Impact damage of plate glass by abrasive trickling with various paricles in different experimental conditions

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With an improved installation for impact damage resistance testing by abrasive particles trickling, the float glass from a recent modernized Romanian factory was tested using various abrasives (silicon carbide, natural quartz sand, and steel balls) from the same granulometric range (0.50 – 0.71 mm).

The improvements brought more experimental facilities forth, especially concerning the functional stability, the uniformity of particle distribution, and the identity of impact velocity of used abrading grains.

Some of the features regarding the phenomenological and structural aspects were investigated in the presence of a synergic action of the gravitational and rotational components of impact.

I. INTRODUCTION

Especially for the float glass used in automotive and architectural purposes, it is of a great interest to know how the windows resist to impact damage with different abrasive particles.

As a particular type of *solid impingement* [1] (i.e. continuous succession of impacts) the *trickling* (free falling of abrading particles) offers the possibility of testing the glass surface in the conditions similar to the natural ones (e.g. the standardized incidence angle [2] is 45^0 as in the case of most road vehicles).

In the literature it is affirmed that the *brittle erosive behavior* is characterized by a maximum volume, removal of surface material occurs for a near normal incidence. Our supplementary investigation was dedicated to describe the influence of different rotation speeds on the erosion efficiency (expressed in terms of diffuse optical transmission) for a variable inclined specimen turntable of new modernized installation, still similar to that recommended in DIN 52348.

II. EXPERIMENTAL

II. 1 The principal new features of the upgraded installation

A. Two specimens with preferred dimensions for mechanical trial and optical testing was placed symmetrically on the turntable (Fig. 1a), the positioning being imposed by the disposable space too [3-5], because in the center of the disk was disposed a hole for its fastening on the rotating axle of used electric motor. In order to minimize the shadowed zones in the vicinity of the fastening Plexiglas pieces of the specimens and their dispersive actions on the “reflected” beam of particles after impact (especially for greater incidence angles – see Fig. 1b), a new constructive design was adopted (Fig. 1c).

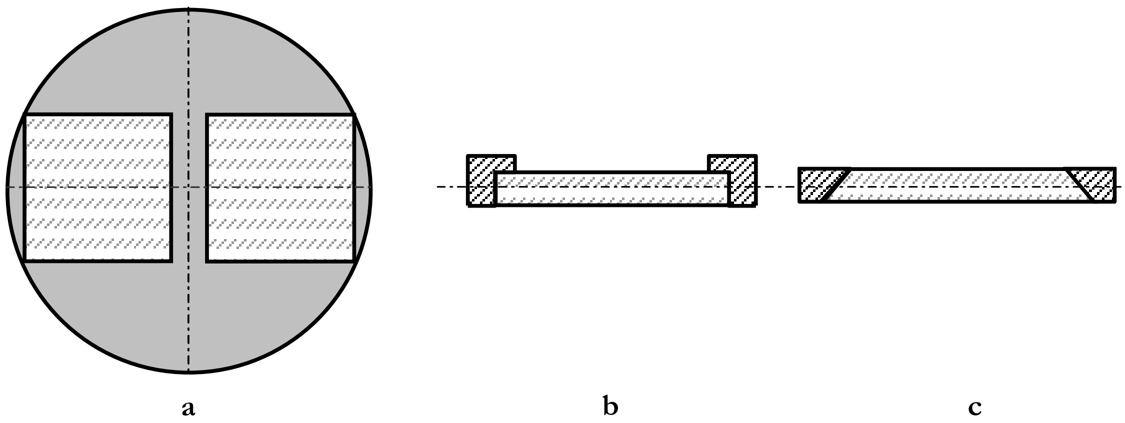


Fig. 1 a - specimens placement on the turntable b - old lateral fastening variant c - new lateral fastening variant

B. In the old variant of particle beam configuration (similar to that of DIN 52348) in order to assure a uniform density of particles on the turntable a group of two sieves was placed at a distance of 500 mm. Some disadvantages of this placement was discussed elsewhere [3-5]. An additional one is the fact that, especially for more inclined positions, an important quantity of particles is lost passing by the lateral sides of the minor axis of apparent ellipsis (in Fig. 2, the minor semi-axis is noted with b, the major axis 2a = D being 100 mm) when the turntable is viewed along the column axis (dependence on the cosine of incidence angle, β). Note: because $S_{ellipsis} = \pi ab = \pi Rb$ and $S_{circle} = \pi R^2$, their ratio equals $100 \cdot b / R$ (%) $= 100 \cdot 2b/D$, i.e. the 2b value expressed in mm.

