

Systematic way to enhance the design of mechanical product by utilizing accelerated testing

Seong-woo Woo, Dennis L. O'Neal, Yimer Mohammed Hassen

Abstract—This investigation shows the use of parametric accelerated life testing (ALT) as an approach to discover design deficiencies and alter them in producing a reliable quantitative (RQ) specification. It covers: (1) product BX life that X% of a population is unsuccessful with parametric ALT plan, (2) fatigue analysis, (3) ALTs with modifications, and (4) judgement as to whether the design(s) acquires the targeted BX life. A (generalized) life-stress model by the linear transport process and a sample size equation are proposed. A pneumatic cylinder in a machine tool was utilized as a case investigation. a cylinder was being unsuccessful in a flexible manufacturing system. To reproduce the market failure and alter the design, a parametric ALT was carried out. At 1st ALT, the metal seal made of nickel-iron alloy (36% Ni) partly cracked and had a metal crispy sound in tested cylinder. It was altered by changing the seal material from a metal to a polymer (silicone rubber). At 2nd ALT, the piston seal leaked due to its hardening and wear. The failure modes of the silicone seal in the lab. tests were alike to those of samples returned from the market. For 3rd ALT, the seal material was amended from silicone rubber to (thermoset) polyurethane. There were no design issues during the third ALT. The life of the pneumatic cylinder thus was manifested to be a B1 life 10 years.

Keywords—Parametric ALT, Mechanical product, Pneumatic cylinder, (metal) seal, Leakage, Design flaws

I. Introduction

Because of market requirements, mechanical products should be designed to have desired performance and reliability. After the crucial factors of a system are assessed in the design phase, new characteristics are swiftly integrated into product and led to the marketplace. Without testing or obvious comprehension of how a new design shall be used by the customer, product initiation with highly expected failures may negatively influence company's brand [1].

A pneumatic cylinder is a mechanical part which may be employed in a flexible assembly line of an automatic manufacturing system as a tool-changing tool. To stop a pneumatic cylinder from being unsuccessful in the market before its expected life, a company might confirm the newly designed cylinder combined with proper ISO Standards [2] and/or carry out required reliability testing before the system is launched.

Material imperfections, such as extraordinarily tiny voids when subjected to repetitive loads, can start to be unsuccessful due to fatigue. Fatigue is the main origin of failure in metallic components, describing about 80–95% of all structural failures [3]. It shows in the pattern of cracks that grow in region where stress may concentrate, such as holes, thin areas, sharp edges, grooves, etc and propagates it. Those failures thus may have an effect on the life of mechanical systems such as refrigerator, automobiles, airplanes, and atomic reactors. Fatigue can also be influenced by the cyclic stress amplitude, mean stress or stress ratio, $R (= \sigma_{\min} / \sigma_{\max})$, which can be stated as the ratio of the minimum cyclic stress to the maximum cyclic stress [4]. A fatigue testing includes some fluctuating stress/time modes: (1) fluctuating stresses, (2) repeated stresses, (3) reversed stresses, and (4) random stress cycles. Especially, the peaks at both the maximum (high side) and the minimum (low side) are significant. As utilizing an elevated load that may be expressed as an accelerated factor (AF), accelerated life testing (ALT) may recognize the design flaws such as a stress raiser in the structure for a reliable quantitative (RQ) specification.

To avoid the non-success of mechanical product in the market, it might be designed to robustly withstand the operating conditions exposed by the customers. Any design flaws thus might be recognized and changed through statistical method or reliability testing before system is launched [5,6]. However, it requires a lot of calculations for optimum answer but have no outputs because of not understanding failure mechanics such as fatigue. That is, if there are design flaws which causes a lack of stiffness (or strength) when a product is subjected to repetitive impact loading, the system will be unsuccessful before its expected lifetime due to fatigue.

As alternative, the ALT integrated with the reliability block diagram can be studied. It includes a test scheme for the system, recognizing failure mechanics such as fatigue, and employing a sample size formulation, accelerated loads, etc. Performing an ALT [7,8] involves numerous ideas such as the BX lifetime for the test scheme, a simpler life-stress model, sample size formula, and fracture mechanics [9–11] because failure may unexpectedly happen because of problematic parts in a product.

