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25% REPORT

STRIKER MECHANISM UPGRADE FOR THE SPLIT-HOPKINSON PRESSURE BAR EXPERIMENT

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This B.S. thesis is written in partial fulfillment of the requirements in EML 4551. The contents represent the opinion of the authors and not the Department of Mechanical and Materials Engineering.

ETHICS STATEMENT AND SIGNATURES

All the submitted work in this B.S. thesis is exclusively prepared by a team composed by Hector Di Donato, Jean Paul Garbezza, Alejandro Infante and Ricardo Lopez and it is unique. Extracts from others' work have been clearly identified, their work acknowledged within the text and listed in the list of references. All of the engineering drawings, formulations, design work; prototype development, analysis and testing reported in this document are also original and prepared by the same team of authors.

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ABSTRACT

At the behest of the Air Force Research Lab's (AFRL), Munitions Directorate, the goals for our team in this Senior Design course are to develop a more effective striking system than the one last year's group has in place, as well as improve the diagnostics to review the test results. Using scholarly sources such as textbooks and research articles, knowledge of the general function of Split-Hopkinson pressure bars (hoppy bars), as well as general formulas related to interpreting the data were obtained. Using one dimensional wave propagation formulas, equations for the potential energy of gas, and kinetic energy of the striker bar, the size of the striking system was estimated.

1. INTRODUCTION

1.1 PROBLEM STATEMENT

A new striking mechanism is to be designed and integrated to the existing Split-Hopkinson Pressure Bar (SHPB) apparatus to improve the consistency, striking speed and overall reliability. Ideally, the integration of the new striking system should not change the physical principles involved with the existing hoppy bar. A compressed gas, crossbow-type or spring-type mechanism is to be designed. Extensive analysis of the physical system was performed to gather as much information as possible to make educated engineering decisions. Also, the diagnostics system is to be improved, resulting in implementing a 100 KHz frequency response oscilloscope, as well as substitute the existing strain gauges if they are below the 100 kHz minimum frequency. Every instrument in the data acquisition system installed must meet the minimum frequency response of 100 kHz to improve the detail of collected data points for material analysis.

1.2 MOTIVATION

Experimentally, it has been shown that material properties such as yield stress and ultimate strength differ when loads are applied statically rather than dynamically. Split-Hopkinson Pressure Bars (SHPB), also known as Kolsky Bars, are used characterize said properties of materials at high strain rates (dynamic loading); in the order of 10-2 – 104 in/in/s. These high strain rates are typical of impacts relating to dropping of personal electronic devices, sporting equipment, car accidents, and armed forces protective equipment. The Air Force Research Laboratory (AFRL) Munitions Directorate’s primary interest in presenting this project to Florida International University’s (FIU) senior design team last year, was to implement the use of air bearings to reduce friction in the input and output bar. The air bearings replaced the linear bearings generally used in SHPB. However, the striking system in operation is primarily driven by gravity, which creates inconsistencies in the striking speed and force with which the striker bar is set into motion. Also, the diagnostics systems were not appropriate to observe the characteristic square waves from the stress-strain diagram. Therefore, the goal of this design is to implement a compressed gas striking system and improve diagnostics in the existing SHPB.

1.3 LITERATURE SURVEY

1.3.1 SPLIT HOPKINSON PRESSURE BAR

The Split Hopkinson Pressure Bar is a device used for characterizing material properties that are submitted to dynamic loading, producing high stress and strain waves. John Hopkinson, in 1872, studied - for the first time - the behavior of iron wires by performing stress wave experiments. [1, 2]. His work consisted of having an iron wire fixed at one end and the free end loaded with a sudden impulse of a mass. He certainly developed the theory of how waves propagate though iron wires. After his experiments, the results yielded the strengthening of iron wires being used under different loading conditions. One of the most important findings of John Hopkinson was “the fixed point of a wire will break only with half the speed that will take the wire to break at the point where the mass is loaded” [1]. His son Bertram Hopkinson continued doing experiments in the same field. Bertram was the first person to use a bar to measure impulse wave generated by materials when impacted [2]. After years of study he came to the conclusion that the most important factor in the failure of materials was the velocity of impact. All of these experiments were conducted in 1914, and his observations were only qualitative. Bertram, in his experiments used a pendulum integrated with pencil and paper to record the movements of the rods as the pendulum would impact the target as seen in Figure1.

