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Damage survey of a vehicle windshield exposed to sandblasting in Sahara

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Abstract

In the present work, we describe the damage of a vehicle windshield caused by sandblasting erosion in Saharan climate conditions. In order to evaluate this damage, we carried out a survey on samples taken from a windshield that was used during two years in the region of Ouargla in the south of Algeria. The survey concerns primarily a description of the damage flaws (morphology, flaw size distribution and density) and an evaluation of the roughness and the optical transmission. The results show that the samples average flaw density (number of flaws per cm$^2$ surface) is 316 ± 65. The mean size based on a large number of flaws from all samples is 245 ± 128 μm. Microscopic observations reveal that the flaws vary also in their morphologies. The main flaw types (micro-cracks, flakes and pits) extend differently in length and depth. The evaluation of the optical transmission reveals a decrease from 92% down to 58% using a light flux normal to the glass samples surface.

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1. Introduction

In previous works, Bousbaa et al. [1,2,3] studied the influence of the pertinent parameters that govern sandblasting erosion on glass in real conditions. The impacts of sand particles deteriorate the exposed windshield glass surface by a slow cumulative process of material removal in a form of micro-cracks and small flakes. At a certain level of erosion damage, the windshield becomes inappropriate for further use because of the generated driving difficulties related to light scattering and fuzziness [4]. One aspect that was previously treated was the light diffused by the

This sandblasted surface diffused light is the main cause of accidents in the Saharan regions. In this context, we determined the limit of fuzziness that allows distinguishing between a usable and a defective windshield by vehicles inspectors. A detector of this limit will help to decide if a windshield needs to be replaced much better than by an intuitive control based on human vision [5].

In the present work, a study of the damage flaws induced by sandblasting on vehicles windshields in real conditions and their effect on the optical transmission was made. For that purpose, we used 25 samples taken from a

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windshield to describe the damage flaws (flaws number per surface unit, size distribution and their morphology). We also studied their effect on the surface roughness and the optical transmission.

2. Experimental procedure

2.1 Materials used

We took 25 samples from a double sheet glass windshield that was used for two years in the south of Algeria. They are square shaped with dimensions (10mm x 10mm x 4.96mm). The glass chemical composition and its main physical properties are given respectively in tables 1 and 2.

Table 1. Mean chemical composition of the used glass.

| Oxides      | SiO₂ | CaO  | Na₂O | MgO | Al₂O₃ | Fe₂O₃ | SO₃ |
|-------------|------|------|------|-----|-------|-------|-----|
| Values      | 72.67| 8.82 | 13.48| 3.88| 0.80  | 0.005 | 0.28|

Table 2. Some physical properties of the used glass.

| Parameters          |         |
|---------------------|---------|
| Thermal expansion coefficient | 9.10⁻⁶ K⁻¹ |
| Young’s modulus      | 75 GPa  |
| Poisson’s ratio      | 0.22    |
| Density              | 2.5 g/cm³ |
| Specific heat        | 0.19 Kcal/Kg/°C |
| Vickers hardness     | 5.4 GPa |

2.2. Characterization equipments used

An optical microscope (Néophot 21) was used for flaws size measurement and observations. The optical transmission was measured on a Carl Zeiss Iena micro-densitometer MD100. A Mitutoyo Surftest 301 profilometer was used for roughness evaluation.

3. Results and discussion

3.1. Flaws size distribution in every sample

In order to estimate the flaws average size on the different samples, only those presenting a flaking were selected. Every flaw was dimensioned in four directions before taking the average value. Figure 1 represents the variation of the flaws size for each sample. The flaws are characterized by a large random dispersion. Their sizes vary between 50 and 480 μm with a mean value of 245 ± 128 μm. A number of 5 measurements per sample were considered in flaw dimensioning.

The dominating damage mechanism is typical of brittle cracking and flaking induced by sharp indentation as it is shown in figure 2. The dimensions and the morphology of these flakes vary as a consequence of the size distribution of the sand particles and the sand velocity. Besides the main cracking and flaking that characterizes larger flaws, material removal is also caused by minor crumbling without cracking leading to tiny pits observable on the entire
samples surface. This type of damage is induced by cumulative small particles impacts or by small velocities. In this context, Hutching [6] showed that even glass tends to be eroded by plastic deformation similarly to ductile materials when eroded by very fine particles or at low velocities. The erodent particles kinetic energy is the most pertinent factor that governs erosion damage.

All these flaws have an effect on the roughness of the glass surface and consequently on its optical properties.

