Development of Hammer Blow Test Device to Simulate Pyrotechnic Shock

Team Number: Team 15

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Figure 1: SDST: Single drop shock test apparatus [6]

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Abstract

A fundamental goal of this project is to facilitate the testing of electronic components subject to high frequency, high acceleration shock loadings. These shock loadings are often difficult to recreate due to their violent nature and individuality. For example, shock created by pyrotechnic charges for staging events in spacecraft or impact shock from a test environment (i.e. air hammer, drop hammer etc.); more specifically, to develop a standardized method of testing and modeling, in a reliable and consistent manner, the shock response of electronic components. The primary hurdle is generating a suitable shock response spectrum. In addition, specifications are missing to accurately recreate this shock response; yet, still be adaptable to any intricate component that needs testing. At the completion of the project a functional prototype as well as a tailored modeling system is expected.

1 Introduction

The project for the development of a hammer blow test device to simulate pyrotechnic shock was brought to the university by the Harris Corporation. Harris has brought this project forward due to the time and money lost by their current test procedures. Their desire is for development of test procedures and modeling methods to accurately replicate pyrotechnic shock loading. Ultimately, the end product will allow for a more precise test setup and elimination of trial and error methods used in the current test procedures.

2 Project Definition

2.1 Background research

Pyrotechnic induced shock can potentially be devastating to electronic equipment. Increasing use of pyrotechnics as a means for mechanical actuation warrants increasing need to validate the effects they have on system components. These shocks were often ignored, yet further work by Moneing has shown critical failures induced by pyrotechnic shock. [1] Mathematical and computational models have difficulty with the computational resources required. In particular the FEM analysis has difficulty modeling the high frequency characteristics of pyrotechnic shock. The requirement of a large number of tests has proven to be an inefficient method of modeling these shock responses. Computational methods often yield much more conservative results due to the sacrifice in processing power. [4]

Not only is this shock difficult to recreate in a testing situation, it is also difficult to model particularly as a function of time. Irvine recommends the use of the Shock Response Spectrum, or SRS, [3] to estimate the damage potential a shock may have. The SRS facilitates the analysis of shock on the component, rather than trying to analyze the extremely short duration, transient shock in the time domain. The SRS shows peak acceleration of a pre-determined series of natural frequencies that would be imparted by a certain shock. [3]

The rapid decay, transient nature, and extreme frequencies are difficult to simulate using a shaker to induce vibrations. Mechanical shock inputs such as pneumatic and hammer blow tests can yield optimal results, yet are time consuming in their tuning. [4] Additionally, the shock imparted often cannot be subjected directly to the component in testing, but through a mounting which could have substantially different mechanical properties thereby hindering the accuracy of the results. [3] High acceleration shock loadings are more accurately created by explosives; however, this is rarely done in practice due to the obvious dangers. [4]

Works by Chu and others have noted significant sources of error in accelerometer measurements in pyrotechnic shock. Actual pyrotechnic explosions can excite piezoelectric accelerometers at their natural frequency. [5] Replicating the pyrotechnic shock mechanically, as opposed to simulating with real pyrotechnics, can potentially solve any issues encountered with accelerometer measurements.

Tests done to electronic components by Luhrs have focused mostly on using a drop test to simulate pyrotechnic shock. He notes the discrepancies between using a drop test and shaker test as opposed to identical testing on a simulated spacecraft structure with a shock induced by pyrotechnics. No equipment failures occurred, until 2500g peak acceleration was reached, where crystal oscillators began to fail. On the other hand, a simulated spacecraft structure test setup experienced no failures until upwards of 7000g peak acceleration. [5] Findings by The Harris Corporation agree with Luhrs in that the drop test was overestimating the shock accelerations. [2]

2.2 Need Statement

This project requires collaborative effort in order to re-design and produce a suitable testing apparatus and modeling system. This is required to reduce the inefficiencies of the current trial and error methods employed by Harris Corp. for testing electronic components in regards to high load, high frequency shocks. [2]

The current shock testing method is lacking in terms of the quality of results, efficiency, accuracy, and repeatability.

