Effect of impact angle on a soda-lime glass erosion eroded by sand blasting.

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In this work, we studied the effect of the incident angle on the erosion of a soda lime glass by sand blasting. We used a sand coming from Algerian Sahara (Ouargla) which is characterised by a mostely rounded shape. We varied the impact angle from 30° up to 90°. We used a sand flux velocity of 20 m/s and sand masses varying from 20 to 200 g. The results obtained show that the mass loss, the roughness and the erosion rate reach their maximum at normal incidence. After exposure to a sand mass of 200 g at normal incidence, the mean roughness Ra reaches about 2.82 µm and the mass loss of the glass is 53.8 mg. The optical transmission is affected proportionally to the sand mass used. It decrases from 91.5% down to 10% when the mass reaches 200 g. The glass surface becomes totally blurred. From microscopic observations, we noticed that the erosion mechanism is often of a brittle kind characterised by the formation of radial and lateral cracks that develop into chipings. With masses exceeding 100 g, we notice that the interaction between cracks of the damaged zones becomes frequent. We also observed that for weak angles (< 45°), the erosion mechanism changes. It seems that the mass removal occurs by a ploughing and crumbling process rather than that by scaling.

1. Introduction

Solid particle erosion of glass can be a severe life limiting particularly in Saharian regions where sandstorms occur in certain periods of the year. In recent years, much interest has been shown in the use of ceramics as erosion resistant materials for many applications. G. H. Jilbert and J. E. Field[1] reported that in a real situation, an aircraft is most likely to encounter dust and sand during take-off and landing. The erosion by solid particles affects optical transmission and strength degradation of glass frequently used for windows covering infrared systems in flying and in the aerospace industry.

In Algerian Sahara, the vehicles windshields damaging by sandstorms is a common phenomenon that can cause serious problems. When the windshield glass is exposed to sand particles flux, the surface becomes blurred[2]. The transmission loss and stray light caused by this type of erosion makes difficult the driving particulary during sunset, sunrise or when facing other cars during night. Windshields are usually made of a soda lime glass and are oriented with a certain angle when placed on vehicles. The orientation is variable according to the type of vehicle. It is well known that the erosion of brittle materials is maximal at normal incidence. In practice, the inclinaison of the windshield glass can be positive not only for reducing air resistance but also for reducing erosion damaging.

The glass erosion mechanism of the brittle kind is characterized by the formation of lateral cracks that develop into chippings. However, it was also shown that even glass tends to be eroded by plastic deformation similarly to ductile materials when eroded by very fine particles or at low velocities[3].

In this work, we studied the effects of the incident angles on the erosion of a soda lime glass by sand blasting using variable eroding masses up to 200 grams.

2. Experimental procedure

The material used in this study is an ordinary laminated soda–lime glass which was delivered in its as received state with a 3 mm thickness. Its mean chemical composition contains essentially 71.56% SiO_2, 7.91% CaO and 13.73 % Na_2O. The Young's modulus, the Poisson's ratio, the hardness and the fracture toughness are respectively : 72.3 GPa, 0.22, 5.78 GPa and 0.84 MPa√m.

The sand chosen for this study comes from the region of Ouargla in Saharian region sited at the oriental Erg in Algeria. It was used in its as received state. Figure 1 represents a sand sample showing the particles shape and their average size. We can notice that the sand is composed from differently shaped and colored particles. Some of these particles are limpid and translucent. The granulometry distribution of the particles made for a sand mass of 100 grams is not very dispersed (figure 2). With successive sieving periods of 15 min, the sand distribution shows that most sizes lay in the interval (200 ÷ 250) μm.