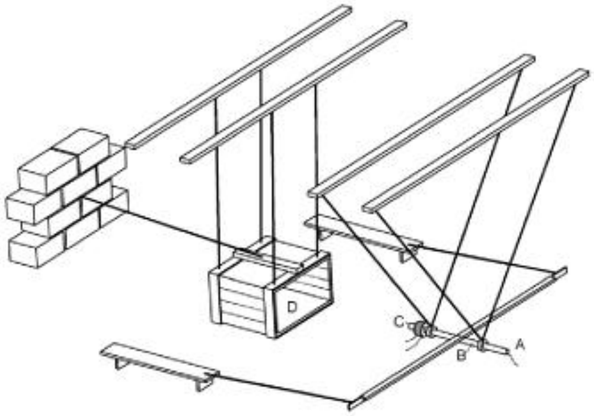

Figure1: Apparatus of Bertram Hopkinson Experiments [2]

On the other hand, Davies, in 1948 led the study of a different technique; he used parallel plates and cylindrical microphones to electrically measure the propagation of those waves. Davies also discussed the propagation and dispersion of waves when they are traveling in long rods. Shown Figure 2 is Davies' principle contribution to improving the HPB mechanism. Davies made several other contributions that can be denoted as follows: he discovered that HPB could not accurately measure rapidly applied pressures - in the 1µs scales; the time it would take to create a pressure wave when an instantaneous force is applied, the wave will reach a constant value that in the end is related to Poisson's ratio; his final contribution was the determination of the length-radius relationship of the bar.

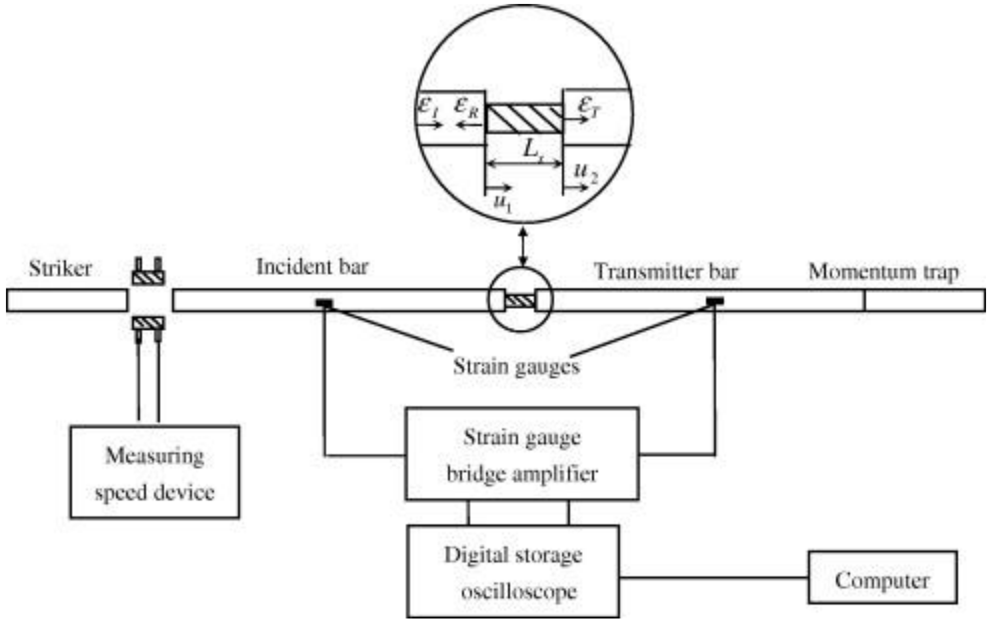

Figure 2: David's New Improved Design OF SHPB [3]

At the same time as Davies, a modification of this idea was done by Kolsky in 1949 [2]. He introduced the concept of having to bars in order to study the dynamics behavior and the relationship of stress-strain for different materials and one dimensional wave propagations. Kolsky presented a complete experimental procedure for operating the SHPB. After the technique of using SHPB to study the dynamic behavior of materials was introduced, it became widely used to test materials at high stress and strain [4] [5]. Kolsky held experiments using materials such as rubber, copper, polythene and lead with a HPB. The so-called SHPB was introduced by Kolsky in his publication and it was known as the "Kolsky Bar" [6].

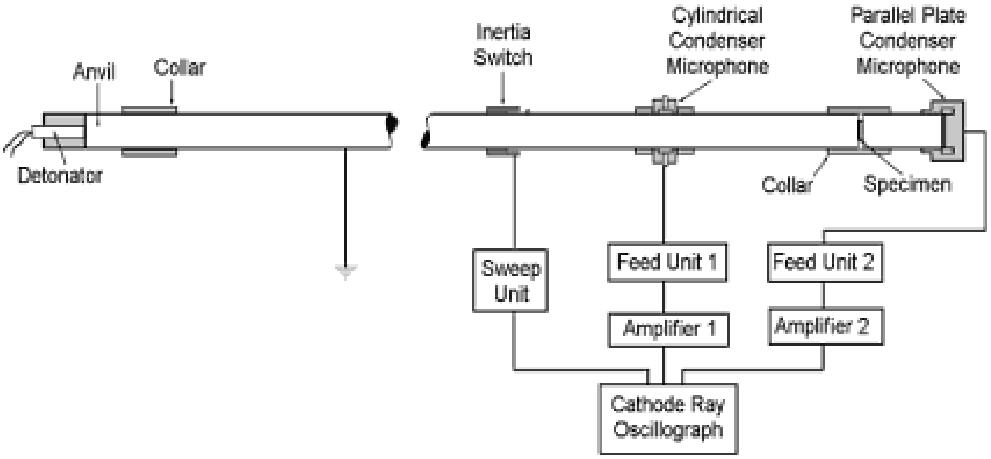

Figure 3: Typical Split Hopkinson Bar Configuration [2]

In Modern times, the SHPB does not use a parallel plate condenser; it uses strain gages that are attached to the input bar and output bars. Those strain gages are generally placed in the middle of the bars, and both of the bars are equal in length so it helps in the accuracy of the data collection. The stain gages send electrical signals to a high speed data acquisition system called an oscilloscope. These types of experiments are also recorded with high speed cameras so an additional visual analysis can be applied for a more complete interpretation of the deformation process.

