Chapter 11
Study on Enhancing the Lifetime of the Pneumatic Cylinder in Automatic Assembly Line by Parametric Accelerated Life Testing

Seongwoo Woo
Ethiopian Technical University, Ethiopia

Dennis O'Neal
Baylor University, USA

Yimer Mohammed Hassen
Ethiopian Technical University, Ethiopia

Gezae Mebrahtu
Ethiopian Technical University, Ethiopia

ABSTRACT

This investigation shows the implementation of parametric accelerated life testing (ALT) as established. It involves (1) a product BX lifetime that X% of a system population is unsuccessful with ALT plan, (2) fatigue design, (3) ALTs with modifications, and (4) discernment as to whether the design(s) fulfills the objective BX lifetime. As a case study, pneumatic cylinder was investigated. The pneumatic cylinder was unsuccessful in a manufacturing line. To reproduce it, parametric ALT was carried out. At the first ALT, the metal seal made of nickel-iron alloy partially cracked and chipped with metal sound. As an action plan, material of the seal was altered from metal to silicone rubber. At the second ALT, due to seal hardening and wear, the piston seal leaked gas. The failure of the silicone seals in the laboratory tests were alike to those returned from the marketplace. The seal material was changed from silicone rubber to (thermoset) polyurethane. For the third ALT, there were no issues. Finally, the lifetime of the pneumatic cylinder was manifested to have a B1 life of 10 years.

DOI: 10.4018/978-1-6684-5381-0.ch011

INTRODUCTION

Due to aggressive circumstances in the marketplace, system operated by a machinery should be devised to have better functioning and big reliability. As the critical attributes of a system that has technical imperfections are assessed in the developing phase, they are quickly integrated into a product and transported to the end-user. Without either unrestricted test or obvious comprehension of how new design can be utilized by the customer, system release with design imperfections may affect the company's brand in a negative way (Magaziner, 1989).

A pneumatic air cylinder is a part which shall be employed in an automatic assembly. It shall thus be employed for a tool-changing implement for a machine tool. To stop an air cylinder from being unsuccessful in the market in its expected life, a producer might substantiate the reliability of a new cylinder linked with proper ISO guidelines and/or carry out required reliability tests before the system is launched.

The field disaster such as Space Shuttle Challenger in the United States' space project was a lethal mishap that happened on 28 January 1986. It was brought about by the unsuccessfulness of O-ring seals used in the booster junction that was wrongly devised to sustain the unusually cold climate that existed at the period of launch. Consequently, as the Challenger travelled through its flying and exploded, all team staffs were dead. The result of this disaster was a stopping of shuttle launching till rectifications were set in the O-ring design. To secure a system isn't unsuccessful in the market, defective parts should be assessed and altered by utilizing a systematic testing method such as ALT, which shall generate reliability quantitative (RQ) statements before the product is released into the field (Woo et al., 2021).

Material imperfections, such as extraordinarily tiny voids, thin surface, contacts, etc. when subjected to repetitive loads, shall start to be unsuccessful because of mechanical failure such as fatigue. It is the main origin of failure in metallic parts, describing approximately 80–95% of all structural failures (McMillan et al., 1982). Metal fatigue shows in the configuration of cracks that emerge in regions where stress shall condense, such as grooves, sharp-edged, holes, etc. It influences the reliability of systems such as aircrafts, automobiles, refrigerator, construction machine, and atomic plants. Especially, a fatigue testing covers as follows: (1) fluctuating stresses, (2) repetitive stresses, (3) reversed stresses, and (4) random stress cycles. Fatigue can thus be influenced by the cyclic stress range, average stress or stress ratio, R ($=\sigma_{min}/\sigma_{max}$), which is elucidated as the correlation of the least cyclic stress to the greatest cyclic stress (Duga et al. in Campbell, 2008). For interval forms, the heights at both the greatest (high side) and the least (low side) are important. As utilizing an accelerated loading, parametric ALT shall be employed to recognize the structural imperfections such as a stress raiser.

The ALT integrated with the reliability diagram representation was explored as an alternative procedure (Modarres et al., 2016). It covered a test scheme for the product, recognizing to use fatigue failure, and employing a sample size expression, elevated loading, etc. Elsayed (2012) grouped statistics, physics/statistics, and physics/test-based frameworks for investigation. Hahn and Meeker (2004) proposed some feasible procedures to set out an ALT. Conducting an elevated test (McPherson, 1989; 2010) entails some basic idea such as the BX lifetime for the testing strategy, a streamlined life-stress prototype, sample size expression, and fracture mechanics (Anderson, 2017) because unsuccessfulness can instantly take place because of weak parts in the structure. However, present test skills (Braco et al., 2021) cannot replicate the design imperfections in a multi-module structure because it assesses limited component samples & testing time.

To attain a structural robust design operated by machine, designers have utilized established skills such as mechanics of materials and fracture mechanics (Weingart & Stephen, 2007). They have employed