

ABSTRACT

The visual impression of gloss is like color, a multidimensional parameter. For many years, glossmeters have been used to measure the specular reflection in laboratory and quality control applications. To characterize the entire visual impression of gloss, we must measure two additional gloss parameters: haze and orange peel.

GLOSS EFFECTS ARE BASED ON the interaction of light with the physical properties of an object. In addition, gloss is influenced by the physiological evaluation of the observer. The first impression of a product is strongly influenced by its surface quality. For many products consistent gloss is considered a decorative quality parameter and is influenced by many production and process parameters.

The human eye is by far the best optical instrument to evaluate gloss. It is able to differentiate, without any problem, lightness differences between 1 and 10 million (1).

Nevertheless, a visual surface evaluation is insufficient because of the following variables:

- Undefined evaluation conditions
- Judgment is dependent on the mood of the observer
- Different observers have different visual acuity.

To guarantee a reliable and practical quality assurance, it is necessary to describe the gloss of surfaces with objective, measurable criteria. Gloss measuring devices have been used in the industry since 1930. Special gloss effects resulted in the development of new measurement systems with better correlation to the visual evaluation (2–4).

Measuring gloss and reflection properties of surfaces

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HOW IS GLOSS VISUALLY PERCEIVED?

Gloss and color are visual sensations perceived when evaluating a surface. We evaluate the capability of a surface to reflect incident light into the specular direction, i.e., light sources or objects are reflected. The gloss impression is influenced by surface properties, the type of illumination, and the visual acuity and mood of the observer.

Surface properties

- Material (e.g., coatings, plastic, metals)
- Surface topography (e.g., smooth, rough, structured)
- Degree of transparency
- Substrate.

Type of illumination

We must have direct illumination to evaluate gloss. A diffuse illumination causes diffuse reflection, resulting in decreased gloss impression.

Observer

Visual evaluation is dependent on the visual acuity (physiology) and the mood of the observer (psychology). We visually evaluate a surface by focusing our eye either on the reflection of a light source or on the surface itself (5). Both types of evaluations influence the overall gloss impression (Fig. 1).

By focusing on the reflected image of a light source (Fig. 2), the distinctness of image is evaluated (6). The reflected image of the light source may appear brilliant or dull (specular gloss). The outlines of the reflected image can be distinct or blurred (image clarity), or a halo can surround the reflected image (haze).

By focusing on the surface we also get an impression for structure size and form (Fig. 3). These structures can be seen as a wavy pattern of light and dark areas. In the industry, this wavy pattern is often referred to as orange peel.

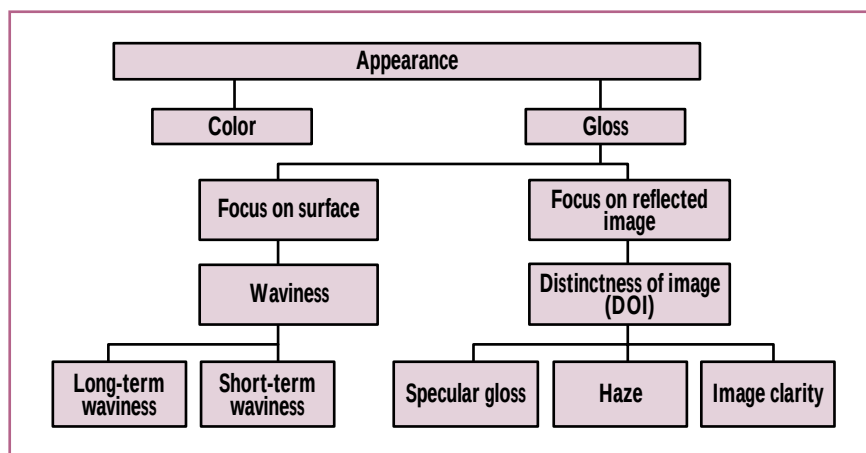
REFLECTION BEHAVIOR OF SURFACES

Gloss is a subjective impression and not a physical property of the surface. Specular reflection—part of the overall gloss impression influenced by the reflection properties of the surface—can be physically and objectively measured.

