Analysis of a Broken Phone Screen: An Engineering Material Failure

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Table of Content

Introduction

Failure is a most common phenomenon, observed everyday on different scales. In engineering, it’s almost always an undesirable event. While designing a circuit, a part, an assembly or a material, we use analysis as a tool to predict and avoid failure when possible and minimize its effects if it were to occur. The most common kind of failure is fracture. Simply put, fracture is a partial or full separation of a member or several parts of a body or an object due to stress, fatigue, temperature variation, etc.[1]

Our team, in this work, is particularly interested in the fracture of glasses, more specifically in portable devices such as smartphones. We’ve all had the misfortune of dropping an electronic device, at least once, at that perfect height and angle, causing its screen to crack. Although the technology has advanced, unverified sources claim repairing smartphone screens is still a multi-million dollar industry, proving the relevance of our choice of this subject based on its highly frequent occurrence. Our objectives are to get into more detail into the nature of this failure, understand the root cause of the failure problem, and finally based on the arguments produce an appropriate alternative solution.

1. Description of the Failure

In the contemporary era, smartphones have seamlessly integrated into various aspects of daily life, evolving into indispensable tools. However, the recurrent challenge posed by the fragility of their screens has sparked a need for a more nuanced understanding of smartphone screen failures. These failures often manifest under specific conditions, with common causes including unintentional drops, placement on unstable surfaces, or exposure to unforeseen forces. The resulting visible damage takes the form of delicate, spider web-like cracks, shattered screens compromising structural integrity, or impact sites warping the image. These cracks not only cast doubt on the overall structural resilience of the device but also compromise its aesthetic appeal.

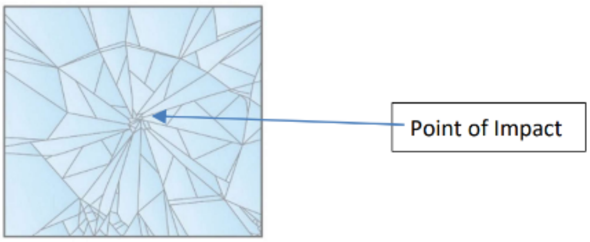

Figure 1: High Stress Mechanical Tension Break

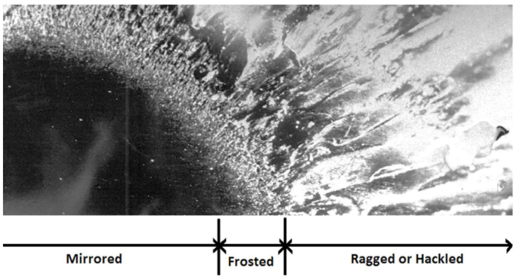

Figure 2: Fracture Face (Edge View)

To comprehend screen malfunctions fully, it is essential to consider the phone's history and purpose. The design, construction quality, and usage habits of the user significantly influence the susceptibility of a phone's screen to damage. Moreover, an examination of the device's role in day-to-day tasks, communication, and online interactions provides insights into the magnitude of impact a screen failure can have. For instance, phones with elegant but delicate designs may be more prone to screen breakage, particularly in demanding or dynamic situations.

This study underscores the importance of combining insights from the analysis of failure scenarios, visible damage patterns, and background context for both smartphone producers and users.

2. Root Cause Analysis

To address the issue of phone screen failure, a comprehensive analysis is necessary. This part aims to delve into various aspects that may have contributed to the failure, considering materials, external factors and user behavior.

2.1 Material Properties

The optical properties of glass are hard to come by in the materials notebook since there exist so few materials that are this well fit, especially for our specific application. Glass is a sub-family of ceramics, basically composed of SiO2 in different concentrations, and may contain other compounds to modify its various properties depending on the type of glass and its applications. [2] Most modern devices are equipped with tempered glass, for which the strength of the material is enhanced by inducing compressive residual surface stresses by different processes.

