HIGHLY ACCELERATED STRESS SCREENING OPTIMIZATION

By

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"In the name of ALLAH S.W.T, The Most Gracious and The Most merciful. Peace is upon the Holy Prophet, Muhammad S.A.W."

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ABSTRAK

Ujian Ketegasan Terpecut Tinggi (HASS) merupakan suatu kaedah ujian yang sangat popular yang digunakan oleh kebanyakan pengeluaran untuk menguji berkenanan dengan prosess oleh sesuatu produk. Ujian HASS terdiri daripada dua fasa - (i) Ujian tekanan dan (ii) Ujian pengesanan. Ujian pengesanan mengandungi ujian tekanan dan ujian fungsi dimana sesuatu produk itu perlu menjalani ujian tekanan pada pelbagai peringkat suhu dan ujian gevibrasi pada 6 darjah kebebasan. Kebanyakan produk Kawalan Penggerak Utama Elektronik (PACE) dikembalikan semula kepada pengeluar pada jumlah yang tinggi kerana kegagalan produk tersebut dimana PACE tidak berfungsi pada suhu yang berbeza di lapangan.Oleh itu, kajian ini adalah untuk menyiasat ujian HASS dalam profil suhu yang digunakan oleh produk PACE mengikut tahap normal. Selain itu, kajian ini juga adalah untuk mengurangkan ralat diantara bacaan terkini dengan bacaan sebenar. Ujian produk HASS memerlukan penambahbaikan berdasarkan pengumpulan data yang telah dibuat dan ujian pengesanan pemeriksaan (POS). Penambaikan terhadap profil suhu daripada 2% kepada 16% berjaya dikecapi melalui kawalan pemprosesan. Kawalan pemprosesan dapat memperbaiki keberkesanan pemeriksaan ujian HASS dengan meminimumkan ralat suhu bacaan. Purata Kuasa Dua Ralat (MSE), Menormalkan Korelasi (NCC), dan Analisis Statistik adalah kaedah yang digunakan untuk mengesahkan keberkesanan profil kawalan pemprosesan. MSE menunjukkan keberkesanan di dalam mengurangkan ralat sebanyak hampir 5% dan penambahbaikan NCC menunjukkan sekitar 3% dan 19.5% untuk ujian tekanan dan ujian pengesanan..

ABSTRACT

Highly Accelerated Stress Screening (HASS) a popular method used by many manufacturing facilities to screen process defects. HASS testing comprises of two phases – (i) precipitation and (ii) detection. The detection includes a functional test at various temperature values and vibration test at 6-degree of freedom. Primary actuator control electronic (PACE) product has high customer returns due to product failure at different temperature in the field. Therefore, this research investigates the compliance in temperature profile used for PACE testing with HASS standard. Proof of Screen (POS) and data collection have shown that product control HASS testing resulted in accurate outcome. A further improvement from 2-16 % in temperature profile is achieved via process control. Process-control improved screen effectiveness to the product by minimizing the error to the set point limit. Mean Square Error (MSE), Normalize Cross Correlation (NCC), and statistical analysis tools are used to verify the process-control improvement profile result. MSE shows that improvement around 5% in minimizing the error and NCC improvement shows around 3% and 19.5% for detection and precipitation phases respectively.

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LIST OF ABBREVIATIONS

FCS	Flight Control System
PACE	Primary Actuator Control Electronic
FCM	Flight Control Module
CAN	Control Area Network
HASS	Highly Accelerated Stress Screening
HALT	Highly Accelerated Life Test
POS	Proof of Screen
SNR	Signal Noise Ratio
Cpk	Process Capability
MTBF	Mean Time between Failures
LOL	Lower Operating Limit
UOL	Upper Operating Limit
LDL	Lower Destruct Limit
UDL	Upper Destruct Limit
DUT	Device under Test

UPS	Uninterrupted Power Supply
DFSS	Design for Six Sigma
SU	Upper Specification
SL	Lower Specification
FBW	Fly by Wire
MSE	Mean Square Error
PDF	Probability distribution function
NCC	Normalize Cross Correlation
RAM	Random Access Memory
GRMS	Gravity Root Mean Square

LIST OF SYMBOLS

φ	Sigma
$\varphi(y)$	Probability distribution curve
$\varphi_E(y, t)$	Probability distribution curve with time
μ	Mean
$L(y)$	Quality loss function

CHAPTER 1

INTRODUCTION

1.1 Background

Fly by wire (FBW) is the term in electronic system designed that works to operate the flight controls replacing the control cables of a conventional airplane. This system develops to provide superior aircraft control over the full flight envelope in aircraft. The benefit of FBW includes protection from the aerodynamic stall and weight reduction for the overall system. Flight control system (FCS) is the most important element in aeroplane. Pilot uses this system to control the force of the flight and the aircraft direction and altitude. FCS composes of primary and secondary flight control surfaces. Figure 1.1 shows for the elements in FCS. The primary control system includes the ailerons, elevator, rudder and multi-function spoiler. The secondary control system includes the spoiler, speed break, horizontal stabilizers and flaps and slats system [1].

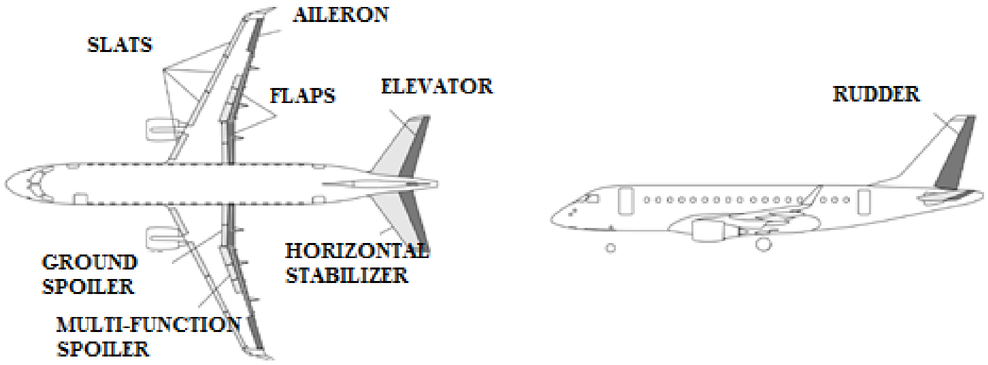


Figure 1.1: Primary and Secondary control system [1]

