Reliable Design of the Frame for Tension Type CRT

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Abstract
The deformation behavior of the frame for tension mask CRT is investigated by experiments and finite element method. We calculate and measure the stress-strain relation at the stress concentrations. The endurance test at 100 °C was performed for checking tension decrease with time.

1. Introduction
The mask tension and frame strength are the main factors to be considered when designing a tension type CRT. It is important to make optimal tension distribution for reliable characteristics such as vibration and thermal deformation(1). The engineer engaged in designing tension CRT should consider the life-time reliability(2). Furthermore, the engineer has only restricted discretion since the size and the shape of the frame can interact with the other parts. Mask tension is sensitive to the deformation of the frame during the mask welding process. The material behavior, the relation between stress and strain, at stress concentrations should be closely investigated to make optimal tension distribution of the mask. We investigate the effect of stress concentration and plastic deformation on the strength and reliability of the frame. The tension variation with time was also experimented using the furnace.

2. Experiment
2.1 Mask
The mask/frame assembly for tension type CRT is shown at figure 2.1. For the investigating the strength of tension type mask-frame assembly, the effective material properties of the mask should be considered. Since the mask has many slits in it, it is difficult to get material properties of the mask. The finite element method using the unit cell modeling is well-known

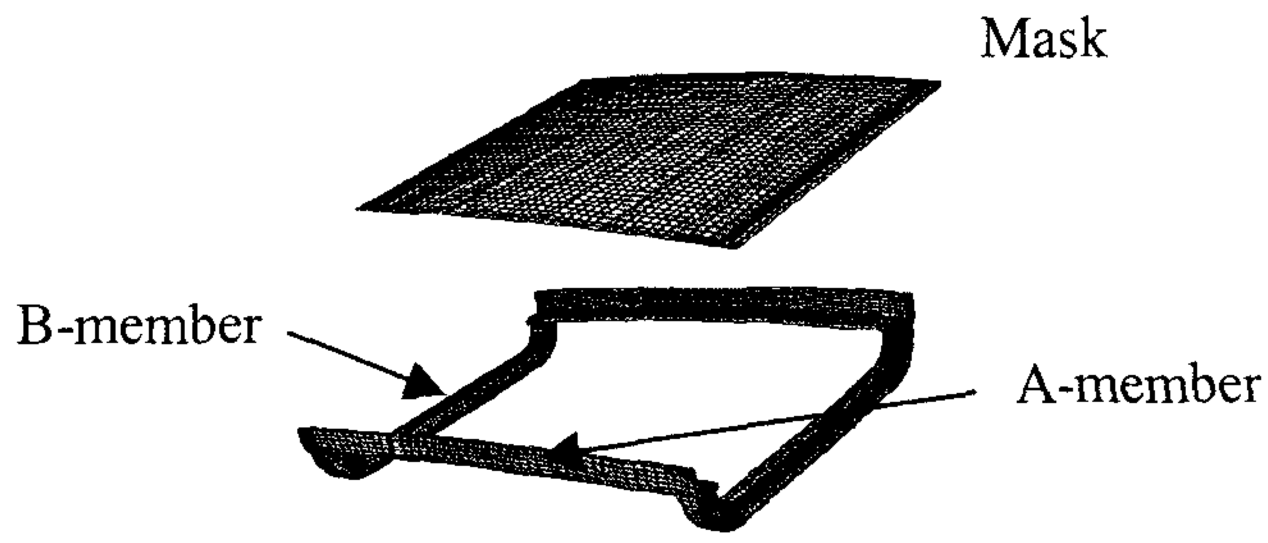

Figure 2.1 Mask and frame for tension type CRT

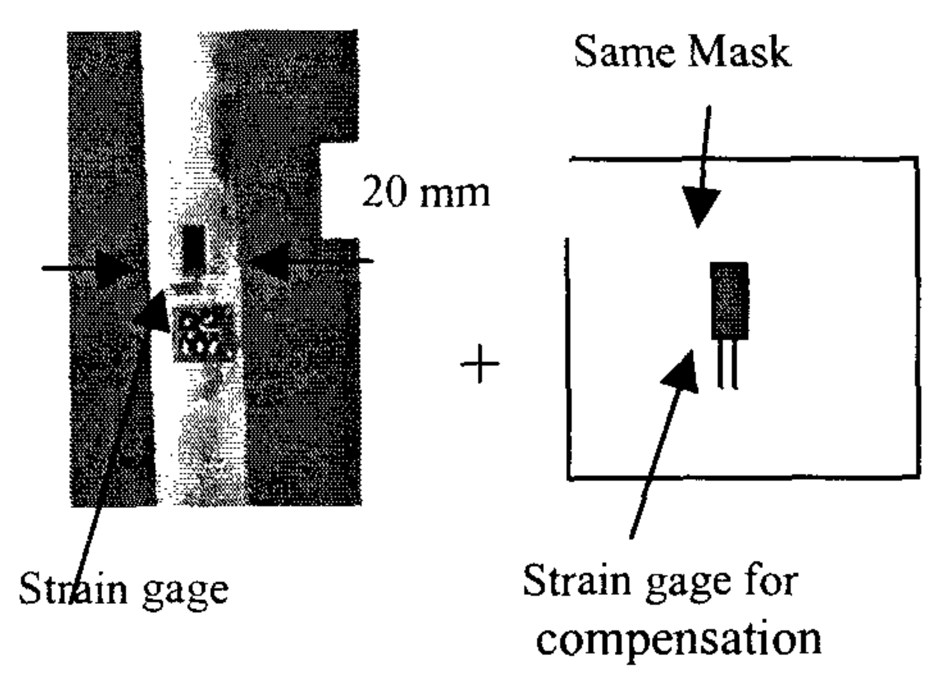

Figure 2.2 Specimen for tensile test