The time loading T produced in a SHPB is related to the length L of the Bars as shown below.

$$T = \frac{2L}{C_{st}}$$

Where Cst is the elastic speed of the wave

When the incident bar has the same material as the incident bar the Strain amplitude is directly affected by the striking bar velocity as shown in the formula below.

$$\sigma_I = \frac{1}{2}\rho_B C_B v_{st}$$

Where ρ_B is de density of bar, C_B the elastic speed of bar

Or

$$\varepsilon_I = \frac{1}{2} \cdot \frac{v_{st}}{C_B}$$

If we assume that stress waves propagate in the incident bar and the striker bar without dispersion, the pulses generated by those waves can be recorded at the end by the strain gages and will result in the following formulas

$$v_1 = C_B(\varepsilon_I - \varepsilon_R)$$

$$v_2 = C_B \varepsilon_T$$

Where subscripts I, R and T represent the final pulse for the incident, reflected and transmitted bars, so from those equations we can obtain the average engineering strain for the specimen as shown below.

$$\varepsilon = \frac{v_1 - v_2}{L_s} = \frac{C_B}{L_s}(\varepsilon_I - \varepsilon_R - \varepsilon_T)$$

The equation above you can see that L is the length of the specimen. So we can calculate the stresses at both ends of the specimen as shown below. Where A_b and A_s are the cross sectional areas and E_b is the young modulus of the specimen.

$$\sigma_1 = \frac{A_B}{A_s} \cdot E_B(\varepsilon_I + \varepsilon_R)$$

$$\sigma_2 = \frac{A_B}{A_s} \cdot E_B \cdot \varepsilon_T$$

When the experiment sequence reaches the point of measuring the strain in the incident and transmitter bars, strain gages are most common devices to do so. Arranged in pairs, the strain gages are placed symmetrically on the bar surface, across its diameter. The signals from the gages are sent to the oscilloscope through a common electrical circuit called a Wheatstone Bridge [7]. The voltage output from the Wheatstone bridge, in general, is of such a small magnitude – typically in the milli-volt order - that a signal amplifier is necessary to record such low voltage on the oscilloscope. The frequency response of all components in the data acquisition system must conform to the minimum of 100 kHz. Lower frequency responses in any of the components will result in distorted signals in the oscilloscope.

Hoppy bar experiments generate stress waves upon impact of the bars. The stress wave originates as a compression wave in the incident bar since it is impacted by the striker bar. That wave propagates through the incident bar until it reaches the interface of the incident bar and the specimen. The specimen has a limit of the amount of the wave it can absorb; upon reaching that transmission limit, the rest of the stress wave is reflected back into the incident bar as a tension wave. The transmitted wave in the specimen gets reflected back and forth due to wave impedance mismatch between the specimen and the bars. The reflections build up the stress level in the specimen and compress it. This stress wave interaction in the transmission/ specimen interface builds the profile of the transmitted signal. Due to the thin specimen used, the stress wave propagation in the specimen is usually ignored by assuming equilibrated stress in the specimen [7].