To reveal the efficacy of recognizing and modifying the design flaws of a mechanical system, an ALT may be utilized as a reliability methodology which may produce the RQ specifications. It contains: (1) a system BX life produced on the ALT plan, (2) a load analysis, (3) customized ALTs with the modifications, and (4) an assessment of whether the system design(s) fulfills the targeted BX life. The sample size formulation, time-to-failure model, and BX life is proposed. To assure ALT outcomes in real life, it might be required to observe the establishment of new design in the field to secure

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it extended the objective reliability. A cylinder in a machine tool subjected to repetitive pressure impact loading is employed to explain the systematic method.

II. Parametric ALT for Mechanical Product

A. Setting an general testing scheme for parametric ALT

In mechanical systems, power may be utilized to a mechanical advantage to supply a task which necessitate forces and motion by adopting the mechanisms. As systems are subjected to repetitive loads, they might have a right life for the anticipated stresses in the product. An instance is a machine tool which is utilized to machine metal or other hard materials by cutting, shearing, grinding, boring, or other form of deformation. One of the parts in machine tools used frequently is the cylinder. A machine tool may cover a span of modules — tool (or pellet) changing device, hydropower unit, tilting index table, spindle/drive unit, turret head, CNC controller, and cooler unit. The life of the machine tool is determined by the (random or wear-out) failure of the new module such as the cylinder that contains design defects (Fig 1).

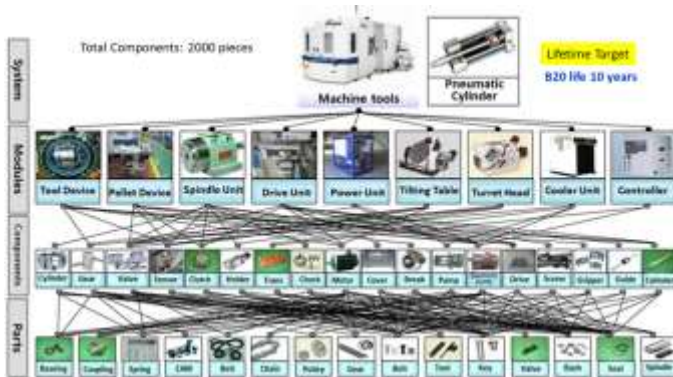


Figure 1 Product lifetime decided by new problematic module (machine tools)

To carry out a parametric ALT, the BX lifetime or “Bearing Life”, L_B , might be established as an index of the product life. It is the passed time for which X% of a population of system is unsuccessful. For example, if a system is a B20 life 10 years, it signifies that 20% of population shall fail in 10 years of working.

The reliability of a mechanical product may be stated as the capability required to do the planned task under specified working/environmental circumstances for a needed period of time. It may be expressed as “bathtub curve”. As design improves, the cumulative failure function in a mechanical product could be calculated from the system life L_B and failure rate λ as follows:

$$F(L_B) = 1 - R(L_B) = 1 - e^{-\lambda L_B} \cong \lambda L_B \quad (1)$$

where $R(\cdot)$ is reliability function, $F(\cdot)$ is unreliability function.

Equation (1) is valid to $\leq 20\%$ of accumulative failure rates, $F(\cdot)$. After setting the target of system life L_B , engineer can identify any design flaws and alter them by ALT (Fig. 2 and Table I).

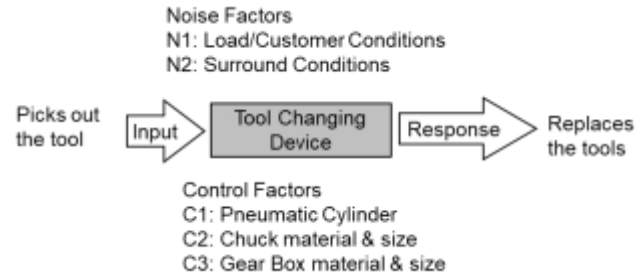


Figure 2 Parameter diagram of mechanical system – tool change device (example)

