Synopsis of Strength of Glass from Hertzian Line Contact

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ABSTRACT

This is a synopsis of the paper *Strength of Glass from Hertzian Line Contact*.[1] It was published in Optomechanics 2011: Innovations and Solutions, edited by Alson E. Hatheway. Proc. of SPIE Vol. 8125, 81250E. The goal of this synopsis is to provide a review and discussion of the work cover here to better understand what happens to glass under stress and once Hertzian Line stress occurs, does it affect the strength of the glass during subsequent applications of stress.

1. INTRODUCTION

We have been given both in this paper and in class, a good general rule of thumb for mounting lenses is that polished glass can withstand tensile stresses of about 1000 psi(6.9 MPa).[2] This paper proposes while there is damage that occurs to the glass during high tensile stress events which tend to occur during compressive stress, it does not necessarily mean that a failure occurs. If failure does not occur, does that mean that the glass is now compromised and can it withstand the subsequent applications of stress. Highly concentrated tensile stress can lead to crack or flaws in the subsurface, but it is expected that shallow damage to the glass may cause failure. This paper examines predictive methods using FEA and statistics then examines the results of a series of experiments to see how well the predictive methods compared to the results.

2. UNDERSTANDING THE STRESSES AND STRENGTH OF GLASS

2.1 Hertzian Contact

Hertzian contact happens when a sharp edge provides contact loading with heavy stresses in a very localize region configured in the elastic range.[3] The formula for this maximum tensile stress for the Hertzian point contact is

$$\sigma_t = \frac{1 - 2\nu_g}{3} \cdot \sigma_c \tag{1}$$

where is the ν_g is the Possion ratio for the glass and σ_c is the contact pressure of the cylinder on the glass. The authors noted that this equation does not have friction as a factor but that friction is an important part of the amount of tensile stress in the glass. See the paper for the formulation of the contact pressure.

2.2 Strength of Glass

The authors use two approaches to modeling the strength of glass since glass does not maintain a single characteristic strength value. The methods used were the *Fracture Mechanics Approach*(FMA) an *Statistical Analysis Approach*(SAA). In the FMA, the strength of the glass depends on the depth of the flaw in the glass. Using this a stress intensity factor is found and compared to a fracture toughness. If the stress intensity factor greater than the fracture toughness an empirical value that is the highest value of stress that a fracture in a material can stand without failure.[2] SSA is a functional relation to probability of failure determined by a two-parameter Weibull distribution. This probability is represented by the equation

$$F(\sigma) = 1 - \exp(-(\sigma/\sigma_0)^m) \tag{2}$$

where σ_o and m are parameters that are empirically determined in the laboratory.

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3. FEA SIMULATION

The authors conducted 2D FEA analysis of the ring contact using ANSYS®. This analysis reflected that the stress depths that occur are quite a bit smaller than those allowable flaw depths for a polished BK7 glass. What this means is that the FEA analysis showed that while the maximum stress at the contact point can be very high,19322 psi or 133 MPa, but the depth of these stress value are quite shallow, on the order of$4\mu m$. In addition with these types of stresses the metal can start to yield.

4. EXPERIMENTS

The authors carried out three different experiments to verify the model. A static load, a shock load, and then the DIN 52292-1 Double ring method[4] for bending strength to investigate if there had been any degradation in the glass after loading. During the static load test the authors applied a maximum load of 160 Ksi contact pressure and 26 Ksi maximum tensile stress. Even with these high stress values they did not encounter a failure. In face they had to switch from aluminum pressing fixture to a hardened steel fixture as the pressures caused the aluminum to yield which cause the applied load to be spread over a larger area. Shock loading was carried out according to MIL-STD-810D[5] which is basically pivoted drop test onto a bench of a package containing the glass sample.

Each sample test with the load test underwent the Double ring method to measure the final strength of the glass and the authors reported no failures with either of the load test.

5. RESULTS, CONCLUSIONS, AND COMMENTS

Once the authors had a complete set of tensile stress data. They fit the Weibull distribution of the data to collect the characteristic σ_o and m. The results from these were compared against a control group and t-statistics were used to determine if the data sets had the same mean. The authors concluded that the strength of the glass is highly dependent on the surface quality of the glass where an optically polished glass surface can withstand a higher value of tensile stress than a course ground surface. They also agree that the current rule of thumb of 1000 psi is a very conservative limit. They concluded that 4.4K N/m or 25 lbs/in static load with a $R = 254\mu m$ and a safety factor of 4 from the experiment, the strength of the glass would not degrade.

This author now wonders what would have happened if the experiment included multiple loading of the glass. In the static load test the experimenters maintain the load for 5 seconds but did not comment on any surface damage. If there is surface damage to the glass, could this over repeated applications of force cause enough damage simulate a course ground polish or worse? The lens mounting system would be in a position to cause repeated loading in the same position of the cell thus duplicating a high stress event with multiple occurances.

REFERENCES

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