Chapter 12
Study on Reliability Design of the Domestic Compressor Subjected to Repetitive Internal Stresses by Parametric Accelerated Life Testing

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ABSTRACT

This chapter explains the parametric accelerated life testing (ALT) to recognize design defects in mechanical products. A life-stress model and a sample size formulation are suggested. A compressor is used to demonstrate this method. Compressors were failing in the field. At the first ALT, the compressor failed due to a fractured suction reed valve. The failure modes were similar to those valves returned from the field. The fatigue of the suction reed valves came from an overlap between the suction reed valve and the valve plate. The problematic design was modified by the trespan dimensions, tumbling process, a ball peening, and brushing process for the valve plate. At the second ALT, the compressor locked due to the intrusion between the crankshaft and thrust washer. The corrective action plan performed the heat treatment to the exterior of the crankshaft made of cast iron. After the design modifications, there were no troubles during the third ALT. The lifetime of compressor was secured to have a B1 life 10 years.

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1. INTRODUCTION

Because of demands in the global market, refrigerators must be designed to have low energy usage and reliability. For those aimed functions, the compressor in the refrigerator often needs to be redesigned to enhance its comprehensive energy efficiency on a yearly basis. It involves recently designed features for the system, which should be rapidly brought to the end-users. With insufficient testing or no assumption of how the new attributes may be utilized, their launching may increase product failures in the marketplace and negatively influence the manufacturer's brand name. These attached features for the product should be totally assessed in the design phase before being released into the marketplace. Therefore, reliability quantitative (RQ) specifications utilizing an established system of method should be presented (CMMI Product Team, 2018; Woo et al., 2021).

A compressor is designed to increase the refrigerant pressure in a refrigeration cycle by several mechanical compression mechanisms. One of the key components of the compressor is the crankshaft that converts the rotational motion into reciprocating motion by a crank mechanism. A compressor is subjected to repeated stresses due to internal pressure loadings over the course of its lifetime. New rotary compressors introduced in 1987 in refrigerators were experiencing large recalls due to the locking of the compressor in the field (Magaziner & Patinkin, 1989). Oil metal sludge formed during normal refrigeration operations was separating from the sintering crankshaft and plugging the capillary tubes, which forced the refrigerator to no longer function. To stop a compressor recall, any flawed components needed to be identified and altered using testing methodology such as parametric ALT, which can produce reliability quantitative (RQ) specifications before the system launches.

The procedures of robust design, such as the Taguchi approach (Chowdhury & Taguchi, 2016; Rosa et al., 2009) and design of experiments (DOE)(Allen, 2020), were developed to help identify the most advantageous designs for products. Especially, Taguchi's method employs design parameters to put it in the right location where ''noise" parameters do not have any effect on the output. As a result, the right designs of mechanical products can be selected. However, without identifying failure mechanisms such as fatigue, this methodology can only pursue system optimization. If there is a design fault, the product may fail during its lifetime as loads are exerted on it. Many parameters must be considered to identify an optimal design of a mechanical structure. However, the large number of parameters may require huge computations unless some options are neglected to reduce computational requirements.

Material faults, such as extremely small voids and contacts when subjected to repeated loads, may begin to fail because of fatigue. Fatigue is the chief source of destruction in metallic elements, explaining roughly 80%–95% of all constructional failures. Fatigue in ductile metals appears itself in the shape of cracks that grow in stress accumulation, such as holes, grooves, etc. Those failures can affect the reliability of mechanical systems such as moving automobiles, airplane wings, marine ships, turbo engines, and atomic reactors. The fatigue procedure covers three fluctuating stress/time modes: 1) symmetrical about zero stresses, 2) asymmetrical about zero stresses, and 3) random stress cycles. The fatigue may also rely on the parameters such as the cyclic stress amplitude, mean stress or stress ratio, R ($=\sigma_{min}/\sigma_{max}$), which can be defined as s the proportion of the minimum cyclic stress to the maximum cyclic stress (Campbell & Fatigue, 2008). In other words, in periodical shapes, the peaks on both the maximum (high side) and the minimum (low side) are crucial. When employing an elevated load which can be stated as an accelerated factor (AF), accelerated life testing (ALT) can be examined to discover the design defects such as stress raiser in the structure.

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