Early Detection of Defects and Energy Cost Reduction through Combined Burn-in and Vibration Test for Switching Power Supplies

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Abstract

Burn-In is a common step in manufacturing process designed to stress all vital machine functions continuously for several hours, in order to identify any potential weaknesses or possible negative trends. It has been already proven that it has the capability to determine possible future malfunctions at an early stage since it uses extreme temperature control however, providing additional stimulus to the burn-in process will make it more effective based on previous studies. This study focused on the improvement of the traditional burn-in test set-up used for switching power supply manufacturing companies. Monitoring the results of the actual burn-in test set-up had been modified through the use of data acquisition module embedded in the test set-up. Applying vibration was also considered as an environment stimulus that has been added to the exsisting set-up. This study determined the effect of vibration as an additional stimulus combined with the traditional burn in test and its capability to easily detect possible future defects of switching power supply units. On the other hand, the output of this study also showed reduction of test time consumed in determining possible future malfunctions, hence, the combined burn-in and vibration test set-up has reduced the energy cost incurred during the testing process. Actual test and development of this project study has been performed at Astec Power-Emerson Network, Cavite Philippines for a specific model of switching power supply units. Though, the test results showed difference in terms of its capability to determine furture workmanship defects compared with the existing burn-in set-up, it is not yet conclusive that it can replace the industrial Highly Accelerated Life Test/Highly Accelerated Stress Screen (HALT/HASS) test machines but it may be recommended as an alternative set-up to reduce energy cost in the testing process.

Keywords: burn-in, vibration, switching power supply, energy, environmental stress, thermal

1. Introduction

1.1 The Problem and its Background

Switching power supplies are normally used for a long period of time to support continuous operations not only in manufacturing settings but also in major company operations which requires continuous power supply. Usually, switching power supply units are being tested through the burn-in process for a certain period of time to see to it that all vital parts were subjected to extreme temperature so that possible weaknesses and workmanship problems were able to determine before the shipping of the units from the manufacturer. Some products like switching power supply units needed to ensure its reliability to support vital company operations is recommended to be subjected through the HASS/HALT machine, a very expensive industrial machine to ensure its quality before shpping from the manufacturing site, however, due to the equipment cost and bulk of switching power supply units to be tested, most of the manufacturing company does not fully implement the use of HALT and HASS machines to all units under test, instead they are more relying to the traditional burn-in test. The concept of Highly Accelerated Life and Stress Screening test is to expose the unit under test into several environmental factors, were used to develop an alternative way of testing power supply units without relying solely on the traditional burn-in test set-up. Based on the concept of HALT/HASS, an additional environmental stimulus added to the testing process will ensure the functional reliability of the device (B. Peterson, 2006). Thus, adding certain number of environmental stimulus to the existing burn-in testing process will guarantee difference in determining future device component malfunctions. In this study, vibration was chosen to be added as a stimulus to the traditional burn-in testing process knowing that from shipping up to the actual usage of switching power supply units mostly involve movements that causes malfunction of the device. Vibration as an additional environmental stimulus will be incorporated with the existing burn-in test set-up and validate its effectiveness compared to the traditional test being conducted in the burn-in section.

1.2 Importance of the Problem

Reliabilty of the product design is very important to the reputation of the manufacturing company thus, extensive product test shall be done to satisfy the needs of the client using the device. The manufacturer is expected to offer reliable product test validity to ensure that the clients will be satisfied with the product design performance and at the same time should not overspend in the testing process in terms of its operating cost. In the case of the modification of the existing burn-in test set-up, one of the primary objectives is to determine possible future failure at an early stage to eliminate or lessen customer complaints and energy cost in the testing process shall also be minimized. Although the purpose of any Burn-In tests process is to expose the hidden defects that were introduced during the manufacturing process by subjecting the units under test to extreme temperature, providing additional stimulus may concisely, identify manufacturing defects such as workmanship problems at an early stage. Burn-in test alone, however, is not designed to find deficiencies in product design although in many cases it does expose design deficiencies. With the combined burn-in and other stimulus, it has the potential to ensure that the product performance is robust enough to meet its design goals. Through this study, it might be useful to switching power supply manufacturing companies to promote their products in terms of customer satisfaction due to its test reliability; it can also help the companies in terms of financial aspects by saving production time and energy consumption during the testing process. Thus, company productivity may also be improved. This study will also serve as future reference in developing a more sophisticated burn-in test set-up designed for future use. This study will also give an idea and relate its outcome to other system especially in other manufacturing company using burn- in testing process.

