Research Article

BIOMEDICAL Journal of Scientific & Technical Research

ISSN: 2574 -1241

DOI: 10.26717/BJSTR.2023.54.008532

Investigation on Enhancing the Fatigue Life of Pneumatic Cylinder Constructed on Quantum-Carried Life Type and Sample Size

Seongwoo Woo[1]*, Dennis L O'Neal[2], Yimer Mohammed Hassen[1], Gezae Mebrahtu[1] and Hadush Tedros Alem[1]

[1]*Manufacturing Technology, Mechanical Technology, Ethiopian Technical University, Ethiopia*

[2]*Engineering and Computer Science, Baylor University, USA*

***Corresponding author:** Seongwoo Woo, Manufacturing Technology, Mechanical Technology, Ethiopian Technical University, Addis Ababa, Ethiopia

ARTICLE INFO

Received: December 11, 2023

Published: January 03, 2024

Citation: Seongwoo Woo, Dennis L O'Neal, Yimer Mohammed Hassen, Gezae Mebrahtu and Hadush Tedros Alem. Investigation on Enhancing the Fatigue Life of Pneumatic Cylinder Constructed on Quantum-Carried Life Type and Sample Size. Biomed J Sci & Tech Res 54(2)-2023. BJSTR. MS.ID.008532.

ABSTRACT

To intensify the construction of system operated by machine, parametric Accelerated Life Testing (ALT) as planned approach is presented to compute the mechancial lifetime repetitively exerted by pressure difference, created on life–stress type and sample size. The organized process permits designer to unexpectedly find the structural defects which have a serious result in product reliability. Ultimately, manufacturer can cease to happen recalls from the marketplace. As an example, the pneumatic cylinder in a machine tool was inspected.

Keywords: Mechanical Product; Cylinder; Seal; Parametric Alt; Leakage; Fatigue; Design Imperfections

Introduction

The product worked by machine proceeds power to keep an intended outcome that requires forces & motion and achieves mechanical advantages by properly fulfilling some mechanisms. A cylinder operated pneumatically is a mechanical device that can be implemented in an automated line. As one of various functions, a pneumatic cylinder can be employed in a tool-exchanging machine. It consists of a rod cap, piston, head cap, etc. Pneumatic cylinder might be designed to be worked under the circumstances exercised by the engineer who really use it. If there are design defects in the structure, pneumatic cylinder may not suddenly function in its expected lifetime. As discovering them by reliability test such as parametric ALT, a designer can design it in the most favourable manner [1]. It contains:

(1) An ALT plan,

(2) Load study,

(3) An ALTs with several rectifications, and

(4) A judgement if product reaches the intended BX life. As an instance study, the cylinder in a machine tool can be examined.

Parametric ALT in Mechanical System

Finding an answer to the Schrodinger's differential equation may be achieved:

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

 DOI: 10.26717/BJSTR.2023.54.008532

Linear transport may be expressed:

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

As a case, solid-state diffusion for silicon, J, can be summarized

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

When Equation (3) takes the reverse, the life-stress (LS) type can be defined:

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

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

1. $(S)^{-1}$ in the onset has almost linear effect,
2. $(S)^{-n}$ is found as a central effect, and
3. $(e^{as})^{-1}$ in the finish is enormous. In the mid effect, an ALT is carried out. As the effect (or stress) appears from effort in transmitting power, Equation (4) may be stated as:

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

To accomplish the acceleration factor (AF), stated as the link between the raised-level stress and standard stress, it can be expressed to combine with this view:

$$AF = \left(\frac{S_1}{S_0}\right)^n\left[\frac{E_a}{K}\left(\frac{1}{T_0}-\frac{1}{T1}\right)\right] = \left(\frac{e_1}{e_0}\right)^{\lambda}\left[\frac{E_a}{K}\left(\frac{1}{T_0}-\frac{1}{T1}\right)\right] \quad (6)$$

To attain the assigned cycles for targeted lifetime - B1 life 10 years in ALT, sample size united with Equation (6) can be expressed as [2]:

