ESHP 2023

Book of Abstracts

Seventh International Symposium on Explosion, Shock wave and High-strain-rate Phenomena

Maribor, Slovenija, September 6-8,2023

Edited by
Zoran Ren, Kazuyuki Hokamoto, Anja Mauko

University of Maribor

Faculty of Mechanical Engineering

ESHP
2023

Book of Abstracts

Seventh International Symposium on Explosion, Shock wave and High-strain-rate Phenomena

Editors
Zoran Ren, Kazuyuki Hokamoto, Anja Mauko

Maribor, Slovenia
September 6 – 8, 2023

Title
ESHP 2023 : Book of Abstracts : Seventh International Symposium on Explosion, Shock wave and High-strain-rate Phenomena

Editors
Zoran Ren, Kazuyuki Hokamoto, Anja Mauko

Printer
Uprint grafične storitve in trgovina d.o.o.

Publisher
Univerza v Mariboru

1st edition – September 2023

Print run
60 copies

Legal deposit
https://eshp.um.si/

CONTENTS

PREFACE

In recent decades, the study of explosion, shock wave, and high-strain-rate phenomena has experienced remarkable growth, mirrored by the exponential expansion of scholarly literature in this field. The industrial sector, attuned to the increasing significance of energetic materials and transient dynamic phenomena, has witnessed a transformative wave with the emergence of novel metamaterials, catalysing advancements across various industrial applications.

Within this evolving landscape, workshops, symposiums, and conferences have emerged as pivotal platforms for exchanging ideas and discoveries. Among these, the ESHP (Explosion, Shock wave, and High-strain-rate Phenomena) symposium series stands as a cornerstone. The inaugural International Symposium on Explosion, Shock wave, and High-strain-rate Phenomena, conceptualized by Prof. Shigeru Itoh and hosted at Kumamoto University in 2004, marked the genesis of an enduring journey. Since then, the significance of ESHP symposia has steadily burgeoned, with subsequent editions convened in Kumamoto, Japan (2007); Seoul, Korea (2010); Okinawa, Japan (2013); Beijing, P.R. China (2016); and Puducherry (a.k.a. Pondicherry), India (2019).

The rhythm of triennial ESHP symposia was perturbed by the Covid-19 epidemic, leading to an unprecedented disruption. Consequently, the seventh iteration of the ESHP symposium, ESHP 2023, makes history by venturing to Europe for the first time, finding its abode in Maribor, Slovenia, from September 6th to 8th, 2023.

ESHP 2023 embraces a focal point on seminal advancements in theoretical, computational, and experimental research concerning explosion, shock wave, and high-strain-rate phenomena, engulfing topics such as:

- The chemistry of deflagration, detonation, and shock waves in energetic and reactive materials.
- Evolutionary material processing techniques like explosive cladding.

- Dynamic material behaviours and the performance of metamaterials under conditions of elevated strain rates.
- The consolidation intricacies inherent in powders and composite materials.
- Exploration of self-propagating high-temperature synthesis.
- Delving into chemistry provoked by detonations and shock waves.
- Unravelling the complexities of shock waves in states of condensed and gaseous matter.
- Computational models elucidating the realm of high-velocity impact.
- Experimental methodologies for the measurement and observation of high-strain-rate phenomena.

The organizing committee extends heartfelt gratitude to the speakers and the attendees, recognizing their unwavering support and invaluable contributions that collectively enrich the symposium's tapestry. We are also very grateful to the company DEWESoft d.o.o. for generously sponsoring the EHP 2023 symposium.

Maribor, September 6th, 2023

Zoran Ren, Kazuyuki Hokamoto and Shigeru Itoh

ORGANISING & SCIENTIFIC COMMITTEES

Organised by

University of Maribor, Faculty of Mechanical Engineering

University of Kumamoto, Institute of Industrial Nanomaterials

Chairs

Kazuyuki Hokamoto, Kumamoto University, Japan

Zoran Ren, University of Maribor, Slovenia

Honorary Chair

Shigeru Itoh, National Institute of Technology, Okinawa College, Japan

Local Organising Committee

Zoran Ren, University of Maribor, Slovenia

Anja Mauko, University of Maribor, Slovenia

Miran Ulbin, University of Maribor, Slovenia

Matej Vesenjak, University of Maribor, Slovenia

Matej Borovinšek, University of Maribor, Slovenia

Nejc Novak, University of Maribor, Slovenia

Yunus Emre Yilmaz, University of Maribor, Slovenia

Conference Webpage

Webpage: https://eshp.um.si/

e-mail: eshp2023@um.si

Webpage editors: Miran Ulbin, Anja Mauko

International Scientific Committee

Airoldi, A., Politecnico di Milano, Italy

Balagansky, I., Novosibirsk State Technical University, Russia

Ben-dor, G., Ben-Gurion University of the Negev, Israel

Buchar, J., Mendel University of Agriculture and Forestry, Czecoslovakia

Chen, P. W., Beijing Institute of Technology, P.R. China

Güden, M., Izmir Institute of Technology, Turkey

Hasebe, T., Kobe University, Japan

Jiroušek, O., Czech Technical University in Prague, Czech Republic

Krstulović-Opara, L., University of Split, Croatia

Kubota, S., National Institute of Industrial Science and Technology, Japan

Li, X., Dalian University of Technology, P.R. China

Liu, Z., Beijing Institute of Technology, P.R. China

Mamalis, A.G., National Center for Scientific Research, Greece

Moatamedi, M., New York University London, U.K.

Petrinić, N., University of Oxford, U.K.

Raghukandan, K., Annamalai University, India

Rittel, D., Israel Institute of Technology, Israel

Sakamoto, S., Daicel Corp. and Kumamoto University

Sucesca, M., University of Zagreb, Croatia

Shin, H.S., Andong National University, Korea

Shim Victor, P. W., National University of Singapore, Singapore

Tanaka, S., Kumamoto University, Japan

Thadhani, N., Georgia Institute of Technology, USA

Wang, C., Beijing lnstitute of Technology, P.R. China

Wang, G., China Academy of Engineering Physics, P.R. China

Wang, J., Nanjing University of Science and Technology, P.R. China

Yamashita, M., Gifu University, Japan

Yoh, J., Seoul National University, Korea

Zhou, M., Georgia Institute of Technology, USA

Supporting organisations

Institute of Industrial Nanomaterials, Kumamoto University

Japan Explosives Society, Technical Committee on Explosion & Impact Processing

Japan Society for Technology of Plasticity, Committee on the High-Energy-Rate Forming

State Key Laboratory of Explosion Science and Technology, Beijing Institute of Technology

Chinese Ministry of Education Engineering Research Center for Explosion Protection and Emergency Response

The International Society of Multiphysics

Faculty of Mechanical Engineering, University of Maribor

Slovenian Society for Mechanics

General Information

Abstracts have been reviewed by the Organising Committee.

The official language of the meeting is English.

General Sponsor

DEWESoft d.o.o., Trbovlje, Slovenia

Webpage: https://dewesoft.com/

ESHP
2023

SYMPOSIUM PROGRAMME

Programme overview

Day 1 Tuesday, September 5, 2023	
18:00–20:00	Welcome reception & registration

Day 2 Wednesday, September 6, 2023	
08:30–09:00	Registration
09:00–09:15	Welcome and Opening
09:15–10:00	Plenary lecture Dr. Marco Peroni
10:00–11:00	Oral presentations
11:00–11:30	Coffee-break
11:30–12:50	Oral presentations
12:50–14:00	Lunch
14:00–15:20	Oral presentations
15:20–15:50	Coffee-break
15:50-17:10	Oral presentations

Day 3 Thursday, September 7, 2023	
08:30–09:00	Registration
09:00–09:40	Plenary lecture Dr. Moji Moatamedi
09:40–11:00	Special Multiphysics session Oral presentations
11:00–11:30	Coffee-break
11:30–12:50	Oral presentations
12:50–14:00	Lunch
14:00–15:20	Oral presentations
15:20–16:00	Coffee-break with poster session
19:00	Symposium Banquet

Day 4 Friday, September 8, 2023	
9:30-13:00	Maribor sightseeing and degustation
13:00-15:00	Free time for lunch
15:00-17:00	General assembly at University of Maribor to discuss the future of ESHP and related issues
17:00-17:15	Close of the symposium

Symposium programme

	Day 1 - Tuesday, September 5, 2023
18:00-20:00	**Welcome reception & registration**

	Day 2 - Wednesday, September 6, 2023
08:30–09:00	**Registration**
09:00–09:15	**Welcome and Opening**
	Session 1
Chair	**Zoran Ren**
09:15–10:00	**Plenary lecture** **European laboratory for structural assessment of the joint research centre: facilities and activities** Marco Peroni, Joint Research Centre of European Commission, Ispra, Italy
10:00–10:20	**Impact loading of isotropic shell-based stochastic cellular materials** Oraib Al-Ketan, New York University Abu Dhabi, Abu Dhabi, United Arab Emirates
10:20–10:40	**Structural properties of interfacial layers of Ta/Cu multi-layer composites fabricated by single-shot explosive welding and accumulative roll-bonding** Henryk Paul, Polish Academy of Science, Institute of Metallurgy and Materials Science, Department of Plastic Deformation of Metals, Krakow, Poland
10:40–11:00	**Strain-rate response of architected polymer-based composite materials** Nikolaos Karathanasopoulos, New York University, New York, USA
11:00–11:30	**Coffee-break**

	Day 2 - Wednesday, September 6, 2023
	Session 2
Chair	**Kazuyuki Hokamoto**
11:30–11:50	**Development of converting pulsed large current explosions of metal foil or wire mesh containing explosives into driving force for metal plates (INVITED)** **Shigeru Tanaka**, Kumamoto University, Institute of Industrial Nanomaterials (IINa), Kumamoto, Japan
11:50–12:10	**Observation of the collision between metal jets** **Akihisa Mori**, Sojo University, Kumamoto, Japan
12:10–12:30	**Optimizing explosive welding conditions for joining aluminium alloys and cast iron** **Daisuke Inao**, Kumamoto University, Institute of Industrial Nanomaterials (IINa), Kumamoto, Japan
12:30–12:50	**Blast-wave mitigation by "blast-wave trap" installed on passageway of underground/subsurface explosive storage** **Tomotaka Homae**, National Institute of Technology, Toyama College, Department of Maritime Technology, Toyama, Japan
12:50–14:00	**Lunch**

	Day 2 - Wednesday, September 6, 2023
	Session 3
Chair	**Shigeru Tanaka**
14:00–14:20	**Detonation of hydrogen–oxygen mixtures in the long stainless steel pipe system (INVITED)** **Shiro Kubota**, National Institute of Advanced Industrial Science and Technology, Tsukuba, Japan
14:20–14:40	**Chemical reactions and materials engineering using shock waves** **Kevin Keller**, TU Bergakademie, Freiberg, Germany
14:40–15:00	**Electro-mechanical-optical ignition mechanisms of energetic materials (INVITED)** **Min Zhou**, Georgia Institute of Technology, George W. Woodruff School of Mechanical Engineering, Atlanta, Georgia, USA
15:00–15:20	**Experimental study of joining pure titanium and stainless steel using explosive welding process** **Bir Bahadur Sherpa**, Kumamoto University, Institute of Industrial Nanomaterials (IINa), Kumamoto, Japan
15:20–15:50	**Coffee-break**

	Day 2 - Wednesday, September 6, 2023
	Session 4
Chair	**Oraib Al-Ketan**
15:50–16:10	**The dynamic response of graphene aerogels** **Jing Xie**, Beijing Institute of Technology, School of Mechatronical Engineering, Beijing, PR China
16:10–16:30	**Numerical assessments of the additively produced Ti64 and 316L lattice-cored sandwiches for the gas turbine engine containment** **Hacer İrem Erten**, Izmir Institute of Technology, Izmir, Turkey
16:30–16:50	**Extension of submicron-order pattern imprinting using polymer molds to plate materials** **Kouki Hasegawa**, Graduate School of Science and Technology, Kumamoto University, Kumamoto, Japan
16:50–17:10	**Preparation of carbon nanomaterials through pulsed wire discharge** **Xin Gao**, Beijing Institute of Technology, School of Mechatronical Engineering, Beijing, PR China

	Day 3 - Thursday, September 7, 2023
08:30–09:00	**Registration**
	Session 5 - Multiphysics
Chair	**Hirofumi Iyama**
09:00–09:40	**Plenary lecture** **MULTIPHYSICS : A dream or reality?** **Moji Moatamedi**, The International Society of Multiphysics, UK
09:40–10:00	**Fundamental experiment for estimation of spalling phenomenon characteristics using underwater shock waves** **Ken Shimojima**, National Institute of Technology, Okinawa College, Okinawa, Japan
10:00–10:20	**Computational modeling and simulation of a spherical shell structures construction using moldless hydro-plastic forming** **Yoshikazu Higa**, National Institute of Technology, Okinawa College, Okinawa, Japan
10:20–10:40	**Numerical analysis of the shape of an apparatus for punching holes in thin metal sheets using underwater shock waves** **Itta Soma**, National Institute of Technology, Kumamoto College, Kumamoto, Japan
10:40–11:00	**Experimental and numerical evaluation of perforation threshold energy in polycarbonate panels for windshields** **Alessandro Airoldi**, Politecnico di Milano, Department of Aerospace Science and Technology, Milano, Italy
11:00–11:30	**Coffee-break**

	Day 3 - Thursday, September 7, 2023
	Session 6
Chair	**Lovre Krstulović-Opara**
11:30–11:50	**High strain rate behaviour of uniform and hybrid TPMS metamaterials** **Nejc Novak**, University of Maribor, Faculty of Mechanical Engineering, Maribor, Slovenia
11:50–12:10	**Investigating the strain rate dependency of metal-based cellgraded TPMS structures: insights for design and optimization** **Yunus Emre Yilmaz**, University of Maribor, Faculty of Mechanical Engineering, Maribor, Slovenia
12:10–12:30	**A new shock absorbing sandwich panel with unconnected trapezoidal corrugated layers** **Hasan Al-Rifaie**, Poznan University of Technology, Institute of Structural Analysis, Poznan, Poland
12:30–12:50	**Mechanical characterisation of advanced axisymmetric chiral auxetic structure** **Anja Mauko**, University of Maribor, Faculty of Mechanical Engineering, Maribor, Slovenia
12:50–14:00	**Lunch**

