



Bayer MaterialScience

Results and Analysis of the Taber Round Robin test

IGPG Meeting in Hamburg
2011-06-14

Polycarbonates

Information

At the 1st meeting of the informal group on plastic glazing (IGPG) on 18.-19.01.2011 in Paris it was decided to establish a task force for conducting a Taber Round Robin test.

The objective of this Round Robin test is to answer the following question as basis for upcoming decisions: “Do the test laboratories all get the same results, when performing the Taber abrasion test?”

Four members of the task force promised to deliver test samples for this Round Robin test. Different types of samples from three members were delivered to the test laboratories, while one sample producer was not able to deliver samples in time for testing and result presentation at the 2nd IGPG meeting.

Available types of samples for the Round Robin test:

- monolithic float glass
- hard coated polymethylmethacrylate (PMMA)
- hard coated polycarbonate (PC)

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Information

Twelve test laboratories indicated their interest in participating and received samples (3 different types of samples (3 identical samples each type)). One test laboratory received two sets of samples since they wanted to check the influence of two different test procedures.

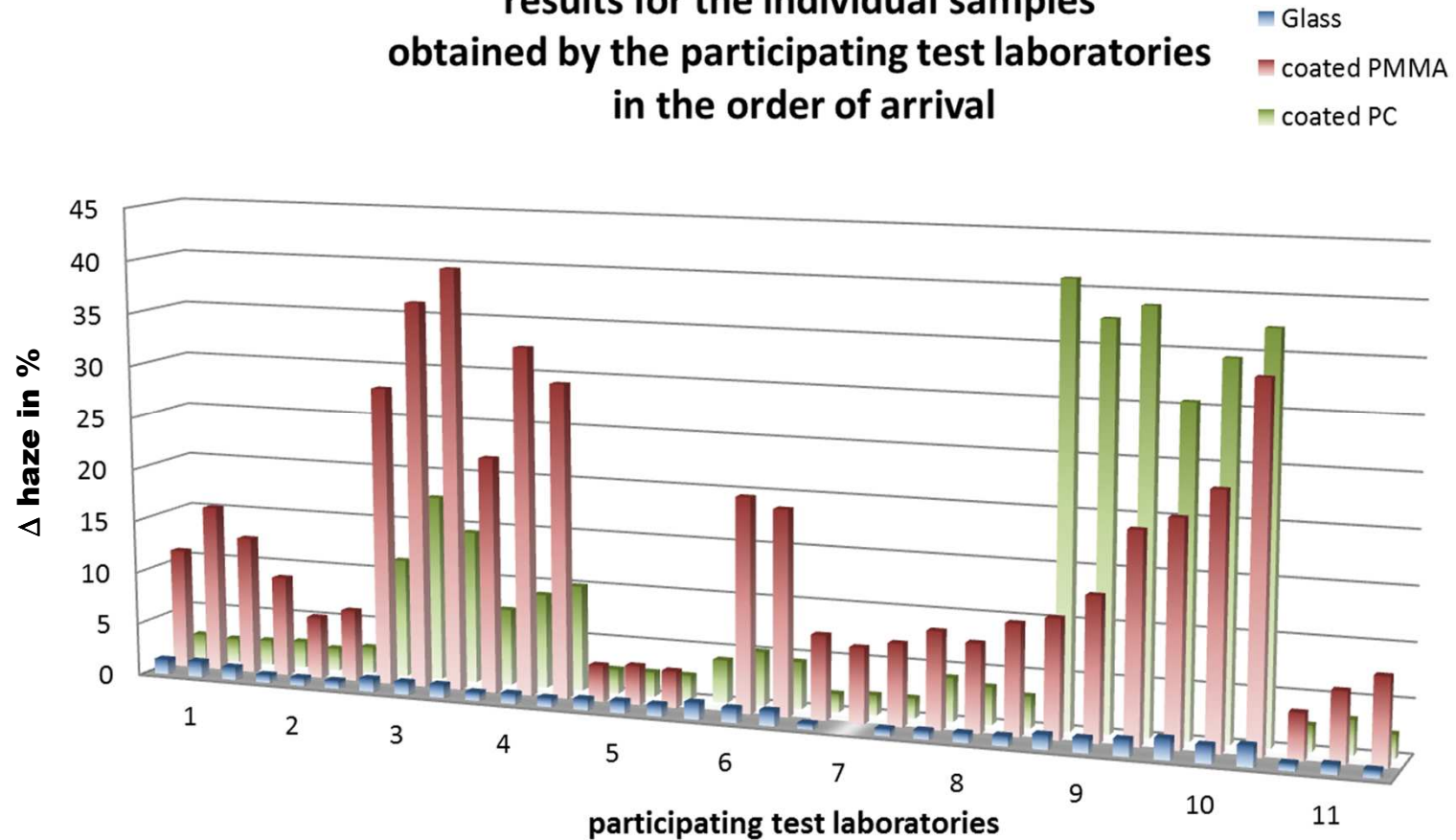
Eleven test laboratories performed the test and transmitted their results, one test laboratory decided however after receiving samples not to participate. One test laboratory which performed the test has already internally decided not to use the test anymore. Since they have used already expired wheels (instead of investing into new ones) their results are not included here.

Therefore on the next pages the results of nine test laboratories for three different types of samples (three samples each type), and of one test laboratory for two sets of samples using two different test procedures are presented (treated on the following pages as two test laboratories).

Test procedure details for these eleven data sets (one set includes three different types of samples with 3 identical samples for each type) can be found in the backup.

Test results per sample

results for the individual samples
obtained by the participating test laboratories
in the order of arrival

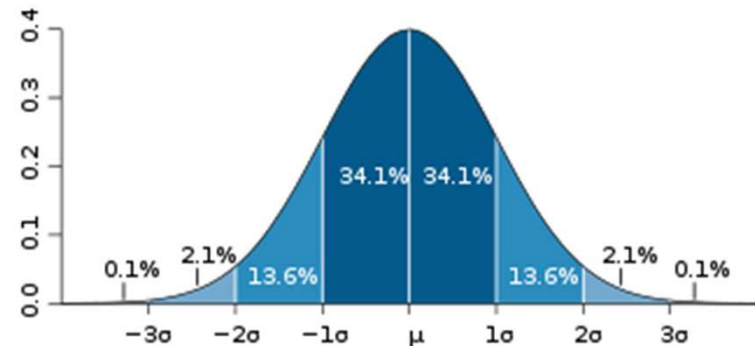
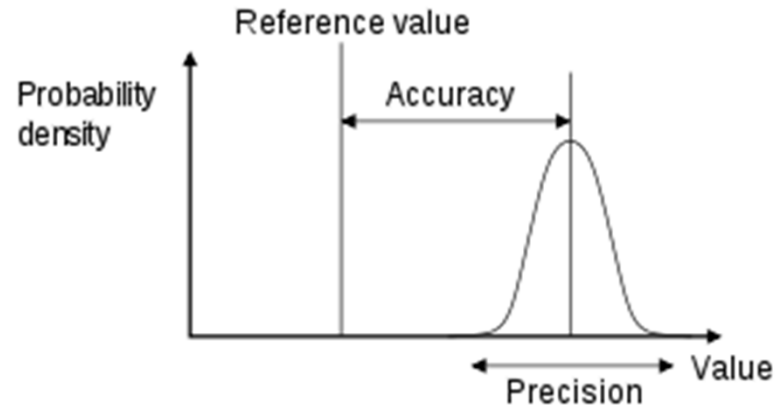


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Definitions from Wikipedia

The **precision** of a measurement system, also called reproducibility or repeatability, is the degree to which repeated measurements under unchanged conditions show the same results.

