LONG-TERM RELIABILITY OF CRT MONITORS

Y. Omoto [1], S. Tani, S. Ohsugi, and T. Karita [2]
[1] Advanced Technology R&D Center, Mitsubishi Electric Corporation,
8-1-1 Tsukaguchihonmachi, Amagasaki, Hyogo, 661-8661, Japan
[2] Image Display Device Center, Mitsubishi Electric Corporation,
1 Babazusho, Nagaokakyo, Kyoto, 617-0828, Japan

ABSTRACT

In this study, an attempt is made to establish design procedures for the CRT (Cathode Ray Tube) monitor based on the statistical evaluation of long-term reliability considering the delayed fracture of the glass that has the scatters and size effect in the strength. The four-point flexure tests are carried out by use of the glass specimens for the examination of fundamental statistical properties of delayed fracture life. On the other hand, a reasonable testing method was developed and employed in order to investigate the long-term delayed fracture properties of CRT monitor under the stress condition corresponding to the atmospheric pressure in place of the conventional hydraulic pressure tests by large-scale equipment. From the test results, the relationship between the reliability and allowable stress for design was clarified and the beneficial information was obtained for the structural design of CRT monitor.

1 INTRODUCTION

CRT monitor (shown in Fig. 1) is the most popular display device that provides the information in clear visual images. The inside of sealed glass tube called “bulb” is vacuumed because of the need to irradiate electron beam, and is exposed constantly to the atmospheric pressure throughout its life. Therefore, the consideration of the delayed fracture is indispensable in the structural design of CRT monitor. It is well known that the brittle material such as glass has the scatters and size effects in the strength, so many works concerned with the strength of brittle materials have been reported [1-4]. In addition, it is important to pay attention to the effect of thermally induced residual stresses during the manufacturing process of CRT bulb on the delayed fracture strength.

The purpose of this study is to establish the design procedures for long-term reliability of the CRT bulb made of glass in consideration of the statistical properties of delayed fracture. In order to investigate the long-term delayed fracture data of CRT bulb efficiently, a convenient testing method was developed in place of the troublesome hydraulic pressure tests by large-scale equipment. The load condition of atmospheric pressure is simulated applying the mechanical load by use of the simple clamp jig. The validity of the proposed testing method is confirmed by the finite element stress analysis under the test conditions and delayed fracture test results. On the other hand, four-point flexural tests were performed using the glass specimens for the examination of the fundamental statistical property [5][6]. From the both test results with regard to the delayed fracture properties of CRT bulb and glass specimens, the relationship between the failure probability and allowable stress was clarified and the beneficial information was obtained for the structural design of CRT monitor.

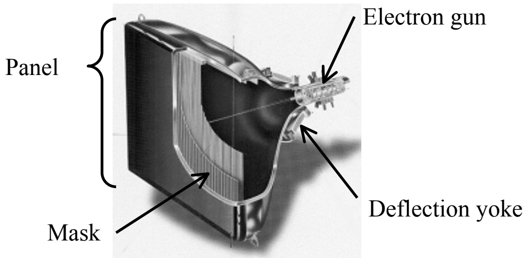

Figure 1: Appearance of CRT bulb

2 MECHANICAL LOADING TEST METHOD FOR CRT MONITOR

A reasonable testing method was developed in place of the troublesome hydraulic pressure tests. In the hydraulic pressure tests by large-scale equipment, it is difficult to perform the long-term test using a lot of specimens. The proposed test was carried out by using a part at the front of the bulb called "panel" as specimen and loading mechanically by clamp jig from a viewpoint of facility. The loading condition by the clamp jig has investigated by FEM analysis in order to generate the stress state of the panel equal to that of the vacuumed bulb exposed to the atmospheric pressure.

2.1 Stress analysis by FEM

To compare the generated stress between vacuumed bulb and loaded panel, the FEM analysis was carried out. The boundary conditions set for 1/4 symmetric model were: (a) uniform pressure for bulb and (b) forced displacement parallel to minor axis of screen, for panel. The distribution of maximum principal stress calculated from FEM is shown in Fig. 2. The analytical results proved that to apply mechanical load to the rear end of the panel makes the stress condition near the fracture origin equal to that of the bulb exposed to atmospheric pressure.