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

Case Investigation: Enhancing Life of a Cylinder Operated Pneumatically in a Machine Tool

End-user sometime employs the pneumatic cylinder to comfortably change the tools in an automated assembly line. To move a pressure load along a straight-line route to the necessitated place, mechanical parts in the cylinder are designed. The major components are composed of a rod cap, piston, head cap, etc (Figure 1). From the market, as repetitively pressure loads in its expected life is exerted, the problematic piston seal brought the cylinder to coincidentally lose gas, through a crack and stop working due to unknown imperfections, following by engineers to ask for the steps of taking the place of it. To properly work the pneumatic cylinder for its anticipated lifetime, its design defects could be unexpectedly discovered and improved by reliability test such as parametric ALT (Figure 2).

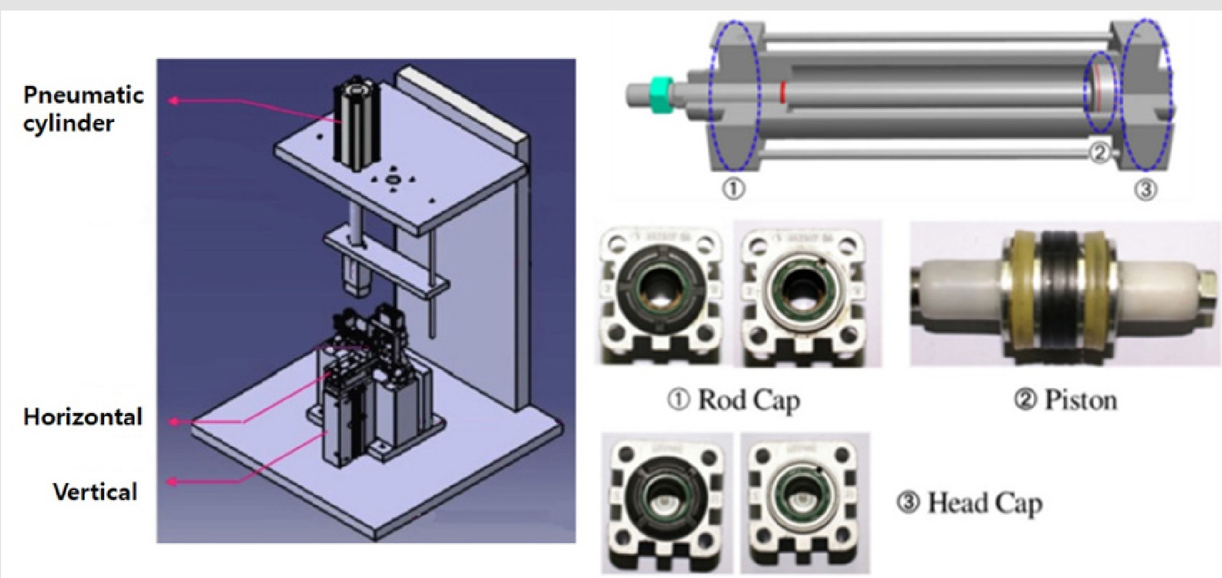

Figure 1: Pneumatic cylinder.
a) Pneumatic cylinder in an automated assembly
b) (1) cap, (2) piston, (3) and head cap

