Design for Manufacturing

Team 12

Development of Hammer Blow Test to Simulate Pyrotechnic Shock

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Acknowledgements

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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 and make use of 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 pyrotechnic shock testing system that currently exists at Harris Corporation. A hammer blow impact test device has been built by a previous design team, but the resulting data lacked consistency and repeatability which provided little insight. The goal of this year's team is to capitalize off of the work of the previous design team while also implementing the necessary design changes in order to produce a repeatable pyroshock test that can be used to gain further understanding of the variables involved with pyroshock testing. To accomplish this several design changes were proposed and analyzed. The appropriate design changes that should be implemented consist of: a bearing hinge at the hammer pivot point, decoupling the frame and plate using a suspension system, stabilizing the entire device via anchoring, and making use of an electromagnetic release mechanism. So far the device has been anchored and the pivot has been replaced. The next steps in the project include trying to obtain repeatable results while also looking into electromagnetic release mechanisms and decoupling of the strike plate. Once repeatable results are obtainable, tests will be run in order to determine how variables affect SRS curve results.

1. Design for Manufacturing

Because this was a continuation of a Senior Design project from last year, there was no new full assembly of the hammer blow test device. Minor adjustments were made to the device to improve the data collected by the accelerometer, but those changes include anchoring the frame to the instrumentation table using two-hole aluminum straps, adding rubber pads between the strike plate and L bracket, removing the sacrificial plate on the front, and changing the hammer arm pivot to a dynamic pivot. All of these individual changes took an inconsequential amount of time relative to the time frame of the entire project.

A larger adjustment involved removing the mounting plate for the accelerometer on the back side of the strike plate and drilling holes into the strike plate in order to screw the accelerometer into the strike plate. It took only a couple hours to make this change. This new mounting of the accelerometer can be seen in Figure 1. Figure 2 shows the front side of the test device.

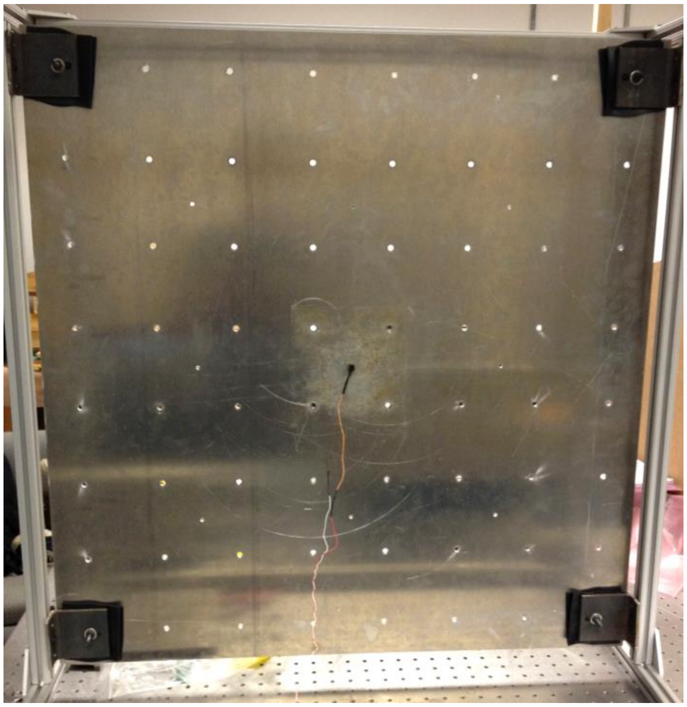

Fig. 1- Strike Plate with Accelerometer Mounted Directly

Fig. 2- Test Device

Figure 3 shows the CAD assembly of the device, with the minor changes mentioned earlier. Figure 4 displays a partially exploded view. This figure shows only the strike plate, hammer arm, and some of the frame exploded in order for simplicity and viewing purposes. Also, the basic connections are all consistent, and thus no new connection types are not exploded.

