Case Report

BIOMEDICAL Journal of Scientific & Technical Research

ISSN: 2574 -1241

DOI: 10.26717/BJSTR.2023.52.008259

Organized Methods to Reinforce the Design of Mechanical System Such as Dispenser Entrenched on Life-Stress Prototype and Sample Size

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ARTICLE INFO

Received: August 11, 2023

Published: August 25, 2023

Citation: Seongwoo Woo, Dennis L O'Neal, Yimer Mohammed Hassen1 and Gezae Mebrahtu. Organized Methods to Reinforce the Design of Mechanical System Such as Dispenser Entrenched on Life-Stress Prototype and Sample Size. Biomed J Sci & Tech Res 52(3)-2023. BJSTR. MS.ID.008259.

ABSTRACT

To reinforce the design of system worked by machinery, parametric Accelerated Life Testing (ALT) as organized way suggests estimating the mechanical lifetime applied by repeated impact loads, constructed on life–stress type and sample size expression. This procedure will permit an engineer to discover the system defects that have a significant outcome on reliability. Eventually, manufacturer may stop recalls from the field. As an instance, the dispenser system in a refrigerator was explored.

Keywords: Mechanical System; Refrigerator Dispenser; Parametric Alt; Fatigue; Design Defects

Introduction

The mechanical product transfers power to reach a purpose that needs forces & displacement and has mechanical advantages by adopting mechanisms. Implementing the vapor-compression refrigeration cycle, a refrigerator supplies chilled air from the evaporator to the freezer and refrigerator department. Particularly, a dispensing system in a refrigerator distributes chilled water. It comprises the dispenser lever, cover, and spring. It should be designed to keep up the operating circumstances applied by the user who uses a product. If there are design defects where the loads are exerted, water dispensing may immediately stop in its lifetime. As discovering the design flaws, an engineer could design optimally [1]. Parametric ALT consists of:

(1) An ALT scheme,

(2) Load analysis,

(3) An ALTs with the revisions, and

(4) An assessment of whether the product reaches the objective BX lifetime. As a case analysis, the dispensing system lever in a refrigerator will be explored.

Parametric ALT in Mechanical System

The means of solving a problem for Schrodinger's governing expression can be obtained:

$$-\frac{h^2}{8\pi^2 m}\frac{d^2\psi_n(x)}{dx^2} = E_n\psi_n; \psi_n(x) = \sqrt{\frac{2}{a}}\sin(\frac{n\pi}{a})x; E_n = \frac{n^2h^2}{8ma^2} > 0 \quad (1)$$

Linear transport is expressed:

$$J = LX \quad (2)$$

For instance, solid-state diffusion for silicon, J, can be expressed.

$$J = B\sinh(aS)\exp\left(-\frac{E_a}{kT}\right) \quad (3)$$

As Equation (3) takes the inverse, the life-stress (LS) formulation can be manifested:

$$TF = A\left[\sinh(aS)\right]^{-1}\exp\left(\frac{E_a}{kT}\right) \quad (4)$$

The $\left[\sinh(aS)\right]^{-1}$ in Equation (4) has characteristics:

1) $(S)^{-1}$ in the begin has a little linear effect,

2) $(S)^{-n}$ is built as a medium effect, and

3) $\left(e^{aS}\right)^{-1}$ in the ending is big. In the medium range, an ALT is usually executed. Because the stress starts from effort, Equation (4) can be expressed as:

$$TF = A(S)^{-n}\exp\left(\frac{E_a}{k_T}\right) = B(e)^{-\lambda}\exp\left(\frac{E_a}{kT}\right) \quad (5)$$

To achieve the acceleration factor (AF), defined as the quantitative relationship between the elevated stress and regular stress situations, it can be substituted to unify with this notion:

$$AF = \left(\frac{S_1}{S_0}\right)^n\left[\frac{E_a}{k}\left(\frac{1}{T_0}-\frac{1}{T_1}\right)\right] = \left(\frac{e_1}{e_0}\right)^{\lambda}\left[\frac{E_a}{k}\left(\frac{1}{T_0}-\frac{1}{T_1}\right)\right] \quad (6)$$

To obtain the mission cycle for an ALT, sample size equation with Equation (6) can be attained as [2]:

$$n \geq (r+1).\frac{1}{x}.\left(\frac{L^*_{BX}}{AF.h_a}\right)^{\beta} + r \quad (7)$$

Case Investigation: Increasing the Fatigue Life of a Dispensing System in a Household Refrigerator

Customer sometime employs the refrigerator to distribute chilled water. To meet these needs satisfy, the water dispensing system in a refrigerator is designed. Distributing water in a domestic refrigerator requires:

(1) The end-user presses the water cup to the dispensing lever and

(2) Water runs into it.

