Investigation of converging and collimated beam instrument geometry on specular gloss measurements

Zwinkels, Joanne C.; Côté, Éric; Morgan, John

Publisher's version / Version de l'éditeur:
https://doi.org/10.1088/1742-6596/972/1/012025
Journal of Physics: Conference Series, 972, 2018-03-02

Investigation of converging and collimated beam instrument geometry on specular gloss measurements

IOP Conf. Series: Journal of Physics: Conf. Series **972** (2018) 012025 doi:10.1088/1742-6596/972/1/012025

Investigation of converging and collimated beam instrument geometry on specular gloss measurements

Joanne C. Zwinkels[1], Éric Côté[1] and John Morgan[2]

[1]National Research Council of Canada, Ottawa, Canada
[2]University of Waterloo, Waterloo, Canada

Joanne.zwinkels@nrc-cnrc.gc.ca

Abstract. Specular gloss is an important appearance property of a wide variety of manufactured goods. Depending upon the application, e.g. paints, paper, ceramics, etc. different instrument designs and measurement geometries are specified in standard test methods. For a given specular angle, these instrument designs can be broadly classified as converging beam (TAPPI method) and collimated beam (DIN method). In recent comparisons of specular gloss measurements using different glossmeters, very large standard deviations have been reported, well exceeding the manufacturers claims. In this paper, we investigate the effect of instrument beam geometry on gloss measurements. These results indicate that this difference in beam geometry can give the magnitude of gloss differences reported in these comparisons and highlights the importance of educating the user community of best measurement practices and obtaining appropriate traceability for their glossmeters.

1. Introduction

In a recent investigation of the inter-instrument agreement of specular glossmeters conducted as part of the European Metrology Research Programme (EMRP) project entitled “Multidimensional Reflectometry for Industry” (xDReflect), it was reported that the reproducibility between 6 different commercial glossmeters on 25 different painted gloss samples exceeded the threshold gloss unit (GU) values given in ASTM D523-14 for more than half of the comparison samples [1]. These threshold values are already extremely high ranging from 3.5, 6.4 and 7.2 GU for measurement geometries of 60°, 20° and 85°, respectively.

At the National Research Council of Canada (NRC), we have developed reference instruments to provide traceable gloss measurements in accordance with different standard test methods. This includes the well-established NRC Reference Glossmeter for specular gloss measurements at 20°, 60° and 85° geometries in accordance with ISO 2813 and ASTM D523 [2,3] which has been providing high-accuracy specular gloss calibration services for more than 30 years and the more recently developed NRC Reference Goniospectrophotometer (GSP) [4,5] which is a highly versatile instrument that can be readily re-configured to provide traceable specular gloss measurements in accordance with several standard test methods for different applications that specify either a collimated beam (so-called DIN method) or converging beam (so-called TAPPI method) geometry. To the best of our knowledge, this is the only reference glossmeter that provides traceable calibrations in a converging beam geometry.

Even for a given application, such as the paper industry, there are different standard test methods for specular gloss measurements at a given specular angle that specify different instrument beam geometries. For coated and supercalendared papers, their specular gloss is typically measured at 75° incident angle using: ISO 8254-1:75° gloss with a converging beam (TAPPI method) or ISO 8254-2: 75° gloss with a parallel beam (DIN method). For other types of glossy papers, such as highly varnished or waxed papers, they are typically measured at 20° incident angle using ISO 8254-3: 20° gloss with a converging beam: TAPPI method or TAPPI T653. The most widely used gloss standard test methods are ASTM D523 and ISO 2813 which cover not only the measurement of specular gloss of paint samples but general non-metallic materials. Since these standards include measurements for a 20° specular angle and allow for either a collimated or converging beam geometry, they could also be used for measurements of certain types of glossy paper samples.

The choice of whether a collimated or converging beam geometry is most appropriate depends upon the nature of the sample. For uniform glossy samples, a collimated beam geometry is generally recommended since it provides better uniformity of the reflected rays received in the detector aperture. On the other hand, for non-uniform or textured glossy samples, where it is desirable to obtain information about the spatial or orientational dependence of the sample gloss, a converging beam geometry is recommended since it provides better uniformity in extent of the angular divergence that is accepted in the measurement. It is also important to note that a glossmeter that conforms to a converging beam geometry must meet additional specifications in terms of spatial uniformity for both the source and receptor aperture, that are not required for a glossmeter conforming to a collimated beam geometry. For this reason, most commercial glossmeters that conform to ASTM D523 or ISO 2813 have a collimated beam geometry.

To the best of our knowledge, there is no published information on the impact on specular gloss measurements for glossy samples measured at a given specular angle for different instrument beam geometries (converging and collimated). For this reason, we began a study with the NRC GSP to study this effect for glossy paper samples at the aforementioned 75° and 20 °geometries.

