Abstracts of the 28th Seminar on

New Trends in Research of Energetic Materials

Pardubice, April 22–24, 2026

University of Pardubice, Faculty of Chemical Technology
Institute of Energetic Materials

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Held at the University of Pardubice

Pardubice, Czech Republic
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Intended as a meeting of students, postgraduate students, university teachers, and young research and development workers, concerned from the whole world.

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Preface

The International Seminar New Trends in Research of Energetic Materials (NTREM) has traditionally been an international meeting of students and early-career researchers involved in the research, development, technology, or industrial application of energetic materials.

It started as a local meeting organized by Research Institute of Industrial Chemistry in Explosia in 1999 with the aim of teaching the youth scientists to present the results of their work to a professional audience. Students from the Institute of Energetic Materials took part in the event and found it useful to their professional development. Therefore, it was decided to continue with these seminars and hand over their organization to the University of Pardubice.

Under the enthusiastic leadership of Prof. Zeman, this local meeting developed into a well-established international event. Although growing in size, it maintained its original focus and always aimed to give students and newcomers to the field of explosives the ability to present their work even in the early stages of development and to build personal relationships with colleagues from countries all over the world.

The 28th NTREM seminar featured a diverse range of topics while maintaining its traditional emphasis on synthesis and preparation. The seminar proceedings contain papers presented at the event either in oral or poster form.

I would like to take this opportunity to express my sincere gratitude to the generous sponsors for their support. Their financial assistance was invaluable in making this event possible and allowed us to keep the registration fee at a minimal level. The seminar was supported by the following:

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- STV Technology, Czech Republic;
- Synthesia Nitrocellulose, Czech Republic.

I also express my deep gratitude to the members of both scientific and organizing committees, the authors of all the seminar papers and, finally, all the participants of this seminar.

Pardubice, March 30th, 2026 Jiri Pachman

Simulation of heat flow curves from microcalorimetry-What has been achieved already

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Keywords: reaction scheme; reaction rate constant; Runge-Kutta-Fehlberg procedure; reaction enthalpy; modelling of heat flow curve.

With isothermal heat flow microcalorimetry (HFMC) one measures the net heat flow of the sample, which can be in total endothermal or exothermal or changes over time the characteristic. In detail the heat flow is determined by the reaction heats or reaction enthalpies of the underlying chemical reactions in the sample. But some so-called physical effects can contribute also, for example relaxation effects of the sample container, evaporation or melting of the sample. In lucky cases with a pure substance only one dominant chemical reaction may occur, and the simulation of the resulting heat flow curve is quite straight forward. One must know the enthalpies of formation from the starting substance and the ones from the decomposition products to determine the reaction enthalpy with the corresponding reaction rate equation. Reaction enthalpies and reaction rate constants are needed to simulate the heat flow curve.

More complicated, but in principle the same procedure, is the prediction of heat flow curves of a stabilized NC-based propellant. The complexity is increased by a lot of reaction rate equations: (1) decomposition of NC, (2) reaction of decomposition products with NC, (3) the reaction of NOX with the stabilizer (4) consecutive reaction products from stabilizer and their reactions. An example is presented with a DPA stabilized ball powder. The NC reactions are discussed as well as the stabilizer reactions. For all of them reaction enthalpies and the reaction rate constants are necessary to know. The next step is to establish the complete reaction scheme for the heat flow with all relevant reactions und to solve it with respect to the measured heat flow curve. This can be done by so-called Runge-Kutta-Fehlberg procedures. The actual or targeted objective is to find out the underlying reactions of the stabilizer. This is a step further to assess its stabilizing quality.

Prediction of ideal detonation characteristics in high explosives – challenges and opportunities

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Keywords: ideal detonation; JWL EoS; thermodynamic equation of state.

For over 120 years, the Chapman-Jouguet hypothesis with equilibrium conditions (mechanical, thermal, and chemical) has provided the basis for "reasonably accurate" condensed phase detonation calculations. In these conditions of high pressure, modern, statistical mechanics based fluid equations of state describing the repulsive region of intermolecular potentials have met with considerable success. This is in spite of the lack of information for some product species, the neglect of pressure effects on intramolecular properties, finite rate processes such as phase transitions, and the uncertainties in inter-species mixture rules. The required level of accuracy of any prediction is application dependent. The challenges of addressing condensed carbon formation and clustering,as well as potential phase changes (amorphous-diamond-graphite) remain for oxygen-negative media. Accurate chemistry-implicit representations of Crussard curves and isentropic expansions as well as freeze-out conditions, are all areas ripe for future development. This paper will briefly review current fundamental equations of state used in computer codes for detonations and discuss possible future refinements to enable more robust calculations for detonation applications in computationall intensive CFD analyses or similar.

Ageing effects on the structure and chemistry of gun propellants

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Keywords: gun propellant; ageing; morphology; porosity; elemental analysis.

Gun propellants mainly consist of nitrate esters, such as nitrocellulose and nitroglycerin, which naturally degrade over time, even under controlled storage conditions. The degradation reaction rate can, however, be mitigated with stabilizers based on aromatic amines (e.g., diphenylamine) or urea derivatives (e.g., centralites). Various standard test procedures are employed to evaluate propellant stability and to predict service life. These methods can provide a snapshot of the propellant condition at a given time or, through accelerated ageing protocols, simulate long-term ageing to estimate remaining lifespan. This work aims to investigate the structural, morphological, and chemical changes associated with ageing in gun propellants of different calibres. The analysed materials include 20 mm, 30 mm, 12.7 mm, and 7.62 mm gun propellants used by the Portuguese Armed Forces. The ageing process followed the principles outlined in AOP-48 (2008), with thermal exposition performed by storing the gun propellants in a controlled oven environment. To assess ageing-related changes, optical microscopy was used to observe surface and internal features; mercury porosimetry to evaluate porosity; helium pycnometry for density measurements; elemental analysis to investigate the chemical nature of mass losses, and high-performance liquid chromatography to quantify stabilizer content. The results reveal distinct differences between gun propellants at various ageing stages, primarily reflected by a progressive loss of stabilizer content. In addition, localized light-coloured regions are observed to be exposed through the grey metallic coating, highlighting structural heterogeneities associated with ageing.

Disc acceleration experiments and simulation of HMX-based aluminized explosives with PTFE addition

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Keywords: aluminized explosive; PTFE; disc acceleration experiment; numerical simulation; post-detonation.

The addition of PTFE (polytetrafluoroethylene) to aluminized explosives has been proved to increase the heat of explosion owing to the post-detonation reaction between PTFE and aluminum. PTFE has a high content of fluorine (76%) among fluorinated oxidizers. The formed AlF_3, comparable to Al_2O_3, has a relatively high heat release and high vapor pressure that volatilizes more readily. In this work, several HMX-based polymer bonded explosives (PBXs) containing varying contents of PTFE and specifications of Al were manufactured by acoustic resonance and rotary cutting methods. In order to verify the energy output from Al, a chemically inert material LiF (lithium fluoride), whose physical properties are similar to Al, was used to substitute Al in counterpart formulations. Four pressed charges with dimension of ■0 mm ■0 mm were used in one disc acceleration shot, a copper disc with thickness of 0.195 mm was attached to one end of the stacked cylindrical charges and the velocity history was recorded by photonic Doppler velocimetry (PDV). Experimental results show that the replacement of HMX by PTFE decreases the detonation pressure and velocity, however, the afterburning between PTFE and Al increase the terminal velocity of the disc. The addition of nano-Al results in a lower terminal velocity of the disc compared with micro-Al, which attributes to the low available aluminum content in nano-Al. The replacement of Al by LiF decreases the terminal velocity of the disc due to the chemical inertness of LiF. In numerical simulation, the JWL (Jones-Wilkins-Lee) parameters of aluminized explosive were obtained from the copper velocity history of corresponding LiF-containing explosive first by genetic algorithm, then the Miller extension parameters were obtained from the copper velocity history of aluminized explosive considering the post-detonation reaction.

Database screening for the identification of potential thermostable and powerful explosives

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Keywords: thermostable energetic material; database screening; TOATF.

The quest for insensitive explosives has been running for decades. From the vast amount of research undertaken in this field, a number of valuable energetic compounds have evolved, which showed reduced sensitivity to various mechanical stimuli, such as impact and friction. However, the thermal sensitivity remains as one of the most difficult challenges to be taken, and known explosives exhibiting both a very high decomposition temperature (higher than 300řC) AND a high performance are very scarce.

In order to identify new energetic compounds as realistic targets for demanding applications, two routes were explored: database screening and literature survey.

This study allowed us to identify TOATF, an energetic molecule with outstanding expected performance compared to HMX and a good thermostability (> 260řC).

The original conditions[1,2,3] were employed then improved to achieve its synthesis in an overall 35% yield, allowing us to characterize TOATF which exhibits the expected thermostability and moderate mechanical sensitivity.

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Harmonization of fertilizer safety testing across manufacturing, storage, and transport

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Keywords: ammonium nitrate; safety; fertilizer; thermal; shock.