	Day 3 - Thursday, September 7, 2023
	Session 7
Chair	**Alessandro Airoldi**
14:00–14:20	**Characterisation of autoclaved aerated concrete under shock loading using high frequency X-Ray radiography** **Jeremie Tartiere**, École nationale supérieure de techniques avancées Bretagne, Brest, France
14:20–14:40	**High-velocity impact to ultra high-performance concrete and flash X-ray radiography** **Jan Šleichrt**, Czech Technical University in Prague, Faculty of Transportation Sciences, Prague, Czech Republic
14:40–15:00	**Dynamic density measurements with proton radiography at GSI** **Thomas Schlothauer**, TU Bergakademie, Freiberg High Pressure Research Center, Freiberg, Germany
15:00–15:20	**Experimental investigation of blast-loaded overpass columns** **Hrvoje Draganić**, Josip Juraj Strossmayer University of Osijek, Faculty of Civil Engineering and Architecture, Osijek, Croatia

	Day 3 - Thursday, September 7, 2023
	Poster session
15:20–16:00	**Influence of impact angle on deformation of axaially compressed aluminum square tube** **<u>Itsuki Maruyama</u>**, National Institute of Technology, Nagano College, Nagano, Japan
	Computational analysis of the compaction fabrication process of composite unidirectional cellular metals **<u>Shun Nakayama</u>**, National Institute of Technology, Kumamoto College, Kumamoto, Japan
	Fundamental study on the impact resistance of unidirectional cellular (UniPore) material using computational simulations **<u>Koyo Nishida</u>**, National Institute of Technology, Kumamoto College, Kumamoto, Japan
	Deformation of paper die on metal sheet forming using the underwater shock wave generated by thin metal wire electric discharge **<u>Hirofumi Iyama</u>**, National Institute of Technology, Kumamoto College, Kumamoto, Japan
	Accurate understanding toward explosive welding process by numerical analysis **<u>Zhiyue Liu</u>**, Beijing Institute of Technology, School of Mechatronical Engineering, Beijing, PR China
	Investigation of effects on wooden molds in shock wave molding **<u>Ayumi Takemoto</u>**, National Institute of Technology, Okinawa College, Okinawa, Japan
19:00-22:00	**Symposium Banquet**

	Day 4 -Friday, September 8, 2023
09:30–13:00	**Maribor sightseeing and visiting the oldest wine tree house**
13:00–15:00	**Free time for lunch**
15:00–17:00	**General assembly at University of Maribor to discuss the future of ESHP and related issues**
17:00–17:15	**Close of the symposium**

ABSTRACTS

European Laboratory for Structural Assessment of the Joint Research Centre: facilities and activities

M. Peroni[1*], G. Tsionis[1]

[1] European Commission, Joint Research Centre, Ispra, Italy
[*] Presenter and corresponding author: marco.peroni@ec.europa.eu

This work presents an overview of the main facilities and activities related to the Safety and Security of Buildings Unit of the Joint Research Centre (JRC E.3) of the European Commission. As the science and knowledge service of the Commission, the mission of JRC is to provide independent, evidence-based knowledge and science, supporting EU policies to positively impact society. The mission of E.3 Unit is to contribute to better EU regulation, competitiveness and innovation in the fields of safety and security of buildings, protection of public spaces, and the green and digital transition of the construction ecosystem and the built infrastructure. In this context, the European Laboratory for Structural Assessment (ELSA) is the biggest European laboratory concerning structural and material testing and supports most of the E.3 Unit activities. ELSA laboratory has two main facilities: Reaction Wall and the HopLab rigs.

ELSA Reaction Wall is the largest European reaction wall facility [1] and it is suitable to test real scale buildings up to four-storeys high under seismic actions using the pseudo-dynamic testing methodology (PSD). The continuous development of the PSD methodology and instrumentation makes possible to perform also distributed or sub-structured testing. In the last thirty years, several large scale testing campaigns have been performed at ELSA Reaction Wall on innovative structures and materials, strongly contributing to scientific advancement in the structural sector and to European and international standardization in the building sector.

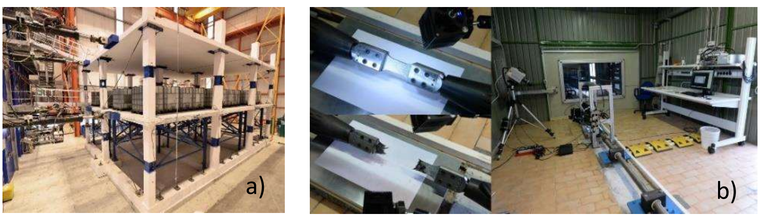


Figure 1. Example test performed at a) ELSA Reaction Wall and b) ELSA HopLab.

ELSA HopLab [2] deals with high strain-rate testing of materials and subassemblies with several facilities for compression and tension tests. In particular, HopLab is equipped with the largest tension (200m long with a pulse up to 1MN) and compression (pulse up to 4 MN) Hopkinson bars suitable to test very large specimens. This feature is essential to test materials with large representative volumes (i.e. composites or cellular materials) that cannot be tested with conventional rigs.

References:
[1] https://joint-research-centre.ec.europa.eu/laboratories-and-facilities/european-laboratory-structural-assessment-reaction-wall-facility_en
[2] https://joint-research-centre.ec.europa.eu/laboratories-and-facilities/european-laboratory-structural-assessment-large-hopkinson-bar-facility-elsa-hoplab_en

IMPACT LOADING OF ISOTROPIC SHELL-BASED STOCHASTIC CELLULAR METAMATERIALS

O. Al-Ketan[1]*, N. Novak[2], A. Mauko[2], Y. Yilmaz[2], L. Krstulović-Opara[3], S.Tanaka[4], K. Hokamoto[4], R. Rowshan[1], R. Abu Al-Rub[5], M. Vesenjak[2], Z. Ren[2]

[1] Core Technology Platforms Operations, New York University Abu Dhabi, Abu Dhabi, UAE
[2] Faculty of Mechanical Engineering, University of Maribor, Maribor, Slovenia
[3] Faculty of Electrical, Mechanical and Shipbuilding Engineering, University of Split, Split, Croatia
[4] Kumamoto University, Kumamoto, Japan
[5] Mechanical Engineering Department, Khalifa University, Abu Dhabi, UAE
* Presenter and corresponding author: oga2@nyu.edu

Lattice-mimicking structures exhibit promising physical properties. However, they also exhibit highly anisotropic properties. In this work, a design procedure to create shell-based stochastic cellular materials based on implicit functions is presented [1]. Finite element analyses (FEA) were employed to assess the mechanical properties and isotropy of the designed structures. Several samples were fabricated with a range of relative densities using the powder bed fusion technique out of 316L stainless steel. The samples were then tested under quasi-static and dynamic (impact) compressive loading conditions up to a strain rate of 11000 s^{-1} to evaluate their mechanical behaviour.

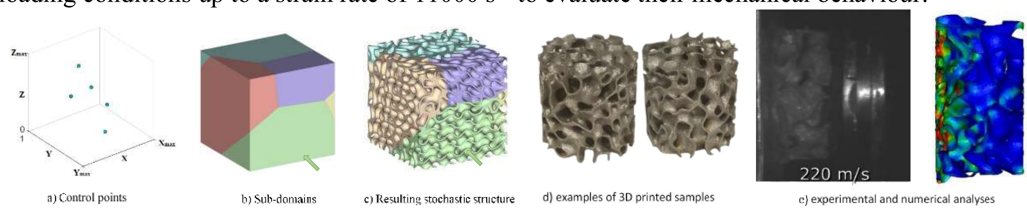


Figure 1. a-c) Design procedure, d) additively manufactured samples, and e) experimental and numerical deformation pattern at high strain rates.

Quasi-static experimental results showed that the stochastic cellular materials exhibit a stretching-dominated mode of deformation where samples deform collectively with no shear band formation. The samples exhibited excellent Specific Energy Absorption (SEA) capacity ranging between 5 J/g and 9.2 J/g in the quasi-static deformation mode while achieving up to 35 J/g in the shock deformation mode at a strain rate of 11000 s^{-1}. Thus, the proposed design approach has great potential for impact and blast mitigation applications. The developed and validated computational models offered a more detailed analysis of the deformation mechanism and provided means to predict the sample's behaviour at very high strain rates. The current study allows for further investigation of non-metallic and metallic stochastic cellular materials and their deployment in different engineering disciplines.

References:

[1] O. Al-Ketan, D.W. Lee, R.K. Abu Al-Rub, Mechanical properties of additively-manufactured sheet-based gyroidal stochastic cellular materials, Addit. Manuf. 48 (2021) 102418.

STRUCTURAL PROPERTIES OF INTERFACIAL LAYERS OF TA/CU MULTI-LAYER COMPOSITES FABRICATED BY SINGLE-SHOT EXPLOSIVE WELDING AND ACCUMULATIVE ROLL-BONDING

H. Paul[1*], S. Puchlerska[2], P. Petrzak[1], R. Chulist[1], M. M. Miszczyk[1], Z. Szulc[3], M. Kwiecień[2], M. Prażmowski[4]

[1] Institute of Metallurgy and Materials Science, Polish Academy of Science, Krakow, Poland
[2] AGH University of Science and Technology, Krakow, Poland
[3] ZTW Explomet, Opole, Poland
[4] Opole University of Technology, Opole, Poland
[*] Presenter and corresponding author: h.paul@imim.pl

New strategies to develop metallic composites for advanced structural applications involve the synthesis of bulk compounds comprising metallurgical bonds. Multi-layer sheets/plates, composed of two or more different metals, are an example of such materials. In this study, a combination of explosive welding (EXW) and accumulative roll-bonding (ARB) has been used to fabricate Ta/Cu multi-layered composite. First EXW is used to fabricate of a large-sized multilayer plate which is, in the next steps, processed via rolling and ARB to increase the number of interfaces and decrease the thickness of the layers. Using a combination of these techniques allows efficiently fabricating of a composite, where the thickness of individual layers can be easily reduced to about 100 nm. A large interface area per unit volume enhances the mechanical properties of the material, providing particular opportunities and challenges for technological applications. The morphology of interfacial regions formed between the Cu and Ta sheets in a multilayer composite was studied using SEM, TEM, and X-ray synchrotron radiation. Optical microscopy characterization confirmed the high quality of the composite without voids and delamination of layers. SEM/EDS/EBSD and TEM/BF/EDS analyses showed that the interfacial layers exhibited a complex and hierarchical microstructure. In particular, the reaction regions in the interfacial layers of the Ta/Cu composite unveiled various morphologies but always consisted of a mixture of pure Cu and Ta elements and does not lead to the formation of intermetallic phases. These microstructural observations have been linked to the solidification mechanism of the systems involving a miscibility gap. Morphological analyses were then correlated with micro-/nano- hardness measurements. The highest hardness value was measured in the solidified melt regions, where the microhardness of the solidified melt was 469 HV. The strong increase of hardness in melted regions, 2 - 3 times compared to the values measured in the strain-hardened layers of joined metals, is attributed to the presence of heterophase interfaces.

Acknowledgement: This research was supported by the Polish National Centre of Science (NCN) within project no.: 2021/41/B/ST5/04283 (Opus-21). Additional thanks also go to Mr. A. Gałka (ZTW Explomet, Opole, Poland) for providing multilayer composites.

Strain-rate response of architected polymer-based composite materials

Agyapal Singh [1], Oraib Al-Ketan [1], N. Karathanasopoulos [1, 2,*]

[1] New York University, Department of Engineering, Abu Dhabi Campus, UAE
[2] New York University, Tandon School of Engineering, Department of Mechanical Engineering, Brooklyn, United States, USA
[*] Presenter and corresponding author: n.karathanasopoulos@nyu.edu

Nature-inspired architected materials premise effective properties that are well beyond the limits of classical engineering materials. Advanced material architectures based on strut, periodic and stochastic topologies have been up to now proposed either in single phase or double phase configurations. The current contribution investigates the static **[1]** and strain-rate performance of polymeric parent-material-based advanced architectures, with topological designs that follow different triply periodic minimal surface and random function stochastic designs in a comparative manner. The effective mechanical properties are thoroughly explored as a function of the metamaterial architecture and loading characteristics. Thereupon, fundamental insights in the role of the reinforcement phase deign of the composite metamaterial on the static and strain-rate mechanical attributes are derived. The performance of stochastic, random function based interpenetrating phase materials is classified with respect to the one of triply periodic minimal-surface based material designs under static loadings. Moreover, the response of interpenetrating phase triply periodic minimal surface based and random function stochastic composite designs at different loading speeds is investigated. The dependence of primal mechanical parameters, namely of the elastic modulus, plateau stress, overall and specific energy absorption on the loading rate are assessed. Overall, substantial strain-rate sensitivities are recorded, with strong underlying topological dependencies. Moreover, machine learning techniques are employed for the modeling of the dynamic interpenetrating phase composite material performance. High accuracy and low numerical cost surrogate models are developed, upon which the importance of the underlying topology and loading influential parameters is classified.

References:

[1] Agyapal Singh, Oraib Al-Ketan, Nikolaos Karathanasopoulos, Mechanical performance of solid and sheet network-based stochastic interpenetrating phase composite materials, *Composites Part B: Engineering*, Volume 251, 2023, 110478

Development of converting pulsed large current explosions of metal foil or wire mesh containing explosives into driving force for metal plates

Shigeru Tanaka[1*], Daisuke Inao[2], Kazuyuki Hokamoto[1]

[1] Institute of Industrial Nanomaterials (IINa), Kumamoto University, 2-39-1 Kurokami, Chuo-ku, Kumamoto 860-8555, Japan.
[2] Technical Division, Faculty of Engineering, Kumamoto University, 2-39-1 Kurokami, Chuo-ku, Kumamoto 860-8555, Japan.
[*] Presenter and corresponding author: tanaka@mech.kumamoto-u.ac.jp

Instantaneous vaporization of metallic foil by pulsed large current is applied to impact welding technique because it enables high-velocity driving of metallic workpieces (flyer plates). Because of the driving force of the flyer plate depends on the potential of the capacitor, a capacitor with greater energy is required in cases where heavier flyer plates are used.