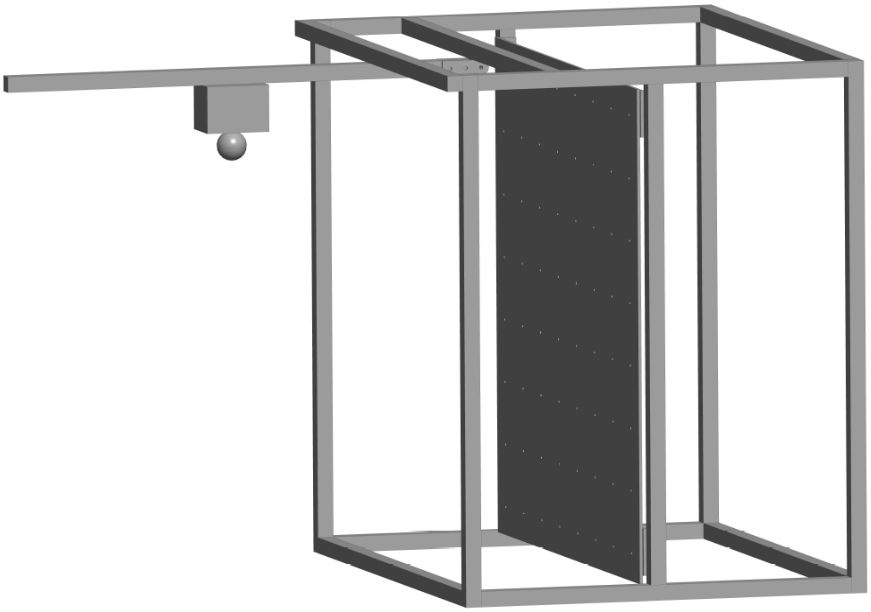

Fig. 3- CAD Assembly of Test Device

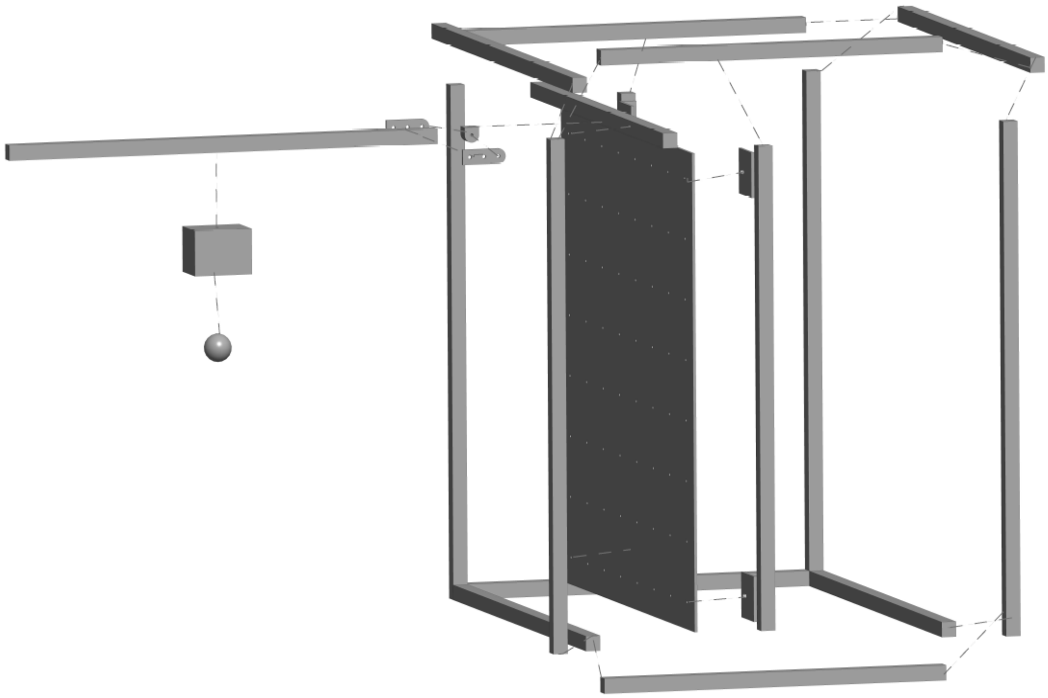

Fig. 4- Partially Exploded View of Test Device

Table 1 lists the components of this design. It can be seen that there are 4 major components. This design would probably benefit from greater complexity in order to eliminate some of the internal noise seen in the data, which cannot be corrected with any external changes. For example, complete isolation of the strike plate from the frame would benefit the data and ensure all aspects of the SRS curves are caused by an intentional action of the hammer.