1.3 Relevant Related Literature

According to previous study, burn-in is a common production-testing step usually applied to electronic appliances, power supplies, semiconductor units, and commonly designed for computers and servers. (Keithly, 2000). The form of Burn-In test chosen by the factory is dependent on the failure mechanisms for the relevant field failures. This kind of test is faulty when it does not expose the locus of faults seen by the customer. The process is a dynamic process which must change as product failure behavior changes. One of the most reliable tests which involve other environmental stimulus is the Environmental Stress Screening. The use of this particular test process has been already a constant practice to some of the electronic manufacturing companies. Environmental Stress Screening test is a process used by factories to precipitate process related defects from latent to patent for detection by a product verification test (B. Peterson, 2006). For most processes, the product verification tests are electrical tests but may include other forms of testing which are non-electrical. To conduct an effective screen, the product must be capable of surviving the high stimulation levels needed to accelerate the failure mechanism of assembly related defects. The participation of design and reliability engineering is to determine the limits of environmental stimulation which the product can endure before its performance is permanently degraded. A mechanically weak design may be changed to improve its margins with respect to a specific form of environmental stimulus. (B. Peterson, 2006). In addition, HALT and HASS also known as Highly Aceelerated Life and Stress Screening Test have also been used introducing several stimuli in the environment in order to test the future possible malfunctions at an early stage. (H.K Hoggs, 2000). Hence, the traditional burn-in test, environmental screening and accelerated life test, are essentials to be considered in a reliable testing process and to be conducted in order to ensure the reliability of product performance and its complete functionality over its entire service life.

1.4 Hypothesis

The main objective of this study is to improve the traditional burn-in test set-up practices through redesigning, experimentation and simulation that will upgrade its capability and increase its performance to detect future malfunctions at an early stage. Specifically, this study aims to increase the capability of the present burn-in test set-up in determining possible future product malfunctions due to workmanship problem by providing an additional environment stimulus (vibration) to be conducted using a pneumatic controlled instrument, to determine the effects of a combined burn-in and vibration test to switching power supply units, to achieve cost reduction on energy consumption during the testing process and to find out if there is a significant effect in the testing process using the existing burn-in test practices and the modified test set-up for AA22300 switching power supply units.

2. Method

The applied and experimental research methodology were used in this study which basically includes literature survey, personal interview, design, simulation, experimentations assessment, and verification of results using basic statistical techniques. A comparative analysis was also used in order to determine the possible cost reduction on the energy consumption during the testing process using the existing test and the modified burn-in test set-up. Interviews and survey were participated by process and test engineering professionals, skilled operators and test technicians. A number of samples from a specific model of switching power supply units were used in the actual testing process. Calibrated electromechanical test instruments were used in the actual design experimentations and simulation for a more reliable test result.

2.1 Participant

The Test Manegement System (TSMS) group of Astec Power-Emerson Network team comprises of production, process and test engineers and burn-in technicians participated in the research project activity. Under the said department where actual test have been conducted, a single model of switching power supply have been identified to be the test samples used in the improved burn-in test set-up. In particular, AA22300 switching power supply unit models were used in the evaluation process of the newly designed burn-in test set-up. Calibrated test instruments, apparatuses and some mechanical devices were also available during the actual design process.

2.2 Sampling Procedure

Out of the existing five models of switching power supply units during the time of actual test, the test has been conducted to a one of the existing model switching power supply unit which is (AA22300) in particular. About one hundred twenty units or approximately twenty percent of the total number of available uints of the said product model were tested using the traditional burn-in test practices and the same number of units from the same lot was also tested using the improved burn-in test design set-up. The test was conducted inside the same chamber with the same temperature settings writtrn in the internal product specification sheet. Some of the AA22300 model units who passed through the existing burn-in test set-up were also tested using the new test set-up for verification, while the other units who passed the testing procedure using the new burn-in set-up were also tested using an industrial type HALT/HASS Machine. All instructions written on test specification sheet for the specified switching power supply model were properly applied.

