Four Point Bending of AMLCD Panel

Issued: February 2021
Supercedes: May 2012

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2012 SID Invited Paper

Abstract

The four-point bend test is used extensively to measure the edge (and surface) strength of AMLCD displays both in panel form and single substrate. The subtleties of four-point bend test for AMLCD panel applications and how one might use additional techniques, such as strain gage, finite element modeling and failure mode analysis, to better understand the data generated, are investigated. This paper attempts to show the following: i) the standard four-point bend equation (Figure 1) is not applicable to thin AMLCD panels, ii) the edges and surface experience different stress, iii) stresses can be quantified by knowing break location and the appropriate strain level and iv) failure mode analysis can support the strain analysis and provide valuable information to the experimenter.

1. Objective and Background

Four-point bend test (Figure 1) is a common way to test mechanical properties of glass. This test has been used extensively on monolithic glass specimens for determining strength in flexure1. For some time now, the test has also been applied to thin glass used for AMLCD panels. Complexities for testing thin glass have been observed due to large deflection and associated slipping. These complexities increase in nature when dealing with a two-piece panel. In view of this, it is not accurate to simply apply the standard four-point bend equation to calculate strength. Instead, a more detailed investigation as to what stresses the panel is experiencing is desired. A combination of strain gages, finite element modeling and failure mode analysis was used to provide a clearer picture of the stresses that occur during four-point bending of a panel. Strain gages placed under the loading knife, on the edge at mid-point of the load span, and at the center of the panel mid span, were monitored and compared with the results from finite element modeling and failure mode analysis.

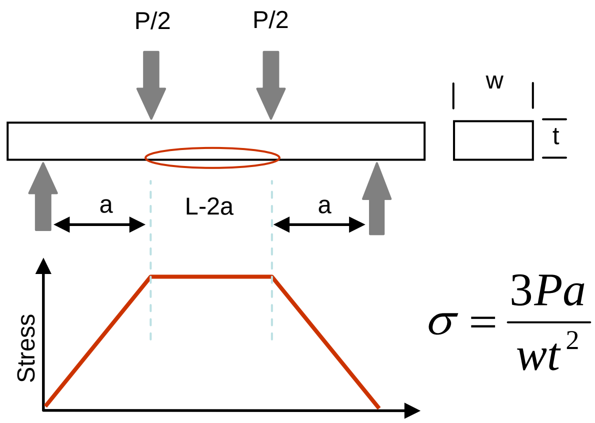

Figure 1. Four-point Bend Schematic with Equation.

2. Setup, Results, and Discussion

a) Four-Point Bend Setup

A standard four-point bend setup is shown in Figure 2 with 50 mm load span, 100 mm support span, loading and support knife diameters of 9.5 mm and a crosshead rate of 5 mm/min. The test specimen consisted of two 0.3 mm pieces of display glass bonded at the perimeter to form a panel without any polarizer attached.

b) Strain Gage Analysis

Three strain gages were placed at various locations (Figure 2) on the panel. Two gages were placed near the edge of the specimen (on the side of the panel placed in tension). One was placed at the mid-span of the edge while the other was placed directly opposite the loading knife to monitor stress concentration due to the loading knife. The final gage was placed on the tensile side of the panel directly in the center and in the middle of the loading span.

c) Finite Element Comparison

A finite element model was created using the test specifics in an effort to understand the strain profiles generated at each strain gage location (Figures 3 & 4).

d) Failure Mode Analysis

Break locations for each failure were noted. The break origins (Figure 5) were identified and mirror radii were measured. The mirror radii were then converted to stress using the appropriate mirror constant for glass.[2]

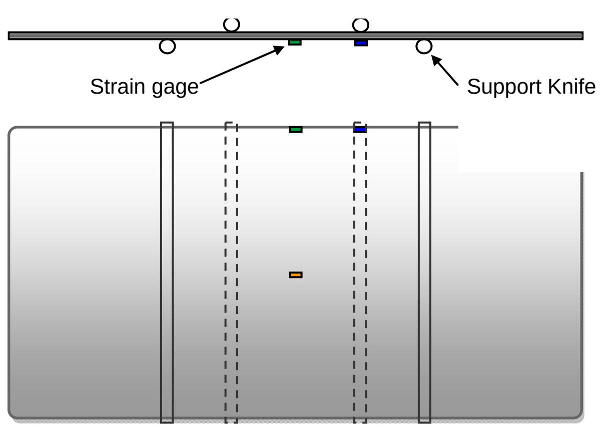

Figure 2. Four-point bend schematic of panel with strain gage locations.