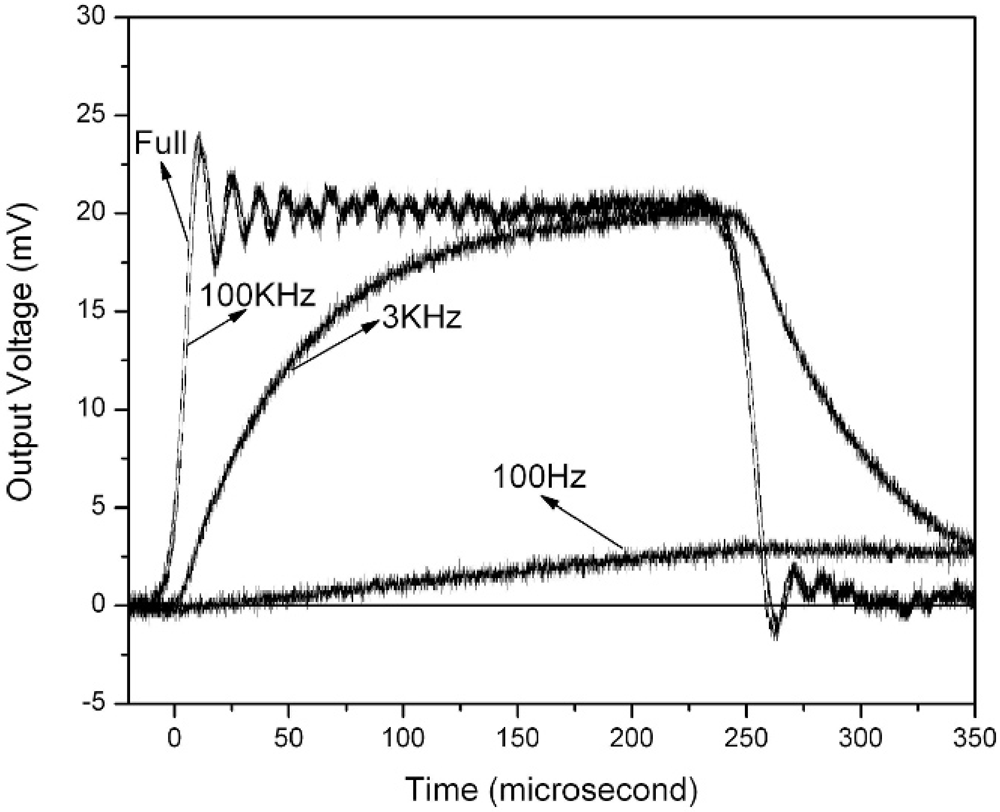

Figure 4: Typical Split Hopkinson Bar Output Voltage vs. Time [1]

1.3.2 COMPRESSED GAS STIKING MECHANISM

Compressed air has been used for a prolonged period of time as a way of storing potential energy. Whether it is to power a locomotive across large distances or to fire a pellet from an air gun, compressed air is an efficient way to store energy. We choose to incorporate this concept of compressed air energy storage (CAES) into our design to generate the force we need to satisfy our requirements.

One of our preliminary concepts of energy storage included a crossbow design, which stored potential energy of a spring into the crossbows limbs. This energy would later be released and transmitted through the striker bar. The problem with using a spring to store the energy we need, would lie in the amount of energy called out in our requirements. Below the general potential energy of a spring formula is given:

$$PE_s = 1/2\ kx^2$$

When calculating the potential energy of a spring, we multiply the K constant of a spring (K constants of springs are directly proportional to the amount of energy that can be stored in said spring) by the square of the displacement of the spring. In simple words, the potential energy of a spring lies in the K constant of the spring and the displacement it undergoes during the energy storage process. Our design requirements call for a very large amount of energy being stored (PE) and released, which leaves us with two variables to work with, K and X. Since X will be limited, the driving variable in this equation is the spring K constant.

The minimum force needed is 70MPa, coppers yield point. To produce said pressure we would need a spring with a very large K constant, too large to work with. Our final concept lies using CAES to produce the required pressure needed to reach the minimum pressure 70MPa.

2. DESIGN ALTERNATIVES

2.1 CONCEPTUAL DESIGN

In the selection of the striking system that we will be designing for the split Hopkinson bar previously designed, different factors are taken into consideration. The previous design team worked engineered a pendulum hammer driven by gravity. The reason this system needed to be changed was that the bar being shot did not have a constant velocity. Two different systems were taken into consideration in order to design a striking system that would resolve the variation in the striking force and speed; a cross-bow and a compressed gas mechanism. Upon formulating design principles, the conclusion was made that a cross-bow type system will have the same loss of force when hitting the striker bar due to losses in elasticity in the bow line. In order to achieve results with consistent impact force and speed, the striking system our team is designing is comprised of compress gas stored in a tank. The potential energy of the compressed air will be rapidly released from the tank resulting in kinetic energy transferred to the striker bar. A solenoid valve is the mechanism used to release the air from the tank in a controlled and consistent manner. A solenoid valve is an electromechanically operated valve. By pressing a button, an electric current is passed through a solenoid and the valve is switched "on," allowing the gas to flow. The valve is fully opened almost instantaneously, in the order of microseconds. By replacing a regular valve with a selenoid bar the system is prevented from human error or from having different shooting speeds.

2.2 PROPOSED DESIGN

The striking system this year's senior design team will be implementing will consist of compressed Nitrogen gas, a holding reservoir, a solenoid valve, steel barrel, and a striker bar.

The diagnostic system will retain the strain gauges previously applied by last year's design team, although, the latest design revision will enhance the oscilloscope to one with 100 kHz frequency.

The compressed Nitrogen will be employed due to the low weight requirement for the gas being used. Once released, the gas must expand quickly to set the striker bar in motion. Other options for the expanding gas are air and carbon dioxide (CO_2).

The holding reservoir must be sufficiently burly to withstand the 4500 psi necessary for the striker bar to obtain the necessary velocity to impact the incident bar. Although the static pressure is 4500 psi, the output pressure setting the striker bar in motion will be approximately 800 psi. The holding reservoir will be an 88 cubic inch tank with a "T" fitting allowing the tank to be filled and have the gas subsequently redirected to the solenoid for firing. The "T" fitting must contain a gate valve to hinder the gas from flowing back into the pipe of the filling tank in the firing stage.