Major fertilizer accidents over the past century demonstrate that ammonium-nitrate-based fertilizer incidents are triggered predominantly through two mechanisms: (i) self-accelerating thermal decomposition (SATD)-often initiated during storage via thermal or contaminant-based stimuli-and (ii) shock-initiated rapid decomposition resulting from accidents or explosive events, including detonation following fire. While both the United States and the European Union regulate ammonium nitrate extensively and share United Nations transport classification testing protocols, their regulatory philosophies differ. The United States emphasizes a bottom-up, facility- and storage-based regulatory system implemented through NFPA codes, state and local fire authority oversight, and OSHA-guided standards, whereas European Union regulations adopt a more top-down approach, principally via the Seveso framework and Regulation (EC) No 2003/2003, thereby imposing product-level compositional constraints and pre-market safety and performance testing as a prerequisite for CE marking prior to commercialization. This presentation examines how these distinct, yet complementary approaches could be strategically harmonized to better address both accident pathways. Although the United Nations framework already includes thermal stability, self-heating, and bonfire-type fire exposure tests, these assessments are primarily applied for transport classification rather than for systematic evaluation of fertilizer safety under storage conditions. For prevention of SATD, we recommend convergence toward a common set of compositional and product-level tests, coupled with thermal stability assessments selected to elucidate bulk self-heating behavior to the greatest extent practicable. These tests should include controlled thermal cycling that is quasi-representative of the dynamic environmental conditions known to exacerbate compositional instability in industrial storage scenarios. For shock- and confinement-driven hazards, we recommend broader adoption of detonation-resistance testing for high-nitrogen ammonium-nitrate fertilizers, such as the EU Regulation (EU) 2019/1009 Resistance to Detonation Test (RDT), UN gap-tests, or equivalent methodologies capable of assessing sensitivity to strong shock under realistic confinement conditions. While such testing is embedded in European market-access requirements-most notably through RDT-its absence from U.S. fertilizer product qualification, except where required for transport classification under the UN Manuel of Tests and Criteria, represents a gap in systematic hazard control. By aligning compositional testing and related product-level analyses with thermal stability, self-heating, and detonation-resistance assessments, this work proposes a pathway toward transatlantic harmonization of fertilizer safety testing. Such alignment would strengthen prevention across the full life cycle-from site-specific storage through transport-and thereby reduce the likelihood of catastrophic incidents arising from either thermal- or shock-driven failure modes.

Synthesis and physicochemical characterization of energetic salts derived from 5-methyl-1-nitraminotetrazole

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Keywords: tetrazole; nitramine; primary explosive; synthesis.

The aim of this study was the synthesis of the novel compound 5-methyl-1-nitraminotetrazole and its energetic salts (Ag^+, K^+, NH_4^+, $N_2H_5^+$ and NH_3OH^+). The resulting compounds were characterized by multinuclear NMR (^1H, ^{13}C, ^{14}N and ^{15}N), IR spectroscopy, elemental analysis, differential thermal analysis (DTA), high-resolution mass spectrometry and single-crystal X-ray diffraction. Sensitivities towards mechanical stimuli were measured using a BAM drop hammer and a BAM friction apparatus. The energetic performance parameters were then calculated using the EXPLO5 code, which incorporated the densities obtained from the X-ray diffraction measurements, recalculated to room temperature, as well as the solid-state heats of formation, which were obtained via CBS-4M calculations using the Gaussian 16 program. The obtained compounds were compared with the regioisomer, 1-methyl-5-nitraminotetrazole, and its salts.

Feedstock scarcity, alternative cellulose sources for gun propellants

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Keywords: nitrocellulose; feedstock scarcity.

The base material for many of the DoDs propellant formulations is nitrocellulose (NC), which is mainly produced via nitration of cellulose from wood pulp or cotton. Yearly hundreds of tons of high-quality nitrocellulose (NC) are required for the gun and rocket propellant industry. Cellulose is marked as becoming a critical raw material for Europe, while on the other hand a large waste stream of textile is apparent. The aim of the proposed feasibility study is to experimentally determine whether cellulose obtained from discarded clothing or other textiles can be used to produce nitrocellulose.

Samples from different recycling sources were investigated. Relevant material properties were determined from the source materials and suitable samples were nitrated and analysed.

The properties of nitrocellulose (NC) can vary significantly depending on the cellulose source used. These differences highlight the importance of optimizing the production and stabilization procedures for nitrocellulose from alternative cellulose sources to achieve comparable performance to conventional NC. Key differences can be found in stability and viscosity, nitrogen content, thermal stability and environmental impact.

Study of LLM-105 porous spherulites: preparation, characterization and crystallization mechanism

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Keywords: LLM-105; porous spherulite; MS simulation; detonation performance.

Two kinds of porous spherulites LLM-105 constructed by different nano-units were successfully prepared by adjusting the concentration and molecular weight of PVP. The XRD and FT-IR results show that both LLM-105 have the same crystalline and molecular structure, despite having different morphologies. The results show that porous spherulites can significantly improve the initiation and detonation performance of LLM-105 due to the special multi-stage structure. According to MS simulation, it is found that changing the molecular weight and concentration of PVP can effectively adjust the bond strength with each crystal plane of LLM-105, which makes the growth rate of LLM-105 crystal differ greatly along the axial and radial directions, and finally affects the morphology of LLM-105 crystal. Based on this, the formation mechanism of porous spherulites is proposed.

Investigation of the reaction of selected pyrotechnic and explosive mixtures to bullet impact

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Keywords: sensitivity; bullet impact; pyrotechnic mixture; homemade explosive.

The scope of this research was an experimental analysis of the reaction of selected pyrotechnic and explosive mixtures to an impact caused by a 5.56x45 mm bullet. The research stemed from the need to support law enforcement agencies and military units involved in counterterrorism and explosive ordnance disposal by providing empirical data on the behavior of energetic mixtures under the influence of a kinetic impulse. Multiple tests were conducted under controlled conditions, ensuring the repeatability of projectile kinetic energy and shot geometry. There were about 25 mixtures of varying composition and energetic properties were placed in plastic containers that constituted a simplified model of the casing used in transport or storage of improvised explosive devices (IEDs). Then, samples of each mixture were shot three times, and reaction was recorded on cameras. The observed effects included: no visible reaction, partial ignition, deflagration, or detonation, depending on the mixture type. The obtained results enabled a preliminary classification of the tested mixtures in terms of their mechanical sensitivity and allowed for improvements in tactics and safety procedures.

Replacement of RDX by TKX-50 in a putty-plastic bonded explosive based on polydimethylsiloxane (PDMS)

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Keywords: TKX-50; PBX; PDMS; detonation.

Dihydroxylammonium 5,5-bistetrazole-1,1-diolate (TKX-50) was synthesized and its crystal morphology was investigated by scanning electron microscopy. TKX-50 was studied as a plastic-bonded explosive using Polydimethylsiloxane (PDMS) polymer and compared to the RDX-based PBX prepared also with the same polymer. Impact and friction sensitivities were determined, and detonation characteristics were calculated using the EXPLO5 code. From a comparative analysis of the obtained results, it was found that substituting RDX with TKX-50 in the PBX formulations led to reduction in the impact and friction sensitivities. Calculations performed with EXPLO5 indicate that the TKX-50-based PBX has enhanced detonation performance relative to the RDX-based formulation.

Friction sensitivity testing variations by porcelain consumable type and plate–peg contact state

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Keywords: friction sensitivity; porcelain consumable; contact pressure; roughness.

Friction sensitivity testing is essential for evaluating the safety of energetic materials, as it assesses their reactivity to inevitable mechanical stimuli encountered during handling and processing. However, variations in experimental data due to differences in testing conditions remain a major challenge associated with this method. The authors previous study investigated the influence of the type of porcelain plates and pegs, which hold the explosive sample and apply friction, on the results of friction sensitivity tests. As a result, the contact area formed between the peg and the plate under an applied load was found to differ among three types of consumables supplied by different manufacturers. This indicates that, even under the same applied load, the pressure acting on the sample varies depending on the consumables. When the surface roughness of the plates is comparable, differences in the contact area, rather than surface roughness, can be regarded as one of the dominant factors causing variations in the friction sensitivity test results. In this study, the factors responsible for the differences in the contact area were investigated by examining the geometries of the peg and plate. In addition, the deformation behavior of the contact surfaces was investigated by observing the surface conditions of the consumables before and after testing.

Evaluation of mixed gas and solid components in detonation products

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Keywords: detonation products; equation of state; thermochemical code; Hugoniot.

The assessment of detonation effects in condensed-phase explosives is crucial for both safety and the effective utilization of explosive energy. If the equation of state (EOS) for detonation products is incorporated into CFD codes, steady-state detonation and its various effects on the surrounding environment can be evaluated. Tanaka developed the KHT code as a commercial code and continued updating it until 2009.The development of EOS codes for detonation products is important, and research concerning EOS must be continued and advanced. We started reconstructing a thermodynamic code that includes KHT EOS by using the KHT-code databases. In this paper, the effects of the equation of state for solid components are examined.

Investigation of energy release characteristics of energetic materials

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Keywords: energetic material; energy release; thermodynamic modelling; VHL thermodynamic code; detonation performance; work capacity.

Accurate characterization of the energy-release behavior of energetic materials remains challenging due to the extreme conditions involved, including ultra-high temperatures and pressures, wide temporal and spatial scales, and strong coupling among multiple physical processes. To address these challenges, this paper presents a systematic investigation that integrates formulation-based performance modeling with advanced experimental diagnostics, aiming to establish a reliable and physically grounded evaluation framework.At the core of this work is an independently developed detonation thermodynamics program, VHL, constructed on a high-fidelity equation-of-state framework suitable for extreme detonation environments. The VHL code enables direct prediction of key detonation performance parameters from formulation-level inputs, including detonation velocity, detonation pressure, product composition, and isentropic expansion behavior. In addition, an automated coupling between thermodynamic calculations and dynamic simulations is implemented, allowing consistent transfer of thermodynamic states into continuum-scale hydrodynamic analyses. This thermodynamics-dynamics integration provides an efficient pathway for evaluating both initial detonation characteristics and subsequent energy-release and work-output processes.The proposed methodology is applied to conventional explosives, negative oxygen-balance explosives, and nitrogen-rich energetic ionic salts. The results elucidate several key thermodynamic mechanisms governing detonation performance. In particular, carbon condensation-induced secondary energy release is identified as an important factor in oxygen-deficient systems, while detonation performance anomalies in nitrogen-rich materials are attributed to small-molecule-dominated product distributions and their influence on temperature evolution and isentropic expansion efficiency.The predictive capability of the framework is validated through comparisons with cylinder expansion experiments and underwater near-field work-capacity evaluations. The good agreement between simulations and experiments demonstrates the robustness and applicability of the thermodynamics-based approach, providing reliable support for energetic material design, performance assessment, and application-oriented selection.