Primary actuator control electronic (P-ACE) is the analog feedback control electronic system that interacts between cockpit electronic system and the electromechanical hydraulic actuator which controls the aircraft elevator and rudder. PACE is a part of the FCS units. FCS consists of 2 complementary parts such as PACE and flight control module (FCM). These units are used to operate the electro mechanical actuator. PACE sends and receives serial data using bidirectional digital input and output from FCM of Control Area Network (CAN) message. Each three units are installed in the aircraft. Two units are in the forward electronic bay and one in the aft compartment.

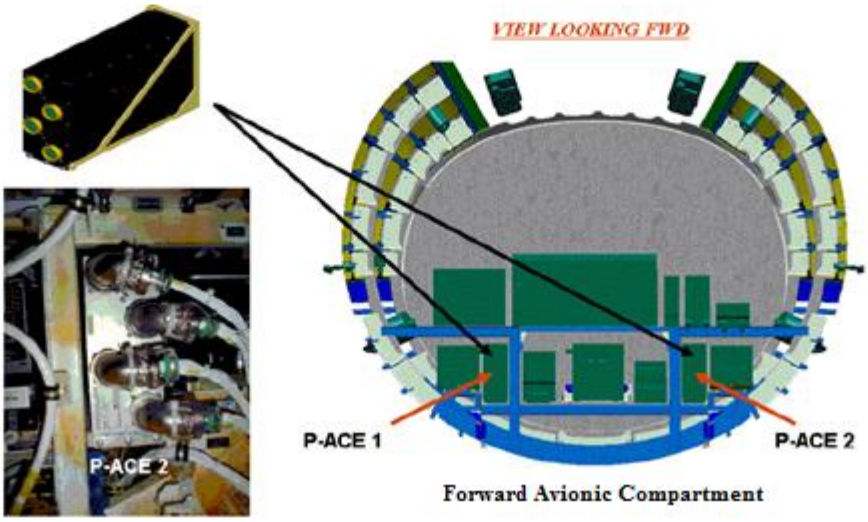


Figure 1.2: Two units of PACE in forward electronic bay

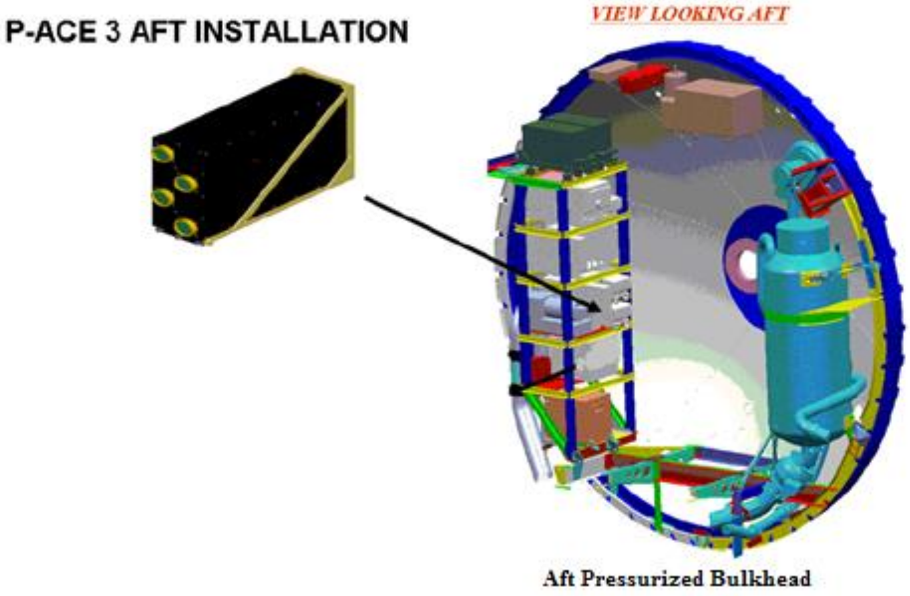


Figure 1.3: One units in aft compartment

Each PACE has two channels and the channels are separated by mechanical construction. Each channel consists of Command Board and Monitor Board that interact with each other. Command board is used for control, while the monitor board is used for monitoring of one primary surface actuator. Each PACE has two channels that will be automatically backup if one of the channel encounter any problem.

PACE is widely used for main aircrafts in the world such as Airbus (France), Boeing (USA), Embraer (Brazil) and COMAC (China) [25]. This product will go through normal production testing such as calibration, pretest, Highly Accelerated Stress Screening (HASS) testing and final test before shipment to customer. PACE have a lot of customer returns due to failure in the system bench at customer side and in the field. Figure 1.4 shows the 13 weeks data of customer return for PACE product. Units failed at various temperature differences because of process failure. This process failure is one of the highest contribution to the root cause of the customer returns. When the units are being returned for further investigation, they discover some component have failed due to latent failures, soldering issues, component tolerance and other process issues.