The launch barrel used is of steel, so it will withstand the pressure of the expanding gas impacting the striker bar. The wall is relatively thick - at least an inch – to make sure it is as straight as possible. At the end of the barrel, vent holes will be drilled to allow the expanded gas to escape into the atmosphere. Prior to venting, the gases accelerate the striker to its final velocity. Subsequent to the venting of the expanding gases, the striker bar is traveling at a constant velocity. Velocity measurements are made prior to impacting the incident bar.

The striker bar is adopted from last year's senior design team. It is a hardened steel bar, 0.5 inches in diameter and 10 inches in length.

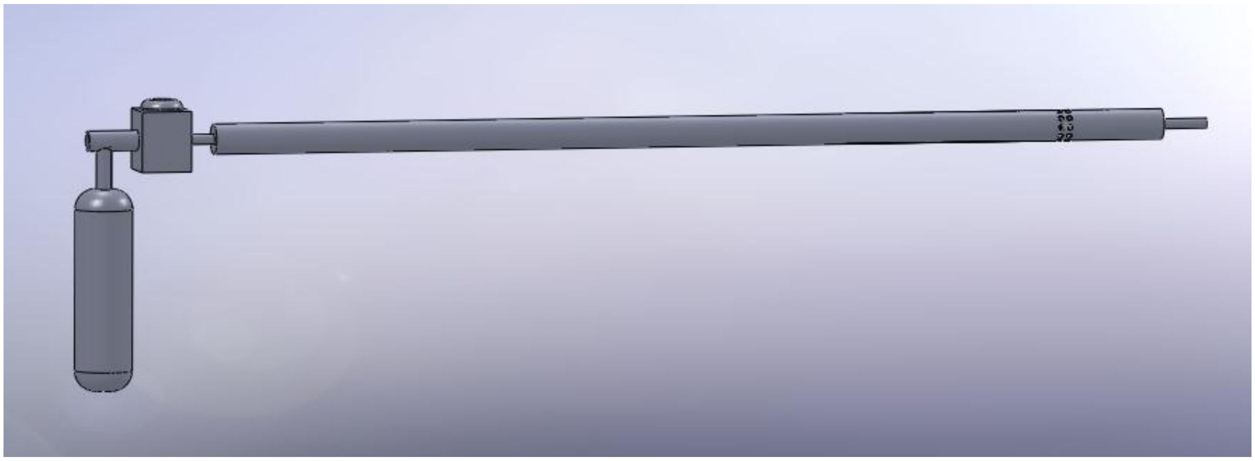

Figure 5: Compressed Gas Striking System Proposed design

3. THEORETICAL ANALYSIS AND SIMULATIONS

3.1 ANALYTICAL ANALYSIS AND STRUCTURAL DESIGN

3.1.1 GENERAL GOALS

The SPHB are extended experimental equipment, most of the times this equipment are longer than 15ft. This type of equipment are very difficult to store because of its size, having said that you will need more components such as air bearings and longer bars which will make the project very costly. Since our objective is to design the striker mechanism, this matter is also taken into consideration since the size of the striker can be long as well. That is one of the main constrains that we need to meet in this project by scaling it down. However the scaling is done very precisely in order to preserve the properties of the SHPB. All calculations will be done analytically and also performed with a computer to run the appropriate simulations in order to make sure all values are correct.

3.1.2 SHPB COMPRESSED GAS STRIKER

As we have the information from the previous team that worked on the air bearing upgrade for this SHPB was analyzed and it was analyzed and the modification to use air bearings was worthwhile. The team from previous year used a SHPB without air bearings and then they understood the properties they have to preserve in order to make the SHPB work under the same conditions [8]. After reading their report we also understand all the properties that we have to preserve when changing from a hammer to compressed gas as striker mechanism. This understanding made us aware of meaningful information that will help us preserve the principle for material testing and energy of system during it use.

3.1.3 SPHB SCALING

In the analysis of SHPB for scaling, if you want to get more information on the air bearing you must reference the report from previous year [8]. For this ne redesigned striking mechanism we need to build a consistent way to impact the input bar so we can generate a stress wave. That it is why we have chosen the compressed gas striker since it will provide with a cleaner and precise stress wave. The gun consist of a long barrel where the air is to be released in order to achieve a constant velocity of striker before hitting the input bar. The striker bar will leave the barrel with a pressure of 300psi converting all that stored potential energy into kinetic energy. Allowing the system to have a very high impact velocity transmitting the required force required to deform elastically copper.

3.1.4 NATURAL DEFLECTIONS

As we know the SHPB experiment is considered to be 1-D, having said that we understand in theory that the bars must be perfectly aligned with each other, but in theory it is very hard to achieve that. Also, it is very hard to have produce rods that are perfectly circular along the entire length of the bar. All these constraints will no longer generate a 1-D wave which will change the data results by a small range. A normal type of deflection that occurs on these bars is due to their own weight, but in this case that will be neglected for better analysis. Since that bar has already been designed and we will be using the same bar the dimensions have been already set as we can see the figure shown below.

