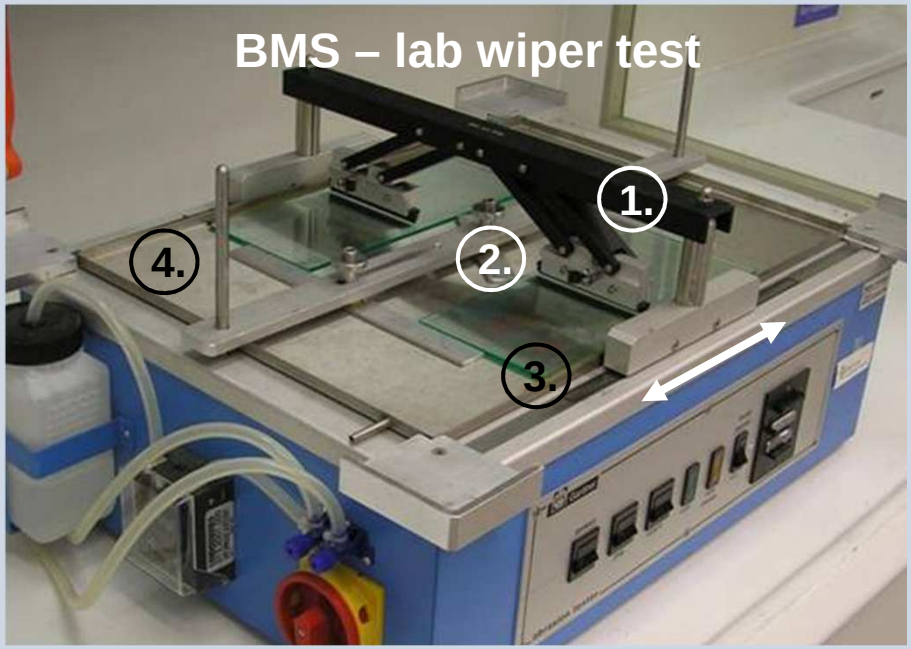
Wiper resistance - lab test

Test conditions:

- wipe speed 14cm/s
- wiper blade load 20g/cm
- artificial dirt: mixture of salt and oxides in water (according to ISO 6255 & ISO 12103) or only Arizona test dust (ISO 12103)
- haze measurement before and after abrasive action

variation of

- the type of rubber for the wiper blade
  - no decisive influence on performance of the glazing part found (different rubber types have varying durability)
- the wipe conditions (dry or wet; with or without standardized dirt)
- the type of samples



1. **holder for a wiper blade moving back and forth**
2. **commercially available wiper blade with 20g/cm load**
3. **fixed test sample**
4. **basin for testing under wet conditions / with dirt**

Polycarbonates

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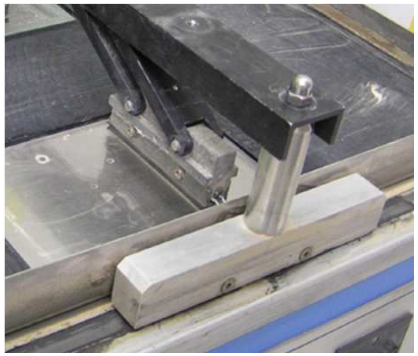
Wiper resistance - different conditions

150.000 double strokes dry without dirt

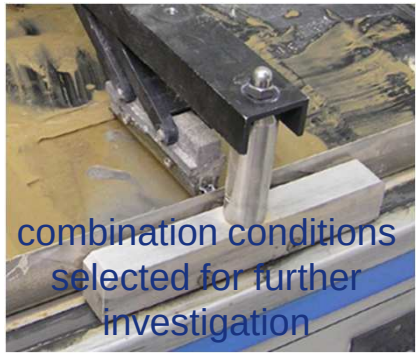


1.000 double strokes dry with dirt

(to determine performance limit of all the different types of samples)