technique to obtain effective material properties. The effective material properties can be calculated from the raw material of the mask. However, the slit size is different at every position due to the variable pitch, it is difficult to consider exact material properties over the entire mask position. The tensile test was performed to get effective mechanical properties of the mask. The strain gage is attached to the mask and the strain was measured. Figure 2.2 shows the tensile test specimen. The strain gage is bonded to the 20 mm wide specimen. The gage length is 6.35 mm and the resistance is 120 Ω. The strain gage for steel can be unstable due to the many slits in the mask. Therefore, the second strain gage is connected for compensation by using half bridge circuit. The output signal remains stable due to the compensation until the specimen broken. Figure 2.3 shows the results of the tensile test. The stress-strain curve shows the linearity over the whole strain range. The plastic deformation does not occur until the fracture. There can be some reasons for the fracture behavior. The stripe in the mask is cut one by one in very short time and the thickness is so small that the fracture style is like tearing. The cracks initiate at the weakest position and finally the specimen is broken like a sheet. Figure 2.4 shows the broken specimen. The fracture occurred along the bridge and the stripes were cut at the center. The fracture toughness of the mask, K_{IC}, may be very small if it can be measured. The tensile test was performed using electric testing machine, INSTRON. Table 2.1 shows the mechanical properties of the mask obtained experimentally. The raw material is the mask position where does not have slits. The fracture stress of the mask center is 49% of the raw material. The fracture stress of the side is larger than that of the center because the pitch of the slit is different from center to edge. The elastic modulus of the mask center is 115GPa. It's 55% of the raw material. Elastic modulus of the side is larger than that of center because it has less opening part due to the large pitch.

