Air Bearing Upgrade for the Split-Hopkinson Pressure Bar System

Senior Design Operations Manual, Team 1 – April 2012

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Introduction

Introduction from the Team

The basis of this project was to research, design and build a small scale split-Hopkinson pressure bar (SHPB) system which utilizes the use of air bushings in place of journal bearings that are commonly used in working systems. This system is compact, a small scale table top version of a current SHPB system located at Eglin Air Force Research Laboratory (Eglin AFRL) which one or two individuals are capable of transporting.

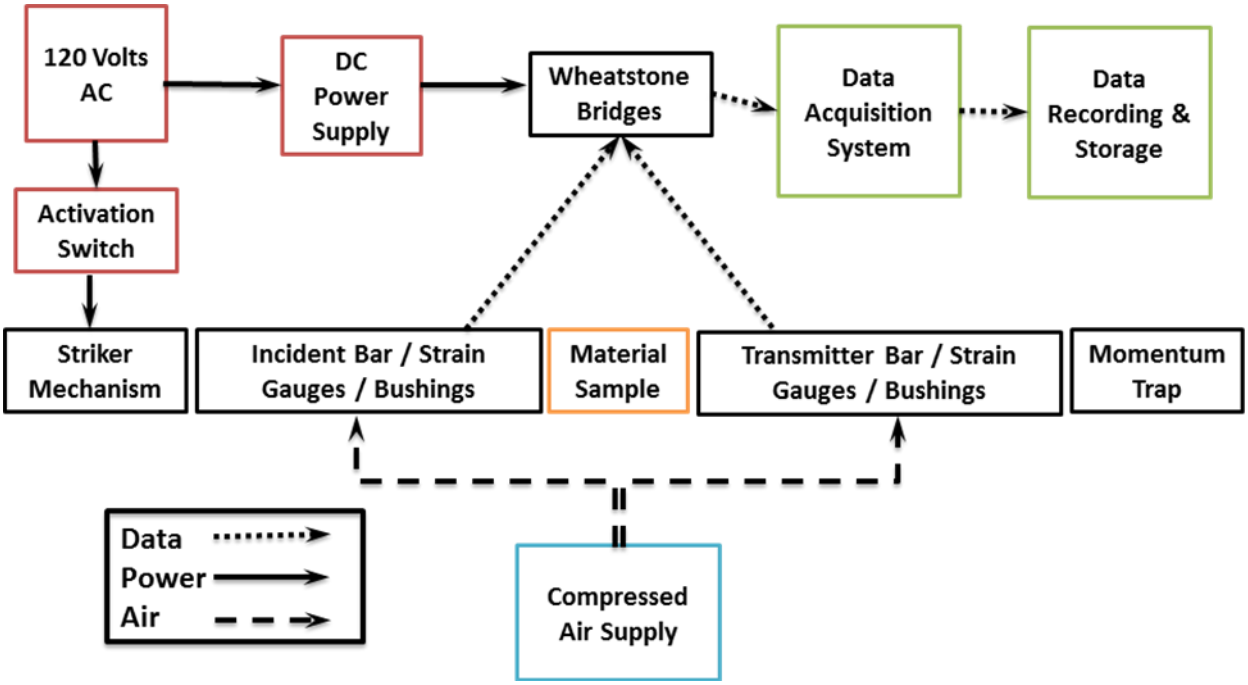
The following assembly, operation and maintenance instructions described in detail in the following manual are to aide in the proper use and lasting performance of this system. All of the cautions listed should be read and understood clearly before assembly and use of the system, in order to ensure user safety.

The following manual was prepared by team #1 of the FAMU/FSU College of Engineering for the use of the split-Hopkinson pressure bar system with air bushings.