50.000 double strokes wet with dirt

3.000 double strokes wet and dry with dirt



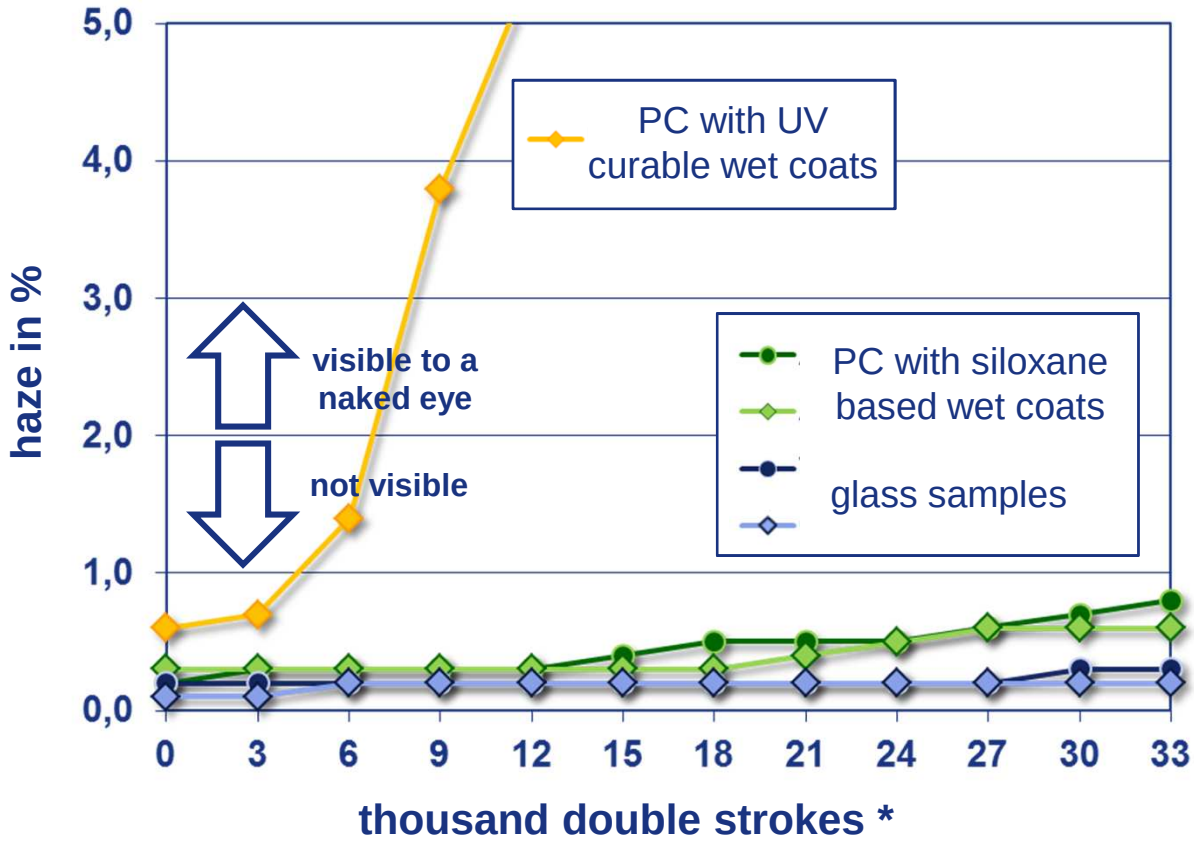
(since every different kind of wear related to wiper should be included here)

Results:

- no influence on glass and polycarbonate coated with siloxane based wet coats
- little influence on polycarbonate coated with UV curable wet coats and
- heavy influence on uncoated plastics

Wiper resistance - different type of samples

Combination conditions with increasing wipe cycles



Results:

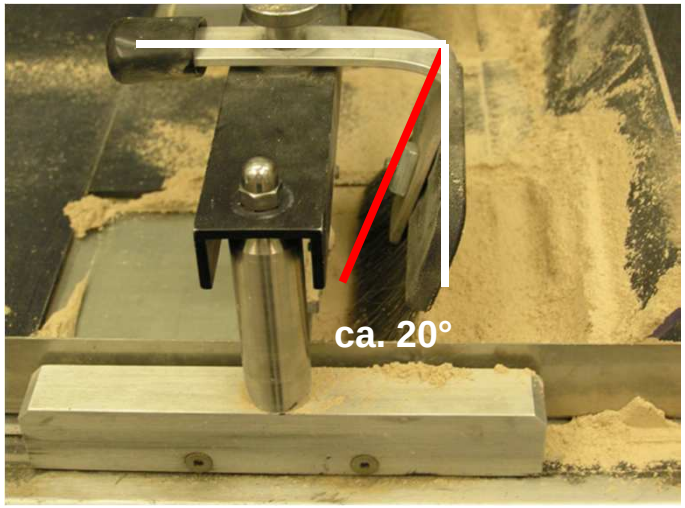
- no issue with siloxane based wet coats on PC up to 33.000 double strokes
- BUT how many cycles correlate to life time in real use?
- abrasive action too low to see the performance limit of all the different systems