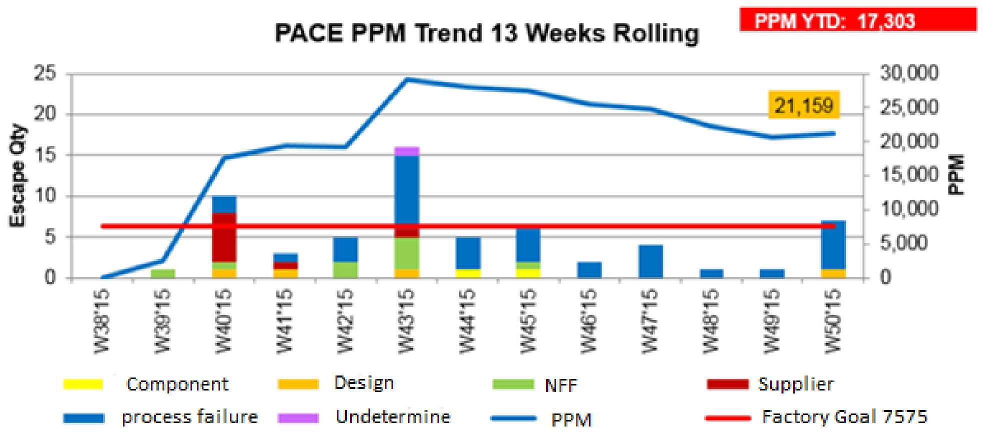


Figure 1.4: PACE customer return for 3 months data

Screening process in HASS detects latent defects in components and assemblies. The screening process specification insures that the product is matched to the end user's requirement. In order to detect product defect in production screening, HASS applies accelerated test beyond the product specification which is determined earlier of Highly Accelerated Life Testing (HALT) testing. The advantage of this improvement shorten the time to identify failure of defective units, shorten the time for corrective action and improve the time to market.

Many issues caused by process changes after HALT screening were previously seen only as early life failures in the field. With an appropriate HASS implementation, these defects can now be detected and corrected prior to customer shipment.

1.2 Problem Statements

HASS test is the most important method in manufacturing testing for quality and reliability test. At the customer end, the main concern is whether or not the product can function correctly, or sustainable in long term period [2]. Moreover, quality plays an important role as it relates to the safety of airplane. This HASS testing consists of a combination of functional and environmental test. Environment test includes vibration test, ramp test, and temperature test [3]. The focus on temperature profile data in this study is mainly due to cases whereby products failed in the field when they are exposed to high or low temperature. This should not be the case since all units shipped out from the company had undergone HASS screening test. .Also the defective units returned by customers sometimes failed after retesting using HASS. This problem shows that the current HASS factory testing is not able to capture the failure at the first time. Therefore, the current HASS profile needs to be studied for improvement. This research focuses in improving the profile temperature. The HASS profile that is used in the production was developed during the development stage (HALT) [13]. This project investigates the accuracy of the current HASS profile in production using data collection and data analysis. Throughout this project, a suitable methodology to improve the current profile to the reference limit has been developed. Both theoretical and statistical analyses are used to analyze the performance of the profile and quality improvement.

1.3 Research Objectives

The objectives of the research project are as follows:

1. To investigate the compliant in temperature profile used for PACE testing with HASS standard.
2. To minimize error between measured and actual profile and improve current temperature profile.

1.4 Research scope

This research is to study the behavior of the current HASS profile testing in production. This research focus on the condition of the profile towards the actual temperature profile. Moreover, this research includes improvement of the temperature profile towards the set point. The behavior of the temperature profile is analyzed by statistical approach to verify the condition of the profile.

1.5 Research Contribution

This research analyzed and optimize the current temperature profile used in production and improves HASS profile by changing the process-control. The improvement analysis utalise statistical analysis and theoretical study to analyze the data and providing the area of focus for improvement. The improvement is achieved by changing the process-control to optimize the temperature profile.

1.6 Thesis outline

In chapter 2, the outcome of a comprehensive literature review is deliberated. The review covers various subjects related to the research including Reliability engineering, HALT and HASS techniques in manufacturing environment. This chapter also provides the test background of HALT and HASS which are an effective tools in a high volume production environment when indicator of the performance includes yield and customer return. Moreover, this chapter also discuss the study of POS which is one of the criteria for profile validation.

Chapter 3 presents the methodology of this research using DFSS approach. There are many methods used under DFSS methodology, however this research only used DMAIC, fishbone and statistical analysis method. Furthermore, reference product profile was also included as reference during this studies. This chapter discuss all 3 phases of data collection and data analysis. The first phase is to verify the condition of current HASS profile data. The second phase is method to improve the current profile. The third phase is to verify the improvement method using statistical analysis and theoretical analysis. By using MINITAB, the types of data distribution is identified and the temperature profile data using probability distribution function methodology. Equipment involved in this data collection also discussed in this chapter.

In chapter 4, the results outline in the methodology presented in chapter 3.Firstly, the result from the first phase data collection is discussed. The outcome of data collection verifies the condition of the profile. Then, after the profile condition study is determined, data collection is continued for the profile improvement using process-control methodology .The measured data and the actual data is compared and discussed. Theoretical data using NCC and MSE together with PDF statistical study is discussed by comparing to the product-control.

Chapter 5 draws the conclusion of this study and present the future works that can be extended to be further improve the HASS testing.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses a variety of the research subject related to reliability engineering including HALT and HASS techniques in manufacturing environment. HALT and HASS are types of the accelerated reliability techniques that are very effective and are being used by companies around the world in various industries. This chapter provides the test background of HALT and its relationship with HASS which an effective tool in high volume production environment whereby the indicator of the performance includes yield and customer return.

2.2 Reliability Engineering

Pursuing high reliability, low cost and short cycle are the tendency of reliability engineering. The author of this paper [9] has 25 years' experience in the reliability industry provided useful information regarding on current studies in this field. This paper does not only focus on product quality and reliability , but also on lower cost and shortening the lead time applied to product design will produce high quality product to satisfy customer thus improve enterprise's competitive power.

2.2.1 Integration of Quality Engineering and Reliability Engineering

Figure 2.1 illustrates the integration of quality engineering and reliability engineering. Most enterprises required quality characteristic within the spec limit SL and SU but conformity is not sufficient. Moreover, it shows that the result of the robust design improves quality characteristic probability distribution curve φ(y), by making it thinner and close to the middle. The robust design will not only increase product reliability but also reduce the quality loss due to product failure. For example, in Figure 2.1, A is a product just pass the specifications and will fail soon in the working condition after delivery; Actually A is almost as same bad as the reject B which is just over size a little bit. Product C which is very close to the design target value and will work for a very long time without failure. Traditional reliability with reverse thinking: according to the given design scheme to consider what failure mode could occur, how to reduce the occurrence probability of the mode and its effects thus may increase the cost in the most cases. From very beginning of market survey, using quality engineering or robust design approach to increase product performance stability, decrease quality variation, and enhance reliability without cost [9].

