Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 173 (2017) 339 – 346

Procedia Engineering

www.elsevier.com/locate/procedia

11th International Symposium on Plasticity and Impact Mechanics, Implast 2016

Computational Modelling of Sub-ordnance Velocity Impact of Conico-cylindrical Projectile with Semi-Infinite Target

Ankur Trigunayak, Devendra K. Dubey*, Anoop Chawla

Mechanical Engineering Department, IIT Delhi, India

Abstract

This work demonstrates a methodology to analyze small time deformations in conico-cylindrical, multi-material projectile containing explosive material during sub-ordnance velocity impact with the semi-infinite target as hard soil. A 3-Dimensional computational model is developed and analysed using explicit analysis in ANSYS AUTODYN Hydrocode for the Lagrangian domain. The problem was studied for two extreme cases by varying the angle of impact between 0^0 -15^0. Deformation and stress propagation patterns are studied in the projectile structure for impact with various targets like sand, concrete, and hard soil. To simulate this millisecond impact phenomenon, Mie-Gruneisen Shock-EOS was selected, strength model for the plastic deformation in ductile materials of the projectile was defined by Johnson –Cook Model and failure criteria defined for failure strain by J-C damage model. To define target as semi-infinite hard soil, compaction model was chosen. Pressure and energy variation with time at different points were observed and analysed for a critical condition for initiation of the explosion. This paper exhibits 3-D impact simulation methodology where deformation in projectile and target both considered for sub-ordnance velocity range impact.

Peer-review under responsibility of the organizing committee of Implast 2016

Keywords: Plastic deformation; Explicit Analysis; Sub-ordnance velocity; Impact Simulation

1. Introduction

Designing a crashworthy structure which can sustain a certain impact condition is a challenge for Automotive, Aerospace, and Defence Industries. In high-velocity impact scenario, the material goes into the plastic stage and are

* Corresponding author. Tel.: (91)-11-2659-1161; fax: (91)-11-2658-2053. *E-mail address:* dkdubey@mech.iitd.ac.in

1877-7058
Peer-review under responsibility of the organizing committee of Implast 2016
doi:10.1016/j.proeng.2016.12.027

subjected to high deformation and strain rates. Hence, to predict the behaviour of a very small time phenomenon, numerical methods (such as explicit Finite Element) are need of the hour.

The phenomenon of projectile impact can be categorized by many schemes like the angle of incidence of the projectile; material characteristics of the projectile as well as target and range of initial velocities. Material characteristics and penetration phenomenon may change with the velocity of impact. Most common applications, by which we can achieve higher velocities, are conventional guns, where muzzle velocity is in velocity range of 500 m/s-1300 m/s, this is called nominal ordnance velocity. Velocities lower than 500 m/s can be categorized as sub-ordnance velocities (25-500m/s) [1]. In the current study, projectile attains a velocity of 300m/s at the terminal end just before impact. Hence, the initial impact velocity of the projectile is in sub-ordnance velocity range (300m/s before it hits target and penetration process starts).

Backman and W. Goldsmith [1] defines target as structurally independent object whose performance is impaired by a projectile and the semi-infinite target is defined when there is no effect of distal boundaries on impact penetration process. So in this case, any object like hard soil, runway made of concrete and sand has been taken as a semi-infinite target.

In the present study, the impact of a conico-cylindrical projectile is studied with hard soil. These projectiles carry high energy materials (explosive) for aerial delivery and normally initiation of explosive is designed to be initiated by an electronic timing mechanism. In the case of unintentional fall, if timing mechanism is not get activated, the impact may happen with any structure, runway, ground and in these situations requirement may be such that this high energy material should not be initiated by the unintentional impact. So the objective of present work is to study this sub-ordnance velocity impact phenomenon and simulate these events to generate data for critical parameters which are responsible for initiation of explosive due to impact. Quantification of critical parameters for initiation through trials is difficult and a highly expensive task. The instrumentation required to measure this dynamic impact phenomenon have certain limitations like operational environment is containing explosive, available event time is very less (in milliseconds) to capture the whole phenomenon, which is why numerical studies are often carried out in parallel with experimental tests in order to complete these analyses.Therefore there is a need to develop a computation model for impact simulation and damage estimation in the projectile for sub ordnance velocities impact with the semi-infinite target as hard soil. Sub-ordnance velocity impact behaviour study is not available in open literature in detail. Moxley et al., [2] have done analytical modelling of the impact of a scaled projectile with the concrete target. To get a complete insight of deformation in 3 D projectile containing high energy materials inside; computational simulation with FE method is necessary.

In high strain-rate and shock & impact loading conditions, large deformation takes place in very small time to both the projectile as well as the target. The constitutive material model is used to define material's behavior completely which consist of strength model and equation of state, strength model represent the deviatoric component of stress and EOS represents a hydrodynamic component of stress. Zukas [3] states that in an impact scenario material is in uniaxial strain state different from regular tensile or compression test where uniaxial stress theory is applicable. As high strain rates were involved and various materials used in this projectile structure, dynamic characteristics of the material and the corresponding material model was identified for close to a practical reproduction of events. Impact simulation was performed for two sets of initial velocity variations 300 m/s and 200 m/s .The problem was studied for two extreme cases by varying the angle of impact between 0° -15° having the above-mentioned two different initial velocities.

2. Methodology

The present work involves large deformation (> 100/s strain rate) in milliseconds; hence methodology needs to be established to simulate 200 -300 m/s (sub-ordnance velocity range) impact. Impact analysis was carried out with computer simulation to avoid the higher cost involved in prototype fabrication and trials. For the prediction of events in this high-velocity impact phenomenon, Finite Element (explicit) method based methodology is used.