



INTERNATIONAL BALLISTICS SOCIETY

The International Ballistics Society (IBS) promotes the science of ballistics internationally. The IBS provides for technical interchange via an International Symposium on Ballistics and provides professional development for its members by providing opportunities for publication, short courses, student programs, and other activities to promote career development.



Letter from the President

Once again many of us find ourselves in continuing challenging economic times. In particular as research and development funding reduces we have to work even harder to justify a research programme or area of study. This can of course have a knock-on

effect in our ability to publish the results of our research in journals and at conferences. I would hope that your conference of choice is the International Symposium on Ballistics (ISB). It is after all your conference. We are now working very closely with the NDIA (Britt Bommeljé and Kari King) preparing for the 28th ISB to be held in Atlanta 22-26th September 2014. I also want to bring you up to date with what the Board and our volunteers have been working on to develop our Society.

Looking Back

In the weeks following an ISB it is useful to take stock and review and implement the lessons learned. There always seems to be so little time to do this before we are into the planning for the next ISB!

Freiburg

I think all of those who attended the Freiburg ISB will agree with me that it was an outstanding technical and social success. I would like to thank formally Klaus Thoma and his team for looking after us so very well in the surroundings of a very beautiful city. Matthias Wickert, Manfred Salk, Thilo Behner and Brigitta Soergel and their team put in a tremendous effort to make sure everything went like clockwork, especially the presentations. The social programme was also outstanding and overall the EMI team provided us with an exceptional environment to talk about our research.

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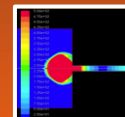
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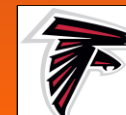
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Help Needed from Members!

1. **Recruit new members** - spread the word and get your colleagues to join
2. **Get involved** - see the website for a list of committees and projects with contacts
3. **Send or post cool photos** - we want good photos showing ballistic events in each field
 - Interior Ballistics
 - Exterior Ballistics
 - Launch Dynamics
 - Vulnerability
 - Terminal Ballistics & Impact Physics
 - Explosion Mechanics

Please upload photos at
www.ballistics.org

Remember to be responsible with sensitive or restricted information!

The technical quality of the papers continued to be very high with an increasing emphasis on the number of papers concerned with Terminal Ballistics. This trend clearly reflected the current research emphasis in many countries.

I was also impressed with the poster papers which generated a considerable degree of networking by delegates compared to previous ISB. The challenge now of course is to repeat this at Atlanta. So far the abstracts submitted for Atlanta seem to be of a high quality. Let's hope the papers live up to this promise!

The number of successful journal papers also increased with a wider range of topics and higher technical quality. They appeared in a special edition of the Journal of Applied Mechanics (JAM) and once again I would like to thank Bo Janzon for his hard work as the guest editor of JAM. On behalf of the Board I would also like to thank members who have acted as reviewers of abstracts and papers. Without your hard work we would not have a symposium.

Student Awards: One of our first tasks has been to initiate the Students Award scheme. The initial hard work was led by Ken Kuo, who championed the idea of offering bursaries to students studying ballistics science. I would like to acknowledge the debt the Society owes him for his efforts in establishing the principles behind the Student Award. Francisco Galvez has taken over the task to bring the Award scheme to fruition and I am sure you have all seen his letter announcing the awards. We are offering one award to a student in each of the 6 ballistics science disciplines who produces the best paper. The award covers the registration fee at the Freiburg symposium and provides \$1000 towards travel and accommodation expenses.

The response to the Student Award scheme in Freiburg was outstanding. However to date we have had no applications for Atlanta. This is a great disappointment. So if you are a student who has contributed to a paper for Atlanta please think about applying for a Student Award.

Business Meeting: The Society's first business meeting, which was held immediately after the end of the symposium on the Friday afternoon, was considered a success. The Board would like to thank all those you attended and contributed to the meeting. Your questions and comments will be acted upon. For example we will be publishing our accounts in future. We will repeat this in Atlanta as this is your opportunity to interact with and be involved in the Society and its business. It will provide you with the chance to hear from and question the Board and the Society's officers about the Society's finances, membership and plans for the future and make your views heard. It will also be an opportunity to meet the Board and put faces to names. I therefore urge you to attend this important meeting.