Generally, ceramics, including glasses, are considered to be hard, with low strength and ductility, making them particularly brittle, they highly resist plastic deformation and have almost no ability to absorb energy upon impact, instead of yielding to the imposed forces, if the stress grows too large, the material experiences catastrophic failure, and fractures.[3] Ceramics are also better at handling compressive loading, they fail under much lower values of tensile forces. Although glasses are the exception to ceramics, since they do deform elastically at very high temperatures, the property is worth nothing but isn't relevant considering the operating temperatures of most electronic devices.

These properties could be in part explained by the amorphous nature of most glasses, the absence of slip systems, and the complex randomized atomic structures limiting the movement of atoms, giving the glasses no chance of deforming plastically.[3] The existence of processing flaws is also likely to cause failure, the presence of cracks, pores internally or on the surface, and inclusions weakens the material, which makes failure likely at lower levels of loading.

Through this quick analysis of the mechanical properties of ceramics in general and those of glasses in particular, it becomes very apparent that the types of imposed forces that a phone screen, for example, may have to endure, could under certain conditions surpass the strength ability of the material.

2.2 External Factors

Understanding the events that lead to the screen malfunction is critical. External forces, such as collisions, drops, or pressure, can exert forces on the screen that are greater than its strength capacity. Tempered glass, which is widely utilized in contemporary technologies, strengthens materials by creating compressive residual surface stresses. Glass failure typically occurs through two primary modes: breakage induced by thermally induced stress, stemming from temperature differences within the glass, and breakage resulting from the tensile forces generated during bending or impact (mechanical stress).[4]

A prevalent cause of breakage is damage to the glass's edges. Such edge damage can significantly diminish the glass's strength by more than 50%, thereby reducing its ability to withstand both thermal and mechanical loads.[4] A glass that has sustained edge damage may remain functional for a certain duration until the necessary combination of thermal stress and/or mechanical loading conditions converge, leading to eventual breakage.

The first step in breakage analysis is establishing the source or location of the breaking. If fragments of the broken light can be maintained or reconstructed into their pre-break configuration, the location of the break origin may typically be recognized. "Wallner Lines" are fracture lines that originate at the origin and radiate along broken branches. [4] When a break develops as a result of defective or damaged edges, the break will occur at the edge of the glass where the damage was present. The fracture direction may be detected by inspecting the lines on the fracture face, as illustrated in the sample.

Whether it's annealed, heat-reinforced, fully thermally tempered, or chemically strengthened, glass is a durable material. Breaks always project into the concave face of these marks, independent of failure mode.

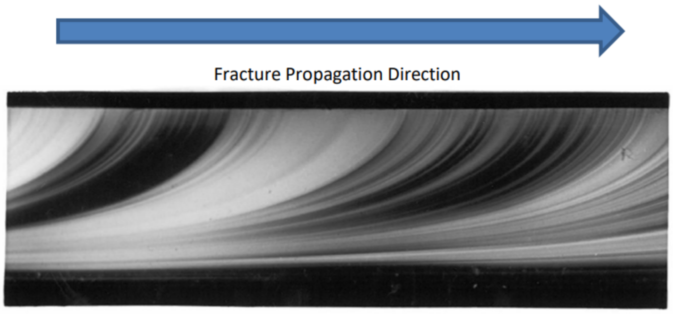

Photo 1A. - Fracture Face Produced by Bending (Edge View)

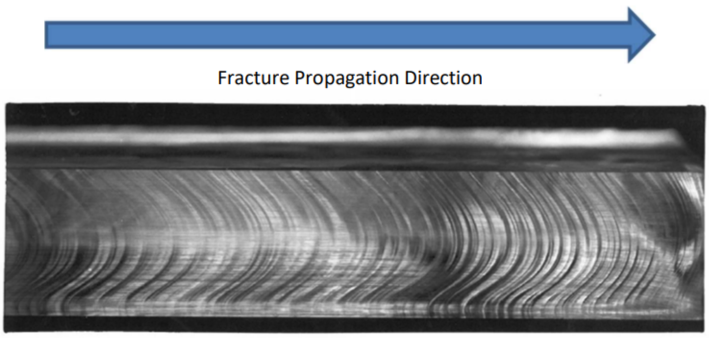

Photo 1B. – Fracture Face Produced by Temperature Difference (Edge View)