![Defects size (μm)](image)

**Fig. 1.** Flaws average size measured on every sample and showing the large dispersion.

![Sample of 1cmx1cm](image)

**Fig. 2.** General view of sandblasting damage flaws of different sizes on a windshield surface (x 100). The larger flaws correspond to material removal by cracking and scaling and the small punctual flaws are caused by crumbling or ploughing without cracking.

### 3.2. Flaws density

Flaws counting reveal that the number of flaws on every sample is variable with a mean value 316 ± 65. This dispersion reveals the random nature of sandblasting erosion damage related to various physical parameters [3]. The flaw density is about 440/cm².

For the sake of comparison, another study made by Timmerman [7] in Germany showed that windshields of vehicles after 80000 km of circulation present some flaws in form of small pits with a density of 180/cm². This damage led to an average stray light of 0.53 Cd/lux.m². The author revealed that drivers can have their visibility hindered when 0.5 Cd/lux.m² of stray light is reached. Replaced windshields because of this discomfort present a stray light varying between 0.7 and 6.0 Cd/lux.m². On the other hand, Köln [4] indicated that when a windshield is
eroded by impacts such that the stray light exceeds 3 Cd/lux.m², the driver visibility was reduced down to 15% of the initial value.

3.3. Roughness measurements

Roughness is an important geometric parameter in the study of the windshields optical transmission. It gives a clear idea on the damage state that affects directly the driver’s visibility. Figure 3 shows the roughness Ra variation for the 25 samples set. It spreads over the range (1.0 to 1.5 μm) and the mean value is about 1.30 μm. We notice that there is homogeneity in the samples damage if we consider most average values and their standard deviation.

![Roughness measurements](image)

Fig. 3. Roughness measurements on each sample showing the mean value of 1.30 μm.

3.4 Optical transmission measurements

Along with the roughness measurements, we also evaluated the transmission loss using a 550 nm light ray. The results presented in figure 4 show that the average values of the optical transmission for the 25 samples is about 70% varying between 58.1% and 83.7%. The initial optical transmission of an undamaged windshield was about 92%.

The minimal tolerated optical transmission for a vehicle windshield is 70% in the United States of America and Japan and 75% in Europe [8]. It is clear that the deterioration of the windshield surface state affects the drivers’ ability to react promptly. In his works on windshields, Köln [4] indicated that for an inclination between the light flux and the windshield larger than 50 degrees, a middle age driver would react at night with more than 2.8 seconds delay for identifying an eventual obstacle on the road.
4. Conclusion

The results obtained from this survey concerning the damage flaws generated on a vehicle windshield exposed to sandblasting erosion in real climate conditions and their effect on the roughness and the optical transmission can be summarized as follows:

- The size distribution of the flaws generated by sand impact in real conditions is random. We observed flaw sizes varying between 50 and 480 μm with a mean value of 245 ± 128 μm.
- The flaws density is high enough (reaching 440 flaws/cm²) inducing stray light that reduce the driver’s visibility.

According to the sand flow velocity and direction, and the sand particles size, the damage flaws present different morphologies. The main observed flaws of variable sizes (cracking and scaling) are caused by brittle erosion. Small punctual flaws (tiny pits) corresponding to a crumbling or ploughing type of damage caused by small erodent particles are also randomly distributed on the entire surface.

Even though we have a large size distribution, the roughness measurements on various samples are less scattered. The optical transmission of the various damaged samples varies between 58.1% and 83.7% with a mean value of 70%. This value is just below the standard admitted values (73 to 75%).

References

[1] C. Bousbaa, N. Iferroudjene, S. Bouzid, M. Madjoubi, N. Bouaouadja, Glass Technology 39 (1998) 24-26
[2] C. Bousbaa, A. Madjoubi, M. Hamidouche, N. Bouaouadja, Journal of the European Ceramic Society 23 (2003) 331-343
[3] C. Bousbaa, Effet des traitements sur l’érosion du verre érodé par impact de sable. Thèse de Doctorat, Université de Sétif - Juin 2004.
[4] K.W. Schneider, Sperchsaal. 122 (1989) 824-829
[5] N. Adjouadi, N. Laouar, C. Bousbaa, N. Bouaouadja, G. Fantozzi, Journal of the European Ceramic Society 27 (2007) 3221–3229
[6] I.M. Hutching., Tribology: Friction and wear of Engineering Materials. Metallurgy and Material Science, 1992
[7] A. Timmerman., Asse. V. Conference Vision on Vehicles. Nottingham United Kingdom, pp 331-343 (1985)
[8] B. Savaëte, Vitrage de l’automobile, Revue Verre Vol. 9 (2003) 36-47