Introduction to the Project

The FAMU/FSU College of Engineering senior design group one has been tasked with upgrading a split-Hopkinson pressure bar (SHPB) system with air bearings. The SHPB experiment is a method of testing energy absorbed in plastic deformation due to shock loading. The experiment is a series of four cylindrical bars all axially aligned. One bar is accelerated to a predetermined velocity; this is known as the striker bar. It then impacts the second bar, which is very long known as the incident bar. The impact wave is then transmitted to the third bar or the specimen being tested; it is much smaller in radius than the other three bars. Its smaller diameter multiplies the stress applied, thus plastically deforming it, before transmitting all of the energy to the fourth bar. The fourth bar is called the transmitter bar and is allowed to travel along the axis in which it then disburses the energy into a momentum trap. Two strain gauges are placed on both the incident and transmitter bars, and data reduction methods are used to show the total energy absorbed by the specimen. The only data that is of interest is the initial impact wave. There will be modal waves, but the experiment is designed to only have the initial wave affect the plastic deformation of the specimen.

Functional Diagram



System CAD Models

SHPB System

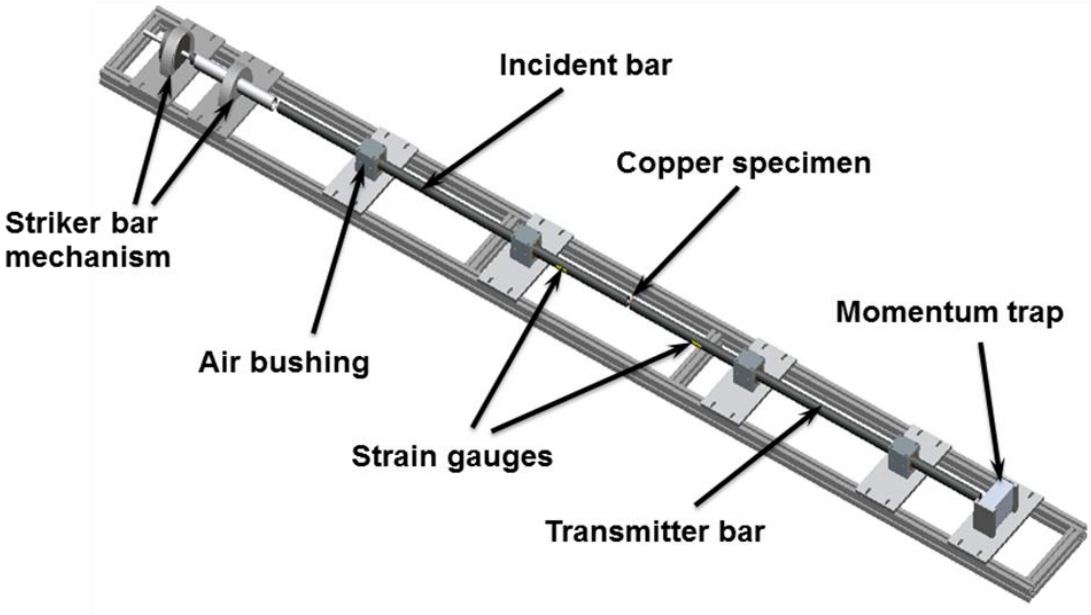


Figure 1 - SHPB assembly

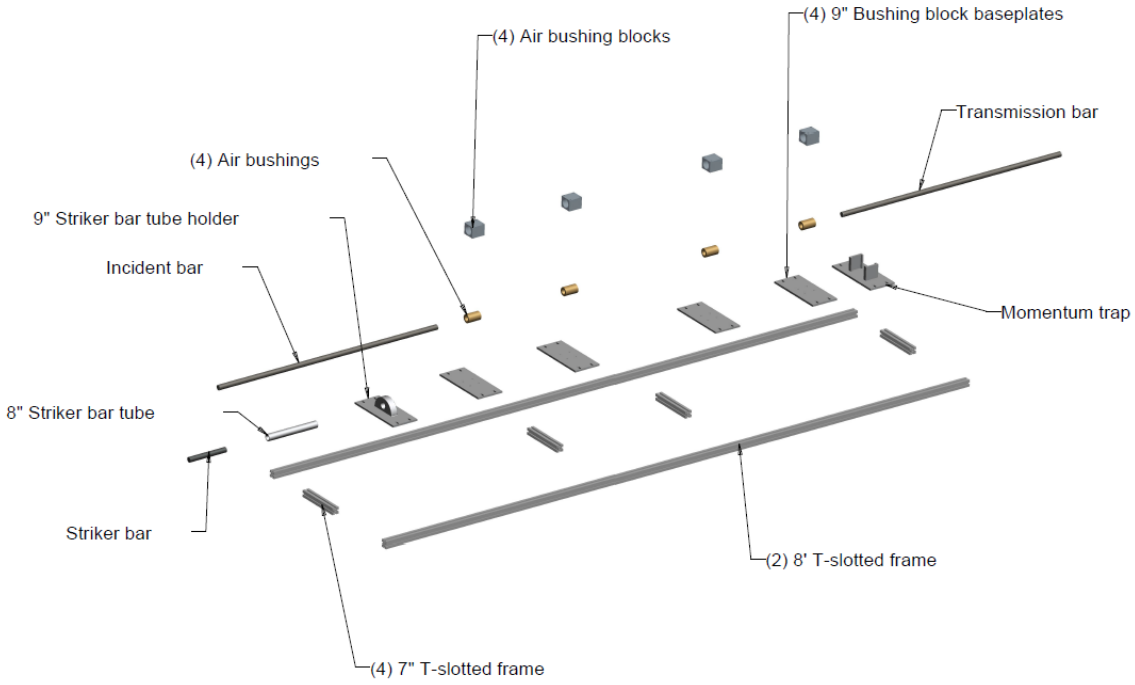


Figure 2 - Exploded view of SHPB system

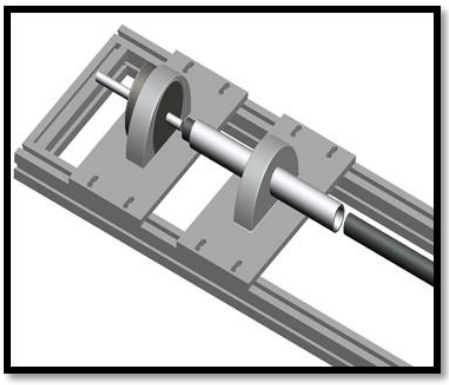


Figure 3 - Striker bar mechanism

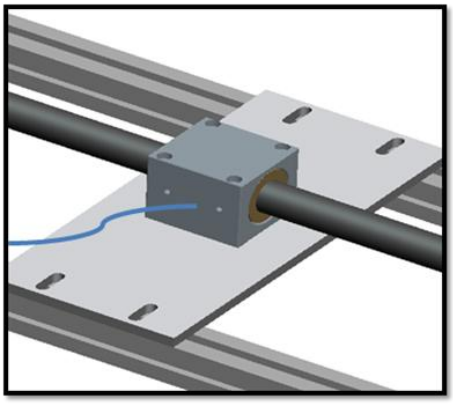


Figure 4 - Air bushing

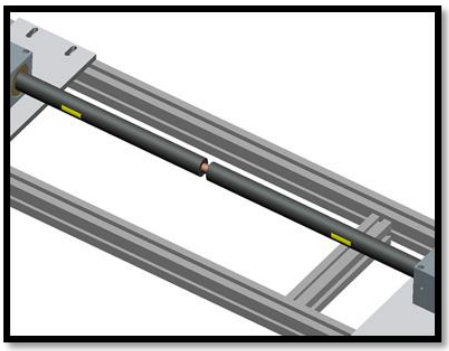


Figure 5 - Strain gauges and copper specimen

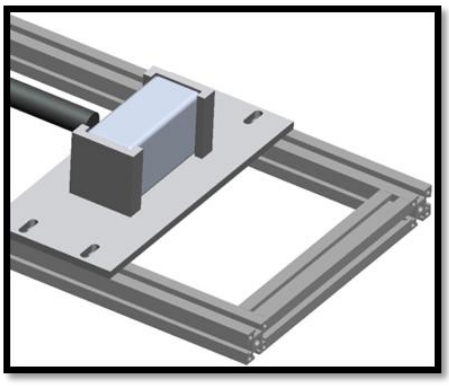


Figure 6 - Momentum trap

Cautions

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Due to the speed at which the solenoid will reach for optimum performance of the system, all persons using the system are to be at least two feet away to ensure no bodily harm.