Research on propagation characteristics of explosion shock waves from typical aluminized explosives under negative pressure environment

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Keywords: explosion mechanics; negative-pressure environment; explosion experiment; aluminized explosive; shock wave overpressure.

Aluminized explosives are one of the most widely used explosives in warheads. High-altitude and rarefied gas environments have a non-negligible influence on the energy output characteristics and damage effects of aluminized explosives. To investigate the effects of negative pressure environment on the explosion shock waves of typical HMX-based and TATB-based aluminized explosives, negative pressure explosion experiments were carried out in a designed adjustable vacuum explosion container. PCB pressure sensors were adopted to measure the overpressure of shock wave in the explosion container under ambient pressures of 100 kPa, 80 kPa, 70 kPa, 60 kPa and 50 kPa, respectively. On the other hand, the tungsten-rhenium sheathed thermocouples were used to measure the temperature variation process inside the explosion container. The experimental results show that the peak overpressure of explosion shock wave decreases with the reduction of air pressure inside the explosion container, with a decrement of approximately 1%-3.5% for every 10 kPa drop in air pressure. When the ambient pressure drops below 80 kPa, the peak overpressure of the explosion shock wave exhibits a more remarkable decrease with the further reduction of ambient pressure. Different air pressure conditions exert a certain influence on the temperature of the explosion field. The temperature inside the explosion container under the standard atmospheric pressure is lower than that under other negative-pressure environment conditions, which is due to the fact that the increased air content accelerates the rapid dissipation of energy and heat released by the explosion. The research results can provide a certain reference for the evaluation of blast damage effectiveness of aluminized explosives in high-altitude regions.

Exploration of differences in anti-static ability of various explosives

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Keywords: static electricity; sensitivity; explosive; analysis.

From the experimental perspective, this study selected typical explosives from commonly used initiating explosives, booster explosives, and main explosives for electrostatic sensitivity tests. The reasons for these different results were analyzed and discussed from various perspectives, including the molecular composition of the samples, the duration of electric field action, the time difference between voltage and current peaks, thermal effect, etc. The initiating explosive selected was lead azide, the booster explosive was PETN, the main explosives included four types: TNT and PBXs separately based on RDX, HMX, and TATB. The experimental design simulated actual application conditions, with lead azide directly subjected to electrostatic sensitivity tests using detonators, while the other five explosives were pressed into small sheet (tablets) samples for testing. The test results showed that when subjected to a stimulus energy of 0.156 J, lead azide exploded, whereas the other five samples did not. Even when the stimulus energy was increased to high-energy 3.430 J or 6.000 J, the other samples still did not exploded. Under high-energy conditions, after repeated stimulation (40 or 100 times), the surfaces of the explosive samples showed discoloration, but no sustained burning or deflagration was observed. The test result photographs are shown in Figures 1-5, and the gap voltage and current waveforms are shown in Figure 6.

Synthesis and characterization of pyrazolo[3,4-b]pyridine fused insensitive high-energy materials

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Keywords: coplanar fused energetic material; pyrazolo[3,4-b]pyridine; peripheral modification; skeleton fusion.

Fused heterocycle-based energetic materials are recognized as highly promising energetic compounds; yet, their practical deployment is frequently impeded by cumbersome synthetic protocols. In this work, 4,6-dichloro-1H-pyrazolo[3,4-b]pyridine (1), a commercially accessible starting material, was utilized to efficiently synthesize a series of energetic derivatives via straightforward reaction sequences. Among these products, 3,5-dinitro-1H-pyrazolo[3,4-b]pyridine-4,6-diamine (CF-1), featuring a distinctive "NH2-NO2-NH2-NO2" substitution pattern analogous to that of TATB, emerges as a promising thermally stable explosive. It exhibits exceptional thermal stability with onset decomposition temperature (Td) of 309 oC, coupled with low impact sensitivity (IS > 40 J) and friction sensitivity (FS > 360 N). Furthermore, this compound possesses a high crystal density (density: 1.892 g/cm3) and favorable detonation performance, with a detonation velocity (D) of 8461 m/s and a detonation pressure (P) of 28.27 GPa. To expand the structural diversity of this energetic scaffold, innovative molecular design strategies were further implemented herein: specifically, azide-mediated cyclization of 6-chloro-3,5-dinitro-1H-pyrazolo[3,4-b]pyridine-4-amine (3) and N-oxide functionalization of CF-1. These synthetic routes successfully afforded two novel energetic compounds: the tricyclic derivative 4,6-dinitro-8H-pyrazolo[4,3-e]tetrazolo[1,5-a]pyridine-5-amine (CF-2) and 4,6-diamino-3,5-dinitro-1H-pyrazolo[3,4-b]pyridine 7-oxide (CF-3). Both CF-2 (density: 1.928 g/cm3) and CF-3 (density: 1.886 g/cm3) display high crystal densities. Notably, the detonation performance of CF-3 (D = 8579 m/s, P = 30.72 GPa) is comparable to that of RDX (D = 8795 m/s, P = 34.9 GPa), while CF-2 (D = 8862 m/s, P = 32.91 GPa) rivals FOX-7 (D = 8870 m/s, P = 34.0 GPa). Concurrently, both derivatives maintain excellent thermal stability and low mechanical sensitivity: CF-2 shows Td = 224 oC, IS = 30 J, FS = 252 N; CF-3 shows Td = 230 oC, IS = 25 J, FS = 240 N. In addition, CF-2 exhibits a crystal density comparable to those of CL-18 and ANTP, while demonstrating superior thermal stability relative to these reference materials. Collectively, compounds CF-1, CF-2, and CF-3 represent promising candidates for next-generation insensitive high-energy materials (IHEMs).

Thermal decomposition and combustion of ammonium dinitramide-based high energetic ionic liquids with improved ignitability

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Keywords: ammonium dinitramide; energetic ionic liquid; rocket propellant; thermal decomposition; combustion.

Ammonium dinitramide (ADN)-based high-energy ionic liquids (EILs) are promising as liquid rocket propellants for small satellites due to their high energy density and low vapor pressure. One of the most promising EIL candidates is obtained by mixing ADN with monomethylammonium nitrate and urea in a mass ratio of 4:4:2 (we call it AMU442). However, its ignitability has been a challenge. We successfully prepared an EIL with good ignitability and combustion characteristics by partially or completely replacing the urea in AMU442 with formyl hydrazide. Furthermore, we investigated the mechanism through condensed-phase reaction analysis based on simultaneous analysis of thermal behavior and evolved gases.

On the use of a closed vessel to determine the effect of novel ballistic modifiers on the burn rate of solid rocket propellants

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Keywords: ballistic modifier; double-base propellant; burn rate.

Lead-based ballistic modifiers are the industry standard for double-base propellants (DBPs), but their toxic nature poses significant environmental and health concerns. Upcoming legislation will restrict their use, necessitating the development of alternative solutions. In order to practically assess the effectiveness of any alternative ballistic modifier, capabilities to measure the burn-rate profile of propellants are required; this work investigates the use of the OZM TSV100 closed vessel to measure the burn rates of nitrocellulose-based propellant formulations by measuring the pressure changes during the combustion of the propellant sample. In order to accurately determine the burn-rate profiles, consistent grain geometries with uniform burn-surfaces are required and therefore this work also looks at optimising the formulation processes for preparing samples within a small-scale research lab. This process has created a setup where novel ballistic modifiers can be easily incorporated into the small propellant samples, facilitating an efficient, high-throughput method of assessing the effects of ballistic modifiers on double-base propellants.

A new synthetic index enabling AI-guided discovery of novel molecules

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Keywords: SVR; synthetic accessibility; molecule complexity; linear regression.

Recent advances in generative models enable the virtual design of molecules with specific functions. However, although these models can produce novel structures, the synthetic feasibility of these generated molecules remains a critical challenge. Existing methods estimate synthetic accessibility (SA) using heuristic calculations or deep learning, but their generalization is limited by small training datasets. In order to address this lack of data, Support Vector Machine (SVM) methods are also used to predict the SA of a molecule. Yet they provide only binary classifications (easy/difficult) without quantifying synthesis complexity. We developed a new method based on Support Vector Regression (SVR) to predict the SA as a continuous score ranging from 1 (easy) to 10 (difficult). This method incorporates human knowledge based on the following assumptions: (1) Molecules composed of previously synthesized fragments should be easier to synthesize, especially if these fragments have been frequently used. (2) Molecules with previously connected fragment pairs should be easier to synthesize, especially if these connections are common. To distinguish between molecules sharing similar fragments, we apply a structural penalty derived from the SAScore heuristic method[1], which accounts for large rings, non-standard ring fusions, stereocomplexity and molecule size. Additionally, molecular descriptors complement these fragment-based features to capture structural diversity. The model was trained and tested on a dataset of 1,770 drug-like molecules assessed by chemists[1, 2], using scaffold-based splitting. It achieved a Q2 of 0.88 on the 353-molecule test set and a cross-validated R2 of 0.87, showing good predictive performance. Although the model was trained on pharmaceutical compounds, synthetic accessibility is a domain-agnostic property driven by molecular topology. Nitroaromatic explosives share core structural features with common aromatic compounds, allowing meaningful extrapolation of SA predictions beyond drug-like chemical space. Notably, our algorithm also yields accurate synthetic accessibility predictions for several key high-energy materials, supporting its applicability outside the pharmaceutical domain.

