Further Calibration and Reconfiguration of Single-Stage Gas Gun for Impact Studies

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Is it possible to modify the performance of an existing gas gun to improve the reliability of high velocity impact testing?

Initial Gas Gun Setup

The single-stage gas gun shown in Figure 1 was used to perform impact testing on samples with specifications of:

- Barrel length of 19 feet
- Barrel inner and outer diameters of 0.5 and 1 inches
- Reservoir maximum pressure of 1500 psi
- Maximum projectile velocity of 1000 m/s (thus far)

All the preliminary tests were conducted at a pressure of 500 psi, as other factors were discussed in relation to the projectiles and fracturing of the samples used.

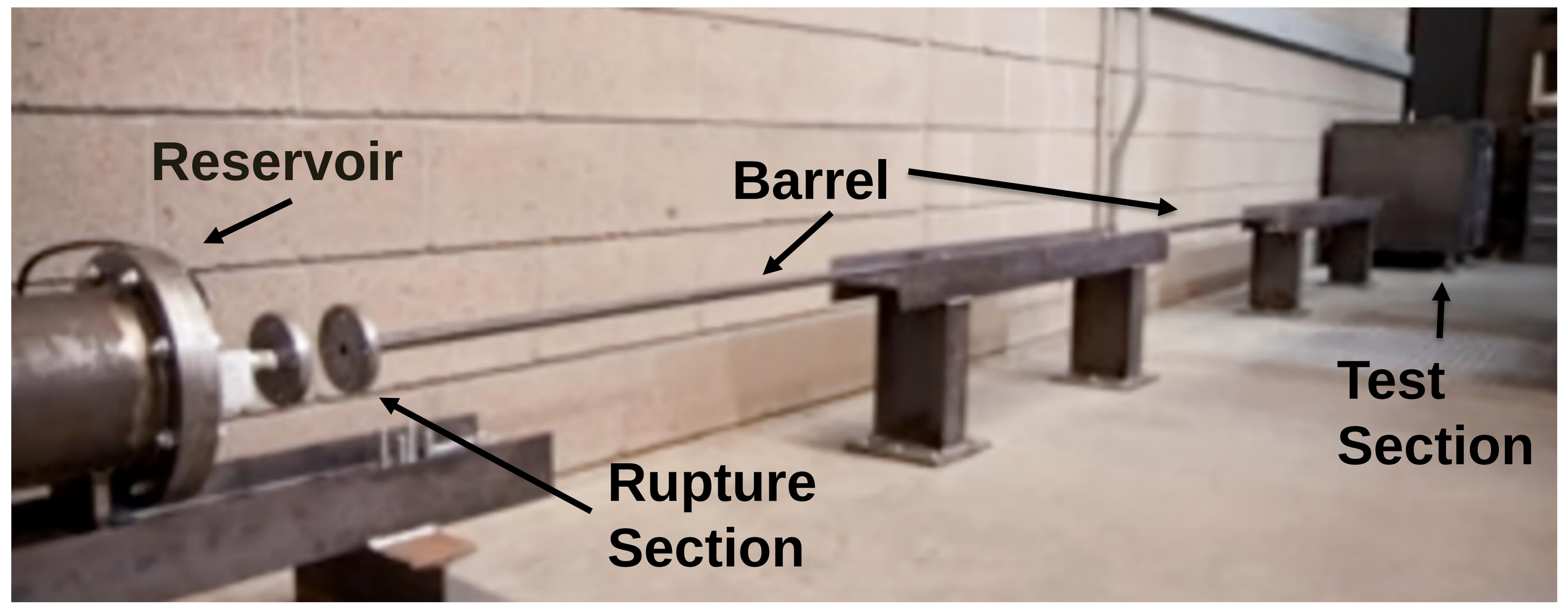


Figure 1. Diagram of the entire single-stage gas gun used at the AIMS Center for impact testing. Major sections of the gun are labeled.