Standard deviation is a widely used measurement of variability or diversity used in statistics and probability theory. It shows how much variation or "dispersion" there is from the average (mean, or expected value). A low standard deviation indicates that the data points tend to be very close to the mean, whereas high standard deviation indicates that the data are spread out over a large range of values.



A plot of a normal distribution (or bell curve). Each colored band has a width of one standard deviation

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Summary of test results

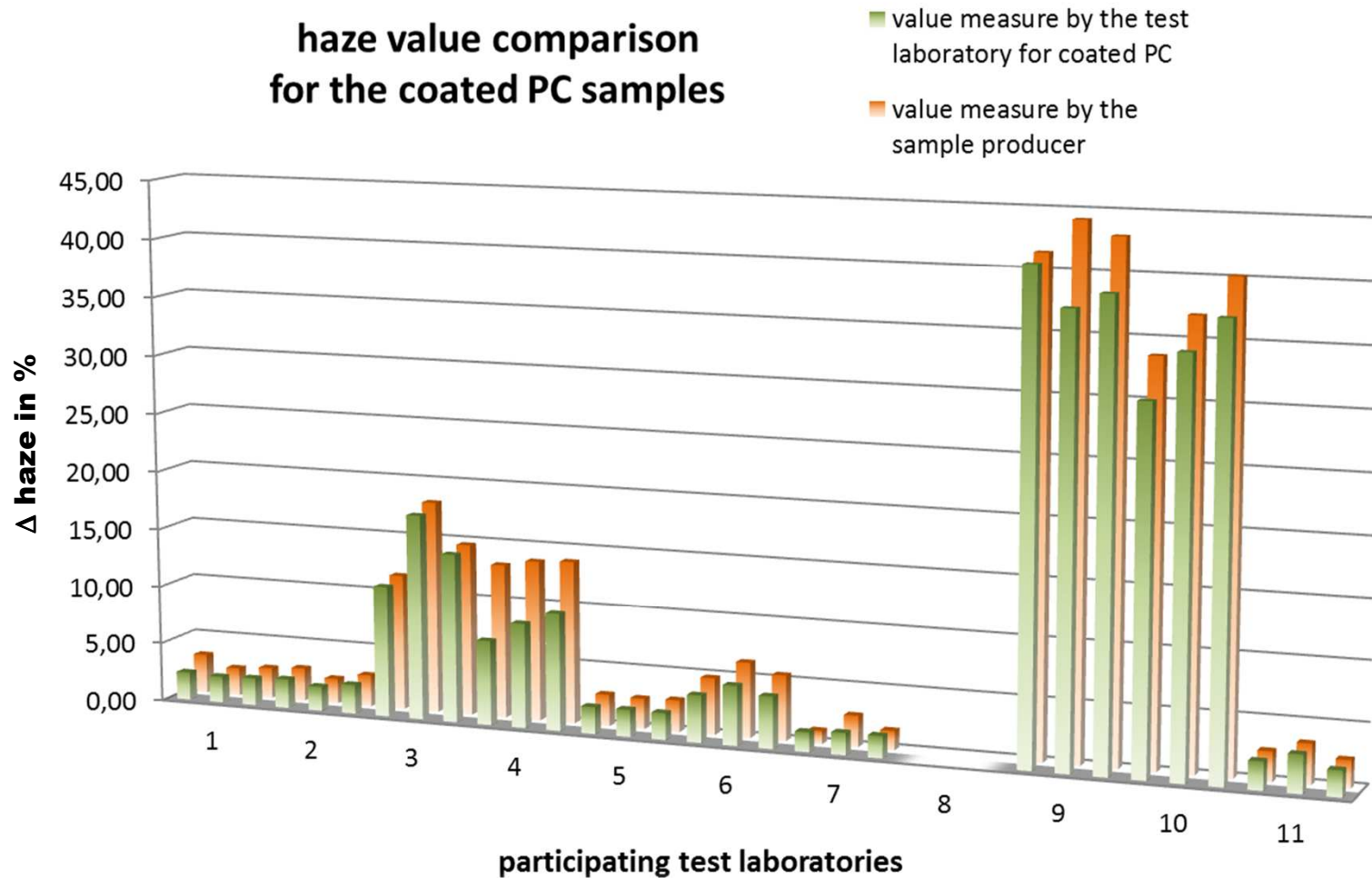
	Glass	coated PMMA	coated PC
	Δ haze [%]		
Lowest measured value	0,58	3,46	1,70
Highest measured value	2,00	39,94	40,90
Arithmetic mean of all values	1,18	15,44	10,52
Standard deviation	0,37	10,59	13,11

Information

In order to distinguish between the abrasion test itself and the haze measurement during evaluation of all test data it was agreed to send the samples after performing the test back to the sample producer for a haze measurement double / cross check.

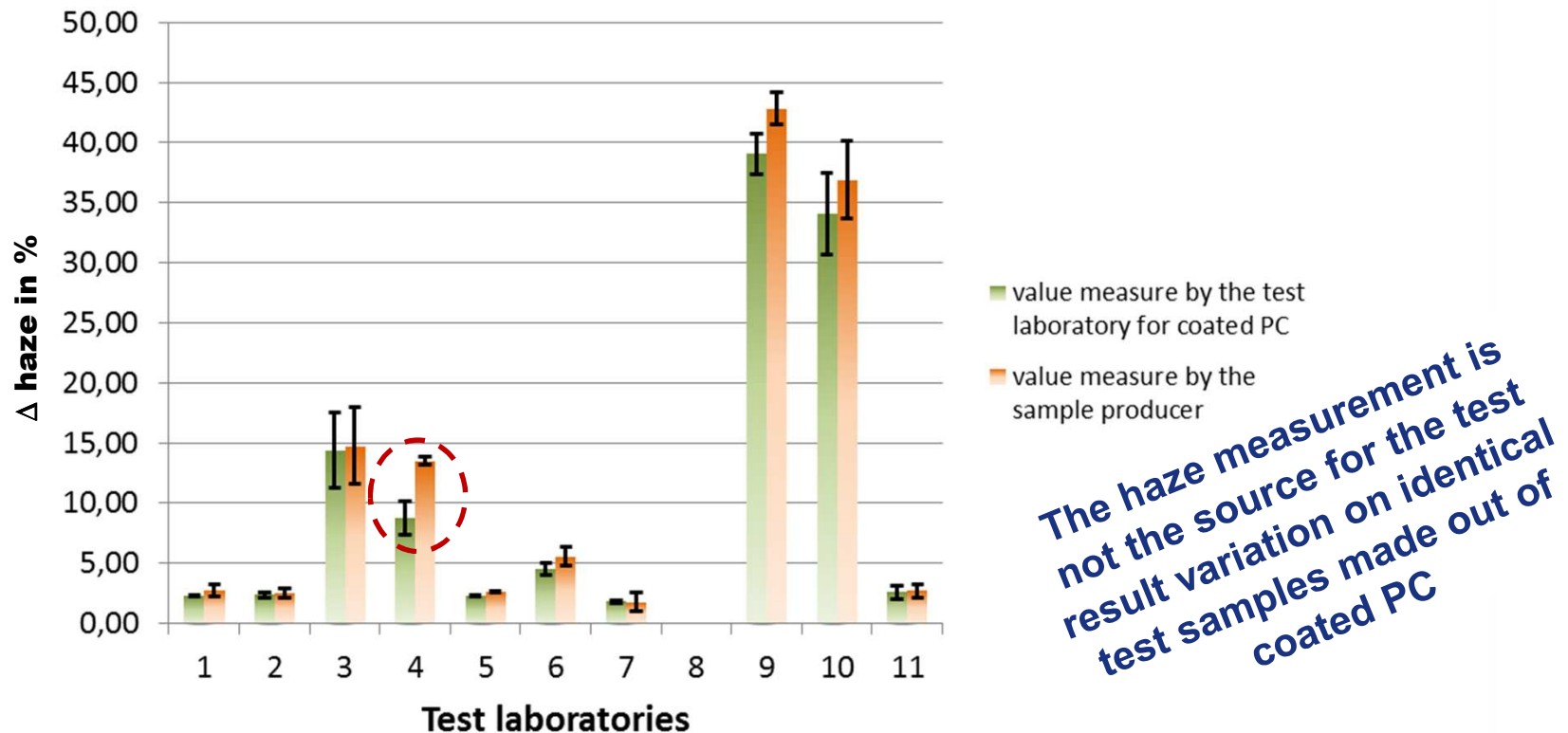
Up to now one sample producer was able to measure the haze value of the abraded track on his samples and compared this value with the initial haze he has measured before shipping the samples. The comparison of two haze values - one by the test laboratory and one by the sample producer - for each sample of this one type of samples is also presented on the next pages.