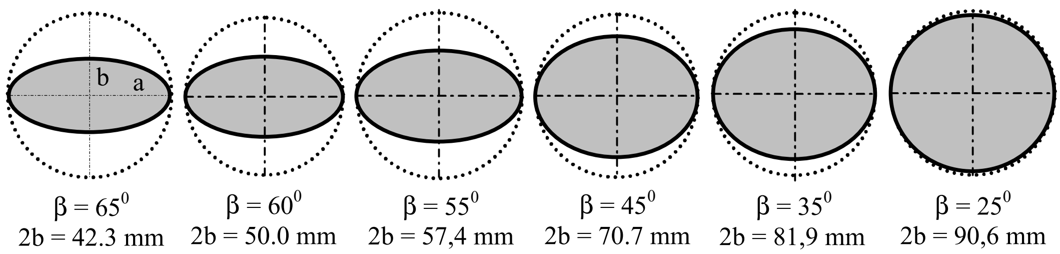


Fig. 2 Apparent ellipsis shape of the turntable viewed in the column axis direction

The lost mass (volume) of particles made impossible to maintain a constant surface density of falling particle on the specimen area and then a realistic comparison of the influence of rotation speed at different incidence angles on the impact damage.

In order to limit the falling beam of abrading particles to a transversal section of identical shape and area with the apparent ellipsis, to obtain a good uniformity in the distribution of particles, and to assure a little dispersion of the speeds of impact two changes were made:

1. The dispersing sieves were placed at a little distance (50 mm) one from the other, and a supplementary one was situated beneath at the same distance. Their meshes were randomly oriented for a better dispersing action. This reciprocal placement had as subsidiary advantage the possibility to eliminate the lower column segment in the case when by vertical column movements must find the crack onset.
2. For each angle of interest and when the difference between two consecutive apparent ellipsis areas implied in the successive trials of surface abrasion resistance was greater as 10 %, at a little distance beneath the last sieve was placed a circular screen with a hole of identical shape and the same orientation as the apparent ellipsis (Fig 2 serves as an illustrative guidance). In order to avoid the particle accumulation in the space from the circular limit of the screen, it was divided in two identical parts by cutting in the direction of the major axis of ellipsis and slightly inclined from to minor axis to this symmetry axis.

C. For a better stability of the turntable rotation speed and to avoid the parasite signals at the counter input, the following improvements were made:

- ✖ a more stabilized power supplier for the electric motor, including the possibility of continuous variations of tension;
- ✖ an independent voltage stabilizer for the pulse shaper connected at the input of the digital impulse counter which has the facility to measure and directly display the rotation frequency (rot/min or rot/s) of turntable.

II. 2 Experimental conditions

This new series of experiments are made in the similar condition as described in ref. [3-5]. It only must be reminded the abrading particle granulometry:

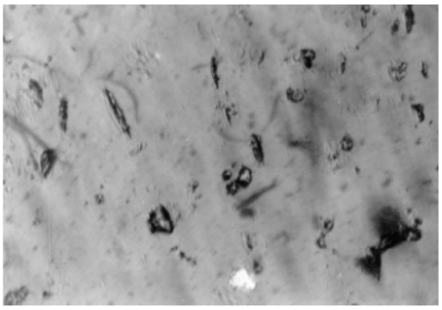
- a mixture (2580 g / 0.51-0.63 mm + 420 g / 0.64-0.71 mm) of <u>natural quartz sand</u> with partially rounded ends;
- <u>silica carbide</u>, 0.5 ... 0.63 mm;
- <u>hardened steel balls</u> for abrasive cleaning, 0.5 ... 0.71 mm, main fraction at 0.6 mm.

II. 3 Experimental results

At this time, a great number of measurements and experimental correlations are in evaluation but some remarks even now are disposable:

- as already elsewhere mentioned [3-5], the frictional effects of the gravitational and rotational components of the impact interaction between the abrading particles and the glass surface create a cumulative (superposition) and synergic contributions to the overall damage;

- the contribution of gravitation is constant in value and orientation but the additional influences of the radial variations in tangential speed or, anymore, in angular speed of the specimen turntable amplifies its action and creates new structural phenomena on the specimen surface (Fig. 3);



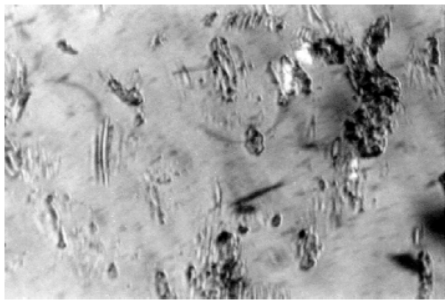


Fig. 3 Imprints at near (left) and remote (right) sides from the rotation axis, for quartz sand trickling at 50 rot/s in standard position (45^0 impact angle)

