8th ICLPRP

INTERNATIONAL CONFERENCE ON LASER PEENING AND RELATED PHENOMENA

October 22-27, 2023
Hwabaek International Convention Center, Gyeongju, Korea

PROGRAM BOOK

HOSTED BY

SUN MOON UNIVERSITY &
HANDONG GLOBAL UNIVERSITY

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WELCOME MESSAGE

Welcome to our ICLPRP Conference!

As Chair of the 8th ICLPRP, I am very honored and happy to give welcoming address for my dear colleagues and friends. Due to COVID-19, it was a heartbreak to postpone our conference at Shanghai, and I have to say we missed everyone of you so much since June of 2018 in Singapore. Thus, it is very grateful that we are able to host our conference in my homeland, Korea this year.

We organized and began our very first conference in Houston, USA in 2008, and we've had a long journey so far to open our 8th conference in Korea. We have about 400 scholars from 12 different countries just in this conference! By now, I believe that all you came here not only as a colleague in same research society, but also as a good friend and even more like a family member on the same research home of the ICLPRP.

We prepared all of the programs to make it "homecoming" for you, and so you can enjoy your stay. Of course, in our conference, we have 10 keynote speeches, 61 talks and 40 posters on new research, but also, there will be a technical tour and a cultural tour that are prepared under the ICLPRP. Furthermore, there are special EPRI workshop on Wednesday and special exhibition booths.

Besides, there is the Fall Conference of Korea Nuclear Society, which will be held from Wednesday to Friday in the same building. There are more than 5 hundreds talks on nuclear engineering and about 2 thousand participants. I hope you can meet there your future collaborators.

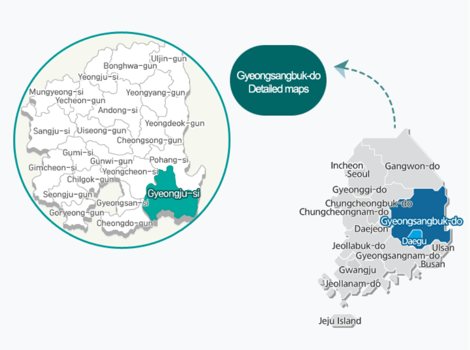
I truly wish all of these program will be an opportunity for you to be enlightened for your future career!

Again, I'm very grateful to see you all again, and please enjoy your stay in Gyeongju and Korea!

Thank you.

Young-Sik Pyun
Chair of the 8th ICLPRP

LOCAL INFORMATION



Gyeongju was the capital city of Silla for 992 years.

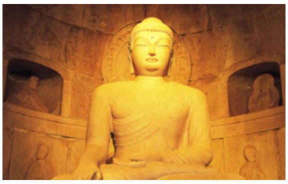
The history of Gyeongju, once called Seorabeol, is also the history of the thousand-year-old Silla Kingdom.

Gyeongju embraces Buddhism, science, and vibrant ancient culture that blossomed by the artistry of the Silla people, and the great spirits of Hwarangdo that enabled the unification of the three kingdoms. Thus, Gyeongju is a UNESCO-designated city which should be preserved by the public.

As one of Korea's national treasures, Gyeongju is one of the world's most important resources of culture and history.

With a clean ocean and magnificent natural scenery along the coast, Gyeongju is an optimal city for leisure and marine tourism.



Gyeongju Tourguide

Gyeongju Tourguide

EN	KR	CN	JP

Gyeongju Tour Guidebook

EN	KR	CN	JP

CONFERENCE VENUE

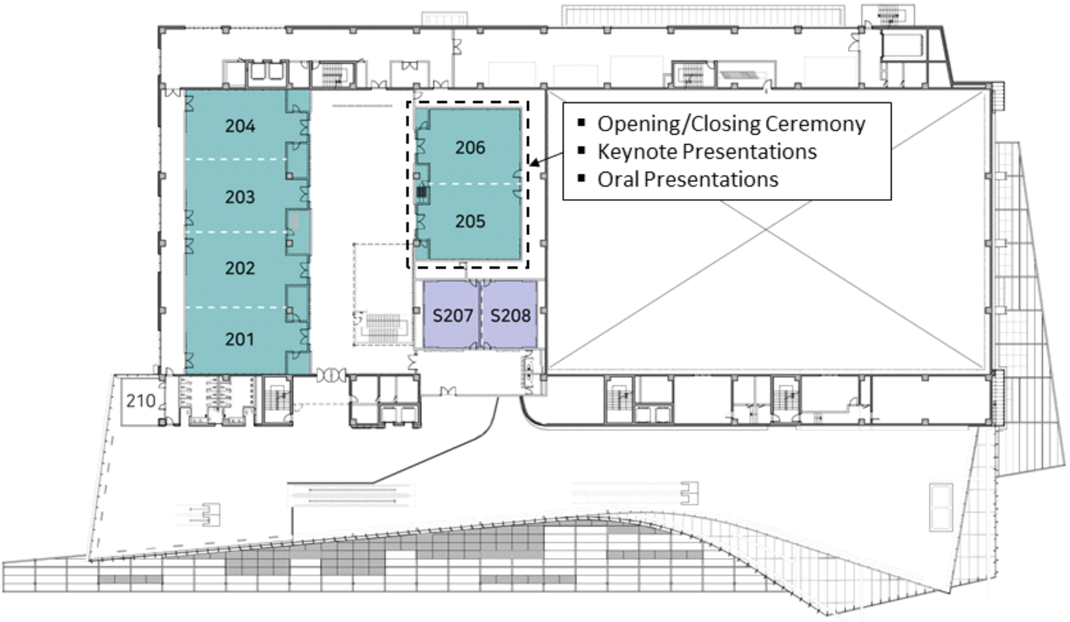
Gyeongju Hwabaek International Convention Center (HICO) is Korea's premier convention venue located in the Bomun Lake Resort Complex, one of Korea's most popular tourist destinations. Hwabaek was the name of the aristocratic council that ruled Korea for 1,000 years (57 BC - 935 AD). The modern center that takes its name from Hwabaek is composed of 15 meeting rooms including a convention hall (3,421m^2), exhibition hall (2,273m^2), and outdoor exhibition space (4,000m^2).

HICO is located near abundant accommodations and tourist attractions, including UNESCO World Cultural Heritage Sites like Bulguksa Temple, Seokguram Grotto, Yangdong Village, and the specially designated Gyeongju Historic Areas.

Overview	▪ Total Grounds: 31,336m^2 ▪ Facilities: 1 convention hall, 14 meeting rooms, 1 exhibition hall, 9 organizer rooms, and outdoor exhibition space ▪ Commercial Facilities: coffee shop, business center ▪ Wi-Fi Capacity: 5,000 users ▪ Parking Capacity: 520 vehicles
Capacity	▪ Convention Hall (Largest): 3500 seats (Theater), 1800 seats (Classroom), 1600 seats (Banquet) ▪ Exhibition Hall: 115 booths (3m×3m)
Nearby Hotels	▪ Total: 21 Hotels, 4,245 Rooms - Within 3 km Distance: 14 Hotels, 2,518 Rooms - 3km~10km: 5 Hotels, 1,531 Rooms - 10km~30km: 2 Hotels, 196 Rooms
Main Distances	▪ Singyeongju Station (KTX): 21 km ▪ Gyeongju Station (Mugunghwa Line): 9.8 km ▪ Gyeongju Intercity Bus Terminal: 11 km ▪ Gyeongju Express Bus Terminal: 11 km ▪ Gimhae Int'l Airport: 90 km

