# Surface topography assessment of textured mold and aesthetic quality of injection molded plastic surface

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## *Introduction*

Visual appearance or aesthetic quality of the surface has come to be significantly important in most industrial products. In order to improve the visual appearance of the plastic products, texturing to the surface of injection mold is often used. From the recent consideration for the environment, texturing on the plastic surface is increasing its importance more and more in contrast to the painting process. However, the design of the texture relies on experience of the engineers. The aim of this paper is to disclose the relationship between the surface topography of the textured mold and the aesthetic appearance of injection molded plastic surface.

## *Geometrical Transfer*

Geometrical transfer of the mold surface texture to the molded plastic surfaces has been investigated using the 3-D surface parameters[1, 2]. In this report, the geometrical transfer was examined using the representative 3-D surface parameters such as amplitude parameter $S_q$, spacing parameter $S_{ds}$ and hybrid parameter $S_{\Delta q}$. In addition, angular distribution of the reflected light on the plastic surface is also examined.

Fig.1 shows the employed injection mold that has nominal depth of 8μm. Plastic samples were made using this mold in 4 different temperatures. Areal surface profile of the mold and injected samples were measured using surface profilometer with diamond stylus. Calculated roughness parameters were shown in table 1. It is clear that the surface topography of the injection mold is transferred to the molded plastic surface more truly with the mold temperature.

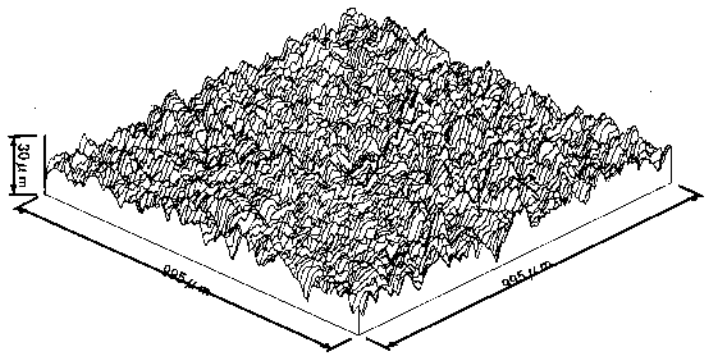
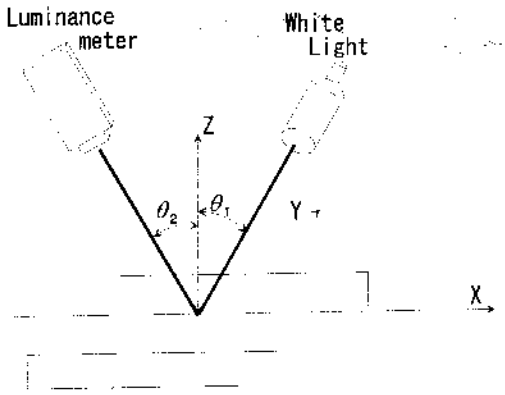


**Fig. 1 3D plots of measured mold profile**

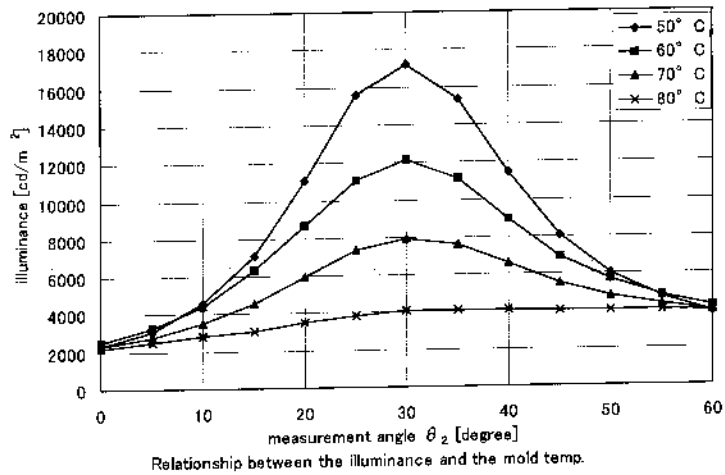
**Table 1 Surface Roughness Parameters of the Mold and Injected Plastic**

