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Fatigue Life Prediction of the LCD Transfer Robot Frame

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Abstract: In this paper, an integrated fatigue life prediction methodology is presented for design validation of the LCD transfer robot. For accurate fatigue life analysis, S-N curves are generated with the materials used in the robot by rotating bending fatigue tests. Static stress analysis is carried out with the FE model of the frame component. Strain gage test results are compared with FE stress analysis results to validate the analysis model. Dynamic load history can be obtained through flexible multi-body dynamic simulations. Then fatigue life of the structural component can be predicted with the dynamic stress history and the S-N data. To validate the proposed methodology, fatigue tests are performed with the sub assembly component.

1. INTRODUCTION

LCDs are widely used to TV's, computers, mobile phones, etc. because they offer some real advantages over other display technologies. They are thinner and lighter and draw much less power. Recently, the size of raw glass is greatly increased in a new generation LCD technology. In order to handle bigger and heavier glasses, it is necessary to develop a large scale LTR (LCD transfer robot) to support various complicated LCD fabrication processes. It will cause many difficult design problems such as vibration and high stresses due to heavier dynamic loads, resulting in inaccurate transfer motion and fatigue cracks. Therefore it is necessary to establish a methodology for predicting deflections, vibrations, and dynamic stress time histories using virtual computer simulation model. An integrated design simulation method would be useful to validate a baseline design and to propose new improved designs. In this paper an integrated fatigue life prediction methodology is presented based on the existing FEM and flexible body dynamics technology. For accurate fatigue life prediction, fatigue tests are carried out to obtain the S-N data for the materials used in the robot. In order to validate the simulation model sub assembly and full system strain gauge tests were executed as shown in Fig.2

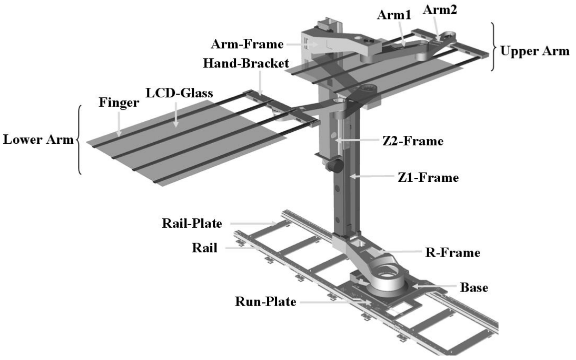

Fig. 1. 8th Generation Commercial LCD transfer robot

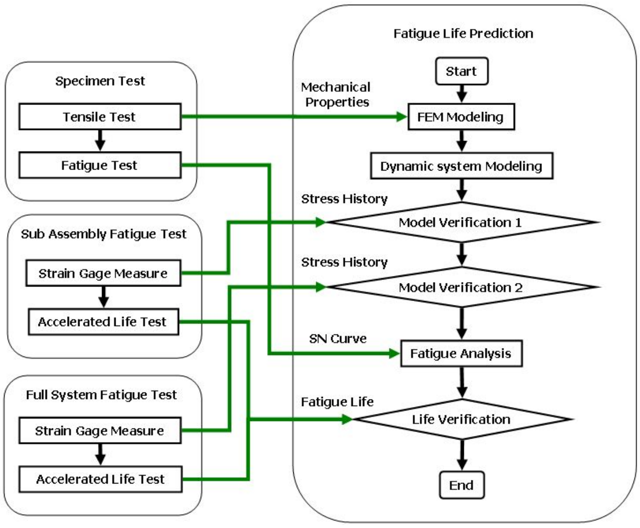

Fig. 2. Fatigue analysis flow chart for the LCD transfer robot

2. MATERIAL TEST

To obtain accurate material data, static and fatigue tests were executed with standard test specimens. The specimens were obtained from the aluminium cast alloys used in the robot, with the same surface condition of the LCD transfer robot frame. Fatigue tests were run on a cantilever rotating bending test machine as shown in Fig.3. Test frequency was 100 Hz. Rotating bending test method was recommended because the speed of the rotating bending test was 5 times faster than the axial loading test in this case. A S-N curve was obtained from 20 specimens.

Fracture surfaces were observed through SEM. Fig.4 shows the crack initiation site was adjacent to the pore. S-N curve represented average life and its distribution. 1% failure probability curve was used to show the fatigue life of LTR conservatively as shown in Fig.5.