TABLE I. OVERALL ALT SCHEME FOR A MECHANICAL PRODUCT – MACHINE TOOLS (INSTANCE)

No	Module Name	Market Data, F ($RN=1.8$)		Design	Conversion	Expected, F ($RN=1.5$)		Targeted, F ($RN=1.0$)	
		Yearly Failure Rate, %/year	L_B Life, year			Yearly Failure Rate, %/year	L_B Life, year	Yearly Failure Rate, %/year	L_B Life, year
1	Module A	0.34	5.3	New	x5	1.70	3.1	0.30	10
2	Module B	0.35	5.1	Given	x1	0.35	5.1	0.30	10
3	Module C	0.25	7.2	Modified	x2	0.50	3.6	0.30	10
4	Module D	0.20	9.0	Modified	x2	0.40	4.5	0.30	10
5	Module E	0.15	12.0	Given	x1	0.15	12.0	0.25	10 ($RN=1.5$)
6	Others	0.50	12.0	Given	x1	0.50	12.0	0.45	10 ($RN=4.5$)
Total	Product (X-Set)	1.79	5.1	-	-	3.60	3.6	1.00	10 ($RN=10$)

In setting the BX life target of a mechanical product for ALT, there are three cases: (1) a new module, (2) a modified module, and (3) same module. A pneumatic cylinder which shall be case-studied is regarded as a new module. Like an itemized module in Table 1, pneumatic cylinder from the field had yearly failure rates of 0.34% per year and a lifetime of B1.8 life 5.3 years. To reply to consumer requirement, a life for the pneumatic cylinder was targeted to B1 life 10 years.

B. (Generalized) Time to Failure and Sample Size Equation

When employing machine tools, manufacturer want their workman to easily change the tools by pushing them. As the pressure difference between the two rooms of pneumatic cylinder push (or pull), the piston rod extends (or retracts). Pneumatic cylinders thus may be employed in apparatus to help move or open mechanical devices. At that time the pressure difference due to impact loading guides a piston through a linear-pathway motion to the required position in a cylinder. It is subjected to repetitive stresses because of (pressure) impact loading/unloading, relied on end masses that are changed with the end uses.

If there is a design flaw in the structure that produces an inadequate stiffness (or strength) when the loading is exerted, the mechanical system may be suddenly unsuccessful before its anticipated life. The pneumatic cylinder shall need service. If problem have, it needs to be fastened and/or replaced (Figure 3).

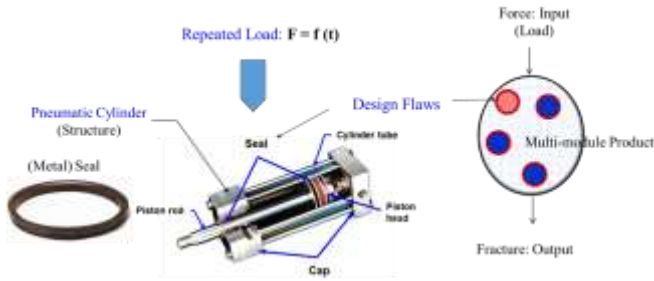


Figure 3 Failure mechanics in the structure generated by repetitive load and design imperfections

The principal issue for accelerated testing is to decide how easily the possible failure mode may be found. To do it, it is required to completely formulate a failure explanation and the related exponents for the simplified model. A life-stress (LS) modeling should be formulated, which has stresses and reaction factors. These concise modelling can cover numerous mechanical failures – fatigue, fracture, etc. Fatigue failures may not only happen due to stresses in a product component but also due to the flaws in tiny cracks or on the surface of a part.

Fatigue can start from material imperfections – electron/void – which are produced on a microscopic or macro range. From such conceptual viewpoint, it may be stated as transport processes – the diffusion of shallow level dopants of silicon in semiconductors, which are regarded as non-equilibrium thermodynamics. When an electric magnetomotive force, ζ , is applied, the material voids, produced by electronic/atomic motion, are easily drifted because the hurdles of junction energy are lowered and deformed/phase-shifted (Fig. 4).