* 3000 double strokes include a sequence of 2500 under wet and 500 drying / dry conditions

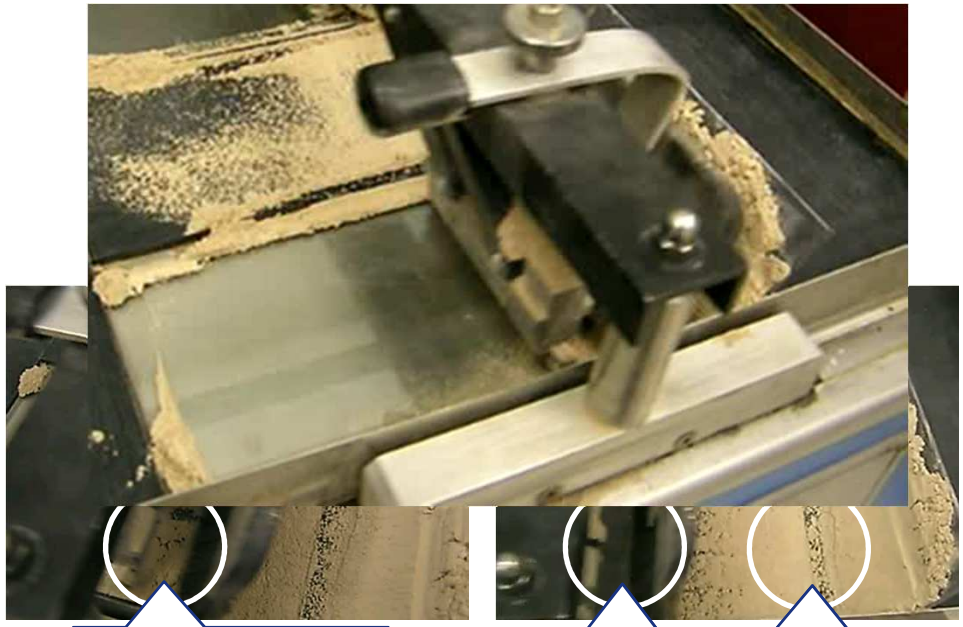
Wiper resistance - different conditions

further test set up modification

using a brush behind the wiper blade at a angle of ca. 20°



to ensure that the part is again covered with dirt after every half wipe cycles (half a double stroke) which of course leads to a surface cleaning