Test results for the haze cross check per coated PC sample

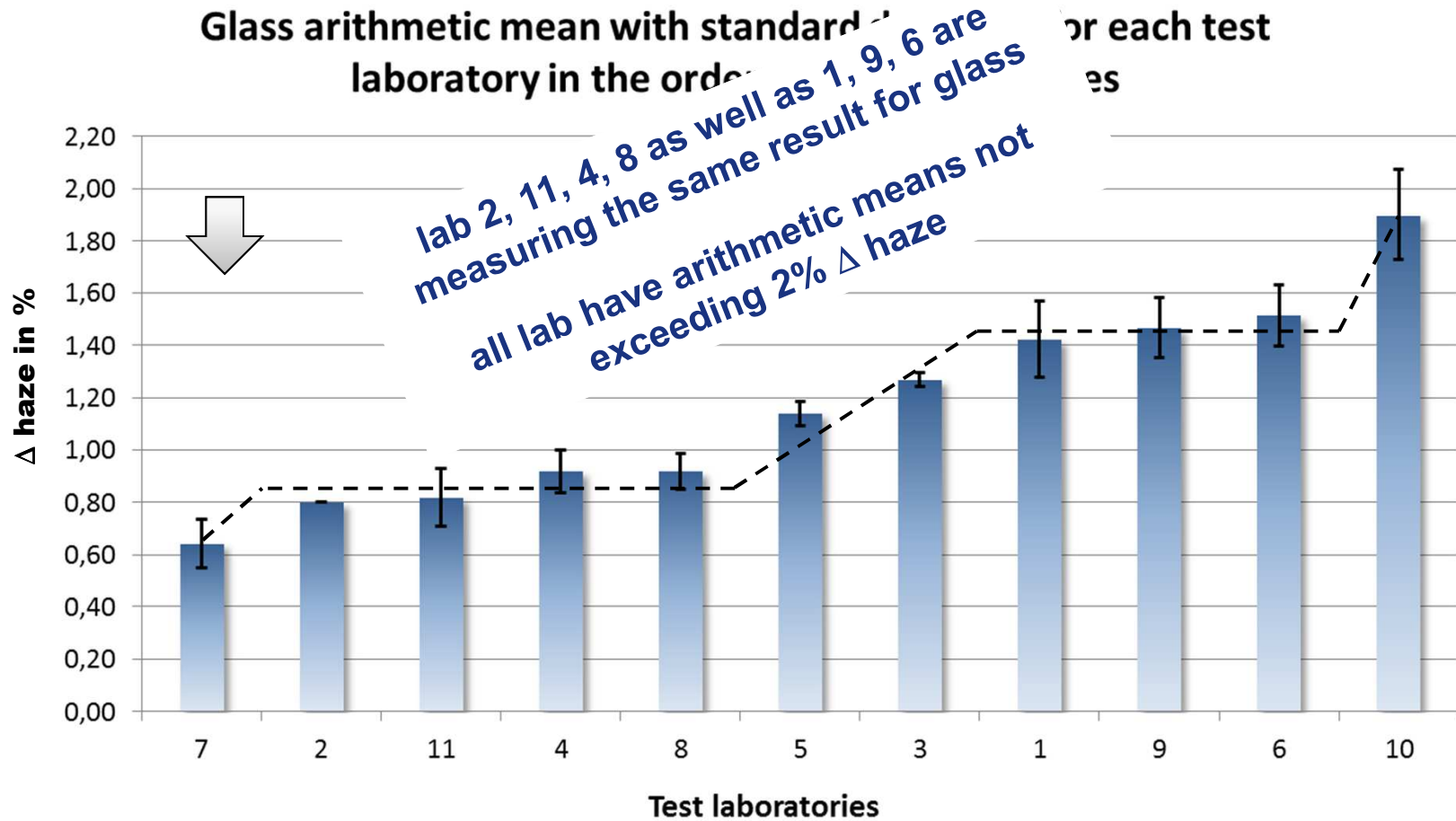


Test results for the haze cross check per test laboratory

comparison of the haze value (arithmetic mean including standard deviation) for the coated PC samples



