Research on the Highly Accelerated Stress Screening (HASS) Test Process of Civil Aircraft Airborne Equipment

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Abstract. The reliability of the airborne equipment of civil aircraft is highly concerned by the aircraft Original Equipment Manufacture (OEM), airlines, passengers and airworthiness authorities, and is the key to ensuring the safety and punctual operation of the aircraft. The Highly Accelerated Stress Screening (HASS) test is one of the effective test methods to ensure that the product reaches the expected reliability level, and it has been widely used in aviation, high-speed rail, automobiles and other fields. Based on the characteristics of civil aircraft airborne equipment, combined with the universal method of HASS test, this paper investigates the application process of HASS test on airborne equipment, and gives the method for determining the test object of airborne equipment by HASS, and the test of HASS, the principles of test profile design, follow-up verification and troubleshooting methods. The research can be applied to the HASS test work of civil aircraft airborne equipment, and guide the development of HASS test, so as to effectively propose defective products in the manufacturing stage and improve the reliability of the installed airborne equipment.

1. Introduction

The reliability level of civil aircraft airborne equipment is not only determined by the design level of the product, but also depends on the assurance capability of the product manufacturing and maintenance process. Especially in the manufacturing process of products, any link of "man-machine-materials-method-loop-test" may cause internal defects of the product and reduce the reliability level of the product. Unexpected failures of airborne equipment will not only cause the equipment itself to be unusable, but will also cause more serious or even catastrophic consequences for other related equipment, systems, aircraft, passengers, airlines and aircraft Original Equipment Manufacture (OEM).

Based on this consideration, the environmental stress screening (ESS) test was first introduced in the production process of the product. During the manufacturing process, the environmental stress slightly higher than the normal product was applied, but it was far from reaching the environmental stress for product damage. Screen out products with inherent defects to ensure the quality of installed products. However, this kind of test method has some drawbacks, because it is slow to screen defective products and misses to select some defective products. In the development process of environmental stress screening test, considering the limitations of ESS, Highly Accelerated Stress Screening (HASS) test was gradually introduced. HASS was developed on the basis of environmental stress screening (ESS) test and highly accelerated life test (HALT).
The environmental stress screening method with higher accuracy and faster screening speed can effectively and quickly eliminate defective products in the batch production stage[1]. HASS has all the basic characteristics of ESS, but unlike ESS, HASS needs to be carried out on the basis of HALT. Only after HALT is completed and all the problems found are resolved, can HASS be allowed. HASS generally uses rapid temperature cycling and random vibration to perform comprehensively. According to the working limit and damage limit obtained by HALT, the HASS design margin of the product is found out, and the environment that exceeds the specified environmental stress of the product but does not cause damage to the product is used stress, in a short period of time, stimulates the failure of the product caused by the inherent defect. In order to formulate the HASS plan and determine the magnitude of the HASS, it is needed to ensure that the amount of fatigue life consumed by the screening is always in an acceptable state, so that the factory product is no quality hazard. According to the product working stress limit and damage stress limit obtained by HALT, and it is also necessary to carry out closed-loop management based on the faults found by HASS, the causes of the faults will be found and resolved, and the period of implementing corrective measures will be shortened to ensure product reliability[2].

In this work, an in-depth analysis of HASS test objects, test profile design and verification, etc. are given, and the test process and framework are given to guide the implementation of the HASS test.

2. Reasons for HASS
The reason for the HASS work on airborne equipment is that the following goals can be achieved through the HASS test:
- Precipitate related potential defects as obvious defects with the lowest cost and shortest time;
- Detect as many defects as possible with the lowest cost and the shortest time to shorten the feedback delay and reduce the cost;
- Improve operational reliability by reducing the total number of operating failures;
- Effectively use the lowest cost and the shortest time to stimulate and detect product manufacturing process and component batch defects, and reduce the total cost of production, screening, maintenance and assurance;
- Significantly improve user satisfaction and increase market share.