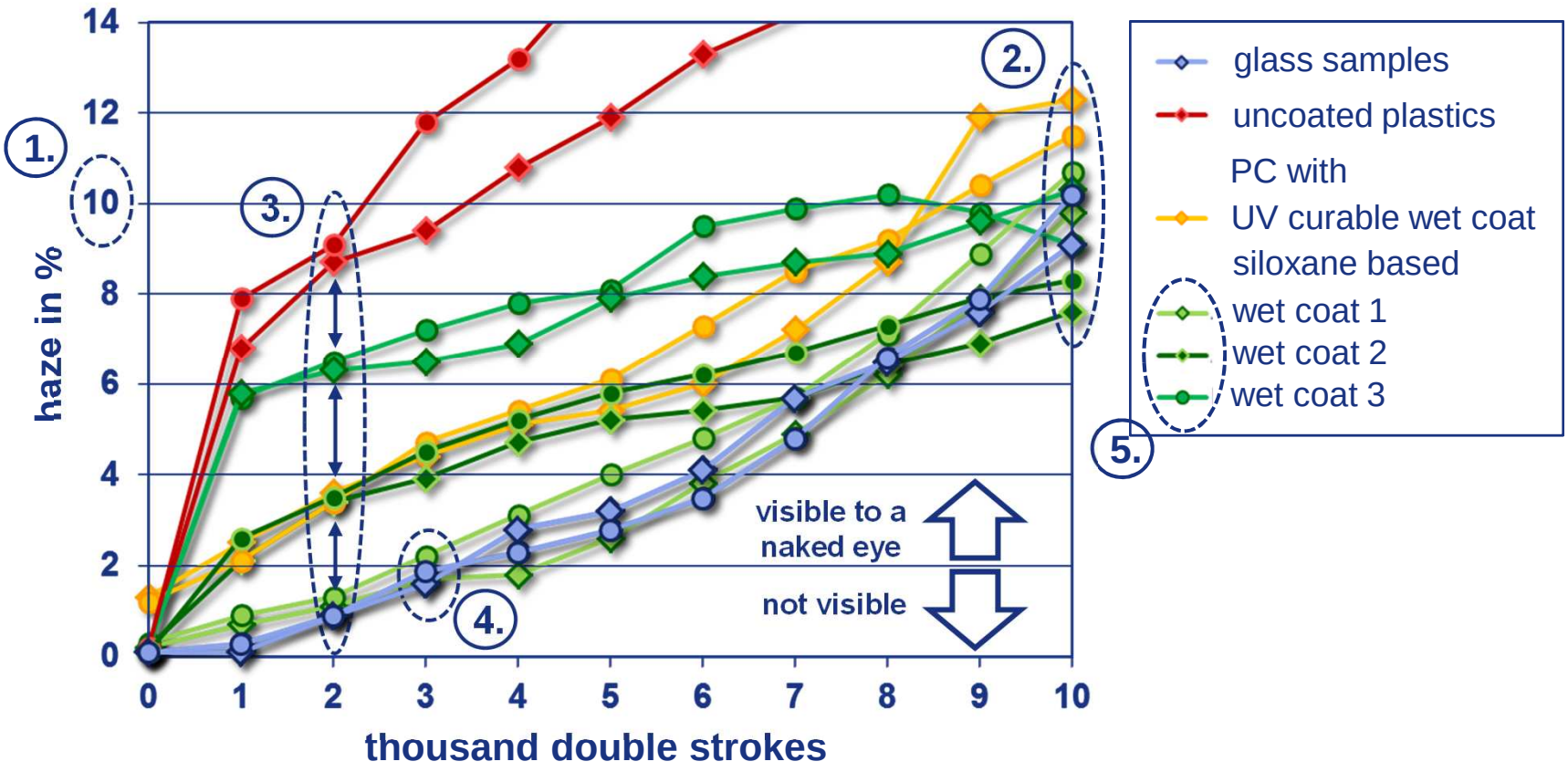
dirt in front of the moving wiper blade

no dirt behind the moving wiper blade

dirt again applied to the cleaned surface by the brush

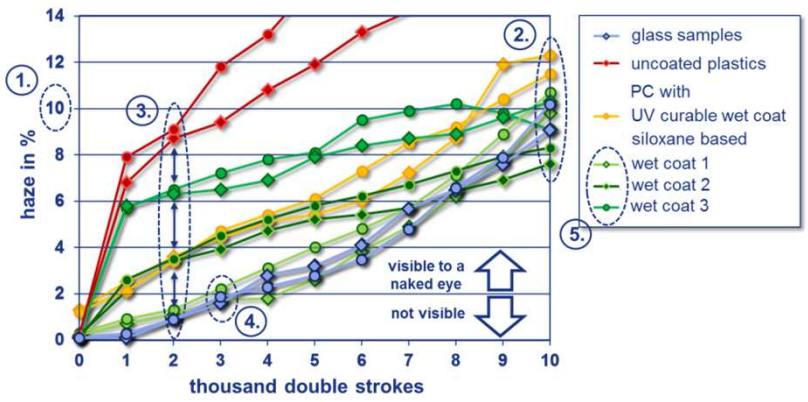
Wiper resistance - different type of samples

harshest conditions (dry with dirt) with increasing wipe cycles



Wiper resistance - different type of samples

harshest conditions (dry with dirt) with increasing wipe cycles



Results:

1. since glass based automotive glazing with a haze level of 10% does not match with experience, these conditions obviously are harsher than real wear, or 10.000 double strokes under these conditions are more than life time

2. at 10.000 double strokes all systems besides uncoated plastics have values around 10%

3. at lower wipe cycle numbers there are larger deviations between the different systems

4. some siloxane based wet coats perform similar to glass, especially they cross the border between visible and invisible at the same wipe cycle number

5. with this test it is possible to distinguish between different siloxane based wet coats (so some would need a constructive solution (always wet conditions) other not)

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Thank You For Your Attention

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