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All persons are to wear protective eye wear while assembling the system to take caution to the eyes.

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All persons handling the bars are to wear latex style gloves so as not to leave prints and oils on the bars once clean. This will allow for the bars to remain as clean as possible for insertion into the bushings.

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Take caution when soldering so as not to be burned by the soldering iron.

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Use caution when mounting strain gages with adhesive so as to not become attached to the bars

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All persons wiring the switch box are to take extreme caution so as not to be electrocuted.

Parts List

Quantity	Part Number	Part Description	Vendor
4	S301901	Air Bushings 0.75in	New Way Air Bearings
4	S8019P02	Bushing Block 0.75in ID	New Way Air Bearings
3	CEA-06-240UZ-120	Strain Gauges (Pack of 10)	Vishay Precision Group – Micro -Measurements
1	7723K12	Solenoid	McMaster - Carr
2	47065T114	T-slot Framing 1 1/2 inch (96 inch length)	McMaster - Carr
2	6061K64	Incident & Transmission Bar: 1566 Steel Bar 0.75 inch (36inch length)	McMaster - Carr
1	47065T119	T-slot Framing 1 1/2 inch (4 foot length for 6 inch braces)	McMaster - Carr
2	6061K14	Striker Bar: 1566 Steel Bar 0.75 inch (6inch length)	McMaster - Carr
16	47065T224	Right Angle Fastener	McMaster - Carr
16	47065T97	Fasteners (Packs of 4)	McMaster - Carr
1	8975K28	0.25”x3”x72” Aluminum Sheet	McMaster - Carr
1	9062K331	0.75” Diameter x 12” Long High Tolerance Aluminum Bar	McMaster - Carr
1	1630T322	12” Aluminum U-Channel	McMaster - Carr
1	6061K14	0.75” diameter x 6” Long High Tolerance Steel Bar	McMaster - Carr

1	5233K52	25’ of 1/4” OD clear vinyl PVC tubing	McMaster - Carr
24	92290A242	Socket head cap screw, M5-20mm, SS	McMaster - Carr
4	5454K65	Barbed adapter, 1/8” ID tube x 1/8” male NPT	McMaster - Carr
1	10-572-D	Two stage regulator	Fisherbrand
1	SM39018	Laser boresight for 357 mag/.38 special	Sightmark
1	446T240N	4”x4” block of wood	Lowe’s (or local lumber seller)
1	PVC 04007 0600	Schedule 40 ¾” PVC pipe	Lowe’s (or local PVC pipe seller)
3	50915K153	Compression tube fitting,female, brass tee, 1/4” OD tube	McMaster - Carr
1	N/A	Argon tank with pure, clean argon (can use clean air as well)	Supplied by the Applied Superconductivity Center
1	1301-7W-SP-L	Light switch, 15A, 120V	Lowe’s (or local electrical hardware seller)
1	8420	Low voltage light switch box	Lowe’s (or local electrical hardware seller)
2	SR754W	393/309 1.55V high drain silver oxide batteries	Energizer
1		Roll of small diameter copper wire for strain gage leads	Micro - Measurements
1		Roll of small diameter solder	Micro - Measurements
1		M Bond 200 adhesive kit	Micro - Measurements
1	MCA-2	M-prep conditioner	Micro - Measurements
1	MN5A-2	M-prep neutralizer	Micro - Measurements
1	FAR-1	M-flux AR kit	Micro - Measurements
1	CSP-1	Box of cotton swabs	Micro - Measurements
1	GC-6	Bottle of isopropyl alcohol	Micro - Measurements
1		Box of chem wipes	Micro - Measurements
1	STP-1	Spatula, double blade	Micro - Measurements
1	SCP-3	400 grit sand paper	Micro - Measurements
1	PCT-2M	Gage installation tape	Micro - Measurements
1	TL-3	BNC to minigrabber test lead set	Elenco Electronics

Tools List

The following tools were used in the construction process for the split-Hopkinson pressure bar system.