Detailed test results for glass

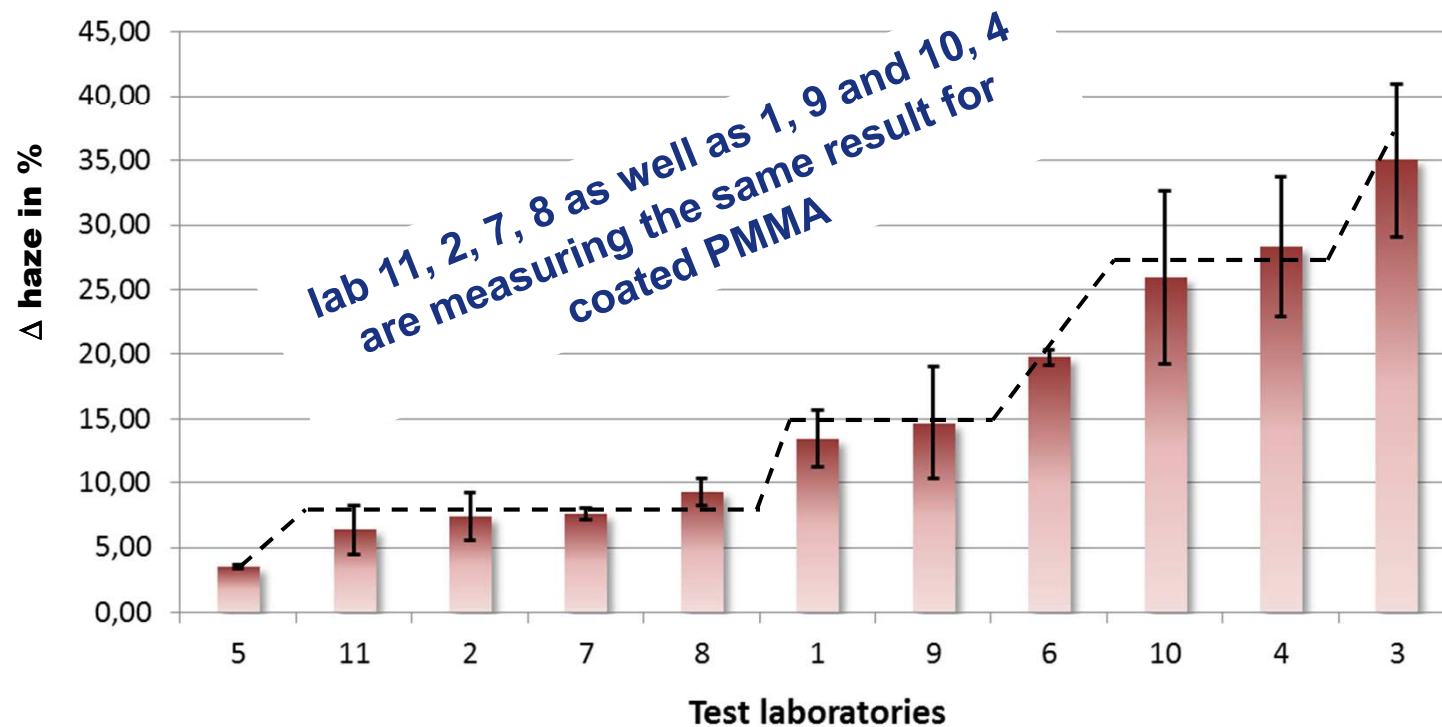


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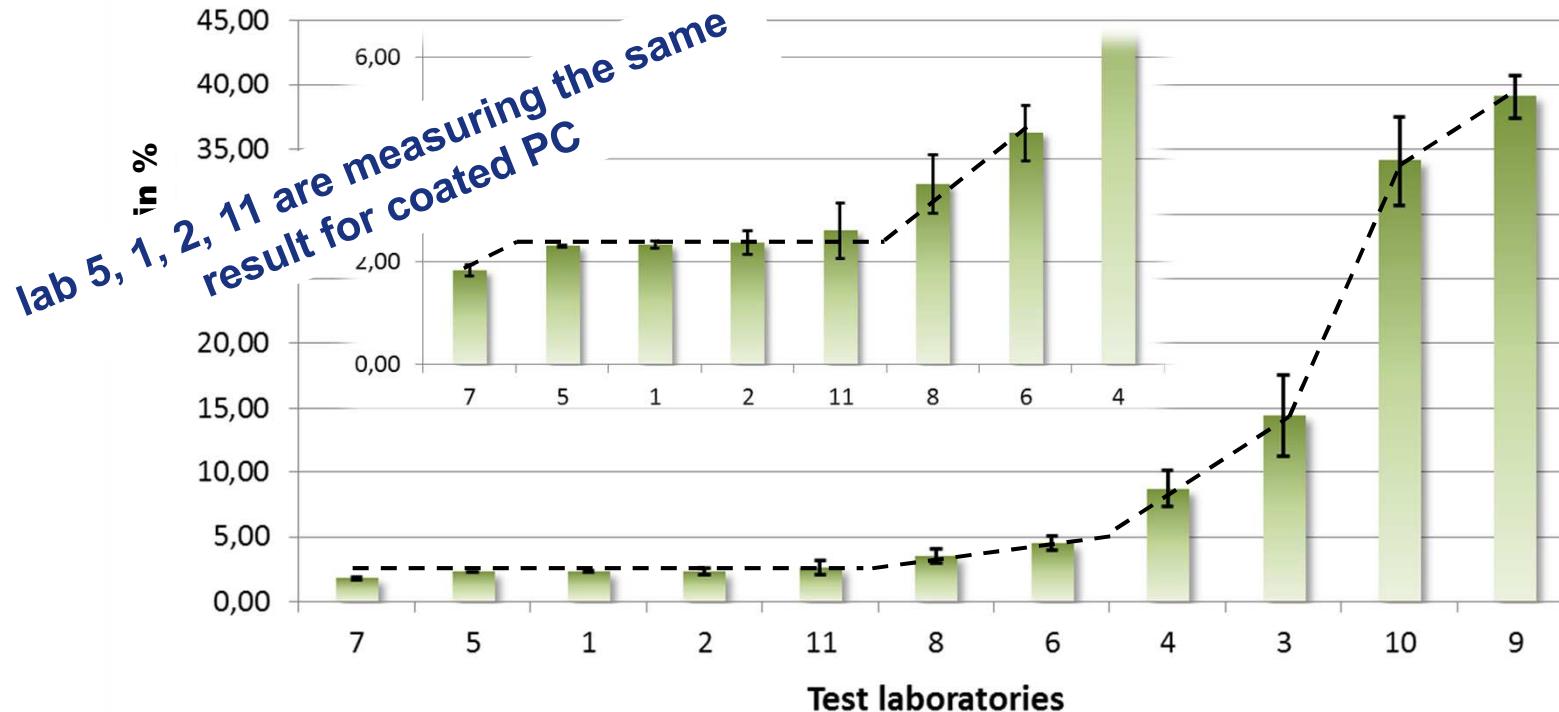
Detailed test results

coated PMMA arithmetic mean with standard deviation
for each test laboratory in the order of increasing
values



Detailed test results

coated PC arithmetic mean with standard deviation for each test laboratory in the order of increasing values



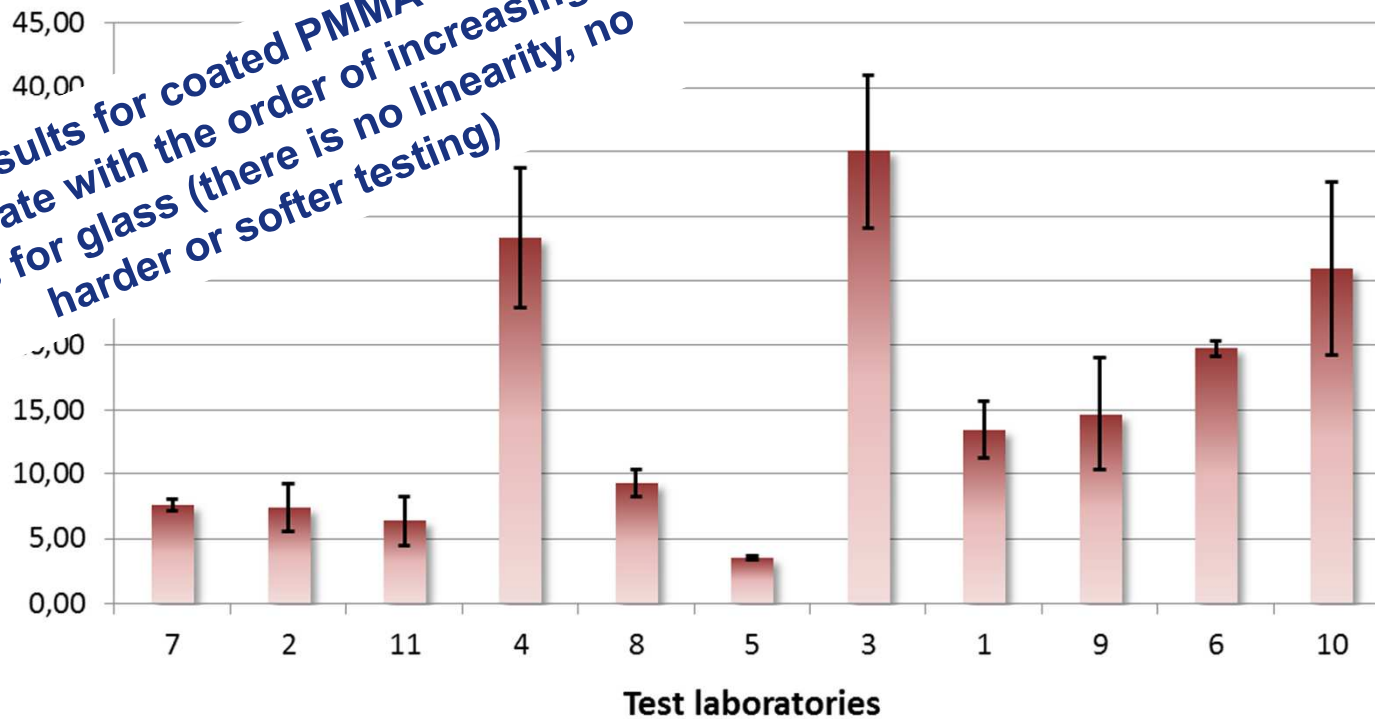
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Detailed test results

coated PMMA arithmetic mean with standard deviation
for each test laboratory (in the order of increasing
for glass)

