Split-Hopkinson Pressure Bar Apparatus
Team 58

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***Abstract*—The goal of this project is to solve the Split-Hopkinson Apparatus Device issue of the incident bar projecting multiple hits in a system where it is to receive only one hit. There are multiple factors that contribute to causing this issue, which lead to many designs for different parts of the device implicated into the project. For the project, there were five different designs made for multiple parts of the Split-Hopkinson Apparatus Device. The designs include redesigning a high pressure air tank and it's operational features, a gun barrel along with its mount, and an enclosure for safety and sample catching.**

I. Introduction

A Split-Hopkinson Pressure Bar apparatus is a device used to dynamically test material properties for constructing constitutive models and can be used for high strain rate deformation research and experiments. It can be used to help determine material constants such as Young's modulus and mechanical stress in dynamic conditions. The main components include a high pressure air supply (compressor), a pressure chamber/air tank, a bun barrel, a striker bar (projectile), and input/incident bar, the specimen sample, an output/transmission bar, and a stopper. The only parts that should be moving during operation are the striker, which travels down the gun barrel, creating an impact on the specimen. After a sufficient amount of air is collected, the backside portion of the pressure chamber releases some pressure causing a pressure drop which pulls the plug from between the pressure chamber and the gun barrel causing pressurized nitrogen through the gun barrel, forcing the striker into the incident bar creating an elastic wave pulse which goes through the specimen and out the output bar. In order to calculate the forces that will be exerted on the material there are strain gauges installed in precise locations to determine the strain caused by the elastic wave pulse.

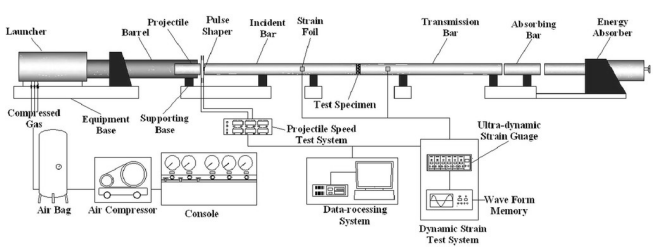

Figure 1. Split-Hopkinson Apparatus Device Schematic. Reprinted from "Assessment of impact mechanical behaviors of rock-like materials heated at 1,000°C," by S Liu, J Xu, X Fang, 2020, High Temperature Materials and Processes, Volume 39 Issue 1. Retrieved from https://www.degruyter.com/view/journals/htmp/39/1/article-p489.xml. Copyright 2020 Walter de Gruyter GmbH.

The Split-Hopkinson apparatus has been continuously worked on for improvements since its original design from 2015. The focus of this project will be on the striker launching module. Once the pressure from the tank is released for the striker's first impact, the pressurized air continues to come out of the tank causing a repeated impacting motion that causes false data points to be collected. The approach is to make the air tank smaller to prevent excessive air within the tank itself. The current gun barrel used in the SHPB apparatus is made with a 4340 high strength seamless tube that has an inner diameter tolerance of ± 0.008 inches. The current air tank was made with a 1022 hot-rolled seamless steel pipe. Figure 2 shows the specific dimensions of the current pressure tank set-up at Northern Illinois University.

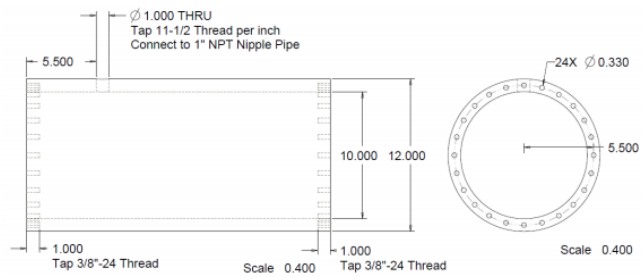

Figure 2. Dimensions of Air Tank. Reprinted from "Stress Analyses on the Gas Pressure Tank for NIU Split Hopkinson" by J. Gau, 2017, p.1.