Board

Education

Jack Riegel and I have been discussing what the International Ballistics Society should embody. In Miami we both recognized that being able to promote on-going training and education for members made the Society stand above an organization 'that simply organized a symposium'.

I share this vision with Jack who has made a strong personal commitment to putting an education program in place for the membership.

Jack will be providing more information on the work of the Education Committee as we move towards Atlanta but I would urge you to let him or me have your views on whether the Society should offer courses and what these courses might entail. Contact me (president@ballistics.org) or Jack (education@ballistics.org).

Looking Forward

Atlanta: Clive Woodley and I have been working with our website developers Vieth and Kari King from the NDIA to develop an ISB website that is part of our website www.ballistics.org. This will place everything concerned with an ISB readily accessible on a single website. Not only will you be able to register and select the social program, you will be able to register for training courses and submit your abstracts, papers and presentations. We will finally be in full control of our ISB. The website was launched in October and has had few problems – thank goodness!

Journal Papers: We learned in Freiburg that the new editor of the Journal of Applied Mechanics has decided not to publish any further special editions with immediate effect. This was a bitter disappointment for the Board, which we were forced to accept. We spent a hectic few months finding an alternative journal and ended up with three possible journals. In the end the only journal that met all of our requirements was Defence Technology, sponsored by China Ordnance, but published by Elsevier. We hope it will soon become an established journal and that you will submit your ISB journal papers to Defence Technology. Once again Bo Janson has agreed to be the guest editor for our special edition for the Atlanta ISB journal papers. If you are invited to review a paper for the journal I do hope you will accept.

VISAS: If you are not a US citizen then you may require a VISA to attend the symposium. This can be a lengthy process so I would urge you to apply in good time and follow the requirements set down by the US Government. If you require a letter of invitation then contact Kari King (kking@ndia.org). Whilst the organizers can provide supporting letters and invitations, they cannot enter into discussions with the US State Department on your behalf.

...and Beyond

We have agreed the venues for the two next ISB after Atlanta. The 29th ISB will be held in Edinburgh Scotland from the 9th to 13th May 2016 and the 30th ISB will be held in Long Beach California from the 12th to 17th September 2017. Please make a note in your diaries. With regards to future symposia Dennis Baum and I have been hard at work revising the Guidelines for hosting a symposium to help those bidding to host a symposium understand what is required and to prepare a winning bid. We would be interested in your ideas on possible venues for future ISB. If you have any suggestions please contact Dennis Baum or me. In Atlanta the Board will be deciding the venue for the 31st ISB.

Communications

Nicolas Echès has taken on the role of Chair of the Communications Committee and he will be talking about how we might improve communication within the Society. Please take the time to carefully read his contribution in this newsletter and get back to him with your comments and suggestions. This is an area where there is plenty of scope for volunteers to help. So if you have some spare time then get in touch with Nicolas.

Remember to visit our website where you will find new links to future events and other features. It is also a useful way to send messages to other members. In addition don't forget the Archive where you can put articles and photographs concerned with your ballistics research, past symposia or the history of ballistics science. We are always interested in receiving new ideas to improve the website, just drop us an email.

More importantly why not get involved in the Society? We would welcome your support in any way.

Talking to the Press

In Freiburg a new member inadvertently spoke to a member of the press. This led to a demonstration outside the conference center by those opposed to the study of ballistics and caused some difficult problems for the organizers and the Board, resulting in Klaus Thoma and I having to provide an interview for the local television company. Can I remind you that you should refer any enquires in any form from the press, directly to one of the Officers of the Society or a Board member.

Offering Advice

We recently received a request for advice on a ballistics related problem that was to feature in a court case. The Board decided that it would not be in the Society's best interest to offer an opinion, since this might lead to future litigation leaving the Society and/or members financially liable.

If you get approached with a request for ballistics science related advice please make sure you are covered by professional liability insurance, which is usually provided by your employer. If you do decide to offer advice or an opinion on a personal basis please do not associate your opinion with your membership of the Society.