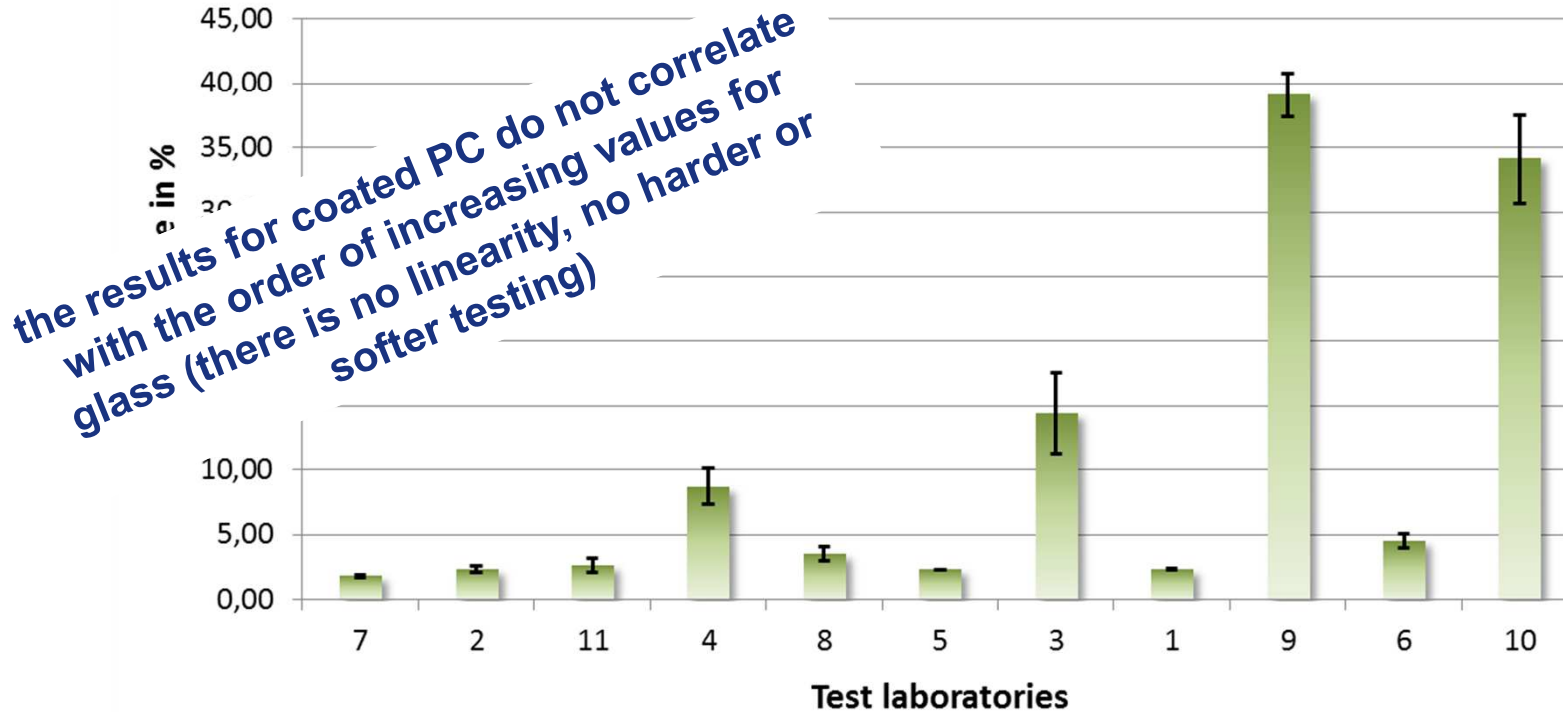
*the results for coated PMMA do not
correlate with the order of increasing
values for glass (there is no linearity, no
harder or softer testing)*



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Detailed test results

coated PC arithmetic mean with standard deviation for each test laboratory (in the order of increasing values for glass)

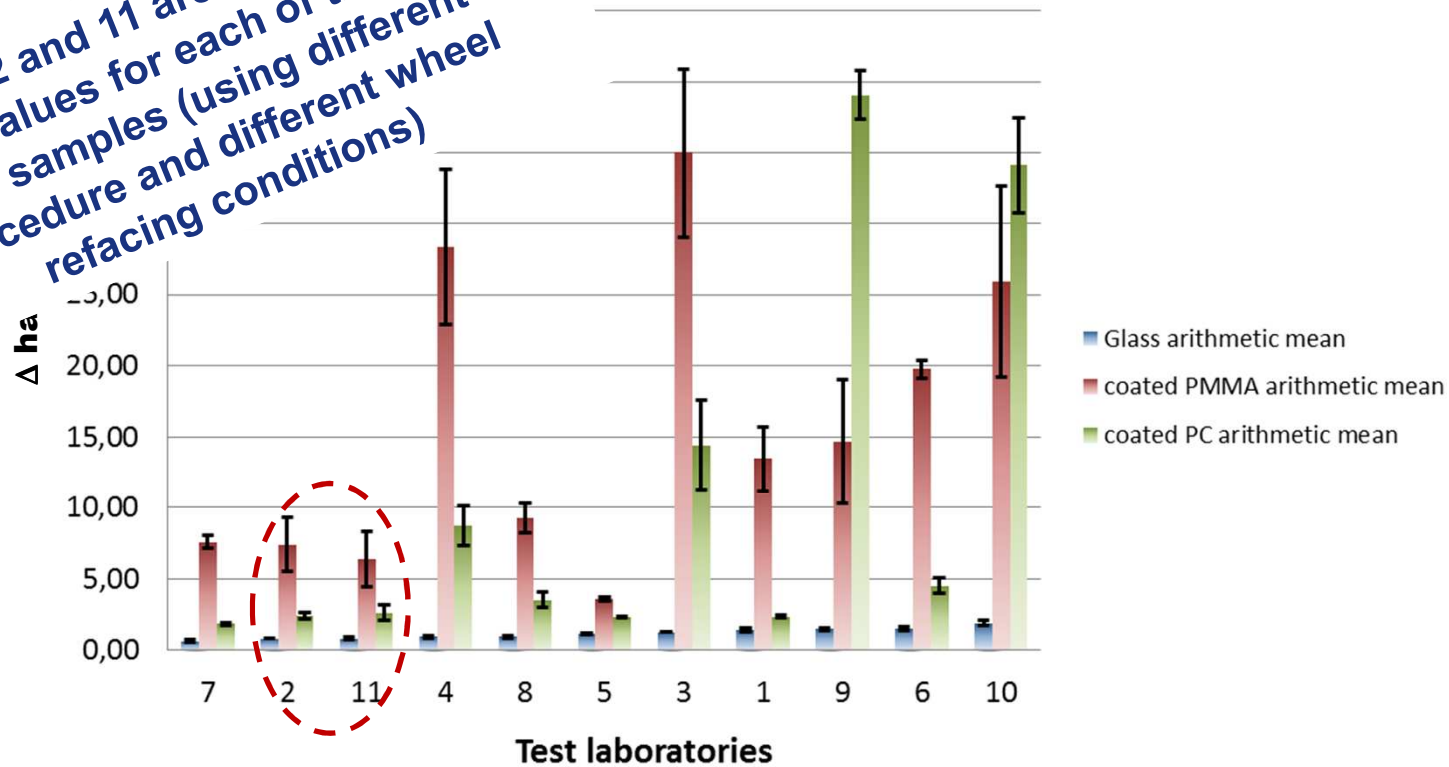


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Summary of detailed test results