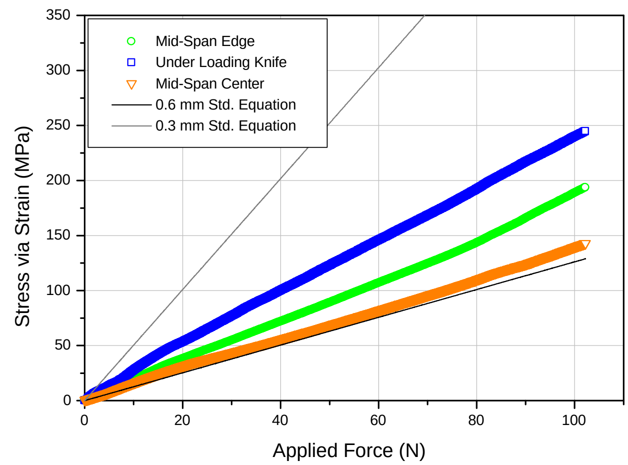

Figure 3. Strain Gage Results with Standard Equation.

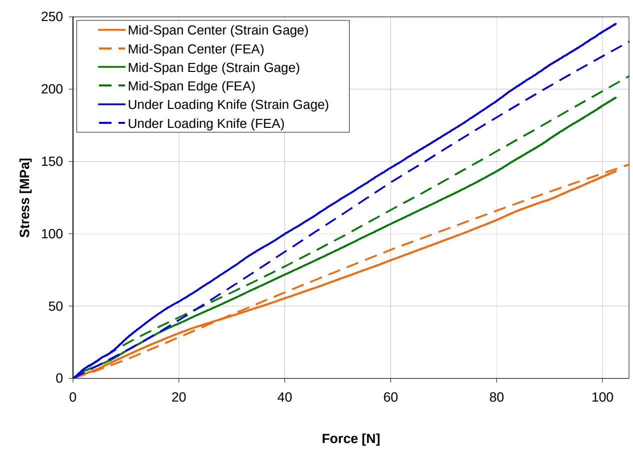

Figure 4. Force to Stress Comparison of FEA Model and Strain Gage Results.

The test was conducted on gaged specimens using the parameters listed previously. Upon breakage, a quick inspection of the specimen is completed to identify break origin location relative to the strain gage. The specimen is then more carefully inspected, break origin is removed and mirror radius is identified, measured and converted to stress. In parallel, the strain gage data are analyzed and converted to stress. The gage closest to the failure origin is used to represent the stress at failure. It is important to know how uniform the stress field is to reduce error when assigning a stress value. The stress derived from the strain gage is then compared with that derived from the mirror measurement. An agreement between these two values of ~10% was observed in most cases. The maximum difference observed was on the order of 30%. This break occurred under the knife edge. It is hypothesized that the stress concentration at that location may develop a rapidly changing stress profile as expected. The strain gage data, when compared to finite element model, agreed to within 10% in most cases.

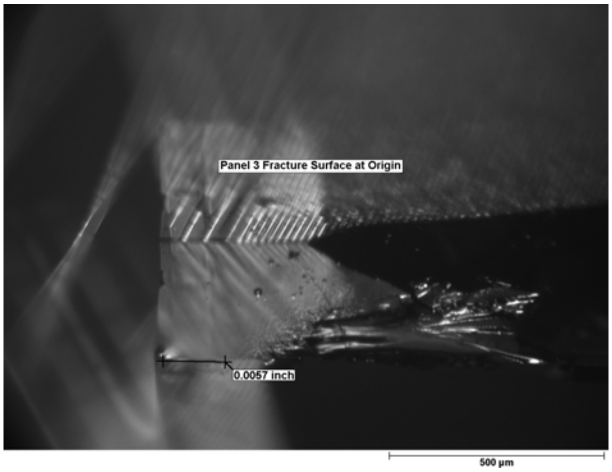

Figure 5. Break Origin with Mirror Measurement.

3. Impact/Conclusions

The four-point bend test is suitable in many applications but it is important to investigate the subtleties of the test when performing the test on AMLCD panels with thin glass substrates. This is true in many cases where the specimen tested goes outside the bounds of standardized testing. In this instance, rigorous use of experience and the tools available can lend credence to experimental data. It is shown that the stress level experienced between the edge and the center of a panel can be vastly different. It is imperative to define the break location and consider the stress at that location when a non-uniform stress field is present. Also, one must take caution to validate test data prior to using standard calculations for reporting strength values.

4. References

[1] ASTM C158, "Standard Test Method for Strength of Glass by Flexure (Determination of Modulus of Rupture)"

[2] S.T. Gulai, et al. (Mirror Contant for Active Matrix Liquid Crystal Display Glass, Ceramic Bulletin, May 2004