 DOI: 10.26717/BJSTR.2023.54.008532

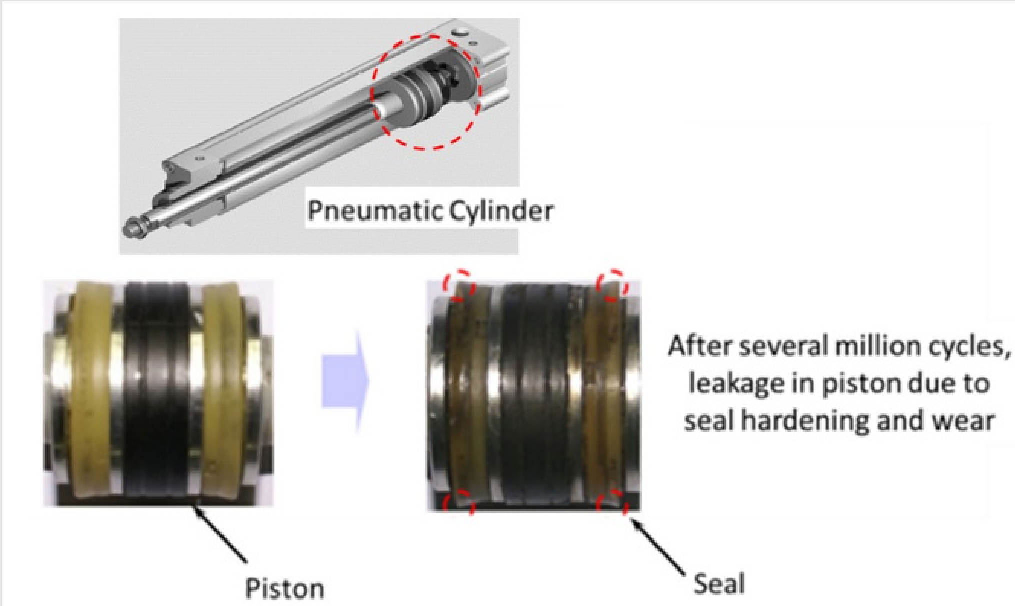

Figure 2: Failed piston seal in pneumatic cylinder.

The pressure difference, ΔP, in the cylinder can be expressed as:

$$\Delta P = \Delta F_{\text{int}} / A \quad (8)$$

where ΔF_{int} = force difference.

As the stress depends on the exerted pressure difference, Equation (5) may be expressed:

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

Therefore, based on Equation (6), the AF may be defined:

$$AF = \left(\frac{S_1}{S_0}\right)^n = \left(\frac{\Delta P_1}{\Delta P_0}\right)^\lambda \quad (10)$$

For the cylinder in an assembled line, the surrounding circumstances are 0–43 °C with 0.2–0.24 g's acceleration, and a relative humidity varying from 0 to 95%. The functioning cycle of pneumatic cylinder a day were from ten to thirty. Based on the lifetime cycles for ten years, the pneumatic cylinder was carried out to 109,500 use cycles. For the most severely case, the pressure difference disclosed to the end-user in changing tools, ΔP_0, was 0.69 MPa. For ALT, the exerted pressure difference, ΔP_1, enlarged to 0.8 MPa. With an accumulative factor, λ, of 2, AF in Equation (10) was 1.6. To achieve the targeted lifetime – B1 life of ten years, if the shape parameter, β, was expected to be 2.0, the mission time for ten cylinders designated in Equation (7) were 200,000 cycles. The problems of pneumatic cylinder may be discovered and altered.

Results and Conclusion

At first, when the raised pressure difference, 0.8 MPa, in the cylinder was filled, samples (n = 10) noised at 6000, 10,500, and 11,000 cycles that peaked at 70 dB and was the source of hearing loss. As taking apart three cylinders, one cylinder cracked and two cylinders chipped. As action plans, the material of seal was adjusted from Fe-36Ni Invar Alloy to silicone rubber (C1) (Figure 3). In 1st ALT, some failed pneumatic cylinders in field reproduced at 50,000 cycles (one cylinder), 6,500 cycles (one cylinder), 100,000 cycles (two cylinders), 110,000 cycles (cylinder), and 115,000 cycles (one cylinder) (Figure 4). The failed mode for cylinders was over the minimum working pressure and stroke time. It happened:

(5) Repeatedly working stress,

(6) Friction heat & lube vaporization of seal, and

(7) Raising hardening & wear in seal.

