22nd YKEM — Yugoslav committee for explosive materials

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THE *22th YKEM — Yugoslav committee for explosive materials* was held 20 - 21 October, 2004 in Bar and was organized by the Military Technical Institute, Belgrade in co-operation with the YUGOIMPORT-MONT, Podgorica.

This symposium with international participation is a sequel to the previous symposia on *explosive materials* in Serbia and Montenegro. Explosive materials are a subject of great importance in the development of science and technology concerning its very large civil and military applications. The aim of the Symposium is to provide a forum to exhibit the progress in the fields of pyrotechnics, explosives, and propellants during the past three years and a place to promote the interaction of production, testing, and modern engineering applications, as well as the mechanism of functioning and terminal ballistics effects of explosive system designs.

The authors from Military Technical Institute, Technical Testing Center, Military Academy, Faculty of Mechanical Engineering, Faculty of Technology and Metallurgy, Institute of Security, Holding Company Krušik, Yugoimport- SDPR, etc., have submitted nearly forty papers fully printed in the special Proceedings.

All papers were classified into three subjects: *plenary section* (2 papers), *section B - powders* (16 papers), and *section E - explosives* (more than 17 papers) and were communicated within the plenary and particular sessions.

It is the author's opinion that out of all the papers communicated during the Symposium, the following ones deserve a special attention of the readers of the Scientific Technical Review.

Contributed lectures

Kinetic modeling of the chemical transformation of stabilizer in single base gun propellants during aging (Miloš Filipović, PhD (Eng), Military Technical Institute, Belgrade)
A suitable kinetic model for the chemical transformation of the stabilizer (diphenylamine, DPA) in single base gun propellants during aging was investigated and successfully verified. This model assumes that the chemical transformation of the stabilizer in single base gun propellants occurs in the three concurrent steps, each representing the complex reaction, whose kinetics can be described by the reaction of the shifting order. It was found that the experimental data were well evaluated by a first-order reaction at high concentrations of diphenylamine in the propellant, but by a zero-order reaction at low concentrations during the final phase of the propellant lifetimes. The mechanism of chemical transformations of diphenylamine was discussed with relation to the model and the ageing behavior of these propellants.

Mechanical properties of RDX-CMDB rocket propellants (Radislav Stojanović, MSc (Eng), Miloš Filipović, PhD (Eng), Military Technical Institute, Belgrade)
The mechanical properties of a control double base and RDX-CMDB (composite modified double base) rocket propellant with 30 mass% of RDX (hexogen) were determined under uniaxial stresses at different loading-rates in a large temperature range. Applying a *time-temperature* equivalence concept, the mechanical behavior of the rocket propellants tested was defined in the conditions, ones in close to the real which the rocket motors operate. The comparative analysis of the mechanical behavior of the control double base and RDX-CMDB rocket propellants was performed and the influence of RDX on the mechanical behavior of CMDB rocket propellants was discussed.

Curing agent effect on solid composite propellant characteristics (Vesna Rodić, Mirjana Petrić, MSc (Eng), Military Technical Institute, Belgrade)
Three different types of curing agents have been discussed in this paper. Their effects on the viscosity were observed, and finally its dependence on the level of the burning rate and pressure exponent at low burning rate. As curing agents dymeril-diisocyanate, isophorone-diisocyanate and toluene-diisocyanate were used. Hydroxyterminated polybutadiene was used as the binder matrix, bimodal mixture of ammonium-perchlorate (ratio 70:30) as oxidant and mixture of aluminum powder (ratio 50:50) as metal component.

The effect of additives on composite solid propellant properties (Mirjana Petrić MSc (Eng), Vesna Rodić, Military Technical Institute, Belgrade)
The effect of different additives on hydroxyterminated polybutadiene based composite rocket propellants containing iron-oxide or copper-chromate viscosity and mechanical properties were investigated. The effect of tetracycline (TC), pyrogallol (PG), phosphor acid diester (RM-410) and curing catalyst comprising triphenyl bismuth (TFBi), maleic anhydride (MA) and magnesium oxide (MgO) on propellant viscosity and cure rate profile were demonstrated.

