Reliability Design Of Mechanical Systems Subjected To Repetitive Stresses

Seongwoo Woo[a*], Dereje Engida Woldemichael[a] and Samson Mekbib Atnaw[a]

[a]Addis Ababa Science & Technology University

***twinwoo@yahoo.Com**

Abstract

Based on field data and a tailored set of parametric accelerated life testing (ALT), the hinge kit system (HKS) of a closing door in a refrigerator was redesigned to improve its lifetime. Using a force and moment balance analysis, the mechanical impact loads of HKS were calculated in closing the refrigerator door. At 1st ALT, the HKS failure happened in the fracture of the kit housing, and oil damper was leaking in breaking up HKS. The failure modes and mechanisms found in 1st ALT were similar to those of the failed samples obtained in the field. The missing design parameters of HKS included the corner rounding, insufficient rib of the housing hinge kit, and the oil sealing way of the oil damper. Based on second ALTs, the fracturing occurred in the cover housing. The missing design parameter of the cover housing in HKS was the plastics material. After two rounds of parametric ALT with corrective action plans, lifetime of a newly designed HKS is guaranteed to be over B1 life 10 years with a yearly failure rate of 0.1%.

Introduction

When a customer uses the door in commercial refrigerator, they want to close it gently. For this (intended) function, the hinge kit system needs to be designed to handle the operating conditions subjected to it by the consumers who purchase and use the Refrigerator. The purpose of this study is to present the reliability methodology to the mechanical system like HKS subjected to repetitive loading in the commercial Refrigerator. The reliability methodology includes 1) load analysis, 2) a tailored of parametric ALTs with design modifications, and 3) checking to satisfy the lifetime targets of the HKS.

Parametric Accelerated Life Testing (ALT)

In the field, HKS parts of a Refrigerator were failing due to cracking and fracturing Based on the customer usage conditions, HKS were subjected to different loads during the opening and closing of the refrigerator door. Under the same environmental conditions, the life-stress model (LS model) can be expresed as

$$TF = A(S)^{-n} = AT^{-\lambda} = A(F \times R)^{-\lambda} = B(F)^{-\lambda} \quad (1)$$

We know that product lifetime depends on applied impact force. Therefore, the acceleration factor (AF) can be expressed as

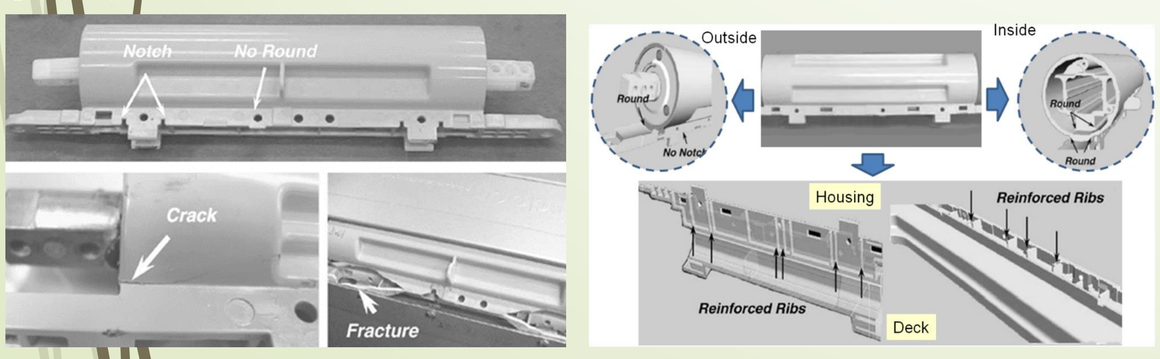
$$AF = \left(\frac{S_1}{S_0}\right)^{n} = \left(\frac{T_1}{T_0}\right)^{\lambda} = \left(\frac{F_1 \times R}{F_0 \times R}\right)^{\lambda} = \left(\frac{F_1}{F_0}\right)^{\lambda} \quad (2)$$

To carry out parametric ALT, the sample size equation with the acceleration factors in equation (2) might be expressed as [1]:

$$n \geq (r+1) \cdot \frac{1}{x} \cdot \left(\frac{L^{*}_{BX}}{AF \cdot h_a}\right)^{\beta} + r \quad (3)$$

RESULTS & DISCUSSION

In 1st ALT, the housing of HKS fractured at 3,000 cycles and 15,000 cycles. (Figure 1).



