

## **REVIEW on Ph.D. thesis**

### **„Study of New Energetic Materials; Plastic Explosives Based on Selected Cyclic Nitramines“**

elaborated by Dipl. Eng. Ahmed Elbeih

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

Presented Ph.D. thesis deals with topical theme of study of new energetic materials. It contains 186 pages (including list of references and appendix). The dissertation work consists of the following parts: declaration, acknowledgement, summary, contents, list of figures, list of tables, nomenclature, list of publications, introduction, aim of the work, five chapters, references and appendix.

INTRODUCTION (page 23) comprises chosen advantages of PBXs when compared with the pure explosives – lower vulnerability and sensitivity to different stimuli are correctly introduced on the first place.

The aim of the work (introduced on p. 24) has been to test BCHMX (bicyclo-HMX) as a plastic explosive and as a highly pressed plastic bonded explosive (PBX). For comparison other different cyclic nitramines have to be tested with the same type of polymeric matrices. The study includes particular tasks in theoretical and experimental branches subdivided into six paragraphs.

**Chapter 1. Theoretical part** (from page 25 to page 66) contains a survey of plastic bonded explosives (PBXs) and their relevant components, possible manufacturing methods and application. Determination of basic characteristics and corresponding testing comprises significant part of the dissertation work.

Note that „Explosives have been discovered in the seventh century by the Chinese...” (see page 25) is somewhat questionable from the point of view of mentioned century.

**Chapter 2. Experimental part** (from page 67 to page 87) describes explosives and polymeric matrices which have been utilized for making the plastic explosives and PBXs. In the next part of this chapter the testing methods for studying the properties of investigated explosives are described.

Penetration ability of shaped charge jet is somewhat complicated task which slightly has exceeded the scope of this dissertation work.

**Chapter 3. Theoretical evaluation of the detonation parameters** (from page 88 to page 100). In this chapter selected theoretical parts of the methods for predermination of

detonation parameters of studied explosives (PBXs) are introduced. The method of Kamlet-Jacobs, CHEETAH code and EXPLO5 code are described in a reasonable extent.

**Chapter 4. Results and discussion** (from page 101 to page 141). The results obtained from experiments and theoretical calculations are presented here. Influences of respective explosive on density, performance and sensitivity to ambient stimuli are analyzed. Theoretical calculations of different methods are compared with results from experimental testing.

On the base of measuring, a linear dependence of detonation velocity on loading density has been reached for all investigated explosives.

The results obtained and supported with theoretical analysis create significant contribution to theory of high performance new explosives and predetermination of their properties, and they could have significant impact to practical utilization.

**Chapter 5. Conclusion** (from page 142 to page 143).

This chapter provides comprehensive summary concerning the sensitivity and stability measurements, measuring and calculation of performance characteristics of studied explosives. Plastic explosives based on BCHMX and silicone matrix seems to be interesting composition for practical application in future. Opinion of the author that the aim of the study has been achieved by studying the characteristics of BCHMX bonded by different polymeric matrix is acceptable.

**Question to be answered:**

At which products is it possible to estimate an application of the chosen results from your work? What preconditions should be fulfilled?

**Examiner's conclusion**

Dip. Eng. Ahmed Elbeih proved his scientific ability to elaborate Ph.D. thesis. He has applied adequate research tools and methods to solve theoretical and experimental objectives. Conclusions are comprehensible derived from results based on experiments and calculation. Presented Ph.D. thesis creates the scientific contribution in the field of PBX.

Taking in to consideration the previously mentioned, I recommend Dipl. Eng. Ahmed Elbeih's Ph.D. thesis for defence.

Dip.Eng.Ahmed Elbeih meets all requirements for obtaining the academical degrese Ph.D..

Brno, January 25, 2012

  
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## **REVIEW**

of Ing. Ahmed Elbeih's PhD Thesis titled  
**“Study of New Energetic Materials; Plastic Explosives Based on Selected Cyclic Nitramines”**

done at the University of Pardubice, Faculty of Chemical Technology;  
Institute of Energetic Materials

BCHMX (bicyclo-HMX) is a new polycyclic nitramine and a high energetic explosive components. But applications of BCHMX in the field of energetic materials are still unknown. To use the new nitramine in practice, sensitivity and detonation performance of explosives based on BCHMX should be determined and compared with properties of other explosives. Therefore, from this point of view, the study Ing. Ahmed Elbeih undertook is fully justified.