Saying Hello

In our last newsletter we said farewell to Sam Campagna who retired from the NDIA last December. I would now like to say 'Hello' to Britt Bommelje who has assumed responsibility for those ISB organized by the NDIA. Britt brings a wealth of experience of organizing conferences and meetings. Kari King will be working with her to make Atlanta a great success.

I hope you find the remainder of this newsletter of interest and will contribute to future ones.

Here's to a very successful ISB in Atlanta.

With every good wish.

A handwritten signature in black ink, reading "Ian Cullis". The signature is written in a cursive style with a long horizontal flourish underneath the name.

Ian Cullis

President

International Ballistics Society

**PEI CHI CHOU (1924 - 2014)**

The Society is sad to announce the passing of one of our founding members, Professor Pei Chi (Peter) Chou, on Thursday, February 13th at age 89. Pete Chou will be remembered as an outstanding ballisticians, who introduced numerical simulation to many areas of ballistics. He was a keen supporter and founding member of the Society. He commissioned the Chou Award to encourage young authors to publish their research. He will be sorely missed. A biography can be found at : <http://www.detrk.com/wp-content/uploads/2013/10/15th-ISB-Chou-tribute-long-versionsearchable.pdf>

**MEMBERSHIP INFORMATION**

Clive Woodley

Chair of IBS Membership Committee

Membership numbers

Currently the IBS has 580 members, of whom 95 are Lifetime Members. Despite the difficulties caused by the budget problems in the USA that affected attendance at the 27th ISB (International Symposium on

Ballistics) in Freiburg, the IBS has maintained a good membership retention rate. Approximately 35% of those members due to renew their membership in April 2013 did so, which compares with 55% renewed at the Miami ISB. Taking lifetime members into account then the membership retention rate was 55%. At the 27th ISB, 228 new members joined the IBS, leaving a net loss of only 74 members.

The IBS has members in 38 countries, an increase of three since the Miami ISB, showing our growing international status and reputation. At the 27th ISB, the IBS gained members from five new countries. A warm welcome is extended to those new members in Argentina, Brazil, India, Jordan and Tunisia. Sadly all the members from Colombia and Thailand did not continue their membership. Four continents are represented by our membership. It would be great to get a member from the missing continent, the Antarctic!

Currently the IBS has only eight student members (although there are seven other students who are delegates of university members). The IBS is trying to increase its student membership because they will be the ballisticians of the future. The main way we are trying to achieve this is by offering training or educational courses. Details of these are described elsewhere in this newsletter and on our website. Meanwhile, we urge all members to encourage students involved in ballistics to join the IBS.

New ordinary members are always welcome. It costs only US\$50, though you might find it better value to become a Lifetime Member. Please encourage your friends and colleagues to join. You could also encourage

your employer to join as a corporate member.

Please remember that one of the benefits of membership of the IBS is the ability to download free of charge a limited number (this varies according to membership level) of individual papers from previous ISB each term. These papers are available from our Online Store.

University Membership

Since the last newsletter, the IBS now has one more University Member: the Royal Military College of Canada.

Other universities have been invited to consider becoming University Members. If you are interested then please contact the Membership Committee (membership@ballistics.org) for further details.

Corporate Members

The IBS has two new Corporate Members: Computational Mechanics Associates and NUMERICS GmbH.

Senior & Fellow Members

The IBS has several individual membership grades, including Student, Ordinary, Senior, Fellow and Ballistic Science Fellow. Promotion to Senior and higher levels may be achieved through attending and presenting papers at ISB and/or by winning awards. A member's membership status may be reviewed at any time. However, the onus is on the individual to apply, with support from Fellow Members, as appropriate. If any member is uncertain on their eligibility then please contact the Membership Committee. We are waiting to here from you!

IBS cotton shirts (short sleeve)

These have been very popular with the members and would make a great present. Dozens have been sold at ISB, at festive occasions and for birthdays.

