Engineering Failure Analysis 18 (2011) 1322–1332

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Reliability design of residential sized refrigerators subjected to repetitive random vibration loads during rail transport

Seong-woo Woo [a,*], Dennis L. O'Neal [b], Michael Pecht [c]

[a] STX Institute of Technology, STX R&D Center, 448-2, Dogok 2-dong, Gangnam-gu, Seoul 135–855, South Korea
[b] Department of Mechanical Engineering, Texas A&M University, College Station, TX, United States
[c] Center for Advanced Life Cycle Engineering (CALCE), University of Maryland, College Park, MD, USA

ARTICLE INFO

Article history:
Received 11 October 2010
Received in revised form 13 March 2011
Accepted 28 March 2011
Available online 2 April 2011

Keywords:
Random vibration
Robustness
Parameter design
Accelerated life testing

ABSTRACT

During railroad shipment of residential refrigerators, two failures due to the repetitive random vibrations were occurring. These included the fracturing tubes between the compressor and condenser and the tearing compressor rubber mounts. Sample inspections, accelerated life tests and corrective action plans were used to identify the key control parameters for the connecting tubes. The failure modes and mechanisms found experimentally were identical to those of the failed samples in the field. The missing controllable parameters of the refrigerator system in the design phase included the shape of the compressor rubber and the connecting tube design. To correct these problems, the compressor rubber mounts and connecting tubes were redesigned. The refrigerators with the targeted B_1 life were expected to survive without failure during rail transport.

1. Introduction

Fig. 1 shows a typical side-by-side residential sized refrigerator and the mechanical compartment that is at the bottom rear of the refrigerator. The compressor (1), rubber (2), connecting tubes (3), fan and condenser (4) are located inside the mechanical compartment, as shown in Fig. 1b. When these refrigerators were transported to their final destinations by rail, they were subjected to unpredictable random vibrations from the train. These vibrations were continually transmitted to the refrigerator (or mechanical compartment) while the train was moving and were large enough to damage some refrigerators during transport or reduce their remaining useful life before the consumers purchased them. The refrigerators needed to be designed to survive the damage that can occur during transport.

Robust design techniques, including statistical design of experiment (SDE) and the Taguchi methods [1], have been developed to help improve the reliability of product designs. The Taguchi methods describe the robustness of a system for evaluation and design improvement, which is also known as quality engineering [2,3] or robust engineering [4]. Robust design processes include concept design, parameter design, and tolerance design [5]. Taguchi's robust design methods place the design in an optimum position where random "noise" does not cause failure and help to determine the proper design parameters [6]. The basic idea of parameter design is to identify, through exploiting interactions between control factors and noise factors, appropriate settings for the control factors that make the system's performance robust in relation to changes in the noise factors. Thus, the control factors are assigned to an inner array in an orthogonal array, and the noise factors are assigned to an outer array.

* Corresponding author. Tel.: +82 2 6944 2770; fax: +82 2 6944 2701.
E-mail address: twinwoo@yahoo.com (S.-w. Woo).

1350-6307/$ - see front matter Published by Elsevier Ltd.
doi:10.1016/j.engfailanal.2011.03.021