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# Ballistic behaviour of gun powder and flash powder for firework chemicals as a function of particle sizes

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ABSTRACT

In this paper, analysis of ballistic behaviour of gun powder and flash powder of firework chemicals with different particle size have been carried out in a closed vessel to find out the maximum pressure when ignited. The experiment was carried out by changing the variables like sample composition, particle size, vessel volume. Works were carried out to synthesis of nanoflash powders and the particle sizes are 139.7 nm for $KNO_3$, 94.5 nm for Al and 92.36 nm for S. The nanoflash powders are mixed with micron powders in different ratios and crackers are manufactured. The maximum pressure during the combustion of different samples and explosivity of the crackers are analysed. Results show that peak pressure is increased by 21.6% and explosive impulse is increased by 60% when burning of 100% nfp compared to 10% nfp cracker.



## 1. Introduction

In fireworks industries, gun powder and flash powder are used to manufacture the rockets and fire crackers. The performance of the fire crackers is decided by the noise level it produces when bursting. As per Govt. of India notification, crackers noise level should not exceed 125 dB (AI) or 145 dB(C)pk at 4 m distance from the point of bursting. This has been framed in order to standardise the amount of chemicals in authorised cake bomb manufacturing (Petroleum and Safety Organization, Government of India, 2008 circular). An explosion in firecracker is defined as a compound or mixture which, upon the application of heat or shock, decomposes or rearranges with extreme rapidity, yielding much gas and heat. The noise emitted depends on the power of explosion or explosivity of the crackers when they are bursting. Explosivity depends not only on the composition of chemical mixtures inside the crackers, but also on factors such as particle size, shape, choice of fuel and oxidizers, fuel to oxidizer ratio, degree of mixing, moisture content, physical form, packing density, presence of additives, local pressure, degree of confinement, degree of consolidation, crystal effects and purity of the chemicals.

Gun powder is a mixture of charcoal, sulphur and potassium nitrate with definite ratios. These chemicals react together to form nitrogen and carbon dioxide gases and potassium sulphide during the combustion [1]. The expanding gases, nitrogen and carbon dioxide with high thrust force will provide the propelling action. This is called as the ballistic behaviour. In space applications, this behaviour is mainly utilised to lift the space rockets. In fireworks industries, aerial display fireworks and rockets are lifted to elevate high by the burning of gun powder. This ballistic behaviour will be varied according to the ratio of the constituents, particle size & morphology, degree of mixing and packing density of gun powder. Flash powder is the mixture of aluminium, sulphur and potassium nitrate, which is the main raw material for manufacturing fire crackers [2]. The maximum pressure is developed during the confined burning which decides the explosivity of the crackers. The explosivity and ballistic pressure of the

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**Table 1**
Various compositions of gun powder.

| Composition | Coal (%) | Sulphur (%) | Potassium nitrate (%) |
|---|---|---|---|
| GP1 | 15 | 20 | 65 |
| GP2 | 25 | 15 | 60 |
| GP3 | 10 | 15 | 75 |

explosives can be recognised by finding the maximum pressure developed during burning in an air tight pressure vessel. The main variable to control noise level is the particle size of the chemicals. With nanosized aluminium (nAl) particles, the specific surface area increases creating easier ignition and increased burn rates. This will lead to burst the cracker with lesser amount of chemicals with high reactivity. This will also lead to reduce the emission of pollutants during the celebrations.

The explosion pressure inside the shell can travel in any direction and pressure from at least two places shall be found. Explosion waves either tend to move to top or side of the confined vessel. So, location of pressure sensor in the pressure vessel is one of the main variables to decide the maximum pressure. So, in this study, the authors have attempted to measure the peak pressure from two places and compared the performance. The accuracy of the results also depends upon the volume of the vessel. Hence experiments are carried out with two vessels with different volumes of inner chamber. The quantity of chemical is selected for all experiment is 2 g. This was based on the trial and error analysis to focus on the safety during testing in a confined vessel.