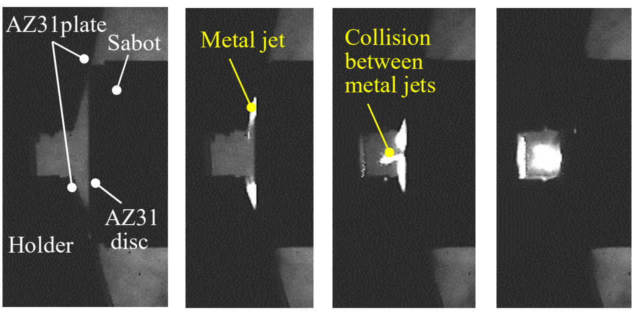
In this study, small amounts of explosives were used to increase the driving force without relying on increased capacitor performance. Aluminum foil or aluminum wire mesh combined with explosives were used as actuators, and the acceleration process of the flyer plates was observed with a high-speed video camera. The electrical energy provided for the vaporization of the actuator, which is a source of the electrical driving force, is at most 30 % of the energy stored in the capacitor. The remaining 70 % is wasted as thermal energy in the form of arc discharge. Wire mesh actuator, which has a larger contact area with the explosive than foil, was effective in initiating the explosive. The initiation of the explosive was the arc discharge that occurs after the wire mesh vaporizes. Because of the initiation of the explosive occurred at almost the same time as the wire mesh vaporization, the electrical driving force combined with the chemical driving force of the explosive increased the driving force.

OBSERVATION OF THE COLLISION BETWEEN METAL JETS

A. Mori[1*], S. Tanaka[2], K. Hokamoto[2]

[1] Sojo University of Maribor, Faculty of Mechanical Engineering, Kumamoto, Japan
[2] Kumamoto University, Institute of Industrial Nanomaterials, Kumamoto, Japan
[*] Presenter and corresponding author: makihisa@mec.sojo-u.ac.jp

The authors have researched to clarify the welding process in explosive welding by proposing a novel method that uses a single-stage powder gun to observe the collision between a metal projectile and an inclined metal plate. This high-speed oblique collision of metals was similar to explosive welding. By applying this method, it was possible to observe the metal jets clearly using a high-speed video camera [1]. Metal jets are essential for welding metals explosively. They are also been employed in material processing, such as the linear-shaped charges. Previous research reported a method for generating extremely high impulsive pressure (1 TPa) by converging metal jets to a single point [2]. In this investigation, we present the results of measuring the luminescence of a metal jet using a simple spectrometer, as well as the optical observations regarding the collision of metal jets generated by the collision of a metal disc to the inclined plate arranged vertically symmetrically. As a result of the spectroscopic measurement, the magnesium peak was confirmed at the metal jet generated by the oblique collision of magnesium alloy, AZ31, similar materials. Contrastingly, the copper peak could not be confirmed for Cu-Cu collision. As shown in Figure 1, the observations for the collision between metal jets in case of metal and non-metal materials were succeeded using high speed video camera. From the observations, the velocity of the metal jet could be obtained and the generated pressure at the collision could be estimated.



(a) t = 0 μs (b) t = 4 μs (c) t = 6 μs (d) t = 8 μs

Figure 1. Collision between the metal jets in case of AZ31-AZ31
(Inclined angle of target plate: 15 degrees, Vp = 495.54 m/s).

References:

[1] A. Mori, S. Tanaka, and K. Hokamoto, Observation for the high-speed oblique collision of metals, Materials Research Proceedings, vol.13, p.74, 2019.

[2] A. Kira, D. Takaenoki, H. Hamashima, R. Tomoshige, M. Fujita, K. Hokamoto, and S. Itoh, Optical observation of extremely high impulsive pressure generator using collision of high velocity metal jets. Materials Science Forum, vols 465-466, p.265, 2004.

Optimizing Explosive Welding Conditions for Joining Aluminium Alloys and Cast Iron

D. Inao[1*], Y. Minghong [1], S. Tanaka[1], K. Hokamoto[1]

[1] Kumamoto University, Kumamoto, Japan
[*] Presenter and corresponding author: inao@tech.kumamoto-u.ac.jp

Abstract

Explosive welding is a process where high energy, generated by the detonation of an explosive, is applied to metal plates, causing them to collide at high speeds and at an angle. This process is a solid-phase bonding method that bonds similar or dissimilar metals in an extremely short time [1]. In this study, we attempted to join aluminium and hard, brittle cast iron using the explosive crimping method. This combination poses challenges due to large density differences and the formation of hard, brittle intermetallic phases. To date, there are no examples of successful explosive pressure welding for this combination of materials. In this study, we conducted several experiments under various bonding conditions to investigate the bonding of aluminium and cast iron.

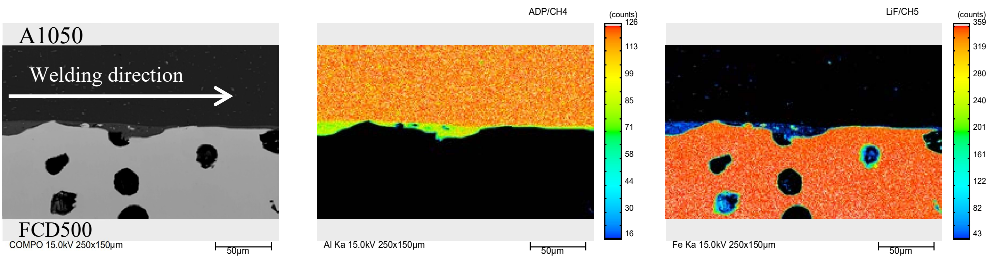


Figure 1. Explosive Weld Interface between A1050 and FCD500: Left - SEM Image, Center - EPMA Image (Al Side), Right - EPMA Image (Fe Side).

We observed that, in both cases, as the Explosive thickness increased, more molten material was found at the interface. Small fragments of hard, brittle cast iron (FC250) were observed in the molten layer. Likewise, in the case of FCD500, a thicker molten layer was produced with increased Explosive thickness. Graphite was observed to be long and elongated near the bonding boundary in both microstructures. For cast irons, work hardening was observed for the ductile FCD500. However, work hardening was not significantly observed for the single graphite FC250, although the values varied. Tensile shear test results for FC250, where relatively good joints were achieved, revealed that the fracture surface occurred on the aluminium side and that the joint strength was comparatively good.

References:

[1] F. Findik, ‘Recent developments in explosive welding’, *Mater Des*, vol. 32, no. 3, pp. 1081–1093, Mar. 2011, doi: 10.1016/J.MATDES.2010.10.017.

Blast-wave mitigation by "blast-wave trap" installed on passageway of underground/subsurface explosive storage

T. Homae[1*], Y. Sugiyama[2], T. Tamba[2], T. Matsumura[2], K. Wakabayashi[2]

[1] National Institute of Technology, Toyama College, Department of Maritime Technology, Imizu, Japan
[2] National Institute of Advanced Industrial Science and Technology, Research Institute of Science for Safety and Sustainability, Tsukuba, Japan
[*] Presenter and corresponding author: homae@nc-toyama.ac.jp

Installation of “blast-wave trap” on passageway of underground/subsurface explosive storage was examined to mitigate blast wave at outside the facility for reducing the damage by an accidental explosion. A specially designed small electric detonator, comprised of 10-mg lead azide, was detonated in a square tube made of PMMA, shown in Figure 1. The blast-wave trap was installed at the opposite end to point of explosion. Pressure histories were measured at three points, shown as T1−T3 in the figure.

First, the mitigation effect of the trap was evaluated by comparing between the peak overpressure of L-shaped (without trap) and empty trap at T3. Since the peak overpressure with empty trap was half of that of L-shaped, the mitigation effect of the trap for blast wave was confirmed.

Then, cushioning materials were set to examine the mitigation effect. A 8-mm thick nonwoven polyester fabric (hereinafter, NF) was adopted as the cushioning material. One sheet of NF (1NF), 1NF soaked with water (1NF+w), five sheets of NF (5NF), and 5NF+w were set at the end of the trap. The obtained pressure histories were compared to that of empty trap, PMMA wall instead of cushioning material, and open end. Figure 2 presents the peak-overpressure ratio of reflected wave to 1st wave at T2. The ratio was less than 1.0 in case of 5NF; hence the mitigation effect of cushioning material was partly confirmed.

The peak overpressure of first wave (direct wave) at the exit was confirmed to reduce to half by the junction of the trap, and the reflected wave is expected to be mitigated by cushioning materials, filled in the trap.

This work was supported by JSPS KAKENHI Grant Number JP21K04574.

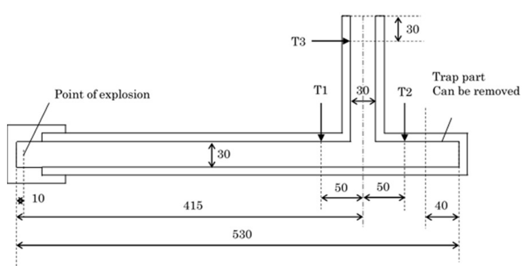


Figure 1. Schematic diagram of the square tube.

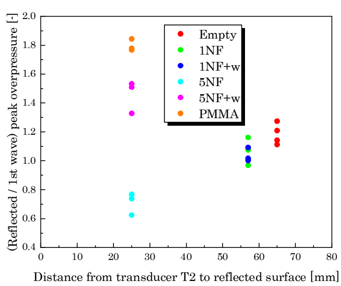


Figure 2. Relationship between peak-overpressure ratio of reflected wave to 1st wave at T2 and distance from transducer T2 to reflected surface of the cushioning material.

DETONATION OF HYDROGEN-OXYGEN MIXTURE IN THE LONG STAINLESS STEEL PIPE SYSTEM

S.Kubota[1*], H. Shiina[1], A. Matsugi[1], T. Tanba[1], T. Saburi[1]

[1] National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, JAPAN
[*] Presenter and corresponding author: kubota.46@aist.go.jp

The detonation phenomenon is experimentally investigated in a pipe filled with hydrogen/oxygen gas. The pipe system is made of SUS pipe with 1-inch diameter, and two types of lengths are used 16 m or more. At the downstream pipe end, for two types of end conditions for pipe, open and close, inside states are examined. In case of open end, mixture is ignited while the mixed gas is flowing with 60 L/mine.

The detonation velocity was measured by placing six pressure sensors on the downstream side of the piping system. Under the same conditions, the detonation velocities evaluated at each sensor point were almost the same. Particularly, inside states of the SUS pipe are investigated by measuring the expansion wave or reflected wave from the pipe end.

CHEMICAL REACTIONS AND MATERIALS ENGINEERING USING SHOCK WAVES

K. Keller[1,2*], T. Schlothauer[1,2], G. Heide[1,2], E. Kroke[1,3], M. Schwarz[1,3]

[1] TU Bergakademie Freiberg, Freiberg High Pressure Research Center, Freiberg, Germany
[2] TU Bergakademie Freiberg, Institute of Mineralogy, Freiberg, Germany
[3] TU Bergakademie Freiberg, Institute of Inorganic Chemistry, Freiberg, Germany
[*] Presenter and corresponding author: kevin.keller@mineral.tu-freiberg.de

Shock waves initiated by the detonation of high explosives can be used to carry out (structural) phase transitions in materials with the change of bonding length and character and frequently the coordination number of atoms. This was shown first for the synthesis of diamond many decades before [1]. Since then many other materials were subjected to shock waves and the exploration of new high pressure phases – in combination with static high pressure methods and theoretical structure predictions – is an ongoing research topic.

Besides phase transitions, where the chemical composition of an substance is unchanged, also chemical reactions can be realised. The high pressure and high temperatures produced by shock waves can be used as a driving force to facilitate a) solid-state reactions, b) decomposition reactions, c) conversion of amorphous to crystalline state and d) change of solid solution composition [2].

In the Si-Al-O-N system numerous high-pressure phases exist, like spinel-type γ-Si_3N_4, spinel-type γ-$Si_{3-x}Al_xO_xN_{4-x}$ and rocksalt-type AlN, which can be synthesised and quenched using different routes and starting materials with the shock wave method [3,4]. It is shown that the use of tailored amorphous precursors is beneficial for the synthesis of pure high-pressure phases, e.g. for γ-Si_3N_4. Besides, chemical formation and decomposition reactions under shock loading can be applied to obtain a targeted composition in this material system. Another example for the production of multi-element phases, is the shock synthesis of the $Sr_2Si_5N_8$:Eu^{2+} phosphor [5].

References:

[1] P. S. DeCarli, J. C. Jamieson, Formation of Diamond by Explosive Shock, Science, vol. 133, p. 1821-1822, 1961.

[2] E. Horvath-Bordon, R. Riedel, A. Zerr, P. F. McMillan, G. Auffermann, Y. Prots, W. Bronger, R. Kniep, P. Kroll, High-pressure chemistry of nitride-based materials. Chem. Soc. Rev., vol. 35, p. 987-1014, 2006.

[3] M. R. Schwarz, M. Antlauf, S. Schmerler, K. Keller, T. Schlothauer, J. Kortus, G. Heide, E. Kroke, Formation and properties of rocksalt-type AlN and implications for high pressure phase relations in the system Si-Al-O-N, High Pressure Res., vol. 34, p. 22-38, 2014.

[4] T. Schlothauer, M. R. Schwarz, O. Moldovan, E. Brendler, R. Moeckel, E. Kroke, G. Heide, Shock wave synthesis of oxygen-bearing spinel-type silicon nitride γ-$Si_3(O,N)_4$ in the pressure range from 30 to 72 GPa with high purity, Minerals as Advanced Materials, S. V. Krivovichev (ed.), p. 389-401, 2012.

[5] K. Keller, S. Rösler, T. Schlothauer, G. Heide, E. Kroke, Shock synthesis of $Sr_2Si_5N_8$:Eu^{2+} phosphor, J. Alloys and Compds., vol. 784, p. 1270-1275, 2019.