The dispensing system thus should be designed to succeed in obtaining the operating situations exerted to it by the customer (Figure 1). From the marketplace, as repetitively pressing/unloading are exerted, dispenser returned from the field had been failing due to some design flaws, resulting in customers to ask for replacement. To correctly operate the dispensing system for anticipated lifetime, stress raiser such as sharp corner, etc. in dispensing assembly should be discovered and altered by parametric ALT (Figure 2a).

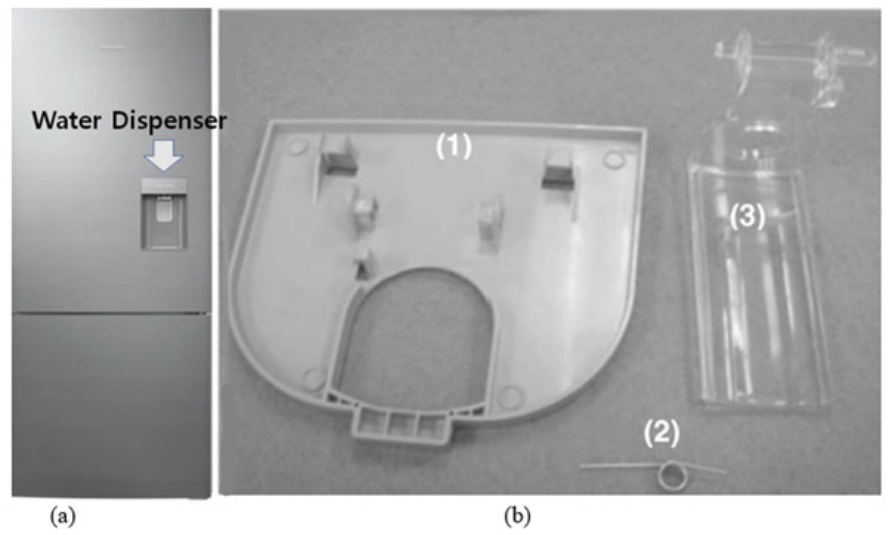

Figure 1:
(a) Refrigerator
(b) Dispenser system
(1) Cover
(2) Spring
(3) Dispenser lever

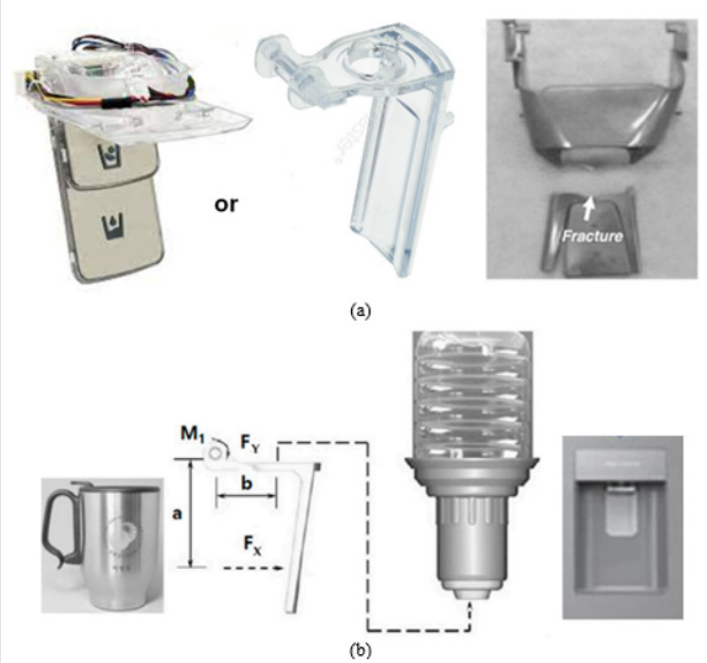

Figure 2: Fractured lever after use.
(a) Failed lever in the marketplace
(b) Force equilibrium

From the free-body diagram (Figure 2b), the exerted loads on the refrigerator dispenser starts from the cup pressing. That is,

$$\sum M_z = aF_X - bF_Y = 0 \quad (8)$$

Because the dispensing stress depends on the cup loading, Equation (5) can be expressed:

$$TF = A(S)^{-n} = A(F_X)^{-\lambda} = B(F_Y)^{-\lambda} \quad (9)$$

Thus, entrenched on Equation (6), the AF can be expressed

$$AF = \left(\frac{S_1}{S_0}\right)^n = \left(\frac{F_1}{F_0}\right)^{\lambda} \quad (10)$$