II. Materials and Methods

Solenoid valves are a binary valve that can either be open or closed. With a solenoid valve system, the current piston tank can be removed and replaced with a simplified pressure tank that has a solenoid valve controlling the airflow to the gun barrel. The current tank with ports on the exterior which can be used to hold attachments. Such as pressure sensors or a pressure release valve and a port on the back which will be used to fill the tank and finally the port on the fron which is where the solenoid valve will be attached, connecting the tank with the gun barrel, and control the release of pressure during operations. Figure 3 is a generic solenoid valve used in the system. Minimum assembly will be required and since the main requirement

for the air tank will be a 300 max operating pressure, most safety testing on the tank will be done by the manufacturers.

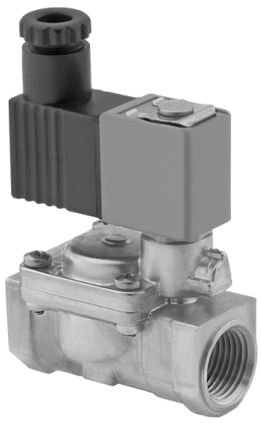

Figure 3. Solenoid Valve. Reprinted from "Brass Body Solenoid On/Off Valve" by McMaster-Carr. Retrieved from https://www.mcmaster.com/4738K158/. Copyright 2017 McMaster-Carr Supply Company.

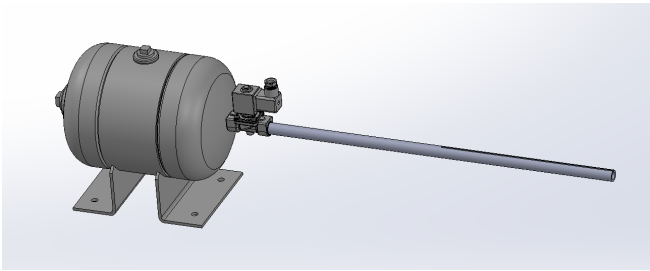

Figure 4. CAD Model of Device. Obtained from "Horizontal ASME-Code Compressed Air Storage Tank" by McMaster-Carr. Retrieved from https://www.mcmaster.com/1481K12/. Copyright 2015 McMaster-Carr Supply Company and "Brass Body Solenoid On/Off Valve" by McMaster-Carr. Retrieved from https://www.mcmaster.com/4738K158/. Copyright 2017 McMaster-Carr Supply Company

III. Results and Discussions

The updates to the Split-Hopkinson apparatus the device will see the data collected in the experiments to have a higher accuracy in the measurements. This is a direct result of fixing the prior problems in the device that were coming from outdated parts that have been updated on the device. Also will have an easier use of the system with the enclosure as the specimen that is being tested will be collected inside of the enclosure which will also reduce any data collection error. With these improvements NIU Engineering students now have the ability to test and acquire the dynamic response of materials at high strain rates.

IV. Conclusion

The Split-Hopkinson Pressure Bar apparatus is a highly sophisticated and advanced material sampling equipment for compressive and tensile testing. The launching module is divided into three main portions; the pressure tank, the pressure release, and the gun barrel. Each portion requires a redesign and replacement. The focus for the pressure tank is to properly mount into position and condense the size as only 300 max psi is required. The pressure release is to control the release of pressure from a safe distance at a high flow rate to reach the 100 m/s required velocity, and the focus for the gun barrel is to prevent corrosion in the bore and to have the correct so that the striker properly fits the inside diameter. The launching module in the Split-Hopkinson apparatus is the most dangerous aspect of the apparatus and is the portion that needs improvements. Currently, false data is taken from secondary strikes on the incident bar directly caused by the launching apparatus. The pressure tank plays a very big role in the system and also could take a big chunk of the budget to replace. Figuring out what is going to be done to the pressure tank needs to be thought out rigorously.

Acknowledgment

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