Preliminary Testing and Results

The single-stage gas gun was used to perform impact tests using carbon fiber samples and a projectile from a range of shapes and weights. The amount that the carbon fiber fractured, if at all, depended heavily on the shape and weight of a projectile. The impact velocities and weights of each projectile used were noted and plotted to determine any relations between the projectile properties and velocity.

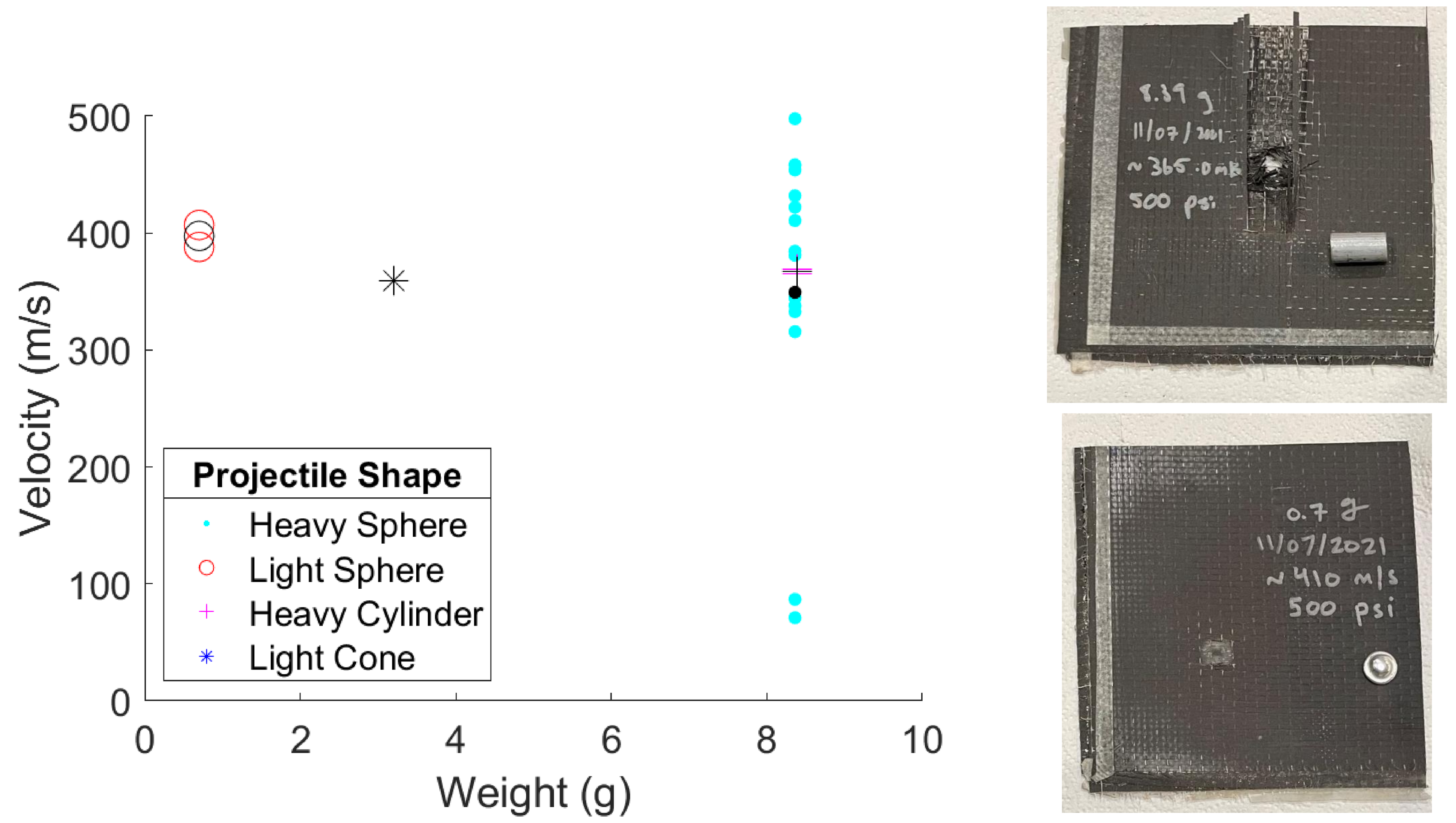


Figure 2. Impact velocity of the projectile against weight for various projectile shapes with mean velocities in black (left). Fractured carbon fiber due to projectile impacts of various shapes and weights (right).

