Fracture Analysis of the Glass Scoring Process

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Abstract

The scoring process is widely used for sizing of glass sheets. In this process, the score wheel generates a small crack on the glass surface, which is then propagated through the glass for complete separation., This report will present a description of the scoring process and an interpretation **of** the marking found on the glass edges. Interpreting these markings can provide process understanding and assistance in problem resolution.

Introduction

The scoring process is often used as a reliable and inexpensive method for sizing of glass sheets. Glass manufacturers use it for removing undesirable portions of their formed sheet and for glass sizing. This report will focus the fracture signatures and an interpretation of their origins. Examples for this discussion are drawn from the scoring of sheet glass for **AMLCD** substrates. In this application, 0.7mm thick glass dominates the market. Score wheels for this application, are often 2.5mm in diameter.

Fundamentals of Scoring

In the scoring process, a score wheel is used to generate a median or vent crack in the glass surface. As the wheel rolls on the glass, the median crack is pushed downward and ahead of the wheel. The wheel rides on top of an open crack, forcing the crack open with a wedging action. The scoring wheel penetrates into the glass surface to a depth of only 2-5pm, yet the median crack typically reaches **a** depth of 50-120 pm. The individual panels are then separated by the application of a bending stress for driving the median crack completely through the glass thickness.

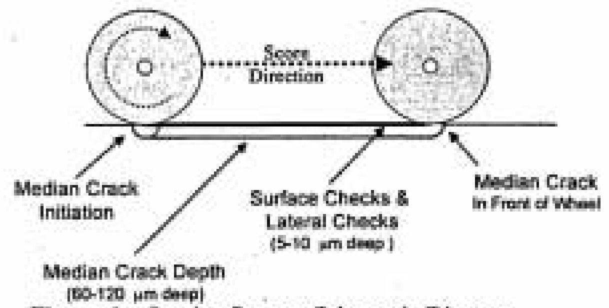


Figure 1a. Scoring Process Schematic Diagram

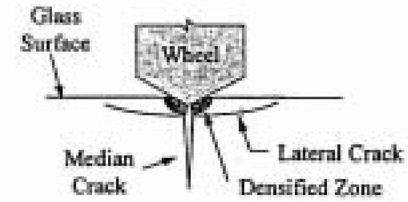


Figure 1b. Scoring Process Schematic Diagram

In addition to driving the median crack along the glass surface, the scoring process generates contact stresses, effecting a 3-7 μm deep zone under the wheel tip. The glass responds to the creation of this region through a combination of plastic flow and brittle failure'. The former results in densification of the glass, while the latter results in the formation of microcracks either on, or slightly below, the glass surface. These microcracks can, in turn, form the nuclei for larger cracks known as lateral cracks. These cracks have a significant impact on the edge strength'. Extensive lateral cracks may also result in the creation of glass chips. Figures l a and l b schematically illustrate these principles.

For the purposes of cleanly separating the glass sheet, it is the goal of the scoring process to maximize the median crack depth, while minimizing any other glass damage. This allows the glass to be separated under the minimal amount of external stress. Unfortunately not all glasses behave the same with respect to the scoring process. Historical procedures, and tooling, mainly derived from the processing of soda lime glass, can be inappropriate for many of the high tech glasses. Critical score wheel parameters include tip angle, wheel diameter, and finish. Other process parameters include scoring pressure, speed and tooling technique. Each glass composition will often respond quite differently.

Much of the crack formation history can be reconstructed from a detailed examination of the glass surfaces created during the scoring and separation processes. This history is an invaluable resource for the identification and correction of process problems.

Fracture Signatures

Figure 2a is an isometric sketch of a scored and separated sheet, labeled with most of the critical features found on a typical edge.

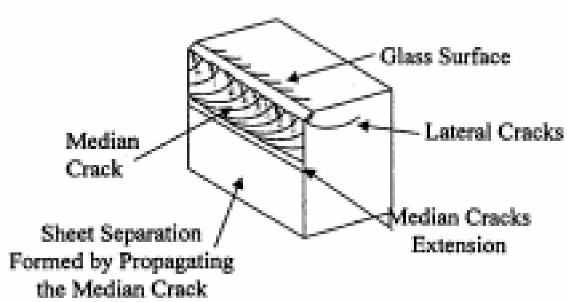


Figure 2a. Schematic view of the separated glass sheet showing some of the common scoring features.