Development of the propulsive charge of improved performances of the pilot seat rocket motor (Vladimir Kapor MSc (Eng), Miloš Filipović PhD (Eng), Milorad Savković PhD (Eng), Ljupka Nenadović, Military Technical Institute, Belgrade)
The results of research and development of a new double base propulsive charge of improved performances of the pilot seat rocket motor were presented. The comparative analysis of the performances demonstrated significant advantages of this new propulsive charge with respect to the reference one. The ballistic performances of the new propulsive charge allow a safer and steadier operating phase and higher degree of security of the pilot seat rocket motor in the considered temperature interval.

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Qualitative and quantitative analysis of poly(ethylene) glycol dimethacrylate deterrent in single base gun propellants (Ljiljana Jelisavac MSc (Eng), Divna Bajramović, Military Technical Institute, Belgrade)

Identification and quantitative determination of poly(ethylene) glycol dimethacrylate deterrent in single base gun propellants was carried out. Different analytical methods have been applied to determine the appearance of triethylene glycol dimethacrylate deterrent and the content of its monomer and polymer components.

Ballistic examination as the necessary factor for checking ballistics characteristic of the powder at the point of view of keeping and storing ammunition for sniper rifle (Zorica Subotić MSc (Eng), Predrag Cerović, Military Technical Institute, Belgrade)

This paper shows the connection between the muzzle velocity, its standard deviation and deviation on the barrel muzzle caused by the condition of keeping and storing ammunition, by mathematical modelling of shooting at the target. This influence is calculated and incorporated into software for determining heat probability for the sniper rifle. The results were analyzed, and suggestions for changing the conditions for keeping and storing sniper ammunition given.

Treatment of detered propellants in interior ballistic calculations (Dejan Micković PhD (Eng), Slobodan Jaramaz PhD (Eng), Faculty of Mechanical Engineering, Belgrade)

In the paper, the procedure for determining the deterred propellant characteristics necessary as input parameters in the interior ballistic calculations is given. The basic features of the developed model for interior ballistic cycle calculation of the systems with deterred propellant propelling charge are presented. The model verification is carried out through comparison of computational results with American experimental data of 20 mm rounds with ball propellant propelling charge.

Thrust calculation methods in the optimization process for the thrust vectoring system (Saša Živković, Military Technical Institute, Belgrade)

In this paper the principles of geometry design for numerical simulation model, thrust calculation method and preliminary analyses of numerical simulations and experimental measurement of combustion products flow for a solid-propellant rocket with thrust vectoring are presented. Models are made in CFD computer application Fluent, and they are predicted for a variation of flow domain geometry parameters. The used parameters have the largest influence on the thrust vectoring.

Pyrotechnical device for cutting rope (Milorad Savković PhD (Eng), Danilo Serdarević MSc(Eng), Military Technical Institute, Belgrade)

Pyro-cutter cartridge is a device that uses pyrotechnical charge for cutting rope, enabling this work to be done without supervision. This thesis shows: construction design, results of internal ballistic testing of pyrotechnical charge and pyro-cutter cartridge as functional device. Using construction solution, the pyrotechnical charge provides the calculated delay period. The scope of this thesis includes statistical analysis of the delay period. Block diagram of the system functions and reliability evaluation has also been given.

Quality examination of napalm powder (Dragoslav Negoičić MSc (Eng), Nikola Petronijević, Mirko Stepanović, Military Technical Institute, Belgrade)

Napalm powder examinations, performed in order to determine the powder correctness and to prolong its expiration date, are shown in this paper. The first part includes the examination of physical-chemical characteristics of napalm powder and the second comprises the possibility of benzene gelatinization and the stability of the obtaitned gelatinous mixture as well as its functional characteristics.

