October 2, 2020

Penetration Resistance of Cast Metal-Ceramic Composite Lattice Structures

Manuel E. Umanzor[1], Romesh C. Batra[2], Christopher B. Williams[3], and Alan P. Druschitz[1]

[1]Department of Materials Science and Engineering, Virginia Polytechnic Institute and State University

[2]Department of Biomedical Engineering and Mechanics, Virginia Polytechnic Institute and State University

[3]Department of Mechanical Engineering, Virginia Polytechnic Institute and State University

Abstract

Cellular solids are structures comprised of networks of interconnected trusses, exhibit high strength to weight ratios, high energy absorption as well as favorable thermal properties. Due to their complex geometry, these lattice structures cannot be manufactured by conventional methods, hence, additive manufacturing (AM) is an obvious choice. AM of metals via fusion process has a significant set of drawbacks, such as limited alloy selection, high residual stresses, and texture, to mention a few. In recent years, a hybrid AM/metalcasting technique was successfully employed to manufacture lattice structures using 3D-printed sand molds. Mechanical properties of the castings manufactured by the hybrid method were found to be similar to those of castings produced with traditional no-bake sand molds. In the present work, the hybrid AM/metalcasting approach is employed, not only to manufacture lattice structures with complex geometrical arrangements, but to include hard ceramic tiles to effectively create a cast metal matrix composite. It is shown that with the proper combination of geometrical parameters, penetration resistance of an otherwise soft material, such as aluminum alloy A356, can be improved. In order to determine the improvement in penetration resistance, testing was performed using armor piercing rounds, particularly the 0.30 caliber M2 design. During the first set of experiments, striking velocities were varied between 817 m/s and 714 m/s, a total of eight 0.30-Cal APM2 shots were fired at the target; two shots were made on the following areas: without tiles, 4 mm tile thickness, 6 mm tile thickness, and 8 mm tile thickness. All testing was conducted at zero-degree obliquity (perpendicular to the striking face). In all cases, a considerable reduction in residual velocity was noted, which varied from nearly 50% to a complete defeat of the projectile. Finite element analysis was used to: first validate a model with the experimental data; the results predictions were within 3.5% of the measured values, and second to predict additional scenarios, e.g. different striking angles as well as impacts on zones other than the centers of the ceramic tiles.

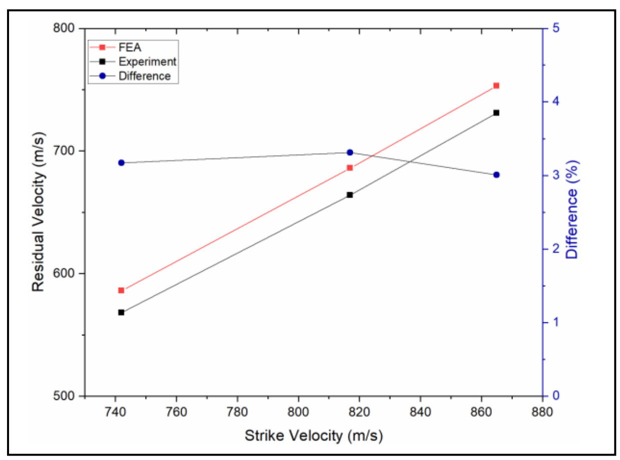

Figure 1. Experimental vs FEA residual velocity comparisons for no ceramic tiles.

Biography

Manuel Umanzor is a PhD candidate in the Materials Science and Engineering Program, he received his BS degree in Mechanical and Industrial Engineering from the National Autonomous University of Honduras in 2004. After graduation, he served the heavy equipment industry for 10 years, during this time he worked on product support, logistics and applications engineering. In 2014, Manuel decided to pursue a MSc degree in Mechanical and Nuclear Engineering, completing his program at Virginia Commonwealth University in 2016. During his journey through graduate school, Manuel has been involved in several research efforts: nuclear materials, powder metallurgy and metal casting. He is advised by Dr Alan Druschitz and is expected to graduate on Spring 2021. Manuel conducts his research at the Kroehling Advanced Materials Foundry, where he uses state-of-the art equipment to produce his complex castings, and he also employs computational tools to model, predict and improve performance of these structures. His most recent work has been presented at numerous metalcasting conferences over the past two years.