Brief description of the project (Lens mount interface)

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Introduction

In lens mount, there is a high stress near the contact area. The deformation in the contact area makes a compressive stress, while tensile stress will occur outside the area and will form a truncated 'cone crack' into the subsurface of the glass.

The project is to analysis this phenomena and its effect on the glass strength. We need to analysis how bad the damage may affect the performance and survive of the glass.

Theoretical analysis

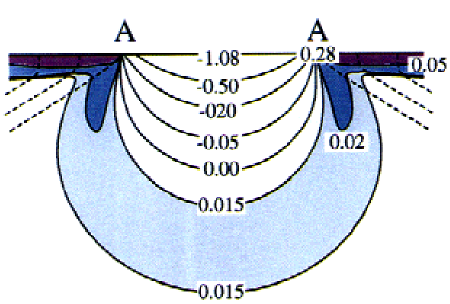
Here I just list some valuable references and concepts to approach the problem, avoiding detail equations.

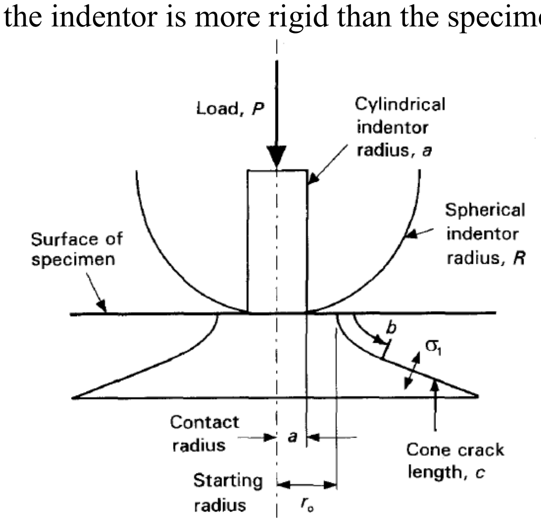
Hertzian contact

(Reference: Contact Mechanics — Johnson K. L. 1985
Rolling Bearing Analysis — Harris T. 2001
Indentation of ceramics with spheres — Lawn B. R.)

By knowing Loading force, contact radii, Young's modulus, poisson ratio, solve for Contact stress field, especially **tensile stress (**first principle stress σ_1**)**. The important feature of the indentation stress field for the initiation of a conical fracture is the tensile region near the specimen surface just outside the area of contact.

Hertzian contact assume that contact is frictionless, but in reality, the use of indentor and specimen materials of different elastic properties leads to **frictional forces** which effectively increase the fracture load when the indentor is more rigid than the specimen.





Fracture Mechanics

(Reference: Fracture of Brittle Solids — Lawn B. R., 1993(book)
The Probability of Hertzian Fracture — Fischer-Cripps, 1994
Weibull distribution — Salamin, opti521Tutorial
Design strength of optical glass — Doyle, Kahan, 2003
Strength of Glass Components — Brian Cuerden
Tie-33 design strength of optical glass and zerodur, Schott)

Auerbach's Law

cone crack appeared when the force reached a critical value which is directly proportional to the radius of the indentor.

Griffith fracture criterion

energy balance criterion relies on a precise knowledge of the indentation stress field.

Weibull distribution

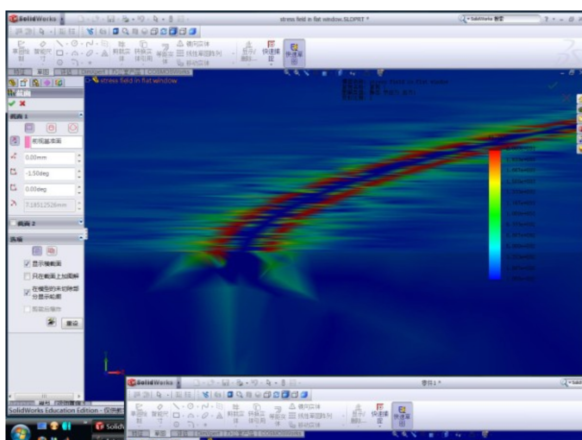
expressed the probability of indentation failure in terms of Weibull statistics which were determined from bending tests involving a stress field which is nearly constant with depth over a distance characteristic of the flaw size.

Crack size

Glass strength degradation from contact damage

Time-to-failure predictions

Static farigue

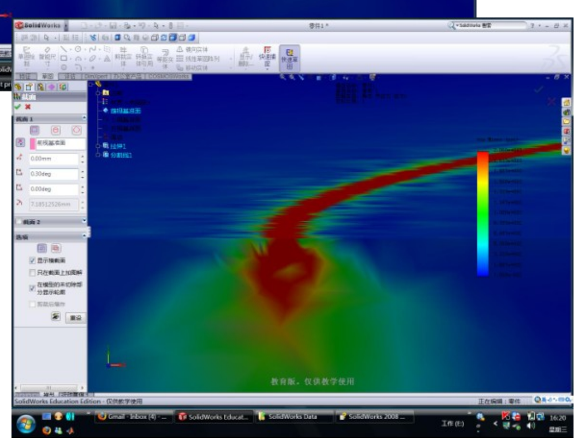


Numerical Analysis

Finite element analysis (FEA)

(Reference: Hand book of optomechanicla engineering)

Using COSMOSWorks in SolidWorks



Upper one is the tensile stress; bottom one is the compress stress.

Contact mechanism
Mesh control(really important)
Nonlinear Static Analysis

Compare result with theoretical analysis

Experiment (in Lab class)

A piece of glass breaks when two conditions coincide. The first is the presence of tensile stress at the surface and the second is the presence of a flaw in the region of the tensile stress. So we first make some flaws due to contact stress on a glass. Then exert different tensile stresses to the cracks on the glass.

Make contact damage
Inspect and classify the surface flaws
Double ring test of strength of the glass

Statistical Analysis
Compare the experiment result with theoretical and numerical analysis.

Goal

Glass does not possess a single characteristic strength. The strength of the material is dependent on the distribution of cracks or surface flaws. These factors, coupled with the inherent brittleness (cause of catastrophic or rapid failure) mean that extremely conservative design approaches are typically used for optical elements made of glass.

The goal of this project is basing on theoretical analysis and experiment data to determine a design allowable for glass elements subject to relatively high stress levels.