| | Mold temp. [°C] | $S_q$ [μm] | $S_{ds}$ [$10^{-4}$/μm$^2$] | $S_{\Delta q}$ [rad.] |
|---|---|---|---|---|
| Injected plastic | 50 | 1.04 | 3.63 | 0.089 |
| | 60 | 1.21 | 4.26 | 0.109 |
| | 70 | 1.22 | 4.99 | 0.112 |
| | 80 | 1.54 | 5.99 | 0.148 |
| Mold | - | 1.74 | 7.96 | 0.166 |




| Light source | COLD SPOT PICS-NLX-150 (NIHON P·I Ltd.) |
|---|---|
| Incidence angle $\theta_1$ [deg] | 30 |
| Measurement angle $\theta_2$ [deg] | 0~60 |

**Fig. 2 Setup of the luminance meter**




Nominal depth 8μm, Flat

**Fig. 3 Luminance of the reflected light (Mold temperature)**

Visual appearance of most engineering surfaces can be determined by the characteristics of the reflected light from the surface. The light reflection depends on the topographic features of the surface as well as optical properties of the material. An instrument to measure the intensity distribution of the reflected light is prepared. The schema of the instrument is shown in fig.2. The measured results shown in fig.3 show that the reflected light distributes widely when the mold temperature is higher. It is because the slope of the surface is steeper when the temperature of the mold is higher as shown in table 1.

***Sensory Test***

Four injection molds that have different spherical radius, 50mm, 100mm, 200mm and ∞(flat), were prepared. The molds were textured with certain nominal depth. Then, the plastic samples were made using the mold in 4 different temperatures. This procedure was repeated twice after removing the texture from the mold. The nominal depths of the texture were 8μm, 16μm and 25μm.

To examine the human impression of the plastic samples, Bradley's method[3] was employed. The inquired characteristics were "softness", "gloss" and "smoothness". Angular distribution of the reflected light on the target sample is also examined

*1. Spherical radius of the surface*

The result of the Bradley's test for the spherical radius is shown in table 2. It was made clear that the larger spherical radius gives the impression that the surface to be soft and smooth.

The angular distribution of the reflected light is shown in fig.4. The results show that reflected light distributes widely when the spherical radius of the surface is small.

*2. Nominal Depth of the Texture*

The result of the Bradley's test for the nominal depth of the texture is shown in table 3. The order of the judgments is different from that of the nominal depth. The angular distribution of the reflected light is shown in fig.5. The order of the width of the distribution is in good agreement with the result shown in table 3. It was made clear that those characteristics are not determined only by the nominal depth of the texture. Further investigation using various roughness parameters is needed to relate the sensory characteristic and the surface topographic characteristics.

*Light Reflection Image*

In addition, software is developed to simulate the intensity distribution of reflected light from the textured plastic surface under the condition that the topography data is given. Example of the generated images are shown in fig.6. The 80°C image is darker than that of the 50°C. This agrees with the result of fig.3. This intensity distribution could be used to presume the visual appearance of the plastic surface in the future.

**Table 2 Result of the Sensory Test for Spherical Radius**

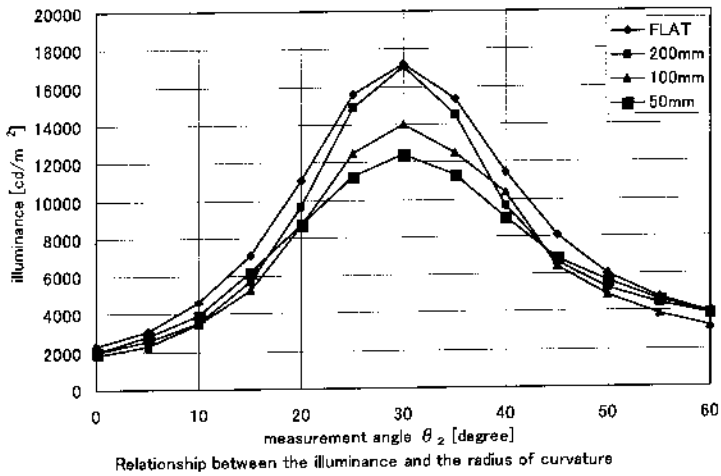
| Characteristic | Judgments |
|---|---|
| Softness | D>C>B>A |
| Gloss | A>B>C>D |
| Smoothness | D>C>B>A |