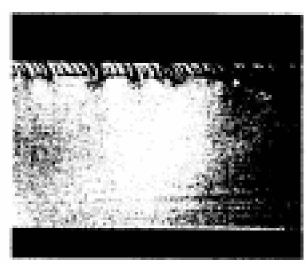


Figure 2b. Sheet Edge

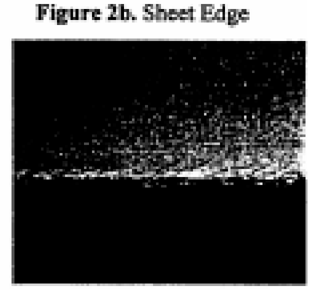
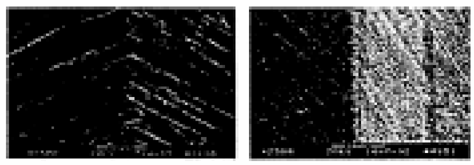


Figure 2c. Surface Cracks

The contoured surface on the median crack surface is created **as** score wheel wedges the crack open. The wheel tip surface finish and tool wobble account for most of the markings. The wheel tip's non-uniform ground surface, the primary contributor, turns the crack by pushing on alternate sides of the crack face. In Figure 2, the score wheel has run from left to right.

In an optimum score, the bottom of the median crack should be continuous, straight, and parallel to the face (top) surface of the glass. Such a feature indicates the wheel is running freely and true in its holder and that it has sufficient force and time to complete its wedging action.

The SEM images shown Figure 3 show typical wheel tip surface finishes. These photos represent the surface finish extremes in commonly used precision wheel. The glass in Figure 2b was scored with a ground wheel as seen in Figure 3a. A repetitive pattern will be seen in these markings which correspond to the wheel's circumference. These features and the orientation of the surface checks, provide a history of the score wheel's diameter, surface finish and rolling direction.



a. Ground Wheel b. Polished Wheel

Figure 3 SEM images of score wheel tips

The median crack is formed as a continuous extension of the initiation crack. The Wallner lines formed during crack formation can also be observed on the crack's face (Figure 4). These Wallner lines very closely approximate the median crack front, because the crack propagation is slow.

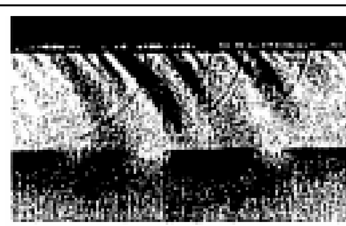


Figure 4. Wallner Lines on Median Crack

Immediately below the median crack we find the median crack extension. In an attempt to relieves residual score stresses, lateral cracks will form and/or the median crack will extend. These processes continue until the stresses are reduced or the sheet is completely separated.

The SEM photos in figures 5 and 6 take a closer looking at the scored edge. These are isometric views of a scored and separated edge. On the sheet surface is the score wheel's 7-10pm wide surface track (1/2 wheel contact width).

On the separated edge the features vary with the glasses composition. 1737 (Figure 5) is densified directly under the wheel contact zone. This response is typical of what is seen on anomalous glasses. Anomalous glasses are composed primarily of glass former oxides. In comparison, "A" Glass (Figure 6) shows extensive subsurface cracking. This response is typical of normal glasses. Normal glasses are glasses with a significant fraction of modifier oxides in their composition.

Figure 5. Subsurface densification - 1737, compositionally higher glass former oxides.

Figure 6. Subsurface cracking - "A" Glass, compositionally higher glass modifier oxides

The scoring process is an integral part of the manufacture of many sheet glass processes. Optimization of the scoring and separation is important to reduce losses from inadequate scoring conditions. Fortunately, a record of the scoring and separation conditions are maintained on the separated glass face. Careful examination and understanding of this record can aid in improving the scoring and separation processes.

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