The IBS still has several blue shirts available for US\$30 each (plus postage). Each shirt has the IBS logo embroidered on the left hand sleeve and the words "International Ballistics Society" embroidered just above the pocket (see photo). Sizes available are M, L, XL and 2XL. Some shirts are available in S size without the pocket for US\$25 (plus postage).

If you are interested in purchasing one or more then please contact the Membership Committee.



SCIENTIFIC PUBLICATION FOR THE INTERNATIONAL SYMPOSIA
ON BALLISTICS

By Bo Janzon,
Chair of IBS Publications Committee

This was initialised in response to requests from Symposia participants, who wanted reviewed publication for their quality control, for advancement or to reach an academic degree, and where publication in the Symposium Proceedings was not seen as sufficient.

Since 2010 a total of about 70 scientifically reviewed papers were published in the renowned Journal of Applied Mechanics (JAM), thanks to a kind offer by Professor Robert McMeeking of the University of California, Santa Barbara, who was the Editor until 2012, and a Special Issue with 20-25 papers, was published at each Symposium. Early this year, however, the new Editor decided not to publish any more Special Issues, so the International Ballistics Society urgently needed to find a new venue for its scientific publication.

Options were discussed at the latest Symposium at Freiburg, Germany, in May 2013, resulting in a short-list of three Journals, which were sent a number of requirements put up by the IBS, among them being

- Acceptance of papers on all topics current at the Symposia,
- Ability to publish a special issue with up to 25 papers from the Symposium,
- Ability to execute the reviews in a timely fashion and to publish in time for the Symposium (but not before), at
- Very limited or no cost to the Symposium or the Society.

Of the Journals selected it turned out that only one would fulfil all our requirements: **Defence Technology** (DT), sponsored by the China Ordnance Society (COS). The aim of this Journal is to become the premier worldwide choice for scientific publishing within defence technology.

The IBS had excellent experience of collaborating with the COS, which is a professional (learned) society of qualified scientists and engineers active in ordnance technology, with over 22 000 members, and it was also the body which very successfully organised the 25th ISB at Beijing China.

Professor Zhongyan Wang of the Nanjing University of Science and Technology is a noted member of the COS, an Associate Editor-in-Chief of the DT and also a member of the IBS Executive Board. It was agreed that DT will publish a Special issue at the occasion of the 28th International Symposium on Ballistics, to be organized by the NDIA at Atlanta, GA, in September of 2014.

All papers submitted will be rigorously reviewed, each by at least two peers. Professor Bo Janzon, who was Guest and Associate Editor for the JAM since 2010, will serve in that capacity also for the DT, in order to ensure continuity. DT has an qualified editorial office at Beijing, which will be responsible for the day-to-day handling of the papers.

Defence Technology is not a new Journal, it was published in China for ten years or more, in the last few years also in English. Beginning in 2013 it will be published by Elsevier as a Gold Open Source Journal, meaning that it will be freely available to all via the Internet, and there will be no charges for the authors. The 28th ISB Special Issue will be available online from the first day of the Symposium, and there will also be a printed issue, to be sent to those interested.

Please assure your copy (at nominal cost) by sending a message titled "DT – printed Special Issue", with your name and postal address to publications@ballistics.org and you will receive it in the mail shortly after the Symposium!



COMMUNICATION COMMITTEE UPDATE

By Nicolas Eches

Chair of IBS Communication Committee

When I told Ian Cullis, during the last ISB in Freiburg that I was willing to give a hand to the Society, I did not expect to get such an interesting and challenging task as the chairman of the Communication Committee.

Fortunately, the task had been already initiated by Tony Russell and Jack Riegel, who were a great help for my debuts.

We are still in a transition phase, as the Committee is not yet totally set. When I asked for assistance for this work, I had the very good surprise to get about twenty positive answers. This is a lot, but this is a chance as we'll have a lot of energy to input into this committee, and will be able to perform several works in the same time. Some sub-committees will be created, whose statement of work, and composition will be unveiled in the next newsletter. The purpose is to improve our visibility outside the society, in order to attract new members and sponsors, which is necessary to have a lively society. A second goal, related to this lively society, is to improve the communication between members, to get to know each other, to make our relationships more fruitful.