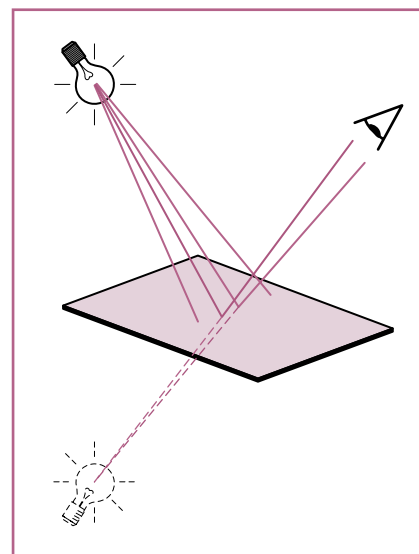
High gloss, flat surfaces

In the case of flat, high-gloss surfaces, the law of reflection is valid: Angle of illumination = Angle of reflection (Fig. 4). Those types of surfaces are also considered image forming because the image of a reflected object can be seen distinctly. The light is reflected at the first surface into the specular direction of reflection.

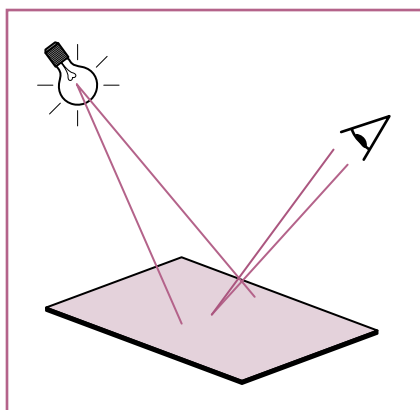
The intensity of the reflected light is dependent on the angle of illumination and material properties (refractive index). The reflected light of metals is high intensity and not particularly dependent on the angle of illumination. Nonmetals reflect the light at a lower intensity that is dependent on the angle of illumination and refractive index of the material. With nonmetals, part of the illuminated light penetrates into the material and is selectively absorbed or diffusely scattered depending on the color of the pigment. The diffusely scattered light comes out of the material and gives us the impres-



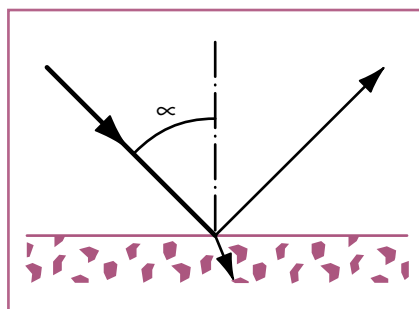
1. Flow chart depicting relationships of various appearance characteristics



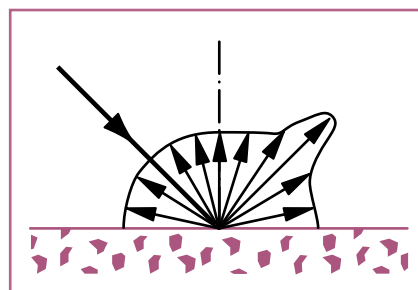
2. Focusing on the image of a light source reveals the image's distinctness.



3. Focusing on the surface reveals structure size and form.



4. Specular reflection on first surface



5. Reflected light distribution from a semi-gloss surface

sion of a specific color. This diffuse component is equally distributed in all spatial directions.

Semigloss surfaces

Rougher surfaces not only reflect the light in the direction of specular reflection, but they also diffusely reflect it in other directions (Fig. 5).

The capability of a surface to reflect an object is strongly reduced. The more evenly the light is distributed in all directions, the less intense the specular component will appear and the less glossy the surface will look.

High-gloss surface with haze (reflection haze)

If there are microscopic defects on a high-gloss surface, there will be

some diffused light of low intensity adjacent to the specular reflection (Fig. 6). Most of the light will be reflected in the specular direction resulting in a high-gloss, distinct, image-forming appearance covered with a haze or milkiness.

Glossy, structured surfaces (orange peel)

In the case of wavy surface structures (0.1–10 mm), the distribution of the reflected light is dependent on the slope of the individual structure element (Fig. 7). The surface elements reflecting the light in the direction of the eye will appear highlighted. In dark areas, the light is reflected in other directions. Therefore, we will see a wavy pattern of light and dark areas on the surface (orange peel).

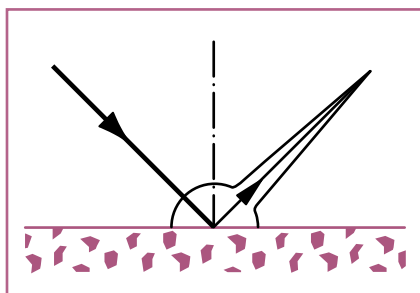
To differentiate high-, semi-, and low-gloss surfaces, it is sufficient to

measure the specular reflection with a glossmeter. However, special surface effects (haze, orange peel) require us to evaluate and measure the reflection with a glossmeter and by independent means.