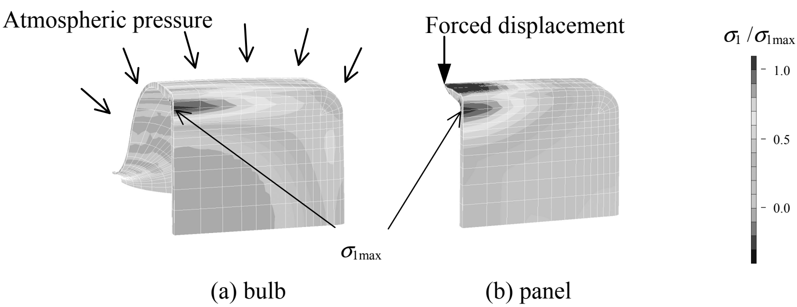

Figure 2: Distribution of maximum principal stress, σ_1 (1/4 symmetric model)

2.2 Comparison of the test results between panel and bulb

Delayed fracture test was conducted in order to confirm the equivalence between the hydraulic pressure test of bulb and mechanical loading test of panel. Each specimen of bulbs and panels were abraded on the surface with emery paper #150. In view of the effect of high temperature during manufacturing process on the residual stress, the panel test specimen was subjected in advance to temperature history equal to the process conditions such as frit seal and exhaust processes. As for the bulb, hydraulic pressure was applied by immersing the sealed bulb into a pressure vessel full of water. As for the panel, a clamp jig shown in Fig. 3 was developed for the test. It has two plates connected by screwed bar, and compressive load can be applied to the position [as shown in Fig. 2(b)] of test specimen sandwiched between the plates by rotating the handle. During the test of panel, strain gages were bonded to the point where maximum stress is induced in order to detect the fracture and to observe whether the load has been maintained during the test.

The obtained results are shown in Fig. 4. As for the bulb, applied stress is translated from applied hydraulic pressure through the result of FEM analysis. As for the panel, it is given by multiplying the applied strain by Young's modulus. The property of panels shows good correspondence with that of bulbs. Furthermore, it was observed that the fracture origins of each types of specimen were almost the same nearby the point where maximum stress is induced. From the study above, the validity of the test method using CRT panel is confirmed.

3 DELAYED FRACTURE STRENGTH PROPERTY OF CRT MONITOR

The delayed fracture properties of glass materials for CRT monitors are shown in Fig. 5. These data are the results of the delayed fracture test of four-point flexure using strip specimen, including that of several types different in finishing process (abrading by emery paper or polishing) or thickness. From the test result, the mean property of delayed

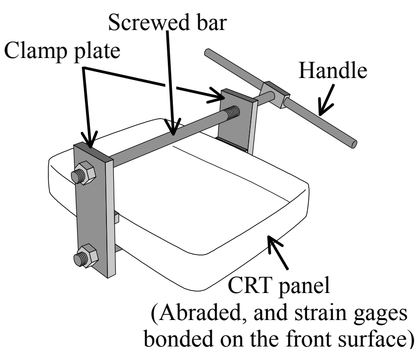

Figure 3: Schematic illustration of clamp jig for CRT panel

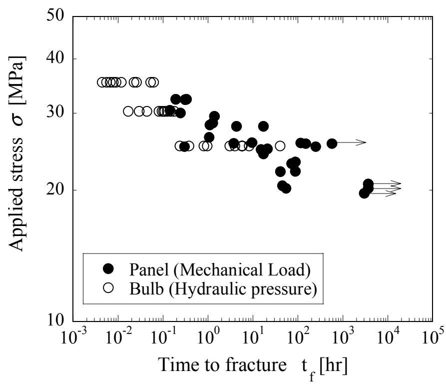

Figure 4: Delayed fracture strength of bulbs and panels

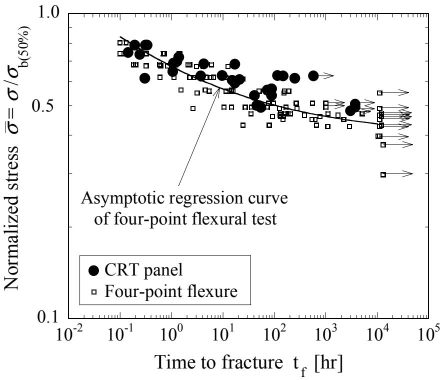

Figure 5: Comparison of delayed fracture properties between glass specimen and panel