As says Ian Cullis in his foreword, this society is yours. Then, if you have any comment, suggestion or idea to improve this newsletter and the IBS Communication in general, do not hesitate to send me a message at communications@ballistics.org

27th ISB Highlights



REVIEW FROM A CHAIRMAN'S PERSPECTIVE

By Matthias Wickert

Co-Chair of the 27th International Ballistics Symposium

On behalf of the International Ballistics Society, Fraunhofer EMI has organized the 27th International Symposium on Ballistics in the Concert Hall Freiburg last April. Finally, we had 432 participants from 33 nations and the accompanying exhibition of scientific instruments and technologies was used by numerous suppliers.

It was the first time that the IBS board together with the chairman decided to use the new web-based abstract submission system. It was clear that there would have to be several extensions to the basic submission system design since we wanted to handle not only the abstracts but also the papers. But this worked out well with the software company in charge and for the future the society can rely on experience with the system.

We have been very pleased to receive more than 200 abstracts qualifying for the symposium and allowing us to make a proposal for an inspiring program to the board based on the electronic reviews of the abstracts. The electronic handling of the documents and the exchange of feedback to the program by electronic communication finally worked out so well that in this case the board was able to accept a preliminary program without having to organize a separate meeting for the paper selection with the resulting substantial travel effort.

After receiving the papers it was very helpful to be able to rely on a publisher, Destech, who is very experienced with the publishing of the symposium proceedings.

The main challenge for me as the chairman turned out at the point when it became clear that US authors from government institutions would not be able to present their contributions due to governmental travel restrictions. So, just a few weeks prior to the symposium I had to contact different authors and ask them if they were willing also to contribute in the form of an oral presentation and I am very grateful for these authors to support the symposium.

We received a large number of registrations in the last weeks before the conference but the Concert Hall did offer plenty of capacity for the event. Together with the revenue of the ballistic tutorial lectures on the Monday before the opening reception we have been able to support the society well while covering the expenses for the organization of the symposium. The good cooperation with the board of our society and the practical attitude of our president Ian Cullis allowed responding to all the challenges in a suitable way.

Especially, I would like to thank my Co-chair Manfred Salk for his support and Brigitta Soergel for managing the organizational issues together with our congress agency Intercongress.

NEW BALLISTICS SCIENCE FELLOWS NOMINATED

During the Gala Dinner held on the Thursday Evening during the Freiburg Symposium, the nomination of three new Ballistics Science Fellows was announced by Ian Cullis.



Pierre Yves Chanteret was awarded for his “outstanding and singular research into the science of Explosion Mechanics and the development of shaped charges. His meticulously executed experimental and modeling studies have elucidated a fundamental understanding of the science that governs shaped charges to the benefit of the ballistics community. Uniquely his contributions to ballistics science have been recognized by twice being the recipient of the Louis and Edith Zernow award. “



Marc Giraud was awarded for “outstanding research in Exterior Ballistics. His unique and creative contributions to classical exterior ballistics and fluid mechanics have been recognized by the award of the “Chevalier de l’Ordre National du Merite”. He is a Fellow of the Aeroballistics Range Association and holds its Ballistics Award. He was one of the founding members of the International Ballistics Committee and as its Chairman showed outstanding leadership to secure the adoption of its Charter, the fore runner of the Society’s Constitution.”




Meyr Mayseless was awarded for his « outstanding research in Explosion Mechanics and Terminal Ballistics. His experimental work and analytical modeling have been seminal in demonstrating the fundamental properties of shaped charge jets and their interaction with a range of armors and other targets. Uniquely his contributions to ballistics science have been recognized as the only member of the Society to have been awarded both the Louis and Edith Zernow and the Neil Griffiths award.




BALLISTICS AWARDS


One of the key events of the International Ballistics Symposiums is the announcement of the different Ballistics awards, which reward remarkable contributions in the different fields in Ballistics. In Freiburg, the ceremony was held on the Friday, at the end of the oral presentations.

The Louis and Edith Zernow award, which rewards the paper containing the best advancement made in the fundamental nature of ballistics, went to J-L. Zinszner, B. Erzae, E. Buzaud and P. Forquin for their work on "Experimental and Numerical Analyses of the Fragmentation of Alumina".

