The Influence of Energy Content and Its Expenditure on the Impact Sensitivity of High-Nitrogen Energetic Materials

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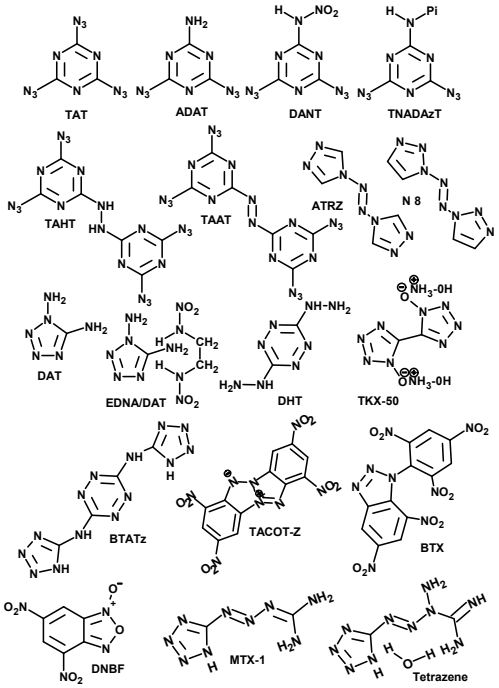
Svatopluk ZEMAN

Institute of Energetic Materials, Faculty of Chemical Technology, University of Pardubice, CZ-532 10 Pardubice, Czech Republic

svatopluk.zeman@upce.cz

Based on the analysis of a large amount of experimental data, Licht has stated [1] that a high level of performance is usually accompanied by an enhanced sensitivity and that insensitive explosives do not exhibit top performance. This statement might be taken as a rule [1,2,3]. Nevertheless, there are some exceptions to it [2,3] (the opposite run of the corresponding relationship), mainly in pure, technically attractive nitramines [3] and in some highly thermostable polynitroarenes [4]. Only recently, the energy gain from the explosion of energetic materials (i.e. the heat of explosion) in that type of studies has been replaced by their energy content, i.e. by their enthalpy of formation, ΔH_{form} [5]. So far, we have dealt with compounds with nitro groups in the molecule. However, the research in the last two decades has focused on energetic materials, mainly with a high nitrogen content, which is bound in their molecules mostly in another form than the nitro groups.



Scheme 1. Formulae of the studied Energetic Materials (here Pi- means 2,4,6-trinitrophenyl-).

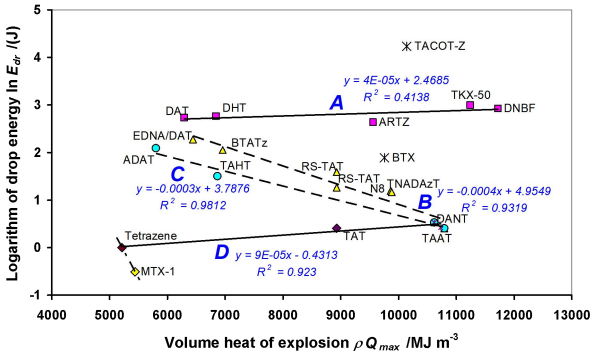


Figure 1. Mutual semilogarithmic comparison of impact sensitivity, expressed as drop energy (E_{dr}) and the volume heat of explosion ($\rho\ Q_{max}$), for the studied energetic materials.

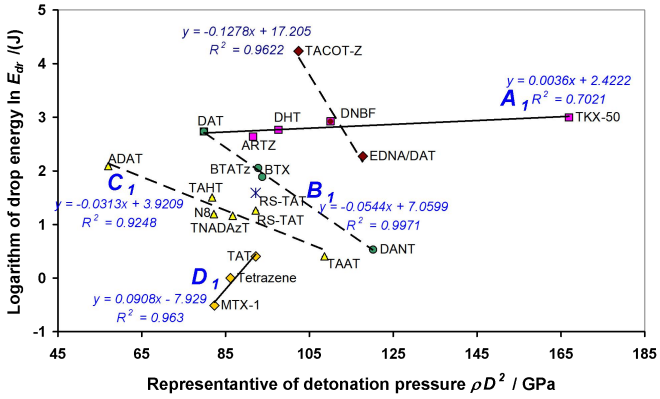


Figure 2. Mutual semilogarithmic comparison of impact sensitivity, expressed as drop energy (E_{dr}) and a representative of detonation pressure ($\rho\ D^2$), for the studied energetic materials.