2. Comparison Samples

Glossy paper samples were obtained from the Collaborative Testing Services (CTS) Paper Program interlaboratory testing of specular gloss measurements. For the measurements at 75° geometry, we used a medium (GU53) and high gloss (GT53) white paper sample, comprising 10 specimens each, obtained from CTS in ~2002, when the GSP was being validated for 75° gloss in accordance with TAPPI T480. For the measurements at 20° geometry, we obtained a medium gloss sample (RG01) comprising 30 specimens.

For each of the specimens, one measurement was to be performed with the centreline of the light beam in the plane perpendicular to the sheet and parallel to its long direction. The sheet was then rotated in its plane 180° and measured again. The mean results for these 2 measurements were reported, giving a total of either 10 or 30 results, depending on test sample.

Coincidentally, CTS recently conducted a 20° gloss comparison using the sample RG01, on behalf of TAPPI, to determine if the technical parameters with regard to acceptance angles could be loosened for the TAPPI method T653: *specular gloss of paper and paperboard at 20°*. CTS kindly provided us these comparison results which are plotted below in a histogram to show the distribution of the 30 data points for the 14 participating labs. There is a bimodal distribution with one cluster of labs reporting a value ~30-40 GU and the second cluster of labs reporting a value of ~50-60 GU, with a grand mean of 44.9 GU and standard deviation (S.D.) of 8.7 GU.

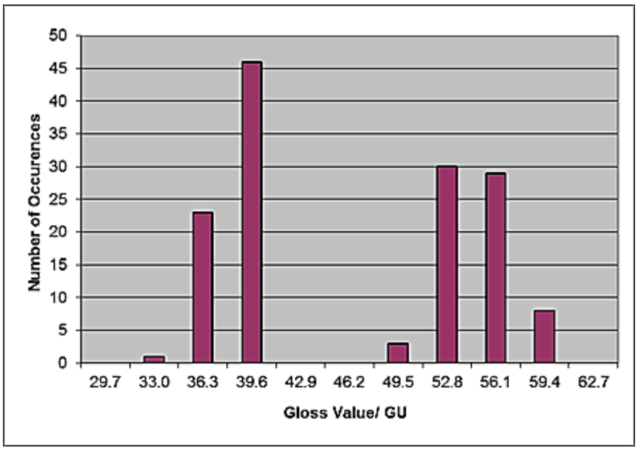

Figure 1. CTS 20° TAPPI gloss inter-lab results reported for glossy paper sample, RG01 (14 participating labs).

3. NRC Gloss Measurement Results

The NRC GSP and these 3 glossy white paper samples were used to investigate the impact of going from a collimated to a converging beam geometry for both 20° and 75° specular angles. To test the precision of these gloss measurements, two independent runs were carried out, reconfiguring and realigning the instrument between repeat runs. Figure 2 shows a schematic drawing of the GSP with an exploded view of the key components that need to be changed when converting the instrument to a different beam geometry; these are the source field stop, receptor aperture and an optional source objective lens assembly (not shown here) to convert from collimated beam (shown here) to converging beam. To validate the instrument performance, two NRC high gloss quality system check standards were used and measured at the beginning, middle and end of each sample run to check for any temporal drift in the gloss measurements. These quality system check standards typically gave agreement within 0.2% with their historical results, indicating a very high level of instrument repeatability.

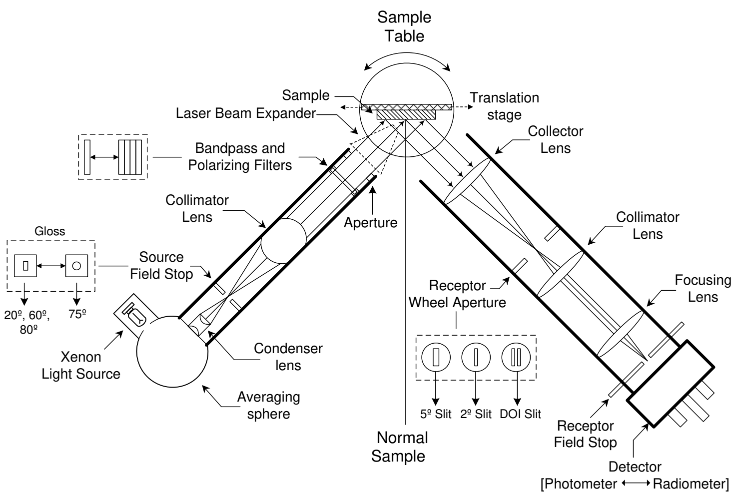

Figure 2. Schematic drawing of NRC Reference Goniospectrophotometer (GSP) indicating the key components (in dashed rectangles) that are changed when converting the instrument from collimated (shown here) to converging beam geometry. An optional lens assembly is also inserted in the source path between the source field stop and the sample stage.

The NRC primary gloss standard is a high optical quality quartz prism whose gloss values are calculated from its known optical constants and the Fresnel relations for the given specular angle and referenced to the refractive index value specified in the relevant gloss standard test method [3]. It should be noted that the primary gloss standard is defined with a different refractive index, n for these two methods; n=1.540 (TAPPI) and n=1.567 (DIN). The calculated values for the NRC quartz wedge standard are included here in the NRC tables of gloss results. These results are given in Table 1 for the 75° geometry for (a) TAPPI and (b) DIN methods, respectively, and in Table 2 for the 20° geometry. For the 20° geometry, the NRC gloss measurement results are also compared with the grand mean and standard deviation (S.D.) results from the CTS 20° TAPPI round-robin comparison.