For the dispensing system, the working (or environmental) circumstances are 0–43 OC with 0.2–0.24 g's acceleration, and a humidity spanning from 0 to 95%. The operating cycles of dispenser a day were from four to twenty cycles. Based on the design of a system life for ten years, the dispensing system was exerted to 73,000 use cycles. For the worst circumstance, the maximum load subjected to the end-user in distributing water, F0, was 15-20 N. For ALT, the applied load, F1, took double to 35 N. With a cumulative quantity, λ, of 2, AF from Equation (10) was 4.0. To keep the life target – B1 life for ten years, if the shape parameter was assumed to be 2.0, the mission cycles for ten samples determined in Equation (7) were 65,000 cycles. The troublesome designs of dispensing assembly thus can be modified after identifying them.

Results and Conclusions

In 1st ALT, water dispensing system failed at 25,000 cycles (Figure 3). As cautiously seeing the fractured dispensing assembly from the first ALT and the marketplace, failure sites were discovered in its front corner and hinge. Due to stress raisers such as no corner rounding and insufficient thickness, the dispenser lever may have been failing. As action plans, these designs were amended by:

(1) Enlarging the hinge rib rounding (Fillet1), C1, from 0.0 mm to 1.5 mm

(2) Thickening the front corner rounding (Fillet2), C2, from 0.0 mm to 1.5 mm

(3) Enlarging the hinge rib (Rib1), C3, from 1.0 mm to 1.8 mm and

(4) Enlarging the front side rounding (Fillet3), C4, from 0.0 mm to 8.0 mm (Figure 5). Stress analysis, combined with parametric ALT, was carried out. As result, the approximated stress concentrations at the front corner and the shaft hinge of the dispenser lever lessened from 8.37 MPa and 5.66 MPa (Figure 4a).

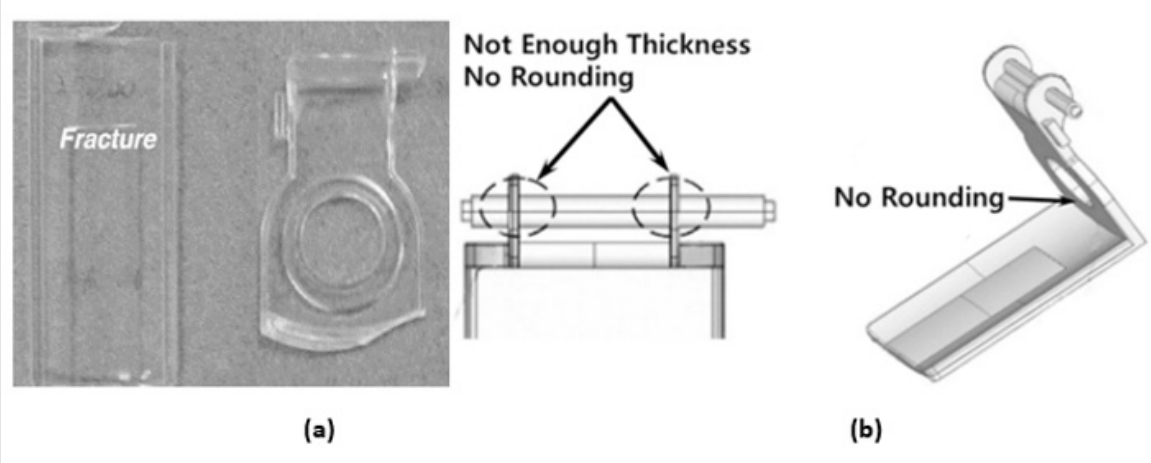

Figure 3: Problematic designs of dispenser in 1st ALT
(a) 1st ALT failure
(b) Its root cause