CONFERENCE FLOOR PLAN

2F



1F

CONFERENCE COMMITTEE

International Panel

Yuji Sano
Institute for Molecular Science, Japan
Domenico Furfari
Airbus GmbH, Germany
Michael Fitzpatrick
Coventry University, UK
Laurent Berthe
Centre National de la Recherche Scientifique, France
José L. Ocaña
Universidad Politecnica de Madrid, Spain
Seetha Ramaiah Mannava
University of Cincinnati, USA
Janez Grum
University of Ljubljana, Slovenia
Vijay K. Vasudevan
University of North Texas, USA
Claudia Polese
University of the Witwatersrand, Republic of South Africa
Kristina Langer
Air Force Research Laboratory, USA
Young-Sik Pyun
Sun Moon University, Republic of Korea
Tomokazu Sano
Osaka University, Japan

International Advisory Committee

International Panel Members

Tomáš Mocek
HiLASE, Czech Republic
Yongxiang Hu
Shanghai Jiao Tong University, China
Shikun Zou
Avic Manufacturing Technology Institute, China
Chang Ye
Huazhong University of Science and Technology, China

CONFERENCE COMMITTEE

8th ICLPRP Organizing Committee

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Young-Sik Pyun
Sun Moon University

Co-Chairman

Sungho Jeong
Gwangju Institute of Science and Technology

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Sungho Jeong
Gwangju Institute of Science and Technology
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DesignMecha Co., Ltd.
Do-Sik Shim
Korea Maritime & Ocean University
Sang-Hu Park
Pusan National University
Auezhan Amanov
Sun Moon University
Sang-Gu Kim
Handong Global University

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Sungho Jeong
Gwangju Institute of Science and Technology
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Ki-Yong Lee
Korea Institute of Industrial Technology
Seong-Sik Hwang
Korea Atomic Energy Research Institute
Jun-Hyong Kim
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Jin-Gwi Byeon
Pavetech Co., Ltd.
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Doosan Enerbility
Won-Geun Yi
Doosan Enerbility
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Korea Atomic Energy Research Institute
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DesignMecha Co., Ltd.
Hwa-Jin Song
Sun Moon University
Se-Young Park
Handong Global University
Se-Jeong Kim
Handong Global University

PROGRAM OVERVIEW

Keynote : 10 / Oral : 54 **(Room 205 & 206)**		Oct. 22, SUN.	Oct. 23, MON.	Oct. 24, TUE.	Oct. 25, WED.	Oct. 26, THU.	Oct. 27, FRI.
AM	07:30 - 08:00		**Registration**	**Registration**	**Registration**	**Registration**	**Registration**
	08:00			**Technical Tour** (Departure time 07:30) <Doosan Enerbility> <KIMM Busan Machinery Research Center> & **Lunch**	**Keynote.6** Laurent Berthe	**Keynote.8** Michael Fitzpatrick	**Keynote.10** Yuji Kobayashi
	08:05						
	08:10						
	08:15						
	08:20						
	08:25						
	08:30		**Opening**				
	08:35						
	08:40				Break	Break	Break
	08:45		**Keynote.1** Yuji Sano		**Special Session** **Session chair** Stephen Tate / Domenico Furfari Nicholas Mohr (A021) Jon Tatman (A025) John Lacy (A026) Robert Grizzi (A029)	**Shock Waves & Process Visualization Methods** **Session chair** Tomokazu Sano / Laurent Berthe Stanley Bovid (A081) Nicholas J. Stiekema (A096) Tomokazu Sano (A042) Naoya Egashira (A040)	**Development of Commercial Laser Peening Systems...** **Session chair** Auezhan Amanov / Vijay Vasudevan Romain Ecault (A088) Seungjin Hwang (A099) Christophe Simon-Boisson (A091) Inho Cho (A094)
	08:50						
	08:55						
	09:00						
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	09:20		**Keynote.2** Hyoung Seop Kim				
	09:25						
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	09:40						
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	09:50						
	09:55		Coffee Break				
	10:00						
	10:05		**Keynote.3** Domenico Furfari		Coffee Break	Coffee Break	Coffee Break
	10:10						
	10:15						
	10:20				**Fatigue Life Extension / Material Hardening & Microstructural Characterization** **Session chair** Chang Ye / Michael Fitzpatrick Shikun Zou (A019) Josef Strejcius (A036) Ziwen Cao (A035) Wei Li (A080) Chang Ye (A053) **EPRI Workshop** (Room 102) **Session chair** Seongsik Hwang	**Keynote.9** Vijay Vasudevan	**Fatigue Life Extension** **Session chair** Niall Smyth / Yuji Kobayashi Junfeng Wu (A020) Ogün Baris Tapar (A090) Niall Smyth (A052)
	10:25						
	10:30						
	10:35						
	10:40		**Residual Stress & Process Performance** **Session chair** Uroš Trdan / Yuji Sano Jan Kaufman (A028) Yuta Saito (A010) Yoshio Mizuta (A047) Uroš Trdan (A009)				
	10:45						
	10:50						
	10:55						
	11:00					**Surface Modifications** **Session chair** Claudia Polese / Michael Fitzpatrick Sungho Jeong (A043) Sunil Pathak (A044) Claudia Polese (A086)	
	11:05						
	11:10						
	11:15						
	11:20						**Closing** / **Best Poster Awards**
	11:25						
	11:30						
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PM	12:00		**Lunch**		**Lunch** / **Poster Session** (12:50-13:10)	**Lunch** / **Poster Session** (12:50-13:10)	
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	13:20		**Keynote.4** Dongil Kwon		**Keynote.7** Yongxiang Hu	**UNESCO World Heritage Tour** (Departure time 13:30) <Bulguksa> <Seokguram> <Gyeongju Wind Hill>	
	13:25						
	13:30						
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	13:55						
	14:00	**Registration**	Break		Break		
	14:05		**Fatigue Life Extension** **Session chair** Kiyotaka Masaki / Domenico Furfari Nikolai Kashaev (A014) Tomoharu Kato (A016) Zbyněk Špirit (A030) Kiyotaka Masaki (A034)		**Laser Peening for High Strength & Alternative Materials** **Session chair** Lalit Mohan Kukreja / Laurent Berthe Rujian Sun (A018) Pratik Shukla - MTC (A022) Sebastjan Žagar (A006) Lalit Mohan Kukreja (A107)		
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	15:00						
	15:05			**Keynote.5** Tomáš Mocek			
	15:10						
	15:15						
	15:20						
	15:25		Coffee Break		Coffee Break		
	15:30						
	15:35		**Surface Modifications** **Session chair** Rodney Genga / Auezhan Amanov Auezhan Amanov (A056) Seongsik Hwang (A004) Rodney Genga (A051)		**Residual Stress & Process Performance** **Session chair** Roman Šturm / Vijay Vasudevan Gilberto Gomez-Rosas (A105) Ondřej Stránský (A045) Roman Šturm (A007)		
	15:40						
	15:45			Coffee Break			
	15:50						
	15:55						
	16:00			**Innovative & Alternative Laser Peening Applications / Development of Commercial Laser Peening Systems...** **Session chair** Pratik Shukla / Tomáš Mocek Jan Brajer (A078) Adam Ayeb (A073) Shota Sekiguchi (A049) Hao Zhang (A062) Mark Bloomberg (A082) Fang Zhang (A032)			
	16:05						
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	16:25						
	16:30						
	16:35		Break		Break		
	16:40		**Laser Peen Forming and Other Novel Processes** **Session chair** Auezhan Amanov / Yuji Sano Ines SMA (A033) Jiancheng Jiang (A013) Mingtao Wang (A015)		**Process Modeling & Simulations / Related Phenomena** **Session chair** Yongxiang Hu / Chang Ye Siyuan Chen (A012) Kai Zhou (A070) Itaru Chida (A087)		
	16:45						
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	17:40				Go to Hilton Gyeongju		
	17:45						
	17:50						
	17:55						
	18:00 - 20:00			**Night Tour** : optional (Departure time 19:00)	**Banquet** / **Next Conference Announcement**		

- **Poster posting schedule : Oct. 23 - 27 (Posters will be posted starting Monday)**

GENERAL INFORMATION & SOCIAL EVENTS

Technical Tour: Tuesday, 7:30 a.m. - 2:40 p.m.

