Research and Application on the Hanging Ear Fracture of Optical Film for Vehicle Display Module

Jie Mei*, Chuanghua Deng*, Cen Yi*, Qianshuang Hu*, Shuliang Yu**, Hongcheng Zuo**, Suimang Song**, Zheng Zhou**, Zhiwei Tan*
*TCL China Star Optoelectronics Technology Co., Ltd., ShenZhen, China
**TCL China Star Optoelectronics Technology Co., Ltd., WuHan, China

Abstract

In recent years, large-screen and multi-screen have become the mainstream trend in the development of vehicle display module, and vehicle display module is an important component of modern car. As the module becomes larger, the hanging ear of module film is more prone to be broken, leading to abnormal display. This paper simulates the vibration testing of module film and quickly and effectively assess the risk of high and low temperature random vibration testing, providing film design guide through finite element analysis, studying the effects of the hanging ear design parameters on fatigue fracture, and combining the high and low temperature S-N curve of the film material.

Author Keywords

Vehicle display module; Random vibration; Simulation; Thermal; Fatigue

1. Introduction

When developing vehicle display module, it is necessary to consider the special usage environments and requirements of automobiles, such as anti-vibration, high and low temperature resistance, and so on. There are various optical films inside the module, which need to be designed to ensure that they can deform freely under high and low temperatures to prevent wrinkles and damage. According to statistics, 27% of environmental failures in electronic products are caused by vibration[1] . Making physical tests can effectively find product problems, but it is costly and time-consuming. Simulation can avoid problems in product design at the beginning of product design, and has the advantages of low cost, safety, rapidity, and repeatability in predicting module reliability. Therefore, it is a cost-saving and feasible solution to determine film design and material selection by simulation.

Figure 1. Failure hanging ear

This paper focuses on the hanging ear fracture of film in vehicle display module. The film hanging ear is mainly used to limit film sliding. During vibration testing, the hanging ear may break due to continuous collisions with the light guide plate(LGP) positioning pillar (Figure 1), and the hanging ear of the upper brightness enhancement film(BEF) is most likely to be broken. This paper provides the suggestions for failure analysis and film design by taking the design of the upper BEF hanging ear as the research object and developing the simulation model for the vibration fatigue of the hanging ear.

2. Simulation Model

2.1 Model of Vehicle display module

The vehicle display module is mainly composed of CELL, frame, upper BEF, lower BEF, diffuser film(DIFF), light guide plate(LGP), reflective film(REF), and back cover(BC) (Figure 2). BC is fixed on the vibration table through fixtures, and the load is applied to the vehicle display module through the vibration table.

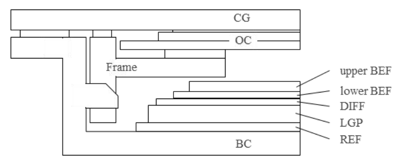
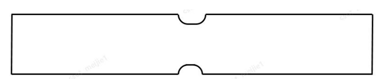
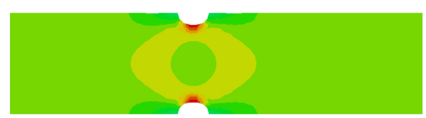


Figure 2. Stacking structure of vehicle display module

Three-dimensional simulation model is established for the module. In finite element analysis, mesh density and element type are particularly important. This paper uses static analysis to get the stress in the hanging ear and compares it to the theoretical calculation value to determine the mesh density and mesh type for the hanging ear. The theoretical force model on this shape is a plate with notches on both sides (Figure 3(a)), and the simulation stress is shown as Figure 3(b).



(a) Schematic of the test hanging ear shape



(b) Simulation stress of the test hanging ear shape

Figure 3. Simulation Model of the hanging ear

The stress concentration factor and the reference stress[2] are：

$$\sigma_{max} = \alpha_\sigma \sigma_n = \alpha_\sigma P/bt$$

α_σ is the stress concentration factor . σ_{max} is the maximum stress σ_n is the nominal stress. t is the thickness of the specimen , and b is the minimum width of the strip. These are all factors that affect the stress concentration. By substituting these values into formulas, we can determine σ_{max} for the notch. Then we use σ_{max} to determine mesh density and type. The result is shown in Figure 4 (a) and (b) through finite element analysis.