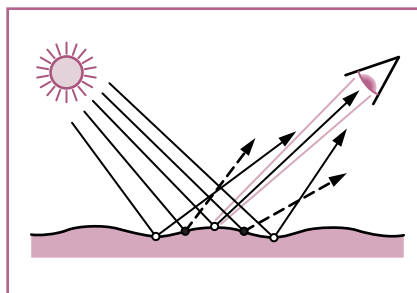
GLOSSMETER

The principle of a glossmeter is based on the measurement of the specular component of the reflected light (Fig. 8). The intensity of reflected light is measured in a specific angle range, which is limited by an aperture "AP."

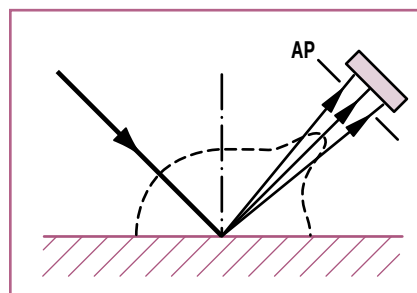
The light source illuminates the surface by passing through another aperture "AP1" (Fig. 9). A photoelec-



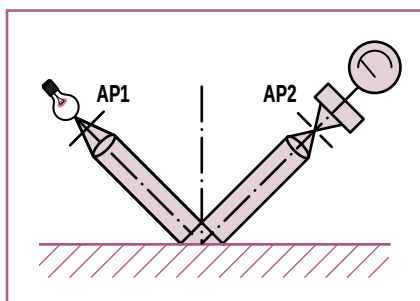
6. Reflected light distribution from a high-gloss surface with haze



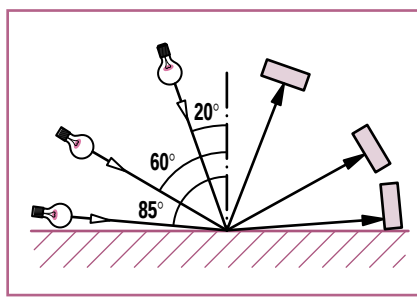
7. Reflection on a wavy surface (orange peel)



8. Measurement of specular component



9. Schematic diagram of a glossmeter



10. Specified positions of source and receptor for high- to low-gloss materials (ASTM D523, ISO 2814)

tronic detector measures the light passing through aperture "AP2."

Gloss value (R_g) is a relative measurement. The measurement results are related to a highly polished, black glass standard with a defined refractive index of 1.567. The black glass standard has an assigned specular gloss value of 100 (calibration).

To obtain comparable results, measurement device and operation have been defined in international specifications: ISO 2813, ASTM D523, JIS Z 8741, and DIN 67530 (7–10).

The specifications define the following parameters:

- Geometric conditions (angle of illumination and reflection, aperture angle, light source, and detector sensitivity)
- Calibration procedure
- Application and limitations (e.g., curved surfaces).

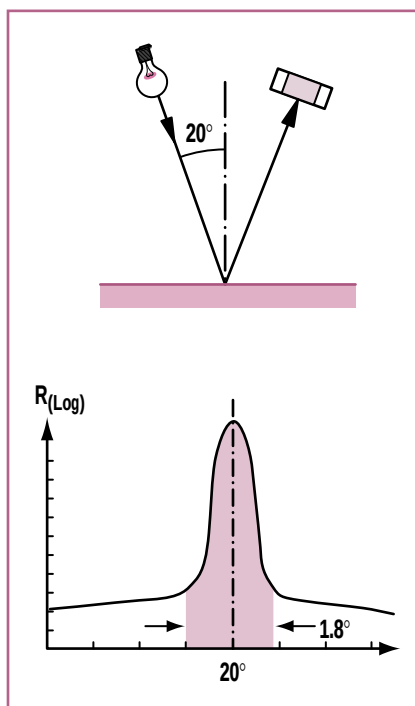
The angle of illumination greatly influences measurement results. In the case of coatings, plastics, and allied products, part of the illuminated light is reflected on the first surface and part penetrates into the material. The greater the angle of illumination, the greater the amount of reflected light.

To obtain good differentiation of the whole range from high- to low-gloss surfaces, three different angles of illumination (i.e., three different measurement ranges) were defined (Fig. 10):

1. 20° = high-gloss surfaces
2. 60° = semi-gloss surfaces
3. 85° = low-gloss surfaces.