The Rosalind and Pei Chi Chou award, which rewards a young author whose paper brings an original contribution to ballistics science, went to D.Klatt for its "Investigation of the Magnus Effect on a Generic Projectile at Mach 3 up to 16 Degrees Angle of Attack." 



 The Neil Griffiths Award, which is presented to the author of the paper judged to have made the most significant contribution to a shaped charge technology went to S.Rassokha, G. A. Kubyshkina, S. V. Ladov and A. V. Babkin, for their works on "Performance Calculation of Shaped Charges with Shear Formed Liners."

The South African Ballistics Organization (SABO) award gives recognition to the author(s) of the best poster as displayed and presented to appointed adjudicators at the International Symposium on Ballistics. In Freiburg, it went to H. Lips and K. Menke for their works on "Fox7/Gap Rocket Propellants for a Shoulder Launched Projectile". 



The Student award provides conference registration and travel support to selected students for attendance at the International Symposiums on Ballistics. This award has been attributed to:

Cyril Robbe

Timo Saileranta

Heath Martin

Alon Weiss

Roman Kostiski



All information to know how to submit for nominations for the Atlanta symposium can be found at:

http://www.ballistics.org/student_awards.php



WINNING PAPERS ABSTRACT

Louis & Edith Zernow Award

EXPERIMENTAL AND NUMERICAL ANALYSES OF THE FRAGMENTATION PROCESS IN ALUMINA

J.-L. Zinszner^{1,2}, B. Erzar¹, E. Buzaud¹ and P. Forquin²

¹CEA, DAM, GRAMAT, F-46500, Gramat, France

*²Laboratoire d'Etude des Microstructures et de Mécanique des Matériaux (LEM3),
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Thanks to their high mechanical properties and their low densities, ceramic materials are commonly used for armour systems. In this work, five spalling tests using ramp loading have been performed on an alumina ceramic. This technique allows determining more accurately the strain-rate at failure, in comparison to plate impact experiments generally performed. A significant strain-rate sensitivity has been highlighted. More, a damaged but unbroken specimen has been recovered, giving us a unique insight on mechanisms activated at very high rates of loading. A micromechanical model based on the description of the underlying physics has been used to model the spalling tests (DFH model). A good correlation is observed between experimental and numerical results, particularly for the free surface velocities where the evolution of the spalling strength due to rate effects is well-represented.

WINNING PAPERS ABSTRACT

Rosalind & Pei Chi Chou Award

INVESTIGATION OF THE MAGNUS EFFECT ON A GENERIC PROJECTILE AT MACH 3 UP TO 16 DEGREES ANGLE OF ATTACK**D. Klatt, R. Hruschka and F. Leopold***French-German Research Institute of Saint-Louis (ISL), 5 rue du Général Cassagnou,
68301 Saint Louis Cedex, France*

The Magnus effect on a generic 6.37 diameter long tangential-ogive-cylinder type projectile was studied by means of 3D Reynolds-Averaged Navier-Stokes (RANS) simulations and wind tunnel measurements. The nominal Mach number was 3 and the Reynolds number based on the model length was 1.09×10^7 . The simulations provided a profound insight in the flow structure and revealed a shift of the cross-flow separation lines as consequence of the spin. This was shown to be the primary source of the Magnus side force for the higher angles of attack in the investigated range. The nonlinear dependence of the Magnus side force on the angle of attack, reaching a maximum value between 10 and 15 degrees before decreasing again was analyzed. The occurrence of secondary vortices in this range of angles of attack is presented as an explanation for a locally negative Magnus side force portion acting on the model.