The dissertation consists of introduction, aim of the dissertation work including the objective and range of work, four chapters and conclusions. The aim of the study is to use BCHMX as a main component in plastic explosives and highly pressed plastic bonded explosives (PBX), and to compare the properties of new compositions with plastic explosives based on different cyclic nitramines. Main part of the work is preceded by list of figures, list of tables, nomenclature and list of Ing. Ahmed Elbeih's publications. The work is closed by list of references and appendix, which contains the results of calculations from the EXPLO 5 code.

Chapter 1 provides an overview of PBXs (Plastic Bonded Explosives), their components, methods of manufacture, application, and examples of them. The chapter also describes tests applied for determination of sensitivity of explosives to selected stimuli, thermal stability, and methods of measurement of some detonation parameters.

The first part of Chapter 2 comprises detailed description of all the ingredients (explosives and polymeric matrices) used for preparation of plastic explosives and PBXs. Four matrixes were applied to prepare the plastic explosives : C4, semtex, formex and silicone matrix. Moreover, PBXs based on Viton A (5 and 9 wt%), fluoret FT and acrylate were prepared. The methods used to characterise some properties of the explosives are described in the second part of the chapter. The elemental contents, internal energy of combustion, impact and friction sensitivity, thermal stability, detonation velocity, and work ability were

determined. In the end, the penetration ability of shaped charges made of selected explosives was tested.


Chapter 3 is devoted to theoretical evaluation of the detonation characteristics. Three methods of calculation of the Chapman-Jouguet parameters are described: Kamlet and Jacobs method, EXPLO5 code and CHEETAH code. Ways are shown how to determine the data necessary to calculate the detonation properties of explosives studied.

The results of investigations and analysis of them are presented in Chapter 4. The author analyzed the particle size distribution of pure explosives used. However, it is not given  whether the distribution refers to the amount or mass of particles. Too small drawings in the work do not allow to answer this question. The empirical formula, internal energy of combustion and enthalpy of formation determined for all the tested explosives are presented in tables. The author discussed the results of the sensitivity to impact and friction and sorted the tested explosives, taking into account the type of polymeric matrix or explosive ingredient. From the thermal stability measurements the conclusions were drawn regarding the effect of the binder or matrix on the decomposition temperatures of the explosives. Applying results of the measurements the author proved that there is a linear relation between loading density and detonation velocity for the studied plastic and pure explosives. Similar linear dependences were obtained for the pressed PBXs. The results of ballistic mortar measurements and jet penetration tests are also discussed. Finally, the measured detonation velocities were compared with those calculated by using three different methods. From this comparison, the author drew some important conclusions.

Ing. Ahmed Elbeih carried out a detailed study that undoubtedly increased the knowledge concerning the sensitivity and detonation characteristics of plastic explosives based on cyclic nitramines. A lot of attention was paid to characterise the explosives with regard to their physical and detonation properties. Author devoted special attention to plastic explosives and PBX's containing BCHMX. Properties of these compositions were compared with those based on other cyclic nitramines. The results of the investigations are of great importance from the practical point of view. But in terms of scientific value, the attempts to establish relationships between the physical properties of explosives and the detonation parameters are the most interesting. Also, comparison of the results of calculations performed by using the codes and Kamlet method with experimental data and among themselves is of great practical importance. Thanks to this, Ing. Ahmed Elbeih's PhD Thesis exemplifies original scientific output. It convincingly shows that he mastered research techniques in the field of experimental and theoretical methods of investigations of explosives and their

detonation. It also indicates that the author is able to write a scientific report with clearly defined objective and range of work. Bearing in mind all the merits of the work, I am convinced that the thesis put forward by Ing. Ahmed Elbeith meets all the prerequisites for obtaining the degree of Doctor of Philosophy and, therefore I strongly recommend it for its public defence.

Warsaw, January 25, 2012

  
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## Ph.D. thesis evaluation report

Name of the candidate: Ahmed Elbeih  
Title of thesis: Study of new energetic materials; Plastic explosives based on selected cyclic nitramines  
University/Faculty: University of Pardubice, Faculty of Chemical Technology, Institute of Energetic Materials

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Date of despatch of the report: 19 January 2012

### Report

The dissertation contains 186 pages, 26 figures, 13 tables, 151 references. It is divided into 5 chapters.