Figure 1: Micrograph showing the morphology and the aspect of the sand used

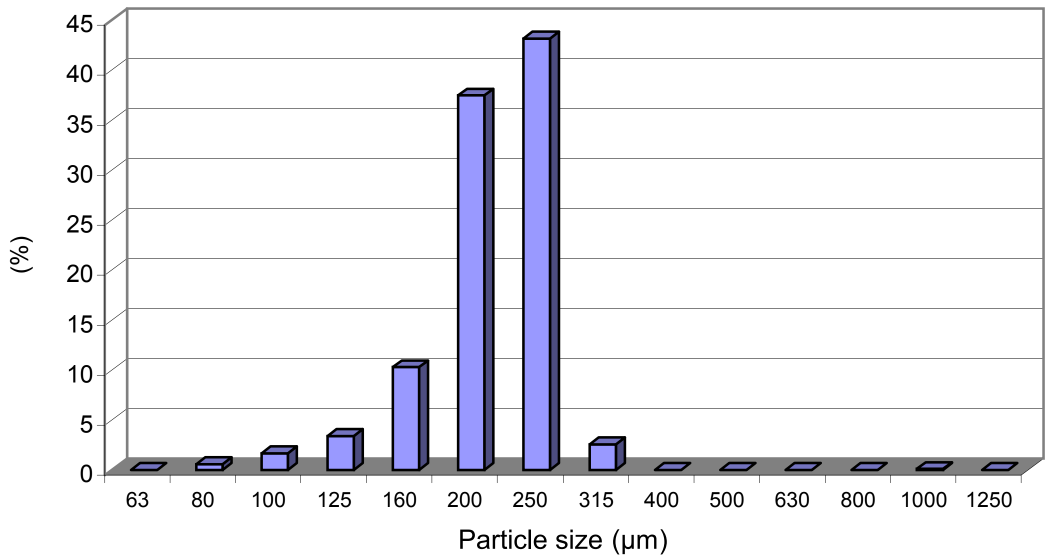

Figure 2: Distribution of the particles size (% in mass) for the sand used

We determined the sand particles hardness using a load of 0.6 N and a dwell time of 15 seconds on a sample of 30 grains. The obtained hardness is Hv = 14.49 ± 3.28 GPa. We attempted to determine the particles fracture toughness with a load of 1 N, but because of the impossibility to measure directly the sand Young's modulus, we could not have an estimation of the fracture toughness according to indentation models. The test conditions are as follows:

Table 1: Parameters considered in the test conditions

Fixed parameters	Variable parameters
Distance convergent-samples: 50 mm Air speed: 20 m/s Sand mass rate: 10 g/min	Erodant mass: 20, 50, 100, 200 g. Impact angle: 30°, 45°, 60°, 90°

3. Results and discussion

Figure 3 shows the variation of the mass loss versus impact angles. We can observe that the mass loss become maximal when the impact angle tends to 90° and gradually increases with the erodant mass up to 200 g. This shows that the mass loss is depending on the incident angle and on the amount of mass projected. These variations were also observed from the measurements of the damaged surface roughness.

For lower angles less than 45°, we have a nearly constant very weak mass loss. This loss is almost null for these angles when the eroding mass is less than 100 g. This probably corresponds to an incubation periods generally observed in the erosion of brittle materials. We have seen that the erosion mechanism in this interval of incident angles (30 – 45)° is characterised by a ploughing and crumbling process.

For greater incident angles (> 45°), the mass loss clearly increases in function of the eroding masses. The impact energy becomes more important and the observed erosion mechanism becomes clearly of the brittle type. The mass removal is made by shippings after formation and development of lateral cracks. We can suppose that a transition from one mechanism to the other exists for some angles between 45 and 60°. This can be made in evidence if we choose different smaller angle steps in this interval.

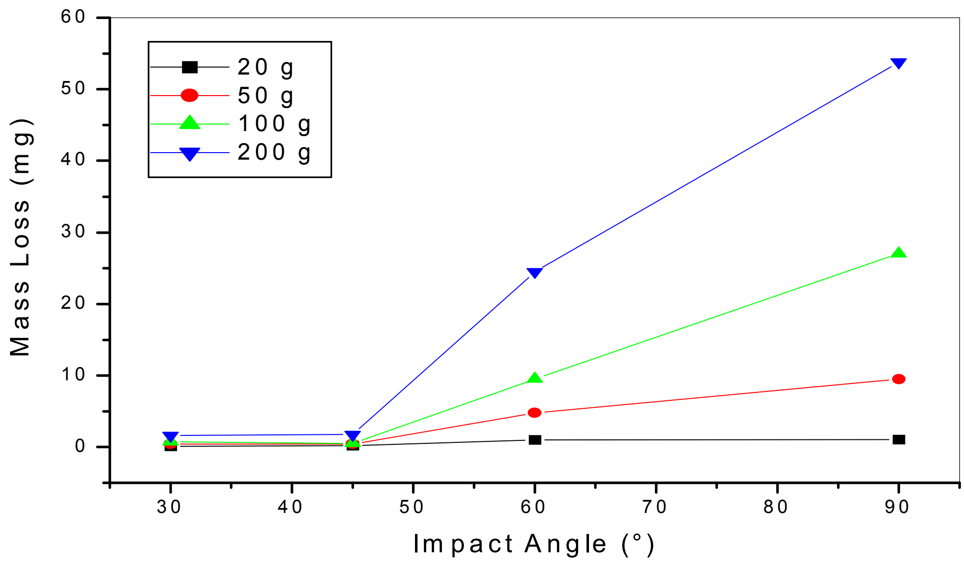

Figure 3. The mass loss variation in function of impact angle

Figure 4 shows the optical transmission variation in function of the impact angle. We can also distinguish two different domains:

- for angles between 30 and 45°, the optical transmission variation shows a weak decrease and a similar behaviour for the eroding masses used. The curves seems to evolve parallely.
- In the second domain (> 45°), a more important optical transmission loss is observed. The decrease is more sharp for higher erodant masses. At normal incident angle, the transmission loss tends toward the same value (about 12 %) when using erodant masses higher than 20 grams. The transmission variation curve for 20 g mass loss presents a smooth decrease for angles less than 60°. The minimal transmission value observed at normal incidence is about 30%.