(a) field & 1st ALT (b) Redesigned HKS housing

Figure 1 Failed products in field & 1st ALT and design modifications

When breaking down HKS, oil damper spilled at 15,000 cycles (Figure 2).

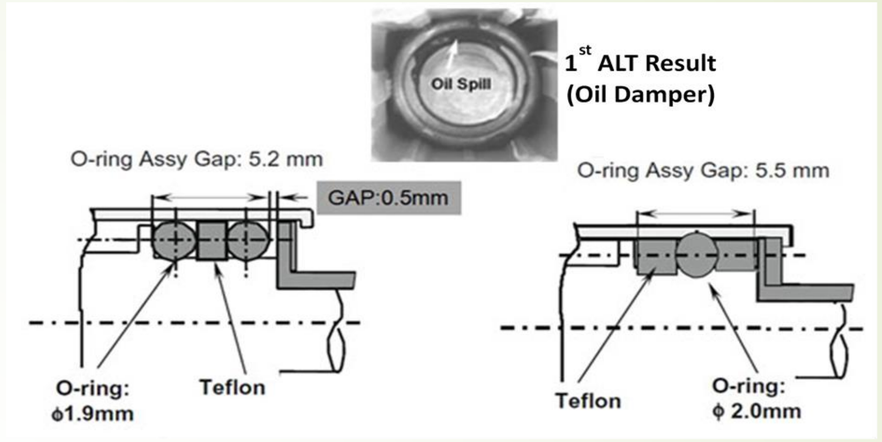


Figure 2: Spilled oil damper in 1st ALT and redesigned oil damper

In the second ALTs, the hinge kit cover fractured in the cover housing of HKS at 8,000, 9,000, and 14,000 cycles (Figure 3).

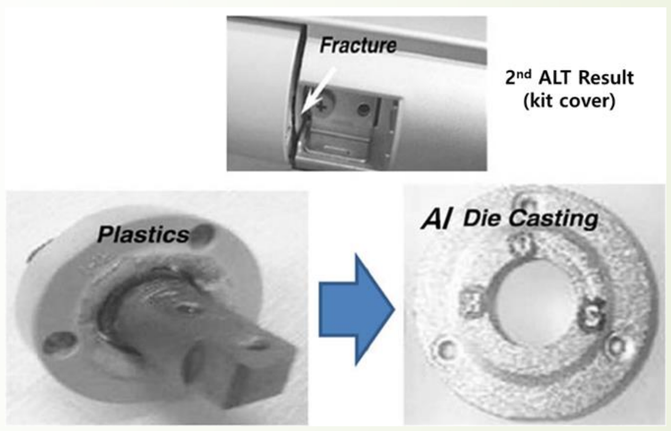


Figure 3: Fractured cover housing in 2nd ALT and its redesign

To withstand the HKS design problems due to the repetitive impact loads, the HKS system were redesigned as follows: (1) reinforcing the housing design of HKS, C1(Figure 1); (2) changing the sealing structure in the oil damper, C2 (Figure 2); (3) changing cover housing material, C3, from plastics to the Al die-casting (Figure 3). With these design changes, the refrigerator could also be opened and closed more comfortably in product lifetime.

Conclusion

To improve the lifetime of a newly designed HKS in refrigerators, we have identified the failure investigation of fractured HKS in field, conducting ALT with design modifications. HKS with the proper design parameters were guaranteed to meet the lifetime target – B1 life 10 years.

References

[1] Woo, S., Pecht, M, O'Neal, D., 2020, Reliability design and case study of the domestic compressor subjected to repetitive internal stresses, Reliability Engineering and System Safety, 193, 106604.