3. HASS test implementation process
The typical HASS implementation process includes three stages: HASS profile design, screening verification and product trial, as shown in Figure 1.
4. HASS test subjects
HASS is only applicable to products that have been performed the HALT test. For products that have not undergone HALT, the inefficient conventional ESS method can only be used to eliminate early faults [3]. As HASS work requires certain conditions and cost is also a consideration, not all products can benefit from HASS at present. Generally, for aircraft airborne equipment, HASS needs to be used to screen airborne equipment in the following situations:
- Newly developed electronic and electromechanical equipment;
- Products with a relatively high level of complexity and no problems exposed by the ESS, but there are still many problems in the operation process;
- Equipment that affects the safety and operation of the aircraft;
- Through the HALT test, it is found that the product has manufacturing process defects or device batch failures, etc., and it is obvious that screening can improve the reliability of the product in the field;

5. Test stress selection
HASS generally selects rapid temperature changes and random vibrations as the stresses for its selection, because rapid temperature changes and random vibrations are the best stresses that can excite manufacturing defects [4].

The HASS stress should be determined according to the working limit and failure limit determined in the HALT test. The relationships between the HASS stress, the limit and margin stress obtained by HALT, and the product design specification stress are shown in Figure 2. It can be found in Figure 2 that the stress used by HASS is located within the destroying stress margin.

![Figure 1. Typical HASS implementation process.](image-url)
Figure 2 HASS test stress design range.

The main principles of HASS stress determination are as follows:

5.1 The strength value should be as high as possible to maximize the compression time.
The higher the stress used by HASS, the faster the loss due to fatigue, abrasion, electro migration, etc., which are caused by stress concentration in the defective part of the product. The damage speed increases with the power exponent of the corresponding force value. The defect-free parts of the product are also damaged, but because the stress is much smaller than the defect, the damage accumulation is much slower. Therefore, when there is not much fatigue damage accumulated in the defect-free area, the defect has already failed due to fatigue failure. It can be seen that HASS can significantly shorten the time for stimulating defects. This effect is accelerated by an exponential multiple of increasing stress. Therefore, the first design principle of HASS is to increase the stress as high as possible to greatly shorten the time of HASS. The benefit is that it greatly reduces the consumption of electricity and liquid nitrogen for screening and technical personnel.

5.2 Slightly lower than HALT to get the stress limit
Exceeding the stress limit determined in HALT, especially the damage limit, will inevitably damage the product, which violates the purpose of HASS, and is not allowed. Although the stress limit obtained by HALT is a clear value, it actually presents a certain distribution. In other words, the limit value of some products in the product group will be lower than this value, and the limit value of some products will be higher than this value. HASS is carried out for each product in batch production. In order to avoid the HASS stress which is used to exceed the limit value of the weaker product of the product group, a value lower than the limit value is often deliberately taken as the maximum stress of HASS.

5.3 Apply the combined effect of low stress to help detecting defects
Although many potential defects can be excited by high stress to become obvious defects, they are difficult to detect under high stress. On the contrary, they can be easily detected under low stress or low stress combined action. Therefore, the HASS profile also includes this type of low-stress or low-stress combination, such as the combination of low temperature and small-value vibration.
6. Profile design

The HASS stress profile is generally composed of rapid temperature change and six-axis random vibration. Temperature and vibration should be applied comprehensively, rather than combined application like traditional ESS, that is, the specified amount is always applied during the entire cycle of rapid temperature change with ruled value random vibration.

For temperature cycle stress, the main indicators should be determined for the temperature cycle in HASS, for example high and low temperature extremes in the temperature cycle profile, the size of the temperature change rate, the holding time at the highest and lowest temperature extremes, the number of temperature cycles, and the tests affected by these parameters expenses and test results.