Jang et al. conducted the ballistic properties for solid propellants at various positions in the sample chamber [3]. DeLuca et al. studied the ballistic properties for composite solid rocket propellants along with flame structure study [4]. Püskülcü and Ulas predicted the combustion performance of solid rocket motors and obtained thrust profiles for various grain sizes. Also, finite element stress analyzes were conducted before the production [5]. Barboza Rodrigues et al. conducted the experiment that propellants were burnt in a closed vessel and the time history of pressures are measured by piezo electric transducers and recorded in digital way. Using this data, lifetime of the gun propellants were predicted by creating a modelling [6]. Stilly assessed the energy released by detonating explosives by Trauzl lead block and the ballistic mortar tests [7]. Kadiresh et al. conducted the experiments on aluminised AP/HTPB propellant ballistic performances at different periods. He found that burn rate do affect with pressure but ageing does not have much effect on burn rate [8]. Jones conducted the experiment on ballistic behaviour of fireworks mortars. He found the effect of parameters as mass of the lift charge, mass of the shell and mortar length have been explored and compared with experimental results [9]. Razus et al. [10–14] had conducted few experimental studies on pressure evolution during closed vessel explosions of several gaseous fuel–air mixtures, at various initial pressures within 0.3–1.2 bar and ambient initial temperature. The explosion pressure measured in a spherical vessel and in three cylindrical vessels with different diameter/height ratios. Li et al. investigated the explosion characteristics of nano-aluminium powders in closed spherical explosion vessel. Maximum explosion pressure was measured under various conditions of dust concentrations, particle sizes [15]. Azhagurajan et al. [16] studied the dust explosion study in a close vessel for fireworks flash powder of various sizes ranging from micron and nano.

Hargather et al. have conducted laboratory scale experiments to measure the deformation of thin plates in response to varying explosive impulse power using PETN and TATP explosive charges [17]. Veldman et al. have studied the deformation of square aluminium plates due to blast experimentally and numerically. Elastic plate deflection was measured using strain gauge. In this experiment, four different explosive load cases are used to identify the plate deflection [18]. Brill et al. carried out a work that described the development, calibration and validation of a passive copper diaphragm gauge aimed at measuring the impulse acting on it, resulting from an explosion in air [19]. Wu and Jayaraman et al. showed that aluminium powder could be added to explosives, propellants and pyrotechnic compositions to improve their performance; nanoaluminium powders have increasingly gained attention because of their potential incorporation in explosive and propellant mixtures [20,21].

The main objective of this work is to analyse the ballistic behaviour and explosivity of gun and flash powder of various compositions with different particle sizes in specific micron and nanometer level. This is used to determine the optimum composition of powder mixture, which provides maximum thrust pressure among the samples.

But, so far no study has been conducted for the explosion pressure measurement for the fireworks chemicals and explosivity of the fireworks crackers. In the present study, particle size and compositions of the gun powder and flash powder are taken as variable factors. It is necessary to know the explosion performance of the flash powders in terms of peak pressure developed during the combustion in a closed vessel. At present, in fireworks manufacturing, the particle size used is around 75 μm.

## 2. Materials and methods

The chemicals of charcoal, aluminium, sulphur and potassium nitrate were procured from open market at Sivakasi, Tamilnadu, India. Then all the chemicals sieved in the 80 mesh to remove the impurities, lumped particles. Then they were sieved according to the sample requirements in the required sieves of 60, 100, 200, 350, 400 meshes to get various particle sizes. Here, the powder which can pass through 60 mesh is denoted as −60.

**Table 2**
Various compositions of flash powder.

| Composition | Aluminium (%) | Potassium nitrate (%) | Sulphur (%) |
|---|---|---|---|
| FP1 | 23 | 57 | 20 |
| FP2 | 20 | 65 | 15 |
| FP3 | 10 | 68 | 22 |
| FP4 | 18 | 66 | 16 |
| FP5 | 14 | 64 | 22 |