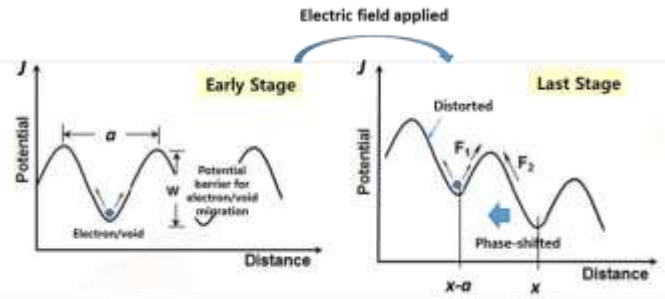


Figure 4 Potential change in material such as silicon as electric magnetomotive field is applied.

Linear transport processes are stated as follows:

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

where J is a flux vector, X is a driving force, L is a phenomenological transport exponent

For example, transport can use the established way for solid-state diffusion of impurities in silicon, which is frequently employed in semi-conducts. These established ways cover electro-migration-induced voiding, growth of chloride ions, and catching of electrons or holes. Solid-state diffusion of impurities in silicon J could be stated as [12]

$$\begin{aligned} J &= [aC(x-a)] \cdot \exp\left[-\frac{q}{kT}\left[w - \frac{1}{2}a\xi\right]\right] \cdot v \\ &= -[a^2ve^{-qw/kT}] \cosh\frac{qa\xi}{2kT} \frac{\partial C}{\partial x} + [2ave^{-qw/kT}]C \sinh\frac{qa\xi}{2kT} \\ &\cong \Phi(x,t,T) \sinh(a\xi) \exp\left(-\frac{Q}{kT}\right) \\ &= B \sinh(a\xi) \exp\left(-\frac{Q}{kT}\right) \end{aligned} \quad (3)$$

where B is constant, a is the distance between (silicon) atoms, ξ is the exerted field, k is Boltzmann's constant, Q is energy, and T is absolute temp.

On the other hand, a reaction process which is relied on speed could be stated as:

$$\begin{aligned} K &= K^+ - K^- = a \frac{kT}{h} e^{-\frac{\Delta E - \alpha S}{kT}} - a \frac{kT}{h} e^{-\frac{\Delta E + \alpha S}{kT}} \\ &= 2 \frac{kT}{h} e^{-\frac{\Delta E}{kT}} \cdot \sinh\left(\frac{\alpha S}{kT}\right) \end{aligned} \quad (4)$$

So the reaction rate, K , from Equations (3) and (4) could be summarized as:

$$K = B \sinh(aS) \exp\left(-\frac{E_a}{kT}\right) \quad (5)$$

If Equation (5) takes an inverse function, (generalized) life-stress modeling could be expressed as

$$TF = A[\sinh(aS)]^{-1} \exp\left(\frac{E_a}{kT}\right) \quad (6)$$

The hyperbolic sine stress in Equation (6) can be described as follows: (1) originally $(S)^{-1}$ in low stress, (2) $(S)^{-n}$ in medium stress, and (3) $(e^{aS})^{-1}$ in high stress. Because ALT shall be carried out in the medium stress span, it can be expressed as follows:

$$TF = A(S)^{-n} \exp\left(\frac{E_a}{kT}\right) \quad (7)$$

Because the stress in mechanical product is not easy to be described instantly, Equation (7) need to be redefined. When

power transfer is stated as the product of effort and flows, stress comes from effort in a multi-port product.

So Equation (7) shall be restated as follows:

$$TF = A(S)^{-n} \exp\left(\frac{E_a}{kT}\right) = A(e)^{-\lambda} \exp\left(\frac{E_a}{kT}\right) \quad (8)$$

Design flaws in products may be obtained by applying larger effort under the accelerated circumstances. From the time-to-failure in Equation (8), an acceleration factor (AF) may be explained as the ratio between the elevated circumstance and common circumstance. AF may be expressed to incorporate the effort concepts:

$$AF = \left(\frac{S_1}{S_0}\right)^n \left[\frac{E_a}{k} \left(\frac{1}{T_0} - \frac{1}{T_1}\right)\right] = \left(\frac{e_1}{e_0}\right)^\lambda \left[\frac{E_a}{k} \left(\frac{1}{T_0} - \frac{1}{T_1}\right)\right] \quad (9)$$