A - Doosan Enerbility
B - KIMM Busan Machinery Research Center
* Tour course: HICO → A → B (Box lunch) → HICO

Night Tour: Tuesday, 7:00 p.m. - 9:00 p.m. (Optional)

A - Woljeonggyo Bridge
B - Gyochon Village
C - Donggung Palace and Wolji Pond
D - Hwangridan-gil Street
* Tour course: HICO → A → B → C → D → HICO
* The night tour fee (USD 50) is not included in the registration fee.
If there are less than 10 applicants, the tour will be cancelled.
Please apply by Monday.

EPRI Workshop: Wednesday, 10:20 a.m. - 12:00 p.m. Room 102

* Workshop registration fee is free.
* Please apply at the registration desk.

Banquet: Wednesday, 6:00 p.m. - 8:00 p.m. Hilton Gyeongju

└ **Next Conference Announcement!**

UNESCO World Heritage Tour: Thursday, 1:30 p.m. - 5:00 p.m.

A - Bulguksa Temple
B - Seokguram Grotto
C - Gyeongju Wind Power Plant, Hill of Wind
* Tour course: HICO → A → B → C → HICO

Best Poster Awards: Friday, 11:20 a.m. - 11:40 a.m.

6 Posters

SUNDAY, Oct. 22, 2023

2:00 p.m. - 5:00 p.m. Conference Registration

MONDAY, Oct. 23, 2023

7:30 a.m. - 8:30 a.m. Conference Registration

8:30 a.m. - 8:45 a.m. Opening Ceremony

- **Welcome Address: Young-Sik Pyun** (Chairman, the 8th ICLPRP)
- **Congratulatory Address: Dosoung Choi** (President, Handong Global University)

8:45 a.m. - 9:20 a.m. Keynote Presentation 1

30 Years Development of Laser Peening without Coating
- System Miniaturization and Process Versatility
Prof. Yuji Sano
(SANKEN, Osaka University / Institutes for Molecular Science, Japan)

9:20 a.m. - 9:55 a.m. Keynote Presentation 2

Experiments and Modelling of Heterostructured Materials Processed
by Ultrasonic Nanocrystalline Surface Modification
Prof. Hyoung Seop Kim
(POSTECH, Republic of Korea)

9:55 a.m. - 10:05 a.m. Coffee Break

10:05 a.m. - 10:40 a.m. Keynote Presentation 3

The use of Lights for Structural Performance Enhancement of Metallic Airframes.
LEOPARD™, a Laser Shock Peening industrial solution
for Maintenance Repair Overhaul Use
Dr. Domenico Furfari
(Airbus Operations GmbH, Germany)

Residual Stress & Process Performance

Session Chair: Prof. Uroš Trdan (University of Ljubljana, Slovenia)

10:40 a.m. - 11:00 a.m. Oral Presentation A028

Laser Peening without Coating to Prevent Stress Corrosion Cracking in Heterogenous Welds

Dr. Jan Kaufman

(HiLASE Centre, Institute of Physics of the Czech Academy of Sciences, Czech Republic)

11:00 a.m. - 11:20 a.m. Oral Presentation A010

Effects of Laser Peening on Compressive Residual Stresses in Aging Aluminum Alloys

Mr. Yuta Saito

(Sintokogio, Ltd., Japan)

11:20 a.m. - 11:40 a.m. Oral Presentation A047

Improvement of Residual Stresses and Fatigue Properties of A7075 Aluminum Alloy using a Compact Low-Energy Laser Peening System

Mr. Yoshio Mizuta

(SANKEN, Osaka University, Japan)

11:40 a.m. - 12:00 p.m. Oral Presentation A009

High-Energy X-Ray Synchrotron Source:
Quick and Accurate Measurement of the Residual Stress Field Reinforced by Laser Shock Peening Process

Prof. Uroš Trdan

(Faculty of Mechanical Engineering, University of Ljubljana, Slovenia)

12:00 p.m. - 1:20 p.m. Lunch: The-K Hotel Gyeongju

1:20 p.m. - 2:00 p.m. Keynote Presentation 4

Material Restoration by Ultrasonic Nanocrystal Surface Modification (UNSM) and Measurement of Mechanical Property and Residual Stress using Instrumented Indentation Technique (IIT)

Prof. Dongil Kwon

(Seoul National University, Republic of Korea)

2:00 p.m. - 2:05 p.m. Break

Fatigue Life Extension

Session Chair: Prof. Kiyotaka Masaki (Saitama Institute of Technology, Japan)

2:05 p.m. - 2:25 p.m. Oral Presentation A014

On the Application of Weight Functions for the Prediction of Fatigue Crack Growth in AA2024 Considering Residual Stresses Induced by Laser Shock Peening and Laser Heating

Dr. Nikolai Kashaev

(Institute of Materials Mechanics, Helmholtz-Zentrum Hereon, Germany)

2:25 p.m. - 2:45 p.m. Oral Presentation A016

Improvement on Fatigue Properties of HT780 Butt-Welded Joints by Portable Laser Peening Device

Mr. Tomoharu Kato

(JSPS Research Fellow / Kindai University, Japan)

2:45 p.m. - 3:05 p.m. Oral Presentation A030

Notch Suppression on Martensitic Stainless Steels by Laser Shot Peening

Dr. Zbyněk Špirit

(Centrum výzkumu Řež s.r.o., Czech Republic)

3:05 p.m. - 3:25 p.m. Oral Presentation A034

Comparison of Surface Crack Propagation Behaviour of A2024 Alloy Subjected to Various Peening Treatments

Prof. Kiyotaka Masaki

(Saitama Institute of Technology, Japan)

3:25 p.m. - 3:35 p.m. Coffee Break

Surface Modifications

Session Chair: Prof. Rodney Genga (University of the Witwatersrand, Republic of South Africa)

3:35 p.m. - 3:55 p.m. Oral Presentation A056

Ultrasonic Nanocrystal Surface Modification: State-of-the-art and Future Perspectives

Prof. Auezhan Amanov

(Sun Moon University, Republic of Korea)

3:55 p.m. - 4:15 p.m. Oral Presentation A004

Research on Feasible Materials and Surface Technology for MSR:
Beginning from Stainless Steel 316H and UNSM

Dr. Seongsik Hwang

(Nuclear Materials Safety Technology Research Division, Korea Atomic Energy Research Institute, Republic of Korea)

4:15 p.m. - 4:35 p.m. Oral Presentation A051

Laser Surface Modification and Femtosecond Laser Chip Breakers
for Improved Machining of Ferrous Alloys
with NbC and WC Cermets

Prof. Rodney Genga

(Academic Development Unit, University of the Witwatersrand, Republic of South Africa)

4:35 p.m. - 4:40 p.m. Break

Laser Peen Forming and Other Novel Processes

Session Chair: Prof. Auezhan Amanov (Sun Moon University, Republic of Korea)

4:40 p.m. - 5:00 p.m. Oral Presentation A033

Laser Shock Adhesion Test of Thermally Aged Epoxy Coatings

Ms. Ines SMA

(PIMM, UMR8006 ENSAM, CNRS, CNAM, France)

5:00 p.m. - 5:20 p.m. Oral Presentation A013

Determination of Peening Pattern with Multiple Process Conditions
for Laser Peen Forming via Topology Optimization

Mr. Jiancheng Jiang

(State Key Laboratory of Mechanical System and Vibration, School of Mechanical Engineering, Shanghai Jiao Tong University, China)

5:20 p.m. - 5:40 p.m. Oral Presentation A015

Research on Deformation of 2024 Aluminum Alloy Panels with Stiffeners
by Laser Peen Forming

Mr. Mingtao Wang

(AVIC Manufacturing Technology Institute, China)

TUESDAY, Oct. 24, 2023

7:30 a.m. - 8:00 a.m. Conference Registration

7:30 a.m. - 3:05 p.m. Technical Tour & Box Lunch

- **Doosan Enerbility**
- **KIMM Busan Machinery Research Center**

3:05 p.m. - 3:45 p.m. Keynote Presentation 5

Pioneering High Average Power Laser Technology at HiLASE

Dr. Tomáš Mocek

(HiLASE Centre, Czech Republic)

3:45 p.m. - 4:00 p.m. Coffee Break

Innovative & Alternative Laser Peening Applications Development of Commercial Laser Peening Systems / UNSM Systems / Cavitation Peening Systems / Water Jet Peening System / Ultrasonic Peening Systems, etc.