An emerging safety hazard: triacetone triperoxide formation in aged 2-propanol

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Keywords: TATP; 2-propanol; safety.

Since the 1970s, and particularly during the first decade of the 2000s, the use of 2-propanol has increased substantially across society, including in healthcare, industry, academia, and laboratory environments. In parallel with this widespread use, there appears to be an increasing trend in reports of spontaneous formation of the high-explosive triacetone triperoxide (TATP) in aged 2-propanol. Several incidents worldwide have involved explosions during the handling of aged 2-propanol, some resulting in serious injuries. Previous studies have demonstrated that TATP can form naturally in 2-propanol upon prolonged exposure to air and that its physicochemical properties and friction sensitivity are comparable to those of laboratory-synthesized TATP, highlighting a significant and potentially growing hazard associated with storage and handling. In Norway alone, one accident attributed to TATP formation in 2-propanol was reported in 2024, followed by three additional incidents in 2025, suggesting an emerging and underrecognized safety issue. Here, we review the documented cases in Norway and further show that TATP is present in a substantial fraction of aged 2-propanol samples analysed in this study, indicating that spontaneous formation may be more prevalent than previously assumed and that the associated risk may be increasing.

A comparison of different methods in the analysis of the nitrogen content of nitrocellulose

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Keywords: nitrocellulose; nitrogen content; titration; elemental analysis; ^{13}C NMR.

The energy content of nitrocellulose (NC) is governed by its level of nitration. This is normally described as the nitrogen content (% N) of the nitrocellulose. In this paper, three different methods were evaluated on seven different NC materials and compared to the specification provided by the producer. The first method was the well-established titration with ferrous ammonium sulphate, which provided a good reference, as this is the standard method in the industry. The second method was elemental analysis, where the instrument was calibrated against trimethylolpropanetrinitrate (TMPTN). This allowed direct analysis without addition of methanol, which is usually to prevent the too low values that can result from the mismatch in burn rate between NC and the inert references. The final method was 13C NMR, which has not been published since the advent of modern integration softwares to the best of our understanding. The methods are compared in terms of relative standard deviation, the effort and time required to prepare the samples and run the analysis, and operator dependency. review.

Burning velocity of pyrotechnic compositions at various compaction pressures

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Keywords: pyrotechnic composition; Fe; CuO; pellet porosity; burning velocity.

Pyrotechnic compositions are energetic materials consisting of intimate mixture between a reducer, generally a metallic fuel, and an oxidizer. The reactivity of these types of materials is affected by intrinsic characteristics and operating or experimental conditions. Hence, this study aims to investigate the influence of fuel particle size and compaction pressure on the burning velocity of iron-rich Fe/CuO pyrotechnic compositions. This will be achieved by defining three iron particle size classes (0-20 microns, 20-40 microns, and 40-80 microns) and by varying the compaction pressure between 115 and 260 MPa for two Fe/CuO compositions, namely 50 wt.% Fe / 50 wt.% CuO and 60 wt.% Fe / 40 wt.% CuO. Combustion experiments were achieved using a butane torch, and the tests were recorded using a high-speed camera operating at 420 fps. The burning velocity was then determined using a MATLAB-based image processing code that analyzes the flame front propagation from the recorded videos. The first analysis shows that increasing the compaction pressure improves mechanical cohesion of the samples and the pellet densities ranged between 4 and 5 g/cm^3, corresponding to 50-70% TMD (Theoretical Maximum Density). These density variations provide insights into the dominant mode of mass and heat transfer within the pellets (conduction or convection). Moreover, we observe that the burning velocity is significantly affected by the compaction pressure of the Fe/CuO mixtures. Lower pellet densities (higher porosities) appear to enhance the burning velocity.

Oxidant filled nanoporous carbon as lead-free primary explosive

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Keywords: lead-free; nanoporous material; primary explosive; detonator.

Primary explosives stand at the very beginning of a pyrotechnic train. Such compounds possess the ability to transform an external stimuli such as impact or spark into a shock wave, capable to detonate a secondary explosive. This particular property comes with a major drawback; an exacerbated sensibility to the smallest stimuli making these compounds highly hazardous. Furthermore, such species are rare and most of the commonly used ones are heavy-metal salts such as lead azide or styphnate. Here, we report a heavy-metal free flame-sensitive primary explosive based on nanoporous carbon filled with an oxidant and displaying the sensitivity to mechanical stimuli of a secondary explosive. Due to the nanoporous structure of the carbon material, filling these pores with oxidant allows an intimate mix at the nanometric scale between fuel and oxidant while preserving a macroscopic structure; therefore avoiding the toxicity and handling issues related to nanomaterials. The ability of this composite material to detonate secondary explosives has been demonstrated and a prototypical detonator has been designed and successfully tested. This new formulation has also been qualified in accordance with NATO standards. It is believed that the simplicity of manufacturing these materials, the robust supply chain of their precursors, and their low overall cost make them a realistic alternative to lead-based primary explosives.

Unraveling the actual safety benefits of adding inorganic fillers to ammonium nitrate

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Keywords: ammonium nitrate; safety; inerting; calcium ammonium nitrate; accidents.

Provided that ammonium nitrate-based fertilizers are stored and transported according to good practices and applicable regulation-driven requirements, no special safety concerns are expected. However, the explosion in Beirut in the summer of 2020 proved all lessons had not been learned from past disasters. It caused all concerned with ammonium nitrate (AN) to review current knowledge and mandatory practices in AN-based fertilizer storage. As France is the largest market in the European Union for high dosage (HD) AN-based fertilizers, questions arose as to the relative safety requirements posed on medium dosage (MD) and (HD) AN. The study reported herein seeks to go beyond a subjective comparison of these and quantitatively evaluate the performance of these fertilizer formulations. Our collaborative approach has combined officially recognized tests in applicable regulations and added a series of rate stick detonation tests. This study provides the disappointing proof that diluting AN, whether with calcium carbonate or sulfate, is providing no more safety than the dilution factor.

Synthesis and characterization of salts based on 1,2-bis(5-(trifluoromethyl)-4H-1,2,4-triazol-3-yl)diazene

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Keywords: triazole; energetic material; synthesis.

The azo-bridged compound 1,2-bis(5-(trifluoromethyl)-4H-1,2,4-triazol-3-yl)diazene represents a promising building block for the design of novel energetic salts with tunable properties. In this work, we report the synthesis and characterization of five salts of this azo compound, obtained by proton transfer or coordination with hydroxylamine, ammonia, sodium, potassium, and rubidium. These salts were prepared under mild conditions and characterized using elemental analysis, NMR, and single-crystal X-ray diffraction where possible. Density measurements reveal changes in density from the hydroxylamine to rubidium salts, correlating with calculated detonation pressures and velocities obtained using EXPLO5. These results highlight how cation selection modulates the structural and energetic characteristics of azo-linked triazole frameworks, opening pathways toward tailored, stable, and high-performance energetic salts.

Influence of water contamination on the combustion behavior of ammonium dinitramide-based formulation containing monomethylamine and urea

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Keywords: ammonium dinitramide; energetic ionic liquid; combustion.

Energetic ionic liquids (EILs) containing ammonium dinitramide (ADN) as the primary component have attracted considerable attention as new liquid propellants for rocket propulsion. AMU is a candidate composition for ADN-based EILs, which involves blending monomethylamine nitrate and urea with ADN as the fuel components. A major concern with ADN-based EILs is their pronounced hygroscopic nature during handling and storage. The influence of moisture contamination on the combustion behavior of AMU remains insufficiently understood. Consequently, this study aims to investigate the influence of contaminant water on the combustion characteristics of AMU by conducting ignition and combustion tests to assess parameters such as the ignition temperature, combustion rate, and combustion temperature. The findings indicate that the presence of water increases the ignition temperature while decreasing the combustion temperature of the AMU mixture.

Cycled DSC-analysis of HNS in energetic melts

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Keywords: melt-cast explosive; crystallization modifier; hexanitrostilbene; crystallization.

Using hexanitrostilbene (HNS) and trinitrotoluene (TNT) as an example combination, a cycled calorimetric study (DSC) is presented which shows measured effects of successful (and unsuccessful) crystallization seeding. Further common energetic melts such as ammonium dinitramide (ADN), pentaerythritol tetranitrate (PETN) and Tetryl were investigated as reference substances. Melt separation effects in DSC samples are shown and interpreted. The comparison of zero-samples with HNS-doped solidification samples showed different, material specific kinetic responses, with strong statistical variations. DSC data of tetryl melting and recrystallization show unexpected signals, interpreted as extraordinarily strong supercooling with crystallization on the heating path, requiring further corroboration. Calorimetry and optical polarization microscopy enable the in-situ observation of relevant crystallization processes. Possible additives and their effects can thus be directly observed during crystallization. The potential benefits of temperature-resolved single-crystal structure determination (S-XRD) for such investigations are discussed.

Investigating the effect of nitration degree on nitroresorcinol-based energetic coordination compounds

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Keywords: initiating substance; priming mixture; dinitroresorcinol; ECCs.

A common approach used to synthesize novel compounds to replace heavy metal based primary explosives is via the formation of an energetic coordination compound (ECC). This allows high variability through combination and alternation of metal center, ligands and anion. While often deployed anions for ECCs focus mainly on perchlorate, nitrate or azide, established organic energetic components such as styphnic acid have also been investigated. ECCs of dinitroresorcinol, which is based on the same structural moiety, have previously not been synthesized. The lacking nitro-group, suggest a lower energetic characteristic and higher stability of the resulting coordination compounds, though this hypothesis has not yet been proven. In the following work, ECCs containing 2,4-dinitroresorcinol (2,4-DNR), have been successfully synthesized, and their constitutions were determined using single crystal X-ray diffraction (XRD). After each compound was confirmed to be pure by elemental analysis (EA), energetic and physiochemical properties such as thermal stability and sensitivities were measured. Furthermore, utilizing the collected data, the differences and characteristics caused by the lack of one nitro group, was investigated through comparison with equivalent copper styphnate based ECCs.