WINNING PAPERS ABSTRACT

Neil Griffiths Award

PERFORMANCE CALCULATION OF SHAPED CHARGES WITH SHEAR-FORMED LINERS**S. S. Rassokha, G. A. Kubyshkina, S. V. Ladov and A. V. Babkin***Bauman Moscow State Technical University, 105005 2nd Baumanskaya 5, Moscow, Russia*

Production of shear-formed liners for rotating shaped charges is of interest since it causes the jet self-spinning effect, which drastically affects the penetration process. A novel fourpart methodology for performance parameters calculation of such charges was suggested. First, the liner strained state is related to the feed rate and mandrel angular velocity during the shear-forming process. Second, based on the polycrystal plasticity theory, a methodology for determining the liner plastic anisotropy parameters depending on its strained state is realized. Third, a general dependence of the jet angular velocity on the liner plastic anisotropy parameters is obtained. The fourth part presents the methodology of shaped charge performance calculation with respect to spinning effects. The results of calculations performed according to the suggested methodology are in good agreement with experimental data.

WINNING PAPERS ABSTRACT

SABO Award

**FOX7/GAP ROCKET PROPELLANTS FOR A SHOULDER
LAUNCHED PROJECTILE****Hendrik Lips¹ and Klaus Menke²**¹ *Dynamit Nobel Defence, 57299 Burbach-Würgendorf, Germany*² *Fraunhofer Institute für Chemische Technologie, 76327 Pfinztal, Germany*

Several Fox7 based propellant formulations were studied in order to obtain a minimum or reduced smoke composite propellant with inherent IM-properties. Two polymer binder systems are examined: the high energy GAP and a low energy poly-urethane binder containing a large fraction of high energetic plasticizers. Variation of the AP level in the Fox7/GAP propellants gives burn rates of between 10 and 20 mm/s with low pressure exponents. Crawford as well motor-firings of Fox7/AP/GAP formulations indicated a surprising plateau burning behavior between 7 and 12 MPa, very similar to Double-Base propellants. Chemical stability and sensitivity data demonstrated acceptable values. Fox7/PU compositions with nitro plasticizers exhibit the best thermal stability within ARC measurements. Shock sensitivity test results correspond to values with a 1.3 hazard classification. The conclusion is that Fox7/GAP propellants are suitable for the rocket propulsion of projectiles in shoulder launched weapons, although the mechanical properties may need further improvement.

Editor's note: see the poster next page

THE NEWSLETTER NEEDS YOU !

The newsletter is one of the means to keep you informed about the life of the society, and about the main events it organizes. You can participate to make this bulletin more lively and closer to your fields of interest by proposing technical papers about works you've performed, or facts about ballistics you've been aware of. For instance, if by browsing the web you find sites related to ballistics you think they may be interesting, funny, or worth to be shared, do not hesitate to send a message to communications@ballistics.org. Nevertheless, be careful not to infringe any copyright, or classification rules.

Also, we all belong to lots of different organizations, industries, or laboratories. It could be interesting for other members if, from time to time, one of you made a short informative presentation of its organization. This presentation should be more information than advertising, and have the same obvious requirements about copyrights and classification. Any other type of contribution is obviously welcomed!!

Thanks in advance!



Hendrik Lips*, Klaus Menke

FOX-7/GAP Rocket Propellants for Shoulder Launched Projectiles



Introduction

Requirements for a future propellant:

- smokeless,
- high energetic,
- insensitive to stimuli,
- thermally and
- chemically stable.

FOX-7 (DADNE) is a solid explosive with designated properties:

- highly energetic,
- insensitive,

- thermally stable
- reduced shock sensitivity (vs. rs-HMX)

Therefore FOX-7 is an attractive ingredient in smokeless composite rocket propellants with reduced vulnerability (→ IM response)

The basic propellant formulation included:

FOX-7 (70 wt%)

GAP binder (30 wt%)

Objective

Development and characterization of an insensitive minimum-smoke fast-burning composite propellant for propulsion of projectiles with high acceleration forces launched from shoulder launched weapons based on FOX-7 compositions by:

- utility of the energetic elastomeric GAP binder
- variation type & amount of energetic plasticizers
- increase burn-rate by varying Fox7/AP ratio
- addition of combustion moderators
- addition of suitable stabilizers

To suit and enhance mechanical properties to survive extreme launch conditions by:

- increasing the GAP crosslink density
- varying type & amount of primer to coat FOX-7