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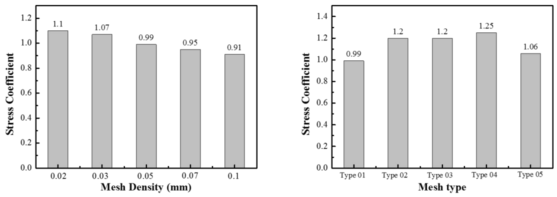


(a) the effect of mesh density (b) the effect of mesh type

Figure 4. The relation between stress coefficient($\sigma_{simulation\ stress}/\sigma_{max}$) and mesh

Through different notch sizes, similar mesh convergence results are obtained. Therefore, the mesh size of the hanging ear is chosen as 0.05mm and the solid-shell element is used.

2.2 Thermal load

During the vibration test, a temperature cycle with a period of 480 minutes will also be applied （ Figure 5） . During the thermal loading, the film may experience thermal expansion and contraction. Therefore, when designing the vehicle display module, the gap between the upper BEF and the LGP positioning pillar is must sufficient consideration. If the gap is too small, it will cause excessive stress on the film. If the gap is too large, it will cause vibration and shaking. In finite element analysis, the high and low temperature cycles are simplified into two independent simulations coupled with vibration separately.

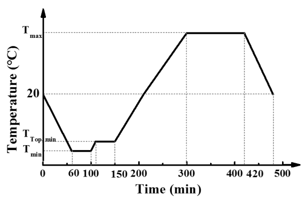


Figure 5. Temperature curve

2.3 Random vibration analysis

Random vibration requires modal analysis first. Modal analysis can achieve modal efficient mass (excluding the mass of the vibration table) over 96%[3] from 0 to 2000Hz.

To simulate the irregular vibrations during real driving, the vibration test uses random vibrations along the X, Y, and Z axes for 8 hours each time with the power spectral density(PSD) of the random vibrations (Figure 6). In finite element analysis, separating simulations are conducted for each of the X, Y, and Z axes.

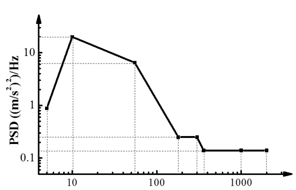


Figure 6. PSD curve

2.4 The life test of specimen

The film hanging ear is subjected to cyclic stress in high and low temperature conditions during the experiment, and the failure mode is high cycle fatigue. The S-N curves of various flanges are different, and need to be obtained through specimen testing. (Figure 7).

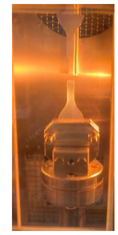
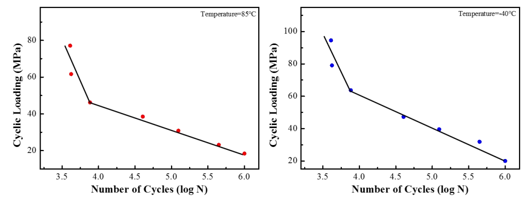


Figure 7. High temperature fatigue testing of film

The film in this paper is tested on a high and low temperature fatigue machine with notches on both sides of the plate. The results are shown in Figure 8 (a) and (b).



(a)high temperature (b)low temperature

Figure 8. Film S-N test curve

3. Results and discussion

During vibration testing, thermal and random vibration loads are applied together, and vibrate separately in the X, Y, and Z axes. In the simulation, the test is divided into three steps: the first step is thermal analysis (high and low temperature calculations), the second step involves modal analysis with thermal stress, and the third step is random vibration. According to the test requirements, this paper uses infinite life judgment (life cycles > $10e^6$) for high and low temperature.

The shape of the film hanging ear is shown in Figure 9. A is the gap between the upper BEF and the LGP in the up and down direction, B is the gap between the upper BEF and the LGP in the left and right direction, H is the width of the LGP positioning pillar, and R is the round corner radius of the upper BEF. In this paper, R is 0.6mm, A is 0.05mm, B is 1.2mm, and H is 1mm in original design. The simulation result is shown in Figure 10, and the maximum stress position is consistent with the fracture position.