Utilising foundation models for energetic materials property predictions

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Keywords: machine learning; FM; energetic material; impact sensitivity.

The high costs and risks associated with the discovery of energetic materials necessitate the development of statistical models capable of generating property predictions to assess the viability of potential materials. The application of deep-learning methods in this area is limited by the availability of high-quality experimental data sets. Large data sets contain labelled molecules in the scale of hundreds, whereas traditional deep learning methods often require millions. Foundation models, such as UniMol and MolCLR, are models pre-trained on large data sets which allow them to 'understand' basic chemical information. These models can then be fine-tuned for a specific application using small experimental data sets. Off-the-shelf, pre-trained models are designed for property predictions of general materials but their use for energetic materials remain unexplored. Energetic materials typically have uniquely high crystal densities and oxygen balances in addition to containing distinct functional groups that store large amounts of chemical energy, potentially causing complications in the use of generalist models. The purpose of this work is to create a benchmark across publicly available materials foundation models to assess their performance in predicting key energetic properties.

Formulation and detonation performance of low-velocity PETN-based plastic explosives

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Keywords: plastic explosive; detonation velocity; hollow glass microballoons; PETN; reactive armor system; explosive welding.

This study presents an experimental investigation of plastic explosive (PE) formulations for specific applications such as reactive armor systems and explosive welding. These formulations were engineered to exhibit reduced detonation velocity (VoD) due to the presence of a significant content of inert ingredients. The examined compositions are based on PETN as an energetic component, with a partly-cured polymer binder, and hollow glass microballoons as inert filler for density reduction and VoD attenuation. The proposed formulations with varied content of binder and glass microballoons were prepared in a horizontal kneading homogenizer. Detonation velocity and density measurements were carried out for all formulations and compared with commercially available conventional plastic explosives with standard VoD characteristics: PPE-01 and MPE (Poliex). Also, detonation properties were calculated with an appropriate numerical model, in order to estimate the agreement between the experimental values and the calculated, considering a high content of inert ingredients. Isoperibolic calorimetry was employed to determine the energetic potential of the formulations, enabling a direct comparison of their thermal output associated with explosive decomposition. The results demonstrate that controlled incorporation of inert hollow glass microballoons, in combination with binder content, enables significant reductions in VoD. The experimental findings provide practical guidelines for the formulation of tailored energetic materials with controlled detonation behavior for defense and industrial applications.

Design and setup of experiments on the penetration of Misnay–Schardin-type explosively formed projectiles

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Keywords: Misnay-Schardin effect; penetration; explosively formed projectile; steel plate.

The paper presents an experimental and analytical study setup of the penetration of Misznay-Schardin type explosively formed projectiles (EFPs) into armoured steel targets, with a focus on the influence of explosive charge variation on penetration depth. A dedicated test setup was designed to ensure reproducible projectile formation and impact conditions, including controlled stand-off distance, confinement geometry, and target positioning. Series of experiments would be conducted using different explosive masses and charge geometries while keeping the liner and target configuration constant. The findings would provide a better understanding of how variations in explosive charge mass and configuration affect the performance of Misznay-Schardin EFPs against armoured steel. The analytical approach should minimize the number of experements and should support improved prediction of penetration depth in design and vulnerability assessments.

Study on the hazard resulting from fragments of detonated propelling charges

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Keywords: fragmentation effect; detonation; propelling charge; nitrocellulose.

Modern ammunition, rockets and missiles have propelling charges with significant quantities of different energetic materials, where different nitrocellulose-based propellants are the most often used. Propellants can be detonated also, where shock waves generated in air by an explosion are considered in safety assessments and many simple calculation methods are developed for engineering usage. After production and during storage, propelling charges are usually inside some kind of a metal case. If propelling charges are detonated, fragments with high velocity will be created, posing a very significant threat to surrounding personnel or objects. In this study, different propelling charges for high caliber artillery ammunition and rockets are considered. Gurney model of explosive output was used to evaluate the performance of fragments of different mass and dimensions. Detonation performances of nitrocellulose-based propellants were used, based on experimental and numerical results of previous studies. Results of fragmentation effect estimations were compared to the appropriate blast effect.

Producing the burn-rate suppressant of solid rocket propellant in a regular crystal structure

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Keywords: oxamide; burn-rate suppressant; catalyst; crystal structure; efficiency.

Oxamide is a thermally stable diamide with high nitrogen content and strong hydrogen bonding capacity which is widely used as a slow-release fertilizer in agriculture and a burn-rate suppressant in solid rocket propellants. The physical structure of the oxamide material varies depending on its intended area to be used. Even though small and irregular crystalline oxamides could be acceptable and widely used in fertilizer industries, complex products such as solid rocket propellant mixtures require standardized sizes and rounded uniform crystalline shapes due to high density packing requirements of propellants. This study proposes a new method for production of oxamides with uniform crystalline structures by using basic catalyst on the batch reaction. The base was used as both a catalyst and a crystal structure modifier. In this study, high yields of crystals of uniform size and structure in a short reaction time were resulted and reliable outcomes were obtained by using analytical methods such as SEM, grain size analysis and XRD.

Experimental analysis on propellant laser ignition and combustion process

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Keywords: solid propellant; laser ignition; combustion; experimental method.

Solid propellants are commonly used for propulsion applications or gas generation, for example in car inflators. In these pyrotechnical devices, the ignition and combustion processes of energetics materials need robustness, dependability and efficiency. To aim this goal, this study seeks to better understand the initiator-propellant interaction, the thermal processes occurring during the early stages of the combustion and modeling the whole process with physical considerations.

To reach this objective, an experimental device has been developed. It consists of a cell fitted with quartz windows and pressurized with an inert gas up to 10 MPa. A continuous infrared laser beam heats the upper surface of a cylindrical bulk of propellant (mainly GUNI/BCN based), leading to ignition. The use of various experimental diagnostics like highspeed imaging, pressure, thermal measurements and their analysis lead to the ignition and combustion performances of the sample.

Results exhibits a trend between ignition delay and the absorbed heat flux. After characterizing the laser beam and considering some laser-matter interaction, we present an analytical thermal model of ignition process. Furthermore, burning rate is presented as a function of the pressure inside the chamber. This trend combined with pressure signal during the combustion process, and compared to data obtained at higher pressure with closed vessel measurements, lead to a combustion model at low-pressure, from 1 MPa to 10 MPa.

Chemical compatibility assessment of three different PBX formulations with silicone sealants

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Keywords: compatibility; PBX; AOP-4147.

Chemical compatibility of energetic materials with their contact materials in munitions is of critical importance due to safety and performance concerns. Therefore, every component of the munition that is in contact or close proximity to the energetic material should be assessed in terms of compatibility before production. In this work, the compatibility of three different PBX compositions (PBX-A, PBX-B and PBX-C) with two different silicone sealants (Silicone-1 and Silicone-2) was investigated, in accordance with AOP 4147 Edition A Version 1 by carrying out Vacuum Stability Test (VST), Heat Flow Calorimetry (HFC), Differential Scanning Calorimetry (DSC) and Thermogravimetric Analysis (TGA) for each interface. The results show that Silicone-1 is incompatible with all three explosives, unless testing after aging proves otherwise. Silicone-2 is compatible with PBX-A, but incompatible with PBX-B and PBX-C. Compatibility of Silicone-2 with PBX-B can be further investigated with performance tests after aging.

Rare-earth styphnates: feasible alternatives for lead styphnate?

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Keywords: styphnate; rare earths; primary explosive; energetic coordination compound.

Significant research is being conducted into finding alternatives for the lead-containing primary explosive lead styphnate (LS), and while valuable alternatives have been found, LS is still used in most commercial and military primers, as well as in electric initiators and impulse cartridges. Whereas its key benefits lie in its reliable ignition capability, its cost-effectiveness and its widespread application, the fact that it contains lead makes it a toxic and hazardous substance, justifying the research efforts towards more sustainable alternatives. Rare-earth (RE) coordination chemistry is the study of coordination compounds involving rare-earth elements (REE) as the central metal ions, with their unique electronic, magnetic and optical properties. Even though many of the REE are considered to be critical elements, due to the balance problem, some of them are mined in excess of their demand, and could be viable sources for novel energetic materials. In this study, we synthesized the styphnate salts of all REE, except for Sc and the radioactive Pm. Preliminary tests indicate that the RE styphnates form as pure compounds with properties of primary explosives, exhibiting decomposition temperatures around 300řC, but with a significantly lower sensitivity to electrostatic discharge than LS.

Fluorescence quenching as a detection method for trace explosives using perylene diimide derivatives in solution and organogels

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Keywords: explosive; detection; fluorescence quenching; TNT.

The detection of energetic materials at trace levels remains a critical challenge for both civilian and military security, especially in the context of increasing terrorist threats. Conventional detection techniques often lack universality and sensitivity, making it necessary to develop innovative approaches capable of identifying a wide range of explosives at very low concentrations. Optical spectroscopic methods, due to their non-destructive nature, cost-effectiveness, and adaptability to diverse chemical structures, represent a promising alternative. This research explores the potential of fluorescence-based techniques, specifically fluorescence quenching, as a sensitive and selective method for explosive detection. The study investigates the use of perylene diimide (PDI) derivatives as fluorophores for detecting nitroaromatic explosives through fluorescence quenching mechanisms. Experimental work involved preparing PDI solutions in dimethylformamide (DMF), N-methylpyrolidone and in organogel structures, determining optimal excitation wavelengths, and constructing calibration curves using a Jasco FP-6500 spectrofluorimeter. Subsequent tests assessed the quenching efficiency for several compounds, including TNT, diazodinitrophenol (DDNP), and sodium picramate. The quenching process was analyzed in terms of spectral overlap and energy transfer mechanisms, such as Fᵉr resonance energy transfer (FRET), to explain the observed detection limits. Results demonstrated that the proposed method achieves detection limits in the ppm range for key nitroaromatic explosives, with TNT and DDNP showing limits of 6.5 ppm and 66 ppm, respectively, and sodium picramate exhibiting an exceptional limit of 2 ppm. These findings confirm the feasibility of fluorescence quenching as a highly sensitive technique for trace detection of explosives. The study opens new perspectives for developing portable, rapid, and cost-effective detection systems based on tailored PDI derivatives, contributing significantly to security and defense applications.