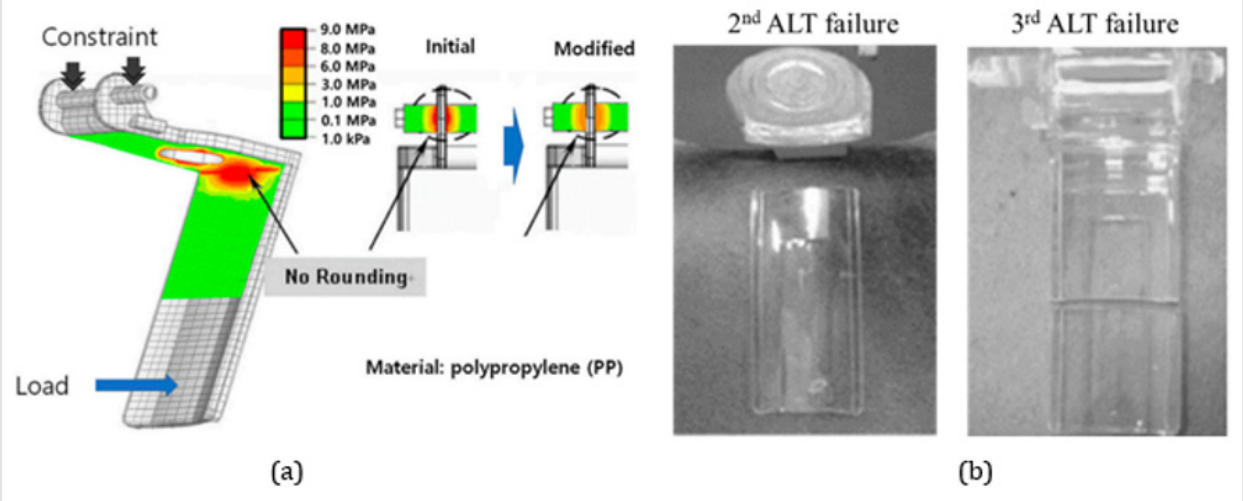

Figure 4: Problematic designs of dispenser in 2nd & 3rd ALT.
(a) Finite element analysis
(b) 2nd and 3rd ALT failure

In the 2nd ALT, the lever system cracked and fractured at approximately 32,000 cycles (Figure 4b). As cautiously checking the failure sites, the front corner of the dispenser lever had insufficient corner rounding. To enhance its lifetime, it was changed by

(1) Thickening the hinge rib rounding (Fillet 1), C1, from 1.5 mm to 2.0 mm and

(2) Thickening the front side rounding (Fillet 3), C4, from 8.0 mm to 11.0 mm (Figure 5).

Though the design of water dispensing assembly was enhanced in the 2nd ALT, the desired life did still not achieve the mission cycles. So, the third ALT was carried out. In the 3rd ALT, there were no defects in the dispensing assembly until the ALT was carried out for 68,000 cycles. The dispenser lever at 68,000 cycles cracked and fractured at the front of the lever (Figure 4b). The front lever (Rib2), C5, was enlarged from 3.0 mm to 4.0 mm (Figure 5). With the structural modifications, the dispensing system in a household refrigerator might function to attain the life goal – B1 life for ten years – because there were no matters until 68,000 assigned mission cycles.

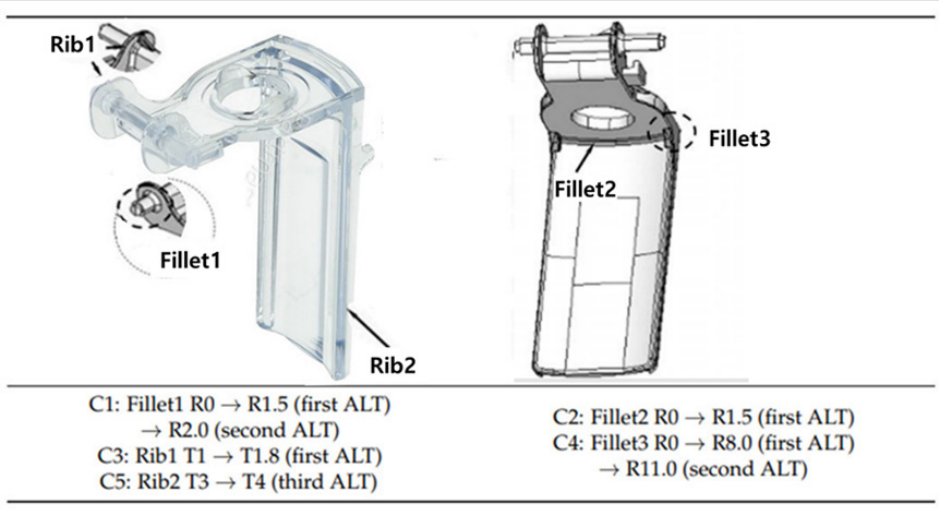

Figure 5: Summary for the redesigned dispenser lever.

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DOI: 10.26717/BJSTR.2023.52.008259

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