- 3/16” allen wrench
- 5mm allen wrench
- Wire cutters
- Volt meter
- Soldering iron
- Electrical tape
- Latex gloves
- Protective eyewear

DAQ System Circuit Diagram

The following diagram is used for the quarter Wheatstone bridges created for the system.

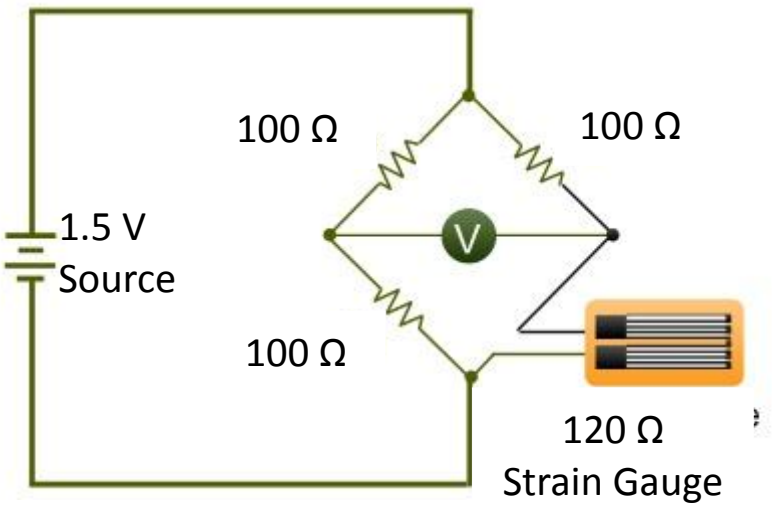

Figure 7 – Wheatstone bridge

LabView

The following Front Panel and Block Diagram were constructed in order to record test data from the system using National Instruments LabView software.