Electro-mechanical-optical ignition mechanisms of energetic materials

J. H. Shin[1], D. H. Olsen[1], M. Zhou[1*]

[1] School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0405, USA
[*] Presenter and corresponding author: min.zhou@gatech.edu

The ignition of energetic materials affects their safety and effectiveness in applications such as airbags, fire devices, and propulsion systems. The development of localized regions of high temperatures known as hotspots controls the ignition process. Historically, thermomechanical dissipation associated with inelasticity, void collapse, fracture, and friction is the primary hotspot generation mechanism. There is a growing interest in developing alternative means for generating hotspots for more precise ignition control, reaction manipulation, and novel multifunctionality. In this presentation, we will discuss the latest progress in developing optical, electromagnetic, and electromechanical means of ignition. Laser excitation, microwave heating, and electromechanical excitation that take advantage of piezoelectricity and flexoelectricity have been successfully demonstrated to be viable means of controlled ignition. To systematically delineate the effects and design materials, multiphysics simulations that explicitly account for electromagnetic wave energy deposition through dielectric heating and eddy current, electric field development, dielectric breakdown induced heating, and chemical reactions are carried out. For example, it is demonstrated that the ignition of poly(vinylidene fluoride-co-trifluoroethylene) binder and nano-aluminum (nAl) [or P(VDF-TrFE)/nAl] composites is driven by both flexoelectricity and piezoelectricity (Fig. 1).

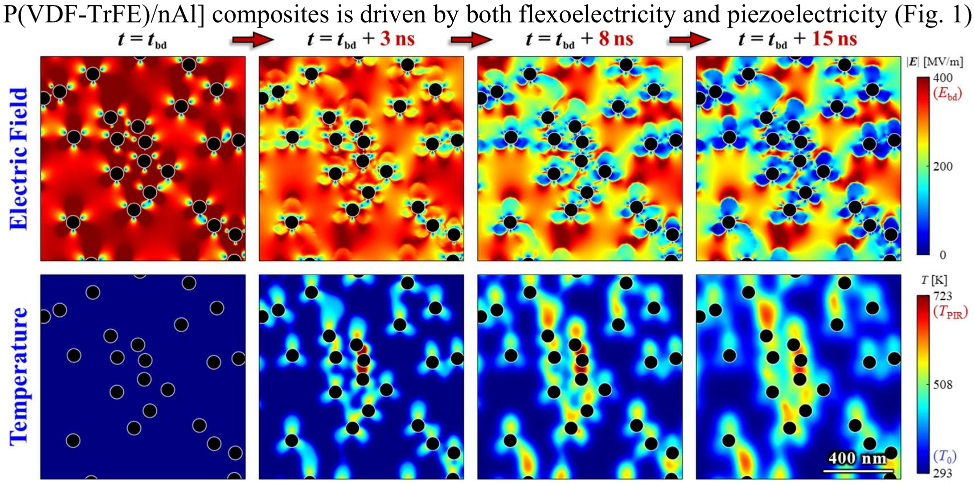


Figure 1. Development of hotspots in a P(VDF-TrFE)/nAl composite via dielectric breakdown due to electric field induced by impact loading.

References:

[1] J. H. Shin, D. K. Messer, M. Örnek, S. F. Son, M. Zhou, Dielectric Breakdown Driven by Flexoelectric and Piezoelectric Charge Generation as Hotspot Ignition Mechanism in Aluminized Fluoropolymer Films, Journal of Applied Physics 132, 085101 (2022).

[2] K. E. Uhlenhake, D. Olsen, M. Gomez, M. Örnek, M. Zhou, S. F. Son, Photoflash and laser ignition of full density nano-aluminum PVDF films, Combustion and Flame 233, 111570 (2021).

EXPERIMENTAL STUDY OF JOINING PURE TITANIUM AND STAINLESS STEEL USING EXPLOSIVE WELDING PROCESS

B. B. Sherpa[1]*, M. Kuroda[2], T. Ikeda[3], K. Kawamura[3], D. Inao[4], S. Tanaka[1], K. Hokamoto[1]*

[1] Institute of Industrial Nanomaterials (IINa), Kumamoto University, 860-8555, Kumamoto, Japan
[2] Faculty of Advanced Science and Technology, Kumamoto University, 860-8555, Kumamoto, Japan
[3] Kumamoto Industrial Research Institute, 862-0901, Kumamoto, Japan
[4] Faculty of Engineering, Kumamoto University, 860-8555, Kumamoto, Japan
* Presenter and corresponding author: sherpa@mech.kumamoto-u.ac.jp and hokamoto@mech.kumamoto-u.ac.jp

Joining of titanium and stainless steel has gained enormous attention in the aerospace, automobile, oil and gas industries, and nuclear sector due to outstanding properties of the bimetal such as good corrosion resistance, low density and high strength. However, the manufacturing of such bimetals using conventional methods is quite challenging due to huge differences in their chemical and physical properties. In this regard, explosive welding has emerged as a promising laminates processing technology to produce weld between similar and dissimilar metal combinations [1]. Therefore, in this study, the explosive welding process was used in a parallel configuration set-up to weld titanium and stainless steel plates. This process uses explosive energy to generate a high-pressure shock wave between the two metals, resulting in a metallurgical bond due to plastic deformation [2]. Microstructure and mechanical properties of the interface zone were investigated to understand the behaviour of the interfacial phenomenon between the clad plates. The micro-hardness results near the weld interface showed change in hardness value caused by work hardening. The work hardening effect was found to decrease as one moves away from the weld interface. The joint strength of the bonded clads was found to be stronger than the individual metals, confirming a strong interlocking between the titanium and stainless steel plate during the explosive welding process [3]. The clad obtained through this process can be utilized in the applications that require strong and reliable joints in harsh environments.

Keywords: Explosive welding process; Titanium; Stainless steel; Weld interface; Bond strength

References:

[1] Hokamoto, K., et al., Single-shot explosive welding technique for the fabrication of multilayered metal base composites: effect of welding parameters leading to optimum bonding condition. Composites engineering, 1995. 5(8): p. 1069-1079.
[2] Hokamoto, K., Explosion, Shock-Wave and High-Strain-Rate Phenomena of Advanced Materials. 2021: Elsevier
[3] Sherpa, B.B., et al., Effect of explosive welding parameters on Al/LCS interface cladded by low velocity of detonation explosive welding (LVEW) process. The International Journal of Advanced Manufacturing Technology, 2021. 113(11): p. 3303-3317

THE DYNAMIC RESPONSE OF GRAPHENE AEROGELS

Jing Xie[1,2*], Yang Qiao[1], Pengwan Chen[1,2] and Daniel Rittel[3]

[1] State Key Laboratory of Explosion Science and Technology, Beijing Institute of Technology, Beijing, China, 100081
[2] Explosion Protection and Emergency Disposal Technology Engineering Research Center of the Ministry of Education, Beijing, China, 100081,
[3] Faculty of Mechanical Engineering, Technion - Israel Institute of Technology, Haifa, Israel, 32000
[*] Presenter and corresponding author: jxie@bit.edu.cn

The experimental investigation of the dynamic mechanical behavior of graphene aerogel is still lacking due to its low impendence. The present work, therefore, reports on the preliminary experimental characterization of the energy absorption characteristics of graphene aerogel by using the split Hopkinson pressure bar emphasis on the influence of the drying method. The graphene aerogels were synthesized by the sol-gel method and dried, either by supercritical CO_2 drying (SD) or by freeze-drying methods (FD)[1]. It was observed that under dynamic uniaxial compression, the SD samples exhibited a negative Poisson's ratio throughout gradual compression. However, FD samples failed by radial shattering without this auxetic behavior. The energy dissipation ratios of SD samples increased from 41% to 73% as expected with the specimen thickness increasing from 3mm to 12mm, being overall higher in comparison with FD samples which rises from 35% to 43%. SD graphene aerogels have a large number of random pores (~50nm), which is beneficial for absorbing the kinetic energy through plastic deformation and pore walls' collapse. By contrast, the FD graphene aerogels' pore walls buckle readily under the impact, and fail due to their ordered porous structure at the micron scale (~1µm), which impairs their energy absorption capability[2].

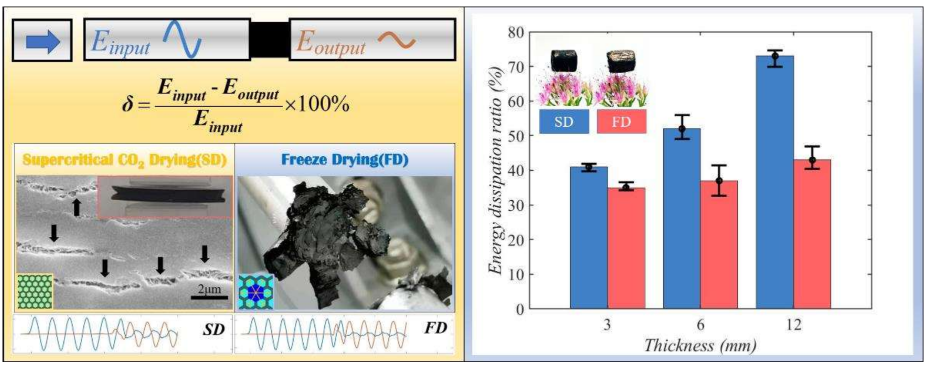


Figure 1. The energy absorption behavior of graphene aerogels investigation via the SHPB.

References:
[1] Jing Xie*, Lulu Niu, Yang Qiao, Yinze Lei, Guangyong Li, Xuetong Zhang, Pengwan Chen*. The influence of the drying method on the microstructure and the compression behavior of graphene aerogel. Diamond and Related Materials, 2022, 122:108772
[2] Jing Xie*, Lulu Niu, Yang Qiao, Pengwan Chen*, Daniel Rittel. Impact energy absorption behavior of graphene aerogels prepared by different drying methods. Materials & Design. 2022, 221:110912.

NUMERICAL ASSESSMENTS OF THE ADDITIVELY PRODUCED TI64 AND 316L LATTICE-CORED SANDWICHES FOR THE GAS TURBINE ENGINE CONTAINMENT

H.I Erten[1*], A. Tasdemirci[1], U.E Ozturk[2], M. Guden[1]

[1] Dynamic Testing and Modeling Laboratory and Department of Mechanical Engineering, Izmir Institute of Technology, Gulbahce Koyu, Urla, Izmir, Turkey
[2] TUSAS Engine Industries Inc. (TEI)
[*] Presenter and corresponding author: hacererten@iyte.edu.tr

Designed engines are expected to resist the released-blade impact damages. The containment rings of turbo engines are usually made of heavy metallic materials and the development of weight efficient engine containment materials still remains a major concern. Present study reports the results of the initial numerical studies on the assessment of additively produced Ti64 and 316L lattice-cored sandwiches potentially being used as containment rings. For comparison, equal-weight monolithic plates were also numerically investigated. The investigated Body-Centered-Cubic lattice had a cell size of 5 mm, a strut diameter of 1 mm with a face sheet thickness of 1 mm at both sides. The results of projectile impact tests at various velocities were used for the assessment of the energy absorption capabilities of monolithic plates and sandwiches. For the studied blade, lattice cell topology, shape and relative density and plates, the monolithic plates were shown more efficient in terms energy absorption, while the lattices were more effective in increasing penetration and perforation time of blade [1,2]. The plate and sandwich impact tests were simulated in LSDYNA. The model geometries of monolithic plate and BCC lattice-cored sandwich are shown in Figure 1(a) and (b), respectively.

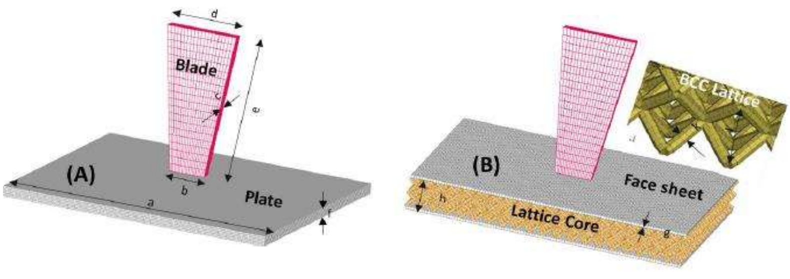


Figure 1. The Numerical Model and Dimensions of (a) Plate and (b) Lattice-cored Sandwich Blade Impact Tests

References:

[1] P.A. Roy, S.A. Meguid, International Journal of Mechanics and Materials in Design 17 (2021) 3-12.

[2] P.A. Roy, S.A. Meguid, International Journal for Computational Methods in Engineering Science & Mechanics 21 (2020) 96-108.

Extension of submicron-order pattern imprinting using polymer molds to plate materials

Kouki Hasegawa[1*], Shigeru Tanaka[2], Kazuyuki Hokamoto[2], Daisuke Inao[3]

[1] Graduate School of Science and Technology, Kumamoto University, 2-39-1 Kurokami, Chuo-ku, Kumamoto 860-8555, Japan.
[2] Institute of Industrial Nanomaterials (IINa), Kumamoto University, 2-39-1 Kurokami, Chuo-ku, Kumamoto 860-8555, Japan.
[3] Technical Division, Faculty of Engineering, Kumamoto University, 2-39-1 Kurokami, Chuo-ku, Kumamoto 860-8555, Japan.
[*] Presenter and corresponding author: hasegawa@mech.kumamoto-u.ac.jp

Recently developed laser shock imprinting (LSI) can easily create nano reliefs [1], and LSI achieves roll-to-roll and high productivity [2]. However, laser shock waves cannot rapidly accelerate heavy workpieces into a mold, so the workpieces are limited to thin metal foils [1-3]. In this study, a polymer stamper was dynamically pressed into a metal plate by applying a high impulse shock wave derived from an explosion (Figure 1). By pressing the stamper in for a few microseconds, a well transferred structure with a submicron scale was obtained on the surface of the aluminum plate. This study was evaluated by pressure measurement experiments and numerical analysis. Numerical simulations revealed the dynamic deformation behavior of the soft polymer stamper and the aluminum plate. The results showed that a long duration of shock wave action is necessary for high imprinting accuracy and transfer to thick metal plates. Therefore, explosion-derived shock waves with long pressure duration are effective for imprinting. This method could be developed into a practical technique for imparting functional micro-surfaces to structural components.