2.3 Measures

The design of the burn-in test set-up with the additional stimulus (vibration) integrated to the system were carefully measured using the appropriate and calibrated test instrument in order to satisfy balance distribution of the added environmental stimulus to all power supply units under test. The monitoring system embedded in the design also passed through series of simulation to ensure real time monitoring the results of all the units under test. The data collected during the evaluation process were validated through actual observation on the existing burn-in test practices, personal interviews with production, process and test engineers, skilled test technicians and operators, a literature survey based on previous test data and internal product guide specifications. Test results gathered by the integrated real time monitoring system were used in the actual data gathering procedure. Process and test engineers validated the result based on the given product specification and previous test results.

2.4 Research Design

The research design used in this study involves actual test system design, simulation, test experimentations, assessment and evaluation. An actual burn-in test rack set-up has been fabricated to test the effect of additional environment stimulus and the entire new burn-in test set–up to all devices under test (DUT). Actual fabrication of the burn-in test rack set-up including the added parameters was repeatedly conducted to achieve the desired test set-up parameters. Several trials of test set-up were designed to ensure that a balance amount of vibration as an added stimulus will take effect to each switching power supply unit under test following the specifications written on the product specifications guide. Data acquisition modules were also incorporated with the improved burn-in set-up for the purpose of real time monitoring and gathering of actual test results on each switching power supply unit under test while inside the chamber.

2.5. Experimental Manipulations

During the actual fabrication of the modified burn-in test set-up, a pneumatic vibrator was used to provide the additional environmental stress to all the units under test. Calibrated accelerometers were used to measure the amount of vibration applied to each unit. The tests were conducted in different vibration levels based on the capacity and specifications of the pneumatic vibrator. The positioning of the pneumatic vibrator was manually done however, it was tried to be based on the centroid calculation while actual measurements were observed during the simulation process. Several trials were considered before establishing the same amount of vibrations applied in each section of the modified burn-in test set-up. A real time monitoring device was also integrated with the modified set-up using data acquisition modules interfaced with the monitoring system for ease of use in monitoring the units under test and gathering of test data.

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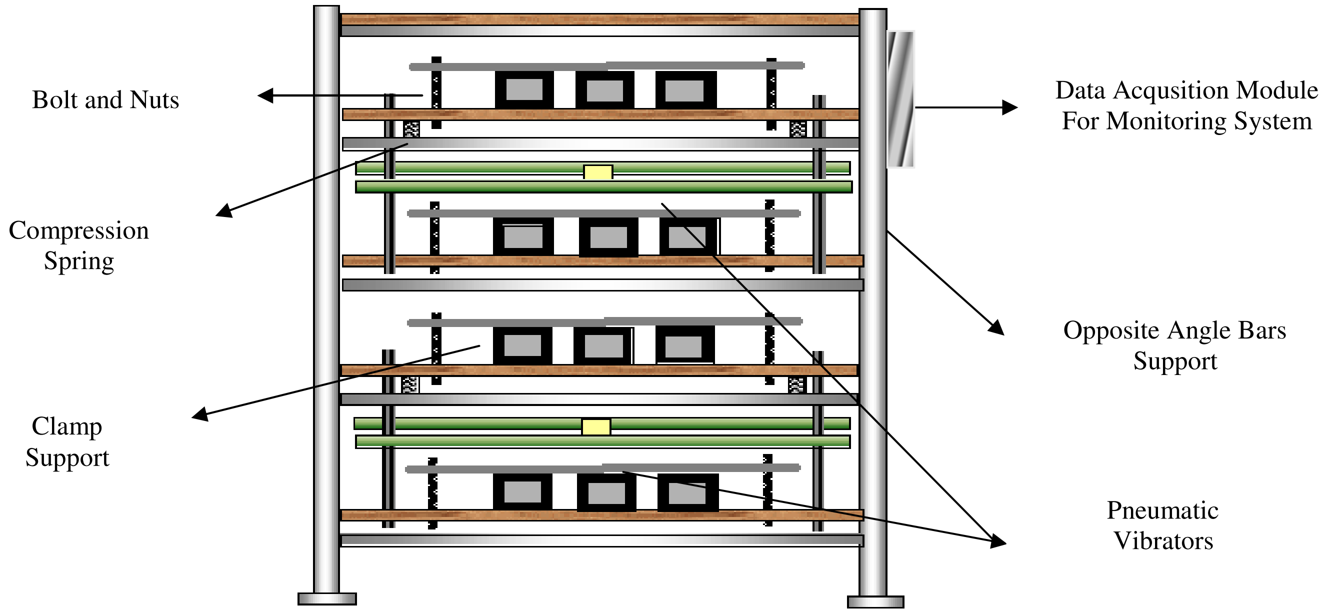