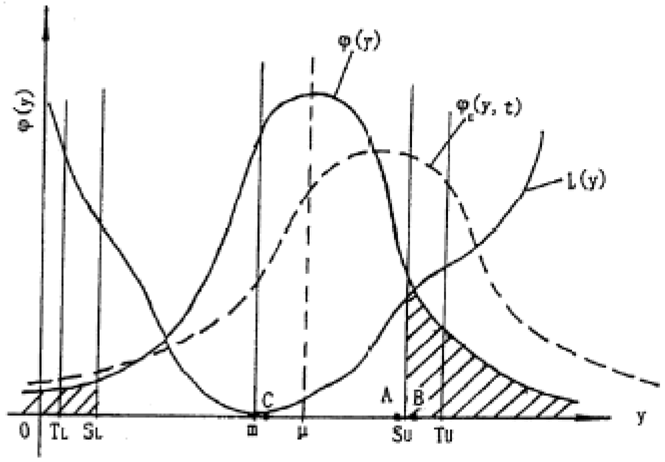


Figure 2.1: Product quality characteristic probability density function φ(y) and quality loss function L(y) [9]

2.2.2 Low-cost Reliability verification technology

Continues process capability (C_{pk}) and Signal to Noise ratio (SNR) established the qualitative and quantitative relationship between reliability index and the index to reflect quality consistency and stability. These two methods exploit low-cost reliability monitor method for all types of reliability test. SNR has applied it as an optimization index for parameter design. This research [9] discovers that actual SNR is positively related to mean time between failures (MTBF). This is a common relationship between distribution and quantitative analytical result for normal distribution.

2.3 Introduction of HALT

HALT is a method of accelerating a life test. This method is only applied in design stage. By applying stressed to product hardware, failure can be easy detectable thereby improving the reliability. HALT does not only detect failures, but correcting the weaknesses that caused the failures. HALT begins by gradually increasing stress or combination of stresses to product until a failure occurs. Once failures are detected during HALT, the root cause of the failure is determined and corrective action is implemented in order to increase the robustness of the product. Then the application of stresses is continued in order to find the additional weakness. [1]

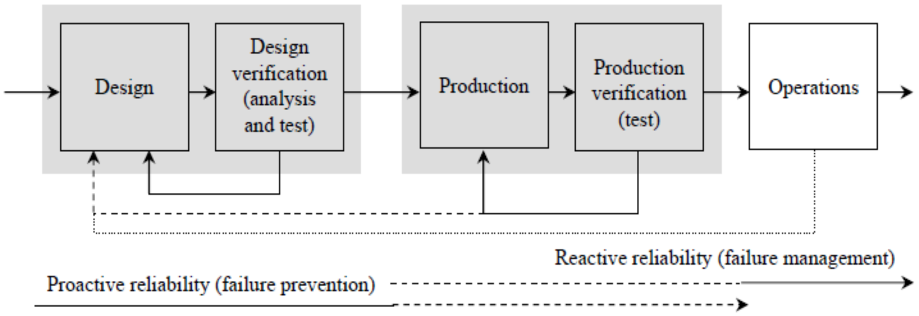


Figure 2.2: Design and production verification [3]

Figure 2.2 shows a typical product development process, emphasizing on design and production verification. The iterative nature of product development (including reliability engineering) is evident. ‘Analysis’ and ‘test’ are the two primary verification methods used in engineering. Many reliability engineering tools and techniques are used for this purpose, including HALT and HASS. During HALT, thermal stress and vibration stress (as well as any other relevant stress) are applied in a step-stress test until an abnormality in operation is detected.

HALT require the use of special environmental test chambers to subject development or production units to stresses exceeding product specification levels. Typical HALT chambers provide simultaneous multi-axes broadband vibration and rapid thermal cycling. HALT can be performed using either a Classical HALT process or by using a Rapid HALT test profile. During Classical HALT, thermal and vibration stress conditions are first applied individually, and finally combined Cold step stress, hot step stress, rapid thermal cycling, and random vibration and combined thermal cycling [3].

HALT is the process for quantifying and expanding design margin by referring to operational limits and destruct limits. Lower Operating Limit (LOL) is the point at which the product stops operating or a specification is no longer being met but returns to normal after the temperature is increased. Lower Destruct Limit (LDL) is the point at which the product does not return after the temperature is increased. Upper Operating Limit (UOL) is the point at which the product stops operating or a specification is no longer being met but returns to normal after the temperature is decreased. Upper Destruct Limit (UDL) is the point at which the product does not return after the temperature is decreased. Figure 2.3 shows the limits of the system.

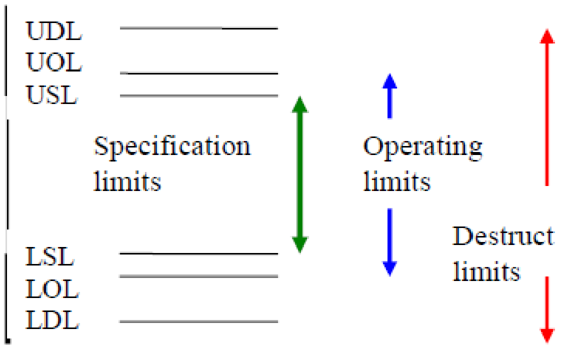
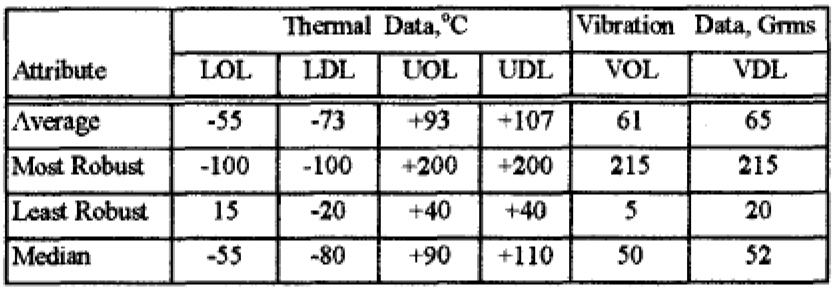


Figure 2.3: Specification, operating and Destruct limit [4]

The specification identifies the range over which the system is guarante to operate. The operating limits are identified as the range of the system will operate. Beyond this point, the system stops operating but will return to operation when the stress is reduced. HALT process is able to identify the operating and destruct limit.