Numerical analysis of unsteady heat transfer through powder grain (Ljubiša Tančić PhD (Eng), Military Academy, Belgrade)

The interior ballistics problem of the firing process in small arms is considered. A mathematical model of the so-called two-phase flow is derived and partial differential equations system is solved numerically by finite difference method. Quantity heat crossing from the powder gasses to powder grains is determined because this heat comes in the flow energy equation. The equation for the distribution of temperature through deepness of the powder grain is defined. As an example of the numerical treatment of the two-phase flow, the numerical modelling of the two-phase flow of powder grains and their combustion products in small arms barrel is shown. The conditions employment and shape of the powder grains are varied and influences on the calculation results numerical analyzed. The distribution of temperature through deepness of powder grain varied and its influence on the calculation results are numerically analyzed. The whole procedure is included in a computer program, and results verified through the comparison with experimental results based on their good agreement. Finally useful conclusions to line of the directions for future work on this problem are given.

Solving the equation system of projectile flight using the modified point mass trajectory method (Dušan Regodić PhD (Eng), Damir Jerković, Ivan Andrejević, Military Academy, Belgrade)

Modified point mass trajectory method enables analytical estimation of the projectile's trajectory and flight elements. Projectile is represented by three degrees of freedom point mass, loaded with aerodynamic forces and moments. Exterior ballistics differential equations are solved by fourth degree Runge-Kutta method.

The accuracy effect of the initial indirect fire data preparation on the group fire performance (Tugomir Kokelj, Dušan Regodić PhD (Eng), Military Academy, Belgrade)

In this paper, the accuracy effect of the initial indirect fire data preparation on the group fire performed by weapon (squad) and platoon-battery has been analyzed in detail. Since the existing methodology of accuracy effect calculation is insufficiently correct, the methodology was finished off and illustrated with adequate calculations. In that way, the noticed errors were corrected. Also, using PC and Excel programs partial calculation automation was performed. Furthermore, a critical analysis of the revealed mean error values accuracy of the initial data preparation while passing to the group fire was carried out. On the basis of those data appropriate conclusions and suggestions were made and given to competent authorities to consider.

Damage detection in ballistic composite materials by using embedded optical fibres (Irena Živković PhD (Eng), Miloš Tomić, Ljiljana Brajović, Aleksandar Kojović, Radoslav Aleksić PhD (Eng), IS Institute, Belgrade)

The object of this paper is the exploration of application of optical fibres as intensity-based sensors in real-time damage detection in ballistic composite materials, and discussion of loading transfer mechanisms through thermoplastic composites. For experimental purposes, thermoplastic laminate composite materials with embedded optical fibres

were made. Two configurations of fibre reinforced composite materials were tested: aramyde fibre/poly(vinyl butyral) and aramyde fibre/phenol resin. Initiation of damage and fracture during testing was detected by observation of the intensity drop of the light signal transmitted through the optical fibre. For high energy impact testing purposes, ballistic ceramic plates were added onto the aramyde fibre reinforced composite material, in case the polymer composite cannot sustain the damage successfully. Manufactured composite specimens with embedded optical fibres were subjected to the ballistic impact with standard weapons and ammunition. Results of the experiments confirmed that optical fibres may be applied as intensity sensors in real-time monitoring of structural changes in thermoplastic laminar composite materials.

Possibility of use of unique propellant charge for ammunition family to be fired from under barrel grenades launcher (Radisav Jovanović MSc (Eng), Miodrag Lisov, Radojka Eraković, Military Technical Institute, Belgrade Snežana Spasojević, HK Krusik, Valjevo)

A part of the "21 Model pattern soldier" project was developed for 40 mm ammunition family to be fired from under barrel grenade launcher. Because of tactical and technical reasons it was necessary to use universal propellant charge for each member of the ammunition family. This paper provides the theoretical analysis of the possibility of the universal propellant charge application and analysis of the results of the performed experiments. Every projectile from the ammunition family has: the same muzzle velocity, same exterior ballistics characteristics, maximum pressure gaseous products of propellant charge, under the permitted limit and different weight.