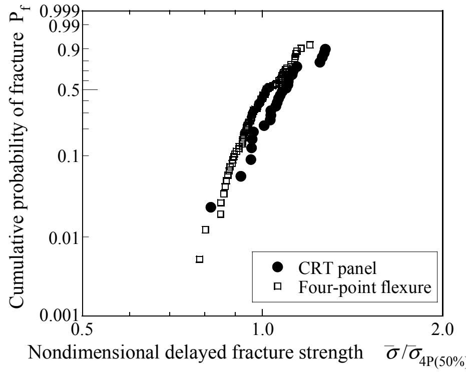

Figure 6: Weibull distribution of non-dimensional delayed fracture strength

fracture can be expressed universally without dependency of finishing process or thickness by using normalized stress $\overline{\sigma}$, i.e., applied stress divided by the mean value of static strength (50% failure probability), $\sigma_{b(50\%)}$. The asymptotic regression curve of the property is shown in Fig. 5. Delayed fracture test of CRT panel was also carried out using the clamp jig described above. The test specimens were abraded on the surface with emery paper #150. The obtained results were normalized by the static strength of the panel as shown in Fig. 5.

It is clear from the test results, expressed in the values of normalized stress, that the data of CRT panels almost correspond to that of the four-point flexural specimen and that the effects of the specimen size and residual stress conditions are canceled. Probability distribution of delayed fracture strength was also investigated for four-point flexural specimen and CRT panel. By using normalized stress $\overline{\sigma}$ mentioned above, the delayed fracture strength for each specimen was evaluated in nondimensional strength $\overline{\sigma}/\overline{\sigma}_{4P(50\%)}$, where $\overline{\sigma}_{4P(50\%)}$ is the average (50% failure probability), normalized delayed fracture strength of four-point flexural specimen at the time to fracture and is given by the regression curve of four-point flexural test shown in Fig. 5. Weibull distribution of delayed fracture strength for each specimen is shown in Fig. 6, in which run-out data are considered. Fig. 6 reveals that probability distribution of strength for CRT panel is almost equal to that for four-point flexural specimen. Based on these results, it is concluded that the strength characteristics of glass by four-point flexural test with abundant data are applicable in evaluating the strength of the actual CRT bulbs by using normalized strength.

4 STRENGTH DESIGN METHOD FOR CRT MONITORS

A study on the reliability of CRT bulb was made using strength properties of glass by four-point flexural test. The delayed fracture strength of glass can be expressed by means of

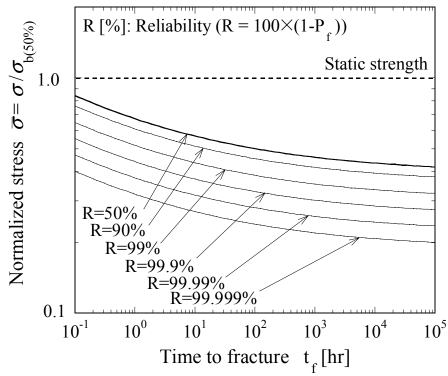

Figure 7: Relationship between reliability and allowable stress normalized by static strength

the average characteristics indicated in terms of normalized stress in Fig. 5 and probability distribution of strength shown in Fig. 6. The relationship chart between the reliability and allowable stress obtained from the characteristics of glass is shown in Fig. 7. This chart and static strength enable to estimate the reliability of CRT monitors at the design life, and it has been confirmed that the products have enough strength for long-term atmospheric pressure.

5 CONCLUSION

For the purpose of evaluating the strength properties of CRT bulb, a test method to mechanically generate the stress state equal to that of a CRT bulb exposed to atmospheric pressure is developed, and confirmed its validity by delayed fracture test. Comparing the delayed fracture properties of CRT panels obtained through the test mentioned above with that of conventional four-point flexural specimen, it is proved that the delayed fracture strength properties of CRT panel normalized by its static strength are almost same as four-point flexural specimen. Based on the result of this study, design procedures for strength of CRT bulb is presented.

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