Because elevated testing is carried out at room temperatures, Equation (9) may be restated as:

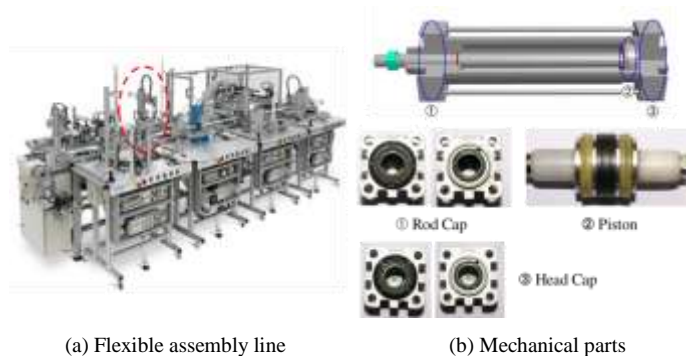
$$AF = \left(\frac{S_1}{S_n}\right)^n = \left(\frac{e_1}{e_n}\right)^\lambda \quad (10)$$

To get the mission revolution of ALTs from the objective BX life on the test scheme in Table I, the sample size formulation integrated with the AF in Equation (10) could be obtained [13].

$$n \geq (r+1) \times \frac{1}{x} \times \left(\frac{L_B^*}{AF \cdot h_a}\right)^\beta + r \quad (11)$$

If the life of a mechanical product, such as the pneumatic cylinder, is targeted to be B1 life 10 years, the mission revolutions may be obtained for a set of sample sizes.

III. Case study: reliability of a Localized Designed Pneumatic Cylinder



(a) Flexible assembly line

(b) Mechanical parts

Figure 5 Pneumatic cylinder in a flexible assembly line

Pneumatic cylinder in equipment such as machine tools is utilized to help move or open mechanical devices. To move a load along linear pathway to the location, mechanical parts in the cylinder are necessitated. They are made of a piston, rod cap, head cap, etc. Depending on the anticipated consumer usage circumstances, the parts of the cylinder was subjected to repetitive mechanical pressure impact loading during usual works (Fig. 5).

According to the market data, during established customer use, the fractured (or harden and worn) piston seal created the (pneumatic) cylinder to leak and stop working. The field data from the problematic cylinders due to the improper material such as polyurethane or rubber were notable for comprehending the use conditions of customers and help to decide design imperfections which is required to be modified in the system. Based on the market data, it was necessary to reproduce and modify them. If the product lifetime were targeted, it could recognize which part(s) in the cylinder is altered to increase its life by parametric ALT (Fig. 6).

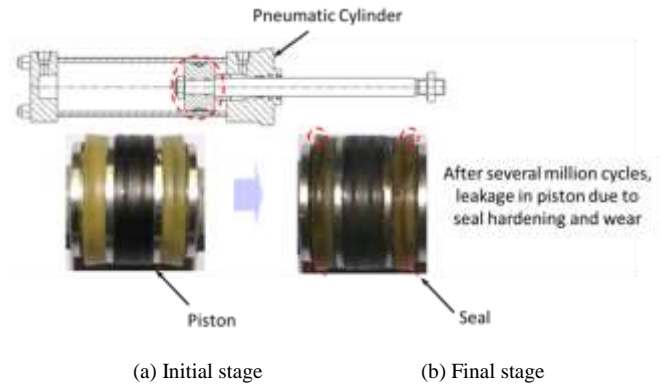


Figure 6 Failed piston seal in field

From the field, some parts in pneumatic cylinder were being unsuccessful due to repetitive pressure loading under unspecified customer operation circumstances. When market data were analyzed, the problematic products in field might have had design flaws. That is, after the pneumatic cylinder was subjected to repetitive pressure impact loading, it experienced the presumed failure mechanisms as follows: (1) overheating of the piston seal; (2) hardening and wear of the piston seal; and (3) surpassing Minimum Operation Pressure (MOP) and Stroke Time (ST).