Explosive characteristics of cast PBX based on HMX, amoniumperchlorate and aluminium (Gordana Antić, Vesna Džingalašević, Milena Stanković PhD (Eng), Zoran Borković, Military Technical Institute, Belgrade)

Explosive characteristics determination of cast explosives based on octogene (HMX), ammonium-perchlorate, aluminium and polyurethane binder are presented. Sensitivity on initiation by shock wave and PBX detonation parameters: detonation velocity, particle velocity, chemical reaction duration, chemical reaction zone width, polytropic exponent of explosion products and detonation pressure are determined.

Granular high explosives based on pentryte (Mirjana Anđelković Lukić PhD (Eng), Technical Testing Centre, Belgrade)

In this paper, different processes of coating high explosives pentryte with different bonding agents and their effects on the detonation velocity are given. By adding the different binders to the explosives in the last phase of the production, explosives decrease sensibility to mechanical influences – impact and friction. A process of coating depends on the bonding agents used. Some formulations based on pentryte and bonding agents are presented. The research showed that the applied explosive binder's different waxes have different effects on the performances of granular coated pentryte. Sensibility, density, grain size, compressibility and detonation velocity are determined by the considered methods.

Investigation of compatibility of mixtures based on isopropyl nitrate and metal powders (Slavica Terzić, Mirjana Dakić - Kolundžija, Milovan Azdejković PhD (Eng), Dušan Mlađenović, Military Technical Institute, Belgrade)

The compatibility of thermobaric mixtures based on isopropylnitrate (IPN), magnesium and aluminium is investigated by micro-calorimetry. Theoretical and experimental curves of compatibility of the examined samples are presented. The burning heat of composition IPN/Mg is determined by adiabatic calorimetry.

Ratio of detonation pressure and critical pressure of high explosives with different compounds (Vesna Džingalašević, Gordana Antić, Dušan Mlađenović, Military Technical Institute, Belgrade)

The experimental data that describe explosive performance (detonation velocity and pressure) are compared with the critical pressure – the value which characterizes the shock sensitivity of explosives, one of criteria for explosive security. Presented values are the result of extensive experimental work and consider explosives with different composition and structure.

Simple method of detonation parameters calculation for CHNO type explosives (Radun Jeremić PhD (Eng), Military Academy, Belgrade)

Based on experimental values of detonation parameters of larger number of explosives and different explosive contents, and in concordance with detonation theory, a simple half-empirical method for pressure and detonation speed calculation of CHNO type explosive was developed. Model is based on Avakjan's method for calculation of content of gaseous detonation products and applied in wide range of densities. Relating to known Kamlet's method a numerical model based on BKW equation of states, there was greatly less deviance of calculated values of pressure and detonation speed relating to experimental values.

Ballistic sensitivity of explosive reactive armour (Marinko Ugrčić PhD (Eng), Military Technical Institute, Belgrade)

Theoretical analysis of the physics of the initial phase of the interaction process of the explosive reactive armour and shaped charge jet, i.e. of the armour piercing projectile, is accomplished. Final issue of this phase, which qualitatively determines the farther course of the interaction process, depends primordially on the explosive charge sensitivity in this armour. The most significant parameters that induce the explosive process impulse in the explosive reactive armour are considered. For the purpose of the theoretical evaluation of the explosive reactive armour sensitivity during interaction with the shaped charge jet, i.e. kinetic penetrator, the attempt of adaptation and generalization of the modified Walker-Wesley criterion is carried out, for both cited cases.