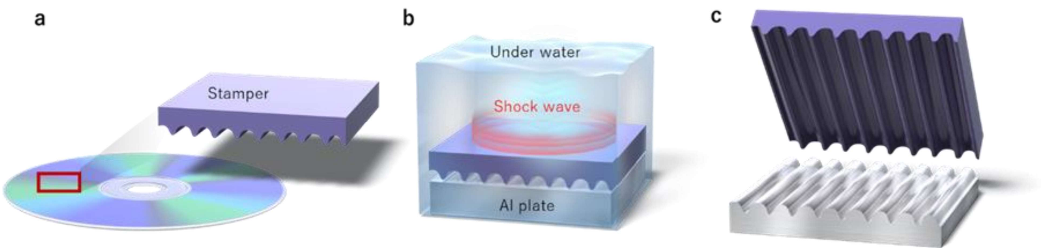


Figure 1. Schematic of the impact imprint process. (a) Preparation of the DVD stamper. (b) Stamper and Al workpiece subjected to the underwater shock wave. (c) Imprinted Al workpiece.

References:
[1] H. Gao, Large-scale nanoshaping of ultrasmooth 3D crystalline metallic structures, Science (1979). 346 (2014) 1352–1356.
[2] D. Goswami, J.C. Munera, A. Pal, B. Sadri, C.L.P.G. Scarpetti, R. V. Martinez, R. V. Martinez, Roll-to-Roll Nanoforming of Metals Using Laser-Induced Superplasticity, Nano Lett. (2018).
[3] Jin S, Zhou Z, Sakr ESA, Motlag M, Huang X, Tong L, et al. Scalable nanoshaping of hierarchical metallic patterns with multiplex laser shock imprinting using soft optical disks. Small. 2019;15:e1900481.

PREPARATION OF CARBON NANOMATERIALS THROUGH PULSED WIRE DISCHARGE

Xin Gao[1,2*], Pengwan Chen[1,2], Hao Yin[1]

[1] State Key Laboratory of Explosion Science and Technology, Beijing Institute of Technology, Beijing 100081, China
[2] Advanced Technology Research Institute, Beijing Institute of Technology, Jinan, Shandong, 250307, China.
[*] Presenter and corresponding author: gaoxin@bit.edu.cn

Pulsed wire discharge refers to the phenomenon when a strong current from pulsed discharge passes through a conductive wire inducing a huge energy deposition during joule heating process.[1] Subsequently, the wire melts and vaporizes in micro- or nano-seconds to produce a mixture of droplets and vapors at high temperature and pressure. The products scatter out with a shockwave in the medium. The pulsed wire discharge method is widely used to prepare nanomaterials.

In previous study, we have successfully obtained graphene through pulsed discharge of graphite stick, implying the application of low dimensional materials. In the further studies, we focus on the nanomaterial preparation through pulsed wire discharge. The graphite strip is utilized to prepare large-size graphene materials in distilled water medium by exfoliating graphitic layers through rapid thermal expansion[2]. Through pulsed discharge of iron wire in graphene suspension, the iron wire vaporizes and forms Fe and FeO nanoparticles anchoring on the surface of graphene nanosheets to form Fe/FeO/graphene nanocomposite materials[3]. We also employed carbon fiber wire to do the pulsed wire discharge experiment with higher energy density, in which carbon fiber wire was completely vaporized to form carbon gas and cooled down to form nanodiamond[4]. The corresponding formation mechanisms are also discussed based on the characterization results of recovered samples and pulsed discharge processes.

Our studies show the high potential application of pulsed wire discharge method for the preparation of carbon nanomaterials.

References:

[1] Y. A. Kotov, Electric explosion of wires as a method for preparation of nanopowders. Journal of Nanoparticle Research, vol. 5, p. 539-550, 2003.
[2] X. Gao, T. Hiraoka, S. Ohmagari, S. Tanaka, Z. Sheng, K. Liu, M. Xu, P. Chen, and K. Hokamoto, High-efficiency production of large-size few-layer graphene platelets via pulsed discharge of graphite strips. Nanomaterials, vol. 9, p. 1785, 2019.
[3] X. Gao, N. Yokota, H. Oda, S. Tanaka, K. Hokamoto and P. Chen, One step preparation of Fe-FeO-Graphene nanocomposite through pulsedwire discharge. Crystals, vol. 8, p. 104, 2018.
[4] X. Gao, K. Huang, Z. Tan, B. Wang, Q. Song, Q. Chen and P. Chen, Formation of nanodiamond by pulsed discharge of carbon fiber wires. Applied Physics Letters, vol. 117, p. 081902, 2020.

Multiphysics of Blast-Loaded Cylindrical and Conical Shells

N. Mehreganian[1], A. S. Fallah[2], M. Moatamedi[3]

[1] Imperial College London, London, UK
[2] Oslo Metropolitan University, Norway
[3] New York University, London, UK
[*] Presenter and corresponding author: m.moatamedi@multiphysics.co.uk

Localised pulse pressure loads can pose a significant threat to structural elements as well as critical equipment, causing failure and damage in the target due to the concentrated energy delivered upon a localised area of the target. The impulse impinged upon the localised zone at the contact interface can exceed 80% of the total impulse that the charge can deliver to an infinite target, leading to potential perforation of the structural element. This necessitates devising superior designs capable of withstanding high overpressures. Hollow cylindrical and truncated conical shells depict enhanced torsional and shear resistance compared to beams and plates and are ubiquitously used in structures in aeronautics, submarines, wind turbines, pressure vessels, and transmission pylons. Upon extensive localised blast, these elements undergo local and global deformation and failure. The detrimental damage to the shell depends on the stand-off and charge mass and is proportional to the emerged local dynamic stresses and inelastic deformations. Large localised translations relocate the structure's original pivot point and induce global rotations about the new one which raises the probability of structural collapse.

In this work, we examine large plastic deformations of hollow cylindrical and truncated conical shells subject to a range of pulse pressures emanated from high explosives at different proximities to the target source. Fluid-Structure Interaction (FSI) phenomenon was investigated using Finite Element (FE) models concerning the flexible and rigid targets corresponding to the coupled and uncoupled techniques, respectively. The (FSI) techniques were developed in each of these scenarios, to discern the characteristics of blasts at various stand-offs and to derive a number of dimensionless functions which linked the load parameters to structural, material, and geometric properties. Concerning the uncoupled technique, the pressure registered with the target gauge points of the rigid target was later implemented on a flexible target which demonstrated different mode shapes occurring in the shell due to each blast scenario. The FSI results for the coupled and uncoupled techniques were also compared against the theoretical solutions in the literature which showed good agreements. A dimensionless impulse parameter was defined based on the Gaussian distribution function associated with the load shape, which renders calculable the probability of the impulse as the total impulse that can potentially be imparted to the target.

Fundamental Experiment for Estimation of Spalling Phenomenon Characteristics using Underwater Shock Waves

K. Shimojima[1*], Y. Higa[1], O. Higa[1], H. Iyama[2],S. Tanaka[3] T. Watanabe[4]

[1] National Institute of Technology, Okinawa College, Department of Mechanical Systems Engineering ,Okinawa ,Japan
[2] National Institute of Technology, Kumamoto College, Kumamoto ,Japan
[3] Kumamoto University, Kumamoto ,Japan
[4] National Fisheries University, Yamaguchi , Japan
[*] Presenter and corresponding author: k_shimo@okinawa-ct.ac.jp

Okinawa National College of Technology has developed a food processing machine using underwater shock waves. Several porotypes machine was developed, and experimental results (sterilization, improvement of juice extraction, milling flour, emulsification etc.) were obtained. There are few examples of shock wave processing to food, and this research begins with seeking the processing effects of specific foods by some companies and governments. we verified the effect through experiments using a test machine by these requirements. For example, we mill high-quality rice flour, increase the juice extraction of essential oils from shell ginger and fruits, softening of meat[1] and sterilize some fruits without heating. However, there are only a few units, including our laboratory, that possess devices using shock waves, and joint research is necessary to verify the above effects. In this study, we compare the drying speed, fiber tensile strength, softening, etc., and obtain basic data for estimate the effect of processing by shock waves. We selected carrots, radishes, and burdocks, as experimental subjects, and compared the results of the above experiments.

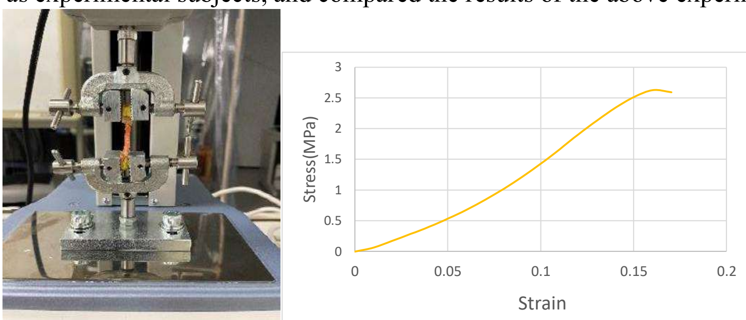


Figure 1 Experiment setup and results of the tensile strength of carrot.

The size of the carrot is 1 cm × 1 cm × 5 cm, and the tensile strength is measured by a tensile testing machine (MX-500N) after complete drying, and the value is Approx.2.45 Mpa. This result is not processed by shock waves. In this report, the results of tensile strength, drying rate, softening, etc. are compared with the processing by shock waves. The purpose of this study is to obtain basic results for predicting processing characteristics due to shock waves.

References:
[1] K.Shimojima, Y.Higa, O.Higa, A.Takemoto, H.Kawai, K.Hokamoto, H.Iyama, T.Watanabewa, S.Itoh, Experimental Study for the Tenderness of Meat using Underwater Shock Waves, Explosion Shock Waves and High Strain Rate Phenomena,Materials Research Proceedings 13 (2019)

COMPUTATIONAL MODELING AND SIMULATION OF A SPHERICAL SHELL STRUCTURES CONSTRUCTION USING MOLDLESS HYDRO-PLASTIC FORMING

Yoshikazu HIGA[1*], Yasuyoshi MIYAHIRA[2], Hirofumi IYAMA[3] and Ken SHIMOJIMA[1]

[1] National Institute of Technology (KOSEN), Okinawa College, Dept. Mechanical Systems Engineering, Okinawa, Japan
[2] Creative Sys. Engng. Adv. Course, Nat. Inst. Tech. (KOSEN), Okinawa College, Okinawa, Japan
[3] Nat. Inst. Tech. (KOSEN), Kumamoto College, Dept. Mechanical and Intelligent Systems Engineering, Kumamoto, Japan
[*] Presenter and corresponding author: y.higa@okinawa-ct.ac.jp

As a method to create spherical shell molding, it is well known a plastic technology using a metal mold. Needless to say, this method requires a special mold and it is also extremely difficult to manufacture such a mold for molding a large spherical shell. On the other hand, hydro-forming plastic technology without the molds has been studied by experiments [1,2] and numerical simulations [3], and its usefulness has been reported. However, the mechanical characterisitics depending welded joints associated with preprocessing and the amount and position of explosive used as a point source have not been systematically investigated [4].

To clarify the effect of various parameters on the final spherical shell shape using moldless hyrdo-plastic forming, we have constructed the computational models using Hyperworks-RADIOSS(R) which is commercial Finite element method solver. In this paper, we investigate the final shape of metal plastic working, in which structures are symmetrically expanded by underwater shock waves and formed into a spherical shape. As a series of numerical simulation results, It was observed that the final spherical shape obeying deformation behavior introduced to the shell varies greatly depending on the mechanical properties of the welding joints, the position of the explosive charge and its position. The numerical simulation results based on these computational mechanics viewpoints will highly contribute to moldless hydro-plastic processing technology for spherical shell shape.

References:

[1] Tiesheng, Z., *et al.*, Explosive forming of spherical metal vessels without dies, *J. Mat. Process. Tech.*, **31** (1992), 135-137.

[2] Zhang, R., *et al.*, Non-die explosive forming of spherical pressure-vessels, *J. Mat. Process. Tech.*, **41** (1994), 341-347.

[3] Zhang, R., *et al.*, Optimum structure design method for non-die explosive forming of spherical vessel technology, *J. Mat. Process. Tech.*, **85** (1999), 217-219.

[4] Iyama, H., *et al.*, Chap. 2, Explosive forming; Explosion, Shock-wave and High-strain-rate Phenomena of Advanced Materials, A volume in Multiphysics: Advances and Applications (2021), Academic Press

NUMERICAL ANALYSIS OF THE SHAPE OF AN APPARATUS FOR PUNCHING HOLES IN THIN METAL SHEETS USING UNDERWATER SHOCK WAVES

Itta SOMA[1*], Hirofumi IYAMA[2], Masatoshi NISHI[2], Yoshikazu HIGA[3] and Shigeru TANAKA[4]

[1] Production Systems Engineering Course, National Institute of Technology (KOSEN), Kumamoto College, Kumamoto, Japan.
[2] Department of Mechanical and Intelligent Systems Engineering, National Institute of Technology (KOSEN), Kumamoto College, Kumamoto, Japan.
[3] Department of Mechanical Systems Engineering, National Institute of Technology (KOSEN), Okinawa College, Okinawa, Japan.
[4] Institute of Industrial Nanomaterials, Kumamoto University, Kumamoto, Japan.

[*] Presenter and corresponding author:

Drilling holes of metal plate have been generally processed by cutting using a drill or punching using a press machine. However, when drilling holes in thin plates, the material cannot withstand the lateral stress caused by the runout of the drill and tears. Punching also requires a clearance to prevent interference between the punch and die. If this clearance is too large, burrs or sagging will occur in the hole. Burrs also occur due to wear and tear of the punch and die, as well as contamination by foreign matter [1]. When holes are punched in a thin plate using this type of processing method, the shape accuracy of the holes becomes poor. Furthermore, in the punching process, once an abnormality occurs in the punch or die, a large number of defective products are generated.

