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SHORT COMMUNICATION

Detonator using Nickel Hydrazine Nitrate as Primary Explosive

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ABSTRACT

Nickel hydrazine nitrate is an energetic coordination compound having explosive properties in between that of primary and secondary. This compound was used to develop a new type of detonator by replacing the sensitive primary explosive, lead azide in conventional detonators and keeping RDX (cyclotrimethylenetrinitramine) as the output secondary explosive. The detonator consists of three regions, viz., initiation, deflagration-to-detonation transition (DDT), and output. The initiation and the electrical rating of 1A/1W no-fire were achieved using a suitable squib. The DDT and the output were taken care of, by pressing requisite quantities of Nickel hydrazine nitrate and RDX, respectively at required densities in a stainless steel stem channel. The detonator assembly involves crimping the squib and the stem channel in a stainless steel housing and applying a suitable resin at the crimped-end for leak tightness. The output was assessed from the dent depth on aluminium plate, volume expansion on lead block, and by achieving veloctiy of detonation of 8200 m/s in mild detonating cords, containing 0.95 g/m of RDX, which indicates full-order detonation. The detonators were tested at system level and found to perform satisfactorily.

Keywords: Detonator, Nickel hydrazine nitrate, primary explosive, deflagration-to-detonation transition, squib

1. INTRODUCTION

Detonators play a vital role in initiating the high explosive systems in rocketry, thereby accomplishing various mission-critical pyro events such as solid motor propellant ignition, stage separation, stage destruction, heat-shield separation, etc. A detonator usually consists of a hot wire sensitive squib composition of required electrical rating, followed by a primary explosive and a secondary detonating explosive in close contact. Primary explosive in detonators gets initiated by the flame from the squib and generates a shock wave required for initiating the adjacent high explosive, like RDX.

Lead azide, which is the presently used primary explosive, enjoys the monopoly in the usage in commercial, military, and space applications. Though lead azide is very important for detonators, the manufacture, handling, and shell-filling operations during processing of the detonators are risky due to its high sensitivity to friction, which calls for extreme care, which in turn makes the operations and plants expensive. Hence, dispensing with the the present communication reports the development of a detonator using a safe, explosive coordination compound, nickel hydrazine nitrate (NHN) as the primary explosive. The relatively high decomposition temperature of NHN coupled with its less sensitivity to friction, impact and electro-static discharge, etc.

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make the processing and handling of the detonators safer. Although synthesis[1, 2] and application[3] of NHN as primary explosive have been reported in literature, no data are available on the design and performance at stand-alone or at system levels.

2. EXPERIMENTAL PROCEDURE

2.1 Materials

All the chemicals used were of analytical reagent (AR) grade. Nickel hydrazine nitrate used was prepared in our laboratory using commercially available nickel nitrate hexahydrate (NICE Chemicals, Cochin, 98 % purity) and hydrazine hydrate (VSSC, Thiruvananthapuram, 95 % purity). RDX (HE factory, Bhandara) was dried and sieved before use. Amorphous boron (Riedel, 95 % purity) was used for making squib charge. The materials for headers, sleeves, squib housings, detonator housings, stem channels, lead blocks, and aluminium plates were procured as per the existing documents and fabricated. The elastomer extruded cord (EEC), simulated explosive transfer assembly, and boosters were used as procured from Explosives Technology Division of the Space Ordnance Group (SOG) of VSSC. The fixtures required for processing and testing the squibs and detonators were fabricated using SOG facility.

2.2 Methods

Nickel hydrazine nitrate was prepared in 95 per cent yield, as per the published literature[3] at constant temperature and rpm using SCHOTT heating and stirring unit. Nickel hydrazine nitrate was characterised by chemical analysis[4,5] and FTIR. For FTIR analysis, sample was prepared as KBr pellets and recorded using Perkin Elmer model spectrum GXA FTIR instrument. Density was measured by specific gravity method using absolute alcohol. Moisture was analysed by actual weight loss on drying at 333 K using OHAUS MB45 moisture analyser. Average particle size was found using Fischer Scientific subsieve sizer.

The ignition temperature and weight loss studies were conducted using differential scanning calorimeter (model-DSC7) and thermogravimetric analyser (model-TGA7) of Perkin Elmer at 10 K/min. Platinum cups with 1-2 mg sample were used as sample holders. Friction sensitivity was found by Julius Peters equipment employing porcelain pins and plates. Heat of combustion and heat of explosion were determined by firing 1 g sample in bomb calorimeter (PARR1261) in oxygen and argon atmosphere, respectively and heat of formation was computed from the heat of combustion value. P-t evaluation was done by firing 100 mg of NHN in a cartridge into a closed vessel of 48 cm^3 using a nichrome resistance wire. Flame temperature, gas volume, per cent condensable, average molecular weight of the reaction products, and oxygen-fuel ratio were computed theoretically.