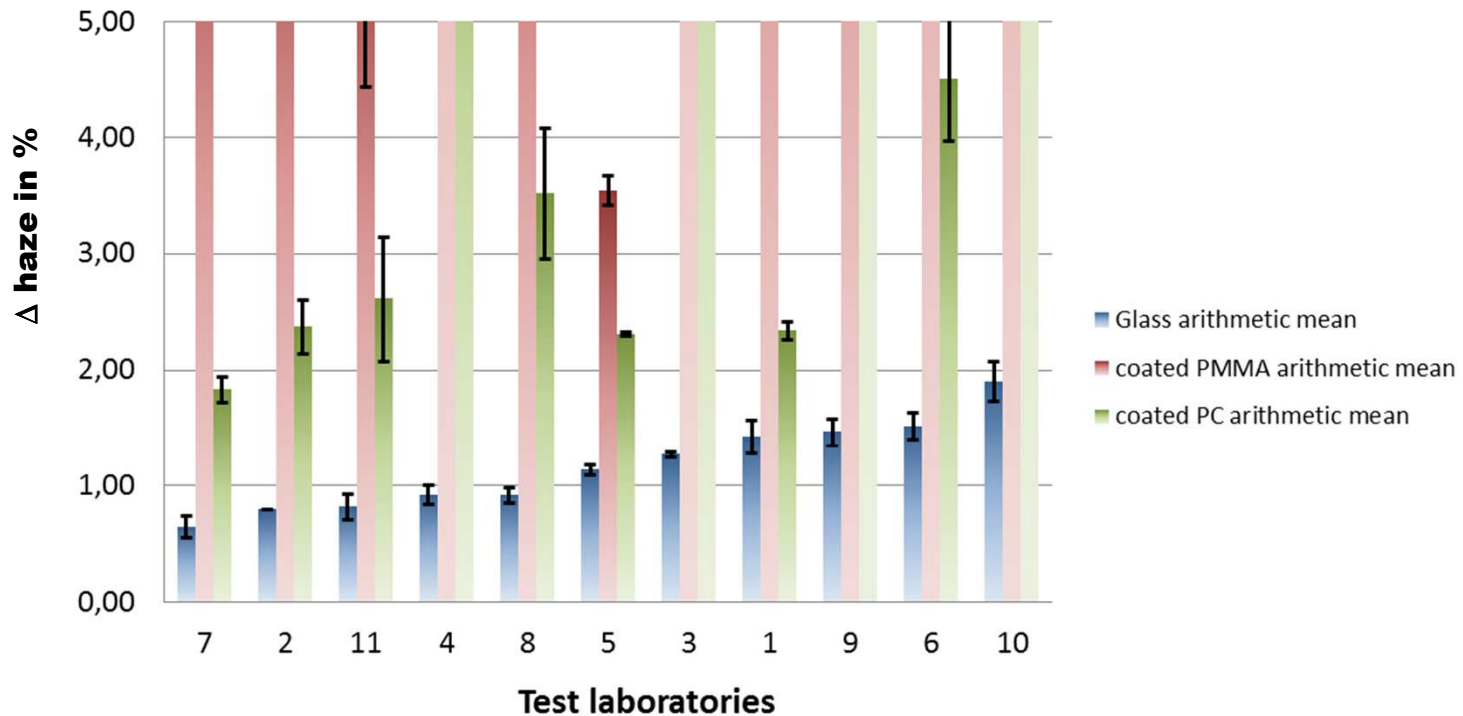
only lab 2 and 11 are measuring the same values for each of the three types of samples (using different test procedure and different wheel refacing conditions)

arithm... as with standard deviation for each test (in order of increasing values for glass)



Summary of detailed test results

arithmetic means below 5% with standard deviation for each test laboratory (in the order of increasing values for glass)



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Analysis of the taber Round Robin test results

1. „We are not measuring all the same results“, there is a large variation, when testing identical samples.
2. The haze measurement is not the source for the variation as shown by the cross check, so the variation comes from the abrasion test itself.
3. There are some similar results regarding a single type of samples like glass for example, but not regarding all types of samples (glass, coated PMMA, coated PC), with one exception (lab 2 and 11 have similar values for each of the three types of samples, despite the fact that they fulfill all – upfront discussed – criteria for variation (different test procedure & wheel refacing conditions)).
4. Test laboratories which gained high values for glass samples, do not automatically also gain high values for plastic substrates. So there is no linear correlation between the results for different types of samples (using a reference sample is not possible). Furthermore we do not all have the same performance sequence for the different types of samples (most laboratories have glass > coated PC > coated PMMA), again no linearity!
 - the abrasiveness of the wheels depends besides other factors (formulation, refacing etc.) also on the tested material

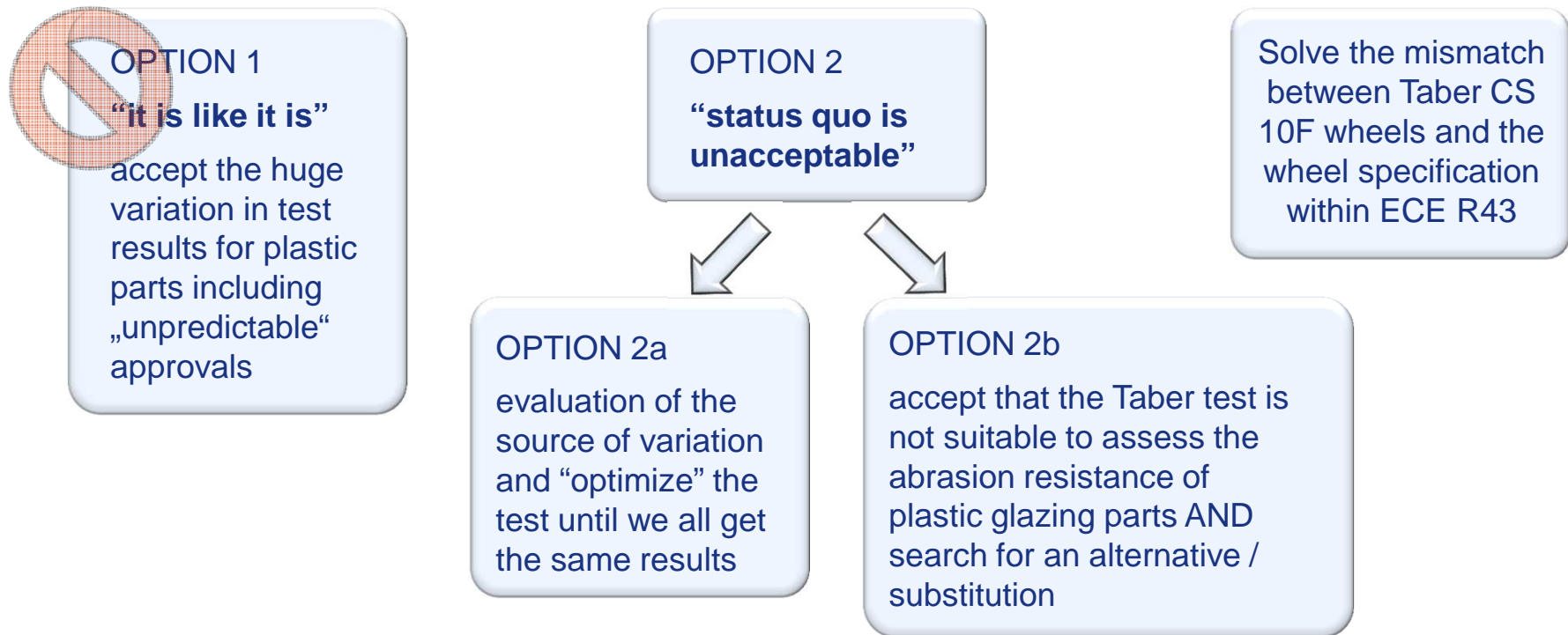
Analysis of the taber Round Robin test results

- see scientific literature (Sun et al in Tribology Letters, Vol.1, July 2002):
The Taber test method is not suited to assess real wear of layered material (like coated plastics) as long as real wear does not include cross-scratches with high forces (which is not the case in automotive glazing).