Spherical radius A: 50mm, B: 100mm, C: 200mm, D: ∞(flat),
Nominal depth of the texture: 8μm, Mold temp. 50°C

**Table 3 Result of the Sensory Test for Nominal Depth of the Texture**

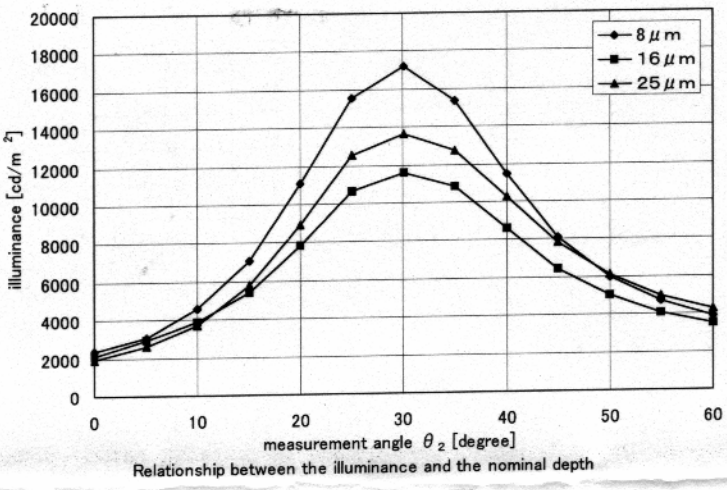
| Characteristic | Judgments |
|---|---|
| Softness | C>A>B |
| Gloss | B>A>C |
| Smoothness | C>A>B |

Nominal depth of the texture A: 8μm, B: 16μm, C: 25μm,
Spherical radius: ∞(flat), Mold temp. 50°C



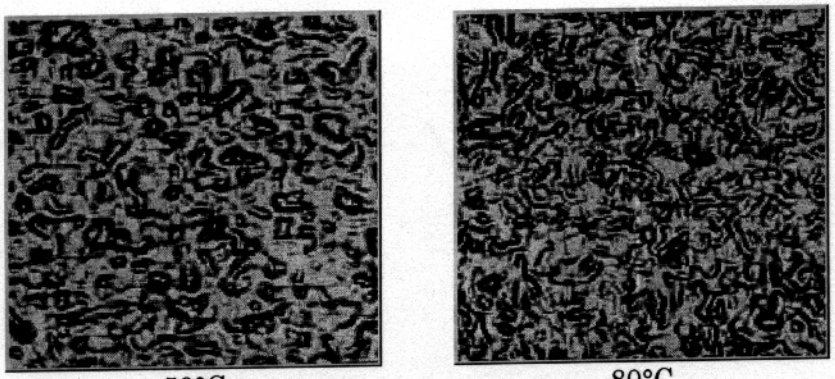

Nominal depth 8μm, Mold temp. 50°C

**Fig. 4 Luminance of the reflected light (Spherical radius)**




Mold temp. 50°C, Flat

**Fig. 5 Luminance of the reflected light (Depth of texture)**



50°C 80°C

Nominal depth 8μm, Flat

**Fig. 6 Simulation results of the surface appearance**

*Conclusion*

1) The reflected light from the textured plastic surface distributes widely when the mold temperature is higher. It agrees the fact that the surface topography of the injection mold is transferred to the molded plastic surface more truly with the mold temperature.
2) Based on the sensory test, a certain relationship between the aesthetic quality of the plastic surface and its topographic characteristics was obtained.
3) The intensity distribution of the reflected light from the textured surface has good agreement with the result of the geometrical transfer and sensory test.

*References*

[1] U. Skands, P. Wahlberg, L. H. Christensen, B. Palfelt, L. Borregaard, N. B. Alexandersen, T. Johansen, A. Rønning, and J. C. Russ : Surface Analysis of Injection Molded TV Components, 7th Int. Conf. on Metrology and Properties of Engineering Surfaces, 1997, pp.55-62

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