Experimental testing of the explosive reactive armour sensitivity (Marinko Ugrčić PhD (Eng), Vesna Džingalašević, Military Technical Institute, Belgrade, Milorad Blagojević PhD (Eng), Faculty of Technology and Metallurgy, Belgrade)

The paper represents a continuation of the theoretical and experimental research of the initial phase of the interaction process of the explosive reactive armour and shaped charge jet, i.e. of the armour piercing projectile. The results of the experimental testing of the explosive reactive armour sensitivity, during interaction with a shaped charge jet and kinetic penetrator (armour piercing projectile) are given. The theoretical evaluation of the explosive sensitivity in this armour by modified Walker-Wesley criterion of the initiation is accomplished and some calculated interaction parameters, like the position of the initiation zone and time of initiation, are compared with relevant experimental results.

Underwater demolition by plastic PETN explosive (Gorgi Minov, Milovan Azdejković PhD (Eng), Zoran Borković, Military Technical Institute, Belgrade)

A critical parameter in all demolition tasks is the necessary amount of explosive. This parameter directly affects the speed and possibility of demolition preparation, possibility of efficient explosive supply, demolition costs, as well as a series of other tactical and logistic parameters on which the demolition efficiency depends. In order to determine minimal amounts of plastic PETN explosive used during the demolition of steel and reinforced concrete construction elements, the planned testing has been done and presented in this paper.

Fragment mass distribution laws for HE projectiles (Predrag Elek MSc (Eng), Slobodan Jaramaz PhD (Eng), Faculty of Mechanical Engineering, Belgrade)

The paper considers fragment mass distribution for HE projectiles from a statistical aspect. The relevant theoretical fragment mass distribution laws are reviewed: Mott law generalized Mott formula, the modification of Stromsoe and Ingebrigtsen, exponential distribution, generalized exponential (Weibull) distribution and Held distribution model. The optimal distribution parameters are determined for six considered models, using the least square method and the available experimental data for 26 different projectiles. The comparison of theoretical results and experimental data shows very good compatibility between experiments and each of the analyzed models. However, the analysis favours three two-parametric models: generalized Mott, Weibull, and Held distribution. The further consideration yields to conclusion that Held distribution has the best correlation with the experiments.

Experimental evaluation of armour-piercing projectile effects (Božidar Žakula MSc (Eng), Military Technical Institute, Belgrade Miroslav Đorđević MSc (Eng), Technical Testing Centre, Belgrade)

In this paper, experimental method and procedure of treatment of the acquired results of fragment effect behind the target (photo of witness plates) are suggested. It enables obtaining more reliable evaluation of effects of armour-piercing and armour-piercing-incendiary projectile action. The given method's framework rests on the projectile action physical base, it is easy to apply, and is employed in the fast check of the effects of the treated ammunition.

Determining mathematical model parameters of fragments action behind the armour (Miroslav Đorđević MSc (Eng), Range Testing Centre, Belgrade, Slobodan Jaramaz PhD (Eng), Faculty of Mechanical Engineering, Belgrade, Zdravko Knežević, Range Testing Centre, Belgrade)

Behind armour plate, penetrated by small-arms armour piercing projectile, fragment cloud is generated. In this paper, mathematical model parameters for predicting the fragments' mass and velocity are designated. Fragments' position is approximated by ellipsoid shell, whose thickness decreases with the distance from the armour plate rear surface. Dimension, mass and fragments' velocity are designated in function of ellipsoid shell thickness. The obtained results of simulation are in good agreement with the experimental results, obtained by metal witness box application.

Methods for determining chemical compositions of the cast composite explosives based on polyurethane binders (Gordana Bošnjakov, Mirjana Dimić, Gordana Antić, Irena Vujičić, Military Technical Institute, Belgrade)

The procedure of determining chemical composition of the cast composite explosives with polymer binder (PBX) has been defined by classical and instrumental analytic methods. Cast composite explosives are the mixture of brisant, crystal explosive (octogen, cyclonite, PETN) and polymer binder, with or without other additives (aluminium, inorganic oxidants). The binding component is thermo reactive and insoluble in organic solvents and inorganic acids. Determining explosive mixture compositions with this type of binder is complex because a total separation of solid components from the polymer net, resistant to solvents, is needed.