Comparative evaluation of double-base and composite rocket propellants in anti-aircraft applications using multi-criteria decision making

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Keywords: multicriteria decision making; double-base rocket propellant; composite rocket propellant.

The selection of rocket propellants for anti-aircraft systems requires balancing multiple, often conflicting criteria such as performance, safety, environmental impact, and cost. This study presents a systematic comparison between double-base (DB) and composite propellants (CP) for use in anti-aircraft rockets, employing a multi-criteria decision making (MCDM) framework. Key evaluation parameters include specific impulse, combustion stability, mechanical properties, storability, sensitivity to external stimuli, and environmental footprint. Double-base propellants, primarily nitrocellulose-nitroglycerin formulations, offer simplicity of manufacture, predictable performance, and relatively low production costs. However, they are limited by moderate specific impulse and higher sensitivity to thermal and mechanical stimuli. Composite propellants, typically based on ammonium perchlorate oxidizers with polymeric binders and metallic fuels, provide superior energy density and thrust performance, but introduce challenges in terms of manufacturing complexity, cost, and environmental concerns related to perchlorate residues.

The MCDM approach integrates quantitative metrics with expert judgment, applying methods such as Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). Results indicate that while composite propellants score higher in performance-related criteria, double-base propellants remain competitive in terms of safety, cost-effectiveness, and ease of deployment. Sensitivity analysis highlights the influence of weighting factors, demonstrating that operational priorities-such as rapid readiness versus long-term sustainability-significantly affect the final ranking.

This study underscores the importance of structured decision-making in defense technology selection. By providing a transparent framework, it enables stakeholders to align technical performance with strategic requirements. The findings suggest that hybrid approaches, combining elements of both DB and CP formulations, may offer optimized solutions for future anti-aircraft rocket systems.

A laboratory study of organic waste materials in emulsion explosives

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Keywords: emulsion explosive; organic waste material; EXPLO5.

As part of research on the potential use of recycled waste-derived fuels in emulsion matrix, the detonation properties of mixtures containing waste plastics and wood dust were researched. This paper presents laboratory test results for emulsion-based mixtures with addition of ground PET packaging material, representing recyclable artificial waste, and wood dust, representing biodegradable natural waste. The emulsion matrix with additives was sensitized with 2.4% GMB (glass micro ballons). Using the thermochemical code EXPLO5, the properties of the above compositions were modeled, and detonation velocities were measured under laboratory conditions.

Real-time ammonia emission monitoring during the composite propellant kneading

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Keywords: composite solid propellant; ammonia diffusion and monitoring; degassing efficiency.

The composite solid propellant (CSP) is generally manufactured with ammonium perchlorate (AP) and HTPB, using a bonding agent, typically TEPANOL. During the kneading process, the mixture promotes reactions between AP and the TEPANOL, generating ammonia (NH_3). However, NH_3 imprisonment inside the mixture leads to the reaction of ammonia with the isocyanate groups during curing, potentially compromising the mechanical integrity of the grain. Therefore, it is important to determine how much and for how long NH_3 is released during kneading. Thus, this work investigated the use of a portable ammonium detector to evaluate ammonia removal during mixing process of CSP under vacuum. The experimental setup involved the use of a portable Harvest E4000 electrochemical sensor positioned at the vacuum pump's exhaust during kneading. Monitoring started after AP addition and continued during vacuum mixing. Initial monitoring showed an increase in NH_3 levels during the early stages of manufacturing. In several instances, concentrations exceeded the sensor's limit, requiring the device to be moved further from the exhaust to maintain monitoring. As the process moved into final stages, such as the addition of coarser AP granulometries and aluminum, a general trend of reduction in ammonia concentration was observed. The data indicated that sensor positioning was critical for measurement stability. In tests where the sensor remained in a fixed position (inside the exhaust), the results showed a more uniform and clear decay behavior. For these optimized trials, ammonia levels stabilized near 0 ppm after approximately 240 minutes of mixing. The results demonstrate that the implementation of a portable sensor provides a viable, low-cost solution for the real-time monitoring of degassing efficiency. This monitoring approach can be utilized as a definitive indicator for the "end-of-process" by identifying when ammonia concentrations stabilize at 0 ppm.

Characterization of Nonel tubes for shock wave generation and sensor calibration

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Keywords: nonel; shock tube; TNT; piezoelectric; blast wave.

Integrated electronics piezo-electric (IEPE) sensors are often used in blast overpressure measurements. They need to be calibrated in order to provide accurate data, but sending them to an authorized company for calibrations can be costly and time-consuming. This paper presents a laboratory-friendly alternative for sensor calibration, by using nonel tubes (thin plastic tubes with a thin coating of HMX/Al mixture) to generate repeatable overpressure inside a 2 m shock tube. By calculating the overpressure from shock wave velocity and comparing it to a value measured by a sensor, a recalibration is possible, making this a simple, quick, and cost-efficient method of IEPE pressure sensor calibration. Minimal effective length of nonels needed for repeatable overpressure generation, and combinations of up to 9 nonels in a single setting were experimentally tested. Simulations in the blastFoam solver were carried out to establish TNT equivalency of the nonel tubes. This would further allow to check the sensor calibration when used in a field setting for actual blast wave measurements and simulations.

Machine learning modelling for nitrocellulose-based propellant ageing

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Keywords: stabilizer depletion; nitrocellulose propellant; Arrhenius extrapolation; machine learning; ammunition; ageing; shelf life prediction.

Stabilizer depletion is a primary ageing indicator in nitrocellulose-based propellants and constitutes a key surveillance parameter within NATO practice. However, translating accelerated ageing results to realistic storage temperatures remains challenging due to the strong temperature dependence of degradation kinetics and the limited availability of low-temperature data.

This study compares two modelling strategies for predicting stabilizer loss in 30 mm- caliber ammunition. Method 1 employs a purely data-driven Gaussian Process Regression (GPR) model trained on accelerated stabilizer measurements, with temporal augmentation and cross-validation for model selection. Method 2 employs a physics-informed hybrid approach in which high-temperature kinetic constants are extrapolated to 16-30řC using an Arrhenius law and first-order decay, thereby generating a thermodynamically consistent degradation surface, which is subsequently emulated by GPR for efficient non-isothermal evaluation.

The results show that embedding Arrhenius kinetics within a machine learning framework enhances predictive robustness, physical interpretability, and scientific defensibility for operational shelf-life assessment.

Bioleaching as a sustainable ex situ remediation method for agricultural soils contaminated with heavy metals and energetic materials

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Keywords: acidithiobacillus ferrooxidans; copper; lead; military pollution; nickel.

A substantial portion of agricultural land in Ukraine has been severely affected by the ongoing armed conflict, resulting in extensive soil contamination by heavy metals and residues of energetic materials. Identifying effective and environmentally sustainable remediation strategies for such multi-contaminated soils represents an important challenge in contemporary environmental research. This paper presents bioleaching using the acidophilic bacteria Acidithiobacillus ferrooxidans as a sustainable and environmentally friendly remediation method for soils contaminated with heavy metals due to military activities. To simulate the conditions expected in war-affected Ukrainian soils, experimental bioleaching tests were conducted on soils collected from military training areas in the Czech Republic, including a grenade range, a shooting range, and a blast-training site. The results show that bioleaching provides an effective ex situ remediation method, achieving particularly high extraction efficiencies for copper and nickel. In several samples, its performance exceeded that of chemical leaching with nitric acid, confirming the potential of bioleaching as a viable and sustainable option for treating contaminated soils.

Testing of detonation products jets from explosive charges containing tungsten powder

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Keywords: metallized explosive; hollow charge; detonation products jet; penetration of steel barrier.

The effect of the tungsten powder content in the mixture with the explosive (DPX-4) on the effects of cavity cumulative charges on steel barriers was investigated. The barriers were sets consisting of 3 steel plates, each 4 mm thick, and a steel plate 50 mm thick. The size of the hole penetrated in the first plate and the deflection of the second plate were analyzed, as well as the size of the crater formed in the thick plate. X-ray images of the cumulative jets formed after the detonation of cone cavity charges were also taken. Calculated detonation parameters of explosive mixtures with tungsten powder were used to analyze the results obtained. Analysis of the test results showed that the effects of detonation product jets from cone cavity charges pressed from an explosive mixture containing different amounts of tungsten powder on thick steel plates are similar. However, differences in the effects of the impact of the jets of detonation products on the system of thin steel plates are evident on the second plate - the height of depth increases with the content of tungsten powder in the mixture. The presented results can be the basis for further research aimed at designing charges with directed energy intended, for example, for attacking ships with double hulls.

Synthesis and characterization of ionic bio-energetic materials based on dinitramide

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Keywords: dinitramide; amino-acid; ionic-bio-energetic-material.

