PLAN D'APPUI SCIENTIFIQUE A UNE POLITIQUE DE DEVELOPPEMENT DURABLE

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- Projet pilote -

Characterization of scuffing on returnable bottles

Abstract

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CHARACTERIZATION OF SCUFFING ON RETURNABLE BOTTLES

ABSTRACT

According to the European wish (directive 94/62/CE) to encourage the reuse of glass containers, an ever increasing percentage of glass bottles are returnable on the North European market. In other words, the bottler takes increasing responsibility for bottles after use. The bottler therefore deals with the washing of bottles, filling them, labelling them and storing them. The bottles are then put back into the distribution circuit for a new cycle of use.

Since the glass which forms the bottles is a brittle material, its potentially very high mechanical resistance is weakened by the presence of defects, which seldom occur in the mass of the glass but are frequently found on its surface. It is therefore of prime importance to protect or strengthen the surface of the glass with one or more films composed of metal oxides or organic molecules. Nevertheless, despite the presence of such treatments, the surface of bottles becomes scuffed after multiple use. As a result of bottle handling and washing operations, whitish surface marks appear. They are mainly present at the different friction points of bottles when they knock against each other, on conveyor belts for example. The term “scuffing” is given to those marks in the jargon of glass-makers and bottlers. They alter not only the mechanical resistance of the glass but especially its transparency and its visual attractiveness.

This article aims at developing a measuring method and apparatus to quantify scuffing. The interest of such a method is based on the following advantages:
- the possibility of defining a tolerable scuffing threshold,
- having a means to determine the rate of scuffing generated by a bottling line,
- being able to adjust and control the effectiveness of new means aimed at fighting the phenomenon of scuffing.

In order to approach this study, a prior analysis concerning the problem and the source of scuffing was made on the basis of bibliographical information. Next, a critical examination of the methods potentially usable to quantify scuffing led to the selection of a measuring principle used for the design of the prototype. First experiments were carried out to validate the apparatus.

METHOD CHOSEN AND DEVELOPMENT OF THE APPARATUS

It is admitted by experts on the subject that the generation of scuffing is caused by the combination of damage of a chemical and mechanical kind arising on the surface of the glass. Scuffing is not a physical scale of size. Outward signs characterising it therefore have to be identified and the means found to measure those signs. Several techniques may be considered to quantify a deterioration of the surface condition of glass such as scuffing: visual evaluation, measurement of the loss of weight, of roughness, transmission or diffuse reflection. All these methods have advantages and disadvantages which have been examined. It seemed to us that diffuse reflection method best met the constraints of the apparatus to be designed; in other words, it enables a

direct, accurate and fast measurement of scuffing regardless of the influence of external parameters.

The basic principle of the instrument developed by the InV, the "scuffmeter", consists of sending a source of light onto the side wall of the bottle using an emitter-sensor cell. The direction of the ray of light is different from the normal so as to be able to differentiate normal reflection and reflection due to the surface defects of the analysed bottle. The information received on the cell is sent to a programmable automatic device and processed by software programs to build up the cartography of the surface condition of bottles. That information is converted into rates of scuffing, which correspond to the ratio of the number of positive responses (= number of defects or scuffs) over the total number of measurements taken.

The selected sensor is an inexpensive, single, digital, photoelectric sensor operating in the "all or nothing" mode in relation to an adjustable threshold of light reflected by diffusion. The sensor is included in a cell where the emitter is also located (light beam of a constant diameter). The cell driven by a stepping motor moves along a vertical axis. The bottle is held through an AGR (American Glass Research, Inc.) type grapping device, that can be manually adjusted and an automatic device operates its rotation. The measurement is taken initially at the bottom of the bottle over the whole circumference and the cell rises by one vertical step after each revolution. Binary type data (defect or no defect) are captured as far as the shoulder of the bottle.

TESTS AND RESULTS

First tests allowed to select the best position for the sensor (distance between sensor and bottle is 22 mm, angle between normal and bottle is 17°), given the geometry of the bottle.

Validation

We measured the scuffing rate of 10 bottles taken on a washing line to validate our method. These bottles have been first measured by TNO. The rate of scuffing of those bottles decreases approximately in a linear way as a function of wearing rate and are well correlated with TNO measurements (table 1).

Moreover, when measuring scuffing only on the two most worn rings (upper and bottom zones) instead of on the whole body of the bottle, the relation has the same behavior as that obtained just before. It is then possible, if necessary, to optimize the measurement time of scuffing. Indeed, the measurement of the two rings only could accelerate the measuring time which is not negligeable when considering a use of the method for on-line measurements.

Table 1 : comparison between measurements done by TNO and those obtained with our apparatus.

Standard	1	2	3	4	5	6	7	8	9	10
mV (TNO)	1000	900	800	700	600	500	400	300	200	100
intensity	heavy				average					light
rate	0.399	0.322	0.318	0.298	0.209	0.131	0.126	0.069	0.019	0.042
scuffs	3192	2577	2540	2380	1669	1047	1006	555	157	334

On another hand, two series of samples that have been submitted to 5, 10, 15, and 20 wearing cycles have been analyzed. Even if the number of samples is limited, they can validate the technical choices we made for the prototype:

- a clear distinction can be made between the wearing obtained after several cycles,
- the dispersion of results is small (low standard deviation),
- the scuffing rate becomes very important after 10 wearing cycles (similar results as for visual observation),
- the noise level, characteristic of the presence of other surface defects (no wearing cycle), is rather low,
- the maximum error obtained on a same bottle is lower than 5%, which is quite compatible with a good reproductibility.

Relationship between rate of scuffing and mechanical resistance

Bottlers wish to know the relationship that exists between the rate of scuffing of returnable bottles and their mechanical resistance. Therefore, a set of worn bottles of the same model has been used.

The rate of scuffing is measured before the bottles are submitted to a destructive test of resistance to internal pressure. For comparison, new bottles resisted an internal pressure of 40 psi (pound per square inch), according to our test. When bottles are simply knocked against each other, their mechanical resistance remains the same. When bottles are scratched, the resistance to internal pressure is highly lowered and reaches values between 26 and 37 psi. When they have been submitted to several wearing cycles, their resistance can be as low as 20 psi.

These tests show that the surface treatments of returnable bottles are very good protecting agents of the glass surface. One scratch eliminates the surface treatment and lowers the resistance of the bottle which can cause very important damages to the bottling line. Such a scratch is the starting point of the scuffing phenomenon because it allows the washing solutions to reach the unprotected glass surface.

Constitution of two standard scuffed bottle series

Two series of 10 standard bottles have been constituted, on one hand to calibrate the prototype, and on the other hand to determine, together with bottlers, the rate of scuffing that can be aesthetically accepted by the client. Two types of bottles commonly used in Belgium (brown APO 25 cl and uncolored Spadel 20 cl bottles) have been scuffed during wearing cycles. This way, a standard curve is obtained, that allows to define an acceptable scuffing rate. Such a standard curve can be reproduced easily for any kind of bottle.

CONCLUSIONS AND PERSPECTIVES

The scuffmeter designed and used at the InV at the present time is a laboratory prototype that still requires some technical improvements to meet the requirements of production line use. Future research will concern, among others, the reduction of measuring time and the programming of automatic statistical processing of results.