HALT helps to develop a robust design for in-service reliability at first product delivery. This situation is very crucial to the manufacturer especially in Aerospace industries that need to have good product reliability and quality to the customer. Moreover, obtaining a robust product design prior to qualification testing or first article testing. This Paper [1] explains the robustness of the design is referred to the how far the product can go Upper Destruct Limit (UDL) and Lower Destruct Limit (LDL) temperature value. Example data as the table 2-1. This data take from all the product is grouped together from difference industries.

Table 2-1: HALT Limit with limit attribute



Attribute	Thermal Data,°C				Vibration Data, Grms	
	LOL	LDL	UOL	UDL	VOL	VDL
Average	-55	-73	+93	+107	61	65
Most Robust	-100	-100	+200	+200	215	215
Least Robust	15	-20	+40	+40	5	20
Median	-55	-80	+90	+110	50	52

The most important concept of the HALT that have been taken will be used as baseline for the best parameters in a Proof of Screen profile (POS) and leading to a HASS profile is performed in the manufacturing phase. This paper [4] explains the challenges when establishing loads for the Devices under Test (DUT), problems with monitoring the HALT and understanding the DUT response. These examples should represent good lessons learned to the researcher.

For this project, HALT data is taken from the original in design stage that will be the benchmark for this study. The HALT data is been performed during design stage before release to production and from this data. Product engineer and reliability team analyze the result. Therefore, from the data analysis and the results its represent the HASS profile for testing the product in manufacturing environment. Result from HALT is very important and which will be taken as reference for the designer to produce HASS profile.

2.3 Introduction of HASS

HASS is proposed by Dr. Greggk K. Hobbs in 1984. According to the product's actual situation, this technology uses a higher accelerated stress to screen and stimulate the product's defects in a more effective way, and controls the damage to the product's lifetime in a minimum range [9]. HASS is a screening process that uses the accelerated technique to filter any manufacturing or process issue during the testing. The process requires HALT test result to design initial temperature profile and tune it for optimal effectiveness. HASS involves the usage of rapid thermal transitioning with various temperature range combined with multi-level (six degrees of freedom) of vibration and performed over a wide frequency bandwidth from 2Hz to 10 KHz. These paper [5] and [7] describe difference methods of developing a screen using the HASS Development methodology and give a guideline on when to change a screen and when to re-submit a product through the HASS development process in order reprove this screen.

This paper [5] present the HASS development process for Uninterruptable Power supply (UPS) product. HASS development process includes fixture, thermal and vibration qualification including proof of screen. During the development of HASS profile, adjustments were made in the profile to optimize its efficiency. With this profile, production units can be stressed to assure that the reliability that was attained in HALT continues to be maintained.

For this paper [7], reproves a screen if the product response due to thermal or vibration stress changes. This is usually either due to a change in the screen or a change in the fixturing. A change in the screen may be anything from a change in the dwelling level, dwell time, ramp rate, or even a change in when a stress is applied in relation to the other stress. A change in the fixturing may be any change in the number of units being screened, the orientation of the units, ramp rate, airflow, and even changes to the environmental equipment itself such as changes in vibrator technology resulting in changes in the vibration spectrum. If an increase in response is expected, reproving the screen is a necessity because of the possibility of damaging good hardware. If a decrease in response is expected, it may also be good to reprove the screen in order to determine where the screen is still able to find defects. However, if the decrease in response is small, trying to reprove the screen will likely lead to inconclusive results. In addition, a screen should be re-proven if a significant change is made to the design of the product, and if it cannot be proven that the design change does not weaken the product in any way. This is especially true if the design change involves a change in technology (i.e. solid state relays to mechanical relays or vice versa. If the change is significant, HALT should be rerun and then based on the results, the screen levels being reprove may require further changes.

HASS test can be improved by time depending on the situation. In order to improve the screening effectiveness, HASS optimization has been developed by using precipitation effectiveness test and detection effectiveness test to calculate screening strength over a combination of screens and test. The model accepts actual or projected manufacturing workmanship and infant mortality defect densities at 4 levels of screening. [7].This paper [7] use HASS optimization model to provides a fast comparison for identification of the most effective screening with respect to the percentage of life consumption. This paper also compare screening fault detection coverage capabilities provided in the effectiveness model including simultaneous fault precipitation and detection test. The factory damage fatigue contribution is added to the service life damage fatigue to ensure the design life margin includes the HASS contribution as part of the service life. Ideally, the factory HASS damage fatigue contribution should be less than 5% of the service life.

This paper [8] proposes a computer simulation method to research the HASS profile. By using this method, the researcher study the current profile of the test cycles and cost involved. This research is used the some of the current model such as the model of temperature cycles from the Darceaux model to predict the fatigue accumulated damage value by temperature cycle. This information is used in computer simulation and its result. The two models is involved for preparing computer simulation method. The ANSYS simulation software is applied to simulate the solder joint under the HASS profile, then the information is used to evaluate the fatigue accumulated damage value that can be obtained. By comparing the research study for this project, this HASS optimization project studies the HASS profile by using statistical analysis to check the condition of the profile instead of using the computer simulation as what this researcher have done. Even though developing this program is able help engineer to analyze in short term of period but the challenge to develop this system is involving high cost involved. This HASS optimization project involve low cost system analysis with statistical analysis in MINITAB and help engineer to analyze the profile data.

