A Research on the Overall Unit Accelerated Storage Test Method for Aerospace Products

Geihong Song, Ting Liu, Shumei Chen
Beijing Research Institute of Mechanical & Electrical Technology
Beijing, China

Abstract—Based on the transformation method, this paper proposes a method of overall unit accelerated storage test with time synchronization. We have done engineering practices on certain pyrotechnics device with this method, and forecasted the storage life of this certain pyrotechnics device.

Keywords—overall unit ; accelerated storage test; weak parts; storage life

I. INTRODUCTION

As aerospace products are characterized by long-term storage, accelerated storage test is an effective way to find out its long-term storage properties. Although there has been some research achievements and application information on accelerated storage life test of components, raw materials and initiating explosive devices in China [1][2][3][4], few cases of overall unit accelerated storage test were reported. As the overall unit is consisted of multiple components and raw materials, and factors or mechanisms which are responsible for the failure of overall unit storage are also complicated, so the requirements of failure mechanism are usually not satisfied. If we randomly choose an accelerated stress to perform a test, the results can hardly reflect the reality of situation. However, it costs too much to test using large numbers of overall unit. Thus, it is hard to study the accelerated storage test on overall unit.

Based on the transformation method, this paper proposes a method of overall unit accelerated storage test with time synchronization. We have done engineering practices on certain pyrotechnics device with this method, and forecasted the storage life of this certain pyrotechnics device.

II. RESEARCH METHODOLOGY OF OVERALL UNIT ACCELERATED STORAGE TEST

There are two types of research methodologies on the overall unit accelerated storage test [3].

2.1 Transformation Method

It is extremely difficult to construct a relation model of failure rate between high stress condition and normal storage condition; moreover, it is also hard to judge the stress condition is appropriate for the overall unit. However, the number of failure modes of components and parts are much less than the overall unit, as their failure modes and failure mechanisms are single, so it is much easier to determine which kind of stress could accelerate failure rate without altering failure mechanism.

According to the wooden barrel theory, the life of a product is determined by its weak parts. No matter how superior are a product’s other key parts, important parts or performance designing, once any part affecting its function fails, the life of this product is finished. Therefore, after weak parts are discovered, the overall unit accelerated storage test becomes an accelerated storage test of components or parts. Then, with the accelerated factors acquired in accelerated storage test of parts and experiment conditions, a small amount of conformation test of the overall unit could be performed.

2.2 Performance Parameter Degeneration Method

When a product is affected by various kinds of energies (environment stress), the performance or status of its materials would change accordingly (This change is closely related to complicated physical and chemical phenomenon). When these energies or stresses accumulate to a certain degree, product damages will appear, featuring in variation of output parameters. When damages reach an extreme value, product failure will appear. Therefore, the possibility of product failure is closely related to the process in which its performance parameters approach extreme condition.

Product failure can be divided into two types according to the model of failure, namely sudden failure and degeneration failure. With continuing improvement of manufacturing technologies and materials, reliability and life of products become higher and longer. For this reason, failure data is difficult to obtain because products are impossible to fail in a relatively short term. If a product belongs to degeneration failure, reliability evaluation of a product could be performed in performance degeneration analysis instead of traditional failure data analysis. In recent decades, more and more researchers in engineering and statistics field measure certain performance parameters to forecast storage life (or storage reliability), developing a new way to perform reliability evaluation (or forecast) with degeneration data instead of failure data.
III. METHOD OF ACCELERATED STORAGE TEST WITH TIME SYNCRONIZATION

Based on transformation method, the method of accelerated storage test with time synchronization is a kind of storage test method applicable to overall unit.

3.1 Forecast of Weak Parts

The analysis of weak parts plays a key role in transformation method. The accuracy forecasted by weak parts has a great effect on test design. Researches must be done from following aspects before test design [6].

1) Analysis of product structure, functions, and manufacturing features. For any newly manufactured overall unit, the analysis of overall unit structure, functions, and manufacturing features is a fundamental requirement to find its weak parts.

2) Analysis of storage environment. Storage process will be affected by environmental factors such as high temperature, low temperature, high moisture, salt spray, mold, vibration and shock. The effects of these factors should be analyzed according to storage profiles specifically.

3) Analysis of storage weak parts. The first step of analyzing the storage failure of a product is to find the weak parts of storage process, which will gradually narrow the analyzing scope of the product.

4) Analysis of storage failure modes and failure mechanisms. Regular patterns and possible could be analyzed to find the key storage failure model and failure mechanism responsible for the loss of product functions or ending of its life.

3.2 Design of Accelerated Storage Test for Weak Parts

The weak parts of a product could be found with forecast of product weak parts. These weak parts should be parts of an overall unit, or further analysis should be continued to part level. There will be only one weak part under most favorable condition. However, there are always more than one weak part, and accelerated storage test should be designed according to features of each weak part.