Table 1-Components of Hammer Test Device

1. Frame
2. Strike Plate
3. Hammer (Arm and Head)
4. Accelerometer and DAQ (including processing equipment)

2. Design for Reliability

Reliability is a prominent concern for this test apparatus. The main objective for this year relies heavily on collecting data and thus having a reliable test apparatus is extremely important. Last year's team did well when choosing the appropriate materials and attachments to successfully run a high number of trials for both years of this project.

However, the test itself has a mildly violent nature, and thus some deformation is seen and expected after running multiple trials. A big concern last year was the plastic deformation of the strike plate, so a plate named as the sacrificial plate was added to alleviate damage to to the strike plate. Plastic deformation was then expected to be seen on the sacrificial plate, so various plates were made to correspond with each hammer size. Their biggest concern last year turned out to be the hammer pivot, seen in their Failure Mode Effect Analysis (FMEA) in Figure 5. This was corrected this year by changing that static pivot to a dynamic pivot, which not only improved repeatability but addressed some of their failure concerns of the static pivot.

Table 4 - Failure Mode Effect Analysis of Physical Test Rig

Input	PFM	PFE	SEV	PC	OCC	Controls	DET	RPN	Action
Hammer	fracture	partial force generation, delay in future testing	6	inadequate material	1	pre/post test inspection, material selection	9	54	replacement-new material
Hammer arm	bending, fracture	partial force generation, delay in future testing	6	off center	1	pre/post test inspection, material selection	9	54	replacement-larger diameter
Arm pivot	bending, fracture	delay in testing, skewed results	6	cyclical fatigue	3	pre/post test inspection, material selection	6	108	replacement-new material
Quick release	premature/failure to release	no results, injury if premature	5	cyclical fatigue	3	pre/post test inspection, material selection	7	105	replacement-redsign
Mount size	sliding, rolling	partial force generation, damage to components, injury	7	incorrect size	2	pre/post test inspection, material selection	3	42	modification/ replacement
Fixture plate	bending, fracture	skewed results, delay in testing, damage to accelerometer	7	off center	1	pre/post test inspection, material selection	4	28	replacement-new material/size

Fig. 5- FMEA from Team 15 Last Year

Table 2- Team 12 FMEA

Component	Potential Failure Mode	Potential Effects of Failure	S	Potential Causes of Failure	O	Current Process Controls	D	RPN	CRIT	Recommended Actions
Hammer Arm	Bending	Skewed data, Decrease in repeatability status, Testing delay while fixing	6	Pivot damage, Mishandling, Material Failure	2	Inspection of part before running any tests.	1	12	12	If cannot re-correct arm, machine T-slotted Al bar to replace arm.
Hammer Head	Major deformation of sphere tip	Change in data, Decrease in repeatability status	6	Impacting strike plate with too much force for a large number of trials	3	Inspection of part before running any tests.	1	18	18	Change out sphere size when possible. Order new sphere if noticing problem.
Strike Plate	Deformation, Undesired Holes/Cracks	Bad data, Inability to make conclusions from test results	7	Too much concentrated force from one impact location	3	Inspection of part before running any tests. Use sacrificial plate when possible.	1	21	21	Do not run too many tests with same strike location for variable testing.
Accelerometer	**Breakage**	**Inability to collect data, Inability to finish testing with time constraints**	**10**	**Mishandling, Direct impact by hammer**	**4**	**Inspection of part before running any tests.**	**2**	**80**	**40**	**Never hit accelerometer directly without any extra plates. Hit slightly off axis.**
Frame	Loosening of screws at attachment points	Skewed data, Decrease in repeatability status	2	Violent nature of impact test	8	Inspection of part before running any tests.	1	16	16	Tighten of all screws with torque wrench after all full hammer swing test runs.