Session Chair: Dr. Pratik Shukla (The Manufacturing Technology Centre, United Kingdom)

4:00 p.m. - 4:20 p.m. Oral Presentation A078

Laser Shock Peening Technology Development at HiLASE Center and Actual Capabilities

Dr. Jan Brajer

(HiLASE Centre, Institute of Physics of the Czech Academy of Sciences, Czech Republic)

4:20 p.m. - 4:40 p.m. Oral Presentation A073

The FLASP Apparatus: Laser Peening with Record-Breaking Laser Energy at the Tip of a Fiber

Mr. Adam Ayeb

(Imagine Optic, France)

4:40 p.m. - 5:00 p.m. Oral Presentation A049

Development of a 10-mJ Handheld Microchip Laser and its Application to Laser Peening

Mr. Shota Sekiguchi

(Optoquest Co., Ltd., Japan)

5:00 p.m. - 5:20 p.m. Oral Presentation A062

Microstructure Evolution and Electroplasticity in Ti64 Subjected to Electropulsing-Assisted Laser Shock Peening

Dr. Hao Zhang

(College of Civil Aviation, Northwestern Polytechnical University, China)

5:20 p.m. - 5:40 p.m. Oral Presentation A082

Considerations and Developments for the Commercialization of Laser Shock Peening Technology

Mr. Mark Bloomberg

(LSP Technologies, Inc., USA)

5:40 p.m. - 6:00 p.m. Oral Presentation A032

50J High Energy Nd: Glass Slab Laser for Shock Peening

Mr. Fang Zhang

(Beamtech Canada, Canada)

7:00 p.m. - 9:00 p.m. Night Tour

- **Woljeonggyo Bridge**
- **Gyochon Village**
- **Donggung Palace and Wolji Pond**
- **Hwangridan-gil Street**

WEDNESDAY, Oct. 25, 2023

7:30 a.m. - 8:00 a.m. Conference Registration

8:00 a.m. - 8:40 a.m. Keynote Presentation 6

Towards Reliable and Versatile Laser Shock Application: from Laser to Parts

Dr. Laurent Berthe

(Lab PIMM CNRS, France)

8:40 a.m. - 8:45 a.m. Break

Special Session

Session Chair: Dr. Stephen Tate (Electric Power Research Institute, USA)

8:45 a.m. - 9:05 a.m. Oral Presentation A021

Recent Incorporations of Welding Residual Stress into ASME Section III Code

Nicholas Mohr

(Electric Power Research Institute, USA)

9:05 a.m. - 9:25 a.m. Oral Presentation A025

Residual Stress Analysis of Cold Spray Deposition for Stress Corrosion Cracking Mitigation and Repair

Jon Tatman

(Electric Power Research Institute, USA)

9:25 a.m. - 9:45 a.m. Oral Presentation A026

Peening Technologies to Mitigate Initiation and Resurgence of Stress Corrosion Cracking in Dry Storage Stainless Steel Canisters

John Lacy

(University of Wisconsin-Madison, USA)

9:45 a.m. - 10:05 a.m. Oral Presentation A029

Evaluation of Peening Effects on NDE Inspection Techniques

Robert Grizzi

(Electric Power Research Institute, USA)

10:05 a.m. - 10:20 a.m. Coffee Break

EPRI Workshop **(10:20 a.m. - 12:00 p.m. Room 102)**

Session Chair: Dr. Seongsik Hwang (Korea Atomic Energy Research Institute, Republic of Korea)

Fatigue Life Extension

Material Hardening & Microstructural Characterization

Session Chair: Prof. Chang Ye (Huazhong University of Science and Technology, China)

10:20 a.m. - 10:40 a.m. Oral Presentation A019

Performance Test for Laser Peening Titanium Integrally Blade Rotor Blade

Prof. Shikun Zou

(AVIC Manufacturing Technology Institute, China)

10:40 a.m. - 11:00 a.m. Oral Presentation A036

Effect of Laser Peening Treatment on High Cycle Fatigue Strength of Cast Martensitic Stainless Steel in River Water Environment

Mr. Josef Strejcius

(Centrum výzkumu Řež s.r.o., Czech Republic)

11:00 a.m. - 11:20 a.m. Oral Presentation A035

Effect of Laser Peering on Fretting Fatigue of Titanium Alloy Fan Blade Tenons

Mr. Ziwen Cao

(AVIC Manufacturing Technology Institute, China)

11:20 a.m. - 11:40 a.m. Oral Presentation A080

Effects of Ultrasonic Nanocrystal Surface Modification on Microstructural Characteristics and Surface Properties of Al5356 Alloy Manufactured by Wire Arc Additive Manufacturing

Prof. Wei Li

(Department of Mechanical Engineering, The University of Texas at Dallas, USA)

11:40 a.m. - 12:00 p.m. Oral Presentation A053

Improving Peening Efficacy through High Amplitude Short Duration Pulsed Current

Prof. Chang Ye

(School of Mechanical Science and Engineering, Huazhong University of Science and Technology, China)

12:00 p.m. - 1:20 p.m. Lunch: The-K Hotel Gyeongju

12:50 p.m. - 1:10 p.m. Poster Presentations

1:20 p.m. - 2:00 p.m. Keynote Presentation 7

Laser Peening of Large-Scale Components: Modeling, Optimization and Applications

Prof. Yongxiang Hu

(Shanghai Jiao Tong University, China)

2:00 p.m. - 2:05 p.m. Break

Laser Peening for High Strength & Alternative Materials

Session Chair: Prof. Lalit Mohan Kukreja (Ruhr-Universität Bochum, Germany)

2:05 p.m. - 2:25 p.m. Oral Presentation A018

Laser Peening of Aluminum-Based Metal Matrix Composites:
Microstructure, Residual Stress and Fatigue

Dr. Rujian Sun

(Aviation Key Laboratory of Science and Technology on Advanced Surface Engineering,
AVIC Manufacturing Technology Institute, China)

2:25 p.m. - 2:45 p.m. Oral Presentation A022

Recent Progress in Laser Shock Peening

Dr. Pratik Shukla

(The Manufacturing Technology Centre (MTC), United Kingdom)

2:45 p.m. - 3:05 p.m. Oral Presentation A006

The Influence of Laser Shock Peening on Surface Integrity of Magnesium Alloy AZ80

Dr. Sebastjan Žagar

(University of Ljubljana, Faculty of Mechanical Engineering, Slovenia)

3:05 p.m. - 3:25 p.m. Oral Presentation A107

Envisaged Strategies and Studies on Laser Shock Peening of Laser Deposited
High Entropy Alloys

Prof. Lalit Mohan Kukreja

(Applied Laser Technology, Ruhr-Universität Bochum / Epi-knowledge Foundation, Germany)