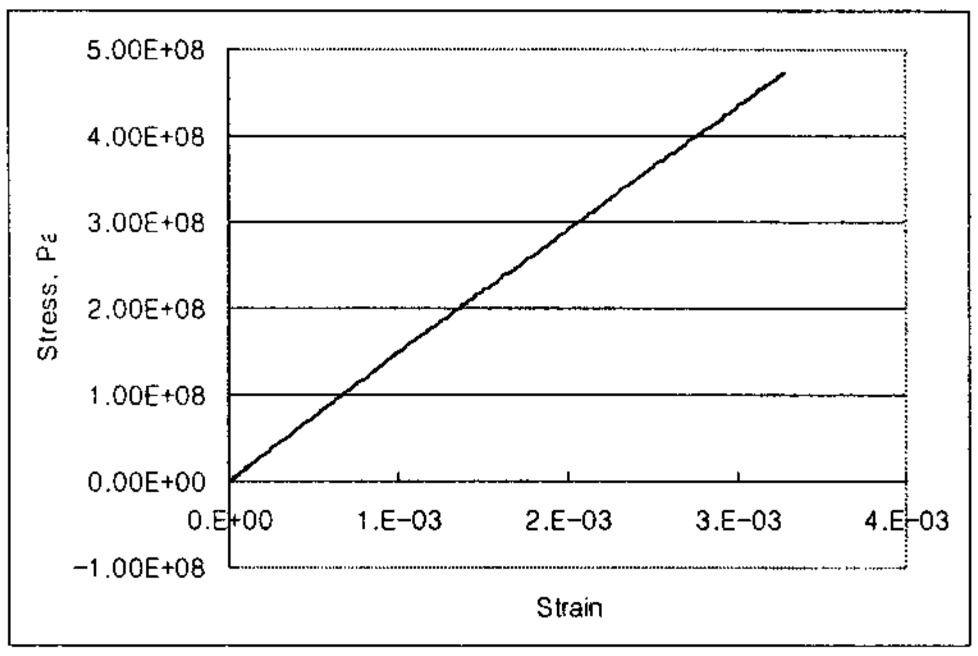

Figure 2.3 Stress-strain relation of the mask

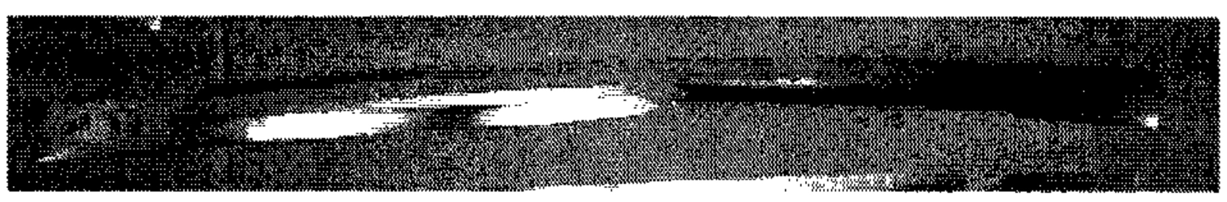

Figure 2.4 Broken specimen

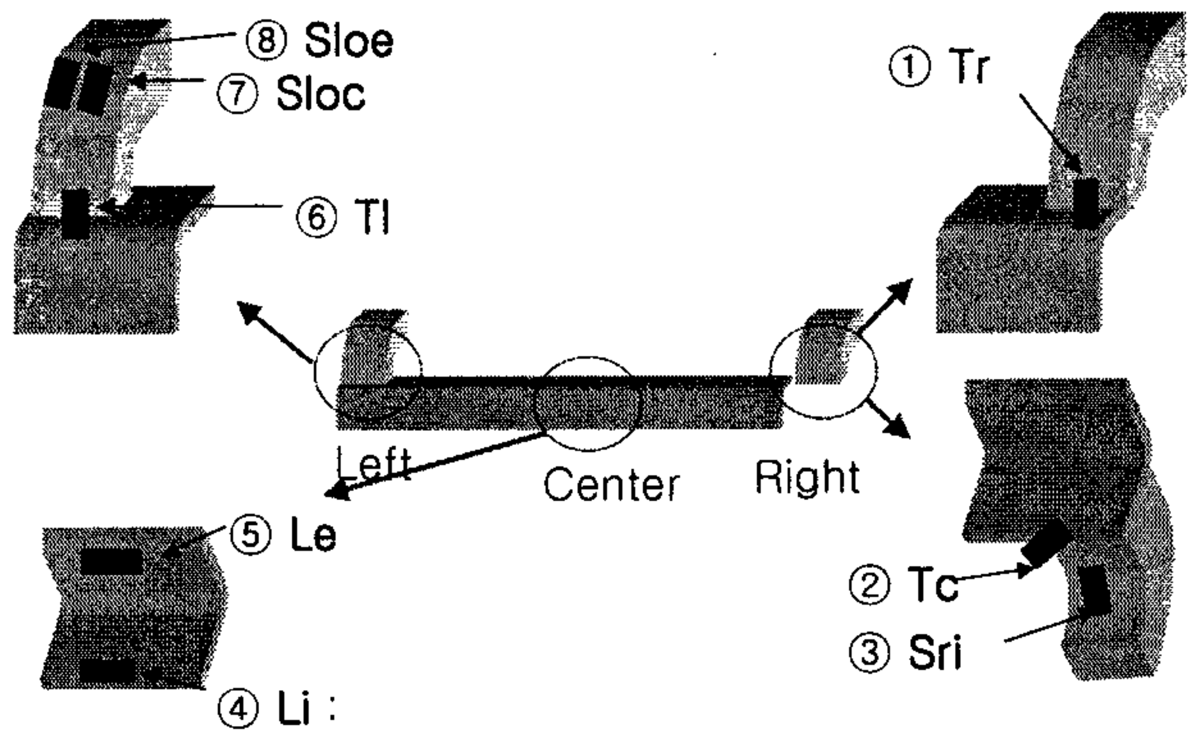

Figure 2.5 Positions to be measured by strain gage

Table 2.1 Mechanical Properties of AK Mask obtained experimentally

	Raw material	Center of mask	Side of mask
Fracture stress, MPa	786 (100%)	382 (49%)	420 (53%)
Elastic modulus ,GPa	209 (100%)	115 (55%)	134 (64%)