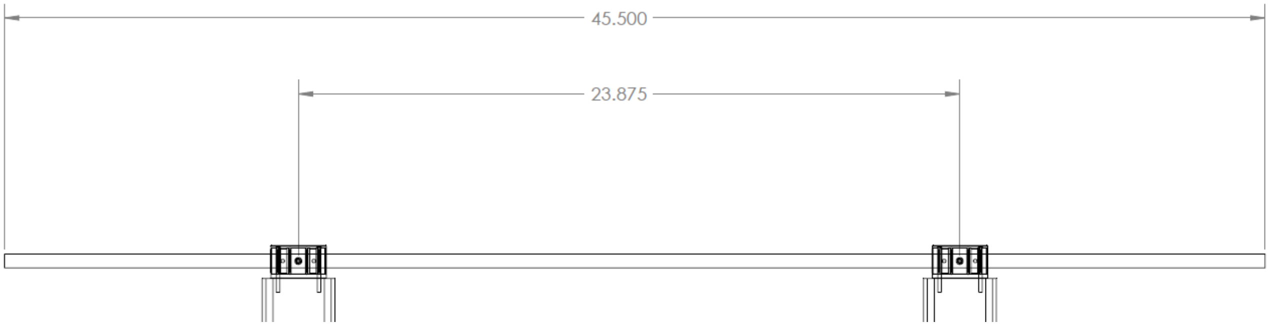

Figure 6: Transmitter bar and bearing location dimensions based on analytical calculations. Dimensions are in inches [8]

The entire SHPB is supported on two supports; they are separated by 52.5 inches so we will have 15.75 inches to overhang the beam. The deflection of the beam was calculated by the previous year team and it came to be located at the end of I beam and it is 0.000127 inches [8]. The figure below shows you a better idea of the setup of our SHPB.

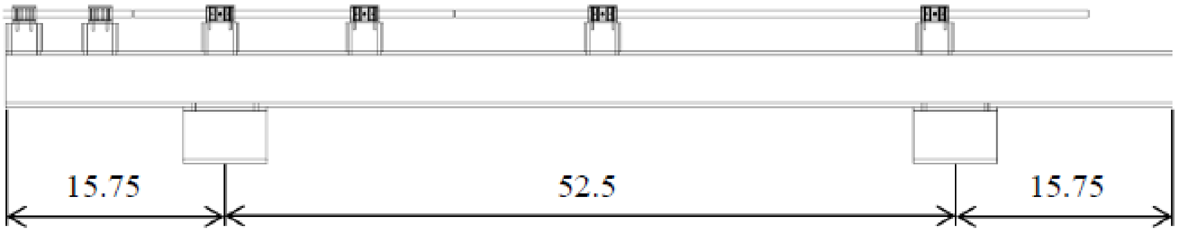

Figure 7: I-beam support spacing and dimensions based on calculations.

Dimensions are in inches [8].

3.1.5 STRAIN GAGES

Strain gages are used to measure the strain history of the waves traveling through both of the bars, the input and output, strain gages that have electrical resistance will be mounted to both bars. This is one of the most popular methods to obtain data due to their small size and ease of installation. An extensive analysis on this strain gages was done by the team from last year [8], since this was already analyzed, our team went over the analysis to get a good understanding of the functionality. This strain gages will be connected to the oscilloscope in order to gather the data and be able to see the deformation of materials in a graph.

4. PROTOTYPE OVERVIEW AND FABRICATION

4.1 MAJOR COMPONENTS

The stress generating system of our compressed gas striking system includes a main supply gas tank, an auxiliary pressure reservoir, a fast release solenoid valve, long barrel, and striker bar – most of which are depicted in figure 5. This striking system is also a major part of the overall hoppy bar, whose major components consist of the incident bar, transmitter bar and momentum catch.

The auxiliary pressure reservoir is employed for several reasons. First of all, the main supply tank cannot provide the high pressure necessary to impact the striker bar upon the actuation of the solenoid. Secondly, for design purposes, we must have a quantifiable and consistent amount of gas being disbursed during subsequent iterations of experiment. This reservoir is the middle point between the main supply tank and the solenoid valve.

The solenoid valve opens fully in milliseconds to maximize the flow rate of the stored gas, and maximize the application of its potential energy. The solenoid converts the potential energy of the gas into kinetic energy in the striker bar upon impacting it. The potential energy is further maximized by minimizing the clearance between the barrel and the striker bar, creating a natural seal.

The following component of the system is the barrel. This component allows the striker bar to gain the necessary velocity before impact. It must maintain the striker bar on a straight and level path to obtain the clearest data possible. The barrel has vent holes to allow the expanded gases to escape once the striker has reached a constant velocity.

The striker bar is adopted from the existing hoppy bar in place, although certain modifications will have to be made to tailor it to our design objectives. The striker bar will be fitted with equipment to reduce friction between the bar and the barrel. Upon impact with the incident bar, it sends a stress wave which propagates through the incident bar in tension.