A qualified boron-based squib charge was used in processing the squibs. These were assembled in detonators and subjected to electrical characteristics at no-fire current (1A for 5 min), all-fire current (3A), and recommended-fire current (5A) monitoring the bridge wire fusing and shell-break time using a computer-based data acquisition system.

The deflagration-to-detonation transition and output of the NHN detonators were assessed using per cent output[6] method obtained by lead block expansion and plate dent tests[7]. Explonet-FO-multichannel VOD meter of Kontinitro AG was used for measuring velocity of detonation (VOD) of RDX in elastomer extruded cord.The initiating ability of the NHN detonators was evaluated at system level by the completion of the assigned task using simulated ETA/detonating cartridge and as stand-alone detonator.

3. RESULTS & DISCUSSIONS

3.1 Chemical Structure & Characteristics

The chemical structure of NHN was confirmed via quantitative estimation of nitrogen, nickel, hydrazine, nitrate contents and through infrared spectra. The general and structural characteristics are summarised in Table1. The qualification of NHN powder for detonator application was decided based on the conventional explosive properties presented in Table 2 along with those of lead azide. From the DSC run, Nickel hydrazine nitrate it is observed that NHN undergoes rapid single-stagexothermic

Table 1. General and structural properties of Nickle hydrazine nitrate

Molecular formula	:	$Ni\,H_{12}\,N_8\,O_6$
Formula weight	:	278.69
Colour	:	Purple violet
Crystal density (g/cm^3)	:	2.1
Average particle size (μm)	:	13
Nickel content (%)	:	21.16 (21.06) [a]
Hydrazine content (%)	:	34.46 (34.45) [a]
Nitrate content (%)	:	44.47 (44.49) [a]
Nitrogen content in coordination sphere (%)	:	30.25 (30.14) [a]
FTIR peaks, (cm^{-1})	:	3238, 1630 (NH_2); 1356, 1321 ($-NO_3$)
Moisture content (at 333 K for 10 min) (%)	:	0.34
Average mol wt of combustion products	:	27.35
Percent condensable Ni (l)	:	18
Oxygen-fuel ratio	:	0.8571

[a] Values in brackets are theoretical

decomposition with onset and peak temperatures at 505.7 K and 506.5 K, respectively. The sudden weight loss (about 95 %) followed by appearance of flash at the above temperature values was observed in TG. Friction and impact sensitivities are relatively low compared to lead azide, which favours press loading of NHN in stem channels while processing the detonators. From the thermal, safety, and explosive data, it is clear that NHN is heat-sensitive and undergoes detonation in open condition, yielding large volume of high pressure gas. The explosivity of NHN lies between those of primary and secondary explosives besides having good thermal stability and improved safety compared to lead azide. All these characteristics qualify NHN for use as primary explosive in detonators.

3.2 Detonator Studies

A schematic illustration of NHN detonator is given in Fig.1. The NHN detonator has three parts, viz., a squib, a steel stem channel of uniform bore, and a steel housing closed at one end. The squib is of 1A/1W electrical rating into which a qualified boron-based squib charge was press loaded under sufficient pressure. The steel stem channel, which contains NHN and RDX, was inserted in the housing with RDX facing the closed end, followed by squib insertion and crimping. A suitable resin was applied to yield leak tightness. Deflagration-to-detonation transition occurs in the NHN column and thereby generating shock wave required for the initiation of RDX at the output region. Loading conditions for NHN are selected in such a way as to get required density to permit gas flow through the column, and consequently to provide reliable transition from deflagration-to-detonation, as inferred from dent depth values. RDX was loaded at a higher density to get increased detonation output.

The required quantity of squibs was processed first and batch qualified for electrical characteristics of 1A (NFC), 3A (AFC) and 5A (RFC). Thirty numbers each of NHN detonators were tested after assembling the squibs, for NFC and AFC ratings by Bruceton statistical method[3]. It was observed that there is no variation in the ratings.

The DDT of NHN in the transition region of the detonator was assessed on the basis of per cent output values obtained in lead block and aluminium witness plate tests, which in turn are related to the percentage of detonation of RDX. The output values such as lead block expansion volume of 1.1 cm^3 and plate dent depth of 2.6 mm on aluminium witness plate, observed in the case of detonators, containing lead azide as primary explosive, were taken as base values for indication of complete detonation of RDX. To achieve complete detonation, various studies related to minimum priming charge quantity, charge diameter and charge density of NHN, which affect the DDT, were carried out. Three tests have been performed for each variation. The quantity, diameter, density, and confinement of the output charge (RDX) were the same as the presently used lead azide-based detonators. On the basis of the output results, the set of parameters, which gave matching results with currently used detonator, was finalised and treated as the correct