In this work, a series of novel ionic bio-energetic materials (IBEMs) derived from natural starting materials, including amino acids, and the dinitramide anion were synthesized and investigated. The bio-inspired dinitramides were prepared via acid-base reactions with dinitraminic acid, which was generated from ammonium dinitramide by ion-exchange chromatography. The resulting ionic compounds were characterized using multinuclear NMR spectroscopy (1H, 13C, and 14N), infrared spectroscopy, elemental analysis, differential thermal analysis (DTA), and single-crystal X-ray diffraction. Sensitivities toward mechanical stimuli were evaluated using BAM drop hammer and BAM friction apparatus measurements. Furthermore, energetic performance parameters were calculated using the EXPLO5 code.

Evaluation of fire suppression performance of organic acid salt/oxidizer mixtures

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Keywords: fire suppressant material; potassium periodate.

In recent years, fire incidents involving lithium-ion batteries (LIBs) have increased, often resulting in significant damage due to thermal propagation between cells and the risk of re-ignition. This study aims to develop novel self-activating fire suppressants composed of oxidizers and fuels, which release fire-extinguishing species upon combustion or thermal decomposition triggered by overheating. Mixtures were prepared using various organic acid salts combined with oxidizers such as potassium periodate and potassium perchlorate. By varying component ratios and particle sizes, we evaluated their effects on combustion behavior and fire suppression performance. Combustion temperature and other thermal properties were also measured to investigate their correlation with extinguishing efficiency.

Synthesis and characterization of a new energetic compound: 1,1,2,2-tetra-(1H-tetrazol-5-yl)cyclopropane (HDEX-252)

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Keywords: nitrogen; synthesis; HDEX-252.

Synthesis of energetic molecules with high nitrogen content is a preferred research topic during the last decades, in the area of explosives, due to their high heat of formation and increased density, especially if this high energy content do not affect their stability and sensitivity properties. The aim of this study was to present a facile synthesis route for a new nitrogen-rich compound, 1,1,2,2-tetra(1H-tetrazol-5-yl)cyclopropane (HDEX-252), starting from readily available materials, and using only water as the main solvent. HDEX-252 has a nitrogen content of 71.32%, its synthesis is safe and rather environmentally friendly, not involving the use of nitric acid.

The use of 3D printing for the fabrication of flexible linear shaped charges

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Keywords: FLSC; FDM; additive manufacturing.

The present research present the use of FDM additive manufacturing, in the FGF (fused granulate fabrication) mode to produce the shaped explosive materials used in the production of flexible linear shaped charges. Insights into the preparation of composite energetic material and the printing process are presented, together with rheological characterization, numerical simulation and performance testing. The results show that additive manufacturing represent a promising manufacturing technology in the shape optimization process.

Method for VoD measurement on spherical charges

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Keywords: FOP; fiber optic probe; detonation velocity; spherical charge.

Detonation velocity is a fundamental parameter for characterizing explosive materials. It can be measured relatively easily along the surface of charges with elongated geometries - such as cylinders, detonating cords, or sheets. Difficulties arise, however, when detonation velocity must be determined in bulk charges initiated internally, for example in spherical charges with a centrally placed detonator. In these cases, surface-based measurements are not feasible, and some degree of intrusion into the charge becomes necessary. Yet drilling multiple probe holes with varying depths builds on the expectation, that the detonation wave is diverging in perfect symmetry from the center of the charge, which cannot be guaranteed. Thus, while minimizing intrusions is beneficial for maintaining undisturbed detonation conditions, obtaining sufficiently dense and reliable data typically requires numerous measurement points. To reconcile these competing requirements, this work proposes the use of a perforated optical-fiber probe for detonation-velocity measurements in spherical charges. This approach enables the acquisition of a large number of datapoints through a single drilled channel, thereby reducing disturbance to the charge while still providing high-resolution temporal and spatial information on the detonation wave.

Influence of ignition source on the dispersed dust clouds

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Keywords: igniter; turbulence; dust dispersion; high-speed camera; unconfined cloud.

Combustible dust present in industrial processes represents a significant hazard due to its potential for accidental ignition and subsequent explosion. The evaluation of such risks is generally accomplished using standardised laboratory tests, such as measurement in the 20-litre chamber. However, it is important to note that the characteristics of the ignition source used in these tests can significantly affect the measured parameters and the resulting safety data. The present study focuses on the effect of different igniters on the dispersion and combustion of lycopodium dust clouds. Reproducible and controlled dust dispersion was achieved through the Hartmann tube dispersal system. High-speed imaging techniques were used to observe dust dispersion, ignition, and flame propagation. The results demonstrate that the type of igniter used has a substantial influence on the combustion of the dust cloud. The standardised Sobbe igniter (500 J; 2000 J; 5000 J) had a significant impact on the dispersion process, while the electric igniter caused minimal turbulence.

These findings highlight the importance of ignition source selection in the interpretation of explosivity data from standardised tests. Consideration of this factor is essential for improving the accuracy of dust explosion assessments and for advancing safety practices in the industrial environment.

Vacuum stability evaluation of pyrotechnic mixture - double-base propellant compatibility

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Keywords: vacuum stability test; double-base rocket propellant; pyrotechnic mixture; chemical stability.

This study investigates the compatibility between a binder-free pyrotechnic mixture and a double-base rocket propellant containing a high nitroglycerin content. Under realistic application and service conditions, these components are separated by a very thin aluminum foil coated with a polymer layer, which serves as a physical barrier preventing direct interaction. The research specifically examines the significance of the presence and integrity of this physical barrier in mitigating hazardous interactions between the two energetic components. Prior to compatibility testing, comprehensive laboratory analyses were performed to assess the chemical stability of each individual component. Subsequently, compatibility was evaluated using the vacuum stability test in accordance with STANAG 4147, selected for its suitability in studying energetic material interactions and for the flexibility it offers in modifying test parameters. Two test regimes were applied: a 40 h test at 100 řC and an extended 240 h test at 80 řC. In the 100 řC test, the pyrotechnic mixture was treated as the energetic material and the propellant as the contact material, while the roles were reversed in the 80 řC test. The results reveal pronounced incompatibility between the two energetic components in the absence of an effective barrier. The findings clearly demonstrate that a solid, continuous, and durable physical barrier is essential to prevent premature or hazardous interactions. Any damage or degradation of this barrier prior to the intended ignition may lead to uncontrolled interaction initiated by combustion of the pyrotechnic mixture. Differential thermal analysis of the individual components and their mixture showed undesirable shifts of the recorded thermal peaks toward higher temperatures, indicating potential interactions between the components that may affect the thermal behavior and compatibility of the system.

The effect of sample confinement in detonation calorimetry

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Keywords: detonation calorimetry; heat of detonation; charge casing.

Heat of detonation is a key parameter of high explosives. However, its experimental determination by detonation calorimetry is more complicated than the other bomb calorimetric measurements. Measured values of the detonation heat can be significantly influenced by experimental arrangement, especially the presence of confinement. Unconfined samples of oxygen-deficient explosives typically provide invalid results that are influenced by high-temperature reequilibration of detonation products, which is specific to conditions present only in the calorimeters and absent in most real-world applications of explosives. This paper compares available types of confinement applied to a common plastic bonded explosive and compares the results with thermochemical code predictions. Correct measurement procedures are deduced and summarized.

Light emission from high explosive samples in a detonation chamber

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Keywords: detonation products; pyrometry; brightness temperature; emission spectra.

Dynamic measurement of high temperatures in explosives testing is usually performed using multi-channel pyrometry, i.e. by analyzing the intensities of emitted light at different wavelengths. One of the key issues in pyrometry is the correct selection of spectral bands ensuring that the captured light is of thermal origin and atomic and molecular emission peaks are excluded. Four explosive samples were involved in this study: PETN-based moldable plastic explosive, liquid explosive based on nitromethane, powdered PETN and its mixture with aluminium powder. The light emission was collected simultaneously by a time-integrating spectrometer and a time-resolved multi-band pyrometer. The tests were performed in a lab-scale detonation chamber and the light was captured by fiber optic probes mounted at a distance from the sample to collect the light originating from the expanding fireball of detonation products. The pyrometric results are discussed with respect to the observed spectral features.

Characterizing the initiation capacity of low-density granular explosives

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Keywords: initiation; low-density; granular; explosive; TNT; PDV.

In the context of an improvised explosive threat, certain "dual use" substances are of particular concern. According to international storage and transportation standards, these substances are not considered explosives because they are too insensitive [1]. While this approach is relevant to transportation and storage safety, it does not address the potential misuse of these substances. Some substances, typically classified as oxidizers, could therefore be misused in explosive devices. One well-known example is the adduct of urea and hydrogen peroxide (UHP) [2-6]. The threat level of these substances is assessed based on their critical diameter and the type of booster required. The threat level is significantly higher if these substances can be detonated with a booster made of homemade explosives, such as TATP (triacetone triperoxide). Such substances are often encountered in granular explosives with low densities, typically below 1 g/cm^3. Thus, threat assessments of "dual-use" explosive substances require descriptions of the initiation capabilities of homemade granular explosives. Current detonation research focuses heavily on high-density military explosives. In contrast, low-density granular explosives (typically <1 g/cm^3) are poorly understood. Existing literature often focuses on their blast wave effects rather than their ability to act as boosters for secondary main charges [7-8]. This study establishes experimental methodologies to characterize the initiation capacity of these materials. Using advanced diagnostics, including photonic Doppler velocimetry (PDV), streak cameras, and witness plate indentation, we compare various granular explosives of different particle sizes and densities against a high-density military reference. The experiments revealed that some low-density granular charges exhibit behavior related to their granular nature that may be associated with particle jetting and granular bed compaction. These findings provide new insights into the detonation mechanisms and initiation capabilities of granular substances.

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Synthesis and characterization of a novel triol-based energetic plasticizer

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Keywords: energetic plasticizer; energetic material; glass transition temperature; synthesis; triol backbone.