6.1 Typical HASS profile with precipitation and detection screening

For products with large differences in working and destruction limit, the profile structure includes precipitation screening and detection screening. The precipitation screening part is used to stimulate various weak links in the product. Not only the temperature change rate is fast, but also the range is wide. The strength level should be selected between the working limit and the damage limit of the product. It is generally recommended to take the average value of the damage limit and the working limit. The temperature change rate of the detection and screening part is lower than the precipitation screening temperature, and the temperature range is narrow. The stress level is lower than the working limit measured in the HALT test process, such as 85% of the working limit. This process exposes the weakness of the product link [4]. This typical HASS profile structure with precipitation and detection screening is shown in Figure 3.

![Figure 3. Typical HASS section structure.](image)

6.2 Standard HASS profile
For products whose working limit and damage limit are close to each other, it is not necessary to use a profile composed of precipitation and detection and screening [4]. The standard HASS profile can be used in Figure 4.

![Figure 4. Standard HASS section structure.](image)

When performing product HASS, according to the specific product and its HALT test results, the corresponding initial screening profile can be flexibly formulated. The results of the verification screening and actual work conditions can be continuously improved to obtain an economic, high-speed and effective HASS profile.

7. Screening Verification

Generally, failure mode and effect analysis (FMEA) should be performed before the high acceleration test such as HALT and HASS.” The common failure modes, fault detection and correction methods of existing products need to be performed analysis to find potential weaknesses in the existing design from a theoretical perspective, it can analyze sensitive stresses that affect product reliability. Determine the best excitation stress for accelerated testing, and determine the testing methods for failures during accelerated testing based on its potential failure mode. Clarify the internal relationship between failure mode and failure mechanism, and analyze facilitate effective failure after accelerated test, the possible failure modes of product in accelerated test can be obtained. Provide improvement plans in advance to better analyze the results of accelerated test and suggest improvement measures. Therefore, before the initial HASS screening profile verification, the target value of the profile verification should be clarified, such as the acceleration target value, the screening degree target value, the effective life consumption value and other quantitative parameters, which can be used as the criteria for the screening profile verification [4].

The effectiveness and safety of the HASS screening process are the criteria for determining the HASS test profile. The first step (validation of the profile effectiveness) is to determine how effective the profile is in detecting manufacturing defects, and the second step (validation of the profile safety) is to prove that the profile is safe, and does not excessively consume the useful life of the product.

8. Product Test Run

The HASS test with profile verification is usually regarded as a high-speed and effective quality screening tool, which can effectively carry out continuous testing and screening of each product in the manufacturing process, thereby ensuring the quality and reliability of the product. However, the
HASS profile is not static and can be adjusted appropriately according to the production process and the data during the test run process. However, every adjustment must be carefully considered and clearly analyzed. If a defect is missed in the screening, the caused reason must be analyzed, if necessary, HASS must be modified. If a failure occurs in the HASS process, the cause reason must be carefully analyzed to understand whether it is caused by the change in the HASS process, regardless of any stress change, it must be performed screening verification again.

In addition, when the product design changes greatly, the HASS screening program must be revised and verified to prove whether this change reduces the reliability of the product. Especially when the product has a large change in design, it is required to perform the HALT test again, and on this basis, perform the HASS screening program and verify the screening effect [4].

9. Failure analysis and corrective measures

If there are any failures in the screening unit, a root caused analysis (RCA) should be performed to determine whether the failure is due to overstress or wear, or due to manufacturing process defects. If a defect occurs during the execution of the profile, and if the continued execution of the profile may further damage the failed unit and cover up the original defect, the test should be suspended, and the failed unit should be removed for RCA and replaced with another unit. Then, the test should resume where it is stop off.

The RCA result will determine whether the test procedure or material is defective. If failure analysis has found the root cause of equipment failure, corresponding corrective measures need to be carried out [4]. All corrective actions need to be recorded and approved by the failure review committee.

10. Summary

This work focuses on the airborne equipment reliability improvement with Highly accelerated stress screening (HASS) which has been widely used in the aviation field. This work proposes the applicable objects of the HASS test, section design and verification, fault handling, etc., and gives the HASS procedure in the work. We have also give some recommend test profile for HASS. This work can be widely used in airborne equipment reliability improvement for OEM and equipment manufacture, can be used to improve the aircraft safety and operational reliability.

References

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