# Development of Hammer Blow Test Device to Simulate Pyrotechnic Shock

Team Number: 12

Submission Date: 9/25/15

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# Abstract

In order to ensure safety and a properly functioning system, thorough tests need to be done on every operational part. This is especially true for systems that encounter pyrotechnic shock. Many advanced systems use controlled explosive devices to accomplish tasks. Examples include rocket separation, pilot ejection, and air bag deployment. During these events it is critical that the components involved with the explosion and those surrounding it, especially the electronics, maintain functionality. This project aims to improve upon the testing of pyrotechnic shock via a hammer blow test. A hammer blow impact test device has been built by a previous design team, and now the goal is to improve the design and modeling of the device. More specifically, to improve repeatability, refine modeling and analysis process, and perform impact tests on the fixture using a reduced set of parameters. So far, our team has researched and learned the fundamentals of pyrotechnic shock, contacted the previous team and viewed the existing device, and reached out to our sponsor for a more accurate definition of needs. From here, the next steps are to have a telecon with our sponsor for defining and concluding the requirements and needs of the project and to begin concept generation for design improvements of the hammer blow impact test device.

# 1 Introduction

The objective of our team is to improve the existing hammer blow impact test device. The previous team encountered problems with repeatability of the test. Currently, too many variables exist in the device. Unnecessary variables need to be eliminated in order to create an accurate and repeatable test. It needs to be determined whether it is more efficient and beneficial to improve upon the existing design or create a new design. The primary idea for a new design would be a pneumatic hammer device rather than a swinging hammer. Ideas for improvement of the existing device include stiffening the frame and mounts, removing the strike plate from the design, and improve hammer stiffness and release.

# 2 Project Definition

## 2.1 Background research

Pyrotechnic devices are becoming more common and more applicable, especially for companies like NASA or Harris Corporation. Therefore, it has become important to be able to test the effects of pyrotechnic shock in a safe and accurate manner because the damage caused by this shock can be significant on affected components, especially electronic components [1].

Accurately recreating the shock and analyzing it is difficult due to its high acceleration with high frequency and very short duration time. It is these same characteristics that also make it damaging to many hardware elements [2]. Harris has found that simulating this shock with a hammer impact test generating a resulting Shock Response Spectrum (SRS) curve to be a decent solution. However, the next aspect is designing an appropriate test rig and analyzing the data in a time efficient manner [3].

This became the basis for the senior design project of Team 15 last year. Harris Corporation then decided to separate the project goals into two years in order to make the goals obtainable without decreasing the scope of the project.

Last year, their goals revolved around creating a testing rig for simulating this pyrotechnic shock and to create an effective way to measure and analyze their resulting data. Over the course of last year, Team 15 was able to generate four different concepts for the test rig, evaluate them, and build a prototype. Their chosen design was a kinetic hammer built from T-slotted aluminum, which offered some desired adaptability in the hammer and locations of the fixture plate [4]. Additionally, they were able to perform tests that looked at five chosen variables: hammer head size, hammer strike location, the location an acceleration is extracted from, fixture plate boundary conditions, and modal stiffening [4]. The creation of Shock Response Spectrum (SRS) curves were another goal of this project, and thus data from these tests were used to create them [4].

All of this can be used as significant research necessary to achieve the overall project goals. However, improvements can be made to refine the design of the test rig, improve repeatability, reduce SRS curve generation and analysis time, and reduce the set of parameters [3]. This year, Team 12 aims to do this.

## 2.2 Need Statement

Harris Corp. has expressed a need for an apparatus enabling an accurate simulation of pyrotechnic shock via a hammer mechanism. The first prototype constructed the previous year – while fulfilling its purpose of gathering information on high load, high frequency shock – yielded noisy data as a result of too many parameters and high tolerances within the structure of the mechanism [3]. A prototype that is more stable and that would yield more repeatable results is desirable.

**The current methods for shock testing lack accurate and precise results, as well as repeatability and efficiency.**

## 2.3 Goal Statement & Objectives

Design a testing apparatus and modeling system for Harris Corporation that would accurately and efficiently simulate shock responses.