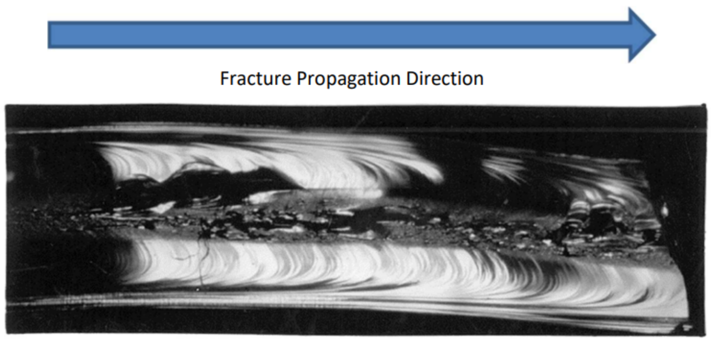

Photo 1C. – Fracture Face of 7/32" Full Tempered Glass (Edge View)

"Glass Breakage - Failure Mode and Stress Estimation." Vitro - Architectural Glass

2.3 User Behaviour

How a user treats their devices has a huge influence on the screen's longevity. Considerations include how the device is being manipulated, whether it is protected with a case or a screen protector to absorb various loads and impacts, and whether any common behaviors may contribute to the screen's vulnerability to damage. Screen failures may be prevented by educating users on correct handling and protective measures.[1]

In summary, understanding and preventing phone screen failures requires a comprehensive strategy that takes into account material qualities, environmental effects, and user behavior. Manufacturers and consumers alike may help in the creation and maintenance of more robust and lasting electronic devices by addressing these aspects.

3. Prevention and Solutions

To ensure durability and increase lifespan, addressing phone screen failures involves a diverse strategy that includes improved materials, preventative measures, user education, and improved device design.

Investing in superior materials or improving screen technology is critical in preventing screen failures. Researchers can investigate materials with improved mechanical qualities, stronger impact resistance, and increased flexibility. Screen technological advancements, such as the development of more robust glass compositions or alternative materials such as flexible polymers, might greatly reduce the vulnerability of phone displays to damage.[5]

The usage of protective cases and screen protectors is one of the most efficient preventative strategies. These attachments serve as a first line of defence, cushioning stress during crashes and reducing the possibility of direct contact between the phone screen and external forces. [1] To ensure complete covering, manufacturers and users should prioritize the development and adoption of durable, well-designed protective covers customized to individual devices.

Additional measures, such as implementing innovative manufacturing techniques to reduce processing flaws, performing thorough quality control checks, or incorporating smart technologies that detect potential hazards and automatically activate protective mechanisms, can help to improve screen durability even further. [5] Regular software upgrades that improve device speed and stability also help to avoid unexpected breakdowns.

Finally, reducing phone screen failures necessitates a multifaceted strategy that includes advances in materials and technology, broad usage of protective accessories, and a commitment to improved device design. By incorporating these steps, the industry can work together to ensure that future gadgets are more durable, dependable, and equipped to endure the demands of regular usage.

Conclusion

Failure is an unavoidable component of engineering, needing a proactive approach to prediction and prevention. Our team dives into the specific context of smartphone screen failures, a common occurrence in our technology-dependent life, focusing on fracture, a most common type of failure. Despite improvements, smartphone screen repair remains a profitable sector, highlighting the importance and frequency of this issue.

Due to unintended drops, precarious placements, and unanticipated pressures, screen fragility offers recurring issues, appearing in fine fractures, shattered displays, and impaired structural integrity. These obvious imperfections not only raise questions about gadget durability but also have an influence on aesthetic attractiveness. One common way that breakage occurs is edge damage, which under certain circumstances can severely reduce strength and ultimately result in fracture.

In conclusion, comprehending and averting phone screen malfunctions requires an all-encompassing approach that takes into account material attributes, external factors, and user conduct. Future screen failures will be lessened by the industry's dedication to implementing improvements in design, materials, and technology as well as the widespread usage of protective accessories.[6] These developments will make electronic gadgets more dependable and long-lasting.

References

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