2.4 Proof of Screen

This paper [1] explains the method of proof of screen (POS) which is sometimes refer as proof of life. This is type of the testing to prove the current profile whether it is fully optimize or not. This method is widely used in many manufacturing industries to confirm the current testing profile is fully optimize with the current product design or any process changed happen at a particular product. One of the challenge for this approach is when the product has run through so many cycles and does not uncover a wear-out mechanism and stop prior to discovering one. Another challenges is when the unit is uncovered wear out mechanism but have another one that is developing. In proof of screen, the result must show the absolute failures and not monitor parameters for degradation.

The purpose of the POS is to prove that the screen parameters based on the HALT limit and prove that the screen parameter is effective in finding defects. It is to prove that the screen parameter is not damaging a product in the long term. This is demonstrated in not more than 1/20th (or as little as 1/50th, depending on how many passes were run) of the life of the product would be removed in a single pass through the screen. In the effectiveness portion of the POS, DUTs are subjected to the proposed screen that has or is suspected to have defects that were not detected by the normal production line testing. The failure rate, time into test of failure and failure analysis information for these DUTs are evaluated. Based on the results of these two portions of the POS, the screen is either implemented or modified and re-checked as necessary until an effective and safe screen is in place [13].

2.5 PACE HASS Product profile

Figure 2.3 shows the current HASS profile used in the factory. This reference profile is design based on the HALT profile data. For overall HASS temperature testing are includes power cycle, difference temperature, ramp rate and vibration test. Temperature profile consists of two phases of the test. There are precipitation and detection phase. Precipitation phase consists of 5 cycles of testing with a ramp rate of 35°C per minutes. The dwelling time is around 10 minutes for extreme hot and 16 minutes for extreme cold. In precipitation phase, there are no functional test applied during this test. Vibration test is applied around 10 Grms with 2 times of power cycles.

For detection phase, consist only one cycles of test with dwelling time for extreme hot and cold is around 26 minutes. Ramp rate for this phase is 2°C per minutes with 6 Grms apply on this phase. During detection phase is including functional testing that test with consist of respective configuration test.

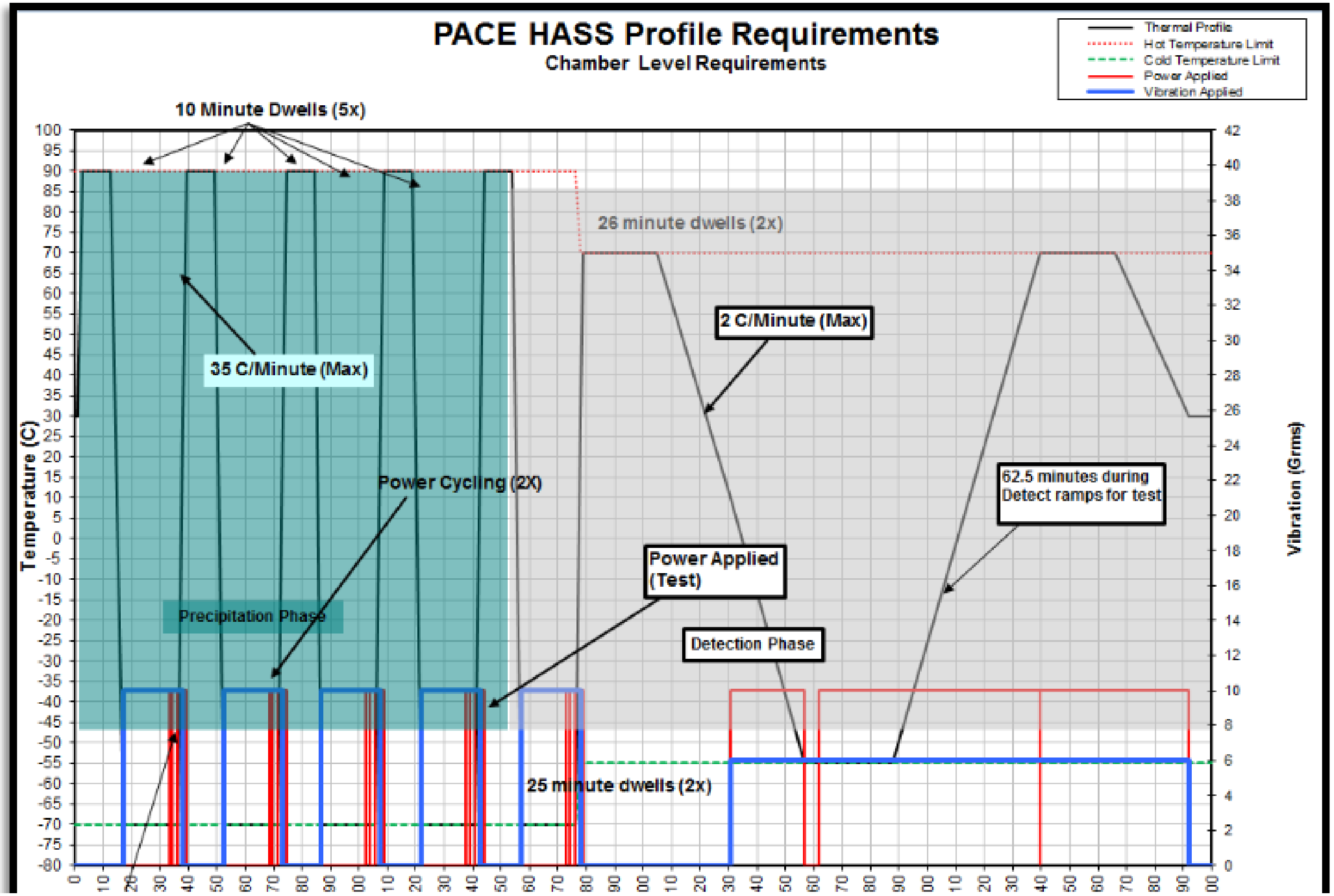


Figure 2.4: PACE HASS profile requirement

2.6 Summary of Research study

Reliability and quality of HASS testing are the main criteria to produce robust design. This approach is important in HALT test perform in design stage. HASS test is created by referring to the HALT test data collection and HASS temperature product profile is created based on HALT data. Based on the current research study of the HASS optimization, there are many ways to verify the robust HASS test by using low cost reliability verification such as Cpk and SNR. Therefore, there are potential in adopting statistical approach to investigate and verify the HASS test performance. For the current research study, the optimization has been performed in many ways such as computer simulation. This project have proposed new methodology in improving the HASS temperature profile and more details are explained in Chapter 3.