To solve these problems, a punching process for thin sheets using high-energy rate forming has been carried out [2]. The processing method proposed in that paper is a high-speed punching process method that utilizes shock waves from underwater explosions of explosives and acts on the surface of thin metal plate. Punching a metal plate at high speed eliminates the need to install a die as in the conventional punching process and may prevent burrs and sagging caused by the clearance between the punch and the die. In addition, since there is no wear and tear of the punch and die, the generation of defective products can be suppressed. We propose new method of the same drilling process using underwater shock waves from underwater electrical discharge of thin metal wire instead of explosives. To accomplish this, it is necessary to use a pressure vessel to maintain sufficient shock pressure. We utilize numerical simulation to develop the equipment and design the vessel for the pressure increase. The goal of this study is to find the optimal pressure vessel shape and to develop a device to obtain sufficient underwater shock pressure for hole drilling of thin metal plate.

References:

[1] Shigeto, N. and Noboru, S., Evaluation of burr during punching process using ae method, *The Japanese Society for Non-Destructive Inspectioon.*, 54 (2005) 557-561.

[2] Shigeru, T. and Ivan, B., *et al.,* Micropunching large-area metal sheets using underwater shock wave: Experimental study and numerical simulation, *International Journal of Machine Tools & Manufacture*, 147 (2019), https://doi.org/10.1016/j.ijmachtools.2019.103457

Experimental and numerical evaluation of perforation threshold energy in polycarbonate panels for windshields

A.M. Caporale[1], A. Airoldi[1*], P. Astori[1], N. Ghavanini[1], M. Di Pilato[1], P.Panichelli[2]

[1] Politecnico di Milano, Dept. of Aerospace Science and Engineering, Milano, Italy
[2] Fédération Internationale de l'Automobile, Vernier, Swiss
[*] Presenter and corresponding author: alessandro.airoldi@polimi.it

Polycarbonate represents a lightweight and efficient materials for windshields requiring high energy absorption capabilities, like in the case of race cars, helicopters and aircrafts. The work presented is focused on motorsport application and includes a thorough experimental campaign aimed at finding a trade-off between the windshield thickness and the protection from sharp debris perforation. Impacts on flat panels made on monolithic and laminated polycarbonate were carried out with the impactors shown in Fig. 1-(a), by using both a drop-weight apparatus and a gas gun. The impact velocities were progressively increased to identify the threshold for panel perforation. The tests made possible the assessment of a numerical approach that combines Von Mises plasticity, damage, Mie-Grüinesen equation of state, strain rate effects, temperature changes due to dissipation based on adiabatic assumptions, and cohesive zone models for laminated panels [1,2]. The approach obtained appreciable correlation in terms of perforation threshold energy and morphology of failures, as exemplified in Figs. 1-(b,c). In a second phase of the activity, impacts were carried out on curved windshields with different thickness, validating the numerical model and evaluating the different behavior of monolithic and laminated panels for the geometries adopted in real-world applications.

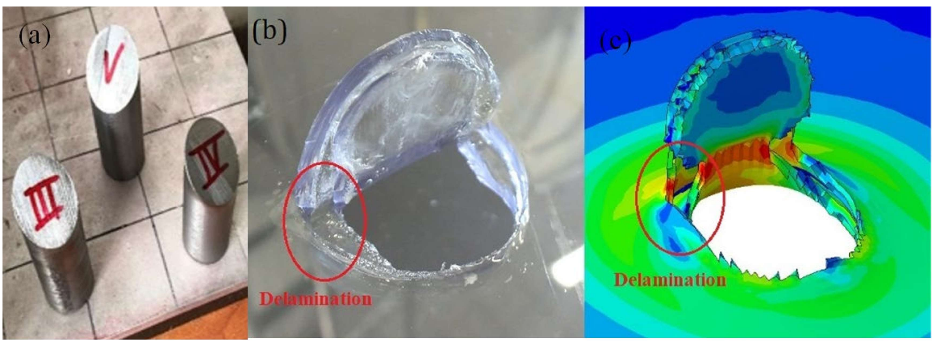


Figure 1. (a) impactors, (b) experimental and (c) numerical perforation.

References:
[1] A. Dorogoy, D. Rittel, and A. Brill, "Experimentation and modeling of inclined ballistic impact in thick PC plates," International Journal of Impact Engineering, vol. 38, no. 10, pp. 804–814, 2011
[2] W. R. Blumenthal, "Influence of Temperature and Strain Rate on the Compressive Behavior of PMMA and PC Polymers," in AIP Conference Proceedings, , vol. 620, no. 2003, pp. 665–668

HIGH STRAIN RATE BEHAVIOUR OF UNIFORM AND HYBRID TPMS METAMATERIALS

N. Novak[1*], O. Al-Ketan[2], A. Mauko[1], Y. Yilmaz[1], L. Krstulović-Opara[3], S. Tanaka[4], K. Hokamoto[4], M. Vesenjak[1], Z. Ren[1]

[1] University of Maribor, Faculty of Mechanical Engineering, Maribor, Slovenia
[2] Core Technology Platform, New York University Abu Dhabi, United Arab Emirates
[3] University of Split, Faculty of Electrical, Mechanical and Naval Engineering, Split, Croatia
[4] Kumamoto University, Kumamoto, Japan
[*] Presenter and corresponding author: n.novak@um.si

Triply Periodical Minimal Surface (TPMS) metamaterials are defined by complex 3D topologies that locally minimise surface area for a given boundary and can be repeated periodically in three perpendicular directions. The TPMS structures have significant engineering potential and have superior mechanical properties, optimal thermal and electrical conductivities, and optimised fluid permeability. In this work, four different geometries of uniform Triply Periodic Minimal Surface (TPMS) cellular structures and hybrid TPMS structures consisting of two different uniform geometries were fabricated and experimentally tested under different compressive strain rates. Three different apparatuses were used, namely a universal testing machine, Direct Impact Hopkinson Bar (DIHB) and a powder gun, achieving strain rates up to 11000 s^{-1}. Limited strain rate hardening is observed at loading velocities below the critical velocities. In contrast, a significant strain rate hardening is observed at impact velocities of 220 m/s, which are well above the second critical velocities, where the deformation transitions to shock mode. The hybrid structures provide the possibility to change the response trend from progressive to degressive only with rotating samples at the highest analysed velocities. Results showed comparable [1] and in some cases superior [2] SEA values for lattices made with the same base material. The computational models were developed and validated based on the experimental results, which offer the framework for further research in the field of dynamic loading of TPMS structures and evaluation for possible future applications.

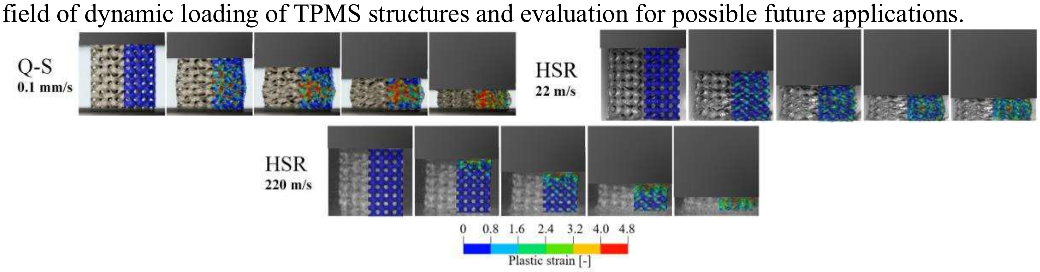


Figure 1. Deformation behaviour of Gyroid TPMS cellular structure at different strain rates.

References:

[1] N. Novak *et al.*, Impact loading of additively manufactured metallic stochastic sheet-based cellular material, Int. J. Impact Eng., no. November 2022, p. 104527, 2023.

[2] X. Cao *et al.*, Dynamic compressive behavior of a modified additively manufactured rhombic dodecahedron 316L stainless steel lattice structure, Thin-Walled Struct., vol. 148, no. December 2019, p. 106586, 2020.

Investigating the Strain Rate Dependency of Metal-Based Cell-Graded TPMS Structures: Insights for Design and Optimization

Y. E. Yılmaz*, N. Novak[1], Oraib Al-Ketan[2], A. Mauko[1], M. Vesenjak[1], Z. Ren[1]

[1] University of Maribor, Faculty of Mechanical Engineering, Maribor, Slovenia
[2] Core Technology Platform, New York University Abu Dhabi, United Arab Emirates
* Presenter and corresponding author: y.yilmaz@um.si

The utilization of cellular materials in engineering applications has witnessed a steady increase in recent years, making the determination of their mechanical properties of utmost importance. Quasi-static experiments have conventionally been used to establish these properties. However, at high strain rates, cellular materials' behavior varies significantly depending on factors such as the cellular material geometry [1], the sensitivity of the base material to strain rates [2], the microinertia effect [3], the internal gas effect [4], and the shock wave effect [3]. Consequently, cellular materials' characterization must be conducted at the strain rate of the intended application. Triply periodic minimal surfaces (TPMS), a unique type of cellular structure, have received considerable attention due to their tunable geometry and exceptional mechanical properties. These non-self-intersecting, continuous structures have zero mean curvature, minimizing stress concentration during deformation.

The present study investigates the mechanical behavior of metal-based cell-graded TPMS structures, specifically primitive, gyroid, and diamond, at different strain rates. Digital image correlation is utilized to analyze non-homogeneous deformation in both quasi-static and direct impact experiments, which are used to identify critical speeds at which deformation mechanisms transition. By determining the critical speed at which deformation behavior changes, this study aims to provide a comprehensive understanding of TPMS structures' mechanical behavior and insights for their future design and optimization. The findings of this study contribute to the field of advanced materials and solid mechanics, providing important information for the development of TPMS structures with superior mechanical properties.

References:

[1] Shinde, R.B. and Mali, K.D. (2018). An Overview on Impact Behaviour and Energy Absorption of Collapsible Metallic and Non-Metallic Energy Absorbers used in Automotive Applications. IOP Conference Series: Materials Science and Engineering, 346, p.012054
[2] Calladine, C.R. and English, R.W. (1984). Strain-rate and inertia effects in the collapse of two types of energy-absorbing structure. International Journal of Mechanical Sciences, 26(11–12), pp.689–701
[3] Sun, Y. and Li, Q.M. (2018). Dynamic compressive behaviour of cellular materials: A review of phenomenon, mechanism and modelling. International Journal of Impact Engineering, [online] 112, pp.74–115. Available at: https://www.sciencedirect.com/science/article/pii/S0734743X17301665 [Accessed 26 Jan. 2020]
[4] Vesenjak, M., Veyhl, C. and Fiedler, T. (2012). Analysis of anisotropy and strain rate sensitivity of open-cell metal foam. Materials Science and Engineering: A, 541, pp.105–109

A NEW SHOCK ABSORBING SANDWICH PANEL WITH UNCONNECTED TRAPEZOIDAL CORRUGATED LAYERS

H. Al-Rifaie*, R. Studziński[1] and W. Sumelka[1]

[1] Faculty of Civil and Transport Engineering, Poznan University of Technology, Poznan, Poland.
* Presenter and corresponding author: hasan.al-rifaie@put.poznan.pl

Sandwich panels can be utilised as blast absorbing sacrificial structures using their plastic deformation potential [1, 2]. To the authors' knowledge, sandwich panels with connected (welded or bolted) corrugated layers has been well investigated by researchers [3]. Therefore, the objective of this study is to create a new, inexpensive, graded sandwich panel with "unconnected" corrugated layers that can be utilised as a multipurpose sacrificial protective structure against a variety of blast threats. The geometry and the selection of the trapezoidal topology was based on the parametric study conducted earlier by the authors [4]. Methodology consists of laboratory testing of the used steel and aluminium materials (18 dog-bone samples) followed by quasi-static compression testing of the 3 fabricated sandwich panels. Based on laboratory outcomes, a non-linear numerical model was developed using Abaqus FE software. Load-deformation curves, plateau stress, energy absorption, stress values, reaction forces, and damage, are among the key parameters that were recorded from the numerical and laboratory analysis. The development of this new sandwich panel may have a great importance to public safety, as those sacrificial panels can be used to retrofit the frontal façade of sensitive buildings.

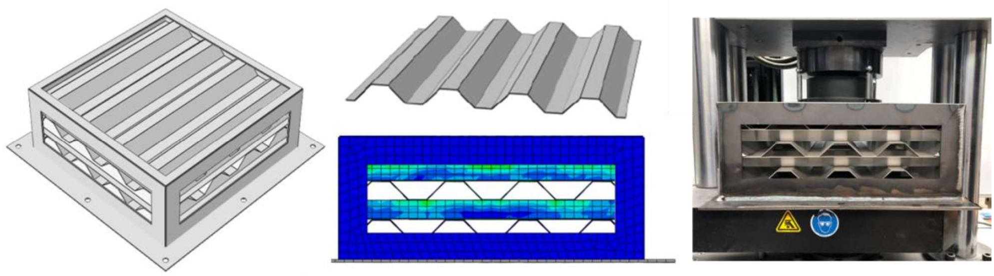


Figure 1. Geometry, numerical model and laboratory testing of the trapezoidal sandwich panel.

References:

[1] H. Al-Rifaie, R. Studziński, T. Gajewski, M. Malendowski, P. Peksa, W. Sumelka, *et al.*, "Full scale field testing of trapezoidal core sandwich panels subjected to adjacent and contact detonations," in *Modern Trends in Research on Steel, Aluminium and Composite Structures*, ed: Routledge, 2021, pp. 393-399.
[2] H. Al-Rifaie, P. Woźniak, and T. Łodygowski, "Improving the blast resistance of steel columns using trapezoidal sandwich panels," in *Science for Defence: Safety for Critical Infrastructure*, 1 ed Warsaw: Wydawnictwo Instytutu Technicznego Wojsk Lotniczych, 2022, pp. 33-54.
[3] H. Al-Rifaie and W. Sumelka, "Improving the Blast Resistance of Large Steel Gates-Numerical Study," *Materials,* vol. 13, p. 2121, 2020.
[4] H. Al-Rifaie, R. Studziński, T. Gajewski, M. Malendowski, W. Sumelka, and P. W. Sielicki, "A new blast absorbing sandwich panel with unconnected corrugated layers—numerical study," *Energies,* vol. 14, p. 214, 2021.