3.3 Design of Composite Accelerated Storage Test with Time Syncronization

1) Accelerated storage test are done to obtain testing results of testing materials in each weak parts.

2) Testing conditions of accelerated storage test in weak parts, which have different accelerated factors and accelerated storage test time, are determined according to testing results.

3) A reasonable level of accelerated stress is selected according to determine accelerated testing time of each weak part under such accelerated stress.

4) Number of sample products being tested is calculated base on testing programs, times and actual testing amounts of each time, which is determined by accelerated stress level.

(5) According to accelerated testing time in each weak part selected in step (3), time points of inputting each weak part to perform accelerated test is calculated.

(6) Based on time points of inputting each weak part, they are installed into products being tested sequently, reaching product storage test time jointly.

IV. ENGINEERING PRACTICE

Based on analysis of function structure and manufacturing features for certain pyrotechnics device, analysis of storage environment factors, analysis of storage weak parts, analysis of storage failure model and failure mechanism, the weak parts of certain pyrotechnics device is defined as its leaf spring and rubber seal ring. Therefore, the method of accelerated storage test with time synchronization is selected, and storage test of certain pyrotechnics device is consisted of three parts:

1) Accelerated storage test of leaf spring;

2) Accelerated storage test of rubber seal ring;

3) Accelerated storage test of certain pyrotechnics device with time synchronization.

4.1 Accelerated storage test of leaf spring

The accelerated storage test conditions of leaf spring are defined according to GBT 10120-96 Metallic Materials-stress Relaxation Test (a Chinese standard). The accelerated storage test of leaf spring was performed under two kinds of loads, one of which is larger than normal load (heated acceleration), and one of which is normal load, to obtain structure status at different stages of failure. Then two kinds of structure could be compared, and the relation between time variable T and load F could be derived to construct a mathematical model of failure time and load. When load and failure time are inputted, failure time under normal load condition can be calculated.

The accelerated storage test was done under different temperatures, 80°C, 90°C, 100°C, 120°C, 140°C, 160°C, 180°C, 200°C. The leaf spring was accelerated to the loss rate of load under different year of operation status. The corresponding accelerated time under different accelerated temperature was derived. When accelerated temperature was 90°C, accelerated test lasted for 95.72 hours, the equivalent storage time was 12 years. Accelerated test lasted for 101.72 hours means 14 years.

4.2 Accelerated storage test of rubber seal ring

The material of rubber seal ring of certain pyrotechnics device is NBR, the accelerated storage test was performed according to GJB92.1-86 Rubber, Vulcanized-directives for Determination of Storage Characteristics Using Accelerated Ageing or Heat Air-oven Method Part 1: Test Code (a Chinese standard), and the data analysis and storage life evaluation refer to GJB92.2-86 Rubber, Vulcanized-directives for Determination of Storage Characteristics Using Accelerated Ageing or Heat Air-oven Method Part 1: Statistical Methods.

The compression sampling test was performed under temperatures of 60°C, 70°C, 80°C, 90°C, 100°C. The regular
physical performance sampling test was performed under temperature of 90°C. Based on test result, when accelerated temperature was 90°C, accelerated test lasted for 47 days, the equivalent storage time was 12 years; when accelerated test lasted for 55 days, the equivalent storage time was 14 years.

4.3 Accelerated storage test of certain pyrotechnics device with time synchronization

According to the result of accelerated aging test for rubber seal ring and leaf spring, temperature point of overall unit accelerated storage test for certain pyrotechnics device was selected as 90°C. The overall unit accelerated storage test was performed under storage life of 12 years and 14 years respectively.

(1) When the storage life was 12 years, the seal ring was firstly installed into 6 samples of certain pyrotechnics device (except for seal ring, leaf spring and initiating explosive device) to test. When the test lasted for 44 days, the leaf spring was installed, and when the test lasted for 47 days, certain pyrotechnics device was pick taken out, electrical detonator was installed, and spreading experiment was performed on ground simulation loader machine (3 samples of certain pyrotechnics device under max contrary wind, another 3 samples under max favorable wind).

(2) When the storage life was 14 years, the seal ring was firstly installed into 6 samples of certain pyrotechnics device (except for seal ring, leaf spring and initiating explosive device) to test. When the test lasted for 50.5 days, the leaf spring was installed, and when the test lasted for 55 days, certain pyrotechnics device was pick taken out, electrical detonator was installed, and spreading experiment was performed on ground simulation loader machine (3 samples of certain pyrotechnics device under max contrary wind, another 3 samples under max favorable wind).

The result of accelerated storage test for certain pyrotechnics device shows that its forecasted storage life was 14 years.

V. CONCLUSION

Based on the transformation method, this paper proposes a method of overall unit accelerated storage test with time synchronization. We have done engineering practices on certain pyrotechnics device with this method, and forecasted the storage life of this certain pyrotechnics device.

REFERENCES