Table 2. Comparative properties of nickel hydrazine nitrate and lead azide

Property	Nickel hydrazine nitrate [a]	Lead azide [b]
Density (g/cm^3)	2.12	4.38
Oxygen balance (%)	– 5.74 [c]	– 5.50
Heat of combustion (kJ/kg)	5225	2635
Heat of formation (kJ/mol)	– 449	469
Heat of explosion (kJ/kg)	4390	1610
Pressure output in closed vessel (100 mg in 48 cm^3) (kg/cm^2)	17.5	8.2 [c]
Onset of decomposition (K)	505.7	463
Peak of decomposition (K)	506.5	618
Friction sensitivity (kg f)	1.6	0.02
Impact sensitivity (cm, 400 g wt, 20 mg sample, 50 % explosion)	21 [b]	10.5
ESD sensitivity (J)	0.02 [b]	0.003
Vol. of detonation gases (ml/g)	884 [c]	308
Detonation temperature (K)	2342 [c]	5600
Detonation pressure (GPa)	20.8 [c] (1.7 g/cm^3)	16.1 (3.0 g/cm^3)
Detonation velocity (m/s)	7000 [b] (1.7 g/cm^3)	4630 (3.0 g/cm^3)

[a] Experimental value, [b] literature value, and [c] theoretical value

configuration where NHN is undergoing reliable DDT, resulting in the complete detonation of RDX. From these studies, it is indicated that NHN powder is having the initiating strength to bring about reliable detonation of RDX in detonators with output comparable to lead azide-based detonators.

Five systems were tested to assess the ability of NHN detonator to initiate a detonation in the adjacent explosive train to achieve the assigned task. The systems tested include: (i) detonator with simulated ETA and output as denting of expected depth on the witness plate, (ii) detonator with simulated

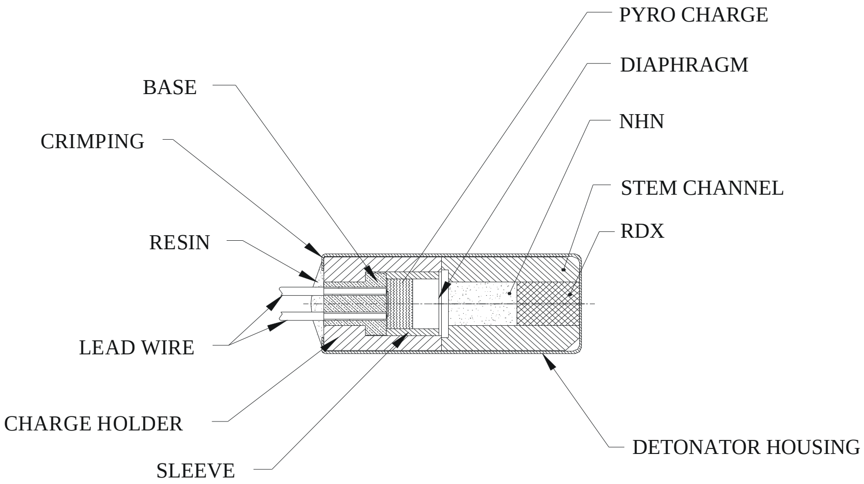

Figure 1. Schematic illustration of nickel hydrazine nitrate detonator

ETA and output as flame generated by TBI, (iii) in a detonating cartridge with booster (RDX) and output as becoming an elliptical SS tube containing RDX to circular after initiation, (iv) in a detonating cartridge and output as rupturing the diaphragm of the fire extinguishing bottle, and (v) as a stand-alone detonator with booster (RDX) and output as propagating the detonation wave of VOD 8200 m/s throughout the length of the elastomer extruded cord containing RDX measured at five probes using VOD meter. The output in all the above cases were found similar to that observed with the present detonator. Hence, it is concluded from the above output results that NHN detonators are capable of initiating complete detonation in a high explosive system.

Further studies related to functional reliability after subjecting to various flight environment and studies related to interface gaps and misalignment of ordnance elements in the explosive train of safe arm, are in progress.

4. CONCLUSIONS

Nickel hydrazine nitrate is an energetic coordination compound, which can be prepared easily in required quantity and in high yields in short time with cheaply available raw chemicals. Because of its low sensitivity to mechanical stimuli, the processing of detonators is quite safe. The detonators are of 1A/1W ratings with simple design and construction. The size and performance of the NHN detonators are matching with the presently used lead azide-based detonator. From the output data, it is clear that NHN can be used in place of lead azide, without compromising on performance.

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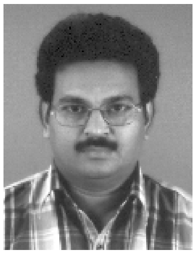

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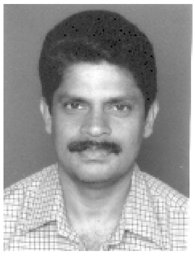

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