- because of the vectorial composition between two constant in value and orientation gravitational components of impact with variable in orientation ones, the effects are position-dependent (Fig. 4);

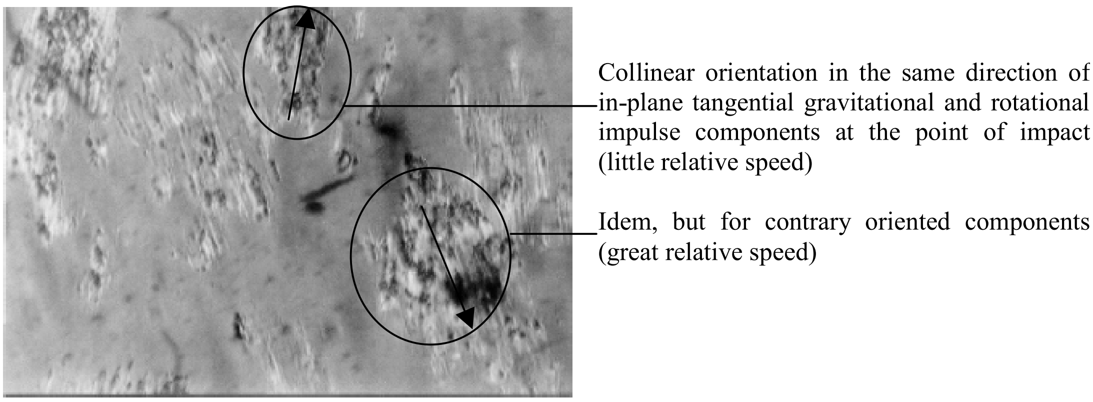


Fig. 4 Dependencies of the impact damages on the reciprocal orientation of impulse components in the impact point for metallic balls at 65^0 incidence angle

- a somehow unexpected comportment had the metallic spheres, giving non-uniform imprints that seems to be the result of a temporary interaction between the glass surface and the turning or/and flattening balls, both in fast vibration (parallel grooves) perhaps with different frequencies (Fig. 5);

- in the same figure it could be observed that the thermal phenomena are present at the glass surface at greater rotation speeds (glass and/or grain debris free cooled in little spheres, especially in the case of metallic spheres.

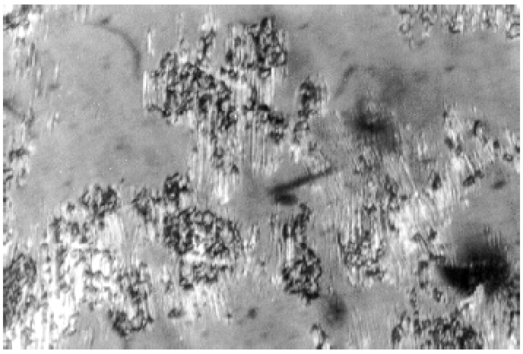


Fig. 5 Variations in shape and extension of the successive imprint grooves and the presence of "archipelagos" of cooled debris

III. CONCLUSIONS

Glass surface impingement by abrading particles trickling in the presence of a rotation movement offers a supplementary possibility to testing its abrasion resistance, especially because the light diffuse transmission is more favorable for measurements, i.e. greater than the usual lower sensitivity limit of photometric devices.

The synergic actions seems to be far of a complete phenomenological explanation.

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[1] *.*.*. - *Standard Terminology Relating to Wear and Erosion, ASTM Designation G 40* – 95, Tribology Laboratory – University of Florida.

[2] *.*.*. - DIN 52 348 – 85: Prüfung von Glas und Kunststoff - Verschleissprüfung – Sandriesel – Verfahren

[3] Protopopescu N., Plaiasu Z., Radu D., *Sand Trickling Abrasion Testing Of Float Glass. Some Methodological And Experimental Considerations*, The 7[th] International Glass Processing Days – 2001, Tampere – Finland, June 2001.

[4] Protopopescu N., Radu D., *Abrasion Testing Of Romanian Float Glass By Sand And Other Abrading Materials Trickling. Experimental And Methodological Remarks*, The XIX[th] International Congress on Glass – Edinburgh, July 2001.

[5] Protopopescu N., Oltean C., Radu D., *Determination Of Glass Abrasion Resistance By Abrading Materials Trickling*, International Conference on Chemistry and Chemical Engineering (ICChChE) – Politehnica University Bucharest - Faculty of Industrial Chemistry, Bucharest, September 2001.