DOI: 10.26717/BJSTR.2023.54.008532

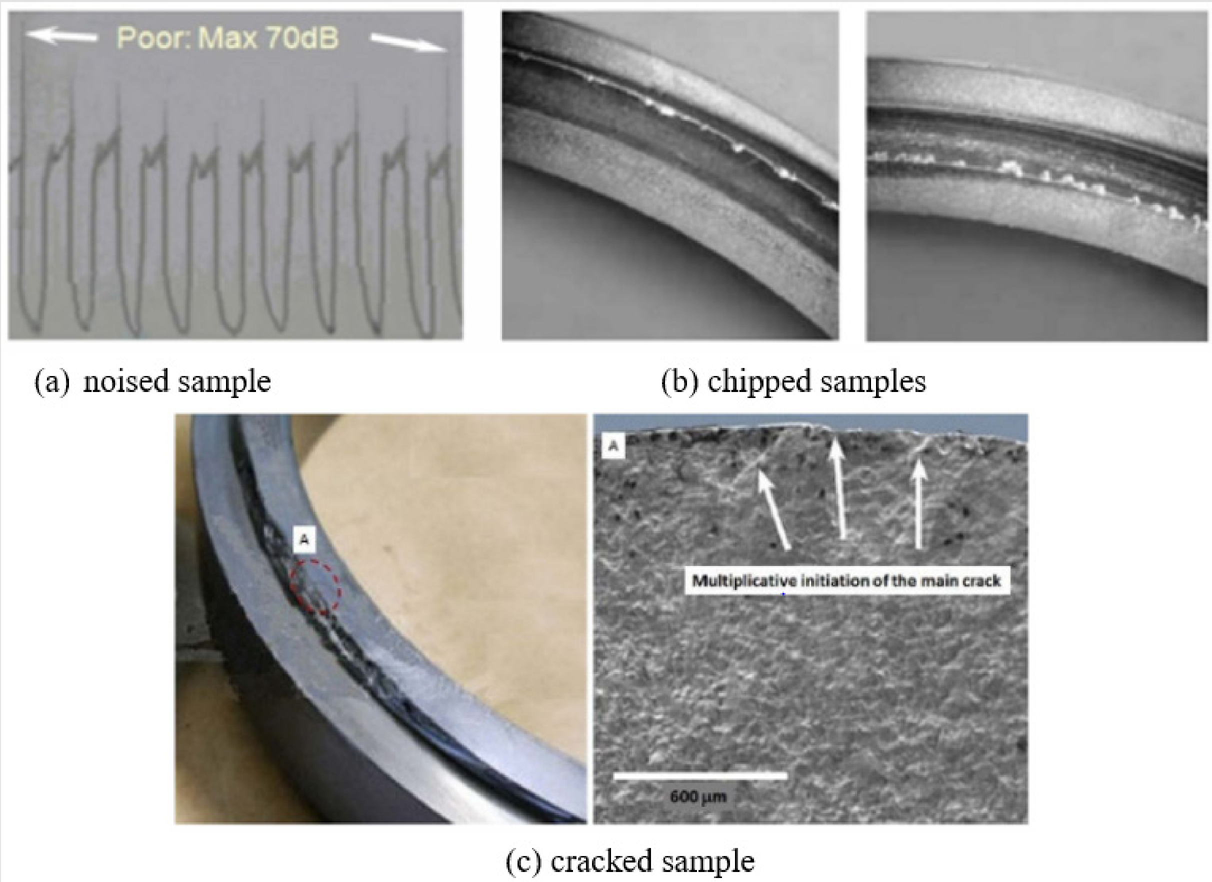

Figure 3: Design difficulties of samples in initial loading.

