Department of Mechanical and Materials Engineering

SENIOR DESIGN PROJECT SYNOPSIS – SPRING 2013

IMPACT LOADING AND RECOVERY OF COPPER
A PROJECT SPONSORED BY AIR FORCE RESEARCH LABORATORY

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The following work focuses on researching and designing five individual packages of projectiles and targets for the Air Force Research Laboratory (AFRL). The Branch Chief of the Damage Mechanisms Branch, of the Ordinance Division in the Munitions Directorate, at Eglin Air Force Base wants to study the formation of incipient spall within a copper specimen. The formation of incipient spall was achieved by shock loading the copper specimens through pressures ranging from 1 to 3GPa using a 60mm powder gun. The impact pressure is controlled by varying the projectile impactor material and thickness, as well as, the diameter and thickness of the copper target plate. These parameters are defined by using the Rankine-Hugoniot relations to calculate the shockwave and release particle speed for each material used. When the release waves, created by the reflection of shockwaves produced at impact over a free surface, meet inside the copper target, they create tension in the material. If the pressure due to tension is greater than the spall strength of the material, then spall ranging from void nucleation to complete spallation is expected to occur.

For each of the five experiments, the gun will be loaded at the breach with the preassembled projectile/impactor combination. The speed of each shot will be controlled by varying the amount of gunpowder used to propel the projectile. After traversing the barrel of the gun, the impactor will travel a length of open space which is less than the length of the projectile it is affixed to. This will help ensure that the impactor makes planar contact with the target assembly and that its flight is not altered in any way. Because the actual target plate will be a separate piece from the momentum trap/target assembly combination, it will be propelled backwards before the edge effects of the target assembly reach its geometry. The target plate will then be soft-recovered in order to evaluate the results of the experiment. It is the first time the High Pressure Particulate Physics Facility at Eglin Air Force Bases utilizes a momentum trap and conducts soft recovery of shock loading experiments.

The first shot was conducted at 350m/s using Poly(methyl methacrylate) (PMMA) for the projectile and copper for the target, with thicknesses of 3.3mm and 7mm respectively. Using the data acquired from the copper target, it was verified that the pressure achieved was 1.17GPa and no spall was

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observed. The second shot was conducted at a higher velocity of 500m/s using the same materials and dimensions for all the assembly components. The numerical results for this second shot could not be collected due to a malfunction in the velocity pins that record the data. The third shot was conducted at 300m/s using aluminum for the projectile and copper for the target, with thicknesses of 6.5mm and 7mm respectively. One dimensional planar spallation split the copper target at 2.3mm from its front face. Impact pressure was recorded at 3.12GPa. The fourth shot involved the same parameters as the failed second shot. In the fourth shot no spallation was observed. Data acquired from local particle velocity in the back of the target for the first and fourth shots presented unexpected peaks pointing to possible microstructure changes.

Extensive analysis of the experimental results will be used to validate the theoretical methods used and improve the predictive capability of finite element continuum codes used in the development of air delivered munitions. The research performed will also be applied to other materials in the future. Two sets of five projectile/target packages have been effectively designed and delivered to the customer's specifications. The results obtained from the shots performed by AFRL are strong evidence of the success of this work.