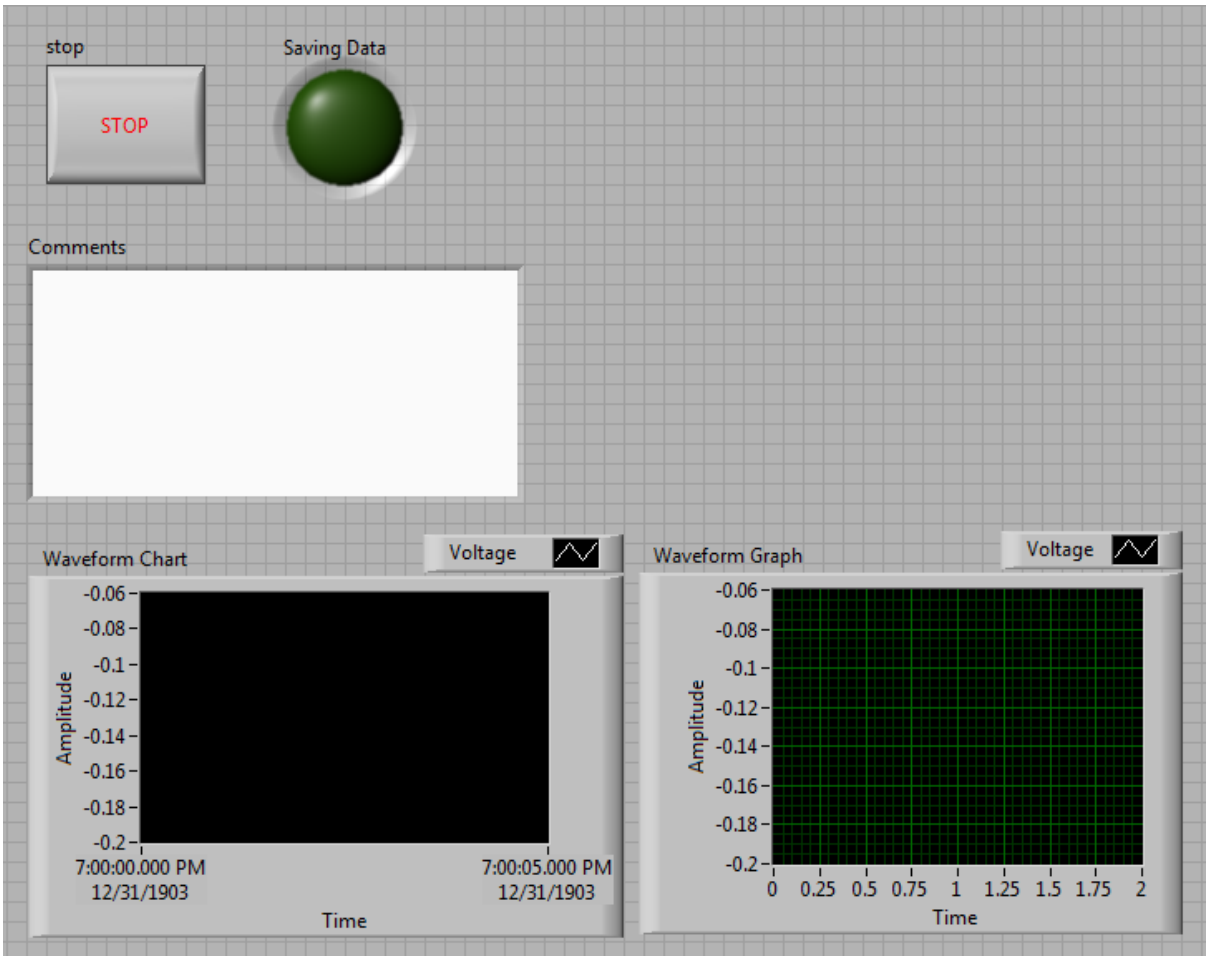

Figure 8 - LabView front panel

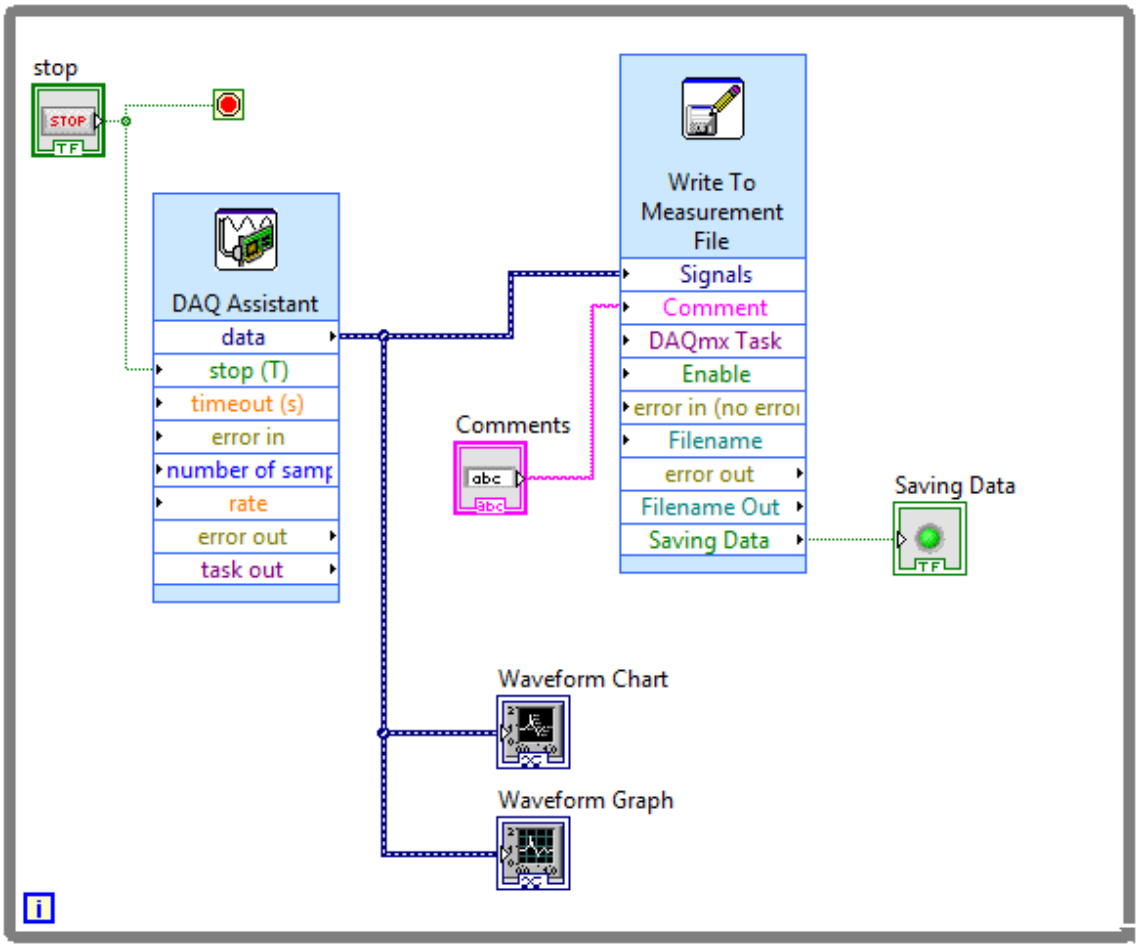

Figure 9 - LabView block diagram

Assembly Instructions

The following set of instructions is for the assembly of this small scale SHPB system, which is a representation of the system in place at Eglin AFRL.

1. Lay out the T-slotted framing so that the long pieces are parallel to one another and the short pieces are equally spaced in between and perpendicular to the long pieces.
2. Using the angle brackets and bolts, secure the T-slotted framing so that it makes a sturdy base that lays flat against a flat surface.
3. Loosely mount the solenoid and striker bar mechanism base plates at one end of the frame so that the solenoid base plate is the one closest to the end.
4. Mount the striker bar mechanism U channel to the striker bar mechanism base plate.

5. At the opposite end, mount the momentum trap base plate as far to the end as allowed.
6. Mount the momentum trap U channel on the momentum trap base plate.
7. Loosely mount the air bushing base plates 12 inches from each other starting at the momentum trap end.
8. Mount the air bushing blocks to the air bushing base plates.
9. Insert the air bushings into the air bushing blocks so that the end faces are flush.
10. Starting at the momentum trap end, place the alignment target in the air bushing closest to the momentum trap and the alignment laser in the next air bushing in line.
11. Align the air bushings so that there is as close to perfect a laser line going from the laser through the alignment target.
12. Repeat step 10 until all air bushings have been aligned.
13. Once aligned, tighten down all air bushing base plates so that the alignment remains intact.
14. Following the instructions of the M Bond 200 kit, clean and sand the incident and transmitted bars and mount two strain gages on each as shown in the previous pictures.
15. Once the strain gages are mounted, solder leads on each strain gage.
16. Upon completion of mounting the strain gages, insert one bar into the two air bushings closest to the momentum trap (transmitter bar) and the other bar into the remaining two air bushings (incident bar).
17. Insert the striker bar mechanism PVC pipe into the U channel provided.
18. Insert the striker bar into the PVC pipe.
19. Mount the solenoid to the solenoid base plate.
20. Add shims between the hole in the striker bar mechanism U channel and the PVC pipe inserted in it until the striker bar and incident bar are axially aligned.
21. Check to make sure that the incident and transmitter bars are as close to perfectly axially aligned as possible by mating the ends to see the offset. If there is offset, realign the air bushings.
22. Once all of the bars are aligned, insert the block of wood into the momentum trap U channel.