5. From a approval standpoint:

- a. no issue for glass – since all values do not exceed 2% haze due to abrasion (despite a low reproducibility (factor of more than 3 between lowest and highest value))
- b. for plastic glazing everything from an approval for all (besides windscreen) glazing locations to no approval for any location which needs a certain abrasion resistance
- c. strictly spoken no ECE R43 approval is possible anymore since the CS 10F wheels do not fulfill the wheel specification with a hardness of 72 ± 5 IRHD mentioned in EC R43

Options after the Round Robin test



- explanation from Taber
- explanation from scientific literature (Sun et al in Tribology Letters, Vol.1, July 2002) ▣

Explanation from scientific literature

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, ..."

Backup

test laboratory	1			
tested according to test details	ASTMD1044-8			
wheel type and lot number	Type: CS-10F; Lot Number: DW23D2 (expire SEP 2012); Load: 500g per wheel			
refacing medium	Refacing Medium: ST-11 Refacing Stone (25 cycles prior to test, lightly brush wheels after refacing)			
vacuum nozzle orifice size	Vacuum Nozzle Orifice: 11mm Vacuum Nozzle Gap: nozzle positioned 1/32" above specimen			
serial number of instrument and date of last calibration	Model Number: Taber Rotary Platform Abraser Model 5150; Serial Number: 968627; Calibration Date: April 14, 2011			
other information	Conditioning Temp: 68°F; Conditioning RH (%): 49%; Conditioning Time: >40h; HazeMeter: Byk-Gardner Haze-Gard Plus with Taber Holder; Initial Haze Measurement > Using soft bristle, anti-static brush lightly brush off any debris > Wipe specimen surface with lint free cloth; Final Haze Measurement > Using soft bristle, anti-static brush lightly brush off any debris > Using Isopropyl alcohol soaked lint free cloth, gently wipe & clean both sides			
test results for 1000 cycles	sample number	initial haze	final haze	delta haze
monolithic float glass from Saint Gobain	SGSD 41	0,33	1,80	1,47
	SGSD 42	0,33	1,87	1,54
	SGSD 43	0,30	1,56	1,26
	standard deviation	0,02	0,16	0,15
	arithmetic mean	0,32	1,74	1,42
one side coated PMMA from Polyplastic	PP28	0,47	11,90	11,43
	PP29	0,37	16,23	15,86
	PP30	0,24	13,33	13,09
	standard deviation	0,12	2,21	2,24
	arithmetic mean	0,36	13,82	13,46
both sides coated PC from Bayer	CAP 3214-A (1)	0,26	2,66	2,40
	CAP 3214-A (2)	0,25	2,50	2,25
	CAP 3214-A (3)	0,49	2,84	2,35
	standard deviation	0,14	0,17	0,08
	arithmetic mean	0,33	2,67	2,33

test laboratory	2			
tested according to test details	ASTMD1044			
wheel type and lot number	CS-10F; Lot Number EE12D2			
refacing medium	ST-11 Refacing Stone (Lot Number 38A80-MV-101522178 MOS: 8120); 25 cycles prior to every sample test			
vacuum nozzle orifice size	vaccuum nozzle diameter 11mm; distance to sample 1mm			
serial number of instrument and date of last calibration	Taber Mod. 352/C from Erichsen with the product label 894601; last calibration Juni 2010 done by Erichsen			
other information				
test results for 1000 cycles	sample number	initial haze	final haze	delta haze
monolithic float glass from Saint Gobain	SGSD 18	0,10	0,90	0,80
	SGSD 26	0,10	0,90	0,80
	SGSD 27	0,10	0,90	0,80
	standard deviation	0,00	0,00	0,00
	arithmetic mean	0,10	0,90	0,80
one side coated PMMA from Polyplastic	PP16	0,20	9,70	9,50
	PP17	0,20	6,10	5,90
	PP18	0,20	7,00	6,80
	standard deviation	0,00	1,87	1,87
	arithmetic mean	0,20	7,60	7,40
both sides coated PC from Bayer	CAP 3214-A (KRD A)	0,50	3,00	2,50
	CAP 3214-A (KRD B)	0,20	2,30	2,10
	CAP 3214-A (KRD C)	0,20	2,70	2,50
	standard deviation	0,17	0,35	0,23
	arithmetic mean	0,30	2,67	2,37

test laboratory	3			
tested according to test details	ASTMD 1044			
wheel type and lot number	CS-10F; Lot No. DD17D2; Expiry date: Feb. 2012; wheel diameter 49,64 mm - 49,19 mm			
refacing medium	TABER Refacing stone ST-11 (Lot No.: 38A180-MV ST-11 MOS 8120); No. of cycles prior to round-robin testing: 4725			
vacuum nozzle orifice size	Modified Vacuum Pick-up nozzle with enlarged holes 11 mm diameter (original TABER spare part); Pick-up nozzle height: 1.1 mm; Vacuum suction level: 100 %			
serial number of instrument and date of last calibration	TABER Abraser: Type: 5131; Serial No.: 20001106; Date of last calibration: 30 March 2011			
other information	Haze measurement: Hazemeter BYK Gardner, Type Haze-gard Plus; Checked by means of calibrated haze standards (set of 5 pcs. 0.28 % - 30.00 % Haze) prior to haze measurements Specimen cleaning procedure before and after abrasion: Wiped with soft linen cloth in a solution of commercial washing-up liquid in water; Rinsed with demineralised water; Blowed dry with clean air; Specimen conditioning and test environment: > 48 hours in climate 23 +/- 2 °C, 50 +/- 5 % relative humidity			
test results for 1000 cycles	sample number	initial haze	final haze	delta haze
monolithic float glass from Saint Gobain	SGSD 20	0,13	1,41	1,28
	SGSD 21	0,07	1,31	1,24
	SGSD 22	0,13	1,42	1,29
	standard deviation	0,03	0,06	0,03
	arithmetic mean	0,11	1,38	1,27
one side coated PMMA from Polyplastic	PP19	0,32	28,73	28,41
	PP20	0,27	36,90	36,63
	PP21	0,31	40,25	39,94
	standard deviation	0,03	5,93	5,94
	arithmetic mean	0,30	35,29	34,99
both sides coated PC from Bayer	CAP 3214-A (MPA A)	0,23	11,47	11,24
	CAP 3214-A (MPA B)	0,20	17,75	17,55
	CAP 3214-A (MPA C)	0,18	14,60	14,42
	standard deviation	0,03	3,14	3,16
	arithmetic mean	0,20	14,61	14,40