The impact of the striker and the incident bar must occur on a plane normal to the direction of stress propagation to maintain wave propagation that is one dimensional. The stress wave initiated by the striker bar travels across the incident bar until it reaches the incident bar/specimen interface, in which the part of the wave not transmitted to the specimen is reflected back into the incident bar. Since the initial stress wave propagated through the bar in tension, the stress wave which is reflected propagates through the bar in compression; this is due to Newton’s third law, which states that every action must have an equal and opposite reaction. The specimen is thus compressed in between the incident and transmitter bar.

4.2 STRESS DETERMINING SYSTEM

This system is the other major component in the hoppy bar. It is made up of strain gauges, voltage amplifiers and oscilloscopes.

The strain gauges read the stress waves initiated and reflected through the incident bar, the specimen, and the transmission bar. The voltage read from the strain gauges is typically so low that voltage amplifiers are needed to raise the signal amplitude seen by the oscilloscope.

4.3 STRUCTURAL DESIGN

The main gas supply tank is an industrial size 292 cubic foot tank. This gas supply is fed through a series of pipes to one end of a "T" fitting which fills the auxiliary reservoir when the one way solenoid valve is closed. The "T" fitting is equipped with a valve to close the line to the main supply tank when the solenoid is set for actuation; this ensures all of the pressure flows in one direction. Along the barrel, at a given distance from the rear - or "breech" end - when the striker bar has reached the velocity required to produce the desired strain in the specimen, the expanded gases will be vented from the barrel through an array of equidistant drilled holes. This is done to allow the striker bar to reach a constant velocity before it impacts the incident bar. Furthermore, the inside diameter of the barrel is slightly greater than the striker bar; this assists in the reduction of losses in potential energy of the gas. The striker bar will also be fitted with bearings or metallic O-rings which will also serve to hinder the escape of gas. The thickness of the barrel will be approximately an inch to account for mechanical stability which provides a straighter surface for the striker bar to travel.

4.4 PROTOTYPE SYSTEM DESCRIPTION AND PLANED TESTES

The prototype shall be made to half scale of the actual system, using a lower tolerance to ensure a low cost model of the conceptual design. By having a scaled down model of the system we will be able make adjustments to any clearance, fabrication, etc. issues we may foresee in the fabrication of the actual system. The prototype shall be made of lower grade material, and shall not include any of our actual full-scale system components. This will further reduce the cost of the prototype, which is a requirement we developed being that the prototype will serve as a reference for providing fit and safety checks as well as fabrication assistance.

While the actual system will consist of precision instruments including, air bearings, oscilloscopes, strain gauges, etc., the prototype will include reference markers in their place. Reference markers will allow us make adjustments to positioning for any high precision instrument, saving us time when working on the actual system. What we will be maintaining in our prototype to ensure its accuracy is proportion to the actual system. This part of the prototype system is crucial in order to produce a viable prototype; we will achieve this proportion by setting the scale to one half of the actual system. For example, our conceptual system calls for a 60-inch steel barrel. Our prototype's barrel will include a 30-inch PVC pipe for the barrels substitution. The choice of PVC lies in few major factors; fit, form, and function. The PVC allows us to represent the barrel to the correct scaled dimension, while maintaining its function as a prototype.

Our prototype, though made of different materials, will still be required to hold pressure. We will be listing this as a requirement to further increase the prototypes accuracy in regards to the original model. While holding pressure much lower than actual testing pressure, the prototype will allow our team to practice proper safety procedures while operating pressurizes vessels. This detail is critical to ensure a safe working environment for testing under high pressure loading.

5. PROJECT MANAGEMENT AND COST ANALYSIS

5.1 TIMELINE

Below is a Gantt chart that illustrates the major task to be performed during fall and spring semesters. The times below are just an estimated time frame for completing all tasks and they may change along the semester.