2.2 Frame

When the frame is loaded before mask welding process, high stress arise in the frame. Since the volume in the tube is not enough to design for avoiding stress concentrations, the stress concentrations in the frame can not be avoidable. There are some stress concentrations such as bending point of B-member, welding line, etc. The strain gages were attached to the positions of the frame where supposed to be weak. The experiments were performed when the thickness of the B-member was 2.5 mm and 3.0 mm. Figure 2.5 shows the check points of stress-strain relation. The strain gages are attached to bending point of the B-member 2,3,7,8, the welding line, 1,6, and the center of the A-member 4,5. Figure 2.6 shows the results obtained from the

Figure 2.7 Furnace for endurance test

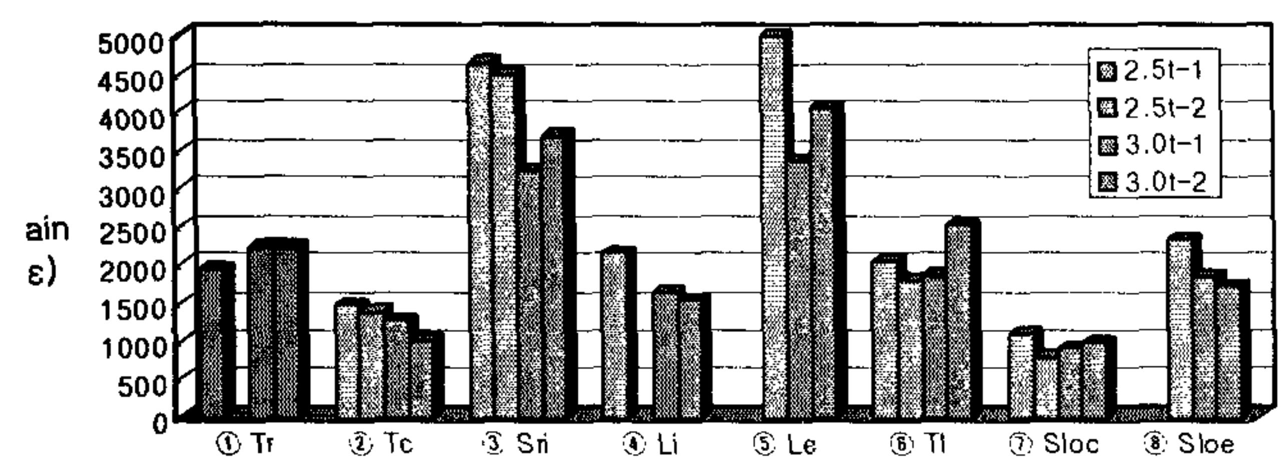

Figure 2.6 Strain at weak positions at the frame

experiment. The largest strain occurs at the center of the A-member; the strain number 5, Le. The load is applied at 6-8 points in one side of the A-member. The stress at the side of A-member is distributed to B-member, but there is no supporter at the center of A-member. The plastic deformation arises at the center of the frame and it makes the high tension at the center of the mask difficult. The bending position of the B-member, 3 Sri, is another weakest point. The unexpected deformation arises at bending process when making frame, which makes a relatively large deformation at this point.

2. 3 Endurance Test

The maximum tension of the mask is over 30% of the effective yield stress. The temperature of the mask during the operation is about 70 °C, so the tension decrease with the time can be a dangerous factor due to the creep. We have made a furnace where tension frame can be inserted and experimented it. We kept the mask-frame assembly in the furnace during 1000 hours and check the tension degradation. The furnce used in the experiment is shown at figure 2.7. The temperature inside of furnace was kept at 100°C. The real mask temperature we have got is about 70 °C, however we controlled the temperature at 100 °C for making severe condition and reducing experiment time. Figure 2.8 shows the results of endurance test. The center, the right side and the left side were measured with the unit of g_f/um. The unit for tension is Pa or something, but it is not easy to measure the tension after the mask attached to the frame. We experimented three specimens, but no tension change was found after 1000 hours as shown in figure 2.8.