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Backup

test laboratory	4	5	6																																																																								
tested according to test details	ECE R43	ECE R43																																																																									
wheel type and lot number	CS-10F; Lot no.: DD 15 D3 (Exp.: AUG 2011)	CS-10F Type 4; Lot no. DW22D2 (EXP JUL/2012)	CS-10F; Lot no. DD15D3																																																																								
refacing medium	Refacing stone: ST-11	Abraser Refacing Stone ST-11	Refacing stone ST 11																																																																								
vacuum nozzle orifice size	Vacuum nozzle: 8 mm	11 mm nozzle diameter of vacuum device	Vacuum nozzle orifice size: 11mm																																																																								
serial number of instrument and date of last calibration	Taber Abraser model 5130 Digital; TELEDYNE TABER, USA; Serial No.: 904 928; Both machines (Taber & Hazemeter) periodically checked by TÜV technical calibration department. Last check of the abramer in October 2010.	Taber Abraser Model 503; test equipment no. :730 2003; date of last equipment check: 22.03.2011	Taber Abraser; Instrument serial no. 20081633 (last calibration: 2011 march 09)																																																																								
other information	HAZEGARD XL-211, Hazemeter, BYK-Gardner, Inc., USA; Temperature: 21,3°C Humidity: 41,5%RH; Samples were cleaned after the abrasion using distilled water and a linen cloth very carefully according to ECE Regulation No. 43.00, Annex 3, § 4; The light scattering was determined after abrasion termination on each tested sample on 4 points of tested plaques.	Hazemeter from the company LMT Berlin; standard illuminant A, diameter of measuring field 7mm ± 1mm; test equipment no.: 730 2006 date of last calibration: 02.05.2011	HazeGuard; specimen conditioning: 36h 21°C, 42% rel. humidity																																																																								
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PP26	0,10	3,79	3,69																																																																								
PP27	0,10	3,58	3,48																																																																								
standard deviation	0,01	0,13	0,13																																																																								
arithmetic mean	0,10	3,64	3,54																																																																								
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PP38	0,10	20,30	20,20																																																																								
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Polycarbonates

Backup

test laboratory tested according to test details	7	8	9																																																																								
wheel type and lot number	CS-10F; batch number: EH19D2 (validity: May 2013)	ASTMD1044 CS 10F (Gen.IV); Lot no. DS 04 D1 (exp. date March 2012)	ECE R43 CS-10F; lot number DY22D2 (expiration date NOV 2012); shore A hardness left 90 & right 92 (72±5 (ECE R43)); initial diameter left 51,83 mm & right 51,96 mm (45-50 mm (ECE R43)); thickness left 12,53 mm & right 12,8 mm (12,5 mm (ECE R43))																																																																								
refacing medium	Abraser refacing CAT ST 11	Refacing Stone ST-11	ST-11 refacing stone (before testing each sample, 25 rotations are made on the fine side of the refacing stone ST-11)																																																																								
vacuum nozzle orifice size	Nozzle modified openings: 11mm	Vacuum Nozzle Orifice: 11mm; Vacuum Nozzle Gap: nozzle positioned 0.8mm above specimen	nozzle opening 11mm; nozzle distance to specimen 1,6 mm; vaccum setting 100;																																																																								
serial number of instrument and date of last calibration	Teledyne Taber Model 5130; Serial Number: 904865 (last calibration 26.09.2008)	Taber Modell: 352; Serial Number: 955822-8;	Taber 5130; serial number 771189																																																																								
other information		Specimen Cleaning: using anti static brush lightly brush off any debris; using Isopropyl alcohol soaked lint free cloth, gently wipe & clean both sides; Haze - Measurement: BYK-Gardener Haze-Gard plus with Taber Holder (Serial No.: 980119; Internal Calibration: 29.04.2011); Sample Conditioning: 36 h at 23°C / 40-45% rel. humidity; Test Conditions: 45% rel. humidity and 23°C	rotation per min 60 (65 to 75 rpm (ECE R43)); XL-211 Hazegard System (serial number HG-8013 S Special; Illuminat A); test conditions 24,0°C & 31 rel. humidity;																																																																								
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monolithic float glass from Saint Gobain	<table border="1"> <thead> <tr> <th>sample number</th> <th>initial haze</th> <th>final haze</th> <th>delta haze</th> </tr> </thead> <tbody> <tr> <td>SGSD 12</td> <td>0,10</td> <td>0,68</td> <td>0,58</td> </tr> <tr> <td>SGSD 22</td> <td></td> <td></td> <td></td> </tr> <tr> <td>SGSD 32</td> <td>0,06</td> <td>0,77</td> <td>0,71</td> </tr> <tr> <td>standard deviation</td> <td>0,03</td> <td>0,06</td> <td>0,09</td> </tr> <tr> <td>arithmetic mean</td> <td>0,08</td> <td>0,73</td> <td>0,65</td> </tr> </tbody> </table>	sample number	initial haze	final haze	delta haze	SGSD 12	0,10	0,68	0,58	SGSD 22				SGSD 32	0,06	0,77	0,71	standard deviation	0,03	0,06	0,09	arithmetic mean	0,08	0,73	0,65	<table border="1"> <thead> <tr> <th>sample number</th> <th>initial haze</th> <th>final haze</th> <th>delta haze</th> </tr> </thead> <tbody> <tr> <td>SGSD 24</td> <td>0,15</td> <td>1,00</td> <td>0,85</td> </tr> <tr> <td>SGSD 37</td> <td>0,08</td> <td>1,01</td> <td>0,93</td> </tr> <tr> <td>SGSD 38</td> <td>0,17</td> <td>1,16</td> <td>0,99</td> </tr> <tr> <td>standard deviation</td> <td>0,05</td> <td>0,09</td> <td>0,07</td> </tr> <tr> <td>arithmetic mean</td> <td>0,13</td> <td>1,05</td> <td>0,92</td> </tr> </tbody> </table>	sample number	initial haze	final haze	delta haze	SGSD 24	0,15	1,00	0,85	SGSD 37	0,08	1,01	0,93	SGSD 38	0,17	1,16	0,99	standard deviation	0,05	0,09	0,07	arithmetic mean	0,13	1,05	0,92	<table border="1"> <thead> <tr> <th>sample number</th> <th>initial haze</th> <th>final haze</th> <th>delta haze</th> </tr> </thead> <tbody> <tr> <td>SGSD 07</td> <td>0,20</td> <td>1,60</td> <td>1,40</td> </tr> <tr> <td>SGSD 08</td> <td>0,10</td> <td>1,50</td> <td>1,40</td> </tr> <tr> <td>SGSD 16</td> <td>0,20</td> <td>1,80</td> <td>1,60</td> </tr> <tr> <td>standard deviation</td> <td>0,06</td> <td>0,15</td> <td>0,12</td> </tr> <tr> <td>arithmetic mean</td> <td>0,17</td> <td>1,63</td> <td>1,47</td> </tr> </tbody> </table>	sample number	initial haze	final haze	delta haze	SGSD 07	0,20	1,60	1,40	SGSD 08	0,10	1,50	1,40	SGSD 16	0,20	1,80	1,60	standard deviation	0,06	0,15	0,12	arithmetic mean	0,17	1,63	1,47
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Polycarbonates

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refacing medium	nozzle opening 8mm; nozzle distance to specimen 0,8 mm; vacuum setting 100;	Vacuum pick up nozzle opening: 11 mm diameter; Height of the vacuum pick up nozzle: 0,8 -1,6 mm above the specimen surface or ST 11 stone; Vacuum suction force: 100																																																																																																																																												
vacuum nozzle orifice size	Taber 5130; serial number 771189	Taber Instruments Abraser Model 503 Standard Abrasion Tester (Ser no.: 71000) (GPG-Prüfmittel 1159); last certification: 20.08.2010																																																																																																																																												
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Thank You For Your Attention

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