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Capstone Group: ARL-MLS 1
Project: Design of Projectile Impact / Drop Test Rig for Damage Modelling
Project Supervisor: Professor Kamran Behdinan
Client: ARL-MLS Lab

Problem Statement

Ceramics have been identified as a favourable material for the development of high protection, lightweight armour systems due to their low densities and high intrinsic strengths. However, ceramics possess the characteristic of brittleness, which means that they are likely to fracture and crack upon impact. Therefore, to fully explore the potential of ceramic use in armour systems, they must be tested in a controlled environment.

As such, the objective of this capstone project is to design and develop a projectile impact drop test rig for testing ceramics and other advanced lightweight multifunctional materials. A drop test can be defined as a test of the strength of a material by either dropping the material from a set height or dropping a projectile of specified weight and size onto the material [1]. The team aims to develop controlled, high-velocity drop testing methods. Figure 1 below depicts a non-functional drop test rig provided by the ARL-MLS Lab which will be retrofitted for this project.

Figure 1. Current setup of the Drop Test Rig in the ARL-MLS Lab.

The current state of the art for testing ceramic armour systems utilises high-velocity ballistic impact experiments. These experiments involve using a gun to fire a projectile horizontally at a velocity between 40 m/s to 900 m/s into a test sample [2]. The gun is typically a multi-stage compressed air gun or a standard rifle. The sample is mounted at a specified distance away from the gun and high speed cameras are used to capture the instance of the impact. Sensors such as a laser velocity screen or an infrared emitted diode-photovoltaic cell are placed between the projectile and sample to capture velocity and impact data [2]. Figure 2 below shows the standard arrangement of a ballistic impact experiment.

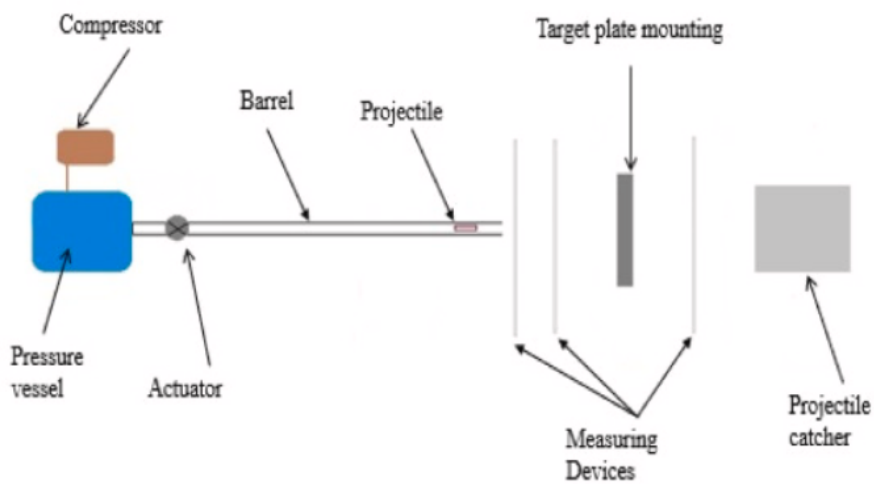

Figure 2. Standard Arrangement of a Ballistic Impact Experiment [2].

When designing the projectile impact drop test rig, the impact velocity, height of drop, weight of projectile, and safety standards need to be considered. With regards to the testing procedure, the type of test sample, method of control, and machine calibration are the influencing factors. As defined by the client, the distance of the drop test must be between 1.8 m to 2.5 m, and the impact velocity must be between 10 m/s to 15 m/s. Based on the client's statement of need, the sample tested needs to be a fixed ceramic sample with a backing layer to simulate lightweight armour systems. Based on similar impact tests done on ceramic samples, metal, composite backing layers, or arranging mosaics made out of ceramic tiles and epoxy resin are all viable options for the team's sample specimens [2]. Fragment-simulating projectile (FSP) has been accepted as a suitable representation on fragmentation for the armour testing community [3]. The most common FSP used to test body armour is the 17 gr FSP which weighs 1.10g [4]. For this experiment, the exact mass and shape will be determined by how the weight is dropped and how the ceramic sample is positioned.

When performing a high-velocity impact drop test, operators are to follow the ISO 45001 standard for safety, which outlines the requirements for an occupational health and safety management system [5]. In addition to the ISO safety standard, ISO 7965-2 outlines the procedure used when impact testing a filled sack made from thermoplastic flexible film, which can be similarly implemented for a ceramic impact test to verify a safe testing procedure [6].

The scope of this capstone project is to design and deliver a high-velocity impact test rig prototype at a level 4 rank on the Technology Readiness Level (TRL) scale. TRL 4 requires complete proof-of-concept work that validates the successful performance of a system that achieves the project requirements and applications [7]. TRL 4 demonstrations can consist of computer-based and/or simulated bench-top testing [7]. The design is to progress to TRL 4 over an eight-month period. As resources for this prototype design, an allocated budget of $500 and existing equipment/machinery, as seen in Figure 1, that can be salvaged or repurposed have been provided.

References

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