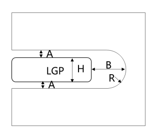


Figure 9. The shape of the hanging ear

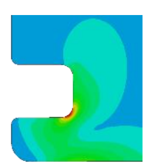
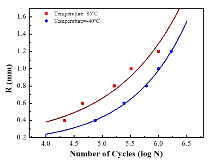


Figure 10. Simulation stress

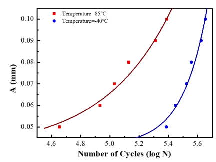
3.1 The effects of R, A, B, H

We simulate the stress when design factors take different values and calculate the corresponding high and low temperature life. Figure 11 shows the effects of parameters R, A, B, and H on the life of the hanging ear. It can be seen from the Figure 11 that the failure life of the film at high temperature is significantly lower than that at low temperature. Each parameter is analyzed below:

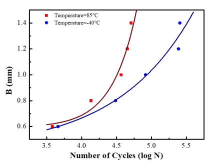
(1) As shown in Figure 11(a), when R ranges from 0.4mm to 1.2mm with a gradient of 0.2mm, the stress of the hanging ear decreases with R increasing. Increasing R can effectively improve the stress concentration phenomenon of the hanging ear;
(2) As shown in Figure 11(b), when A ranges from 0.05mm to 0.1mm with a gradient of 0.01mm, the stress of the hanging ear decreases with A increasing. The reason is that after increasing A, the force between the film and LGP decreases;
(3) As shown in Figure 11(c), when B ranges from 0.6mm to 1.4mm with a gradient of 0.2mm, the stress of the hanging ear decreases with B increasing. The reason is that after increasing B, the force between the film and LGP decreases;
(4) As shown in Figure 11(d), when H ranges from 1mm to 1.8mm with a gradient of 0.2mm, the stress of the hanging ear decreases slightly with H increasing. The reason is that after increasing H, the gap between the film and LGP does not decrease, and the force changes are not significant.



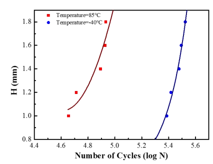
(a) The effect of R



(b) The effect of A



(c) The effect of B



(d) The effect of H

Figure 11. Effects of R, A, B and H on the hanging ear life

3.2 Testing and Analysis

Based on the above analysis, H has a little effect on the life of the hanging ear, so we choose the design upper limit of 1.8mm. Both A and B have effects on the life of the hanging ear, and increasing A and B can also effectively improve the stress concentration of the hanging ear. However, in the product, if A and B are too large, it will cause the film to rotate excessively. Therefore, A and B are set to the design upper limits of 0.1mm and 1.4mm respectively. R has a significant effect on the life of the hanging ear, and increasing R of the hanging ear can effectively improve the stress concentration. As shown in Figure 11, when R is 0.6mm, 0.8mm, and 1.0mm, the film life is less than $10e^6$ and has high risk of fracture. The film life is more than $10e^6$ when R is 1.2mm. So we use R=1.2mm in the actual product, and the product did not experience the hanging ear fracture in the high and low temperature vibration test.

4. Conclusions

This paper analyzes the effects of R (the round corner radius of the upper BEF), A (the gap between the upper BEF and the LGP in the up and down direction), B (the gap between the upper BEF and the LGP in the left and right direction) and H (the width of the LGP positioning pillar) through simulation analysis and experimental testing. The following conclusions are drawn:

(1) The position of the maximum stress on the hanging ear in the simulation model is consistent with the actual fracture position, so simulation can effectively evaluate the life of the hanging ear;

(2) The fatigue limit of the film is greatly affected by temperature, and the high temperature life is significantly lower than the low temperature life;

(3) H has a little effect on the test life of the hanging ear, while A and B have moderate effects, and R has a greater effect on the life of the hanging ear.

In summary, since R has the greatest impact, it is necessary to consider increasing the R of the film first in the subsequent product design, and then consider increasing A and B, but not exceeding the design limit to avoid flipping of the film. Simulation can effectively predict the test life of the film vibration and guide the product design.

5. References

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[3] Yiping Shi, Yurong Zhou. Detailed Explanation of ABAQUS Finite Element Analysis Example, pages 280~301, 2006