In addition, industry-specific geometries were established:

- 45° = Ceramic
- 75° = Paper industry.

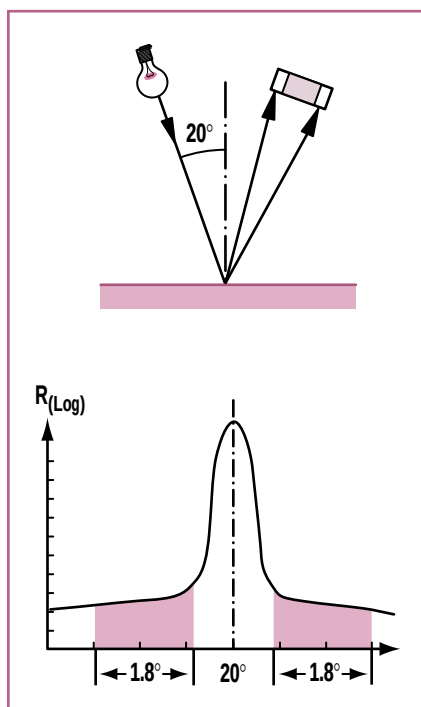


11. Measurement of specular component at 20° geometry

Glossmeters are available as stationary, bench-type versions developed for laboratory use. For application in the field, very handy instruments are available today that are equipped with the three standard geometries: 20°, 60°, and 85°.

MEASUREMENT OF REFLECTION HAZE

Haze is very often caused by specific parameters during the production process:



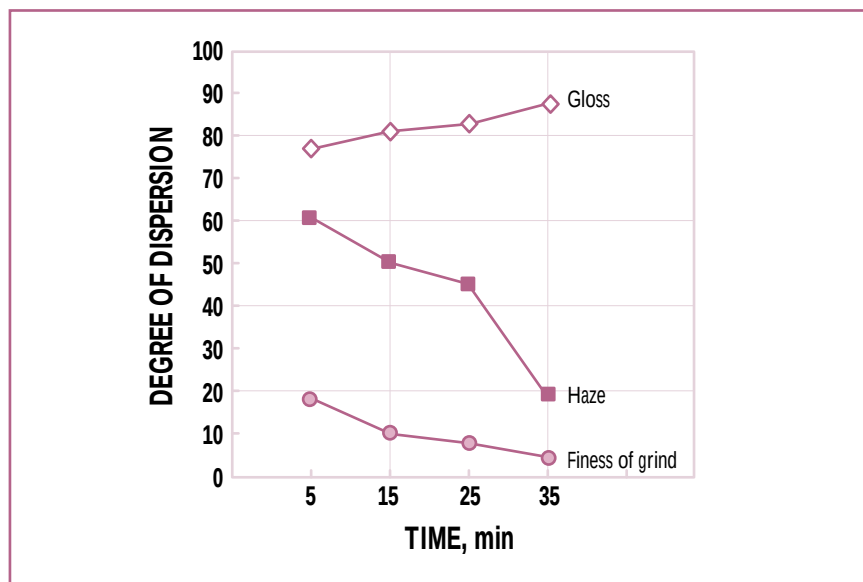
12. Measurement of haze

- Pigment type and degree of dispersion
- Resin type
- Compatibility of raw materials (pigment-additive-resin)
- Application procedure
- Calender marks and wear of calenders
- Anodizing process.

In addition, normal weathering and mechanical wear (polishing, cleaning, abrasion) can result in a hazy appearance.

Hazy surfaces show diffusely scattered light in the range of one to three degrees adjacent to the specular reflection. In the past, goniophotometers were used to measure the so called reflection indicatrix (Fig. 6). This method is quite time consuming.

Haze can only be seen on surfaces that can reflect the image of an object, i.e., high-gloss surfaces. Therefore, the 20° geometry should be capable of detecting haze. Yet the



13. Influence of dispersion time on gloss, haze, and fineness of grind

20° glossmeter cannot sufficiently characterize haze because the diffusely scattered light is too low in intensity to contribute a significant difference in the specular component (Fig. 11).

The aperture range of the 20° geometry is $\pm 0.9^\circ$. By measuring the diffusely scattered light adjacent to the specular with additional detectors, haze can be objectively evaluated (Fig. 12).