Plasticizers are important components in energetic formulations due to their ability to improve mechanical flexibility, lower the glass transition temperature, and enhance the processability of propellants and explosives. Energetic plasticizers are of particular interest due to their contribution to the overall energy content of the formulation. In this study, a new plasticizer based on a triol backbone was synthesized and investigated. Different synthesis approaches were compared, and the thermal stability and physicochemical properties of the resulting product were systematically characterized. Various synthesis approaches were compared in terms of yield and efficiency, and the thermal stability and physicochemical properties of the resulting product were systematically characterized. The new plasticizer was compared with established energetic plasticizers in terms of volatility, decomposition onset, and glass transition behavior.

Novel binder formulation for rocket motor designed for use in HEAT shoulder fired weapons

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Keywords: binder formulation; APCP rocket motor.

The paper presents the use of PVC-plastisol binder in ammonium perchlorate composite propellants (APCP). Two types of formulations are investigated, one based on binder and oxidizer and the other one having additional fuel present, as aluminium powder. The thermal properties and the fusing process of the composites are presented together with performance measurements of the mentioned propellants, test fired in a 40mm rocket motor. The results show a consistent rise in the burn rate of the propellant when using the novel binder formulation, compared with classic HTPB formulations. The solution can be used in small size rocket motors, where high burn rate is desired, like rocket assisted HEAT shoulder fired weapons.

Characterization of new castable formulations for insensitive munitions

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Keywords: insensitive munition; castable.

The present research highlights the potential use of TNT-RDX-Aluminiun-Wax energetic mixture for the filling of explosive ordnance by melt-cast method. Several proposed composition are evaluated regarding the theoretical performances, based on Explo5 software and the friction, impact and temperature sensitivity are investigated. The optimized composition was casted into mortar bombs and the munition was investigated regarding the IM response to fast cook-off (fire), fragment impact and shaped charge impact. The results highlights the potential use of the composition in insensitive ammunition.

Optimizing stand-off distance and sealing methods using additive manufacturing for engineering support explosive tasks

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Keywords: additive manufacturing; engineer support; improvised charge; confinement; stand-off distance; 3D-printed component.

The paper deals with the issue of additive manufacturing (3D printing), in combination with the design of accessories for demolition work in the performance of engineering support tasks. The paper discusses the solution of the stand-off distance for cut charges and also the possibility of sealing improvised charges. In this context, improvised charges are charges using plastic explosives and 3D printing accessories, which are similar in their properties to standardized charges such as SEMTEX Razor 20. The aim of this paper is to evaluate the design of the stand-off distance in terms of effectiveness and user-friendliness in terms of preparation and use. The second objective is to compare the results of explosions of sealed and unsealed improvised explosive charges. The benefit of this study is the assessment of the possibility of replacing standardized explosive charges with their available equivalents, which are commonly available in military practice and widely usable for engineering support tasks. The effectiveness of 3D printing material for the stand-off distance and as a sealing layer replaces the complexity of the logistics chain for the supplied material and allows for unique creation that can be applied precisely to the destructed object. The limitation is the cutting effect of the shaped charge jet and slug, which is determined by the composition of the filament for 3D printing, in this case CooperFill.

Nitro esters of oxetane and oxirane dialcohols as monomers for energetic dendrimeric co-polymers

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Keywords: oxetanes; oxiranes; co-polymerisation; dendrimer; hyperbranched.

This work describes attempts for the synthesis and characterisation of core-shell type co-polymers of dendrimeric poly(3-ethyl-3-(hydroxymethyl)oxetane) core (pEHMO) and varying contents of either poly(3,3-bis(nitratomethyl)oxetane) (pBNMOxt) or poly(2,3-bis(nitratomethyl)oxirane) (pBNMOxr) shells. The structural and energetic properties of the 3,3-bis(nitratomethyl)oxetane monomer were re-investigated. As well, the synthesis and characterisation of the rather reactive 2,3-bis(nitratomethyl)oxirane monomer was revisited.

The hyperbranched energetic co-polymers were prepared by sequential cationic ring-opening polymerisation using boron trifluoride etherate as the initiator. Characterisation was carried out by employing multinuclear NMR (^{1}H, ^{13}C, ^{14}N), IR spectroscopy and differential thermal analysis. Additionally, the effects of external stimuli on the produced polymers (impact and friction) were determined.

Characterization of novel formulations designed for hail suppression and rain enhancement technologies

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Keywords: hail suppression; rain enhancement.

This paper presents some new polymer bonded pyrotechnical compositions designed for hail suppression and rain enhancement. The chemical composition of the formulations is optimized based on the silver iodide thermal stability and two perchlorate type of oxidizers are evaluated for perspective use. The main combustion parameters combustion temperature and burn rate are presented in conjunction with the resulting aerosols, investigated trough SEM-EDS. The chemical stability of the novel formulations are evaluated by VST studies. The research highlight the potential use of the presented formulations in the fabrication of drone/aviation delivered pyro cartridges aerosol generators.

Optimization of pyrotechnic delay compositions

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Keywords: response surface methodology; central composite design; optimization; pyrotechnic composition; delay composition.

This work applies Response Surface Methodology (RSM) combined with a Central Composite Design (CCD) to systematically model and optimize the burning rate and electrostatic discharge sensitivity, expressed as minimum ignition energy (MIE), of pyrotechnic delay compositions. Experimental models were developed to describe the influence of formulation parameters on both performance and safety responses. A multi-objective optimization strategy based on the desirability function was employed to identify two optimal formulations, aiming to maximize ESD safety, impose a target burning rate, and simultaneously enhance formulation robustness. To account for uncertainty propagation and experimental variability, Monte Carlo simulations were integrated into the optimization framework, allowing robustness to be explicitly quantified and maximized. The experimentally validated results showed excellent agreement with the optimized model predictions, with the optimized formulations achieving high overall desirability values. These findings demonstrate that the combined use of CCD-RSM, desirability-based optimization, and Monte Carlo-based robustness analysis provides a reliable and effective approach for the design and optimization of pyrotechnic delay compositions.

The idea of color-ranking-based laboratory safety

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Keywords: color ranking; laboratory safety; description of safety measures.

Laboratories can represent a wide range of indoor and outdoor spaces in which a large number of specific activities (SA) can be performed. These SAs can be chemical and physical. At the same time, some tasks are performed regularly, while others are performed very rarely. Each SA represents a different level of risk to its surroundings. The basis for the safe performance of a task is standard operating procedures (SOP), which should also include a description of safety measures (DSM). The first objective of the procedure under preparation is to propose a standardized DSM form with several levels based on the SA's risk level. The second objective is to create a simple procedure for determining the required DSM for each SA. The third objective is to create a simple procedure for selecting and using a method to achieve the necessary DSM level. Three steps are also planned to achieve these objectives. The first step is to divide the DSM into several colors according to the increasing level of risk of the SA. For this reason, the name color ranking based laboratory safety is used. The safety assessment of the investigated SA must be fast, simple, and user-friendly. For this reason, the decision-making system is based on several simple decision trees that provide colored results. The color results are entered into prepared color matrices. The proposed procedures must be suitable both for preparing SOPs for completely new SAs and for preparing SOPs for SAs created by modifying other already established SAs with their SOPs. The second type of situation is likely to be more common and corresponds to the approach known as Management of Change (MoC). This paper focuses on demonstrating the proposed DSM grading, the framework of the decision-making process, and examples of individual decision-making tools.

Reliability of bridge wire fuse heads for serial ignition firing applications

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Keywords: electric bridge wire fuse head; serial ignition; statistical interference; reliability.

Serial chains of electric fuseheads are used in industrial and safety applications like detonators in mining or as integral part of pyrotechnic actuators in explosion prevention and fire extingushing systems.

Reliable initiation of all fuse heads is a crucial property of serial ignition chains. The risk of misfires caused by interuption of electrical energy supply must be kept as low as possible.

The bridge wire can be regarded as critical part. It initiates the primary charge by electro-thermal heating to autoignition temperature. On the other hand it is responsible for the transfer of electric energy to other fuse heads as part of the serial chain.

An optimized design with respect to safety against misfire requires a proper selection of bridge wire material and also thermo-chemical properties of the primary charge.

The traditional approach for assessing wether a fuse head design is suitable for serial ignition or not, is to perform a number of repetitions of serial ignition tests for the target number of fuse heads and ignition current. The manufacturer afterwards decides from that limited tests that serial ignition can be guaranteed.

A new customer demand is to provide an estimation of reliability in discrete numbers. For this purpose a test methodology will be discussed, that provides statistical parameters for initiation of primary charge and current break down.

A well known method to estimate failure probalities in structural design of mechanically loaded components is the Load-Resistance Interference Method. If statistical distributions of mechanical loads and structural strength are available, a reliability margin and failure probability can be provided. From literature it is known, that this method can be used to other situations, where the extent of overlap of two distributions determines failure probability.

This presentation proposes the estimation of failure probability by use of the Load-Resistance Interference Method with consideration of distributions for the characteristic parameters: time to first reaction and current break down.

Photo-curable 1-alkyl-3-vinyl-imidazolium energetic monomers for the production of tunable fuel-binders for energetic propellants

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Polymers derived from 1-alkyl-3-vinylimidazolium perchlorate and nitrate energetic ionic liquid monomers can serve as fuel-binders in composite propellants. Side-chain engineering provides wide tunability of mechanical response, energetic performance, ammonium perchlorate (AP) interfacial binding, and self-healing behavior. The vinyl functionality enables covalent network formation, while poorly packing substituents (e.g., isopropyl, long alkyl chains, and oligo(ethylene glycol) groups) act as internal plasticizers that control mechanical properties, while the latter also promote wetting of AP crystals. Favorable oxygen balance and heats of formation allow a reduced oxidizer-to-binder ratio without compromising the energetic output of the resultant propellant.

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