3:25 p.m. - 3:35 p.m. Coffee Break

Residual Stress & Process Performance

Session Chair: Prof. Roman Šturm (University of Ljubljana, Slovenia)

3:35 p.m. - 3:55 p.m. Oral Presentation A105

Laser Shock Processing using Nano and Pico Seconds Pulsed Lasers

Dr. Gilberto Gomez-Rosas

(CUCEI, Guadalajara University, Mexico)

3:55 p.m. - 4:15 p.m. Oral Presentation A045

Effect of Laser Peening without Coating on Additively Manufactured AlSi10Mg

Mr. Ondřej Stránský

(HiLASE Centre, Institute of Physics, Czech Academy of Sciences, Czech Republic)

4:15 p.m. - 4:35 p.m. Oral Presentation A007

Cavitation Peening of Precipitation Hardened AA7075

Prof. Roman Šturm

(University of Ljubljana, Faculty of Mechanical Engineering, Slovenia)

4:35 p.m. - 4:40 p.m. Break

Process Modeling & Simulations Related Phenomena

Session Chair: Prof. Yongxiang Hu (Shanghai Jiao Tong University, China)

4:40 p.m. - 5:00 p.m. Oral Presentation A012

Modelling of Dynamic Crystal Plasticity and Study on Anisotropic Mechanical Response of FCC Single Crystal

Mr. Siyuan Chen

(School of Mechanical Engineering, Shanghai Jiao Tong University, China)

5:00 p.m. - 5:20 p.m. Oral Presentation A070

Predicting the USP Process of Aero-Engine Turbo Disk Grooves using a Sequential DEM-FEM Method

Mr. Kai Zhou

(College of Civil Aviation, Northwestern Polytechnical University, China)

5:20 p.m. - 5:40 p.m. Oral Presentation A087

Study on 30MW Laser Pulse Transmission by End Cap Fiber

Mr. Itaru Chida

(Toshiba Energy Systems & Solutions Corporation, Japan)

6:00 p.m. - 8:00 p.m. Banquet: Hilton Gyeongju

THURSDAY, Oct. 26, 2023

7:30 a.m. - 8:00 a.m. Conference Registration

8:00 a.m. - 8:40 a.m. Keynote Presentation 8

Laser Shock Peening: Recent Developments and a Look Ahead

Prof. Michael Fitzpatrick

(Coventry University, United Kingdom)

8:40 a.m. - 8:45 a.m. Break

Shock Waves & Process Visualization Methods

Session Chair: Prof. Tomokazu Sano (Osaka University, Japan)

8:45 a.m. - 9:05 a.m. Oral Presentation A081

Exploring the Impact of Opaque Overlays on Laser Shock Peening: Pressure Variations and Efficient Characterization

Dr. Stanley Bovid

(LSP Technologies, Inc., USA)

9:05 a.m. - 9:25 a.m. Oral Presentation A096

Laser Shock Peening Technology Development: Cavitation Bubbles as a Process Diagnostic

Mr. Nicholas J. Stiekema

(School of Mechanical, Industrial and Aeronautical Engineering, University of the Witwatersrand, Republic of South Africa)

9:25 a.m. - 9:45 a.m. Oral Presentation A042

Dry Laser Peening using Femtosecond Laser-Driven Shock Wave

Prof. Tomokazu Sano

(Osaka University, Japan)

9:45 a.m. - 10:05 a.m. Oral Presentation A040

Direct Observation of Transient State under Femtosecond Laser-Driven Shock Formation in Cu

Mr. Naoya Egashira

(Osaka University, Japan)

10:05 a.m. - 10:20 a.m. Coffee Break

10:20 a.m. - 11:00 a.m. Keynote Presentation 9

Progress in the Engineering Science and Application of Laser Shock Peening and Related Mechanical Surface Treatments in Materials Manufacturing and Future Opportunities

Prof. Vijay K Vasudevan

(University of North Texas, USA)

Surface Modifications

Session Chair: Prof. Claudia Polese (University of the Witwatersrand, Republic of South Africa)

11:00 a.m. - 11:20 a.m. Oral Presentation A043

Enhancement of the Surface Properties of Additively Manufactured Ti-6Al-4V by Laser Shock Peening

Prof. Sungho Jeong

(School of Mechanical Engineering, Gwangju Institute of Science and Technology, Republic of Korea)

11:20 a.m. - 11:40 a.m. Oral Presentation A044

Surface Properties of Additively Manufactured Produced Meso-Sized Gears in Laser Shock Peening

Dr. Sunil Pathak

(HiLASE Centre, Institute of Physics, Czech Academy of Sciences, Czech Republic)

11:40 a.m. - 12:00 p.m. Oral Presentation A086

Surface Engineering Additive Manufactured Components for Biomedical Applications

Prof. Claudia Polese

(School of Mechanical, Industrial and Aeronautical Engineering, University of the Witwatersrand, Republic of South Africa)

12:00 p.m. - 1:20 p.m. Box Lunch

12:50 p.m. - 1:10 p.m. Poster Presentations

1:30 p.m. - 5:00 p.m. UNESCO World Heritage Tour

- **Bulguksa Temple**
- **Seokguram Grotto**
- **Gyeongju Wind Power Plant, Hill of Wind**

FRIDAY, Oct. 27, 2023

7:30 a.m. - 8:00 a.m. Conference Registration

8:00 a.m. - 8:40 a.m. Keynote Presentation 10

Outlook for the Contract Business using Laser Peening in Japan

Dr. Yuji Kobayashi

(Sintokogio, LTD., Japan)

8:40 a.m. - 8:45 a.m. Break

Development of Commercial Laser Peening Systems / UNSM Systems / Cavitation Peening Systems / Water Jet Peening System / Ultrasonic Peening Systems, etc.

Session Chair: Prof. Auezhan Amanov (Sun Moon University, Republic of Korea)

8:45 a.m. - 9:05 a.m. Oral Presentation A088

State of the Art of Laser Shock Adhesion Test - a Wide Range of Possibilities

Dr. Romain Ecault

(Airbus Operations SAS, France)

9:05 a.m. - 9:25 a.m. Oral Presentation A099

Fiber Delivered 200mJ Nanosecond Green Laser System
for Laser Peening without Coating

Dr. Seungjin Hwang

(HIL Lab. Inc., Republic of Korea)

9:25 a.m. - 9:45 a.m. Oral Presentation A091

Fast Laser Shock Peening using High Repetition Rate Lasers

Mr. Christophe Simon-Boisson

(Thales LAS, France)

9:45 a.m. - 10:05 a.m. Oral Presentation A094

Introduction of UNSM Device and Equipment Depending on their Application

Dr. Inho Cho

(DesignMecha Co., Ltd., Republic of Korea)

10:05 a.m. - 10:20 a.m. Coffee Break

Fatigue Life Extension

Session Chair: Dr. Niall Smyth (Coventry University, United Kingdom)

10:20 a.m. - 10:40 a.m. Oral Presentation A020

Anti-Fatigue Extension Life Mechanism of Al7050-T7451 Hole Structures with Laser Shock Peening

Dr. Junfeng Wu

(Aviation Key Laboratory of Science and Technology on Advanced Surface Engineering, Aviation Industry Corporation of China (AVIC) Manufacturing Technology Constitute, China)

10:40 a.m. - 11:00 a.m. Oral Presentation A090

Increasing the Fatigue Strength of Rivet Lap Joint of Aerospace Grade 7xxx Series Aluminum Plates by Laser Shock Peening

Mr. Ogün Baris Tapar

(Leibniz Institute for Materials Engineering - IWT, Germany)

11:00 a.m. - 11:20 a.m. Oral Presentation A052

The Role of Residual Stress Distribution on Fatigue Crack Growth

Dr. Niall Smyth

(Centre for Manufacturing and Materials, Coventry University, United Kingdom)