Table 2 shows the FMEA made this year since changes were made to the test apparatus that affect the components and failure modes. For example, the removal of the sacrificial plate means a larger concern for plastic deformation of the strike plate. However, Harris has assured the team that any damage from the hammer on the strike plate will not be of consequence considering the fact that strike location will be moved for the next set of trials. Removal of the accelerometer mounting plate means an increased damage possibility to the accelerometer, so it has been decided to not hit directly where the accelerometer is mounted, but slightly off axis. This damage possibility to the accelerometer has thus become the largest concern as seen by the Risk Priority Number (RPN) and Criticality rating (CRIT) in the FMEA table. The table shows that the identified failure modes for the other components have a much smaller severity, and are more easily corrected than if ordering a new accelerometer ever becomes necessary, especially at this point in the project.

3. Design for Economics

This project was originally given a $5,000 budget for this year. Because the test device was already built, a significant amount of money was not spent, and thus this project can be deemed as economically sound. Figure 6 displays a pie chart of the items purchased and what percentage of the budget they encompassed. It can be seen that approximately $3,138.00 is expected to be remaining at the end of this project, when using an estimated value from last year's team for the team to travel down to Harris before the end of the semester. Table 3 lists each purchased item and its respective cost.

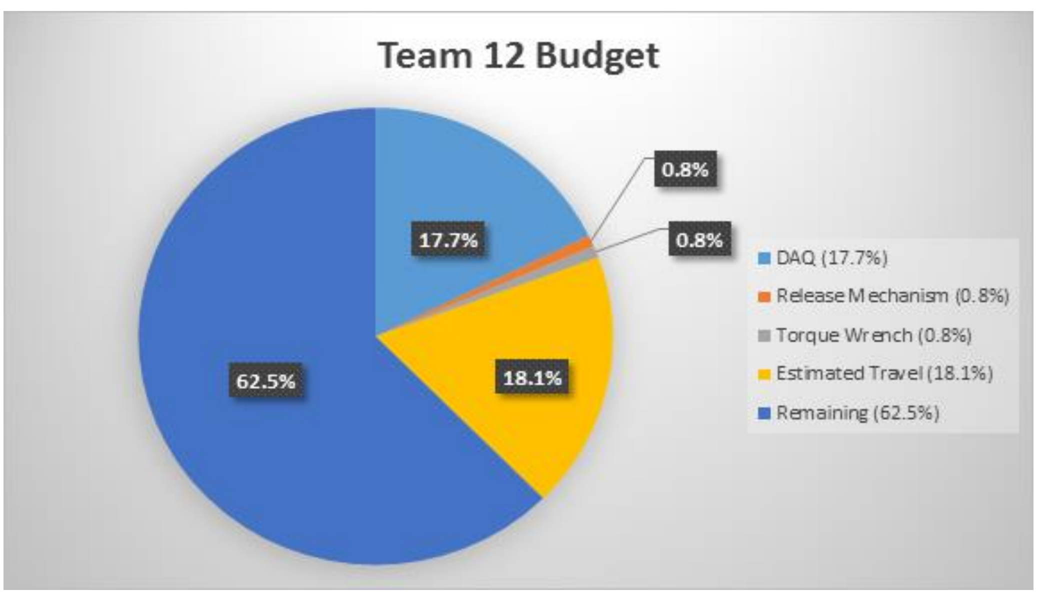

Fig. 6- Pie Chart of Purchased Items

Table 3- Individual Purchased Items

Part/Item	**Price**
National Instruments DAQ	$880.00
GearWrench Torque Wrench	$41.96
Electromagnet	$13.39
Battery	$20.00
Switch	$6.88
Estimated Travel	~$900.00
Total:	$1,862.23

Similar test apparatuses to the hammer blow test device, designed by the team last year, have not been found on the market, thus making cost comparisons difficult. The total spent last year for just the device was approximately $1,130.00. After working with this device for the second year, various changes to the initial frame design could have been made in order to eliminate internal noise that could not be corrected by external adjustments, and thus it can be inferred that more money could have been spent to design and build a device with fewer design flaws, but obviously time always adds an additional constraint.

References

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2. Wells, Robert. "University Capstone: Development of Hammer Blow Test Device to Simulate Pyrotechnic Shock (Second Year Project)." 14 Aug. 2015.