Figure 1. Final Burn-in Test Design Set-up

The figure shows the final burn-in rack design set-up implemented after a series of experimental procedure in locating the required pneumatic vibrator that will provide the necessary vibration which act as an added environmental stress. The actual design was based on a series of trials considering vibration measurement that will satisfy the product device test specifications. During the experimental and simulation process, some of the materials are considered re-use materials, thus, equal amount of vibration measurements were not achieved on each unit under test, although the vibration measurement test results for each section may be acceptable since it is still within the desired acceptable level of stimulus based on the product specification guide.

Table 1. Burn-in test rack set-up final vibration measurement

Pressure	**2 Bar**			**3 Bar**			**4 Bar**			**5 Bar**		
Axis	**x**	**y**	**z**	**x**	**y**	**z**	**x**	**y**	**z**	**x**	**y**	**z**
Slot	G_{rms}	G_{rms}	G_{rms}	G_{rms}	G_{rms}	G_{rms}	G_{rms}	G_{rms}	G_{rms}	G_{rms}	G_{rms}	G_{rms}
1	1.66	1.70	1.68	1.73	1.77	1.75	1.78	1.77	1.80	1.80	1.78	1.81
2	1.66	1.70	1.68	1.73	1.77	1.75	1.78	1.77	1.80	1.80	1.78	1.81
3	1.66	1.70	1.68	1.73	1.77	1.75	1.78	1.77	1.80	1.80	1.78	1.81
4	1.60	1.66	1.66	1.62	1.68	1.68	1.63	1.70	1.68	1.65	1.72	1.71
5	1.60	1.66	1.66	1.62	1.68	1.68	1.63	1.70	1.68	1.65	1.72	1.71
6	1.60	1.66	1.66	1.62	1.68	1.68	1.63	1.70	1.68	1.65	1.72	1.71
7	1.66	1.70	1.68	1.73	1.77	1.75	1.78	1.77	1.80	1.80	1.78	1.81
8	1.66	1.70	1.68	1.73	1.77	1.75	1.78	1.77	1.80	1.80	1.78	1.81
9	1.66	1.70	1.68	1.73	1.77	1.75	1.78	1.77	1.80	1.80	1.78	1.81
10	1.60	1.66	1.66	1.62	1.68	1.68	1.63	1.70	1.68	1.65	1.72	1.71
11	1.60	1.66	1.66	1.62	1.68	1.68	1.63	1.70	1.68	1.65	1.72	1.71
12	1.60	1.66	1.66	1.62	1.68	1.68	1.63	1.70	1.68	1.65	1.72	1.71

The table shows the final vibration measurement results after several trials. The burn-in test slots were grouped into three sections comprising of four rows. The first row consists of units (1, 2 &3), the second row with units (4, 5 &6), the third row with units (7, 8 & 9) and the last row consists of units (10, 11 &12). Though, vibration measurements are not equivalent in each unit, the test shows almost equivalent vibration readings in each row considering different level of vibration settings, without violating the product test specifications. Hence, the final location of pneumatic vibrators specifying these vibration measurements was used in the actual modification of the burn-in test rack settings.

3. Results

3.1 Recruitment

From the different burn-in test conducted, it shows that the existing burn-in test set-up have proven its effectiveness in detecting future problems in terms of workmanship to a certain number of power supply units, however, using the improved burn-in test set-up has proven its capability and potential to detect more units with possible negative trends and workmanship problems. The tests have been conducted for two months in several occasions due to limitation of the actual testing and the availability of AA22300 model switching power supply units.