23. Insert the tube fittings into the air bushing blocks.
24. Create a manifold using the tubing and T fittings that connects a line to each of the fittings inserted into the air bushing blocks.
25. If using argon gas as this system used, attach a pressure regulator for argon gas up to 6500 psi to the outlet on the argon gas tank.
26. Attach the tubing from the manifold to the pressure regulator on the argon gas tank.
27. Set up a Wheatstone bridge as indicated by the electrical diagram and connect the leads from the strain gages on the incident and transmitter bars to complete the circuit.
28. Create or use the attached LabView program and connect the Wheatstone bridge circuit to the DAQ system.
29. The system is now ready for testing.

Operating Procedures and Maintenance

Operating Procedures

The following section outlines the process for operating the split Hopkinson pressure bar experiment. With all steps and with each use it is mandatory that a high awareness of safety be observed.

1. Safety check
2. Hardware connection
3. Functional check
4. Specimen placement
5. Gas application
6. Safety check
7. Initiate countdown
8. Begin data acquisition (begin experiment)
9. Apply solenoid voltage
10. End recording
11. Shutdown experiment

Detailed Process Documentation

The following section outlines the details of the recommended usage methods for the split Hopkinson pressure bar experiment. With all steps and with each use it is mandatory that a high awareness of safety be observed.

1. Safety check

To begin the experimental setup, check all dangerous areas to ensure safety. Check the following areas and eliminate any potential hazard. This is a recommended list and is not designed to be a comprehensive method for safety.

- Electrical outlets for complete connection and no potential fire hazards
- Compressed gas system for possible leaks or the potential for sudden pressure discharge
- Electrical connections between outlets and solenoid
- Impact area between striker bar and incident bar must be covered by PVC shield
- Ensure momentum trap is in place

2. Hardware Connection

Connect the system to its support systems:

- Data acquisition
    - Attach one lead to each spade for every strain gauge
    - Set up each strain gauge as a quarter Wheatstone bridge in the LabView program
    - Prepare the LabView program to record the strain gauges at maximum data acquisition rate
- Gas supply
    - Ensure regulator is connected tightly to the tank
    - Ensure connection hose is connected tightly to regulator
- Solenoid
    - Attach the solenoid spades to the female connections from the activation switch
    - Ensure the activation switch is in the “OFF” position

- Plug the activation switch into the wall
- Ensure the striker bar is flush with the outer surface of the solenoid faceplate
- Ensure the plunger is just barely touching the striker bar

3. Functional check
   - Ensure the plunger will be able to make the striker bar reach full velocity
4. Specimen placement
   - Ensure the specimen is placed between the incident and transmitter bars
   - Ensure the connected bars are not flowing towards the striker mechanism, in order to maintain full velocity potential of the striker bar
5. Gas application
   - Turn the Argon tank on
   - Turn the Argon regulator to between 60- 80 psi
   - Ensure there is no leakage anywhere in the system—typically audible
6. Safety check
   - Look through the system and repeat the safety checks in step #1
   - It is the responsibility of the operator to ensure safety of the experiment
7. Initiate countdown
   - Begin a timed sequence with no more than approximately a quarter second between data acquisition and the application of the solenoid voltage
   - Begin data acquisition (begin experiment)
   - Flip solenoid activation switch to the “ON” position
   - Flip solenoid activation switch to the “OFF” position no more than 1 second after activating the solenoid
8. End recording approximately 0.5 seconds after turning activation switch off
9. Shutdown experiment
   - Ensure data quality
   - Save data (may take time, there will be between 1×10^5 and 1×10^7 individual sample points depending on sample rate and test time)
10. Turn off gas
11. Continue on to the data reduction methods

Maintenance

This SHPB system is very low maintenance and only requires the use of clean, pure air or argon gas and extremely clean, precision machined incident and transmitter bars.

Before each use (if within long periods of time), the bars should be disassembled from the system and completely cleaned and sanded before being inserted for use. This would ensure that no air pollutants or oils that could be on the bars from sitting idle, are transferred into the air bushings, causing build up and eventually undesirable data.

The strain gages should also be checked using a multi-meter to ensure their accuracy, according to the manufacturer's specifications. If the strain gages are not reading correctly, new strain gages may need to be implemented on the bars in the place of the old ones to ensure desirable data during testing.