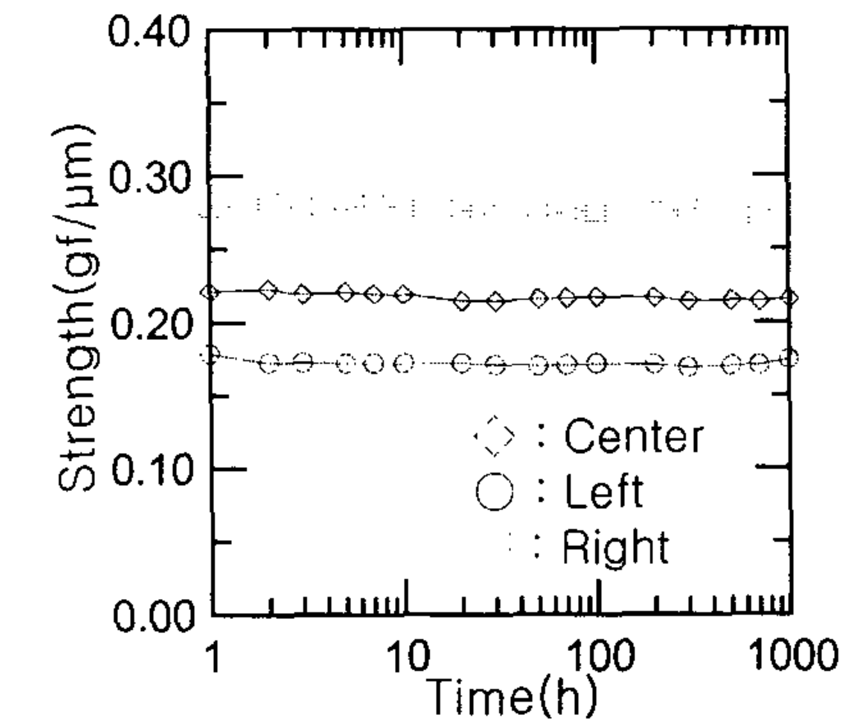

Figure 2.8 Results of endurance test

3. Simulation

The stress distribution of the frame and mask were calculated by using finite element method. The commercial package ABAQUS was used. The calculation process was same with the real mask-frame assembling process. The frame was loaded at the first step, mask attached at the second step and finally the frame was unloaded. Eight node solid element and Von-Mises yield criterion were used. The stress in the frame is the maximum when loading the frame. Figure 3.1 shows the Von Mises stress of the A-member at first step. The maximum stress arises at the center of the frame. The stress is over the yield stress, so plastic deformation was occurred. These results agree well with the experimental work. Although the center of the A-member should be reinforced to increase the strength of the frame, it is not easy when considering the productivity and the cost to make the frame. The B-member stress distribution is shown at figure 3.2. In the experiment, the maximum stress occurred at the bending position, red circle area in figure 3.2. However, the high stress does not occurred at the position in FEM results. In experiment, the stress concentration arises due to the