3.2 Statistics and Data Analysis

The study was participated by Test, Process and Production Engineers and Test support technicians from the design development to the actual testing evaluation process considering proper product test specifications. During the development stage, simulation has been conducted to ensure that equal amount of vibration as an added stimulus will be applied to each unit under test. About six simulation trials have been conducted before coming up with the desired parameters. From the results obtained in measuring vibration from several trials, we can observed that the vibration measurement in the final design are more stable compared to the previous vibration readings from the previous simulation trials. Although vibration measurement results from the final design did not actually achieved the $2G_{rms}$ level of vibration due to some factors, the value can be considered, as indicated in the Internal Product Specification guide that the vibration level of $2G_{rms}$ + or – 10% can be applied to AA22300 switching power supply unit models. After finalizing the modified burn-in test design, it was set-up based on the final positioning of pneumatic vibrator shown in Figure 1, following the indicated vibration measurement as shown in Table 1. About one hundred twenty units of AA22300 model switching power supply in a lot present during that time or about twenty percent of the total number of units present was considered to be tested using the existing set-up. On the other hand, after the final burn-in test set-up design was esatablished, another one hundred twenty units of AA22300 model power supply were tested using the improved burn-in test set-up. Based on the test data gathered through the real time monitoring system, the test using the traditional burn-in test set-up detected fourteen units with possible workmanship problems while eighteen units with workmanship problem and possible units with negative trends were detected using the new burn-in test set-up.

Table 2.Comparison of Burn-in test result for AA22300 Switching Power Supply Units

	Total Number of Units Under Test	Average Time of Completion during the Testing Process	No. of Units Detected with Workmanship Problem
Existing Burn-in Test Set-up	120	8.357 hours	14
Modified Test Set-up	120	7.871 hours	18

The table shows the test comparison between the use of the existing burn-in test set-up and the modified design for the burn-in set-up. Simple statistical method such as mean, standard deviation and a one-tailed test, a common statistical tool was applied in order to know the difference between the two burn-in test set-ups. Using this particular statistical analysis, the Z-test was set at 5% level of significance, thus the corresponding Z score for a one tailed test must be at least 1.645. The test result decided that the implementation of the newly design burn-in test set-up in detecting future possible failures gave significant difference compared to the existing set-up in terms of its detection capability. Based on statistical calculation having $\sigma = 0.929$ and $Z = 2.220$, the test concluded that there is a significant difference between the use of the existing set-up and the improve burn-in design set-up in terms of its capability and potential to detect future workmanship problem and future negative trends.

4. Discussion

Based on facts and actual data gathered, the study showed that burn-in test is an effective test in determining possible malfunctions of a switching power supply units however, it is more effective having an additional environment stimulus, for instance, vibration, to be able to detect future workmanship problem at an early stage.

Based on the data gathered during the testing process using the existing burn in set up and the proposed burn-in set up to test 120 units of AA22300 switching power supply model seems to have a difference. As we compared, the total number of failed units detected using the existing burn-in test set-up is lesser compared with the improved burn-in test set-up. In addition, considering the average number of hours the existing set-up detected those failed units is different with the average number of hours the improved burn-in set-up detected failed units. Statistical analysis proved that the combined burn-in and vibration test set-up has proven its capability of detecting units with possible negative trends at an early stage due to workmanship problem rather than the existing. The result of the study considering the mean time in detecting future workmanship problem can also claim a saving of about 6.17% of the energy operating cost considering only 120 units of AA22300 switching power supply tested. With regard to the integrated real time monitoring system with the aid of data acquisition modules, results of power supply units under test may be easily monitored through the system interface and eliminate the need to regularly enter into the chamber to manually check the units during the testing process, considering that the chamber is maintained at 40 to 45 degree Celsius and can cause any harm to our body system. Hence, using the monitoring system will eliminate the risk for the operators on getting any harm effect from the thermal chamber. The improved combined burn-in and vibration test set-up can be recommended as an alternative but not as a replacement to the existing industrial HALT/HASS machine however, further test to other power supply units are recommended before full implementation of the new set-up. The newly designed combined burn-in and vibration test set-up implementation will lessen if not eliminated having problems on some customer complaints and negative feedbacks regarding product performance due to possible workmanship problem. Furthermore, it is recommended to observe and conduct extensive study on the possible negative caused of the pneumatic controlled instrument to the system for future studies.

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