Approach

FOX-7 End-burning grains for ballistic test firings



Fig. 1: inhibited FOX-7/GAP propellant grains DNX-06 and DNX-16 prepared to be tested in Ø 70 mm rocket motor



Fig. 2: Plume signature of a static motor firing with minimum-smoke DNX-06 propellant FOX-7/GAP/AP composition

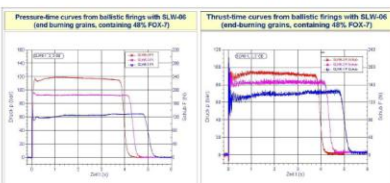


Fig. 3: Pressure and thrust curves from ballistic test-firings of minimum-smoke propellant DNX-06

Results

Signature-classification (STANAG 6016)		Smokeless AA		Minimum Smoke AB		Reduced Smoke AC		
Formulation		DNX-08	DNX-12	DNX-06	DNX-13	DNX-14	DNX-16	DNX-00
	Ingredients	max Fox7						max AP
Energetics	Fox7	68	54	48	38	33	28	/
	AP	/	14	20	30	36	42	68
Binder	GAP	15	15	15	14	15	14	15
Plasticizers	BTTN/TMETN	15	15	15	15	14	14	15
modifiers (Stab.+Ballist)		2	2	2	2	2	2	2
Ox balance	%	-43,0	-35,2	-31,9	-30,8	-22,6	-17,8	+1,4
Flame Temp.	K	2156	2402	2500	2470	2760	2890	3055
specific imp.	s	216	225	228	227	237	240	250
Crawford results								
Burn-rate (70 bar) mm/s		8,3	9,3	11,0	11,0	16,0	19,3	30
Pressure exp.	2-25 MPa	0,66	0,57	0,49	0,41	0,34	0,27	0,2

Fig. 4: Thermodynamic performance FOX7/GAP formulations vs. experimental burn-rates and pressure-exponents from Crawford ballistic-bomb tests

Comparison of Crawford results with static motor firings

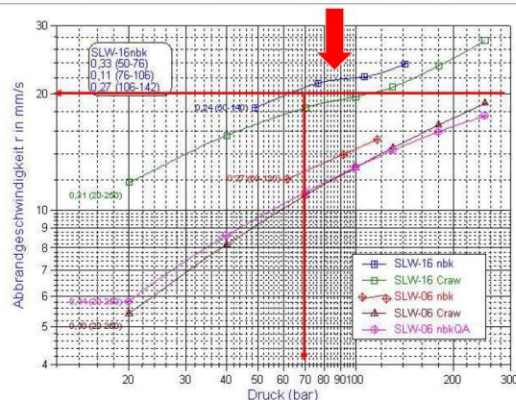


Fig. 5: Motor-firings confirm plateau-burning behavior of reduced-smoke DNX-16 composition

Conclusions

FOX-7 based propellant formulations were studied in order to obtain a minimum- or reduced- smoke composite solid propellant with inherent IM-properties. The cast-cured composite propellant system is examined, including the high energy GAP elastomeric polymer binder containing a large fraction of high energetic plasticizers. Variation of the AP level in the FOX-7/GAP propellants give burn rates between 10 and 20 mm/s with low pressure exponents. Crawford as well as motor firings of FOX-7/GAP/AP formulations indicated a surprising plateau-burning behavior between 7 and 12 MPa, very similar to Double-Base propellants. Chemical stability and sensitivity data demonstrated acceptable values. Finally, FOX-7/GAP compositions with energetic TMETN-BTTN plasticizers exhibit suitable thermal stability and adequate mechanical properties within the investigations. Shock sensitivity test results correspond to values with 1.3 hazard classification. In conclusion, FOX-7/GAP propellants are suitable for rocket propulsion of projectiles in man-portable shoulder launched weapons, although mechanical properties may need further improvement.

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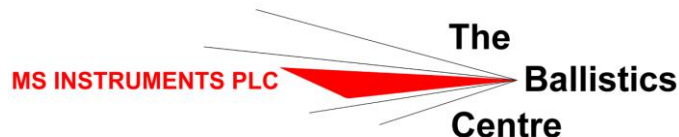
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