Objectives [3]:

- Research existing methods for simulating and testing shock responses
- Improve repeatability of last year's test device
- Improve hammer mechanism stiffness and release from last year's device
- Evaluate designs to improve attachment of plate to frame
- Optimize processing for modeling SRS curves
- Improve FEM analysis process using results from improved test device
- Reduce set of parameters used for tests from last year
- Perform impact tests with improved device and improved modeling

An additional goal, if time permits, is to work on adding damping effects, more mass, and stiffeners to the fixture plate and analyze these results against the previous ones [3]. Table 1 displays what was specifically provided by Harris.

Table 1- Requirements Provided by Harris for Second Year Project

| Requ. # | Category | Description |
|---|---|---|
| 1 | Mechanical | Refine impact test device and fixture plate developed on year 1 project to improve repeatability. |
| 2 | Mechanical | Evaluate SRS generation from year 1 project and develop improvements to speed up processing |
| 3 | Mechanical | Fabricate design improvements and validate repeatability. Use results to improve FEM analysis process. |
| 4 | Mechanical | Perform impact test on fixture under a reduced set of test parameters. Test parameters to be identified by Harris by SDR. |
| 5 | Cost | Bill of Materials shall be generated early enough to budget costs for test fixture improvements and any needed instrumentation purchases |
| 6 | Mech (stretch goal) | Evaluate ability to tune fixture plate by adding damping, mass, stiffeners. Correlate results to FEM analysis |

## 2.4 Constraints

The constraints provided by the sponsor last year continue to affect this year's work. The list of constraints can be seen in Figure 1 [5]. Additionally, there is a monetary constraint of $5000 for the team to use.

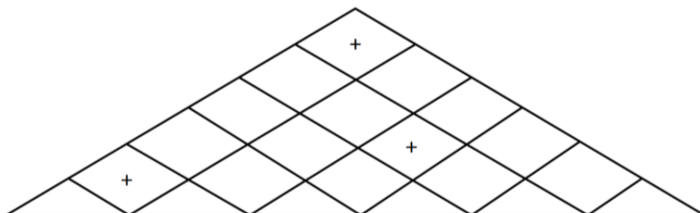
Table 1: Requirements and constraints provided by Harris.

| 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 |

Fig. 1 - Table of Constraints Provided by Harris for Senior Design Team 15.

## 2.5 Methodology

A very general strategy for the team involves working with the sponsor and the advisors to improve the final products of the project from last year while following the given requirements and constraints. As the year progresses, iteration will be key to maintaining success and staying on track, especially as any obstacles arise. Figure 2 displays a House of Quality (HOQ) made using the customer's requirements and engineering characteristics from Harris. It can be seen that the strike plate connection and the adjustment of the hammer ranked the highest.




| | | Engineering Characteristics | | | | | | Comparison | |
|---|---|---|---|---|---|---|---|---|---|
| **Customer's Requirements** | **Customer's Importance** | Frame Stiffness | Strike Plate Connection | Hammer Adjustment | SRS Modeling Processes | Swing-arm Connection | Frame Mount | Prototype | Our Goal |
| Accuracy | 4 | 4 | 5 | 4 | 5 | 3 | 2 | 3 | 4 |
| Repeatability | 5 | 5 | 5 | 5 | 4 | 3 | 3 | 2 | 5 |
| Simplicity | 4 | 2 | 3 | 3 | 3 | 3 | 2 | 3 | 4 |
| Cost | 3 | 2 | 2 | 2 | 1 | 1 | 2 | 4 | 4 |
| Reliability | 2 | 3 | 2 | 3 | 1 | 3 | 3 | 3 | 4 |
| **∑(CI x EC)** | | 61 | 67 | 65 | 57 | 48 | 43 | | |
| **Relative Weight** | | 17.9% | 19.6% | 19.1% | 16.7% | 14.1% | 12.6% | | |
| **Rank** | | 3 | 1 | 2 | 4 | 5 | 6 | | |

Fig. 2 - House of Quality.

## 2.6 Schedule

Within the next week, a Gantt Chart will be made using Microsoft Project to act as a scheduling tool for the team.

# 3 Conclusion

After being assigned this project to improve the hammer blow impact test device designed by a previous senior design team, Team 12 has worked to establish communication with that team and the sponsor at Harris Corporation. The existing prototype device from last year was looked at along with their reports and findings in addition to some background research about pyrotechnic shock. To continue moving forward this year, more communication with the sponsor, advisor, and previous team needs to occur. Also, scheduling with a Gantt chart will be completed and brainstorming will begin to start achieving the goal of improving the test rig and modeling system for Harris.

# 4 References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