The pressure difference of the pneumatic cylinder may be stated as:

$$\Delta P = \Delta F_{int} / A \quad (12)$$

Because the stress in pneumatic cylinder relies on the pressure, Equation (8) may be stated as:

$$TF = A(S)^{-n} = B(\Delta P)^{-\lambda} \quad (13)$$

Because elevated testing is carried out at room temperatures, AF from Equation (10) could be restated as:

$$AF = \left(\frac{S_1}{S_n}\right)^n = \left(\frac{\Delta P_1}{\Delta P_n}\right)^\lambda \quad (14)$$

For a cylinder in a machine tools, the representative working temp. varied from 0 °C to 43 °C with relative humidity varied from 0 to 95 percent. Vibration circumstances presumed for operating the cylinder varied from 0.2 to 0.24g of acceleration. When the cylinder worked, the piston transported the load along a linear pathway to the needed location. Altering a machine tool was anticipated to happen a mean of ten to thirty times per day. Under the worst cases, the cylinder operating for ten years can experience about 109,500 use cycles.

To decide the stress amount for ALT, based on the expected use span of cylinder in bench-marked data which were attained from other companies, we used the step-stress life test that might assess the life under used-circumstances for some accelerated loads (or end load masses). As the diverse stress quantity due to end loads was modified, we might see the failure cycles of the cylinder at 0.8MPa, 1.2MPa, and 1.4MPa which depended on end load masses in numerous usage [14]. For an ALT, the pressure difference was lastly accelerated to be 0.8 MPa with a cumulative damage quantity, λ , of 2 because there was a good trend on Weibull plot. The whole AF computed from Equation (14) was 1.6.

The mission revolutions of the parametric ALTs computed from Equation (11) were 200,000 cycles for ten samples if the shape parameter, β , was assumed to have 2.0. The ALT was designed to assure a life target — B1 life 10 years — with an about 60% level of confidence that it would fail less than once during 200,000 cycles (Fig. 7).



Figure 7 Equipment utilized in the ALT

IV. Results and discussion

To decide the stress quantity by the step-stress life test, we observed the failure revolutions at 0.8 MPa, 1.2 MPa, and 1.4 MPa which may be attained from the end of load mass. For 0.8 MPa, the cylinder noised at 6000 cycles and 10,000 cycles. For 1.2 MPa, the cylinder noised at 4000 cycles and 8000 cycles. Otherwise, for 1.4 MPa, the cylinder noises at 1000 cycles. So, we determined the stress level as 0.8MPa for ALT because it had a relatively better data-linearity, comparison to other stress quantities.

At first, when 0.8 MPa as the accelerated pressure difference in a cylinder was loaded, the cylinder ($n = 10$) noised at 6000 cycles, 10,500 cycles, and 11,000 cycles which had a 70 dB (maximum) and caused moderate-to-severe hearing loss. After disassembling three failed cylinders, one sample was partly a cracked sample and two samples were chipped due to the repetitive pressure impact load. The problematic samples were inspected utilizing scanning electron microscopy (SEM). The position of the multiplicative

crack initiation and the microscopic growth at the beginning of the crack were found. We therefore conjectured that loading and material was feasibly the most usual cause of failure. In other word, as pressure impact loading was repetitive exerted to the wrongly-selected material seal such as Fe-36Ni Invar Alloy along the axial direction of the pneumatic cylinder, it might conduct to chipped and partially cracked samples. Though the metal (Fe-36Ni Invar Alloy) had better sealing characteristics, it was finally unsuccessful under repetitive pressure impact loading. As action plan, the seal in the cylinder was altered from Fe-36Ni Invar Alloy to a silicone rubber, made of silicone — just kind of a polymer — holding silicon with carbon, hydrogen, and oxygen (C1) (Fig. 8).