MECHANICAL CHARACTERISATION OF ADVANCED AXISYMMETRIC CHIRAL AUXETIC STRUCTURE

A. Mauko[1*], N. Novak[1], M. Ulbin[1], M. Vesenjak[1], Z. Ren[1]

[1] University of Maribor, Faculty of Mechanical Engineering, Maribor, Slovenia
[*] Presenter and corresponding author: anja.mauko@um.si

In this study, we focused on the development and mechanical testing of a unique cellular metamaterial with an axisymmetric chiral auxetic structure [1]. These metamaterials are designed to possess high energy absorption capacity and specific stiffness, while still maintaining a lightweight nature. The structure was created by spatially scaling and distributing 3D chiral unit cells in the radial and axial directions. Radial grading was achieved by adjusting the length and amplitude of the horizontal struts from the inner to the outer layer of cells. The fabrication process utilized the powder fusion method (PBF) with 316L stainless steel as the base material. Quasi-static [2] and dynamic compression tests were conducted on the fabricated structures, covering a range of strain rates from 0.005 s-1 to 1050 s-1. The experimental results demonstrated a pronounced auxetic response, with smooth deformation and a gradual increase strength until final densification. The deformation process was captured using digital cameras, and the advanced Digital Image Correlation (DIC) method was employed to analyse the full-field strain data. Additionally, a computational model of the novel chiral auxetic structure was developed and validated against the experimental results. The validated model was then utilized to optimize the parameters of the axisymmetric chiral auxetic structure, aiming to achieve the desired mechanical response.

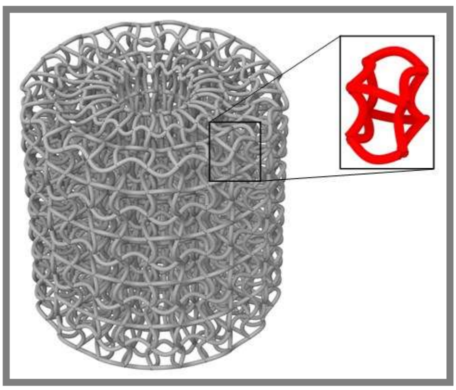


Figure 1. Cellular material with axisymmetric chiral auxetic structure.

References:

[1] Z. R. M. Vesenjak, N. Novak, "Axisymmetric chiral auxetic structure, EP21197296.3 patent pending," 2021.
[2] N. Novak, A. Mauko, M. Ulbin, L. Krstulović-Opara, Z. Ren, and M. Vesenjak, "Development and characterisation of novel three-dimensional axisymmetric chiral auxetic structures," J. Mater. Res. Technol., vol. 17, pp. 2701–2713, Mar. 2022, doi: 10.1016/J.JMRT.2022.02.025.

Characterisation of autoclaved aerated concrete under shock loading using high frequency X-Ray radiography

J. Tartière[1,a], M. Arrigoni[1,b], B. Lukic[2], A. Rack[2], D. Chapman[3], B. Reynier[1,4], J. Le Clanche[1], P. Pradel[4], T. De Resseguier[5], P. Froquin[6], D. Eakins[3]

[1] Ecole Nationale Supérieure des Techniques Avancées Bretagne, Brest, France
[2] European Synchrotron Radiation Facility, CS40220, 38043 Grenoble Cedex 9, France
[3] Department of Engineering Science, University of Oxford, Oxford OX1 3PJ, UK
[4] CEA CESTA, 15 avenue des Sablières CS60001, 33116 Le Barp Cedex, France
[5] Institut Pprime, UPR3346, CNRS, ISAE-ENSMA, 11 boulevard Marie et Pierre Curie, Futuroscope Chasseneuil Cedex, France
[6] Univ. Grenoble Alpes, CNRS, Grenoble INP, 3SR, 38000 Grenoble, France

[a] Presenter, [b] Corresponding author: michel.arrigoni@ensta-bretagne.fr

Keywords: Autoclaved Aerated Concrete, shockwave, compaction, fast X-Ray imaging, plate impact.

Mechanical impacts or high explosive detonation can provoke severe physical damages on structures. However, through their compaction phase, porous materials can absorb a part of mechanical energy and efficiently attenuate the shock wave. Autoclaved Aerated Concrete (AAC) owns this faculty and is at the same time non-flammable, which is of interest for most structures that must resist both impacts and fire. AAC is therefore a good material for the elaboration of sacrificial coatings in protective design.

The AAC is an insulating porous material which exhibits a unique mechanical behaviour under shock loading: it has the capability to mitigate the shock wave while crushing. Few reports of its behaviour under dynamic loading and blast can be found yet in open literature [1,2]. It is indeed difficult to study in real time, especially because of the cloud of dust produced during compaction. In the present study, two AAC are considered: Siporex© (density of 550kg/m^3) and Multipor© (density of 115kg/m^3), both manufactured by Xella®. In order to investigate their shock behaviour, plate impact tests were performed in the European Synchrotron Radiation Facility (ESRF) and the dynamic compaction process of AAC could be observed by fast X-Ray imaging for impact velocities ranging from 250 to 400 m/s.

Through the post-processing of X-Ray radiographs, a compaction front in the AAC is identified. Its velocity as a function of time, as well as those of the projectile and the buffer, are fitted. Based on shock physics, this tracking of the compaction front and the initial velocity of the projectile provide a portion of the AAC Hugoniot. A simple analytical model is also proposed to reproduce the development of the compaction front.

References:

[1] Mespoulet, J. et al (2015). Strain rate sensitivity of autoclaved aerated concrete from quasi-static regime to shock loading. In EPJ Web of Conferences (Vol. 94, p. 01053). EDP Sciences.
[2] Liu, C. et al (2021). Effect of high strain rate and confinement on the compressive properties of autoclaved aerated concrete. International Journal of Impact Engineering, 156, 103943.
[3] Mollaei, S. et al (2022). Investigation of Behavior of Masonry Walls Constructed with Autoclaved Aerated Concrete Blocks under Blast Loading. Applied Sciences, 12(17), 8725.

HIGH-VELOCITY IMPACT TO ULTRA HIGH-PERFORMANCE CONCRETE AND FLASH X-RAY RADIOGRAPHY

J. Šleichrt[1*], J. Falta[1], N. Krčmářová[1], P. Koudelka[1], T. Fíla[1]

[1] Czech Technical University in Prague, Faculty of Transportation Sciences, Prague, Czechia
[*] Presenter and corresponding author: sleichrt@fd.cvut.cz

Ultra high-performance concrete reinforced by short steel fibers (UHPFRC) is a modern material used mostly in civil engineering. It exhibits excellent mechanical properties in comparison to traditional concrete such as high damage tolerance, fracture toughness and durability. Therefore, it can be used in special applications such as underground spaces, nuclear waste containers, and military facilities [1].

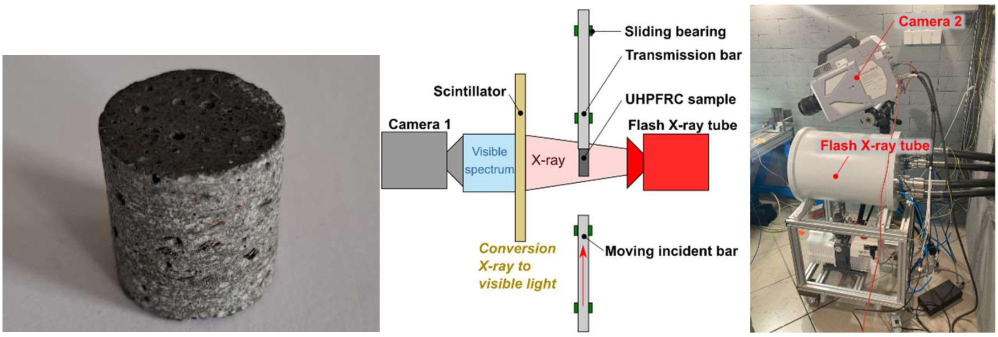


Figure 1. UHPFRC sample (left), principle of the measurement (middle), X-ray tube with the second camera (right).

In this study, the samples of UHPFRC material were subjected to a direct impact test using an Open Hopkinson pressure bar (OHPB) [2,3]. To capture the internal damage in time of loading, fast radiography was applied based on the usage of a Flash X-ray system producing a series of short high intensive pulses. The radiographs were acquired by a scintillator panel converting to visible light and recorded by a high-speed camera. The second camera observed a scene around the sample and was placed in a similar direction as an X-ray tube.

References:

[1] L. Ren, X. Yu, Y. He, et al. Numerical investigation of lateral inertia effect in dynamic impact testing of uhpc using a split-hopkinson pressure bar. Construction and Building Materials 246:118483, 2020. /https://doi.org/10.1016/j.conbuildmat.2020.118483

[2] Fíla T., Koudelka P., et al. Dynamic impact testing of cellular solids and lattice structures: Application of two-sided direct impact Hopkinson bar. International Journal of Impact Engineering 148: 103767, 2021. https://doi.org/10.1016/j.ijimpeng.2020.103767

[3] Falta, J., Adorna, M., et al. Direct measurement of reaction forces during fast dynamic loading. Acta Polytechnica CTU Proceedings, 25, 32–35, 2019. https://doi.org/10.14311/APP.2019.25.0032

Dynamic density measurements with proton radiography at GSI

T. Schlothauer[1*], D. Varentsov[2], M. Schanz[2], A. Blazevic[2], G. Heide[1]

[1] TU Bergakademie Freiberg, Freiberg High Pressure Research Center
[2] GSI Darmstadt, Plasma Physics- Plasma Physics Detectors
[*] Presenter and corresponding author: thomas.schlothauer@mineral.tu-freiberg.de

EoS-measurements in samples with larger volume with common velocity based methods like PDV are very difficult or nearly impossible. This concerns especially hard and brittle granular matter, matter with chemical reactions under shock wave conditions and also natural samples like natural carbon bearing rocks. In this case the bulk-EoS-measurements gives only an overview about the whole matter but without precise statements about the local shock behaviour in the sample. One sample is given in fig. 1 left [1]. It shows shocked tungsten carbide, which decays above 20 GPa into W_2C and diamond. In this case EoS-measurements as performed for WC, as performed in Sandia, are no longer valid for this substance under these extreme conditions [2] and the pressure actually reached in the sample is currently unknown.

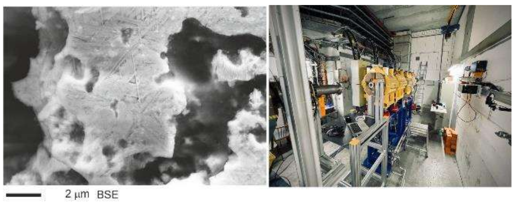


Figure 1. left: snow-flake shaped crystals of W_2C after its condensation from its vapor phase. Right: focusing magnets for the proton beam @ PRIOR

To overcome these problems and to determine the EoS if this kind of brittle hard substances proton radiography will be the only possibility [3]. With the possibilities of the planned HE-driven proton microscope (up to 5^{10} protons in four bunches in 800 ns, density resolution of 1%, 20-25µm spatial resolution, 40-50mm field of view) it will be possible to measure shock wave directions, its velocities and density gradients in complex large volume samples together with local shock wave perturbations (e.g. on single grains), shock reflections and attenuations in a larger volume over time directly.

References:

[1] Schlothauer, T.; Schimpf, C.; Heide, G.; Kroke, E., Mechanical behavior of shocked porous tungsten carbide in the Mbar-range. In: O. A. Golosova und M. I. Alymov (Hg.): Explosive Production of New Materials: Science, Technology, Business, and Innovations: Torus Press, S. 225–231 2018

[2] Vogler, T. J.; Root, S.; Knudson, M. D.; Reinhart, W. D., High-Pressure Shock Behavior of WC and Ta_2O_5 Powders. Hg. v. Sandia National Laboratories. Albuquerque, New Mexico 87185 and Livermore, California 94550 (SAND2011-6770). 2011

[3] Sharkov, Boris; Varentsov, Dmitry : Experiments on extreme states of matter towards HIF at FAIR. In: Proceedings of the 13th National Synchrotron Radiation Conference 733, S. 238–241. 2024

EXPERIMENTAL INVESTIGATION OF BLAST-LOADED OVERPASS COLUMNS

H. Draganić[1*], S. Lukić[2], G. Gazić[1], M. Jeleč[1], I. Radić[1]

[1] Josip Juraj Strossmayer University of Osijek, Faculty of Civil Engineering and Architecture Osijek, Osijek, Croatia
[2] Respect-ing d.o.o., Osijek, Croatia
[*] Presenter and corresponding author: draganic@gfos.hr

The use of reinforced concrete structures is dominant globally due to a favourable balance of cost and quality. Given their popularity, it is understandable that RC is the most commonly used material for constructing bridges. Despite their frequency, the literature overviews relatively few blast tests of RC columns. Due to the complexity of the implementation and high costs, no real-scale blast-load experiments are performed for bridge columns. Conducting experimental tests to study the impact of explosions on structures is a highly challenging and intricate task. Factors affecting the analysis's complexity include the high costs, the requirement of experts for handling explosives, and the limited availability of suitable areas for detonating significant explosive charges. Furthermore, using different types of explosives with varying chemical compositions, diverse amounts of explosives depending on the attack scenario, various shapes of charges, and various positions concerning the structure/element can also significantly complicate the analysis procedure **[1]**.

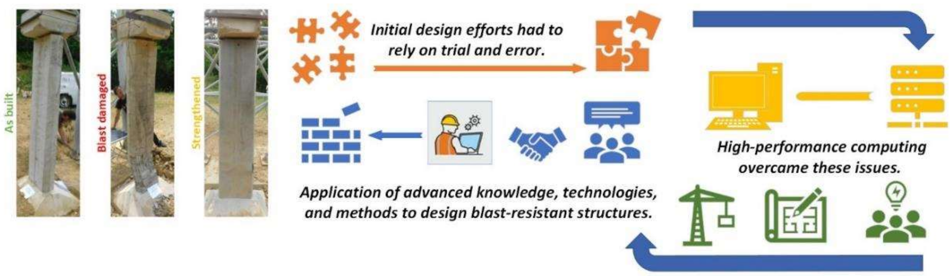


Figure 1. Design development of blast-resistant structures.