The BYK-Gardner haze-gloss device has an additional detector on each side of the specular aperture and can measure 20° gloss and haze simultaneously.

Figure 13 shows the influence of the dispersion degree of TiO_2 on gloss and haze. The reduction of particle size in the range below 10 nm shows hardly any change in the gloss value but can be clearly seen in the reduced haze value (11).

MEASUREMENT OF ORANGE PEEL
The human eye can see structures between 0.1 mm and 10 mm. The resolution of the eye is too low to measure the real height differences of structures such as orange peel. Therefore, we do not actually see the

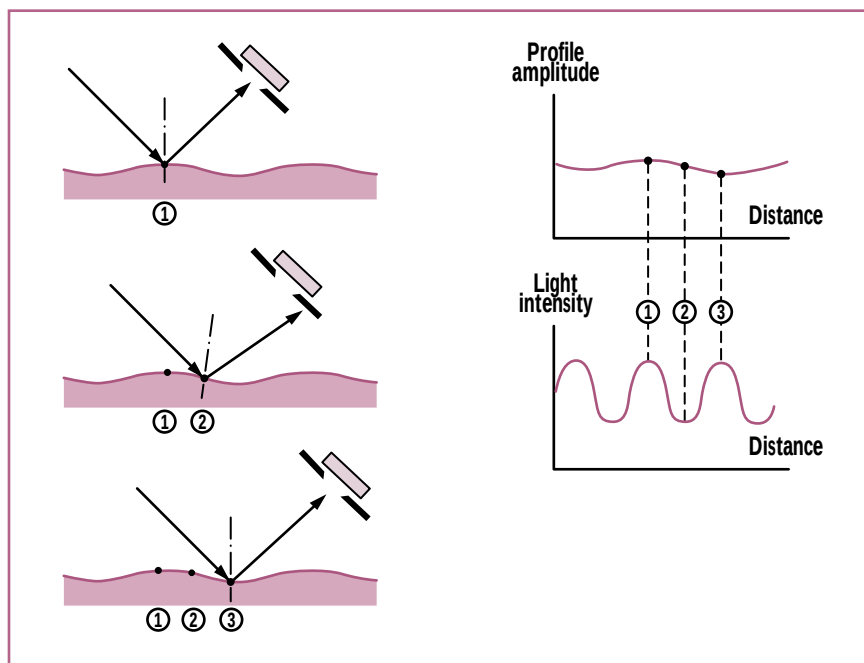
mechanical profile, but we interpret the light intensity pattern as a three-dimensional structure. The structure is more obvious the greater the contrast between the light and dark areas.

The measurement of specular gloss and reflection haze does not take into account the visual impression of orange peel. Presently, the phenomenon is either evaluated visually or by profilometry that can only be used in laboratory applications.

The BYK-Gardner wave-scan has been designed to simulate the visual evaluation of focusing on the surface (Fig. 7). The instrument uses a point source laser to illuminate the specimen (Fig. 14).

The sample surface is scanned by moving the instrument over a distance of 10 cm. The light source illuminates the surface at 60°, and the reflected light is measured at the same but opposite angle. When the light beam hits a peak or a valley of the surface we detect a maximum signal. On the slopes, a minimum signal is registered.

The wave-scan measures the optical profile (what we see); a pro-



14. Measurement principle for evaluating orange peel

KEYWORDS

Gloss, gloss meters, haze, measurement, orange peel, parameters, reflection, vision, visual efficiency.

filometer measures the mechanical profile (what we feel).

To simulate the resolution of the human eye at a distance of 50 cm and at a greater distance of 2.5 m, the detected signal is divided into short-term (<0.6 mm) and long-term (>0.6 mm) waviness.

The measurement of long-term waviness and short-term waviness allows an objective evaluation of the visual impression "orange peel." In addition, long-term waviness and short-term waviness are an indirect measure to determine influencing process parameters such as substrate roughness, flow and leveling properties, and application technique.

SUMMARY

The visual impression of gloss is like color, a multidimensional parameter. For many years, glossmeters have been used to measure the specular reflection in laboratory and quality control applications. To characterize the entire visual impression of gloss, we must also measure haze and orange peel.

An accurate characterization of gloss sensation allows the user not only to control quality but also to improve it and help to optimize the production process. Reflection properties are dependent on material and process parameters that require more information than simple pass/fail analysis. The measurement of gloss parameters makes the relationship between surface quality and its causes more obvious and consequently contributes to an efficient process. TJ

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