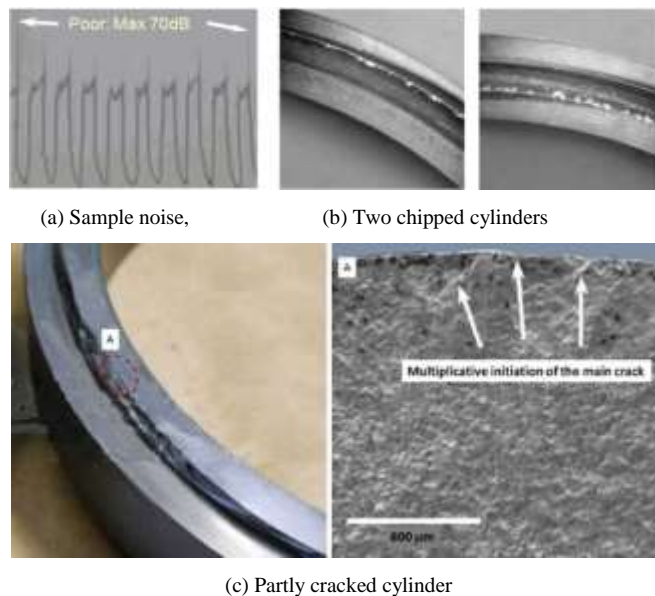


Figure 8 Design problems of cylinder in 1st ALT



(b) Failed cylinders in parametric ALT.

Figure 9 Failed cylinders in market and parametric ALT

Cylinders in 2nd ALT ($n = 10$) was unsuccessful at 50,000 cycles (one cylinder), 100,000 cycles (two cylinders), 110,000 cycles (one cylinder), and 115,000 cycles (one cylinder). The failure mode of the samples was over the minimum operating pressure and piston stroke time. As the issued cylinders were taken apart, the hardening and wear of piston seals were like those of cylinders returned from the field. The failure mechanism occurred as follows: (1) repeated operating stress, (2) friction heat in seal, (3) lube vaporization in seal, (4) elevating seal hardening, and (5) elevating seal wear. The forms and positions of the problematic cylinders attained from 2nd ALT and the market (or normal condition) were alike (Fig. 9).

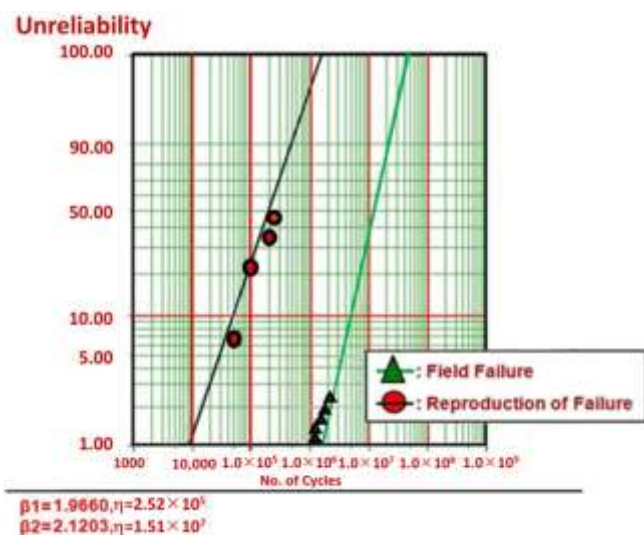


Figure 10 Field statistics and results of ALT on Weibull plot.

The second ALT and field failure data demonstrated an alike pattern on a Weibull plot. Thus, each loading circumstance of 2nd ALT and that from the market over the system life were expected to have alike. For the shape parameter, β , the shape parameter from the Weibull chart was confirmed to have 1.97, comparison with the guessed amount of 2.0. Based on both tests in the Weibull graph and ALT representation, we can recognized that the ALT was helpful because it determined the design imperfections which were responsible for the market failures (Figs. 9 & 10).

When carefully investigating the system failure in 2nd ALT, it was decided that the hardening and wear of piston seal in the cylinder originated from utilizing an inappropriate material such as silicone rubber. Though the seal material had better sealing characteristics, it was yet unsafe to endure under repetitive pressure impact loads. The seal material, C2, was altered from silicone rubber to a (thermoset) polyurethane with excellent abrasion and wear resistance that supplied reliability versus ordinary rubber-based seal.