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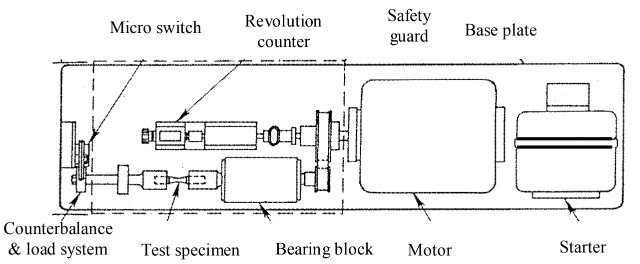


Fig.3. Rotating bending fatigue test machine

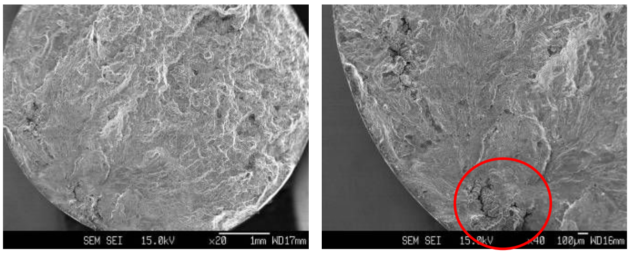


Fig.4. Representative fracture surfaces.

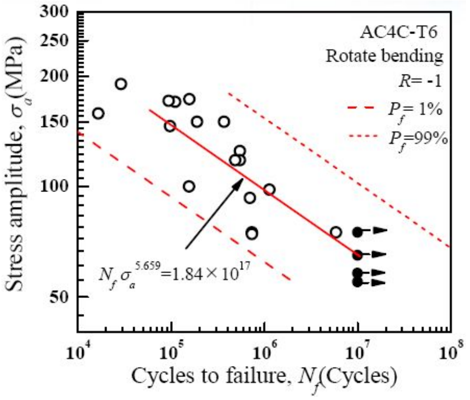


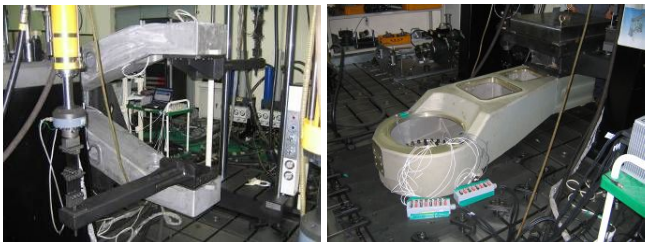
Fig. 5. S-N curve

3. SUB ASSEMBLY FATIGUE TEST

To verify FE model sub assembly strain measuring and fatigue test were done. Sub assembly fatigue test can accelerate testing time faster than full system test. 5Hz frequency sine wave type loads were given. The load amplitude was calculated by dynamic simulation of real system load amplitude when it was running. As shown in the Fig.6 the sub assembly fatigue test equipments were made of jigs and hydraulic linear actuators. The fatigue tests were completed until 10 million cycles which were the required fatigue limit in the LCD production line and there was no fatigue crack found.

4. FATIGUE LIFE PREDICTION ANALYSIS

In order to get stress history the dynamics simulation model was made. All of the structures were made of FE flexible bodies to apply vibration effect. The stress histories of the frames were achieved by modal superposition method and they were compared to the test results through the strain gauge measure. The differences of the stress of the test and simulation were under 13.9 % (table 1).



(a) Arm frame (b) Base frame

Fig. 6 Sub assembly fatigue test equipment

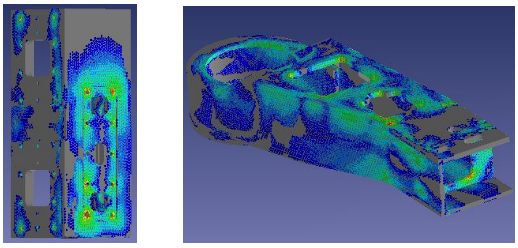
Table 2 shows the fatigue life of the arm frame and the base frame at the most critical locations. The fatigue life was more than 10 million cycles in the condition of 1% fracture probability, so we could conclude the structure would be safe.

Table 1. Stress range difference of test and CAE

	Arm frame	Base frame
Sub assembly	10.1 %	8.6 %
Full system	13.9 %	12.8 %

Table 2. Fatigue life estimation results

	Arm frame	Base frame
Life (cycle)	1.45 E7	3.79 E7



(a) Arm frame (b) Base frame

Fig. 7 FE results of fatigue life on the 8G LTR frame

5. CONCLUSIONS

A computer simulation methodology was presented for fatigue analysis of the LTR system. To have a valid simulation model, stress analysis results were compared with the strain gage test results. Comparison of the analysis and test results shows that they correlate well with each other. Fatigue crack failure can be predicted with the baseline design. The results of the virtual durability assessment are quite good, and show good correlation with the areas of failure on the test. The value of being able to predict service lives based on results obtained exclusively in the virtual domain is obvious. The proposed methodology can be used to develop a new large scale LTR robot in the early design stage.