A reinforced concrete overpass column with an irregular cross-section was field blast tested (**Figure 1**). The selected overpass is part of the existing road network and was designed using pre-euro norm regulations. Among other column types, it is chosen due to its dimensions, occurrence frequency, and highest blast pressure exposure determined by preliminary numerical simulations. An experimental model of the RC column was built at a scale of 1:3 to investigate its blast resistance **[2]**. This scale was chosen due to the column's dimensions and the excessive amount of explosives that would be required for testing a full-sized column in real-life conditions.

References:

[1] Lukić, S. & Draganić, H. (2021) Blast Loaded Columns—State of the Art Review. Applied Sciences-Basel, vol. 11, p. 7980-8008, 2021. doi:10.3390/app11177980.

[2] Lukić, S. (2023). Blast load capacity of highway bridge columns. [Doctoral dissertation, Josip Juraj Strossmayer University of Osijek, Faculty of Civil Engineering and Architecture Osijek]. Dabar GrAFOS Repository.

INFLUENCE OF IMPACT ANGLE ON DEFORMATION OF AXAIALLY COMPRESSED ALUMINUM SQUARE TUBE

I. Maruyama[1*], M. Miyazaki[1**], A. Karasawa[1]

[1] National Institute of Technology, Nagano College, Department of Engineering, Nagano, Japan
*Presenter
**Corresponding author: miyazaki@nagano-nct.ac.jp

Aluminum tubes are energy-efficient absorbing components and are widely used for frameworks and reinforcement materials of the structures. The effect of the axial length and cross-sectional shape on the deformation behavior were investigated. Regarding the axial length, it has changed only to a certain length, and there are few studies on it. It is known that when the aluminum rectangular tube deforms, elastic deformation occurs in the entire square tube prior to plastic deformation. Since this is periodic and wavy, it seems that the axial length will have a big influence.

This paper deals with the influence of impact angle on deformation of axially compressed aluminum square tube.

An analysis of the dynamic deformation process of the square tube was made with a finite element method. The specimen used in this analysis is an aluminum polygonal tube (A6063-T5, 40 mm width, 1 mm thickness). The weight is 15.0 kg and the impact velocity is 10 m/s. The cross-sectional shapes are square. In the analysis, the deformed tube is assumed to be composed of bilinear four-node shell elements, and the weight is assumed to be a rigid body of three-dimensional with eight-node, isoparametric element.

The results shows that the load reached the peak immediately after the weight hit the rectangular tube, then declined gently. The same tendency was obtained even if the impact angle was changed. However, as the impact angle became larger, the time to reach the maximum load increased, and the maximum strain increased as the collision angle of the weight increased. Maximum strain occurred at almost the same position from the end of the model at any collision angle. Other than that, small strain occurred.

Computational Analysis of the Compaction Fabrication Process of Composite Unidirectional Cellular Metals

M. Nishi[1*], S. Nakayama[1*], S. Tanaka[2], M. Vesenjak[3], Z. Ren[3], K. Hokamoto[2]

[1] National Institute of Technology (KOSEN), Kumamoto College, Kumamoto, Japan
[2] Institute of Industrial Nanomaterials (IINa), Kumamoto University, Kumamoto, Japan
[3] Faculty of Mechanical Engineering, University of Maribor, Maribor, Slovenia
[*] Presenter: S. Nakayama and corresponding author: nishima@kumamoto-nct.ac.jp

Cellular structures have attracted wide attention as structural materials that are light and strong. Consequently, numerous previous cellular structures have been fabricated using a single metal as the base material due to the complexity of the fabrication method. Therefore, studies on the fabrication of multi-material cellular structures are rather limited [1]. In this study, we computationally analyse the fabrication process of two types of copper/stainless-steel composite unidirectional cellular (UniPore) structures with a stainless-steel cover layer over the entire inner surface of the copper pipe to clarify the conditions of the experimentally fabricated UniPore structures using the explosive compression method. Our results regarding the collision velocity of the metals during compression and the temperature at the time of collision indicate that wider gaps are required between the metals to increase their collision velocity and that some metals are some metals are melted between pipes.

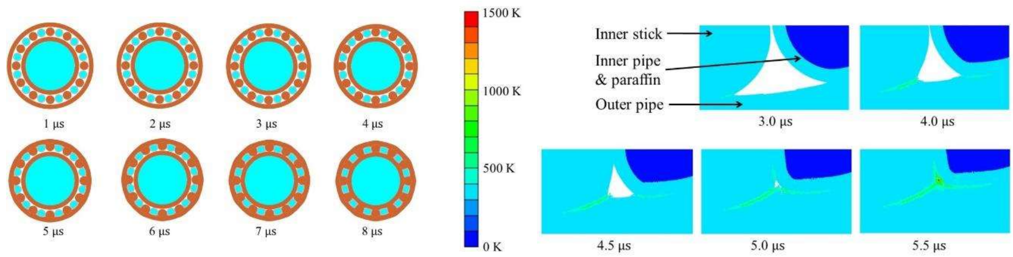


Figure 1. Analysis of the compression process (left) and compression forming process with a temperature contour (right).

References:
[1] M. Nishi, S. Tanaka, M. Vesenjak, Z. Ren, and K. Hokamoto, Fabrication of Composite Unidirectional Cellular Metals by Using Explosive Compaction. Metals, vol. 10, p. 193, 2020.

Fundamental study on the impact resistance of unidirectional cellular (UniPore) material using computational simulations

M. Nishi[1*], K. Nishida[1*], Y. Kiritani[1], S. Tanaka[2], M. Vesenjak[3], L. Krstulović-Opara[4], Z. Ren[3], K. Hokamoto[2]

[1] National Institute of Technology (KOSEN), Kumamoto College, Kumamoto, Japan
[2] Institute of Industrial Nanomaterials (IINa), Kumamoto University, Kumamoto, Japan
[3] Faculty of Mechanical Engineering, University of Maribor, Maribor, Slovenia
[4] Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, University of Split, Split, Croatia
[*] Presenter: K. Nishida and corresponding author: nishima@kumamoto-nct.ac.jp

One of the characteristics of cellular materials is their impact resistance. In this study, the unidirectional cellular (UniPore) structure with aligned isolated pores in one direction was computationally analysed to develop a cellular structure with improved impact resistance under high-speed impact. In previous studies, the behaviour of through pores perpendicular to the pore direction and the direction of flight has been investigated [1]. In this parametric study, the impact resistance of UniPore structures with pores parallel to the direction of flight is investigated with regard to the appropriate shape, size and spacing of the pores.

Figure 1 shows the stress-strain diagram and the deformation process of the projectile as seen from the wall side during the collision. It is confirmed that the impact resistance of the cellular structure changes when the proposed cellular structure impacts a rigid wall surface due to the densification.

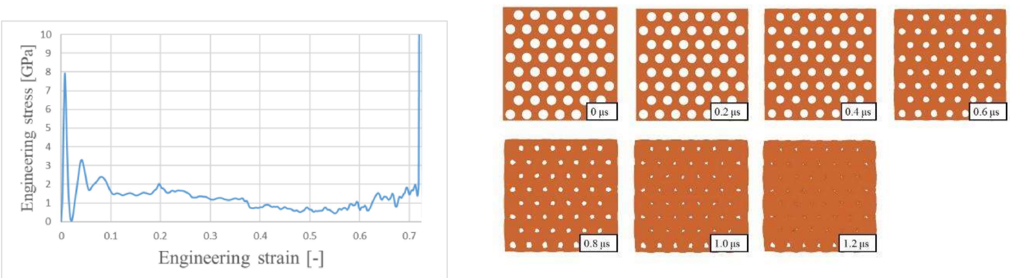


Figure 1. Stress-strain relationship (left) and the deformation process of the projectile (right).

References:
[1] M. Nishi, S. Tanaka, M. Vesenjak, Z. Ren, and K. Hokamoto, Experimental and computational analysis of the uni-directional porous (UniPore) copper mechanical response at high-velocity impact. International Journal of Impact Engineering, vol. 136, p. 103409, 2020.

DEFORMATION OF PAPER DIE ON METAL SHEET FORMING USING THE UNDERWATER SHOCK WAVE GENERATED BY THIN METAL WIRE ELECTRIC DISCHARGE

Hirofumi IYAMA[1], Soya AKAZAWA[2], Yoshikazu HIGA[3] and Masatoshi NISHI[1]

[1*]Department of Mechanical and Intelligent Systems Engineering, National Institute of Technology (KOSEN), Kumamoto College, Kumamoto, Japan.
[2] Yamaha Kumamoto Products Co., Ltd., Kumamoto, Japan.
[3] Department of Mechanical Systems Engineering, National Institute of Technology (KOSEN), Okinawa College, Okinawa, Japan.

[*] Presenter and corresponding author:

Although a metal die is usually used in the explosive forming, Prof. Fujita focused on the fact that the metal sheet to be formed at high speed and undergoes sufficient plastic deformation when it impacts comparatively soft materials such as a paper [1]. In his research, it was confirmed that even if paper, plaster, resin, or sand is used as the die material, sufficient formed products can be produced [2]. This technology was applied to the production of art works, leading to the practical use of the technology for panels on the exterior walls of buildings. Unlike metal die, the paper die is easily deformed, and this deformation is thought to have a significant effect on the shape of the formed plates. For the industrial development of this technology, it is necessary to understand the deformation characteristics of these die materials and how they affect the deformed shape of the formed plate.

In this study, the shock wave is generated not by explosives, but by underwater thin metal wire electric discharge using a high-voltage power supply [3]. The shock waves generated by the underwater discharge were act to a metal plate to investigate the thickness of the paper sheet used as the die material and how much the edge of the paper would be deformed.

References:

[1] Fujita, M., Explosive Forming Techniques od Making Artistic Work Pieces -An Attempt of EXPLOGRAPHY-, Proceedings of the Symposium on Shock Waves in Japan, FY2015, 2016-03.

[2] Fujita, M., et al., Products of Art Works by Explosive Forming of Titanium Sheet, Proceedings of the Japanese Joint Conference for the Technology of Plasticity, vol. 63, pp.411-412(2012).

[3] Iyama, H., et al., Study on High-Strain-Rate Deformation of Magnesium Alloy Using Underwater Shock Waves Generated by High-Voltage Electric Discharge of Thin Wire, Metals 12(11), 1939 (2022).

ACCURATE UNDERSTANDING TOWARD EXPLOSIVE WELDING PROCESS BY NUMERICAL ANALYSIS

Z. Liu*, H. Jiao

Beijing Institute of Technology, School of Mechatronic Engineering, Beijing, China
* Presenter and corresponding author: zyliu@bit.edu.cn

Explosive welding is a manufacturing technology method which has been in production application for a long time. Until to present, there are still several not-cleared puzzles toward this issue owing to its experimental dependency. This paper presents some insights to those problems by modelisation and computational work. From the basic properties of the explosives being employed in production to the metal characteristics for welding, the phenomena accompanying this manufacturing method are thoroughly addressed. The detonation performance of the explosive, the acceleration of the flyer by the explosion, the collision process with stress wave and temperature rise, and the interface of the welded plates, are computed by computer modelling as well as theoretical analysing procedures.

Investigation of Effects on Wooden Molds in Shock Wave Molding

A. Takemoto[1*], K. Tamashiro[1], H. Teruya[1], S. Itoh[2]

[1] National Institute of Technology, Okinawa College, Department of Bioresources Engineering, Okinawa, Japan
[2] Kumamoto University, Kumamoto, Japan
[*] Presenter and corresponding author: tkmt@okinawa-ct.ac.jp

Shock wave molding, also known as "explography," is a technology that uses the properties of metal deformation caused by shock waves to instantly form metallic materials into three-dimensional shapes through high-speed deformation [1]. With shock wave molding technology, things which are normally destroyed by touching, for example, thin leaves of plants and insect wings, are finely transferred. Therefore, it is expected to be used for hands-on exhibitions in museums and teaching materials for schools for the blind. However, the effects of shock waves on original molds cannot be ignored from the standpoint of preserving materials, especially in museums. For this reason, this study investigated the effects of shock molding on wood used in Japanese woodwork.

For each of the 30 tree species, a 0.02 mm aluminum foil was placed on a piece of wood formed into 1.5 x 1.0 x 0.5 cm specimens. The underwater shock waves generated by detonating 3 g of SEP explosives with an electric detonator at distances of 30 mm and 60 mm from the specimens were loaded with shock waves of approximately 1.25 GPa and 300 MPa, respectively [2]. Under each condition, cracks were observed in each species by scanning electron microscopy and deformation of the specimens was observed by digital microscopy.

These results suggest that replica specimens made by shock wave molding should be used as a technique for palpating the shape of objects that can be prepared in abundance, but which break when touched.

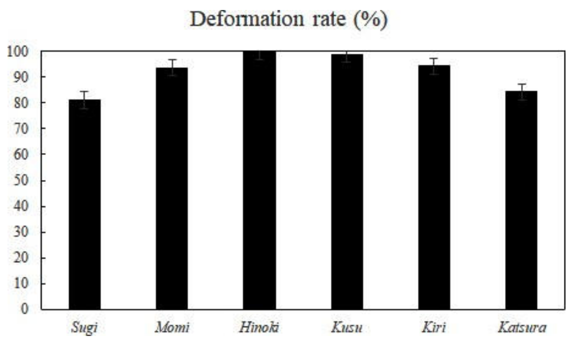


Figure 1. Thickness deformation rate of wood pieces from 6 of the 30 species by 300 MPa shock wave. Smaller values indicate more compression. The scientific names of the tree species are; Sugi: *Cryptomeria japonica,* Momi: *Abies firma,* Hinoki: *Chamaecyparis obtusa,* Kusu: *Cinnamomum camphora,* Kiri: *Paulownia tomentosa,* Katsura: *Cercidiphyllum japonicum.*

This research was carried out with the support of the Public Interest Incorporated Foundation JKA "Keirin and Auto Racing Subsidiary Project".

References:

[1] M. Fujita, Plate Forming Using an Explosion Energy. Materia Japan, Vol. 36, Issue 5, p. 464-467, 1997.
[2] S. Tanaka, I. Bataev, M. Nishi, I. Balagansky, K. Hokamoto, Micropunching large-area metal sheets using underwater shock wave : Experimental study and numerical simulation, International Journal of Machine Tools and Manufacture, Vol. 147, 103457, 2019.

NOTES

NOTES

NOTES

ESHP
2023

ESHP 2023