Statistical analysis of the radiosounding atmospheric data (Dragoslav Petrović PhD (Eng), Military Technical Institute, Belgrade)

Dependence of the radio sounding meteorological data on the method for statistical analysis is presented. It is found that the best method can not be applied for the case of radar radio sounding for it precludes check of the radar data accuracy. In the case of contemporary radio sounding device, the best method can be applied. Statistical characteristic of experimental test results for horizontal pulsation velocities distribution is given, confirming that their part in the total turbulence energy is important.

Transformation of meteo-message data (Dragoslav Petrović PhD (Eng), Military Technical Institute, Belgrade)

In the paper, the possibility for transforming the data from meteo-message "meteo-average" – ME into data of "meteo-real" – MST was analyzed. Procedure which ought to be incorporated into ballistic module of fire control system is given. Procedure for transforming the data from ME into data of MST is illustrated by a numerical example.

Ballistic values of meteorological elements (Dragoslav Petrović PhD (Eng), Military Technical Institute, Belgrade)

The procedure for determining the ballistic values of meteorological elements that are used for proving ground external ballistics experiments data processing is presented. For army troupes' purposes, automatic calculation coefficients for meteo-message, the so called "meteo-average" usage is given. Numerical experimental results are given.

Estimation of regular fragmentation of high explosives missiles by unique statistic value (Jovanović Radisav MSc (Eng), Momirović Vladimir MSc (Eng), Jokić Vladan, Military Technical Institute, Belgrade, Milosavljević Gordan, HK Krusik, Valjevo)

High explosives missiles are very important in combat. In their development, reconstruction and assembly-line production it is very important to know their characteristics and test their performance. Fragmentation of HE missiles is the final performance when rounding up the function as complex thermodynamics system. Because of that, it is possible to estimate the regular fragmentation which depends of the purpose of analysis. It is necessary to make a mathematical connection between the fragmentation characteristics and then use the mathematical function. This subject shows a correlation between four main characteristics of fragmentation of HE missiles by one statistic value (here named USP) and results of the estimation of regular fragmentation by USP.

Calibration of system for digitalized recording by high-speed electronic camera Imacon 790 (Gordana Kekić, Vesna Džingalašević, Military Technical Institute, Belgrade)

Digital imaging system for ultra high speed recording consists of: ultra high speed converter camera Imacon 790 (UHSC), video camera optically coupled to UHSC output phosphor and personal computer with video board

miroVideo DC30. Calibration was made for system characteristics determination and comparison with previous recording technique. Dynamic range, linearity and space resolution of this system, as well as transfer characteristics of the video camera were determined. Verification of video camera resolution and linearity - distortion checking, were made.

Special events

During the Symposium, a visit to the stone-pit, near to the port of Bar, was organized for the participants. The procedures of rock undermining, crumbling, and final treatment of the stone were represented *in-vivo*.

Also, an unforgettable sightseeing tour whose highlight was the old town of Bar was arranged.

Organization

The organization of the Symposium, as well as the above mentioned social events, was excellent, mainly due to the permanent care and enormous efforts of the chairman of the Committee, Mr Radislav Stojanović, and his tireless collaborators from the Military Technical Institute as well as the very kind host Mr Zoran Damjanović from YUGOIMPORT-MONT.

During the final meeting, the election of the new chairman of the Committee for explosive materials from the Technical Testing Centre, Miroljub Vukašinović PhD (Eng) was unanimous.

Conclusion

The Symposium provided an extraordinary opportunity for the participants to meet and discuss recent advances in *explosive materials* in our country. The participants presented a wide range of topics, from pure theoretical analyses to practically oriented applications. Significant achievements of the Symposium were very extensive discussions taking place over the whole range of actual problems concerning the production, safety, and application of explosive materials.

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22 JKEM – Jugoslovenski komitet za eksplozivne materijale

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22-ой Югославский комитет о взрывчатех веществах

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Le 22ième YKEM – commité yougoslave pour les matières explosives