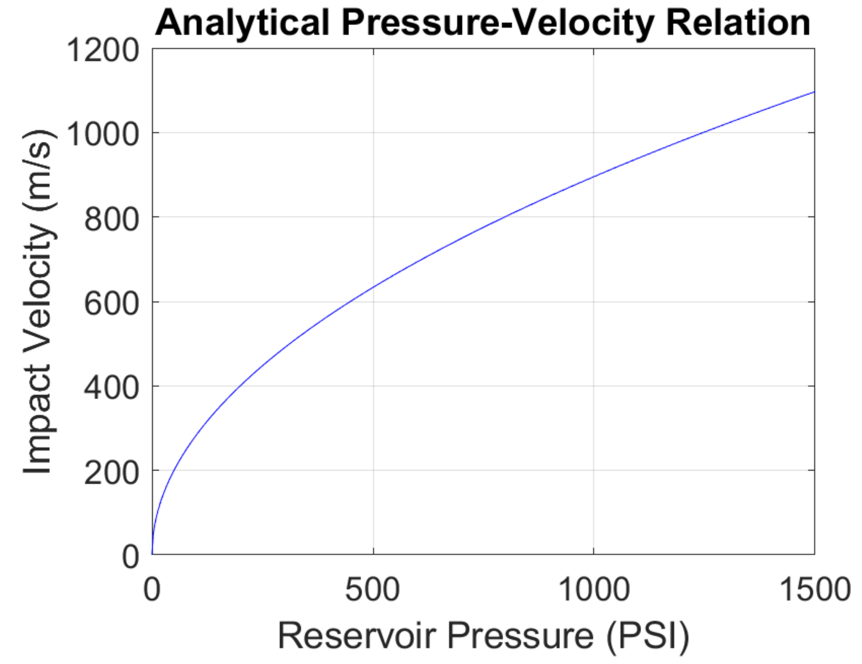
Reconfiguration

Due to a wide range of velocities captured using the initial gas gun setup, the components that made up the gas gun were considered to have been the cause of the inconsistent results, and were replaced with newer, more reliable components. The most noteworthy of these replacements were a stainless-steel barrel, stainless-steel rupture section, and an electromagnetic chronograph used to recording the impact velocity of the projectile. The barrel and flange work to decrease the amount of friction acting on the projectile as the inner surface is well-polished and free of any corrosion. The chronograph uses electromagnets as opposed to the original infrared sensors which provide higher accuracy and precision for a given impact test.

Acknowledgements: Dr. Aditi Chattopadhyay, Khaled Khafagy, and Karthik Rajan Venkatesan: AIMS, SEMTE, ASU

Analytical Predictions

In order to examine the accuracy of the experimental setup, it was necessary to derive analytical equations for modeling the impact velocity as a function of reservoir pressure. The experimental process was modeled as a variety of thermodynamic reactions, such as isobaric, isothermal, and adiabatic. The isobaric and isothermal assumptions proved to be inaccurate due to the pressure and temperature changing throughout the impact test, with the adiabatic reaction being left as the most reliable analytical model.



$$v_{impact} = \sqrt{\frac{2P_iV_i^{\gamma}\left(V_f^{1-\gamma} - V_i^{1-\gamma}\right)}{m(1-\gamma)}}$$

Figure 3. Graph of impact velocity as function of reservoir pressure (left) using the closed form equation (right). Velocity depends on the geometry of the gas gun as well as the initial pressure from the reservoir.

Conclusion

By using an existing gas gun setup, changes were successfully made to specific components in order to facilitate more consistent testing that aligns with the analytical impact velocities calculated from a simplified model. By testing the new configuration, conclusions can be made regarding the setup's effectiveness compared to the initial results and whether subsequent modifications are necessary.