2.3 Goal Statement & Objectives

Design a test apparatus and modeling system for Harris Corp. with a clear and concise method for accurately simulating shock responses.

Objectives:

- Research and explore alternative testing methods
- Devise systematic approach to maximize repeatability
- Develop computational modeling method for test standardization
- Find suitable shock load sensors for hands-on testing
- Explore possible apparatus designs; Material selection
- Design selection base upon feasibility, budget, and constraints
- Produce prototype and modeling method.

2.4 Constraints

Table 1: Requirements and constraints provided by Harris.

Requ. #	Category	Description
1	Mechanical	Test device capable of testing unit up to 50 lbs and 16" L x 16" W x 12" H
2	Mechanical	Generate SRS pyrotechnic shocks of up to 5000 g peak and 10 kHz
3	Mechanical	Develop method to model test system to guide adjustment of test parameters (hammer drop height, air hammer pressure, hammer head shape / material, etc) and sizing / tuning of resonant fixture.
4	Mechanical	Create software tool allowing input of various test and fixture parameters to estimate an SRS response
5	Mechanical	Software tool can be based on analytical methods, experimental methods or a combination of both
6	Mechanical	Build prototype test device and correlate software tool to generate a specific SRS with shock test results
7	Cost	Bill of Materials shall be generated early enough to determine level of detail to be built given the limited budget

1. Fluid constraint: proof of concept is more important than absolute size and weight capabilities. Weight rating and size requirements are subject to change. [2]
2. Hard constraint: load and frequency are based upon the material being tested.
3. Requirement: necessary for producing accurate results.
4. Requirement: modeling method is necessary to properly tests equipment.
5. Fluid Constraint: analytical or experimental methods are both acceptable.
6. Requirement: final goal.
7. Hard Constraint: budget determines feasibility of producing prototype and modeling system.

Fluid constraints are subject to modification as needed to fulfill project goals. Hard constraints are necessary in order to meet the objectives set by Mr. Wells and Harris Corp. Requirements describe Harris Corp.'s expectations of the project outcomes. Other constraints and requirements may be imposed during the project if necessary.

2.5 Methodology

Our design team plans to follow our objectives as closely as possible. However, interim constraints or requirements may be added as necessary. In this case our objectives may be modified to best suit the project goals. Our methodology will rely heavily on close guidance from both Dr. Kumar and Mr. Wells (including his supporting staff) of Harris Corp. With the complexity of the modeling and analysis our first step is to become familiar with the language, theories, and principles that govern the test. Once this is accomplished we can begin evaluating possible alternative solutions. A tentative schedule will be included in our next report.

3 Conclusion

This project requires a lengthy process of understanding how to properly model the high acceleration loads in combination with high frequency transient shock pulses. This is the brunt of the workload at this point. We will examine the background research and current methods in order to develop a streamlined process that ends with accurate results. Future plans include project timeline, workload delegation, website development, equipment allocations, concept generation, modeling ideation, and collaborative analysis.

4 References

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[2] Wells, Robert. "Conference Call with Robert Wells." Telephone interview. 24 Sept. 2014.

[3] Tom, Irvine. "AN INTRODUCTION TO THE SHOCK RESPONSE SPECTRUM." (2012): 1-3. 9 July 2012. Web. 23 Sept. 2014. <http://www.vibrationdata.com/tutorials2/srs_intr.pdf>.

[4] Robert, Wells. "University Capstone Development of Hammer Blow Test Device to Simulate Pyrotechnic Shock." 19 July 2013. Web. 23 Sept. 2014. <https://campus.fsu.edu/bbcswebdav/pid-6907001-dt-content-rid-38425464_2/xid-38425464_2>.

[5] United States. The Shock and Vibration Information Center. The Under Secretaty of Defense for Research and Engineering. *The Shock and Vibration Bulletin*. By Anthony Chu and Henry Luhrs. Washignton, D.C.: Naval Research Laboratory, 1987. Print.

[6] *SDST Machine*. Digital image. *Yoshida-Seiki.com*. Web. 24 Sept. 2014.