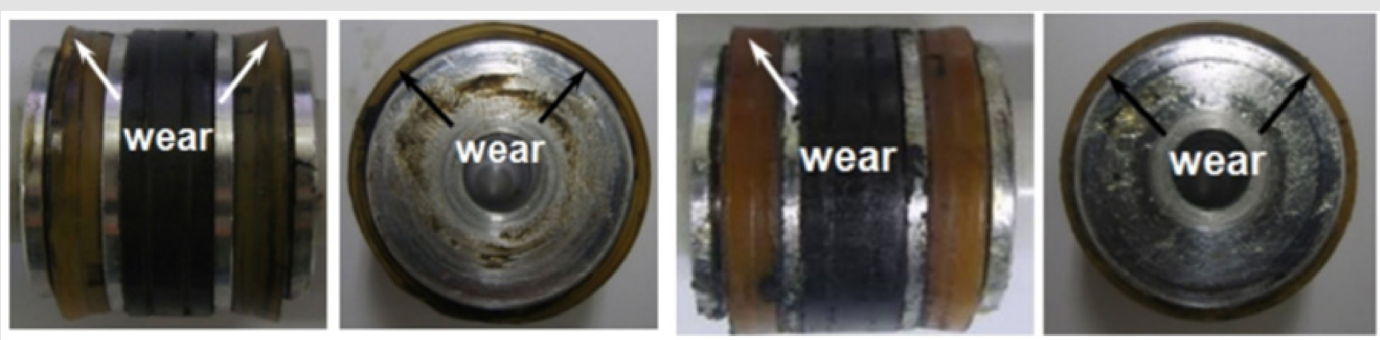

Figure 4: Design issues of samples in 1st ALT.

a) Failed products at the field

b) Failed products after parametric ALT

When the failed cylinders were took apart, the hardening and wear in piston seal were like cylinders failed from the marketplace. The material of seal, C2, was modified from silicone rubber to a polyurethane (Figure 4). To unexpectedly find the cylinder failures under another raised conditions of 1.2 MPa and 23 °C, ALT was accomplished. As an outcome, the failed cylinder occurred in 5 out of 6 samples: 30,000 cycles (one cylinder), 70,000 cycles (two cylinders), and 80,000 cycles (two cylinders). Their failed mode was over the minimum operation pressure and stroke time piston. When the samples were took apart, it was known that there was hardening and wear in piston seal, and the rod cap was clogged. The repeated pressure loading of sample brought the seal wear, which resulted in the slurry and its flow into the port. The accumulated slurry at the port and clogged it (Figure 5). In 2nd ALT, there were no matters until ALT came to 220,000 cycles. As the designs were altered, the cylinder used will acceptably carry out the objected life – B1 life for ten years.

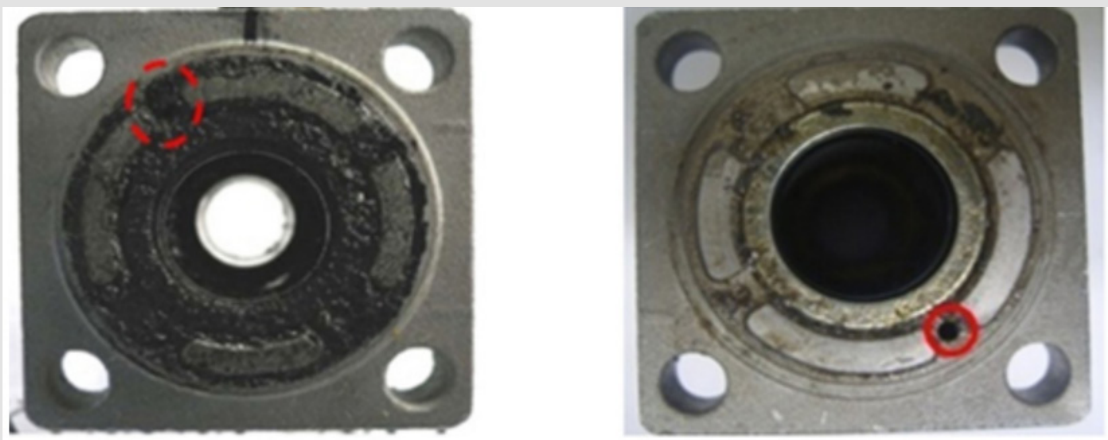

Figure 5: Clogged rod cap found by parametric ALT.

References

1. Woo S, O'Neal D, Pecht M (2023) Improving the lifetime of mechanical systems during transit established on quantum/transport life-stress prototype and sample size. Mechanical Systems and Signal Processing 193: 110222.
2. 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.

ISSN: 2574-1241

DOI: 10.26717/BJSTR.2023.54.008532

Seongwoo Woo. Biomed J Sci & Tech Res