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A Study of the effect of aspect ratio on fragmentation of explosively driven cylinders

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Abstract

The work presented in this paper consists of a parametric study of explosively driven fracture and fragmentation of steel cylinders. The effect of cylinder height to wall thickness ratio on the failure mode and fragment shape is studied using a numerical model based on the meshless Smoothed Particle Hydrodynamics (SPH) method. The simulation results are supplemented with experiments with identical charge geometries and materials, to analyse the natural fragmentation behaviour of the different cylinders. Characteristic fragments were softly recovered in a water basin and fragment mass distributions are compared to the simulation results.

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Keywords: explosively driven cylinders; fragmentation; dynamic fracture; smoothed particle hydrodynamics; soft recovery;

1. Introduction

The effect of cylinder aspect ratio on the fragment shape and failure mode has been observed in electromagnetically driven expansion of aluminium rings [1], and has also been reported for Ti-6Al-4V in [2]. For

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Nomenclature

δ	Kernel smoothing length
ε_0	Reference strain rate
$\dot{\bar{\varepsilon}}$	Effective strain rate
$\bar{\varepsilon}_{pl}$	Effective plastic strain
ν	Poisson's ratio
ρ_a	Particle a density
σ	Stress
σ_{eq}	Von Mises stress
σ_Y	Flow stress
d_i	Cylinder inner diameter
d_o	Cylinder outer diameter
e	Internal energy
h	Cylinder height
m_a	Particle a mass
p	Pressure
w	Cylinder wall thickness
x_a	Particle a position
D	Damage
$\dot{D}$	Damage rate
E	Young's modulus
W	Kernel function
T	Temperature
T^*	Homologous temperature

ductile materials and a 1:1 aspect ratio diffuse necking dominates [1], while for larger aspect ratios shear bands occur. For longer cylinders with aspect ratio of the order of 1:10, the fragments tend to be elongated along the cylinder axis. This observation was already made by Mott in 1947 [3]. In this paper the explosively driven fragmentation of EN 34CrNiMo6 study steel cylinders are studied. Similar to the experiments performed by Mock and Holt [4] on cylinders of Armco iron and HF1 steel, the cylinders are filled with explosive to drive the radial expansion and fracture of the cylinders (see Fig 1). In the current study the wall thickness to height ratio of the cylinders is varied in the range 1:1 to 1:10, and the effect of this change in aspect ratio on the fracture and fragmentation is studied. Numerical simulations using the meshless Smoothed Particle Hydrodynamics (SPH) method were performed and these simulation results are supplemented with experiments with identical charge geometries and materials, to analyse the natural fragmentation behaviour of the different charges. Characteristic fragments were softly recovered in a water basin.

2. Experiments

2.1. Steel cylinder dimension and material

The experimental setup consists of placing the hollow steel cylinders over the explosive charge (Fig. 1). The outer diameter d_o and inner diameter d_i of the steel cylinders are the same for all conducted experiments. Keeping the cylinder wall thickness w constant, different cylinder heights h were tested. The cylinder height h was taken as a