11:20 a.m. - 11:40 a.m. Closing Ceremony

- **Best Poster Awards**

POSTERS

Poster No.1 A002

The FEM Simulation of Laser Shock Peening Process for Stainless Steel 304

Mr. Ryoonhan Kim

(Busan Machinery Research Center, Korea Institute of Machinery & Materials, Republic of Korea)

Poster No.2 A005

High-Speed Gas Effect on Aluminum and Silver Surfaces Irradiated by a Nanosecond Laser

Mr. Mohamed Ezzat

(Center for Relativistic Laser Science, Institute for Basic Science (IBS), Republic of Korea)

Poster No.3 A011

Investigation on the Residual Stress Distribution of 304 Austenitic Steel Induced by Laser Shock Peening

Ms. Danbi Song

(Korea Institute of Machinery & Materials, Republic of Korea)

Poster No.4 A017

Fatigue Properties Improvement by Portable Laser Peening Device

- Application to SBHS500 Butt-Welded Joints

Mr. Tomoharu Kato

(JSPS Research Fellow / Kindai University, Japan)

Poster No.5 A024

Laser Shock Peening Processing of Big-end Bearings

Dr. Pratik Shukla

(The Manufacturing Technology Centre (MTC), United Kingdom)

Poster No.6 A027

Contact-Free Paint Adhesion Test via Laser-Plasma Interaction

Dr. Laurent Berthe

(CNRS, ENSAM-Paris Tech, France)

Poster No.7 A031

Microstructure and Corrosion Resistance Estimation of Nickel-Aluminum Bronze after Ultrasonic Nanocrystal Surface Modification

Mr. Changliang Yao

(Department of Ocean Advanced Materials Convergence Engineering, Korea Maritime and Ocean University, Republic of Korea)

POSTERS

Poster No.8 A037

Inducing Damage by Laser Shock Plasma:
Application for Dismantling Laminated Composites for Recycling
Ms. Ines SMA
(PIMM, UMR8006 ENSAM, CNRS, CNAM, France)

Poster No.9 A038

Fatigue Strength Improvement of Non-Oriented Electrical Steel Sheets
by Low-Energy Laser Peening
Mr. Toshihisa Sendai
(Tokyo City University, Japan)

Poster No.10 A039

Simultaneous Improvement of Residual Stress and Surface Morphology of Ti-6Al-4V ELI
by Low-Energy Laser Peening
Mr. Yuki Iino
(Tokyo City University, Japan)

Poster No.11 A041

Behavior at an Early Stage of Femtosecond Laser-Driven Shock Wave in Aluminum
Mr. Seiru Inoue
(Osaka University, Japan)

Poster No.12 A046

Laser Shock Peening Acoustic Emission Measurement by Evaluation
of Acoustic Wave Propagating through Air
Mr. Marek Böhm
(HiLASE Centre, Institute of Physics of the Czech Academy of Sciences, Czech Republic)

Poster No.13 A048

Effect of Laser Shock Peening on Inconel 738LC for the Improvement
of Mechanical Properties
Mr. Seongguk Bae
(School of Mechanical Engineering, Gwangju Institute of Science and Technology, Republic of Korea)

Poster No.14 A050

Expanding LPwC Applications with High-Power Microchip Lasers Mounted
on Industrial Robots
Mr. Sebastian Holz
(sentenso Smart Peening Solutions, Germany)

Poster No.15 A055

Dry Laser Peening of High Tensile Strength Steel

Mr. Yoshiki Komatsubara

(Osaka University, Japan)

Poster No.16 A059

Development of Ultrasonic Nanocrystal Surface Modification Device to Improve PWSCC Characteristics of Reactor Nozzle

Dr. Junhyong Kim

(DesignMecha Co., Ltd., Republic of Korea)

Poster No.17 A060

Effect of Substrate Preheating on the Hardness Behaviors of Inconel 718-WC Composite Coating Synthesized by Laser Directed Energy Deposition

Ms. Shanshan He

(School of Mechanical Engineering, Pusan National University, Republic of Korea)

Poster No.18 A061

UNSM Process Parameter Evaluation for Increasing Hydrogen Embrittlement Resistance in Direct Energy Deposited STS-316L Considering Strain-Induced Martensite

Mr. Seoungho Baek

(Research Institution for Mechanical Technology, Republic of Korea)

Poster No.19 A065

A Study on the Development of Underwater Laser Ablation System

Prof. Choonman Lee

(Mechatronics Research Center, Changwon National University, Republic of Korea)

Poster No.20 A066

Simulation of Laser Impact Welding Considering Influence of Microstructure

Prof. Arif Malik

(University of Texas at Dallas, USA)

Poster No.21 A067

High-Strength Laser Impact Welding by Laser-Shock Post-Treatment

Prof. Arif Malik

(University of Texas at Dallas, USA)

Poster No.22 A071

Effect of Electropulsing-Assisted Ultrasonic Nanocrystal Surface Modification on Microstructures Properties of Additive Manufactured Ti64

Ms. Yixuan Ye

(School of Mechanical Science and Engineering, Huazhong University of Science and Technology, China)

Poster No.23 A072

Simulation of the Effects of Laser Shock Peening at Different Incidence Angles on the Surface Morphology and Residual Stresses of Ti-6Al-4V

Mr. Ziheng Xu

(School of Mechanical Science and Engineering, Huazhong University of Science and Technology, China)

Poster No.24 A074

Enhancing Wear Performance of WAAM Manufactured IN718 and 17-4PH Materials through UNSM Treatment

Mr. Sungho Heo

(BEES Inc., Republic of Korea)

Poster No.25 A075

Modeling of 100mJ Class Laser Peening System for Real-Time Peening Process Monitoring

Mr. Sanghyun Park

(Dept. of Advanced Convergence, Handong Global University, Republic of Korea)

Poster No.26 A076

Performance Comparison of LOXAFH and LASOX Cutting Methods with Laser Beam Diameter

Mr. Sion Kim

(Dept. of Advanced Convergence, Handong Global University, Republic of Korea)

Poster No.27 A079

Laser Shock Peening to Improve the Wear Characteristics of Tool Steel

Prof. Dong Qian

(Department of Mechanical Engineering, The University of Texas at Dallas, USA)

POSTERS

Poster No.28 A083

Technological Advancements in Delivering an Industrial Hardened Laser Shock Peening System Solution for Laser Peening in Nuclear

Mr. Mark Bloomberg

(LSP Technologies, Inc., USA)

Poster No.29 A089

A Study on the Mechanical Properties and Microstructure of SKD 61 Repaired using Directed Energy Deposition (DED)

Mr. Minseong Ko

(Korea Maritime and Ocean University, Republic of Korea)

Poster No.30 A093

Superior Gradient Heterostructured Alloys Fabricated by Laser Powder Bed Fusion via Annealing and Ultrasonic Nanocrystal Surface Modification

Mr. Rae-Eon Kim

(POSTECH, Republic of Korea)

Poster No.31 A095

Effect of Different Tape Overlays on the Surface Integrity and Mechanical Properties of Aeronautical Aluminium Alloy 7075 Processed by Laser Shock Peening

Prof. Claudia Polese

(School of Mechanical, Industrial and Aeronautical Engineering, University of the Witwatersrand, Republic of South Africa)

Poster No.32 A097

Investigation of Corrosion Behaviour of Aeronautical Aluminium Alloy 7075 Processed by Laser Shock Peening without Coating

Ms. Natsai Shonhai

(School of Chemical and Metallurgical Engineering, University of the Witwatersrand, Republic of South Africa)

Poster No.33 A098

Reaction Characteristics of Laser-Induced Graphene-Based Hydrogen Sensors using UV Laser

Mr. Jinsu Kim

(Pusan National University, Republic of Korea)

