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Multiphase CFD Simulation of Solid Propellant Combustion in a Small Gun Chamber

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The interior ballistics simulations in 9 mm small gun chamber were conducted by implementing the process into the mixture multiphase model of Fluent V6.3 platform. The pressure of the combustion chamber, the velocity, and the travel of the projectile were investigated. The performance of the process, namely, the maximum pressure, the muzzle velocity, and the duration of the process was assessed. The calculation method is validated by the comparison of the numerical simulations results in the small gun with practical tests, and with lumped parameter model results. In the current numerical study, both the characteristics and the performance of the interior ballistic process were reasonably predicted compared with the practical tests results. The impact of the weight change on the interior ballistic performances was investigated. It has been found that the maximum pressure and the muzzle velocity increase with the increase of the charge weight.

1. Introduction

Small guns have been used for a long time. Nowadays, they are still the most used in military, sports, and tests. A hand gun can be modeled with two connected cylinders representing, respectively, the combustion chamber and the launching tube (the barrel of the gun). We can assume that the two cylinders have the same diameter because for small gun using riniless ammunition the diameters are almost the same (see Figure 1). The breech contains the primer, a small space filled with black powder. The space defined by the combustion chamber, sealed by the projectile, is filled with solid propellant [1].

The basic interior ballistic process may be considered as a heat engine which, through combustion, converts the chemical energy stored in solid propellant into kinetic energy for the projectile [2]. This process is well described by Farrar and Leeming [3]. The sequence of this process can be briefly described as follows. The firing sequence begins with the ignition of the primer. This injects hot gases and incandescent particles into the propellant bed which cause the ignition of the solid propellant grains. The gases and energy liberated by the combustion of the propellant increase dramatically the pressure and the temperature within the sealed chamber. Since the burning rate of the propellant is roughly proportional to the pressure, the increase in pressure is accompanied by an increase in the rate of combustion at which further gas is produced. Usually slightly before peak pressure, the projectile starts travel down-bore. The movement of the projectile causes the chamber volume to increase and generate refraction waves, which lower the pressure [4]. The projectile continues to accelerate until it reaches the muzzle where the propellant gases expand, the pressure falls, and so the acceleration lessens. The sequence of interior ballistics ends when the projectile leaves the muzzle. The entire sequence takes less than 2 milliseconds for small guns.

Since computational efforts increased dramatically in the last decade, numerical simulations of interior ballistics process have been established as valuable tools in research and development of high-performance guns. Besides their simplicity, low cost, and safety, they provide data that cannot be directly measured by experiment.

The main purpose of computer modeling of the interior ballistics process is to predict the muzzle velocity of the projectile, the maximum pressure in the chamber, and

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