CHAPTER 3

METHODOLOGY

3.0 Introduction

This project methodology consists of three phases. The first phase is to study the current HASS profile using data collection and data analysis to verify the condition of the profile. The method of the improvement profile with process control and product control methodology is discussed in the second phase. Finally, the third phase is to validate the improvement profile using theoretical and statistical analysis. This project uses Design for Six sigma approach (DFSS). Figure 3.1 shows the 3 phases of methodology.

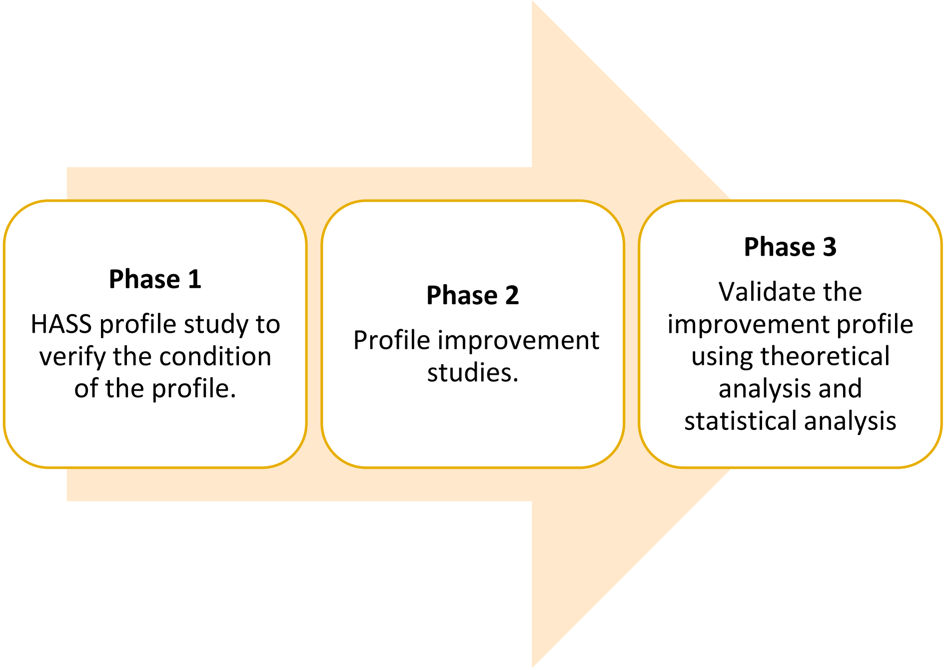


Figure 3.1: Three phases of HASS optimization methodology

3.1 DFSS methodology

This project used DFSS approach. DFSS is a method for managing variation in a product or process in such a way that customer expectation are met and the product can be produced or service provided at 6 sigma quality level. For this project, the tools of six sigma used are DMAIC (Design, Measure, Analysis, improve and control), fishbone and statistical analysis.

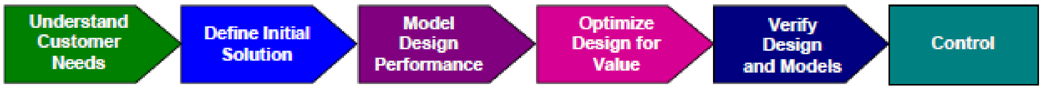


Figure 3.2: The full step process of the Design for six sigma.

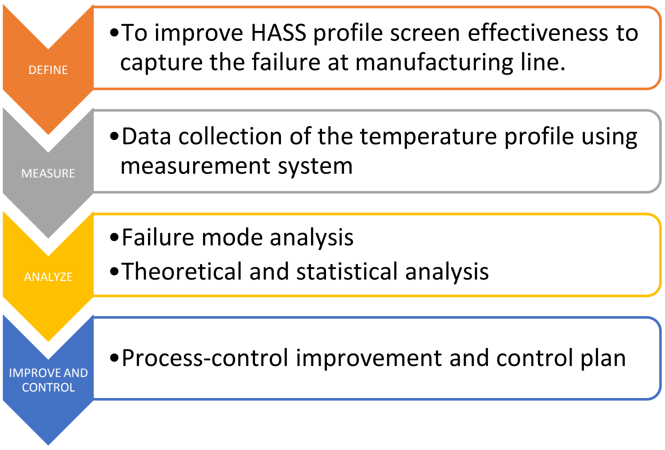
Understand the customer need is the first step process in DFSS. This is the most important factor to identify the problem statement. Customer encounter problems in the field is able to provide the general view of the failure mode. Besides, further deeper investigation needs to understand the contribution factor of the failure. For this research project, customer encounter temperature failure at the field and it involves the process test failure.

Next, define initial solution is a method to identify the customer's needs and linking to process characteristic.This stage is to verify the key product functional requirement. For this research, HASS test is the best area for improvement that suits to the test coverage of the process characteristic. In addition, this HASS test is the only test with different temperature range compared to pretest and final test which only test at ambient temperature.

Model the design performance captures all the relevant variables, constants and output of the element. In this research, temperature is used as the variable for this study and all the other elements are constant such as ramp rate, vibration and power cycling.

Optimize design for value is making the design “best” according to some set of objective measures to close the gap between requirement and capability. Process control design is the optimum design to improve the temperature profile proven by using statistical analysis and theoretical analysis approach. This statistical technique is important to validate the success rate of the optimization model. Finally, the optimization model need to have a control plan to maintain the implementation of the optimized model in the production line.