It can be seen that for the 75° geometry, the gloss differences are a factor of 3 to 6 times the measurement precision, whereas for the 20° geometry, the gloss differences are more than a factor of 20 times. In comparing the NRC gloss results in Table 1 and Table 2, it is interesting to note when going from the converging to the collimated beam instrument geometry, in the case of 75°, the NRC gloss results for both the medium and high gloss paper sample increased, whereas for 20°, the NRC results for the medium gloss paper sample decreased. This suggests that it is not possible to necessarily predict and correct the measured gloss values for the impact of change in beam geometry and that this impact would need to be evaluated for each different gloss geometry and type of specimen.

Table 1. Comparison of measured specular gloss, expressed in GU values, at 75° on NRC GSP for a medium and a high gloss paper sample for: (a) a converging beam (TAPPI method) and (b) a collimated beam (DIN method) geometry.

ID	Run 1 (GU)	Run 2 (GU)
GU53	33.03	31.03
S.D.	±0.75	±0.73
GT53	66.43	65.30
S.D.	±2.00	±2.36
Quartz Standard	92.65	92.65

(a) TAPPI method

ID	Run 1 (GU)	Run 2 (GU)
GU53	37.94	38.73
S.D.	±0.82	±0.83
GT53	73.38	73.98
S.D.	±1.94	±1.91
Quartz Standard	94.22	94.22

(b) DIN method

Table 2. Comparison of measured specular gloss, expressed in GU values, at 20° for paper sample RG01 on NRC GSP for: (a) a converging beam (TAPPI method) and (b) a collimated (DIN method) geometry and compared with the results reported by CTS for 20° gloss (TAPPI) comparison for 14 labs.

Gloss Standard: (GU value)	**Run #**	**NRC results: RG01**		**CTS results (14 labs): RG01**	
		Gloss (GU)	**S.D. (GU)**	**Gloss (GU)**	**S.D. (GU)**
TAPPI Quartz Standard: (77.39)	1	36.02	0.65	44.90	8.70
	2	34.51	1.22		
DIN Quartz Standard: (71.72)	1	58.98	0.61		
	2	58.96	0.76		

4. Conclusions

The results of this gloss comparison using the NRC reference goniospectrophotometer configured in both a converging and collimated beam geometry for measuring specular gloss of paper samples at 75° and 20° geometries showed that for the paper samples studied here, for a given specular angle and beam geometry, the measurement reproducibility was very good, ranging from 0.6 -2.4 GU. However, for both 75° and 20° geometries, for a change in the beam condition, the measurement reproducibility significantly deteriorated. In the case of both the medium (GU53) and high gloss (GT53) coated paper samples measured at 75° geometry, the differences in the measured gloss values for the two different methods (6.3 –7.8 GU) were a factor of ~4 to 8 times larger than the measurement reproducibility for a given beam condition (0.7 -2.4 GU). In the case of the medium gloss paper sample (RG01) measured at 20° geometry, the NRC results showed a very large gloss difference of 23.4 GU in going from the converging (TAPPI) to the collimated (DIN) beam method compared with an excellent measurement reproducibility of 0.6-1.2 GU for a given beam condition . It is interesting to note that the NRC mean result for sample RG01 using these two methods (47.1 GU) is in very good agreement with the grand mean result of 44.9 GU that was reported for the CTS 20° TAPPI round-robin study using this glossy paper sample (see Figure 1).

These results strongly suggest that differences in beam geometry can account for the very large inter-instrument differences reported in recent gloss comparison studies that greatly exceed both gloss manufacturer and test method specifications for repeatability and reproducibility. These NRC results also highlight the need for better education of the user community on the traceability of their commercial glossmeters and to confirm that it strictly conforms to the geometric, spectral and photometric conditions of the specified gloss standard test method, including the conditions of the incident beam (converging or collimated).

References

[1] F..B. Leloup, J. Audenaert, and P. Hanselaer, Investigation of the inter-instrument agreement of specular glossmeters, in Proceedings of 28th CIE session, CIE 216:2015, 355-362, 2015.
[2] W. Budde, A reference instrument for 20°, 60°, and 85° gloss measurements, Metrologia, 16, 1-5, 1980.
[3] J.C. Zwinkels and M. Noël, Specular gloss measurement services at the National Research Council of Canada, Surface Coatings International, 78, 512-515,1995.
[4] J. Liu, M. Noël and J. Zwinkels, Design and characterization of a versatile reference instrument for rapid, reproducible specular gloss measurements, Appl. Opt., 44, 4631-4638, 2005.
[5] M. Noël, J. Zwinkels and J. Liu, Optical characterization of a reference instrument for gloss measurements in both a collimated and a converging beam geometry, Appl. Opt., 45, 3712-2720, 2006.