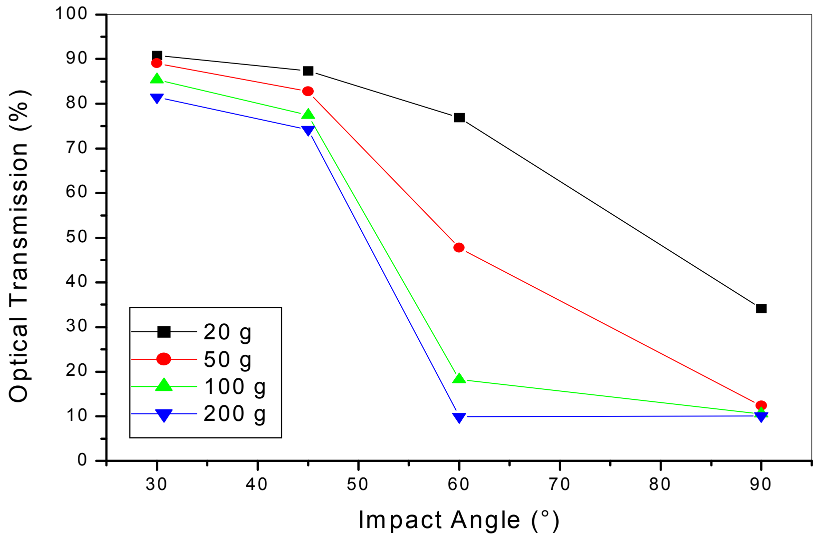

Figure 4: Variation of the optical transmission versus the impact angle

The hazeness variation caused by sand blasting damage in function of the impact angle is shown on figure 5 for two different masses (100 and 200 g). The curves evolve in the same way and show three domains:

- a weak variation (≈ 5%) for lower angles than 45°
- a sharp increase (≈ 75%) for angles between 45 and 60°
- a constant maximum level (≈ 95%) for angles between 60 and 90°.

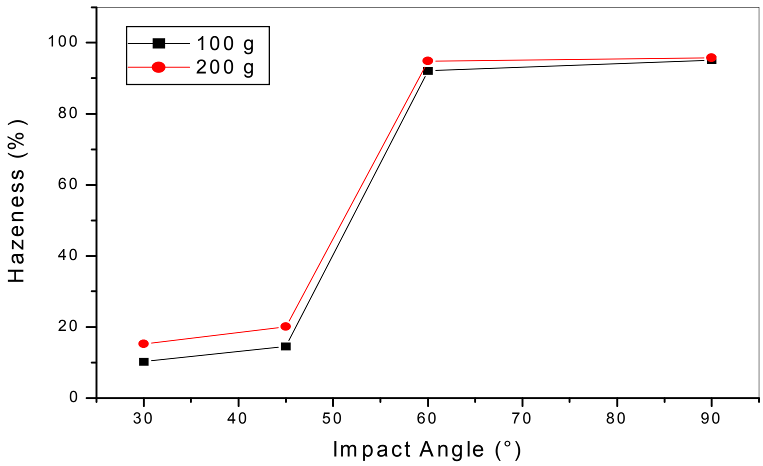

Figure 5: Variation of the hazeness versus the impact angle for two erodent masses

4. Conclusion

We have studied the effect of the impact angles on the erosion of a soda lime glass by sand blasting using four erodant masses (20, 50, 100 and 200 g). We varied the impact angle from 30° up to 90° with a constant sand flux velocity of 20 m/s.

The results show that the mass loss and the roughness reach their maximum values at an impact angle of 90° and for 200 g of erodant mass which are respectively 53.8 mg and 2.82 µm. The mass loss remains nearly constant between 30 and 45° and increases for higher angles. The glass mass removal is very limited for impact angles lower than 45°. For higher angles, the mass loss increases sharply and reach a maximal value at 90°.

The optical transmission is affected proportionally to the sand mass used. It decrases from 91.5% down to 10% when the mass reaches 200 g. The glass surface becomes totally blurred. Microscopic observations show that the erosion mechanism change between 45 and 60°. For angles lower than 45°, it is a ploughing and crumbling mechanisms which are prepondering, but for angles higher than 60°, it is a scaling mechanism which governs the glass erosion. We suppose that between 45 and 60°, there is a transitory mechanism including both ploughing and scaling mechanisms.

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