Poster No.34 A100

Comparative Study of Laser Polishing Employing Spatial Beam Modulation

Mr. Minho Lee

(Institute of Advanced Convergence Technology, Kyungpook Nat. Univ., Republic of Korea)

Poster No.35 A109

Effect of Laser Beam Overlap Rate on Mechanical Properties of Aluminum Alloy Arc Welding with Laser Peening

Mr. Jaeook Jeon

(Graduate school, Korea Maritime & Ocean University, Republic of Korea)

Poster No.36 A110

Improvement of Wear Resistance at High Temperature by Hybrid Cladding Combined UNSM and Laser DED Process

Mr. YeongKwan Jo

(Pusan National University, Republic of Korea)

Poster No.37 A112

Development and Verification of Laser Peening System for Mitigation of Main Equipment of Nuclear Power Plants

Mr. Sungchan Bae

(Pavetech Co., Ltd., Republic of Korea)

EXHIBITORS

GIST 광주과학기술원 Gwangju Institute of Science and Technology
KIMM 한국기계연구원 KOREA INSTITUTE OF MACHINERY & MATERIALS
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Korea Institute of
Materials Science

ABSTRACTS

Keynote 1

Title:

30 Years Development of Laser Peening without Coating - System Miniaturization and Process Versatility

Authors & Affiliations:

Yuji SANO
SANKEN, Osaka University / Institutes for Molecular Science

Abstract:

The author reviews the development of laser peening without coatings (LPwC) over the past 30 years in terms of pulse energy reduction. The development began in the early 1990s as an application of Copper Vapor Laser (CVL), the first high-power laser with visible wavelengths that could penetrate water. By reducing the CVL pulse width from the original several tens of nanoseconds to less than 10 nanoseconds, surface compression was achieved without an ablative layer on the material. During this period, frequency-doubler using nonlinear crystals matured, therefore CVLs were replaced by frequency-doubled Nd:YAG lasers. In 1999, LPwC with a pulse energy of 200 mJ applied to reactor components to prevent stress corrosion cracking (SCC) and then expanded by fiber-delivery technology of 100 mJ laser pulses. Recently, a finger-sized laser has been realized using monolithic microchip laser technology. Although the pulse energy is limited to 10 mJ, the pulse width is 1/10 of current Nd:YAG lasers and the peak power is maintained equivalent to that of 100 mJ laser pulses. LPwC using the finger-sized laser induced compressive residual stresses on the surface of an aluminum alloy and a high-strength steel. Fatigue properties were improved to the same level as results using the current Nd:YAG lasers.

Keyword:

LPwC, Finger-sized laser, Pulse energy, Residual stress, Fatigue

Keynote 2

Title:

Experiments and Modelling of Heterostructured Materials Processed by Ultrasonic Nanocrystalline Surface Modification

Authors & Affiliations:

Hyoung Seop Kim
Pohang University of Science and Technology

Abstract:

The advantages of heterostructured materials as structural materials include superior mechanical properties and the ability to tailor the strength-ductility combination via microstructure customization. To maximize heterostructure effects, we employed various processes, e.g., casting, severe plastic deformation, and additive manufacturing, combined with ultrasonic nanocrystalline surface modification processes to create multi-layered microstructured heterostructures. The fabricated materials have a novel microstructure composed of multiple layers of repetitive microstructures with heterogeneity and demonstrate a remarkable synergetic strengthening effect in comparison to conventional heterogeneous materials. The outstanding mechanical properties derived from various hard and soft layer interfaces, as well as the effects of each layer and interface, were quantitatively analyzed using grain-scale digital image

correlation technology. The multi-layered microstructure with multiple heterogeneous boundaries breaks the conventional wisdom regarding heterostructured materials having only one or two heterogeneous interfaces. Constitutive modeling implemented into the finite element method was demonstrated.

Keyword:
Ultrasonic nanocrystalline surface modification, Heterostructured material, Microstructural tailoring, Constitutive model

▪ Keynote 3

Title:

The use of Lights for Structural Performance Enhancement of Metallic Airframes. LEOPARD^{TM}, a Laser Shock Peening industrial solution for Maintenance Repair Overhaul Use

Authors & Affiliations:

Domenico Furfari(1), Richard Redon(2), Romain Ecault(3), Olivier Collin(4)
(1) Airbus Operations GmbH, Kreetslag 10 21129, Hamburg Germany
(2) Airbus Central Entities SaS, All. Pierre Nadot, 31700 Blagnac, France
(3) Airbus Operations SaS, 42 Chem. de l'Espeissière, 31300 Toulouse, France
(4) Airbus Operations SaS, All. Pierre Nadot, 31700 Blagnac, France

Abstract:

The use of surface technologies inducing residual stresses can be employed in aeronautical industry as technologies to ensure salvage for identified hot spots in terms of fatigue and crack growth performance. Technologies and methodologies that improve the resistance of structures to in-service degradation processes such as fatigue are of benefit to the aircraft industry in terms of extending the service life of the structure and thus reducing maintenance costs. Laser Shock Peening (LSP) is a surface technology which introduces deep residual compressive stresses into a metallic structure aiming at improving the economical and ecological impact of an aging fleet as well as of future aircraft structures by controlling the residual stresses. A newly developed low energy portable equipment (Airbus IP) for MRO deployment capable of LSP in fully assembly aircraft while at repair station will be presented. The LEOPARD™ (**L**aser **E**quipment for **O**perations of **P**eening in **A**ircraft **R**etrofit **D**eployment), first around the world laser peening portable equipment receiving ATEX (Atmosphere Explosive Environment) certification for CLASS IV laser, will be described in detail.

Current LSP systems are not compatible with commercial aircraft maintenance environments. Rigid and complex mirror-based beam delivery systems may be a showstopper for applying LSP treatment at fatigue critical components for in-service commercial aircraft during standard maintenance and repair operations. To make LSP applicable at Maintenance Repair Overhaul (MRO) and ensure reasonably simple setup and easy transportability requires developing a “portable” device. A newly developed low energy portable equipment (LEOPARD™) for MRO deployment capable of LSP in fully assembled aircraft will be presented. LEOPARD™, is the first around the world laser peening portable equipment receiving ATEX (Atmosphere Explosive Environment) certification for CLASS IV laser.

■ Keynote 4

Title:

Material Restoration by Ultrasonic Nanocrystal Surface Modification (UNSM) and Measurement of Mechanical Property and Residual Stress Using Instrumented Indentation Technique (IIT)

Authors & Affiliations:

Dongil Kwon[1], Kwangho Kim[2], Jae-Hun Choi[2], In-Ho Cho[3], Young-Sik Pyun[4]
1Department of Material Science and Engineering, Seoul National University, Seoul, Korea
2Frontics. Inc., Seoul, Korea
3DesignMecha Co., Ltd., Asan, Korea
4Department of Fusion Science and Technology, Sun Moon University, Asan, Korea
* Corresponding author: dongilk@snu.ac.kr

Abstract:

In this study, an ultrasonic nanocrystal surface modification (UNSM) technology is considered a surface severe plastic deformation (S^2PD) method, which increases the hardness of the material and also transfers tensile residual stress into compressive residual stress. The effect of UNSM technology on the hardness and residual stress of in-service components can be measured directly in the field by an instrumented indentation technique (IIT) to understand the hardening and generation of compressive residual stress mechanisms.

The IIT can evaluate not only hardness but also fracture characteristics and residual stress based on analytic interpretation of the indentation load-depth curve of the target material. Also, IIT can be directly applied to the structure under operation or installation where destructive test cannot be performed due to the issues of collect specimens. And IIT can be a very good alternative. Therefore, for the safe use of large facilities, IIT and UNSM technology can be used to accurately predict the lifespan through the regular on-site diagnosis of facility component.