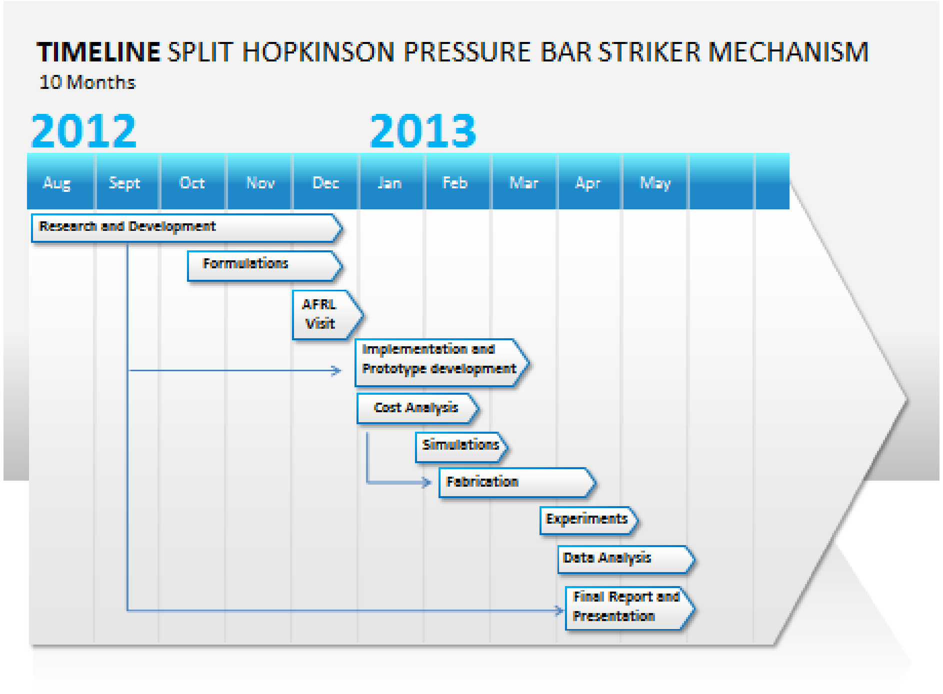

Figure 8: Time Line Gantt chart

Table 1: Account of total hours spent by team members

Team Member	Assignment	Time Spent (Hours)
Hector Di Donato	Problem Statement	1
	literature survey	2
	Analytical Analysis	3
	Cost Analysis	2
Ricardo Lopez	Procurement of Material	5
	Solid-work Modeling	2
	Poster Design	2
Jean Paul Garbezza	Literature Survey (Diagnostic System)	3
	Abstract, Motivation	1.5
	Major Components	2
	Structure Design	4
Alejandro Infante	Prototype System Description	2
	Prototype Cost Analysis	3
	Plan for Tests on Prototype	2
	Literature survey (Striking mechanism)	1

total hours	**35.5**

5.2 PROTOTYPE COST ANALYSIS

Our system consist of a main supply tank that supports up to 292 cubic feet of compress air connected with ¾ pipes outlets, from this tank we will be receiving all the air that feeds the system, this tank comes with a valve that let us control when we want the air released in order to fill out a reservoir with compress air. We chose this type of tanks because it is the best way to obtain compress air for the lowest price.

The reservoir is the tank where we will be collecting the compressed air from the main supply tank. The reservoir will hold the air until a bottom on the solenoid is pressed. For this tank our team chose a Pure Energy N2 Tank that holds up to 68ci at 3000 psi. This tank was chosen because for its size is the one that holds the most cubic inches, since most of the tanks in the market only holds 32 ci. This reservoir will be connected through a T ¾ pipe DURA 4 in. Schedule 40 PVC Tee SxSxFPT.

In order to shoot the same amount of air into the striking bar after the reservoir a solenoid will be connected. After researching different types we selected an Alcon - 04EZ003A1-1ECA - Solenoid Valve, 2 Way, NC, Delrin, 3/4 in. this solenoid can open the valve as fast as 38 millisecond. Every time the button is pushed.

All this components will be attached one from the each other with a ¾ pipe Thick-Wall (Schedule 80) Dark Gray PVC Threaded Pipe Nipples 4" 3/4 Pipe Size.

The striker bar will be inside of the last ¾ pipe waiting for air to be released to be shoot through the apparatus.

Table 2: Cost Analysis of all Components

Part	cost ($)	qty	total
Pure Energy N2 Tank 68ci 3000psi	62	1	62
DURA 4 in. Schedule 40 PVC Tee SxSxFPT	16.13	2	32.26
Thick-Wall (Schedule 80) Dark Gray PVC Threaded Pipe Nipples 4" 3/4 Pipe Size	1.26	4	5.04
Thick-Wall (Schedule 80) Dark Gray PVC Threaded Pipe Nipples 8" 3/4 Pipe Size	3.66	4	14.64
Alcon - 04EZ003A1-1ECA - Solenoid Valve, 2 Way, NC, Delrin, 3/4 in	31	1	31
292 cf compress tank	60	1	60

Figure 9: Figures of Items to be Purchased.
(All these images were kidnaped from our vendor’s catalogs)
mcmaster.com

6. CONCLUSIONS

Upon collaborating with Dr. House of the Air Force Research Laboratory to obtain a clear picture of what was expected and researching scholarly sources, a compressed gas striking system was engineered. This striking system encompasses the expectations of the client, AFRL, and the Industrial Advisory Board. The systems expectations were to be integrated to the existing hoppy bar, produce a consistent striking velocity, and upgrade the diagnostics equipment utilized.

The newly upgraded hoppy bar produces a consistent and reproducible striker bar velocity up to 120 fps which furnishes strain rates up to 104 in./in/sec. The diagnostic system implemented upgraded the frequency response of all the components to 100 kHz. This minimum frequency required to interpret the data clearly without any distortion in the oscilloscope recordings is driven by the loading duration in the specimen. Unknowingly, the previous design team had problems viewing the characteristic square strain waves due to the low frequency response of the data acquisition system.

In conclusion, the crossbow-type striker demonstrated excessive losses in striking force, leading to inconsistent striker bar velocities, which would have resulted in inconsistent data. Therefore, the compressed gas striking system proved to be the most reliable conceptual system.

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