DMAIC is a step-wise model of identifying of the details in the process factors and reduces other variations. Based on figure 3.3 of DMAIC model, in the Define stage information regarding customer feedbacks are gathered. In measurement stage, it involves data collection with the correct tools which in this research, a tool to collect temperature data is identified. There are a lot of processes involve in Analyze stage whereby in this stage it involves data analysis and failure analysis to identify the area for improvement, discussion and decision making for any possible method used in the improvement project. Besides, the improvement tools itself need to be study for feasibility.The control plan is important to sustain the improvement in long term period as emphasized in the DFSS methodology.



- To improve HASS profile screen effectiveness to capture the failure at manufacturing line.
- Data collection of the temperature profile using measurement system
- Failure mode analysis
- Theoretical and statistical analysis
- Process-control improvement and control plan

Figure 3.3: DMAIC Model for HASS optimization.

3.2 Product HASS profile reference

The HASS profile test takes 400 minutes (6 hours 48 minutes) to complete. It consists of 2 phases: precipitation and detection phase. The maximum temperature for extreme heat is 90℃ and for extreme cold is -70℃. The precipitation phase contains 5 thermal cycles between extreme heat and extreme cold. Dwelling time is the condition in which the DUT soaks constant temperature in certain period of time. At extreme heat, dwelling time is around 10 minutes and at extreme cold dwelling time is around 16 minutes. The ramp rate of the precipitation test is about 35℃ per minutes.

Meanwhile, the detection phase contains only 1 thermal cycle which consists of 2 extreme heat dwelling time and 1 extreme cold dwelling time. The maximum temperature for extreme heat and cold are 70℃ and -55℃, respectively. Dwelling time for extreme heat and extreme cold is about 26 minutes. The ramp rate of the detection test is 2℃ per minutes. The graph of the temperature profile is shown in figure 3.4. This actual profile is the main reference of the temperature profile.

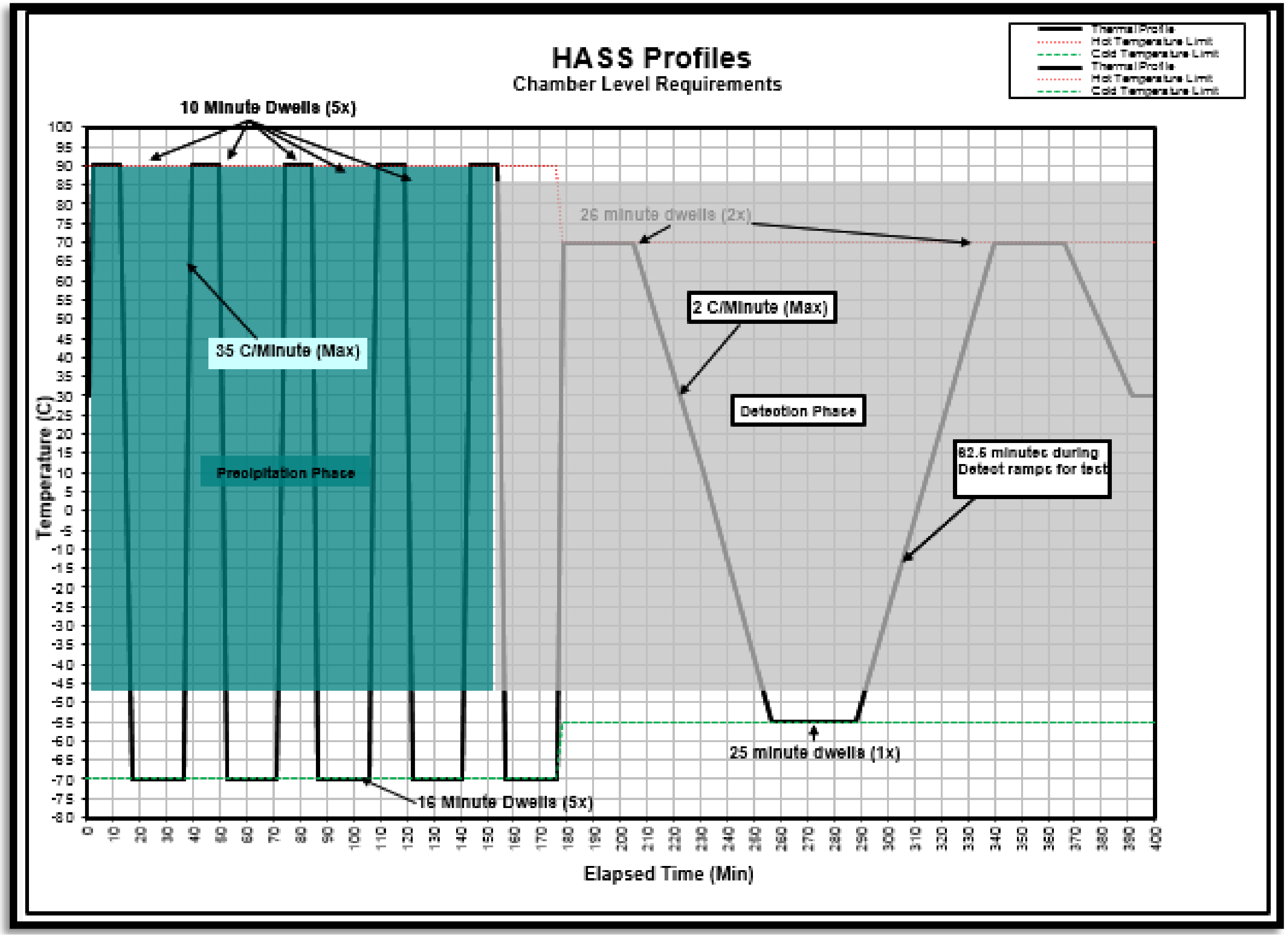


Figure 3.4: Product profile reference