The main aim of the dissertation is to test potential application of BCHMX (cis-1,3,4,6-tetranitro-octahydroimidazo-[4,5-d]imidazole) as a explosive filler in highly pressed plastic bonded explosive.

In the chapter **Theoretical part** the candidate gives an introduction to plastic bonded explosives (PBX) and their characteristics; typical binders, plasticizers, and explosives used to make PBX; manufacturing technologies, and application.

The chapter **Experimental part** describes explosive and non-explosive materials used in the study, explains methods of preparation of studied explosive mixtures, and experimental methods used to study physical, chemical, and detonation properties of studied PBXs.

In the chapter **Theoretical evaluation of the detonation parameters** the candidate describes theoretical background of the methods used to predict theoretically detonation properties/ performance of studied PBXs. The candidate describes empirical Kamlet-Jacobs method, and two thermochemical equilibrium codes (Cheetah and EXPLO5) used in the study to predict theoretically detonation parameters of the explosives.

In chapter **Results and discussion** the candidate gives results obtained by experiments and calculation, and gives explanations of the findings. The candidate discusses effects of type of explosive/binder on density, heat of combustion and enthalpy of formation, sensitivity to impact and friction, thermal stability, detonation properties, and performance (strength and penetration ability).

In the second part of the chapter the candidate gives results of prediction / theoretical calculation of detonation parameters of studied explosives, and gives an comprehensive analysis of obtained results, comparing different methods with experimental results

In the chapter **Conclusion** the candidate summarizes the main results and conclusion of his research. On the basis of numerous and extensive results, obtained by studding 5 different explosives and 7 different polymeric binders, the candidate has concluded that plastic explosive based on BCHMX and silicone matrix may have potential practical application.

## Conclusion and suggestion

The topic chosen for the dissertation and its relevance in the field of explosives has been brought out clearly. The title adequately and relevantly indicates the work undertaken in the thesis. The objectives have been set clearly.

The candidate has presented an up-to-date review of the literature pertaining to the topics. The review includes citations of all publications that are considered by the examiner as relevant to the topics, and reflects full grasp of up-to-date published information on the subject.

The materials have been scientifically collected in accordance with the objectives. Methods and techniques adopted for experimental part and analysis of data are quite adequate to the topics of research undertaken.

The candidate was able to interpret the data in a scientific way. The candidate has evolved the results critically, conclusion are clear and based on experimental results and calculation, as well as in the light of known facts. The candidate has shown good knowledge of theoretical background and relevant up-to-date literature pertaining to the topics.

The results of the dissertation present valuable and original scientific contribution to the area of PBX

### Questions to be clarified in the *viva voce* examination

#### Question 1:

It follows from data given in Tables 4.5, and 4.9 and 4.10 that the explosives based on HNIW and BCHMX have higher  $Q_d$  (and  $Q_{max}$ ) than RDX and HMX based formulations. At the same time these formulations have higher relative strength.

Did you find a correlation between the heat of detonation and relative strength of studied explosives? Do you think such correlation exist, i.e. do you think the heat of detonation may be used for rough estimation of relative strength of explosives?

#### Question 2:

Can you comment meaning of the terms "Heat of detonation" calculated by EXPLO ( $Q_d$ ) and "Heat of explosion" ( $Q_{max}$ ) calculated by Kamlet-Jackobs methods. Do these two terms describe the same or different parameters?

#### Question 3:

In some PBX (e.g. PBXN-111, PBXW-115, etc.) detonation process may be non-ideal and as a consequence of non-ideality of detention, the detonation velocities calculated applying EXPLO5 or Cheetah codes may be considerable higher than experimental.

Did you find any evidence of non-ideality of detonation of studied plastic explosives?

By taking into account the above mentioned I recommend that the thesis submitted by Ahmed Elbeih, in the University of Pardubice, Faculty of Chemical Technology, Institute of Energetic Materials, be accepted for the award of Ph.D. degree by University of Pardubice, Czech Republic.

Signature of examiner



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Zagreb, 19 January 2012