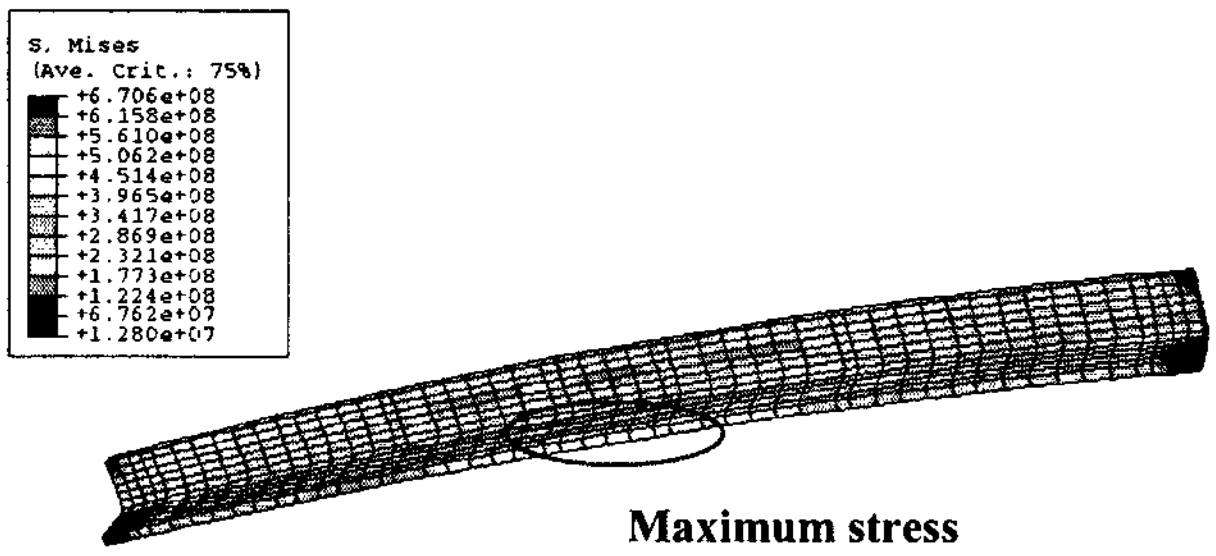

Figure 3.1 Stress distribution in A-member

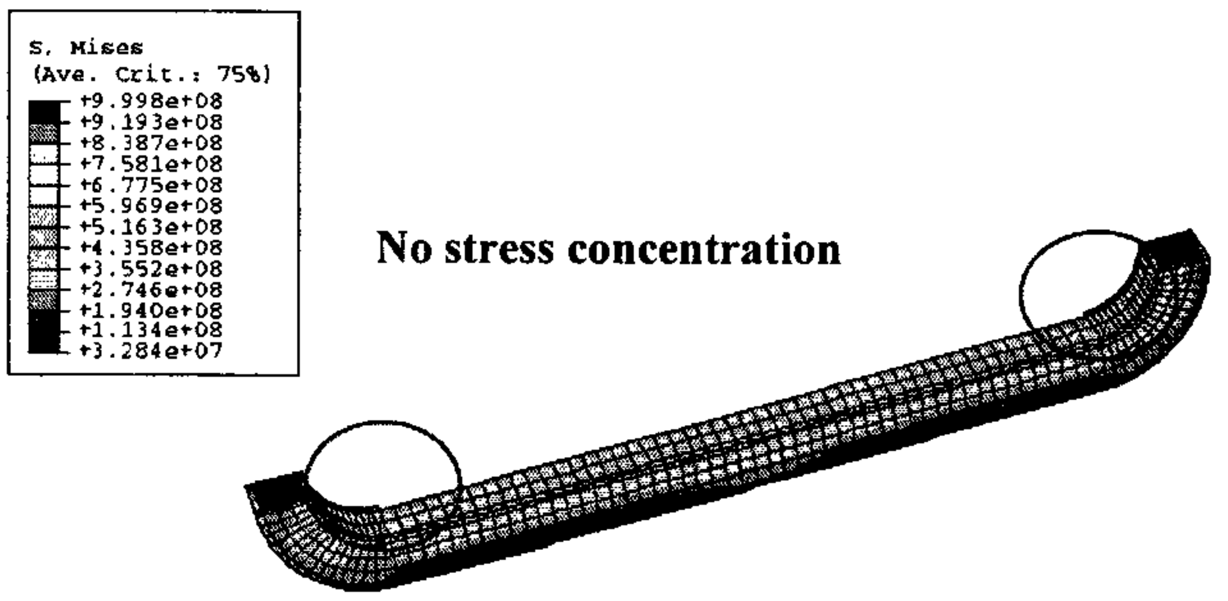

Figure 3.2 Stress distribution in B-member

dent made in bending process of production. The dent has been removed by improving bending process.

4. Conclusions

The deformation behavior of the frame for tension mask CRT is investigated by experiments and finite element method. For the reliable design, We measured the mechanical properties of the mask and strain at stress concentrations in the frame. Some weak points were found, which can be a factor to decrease the strength of frame. Finally, we check the tension variation at 100 °C with time. There were no problem about the tension degradation.

5. References

[1] Kuendong Ha, Dong-Hwan Kim, Jun-Kyo In, 'Vibration Prevention Technology in Jumbo Flat CRTs of Tension Type Iron Mask,' SID '00 Symposium Digest, 32,1210-1213, (2001)

[2] Arimoto Nozomu, 'Color Picture Tube,' Japan Patent No.1998-045722, 1999