In 3rd ALT, there were no design issues in the pneumatic cylinder until the parametric ALT fulfilled 220,000 cycles. It

was thus deduced that the design alternations obtained from 1st and 2nd ALTs were effective in fulfilling the required lifetime of the system. Table II abridges the ALT outcomes. With the modified designs, the cylinder was assured to fulfill the life objective — B1 life 10 years.

TABLE II. RESULTS OF ALT

Parametric ALT	First ALT	Second ALT	Third ALT
	Original Design	Design	Final Design
In 220,000 cycles, there are no issues in the pneumatic cylinders	6000 cycles: 1/10 noise (partially cracked sample) 10,500 cycles: 1/10 noise 11,000 cycles: 1/10 noise (two chipped samples)	50,000 cycles: 1/10 fail 100,000 cycles: 1/10 fail 110,000 cycles: 1/10 fail 115,000 cycles: 1/10 fail (Hardening and wear of piston seal)	220,000 cycles: 10/10 OK
Structure			
Action plan	C1: material: Fe-36Ni Invar Alloy → 5d core rubber	C2: material: Silicone rubber → (thermoset) Polyurethane	

v. Conclusions

To increase the life of a new mechanical product such as a cylinder utilized in a machine tool, we employed a reliability methodology that included a (generalized) life-stress model by a linear transport process and a sample size. It included the following: (1) the system BX life produced the ALT scheme, (2) ALTs with alternations, and (3) determination if the system design attained the desired number of mission cycles. The failure and redesign of a pneumatic cylinder were used as a test case for the methodology.

- (1) In 1st ALT, the pneumatic cylinder ($n = 10$) noised near 6,000 cycles, 10,500 cycles, and 11,000 cycles. As breaking down three failed samples, we observed they are one partly cracked cylinder and two chipped cylinders due to heavy load. As action plan, the seal in an cylinder was altered from Fe-36Ni Invar Alloy to silicone rubber.
- (2) In the second ALT, we found out the hardening and wear of piston seal like those of field cylinders. It occurred as follows: (1) repeated operating stress, (2) friction heat in seal, (3) lube vaporization in seal, (4) elevating seal hardening, and (5) elevating seal wear. As action plans, we altered the seal material, C2, from silicone rubber to (thermoset) polyurethane.
- (3) During 3rd ALT, no issues were discovered. The pneumatic cylinder systems might get the life target—B1 life 10 years with roughly a 60% confidence level. By investigating problematic market cylinders and conducting ALTs with alternations, it was plausible to enhance the life of pneumatic cylinder.

This systematic method has been exerted successfully to other mechanical products and, as demonstrated here, was effective in improving the reliability of the pneumatic cylinder. It should be applicable to other mechanical systems. Designers need to understand why multi-module product is unsuccessful during their life. If there are design defects in the newly designed module structures and are subjected to repetitive loading during its work, the system may be

unsuccessful before its anticipated life. Engineers might be required to characterize the (dynamic) loading of a mechanical system so that the accelerated testing expressed as the proportion of maximum stress/minimum stress may be performed until the required mission cycles (reliable quantitative specification) are obtained from the sample size formulation. In the meantime, parametric ALT may be employed to place and modify the design matters of a mechanical system.

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Dr. Woo has a BS and MS in Mechanical Engineering, and he has obtained PhD in Mechanical Engineering from Texas A&M. He major in energy system such as HVAC and its heat transfer, optimal design and control of refrigerator, reliability design of mechanical components, and failure Analysis of thermal components in marketplace using the Non-destructive such as SEM & XRAY. Especially, he developed parametric accelerated life testing (ALT) as new reliability methodology. If there is design fault in the mechanical system that is subjected to repetitive stress, it will fail in its lifetime. Engineer should find the design faults by parametric ALT before product launches.

In 1992–1997 he worked in Agency for Defense Development, Chinhae, South Korea, where he has researcher in charge of Development of Naval weapon System. In 2000-2010 he had been working as a Senior Reliability Engineer in Side-by-Side Refrigerator Division, Digital Appliance, SAMSUNG Electronics, where he focused on enhancing the life of refrigerator as using parametric the accelerating life testing. Now he is working as associate professor in mechanical department, Ethiopian Technical University.