The mutual difference of the relationships in figures 1 and 2 lies in the definition relation between the detonation velocity, D, and the heat of explosion , Q, in the CJ plane:

$$D^2 = 2\ (\gamma^2 - 1)\cdot Q$$

where γ is a polytropic exponent.

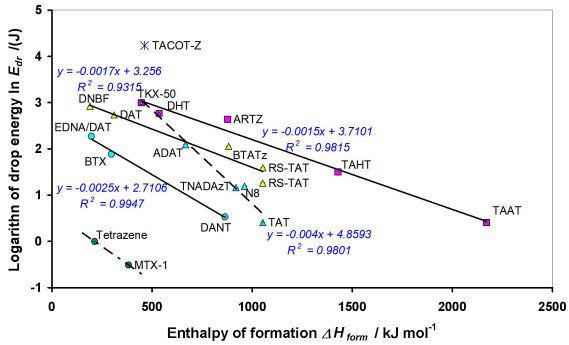


Fig. 3. Mutual semilogarithmic comparison of impact sensitivity, expressed as drop energy (E_{dr}), and a representative of the energy content, i.e. the enthalpy of formation, in molecules of the high-nitrogen energetic materials studied

The paper [5] has shown that the impact sensitivity of nitramines, their PBXs, polynitro arenes and their derivatives unambiguously increases with an increase in their energy content, which was represented there by the corresponding enthalpies of formation, ΔH_{form}. The same approach to the impact sensitivity of polynitro arenes in this paper is provided by figure 3.

It is possible to state that structurally similar energetic materials will produce similar most reactive primary fragments and that the molecular crystals of the explosives of related molecular structures should involve similar intermolecular interactions. Both of these facts are the reason why the group of the compounds studied in this paper breaks down into several subgroups.

Like in nitramines, plastic-bonded explosives on their basis and in polynitro arenes, also in high-nitrogen energetic materials (EMs), there are semi-logarithmic relationships between their impact sensitivity on the one hand and the volume heat of explosion or detonation pressure on the other. However, there seem to be far more exceptions to the general "sensitivity-performance" relationship (i.e. the course of the relationship different from the expected one), than with the explosives mentioned. On the other hand, the course of a similar correlation of the compounds studied with the enthalpies of formation as an independent variable follows the expectations (i.e. increasing sensitivity with increasing energy content in the molecules of EMs); it should be emphasized that no exceptions to the expected course of relationships with the enthalpies of formation have been found in the studied energetic materials with a high nitrogen content. Like in the case of polynitro arenes, it can also be claimed in the case of the substances studied here [4] that it is necessary to distinguish between the influence of performance and the influence of the energetic content in the molecules of energetic materials on their initiation reactivity. In connection with this fact, it is useful to correct the statement of Dr. Licht [1] concerning the relation between performance and sensitivity, i.e. to replace performance by the energy content in energetic molecules.

The full version of this abstract will appear in Defence Technology in 2020.

References.

[1] Licht HH. 2000 Performance and sensitivity of explosives. *Propellants, Explosives, Pyrotechnics* **25** 126-32

[2] Zeman S. 2007 Sensitivities of high energy compounds. In: Klapoetke T, editor. High energy density compounds, structure & bonding *Hedelberg, Germany: Springer* **125** 195-271

[3] Zeman S, Jungova M. 2016 Sensitivity and performance of energetic materials. *Propellants, Explosives, Pyrotechnics* **41** 426-51

[4] Zeman S. 2019 Influence of the energy content and its expenditure in polynitroarenes on their sensitivity. *Journal of Energetic Materials* **37**(4) 445–58

[5] Zeman S, Hussein AK, Jungova M, Elbeih A. 2019 Effect of energy content of the nitraminic plastic bonded explosives on their performance and sensitivity characteristics. *Defence Technology* **15** 488-94