Keyword:

Hardness, residual stress, IIT, UNSM

■ Keynote 5

Title:

Pioneering high average power laser technology at HiLASE

Authors & Affiliations:

Tomáš Mocek
HiLASE Centre

Abstract:

Recent advances in high average power pulsed laser sources and technologies at the HiLASE Centre of Excellence will be presented. We have demonstrated efficient and stable operation of diode pumped solid state laser system BIVOJ delivering 145 J, 10 ns, 1030 nm pulses at 10 Hz thus confirming the power scalability of multi-slab cryogenic gas-cooled Yb:YAG amplifier technology. We have also achieved kilowatt-class high energy frequency conversion at 515 nm, and half-kilowatt-class at 343 nm, respectively. Recently, a Faraday isolator capable of stable protection of the laser amplifier chain delivering 100 J nanosecond laser pulses at the

repetition rate of 10 Hz has been developed and successfully tested. The thin-disk laser platform PERLA® has been developed, capable of generating 1-ps pulses with an average power of up to 500 W at a wavelength of 1030 nm, with exceptional beam quality and power stability. Both laser platforms are employed in diverse high-tech industrial and scientific applications such as laser shock peening, laser nano-processing, material functionalization, laser damage studies, particle generation & acceleration, and laser propulsion.

Keynote 6

Title:

Towards reliable and versatile laser shock application: from Laser to parts

Authors & Affiliations:

Laurent Berthe
Lab PIMM CNRS

Abstract:

The expansion of application of shock produced by laser plasma is often limited by the lack of process control. Since last conference, many progresses have been done on all topics : Laser metrology, Beam focalisation, laser interaction. These efforts make possible new applications requiring reliable and versatile loadings : adhesion test, laser damaging, mechanical testing at high strain rate. Some propose also perspective for Laser shot peening. This keynote will present an exhaustive review on these new developments accessible for the communauty of laser shock and material science. It will show some demonstrations on industrial applications very promising. It will open discussions on new issues and perspectives for academic and industry.

Keynote 7

Title:

Laser peening of large-scale components: modeling, optimization and applications

Authors & Affiliations:

Yongxiang Hu
Shanghai Jiao Tong University

Abstract:

large-scale components such as integral panels, are commonly used in the aerospace industries. How to design the process is challenge for the application of laser peening in these components for shape control and fatigue resistance. In this talk, we present the recent progress in the modeling of laser peening process, which include dynamic and static model by including crystal plasticity in mesoscale, and further propose an inverse problem framework for the process design of laser peen forming. Finally, we provide several cases for laser peening of large-scale components to demonstrate the model capabilities.

Keynote 8

Title:

Laser shock peening: recent developments and a look ahead

Authors & Affiliations:

Michael Fitzpatrick
Coventry University

Abstract:

Laser shock peening (LSP) has become an accepted and valued method of surface engineering, with numerous successful applications in high-value industries including aerospace and nuclear power. Its growth in application has slowed in recent years, so the question needs to be asked as to where it fits into the landscape of manufacturing and repair technologies.

To-date, almost all the applications of LSP have been in surface treatment for the improvement in fatigue lifetime, through the introduction of deep, high-magnitude, compressive residual stress that acts to prevent or delay the initiation of cracks, and reduce their growth rate when and if initiated. The method has shown itself to be highly successful for this, with the proviso that the peak stress in the component needs to co-locate with the compressive layer induced by the LSP.

For many aerospace structures, life enhancement involves the retardation of a long, growing, crack that may be many millimetres in length; and that in consequence is already generating high levels of stress intensity factor at the crack tip. As peening of the entire structure is neither feasible nor desirable, the possibility of using localised peen patches as crack retarding features is being actively explored. This talk will present results of recent work on the effectiveness of peen patches in aerospace aluminium for crack retardation, as well as methods for optimum peening of assemblies during manufacturing.

It will also look at the challenges for widespread adoption of LSP into new, high-volume, manufacturing industries.

Keynote 9

Title:

Progress in the Engineering Science and Application of Laser Shock Peening and Related Mechanical Surface Treatments in Materials Manufacturing and Future Opportunities

Authors & Affiliations:

Vijay K Vasudevan
Department of Materials Science and Engineering, University of North Texas

Abstract:

Research, modeling, and application of advanced mechanical surface treatments like laser shock peening (LSP) has grown considerably in the past four decades, from initially and mainly aerospace/engine to the biomedical and energy sectors (USC powerplants, nuclear). In this talk, the advances made in the understanding of the effects of various types of advanced mechanical surface treatments on residual stress generation and near-surface microstructural modifications in a variety of materials for various applications will be reviewed and discussed, including newer approaches such as coating-free and hybrid treatments. Future opportunities for application and integration of these techniques in additive manufacturing of parts and use of

modeling and machine learning approaches for predictive purposes and process design will also be discussed.

Keynote 10

Title:

Outlook for the contract business using Laser peening in Japan

Authors & Affiliations:

Yuji Kobayashi
Sintokogio, LTD.

Abstract:

Sintokogio is proud to be a leading company in surface treatment processing in Japan, and shot peening is one of our core technology. We have established a wealth of knowledge through the application of shot peening to automotive parts and other products. On the other hand, there are only a few manufacturers in the world that use laser peening. Characteristics of shot peening and laser peening are clearly different. Therefore, it is necessary to determine the processing conditions according to the characteristics of both technologies and the target material or purpose of use. Naturally, measurement and verification of the effects are required. Therefore, we installed "The Procudo® Laser Peening System" from LSPT, which is the top manufacturer of laser peening, for the first time in Japan, and established a laser peening contract processing company that combines our original knowledge of peening with LSPT's know-how.

This specialized company was established in June 2023. In this presentation, we will explain the appplication of laser peening and shot peening in Japan and its expectations.

A002

Title:

The FEM Simulation of Laser Shock Peening Process for Stainless Steel 304

Authors & Affiliations:

Ryoonhan Kim[1], Jeong Suh[1], Dongsig Shin[1,*], Kwang-Hyeon Lee[1], Seung-Hoon Bae[1], Dae-Won Cho[1,*] and Won-Geun Yi[2]
1 Busan Machinery Research Center, Korea Institute of Machinery & Materials, Busan 46744, Korea
2 Doosan Heavy Industries, Changwon 51711, Korea

Abstract:

Laser shock peening(LSP) produces compressive residual stress on the surface of the material, which can reduce the stress corrosion cracking and increase the fatigue life. Several studies of FE simulation of laser shock peening has been reported for titanium and aluminium material. In FE simulations of LSP, explicit analysis is used while the plasma pressure loads are applied and the result of explicit analysis put into implicit analysis as an input to dissipate the kinetic energy. In this study, static damping method was adopted to dissipate kinetic energy without conversion into implicit analysis. Simulation of a single and multiple LSP was performed, and deformation and minimum principal stress were compared to evaluate the static damping effect. The time based internal and kinetic energy changes were also analyzed to compare the stabilization time, depending on the damping value. LSP experiments were also

performed on stainless steel 304 material. The residual stress of the specimen was measured by the hole drilling method and it was compared to the FE simulation result. The residual stress from the experiment and the simulation results showed similar distributions in the depth direction. Anisotropic residual stress distribution due to the laser path was observed in both results.

Keyword:
Laser shock peening; residual stress; simulation; static damping

■ A004

Title:
Research on feasible materials and surface technology for MSR : Beginning from Stainless Steel 316H and UNSM

Authors & Affiliations:
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1 Nuclear Materials Safety Technology Research Division, Korea Atomic Energy Research Institute, Daejeon 34057, Korea
2 DesignMecha Co., Ltd. Asan 31460, Korea
3 Department of Fusion Science and Technology, Sun Moon University, Asan 31460, Korea

Abstract:

MSR(Molten salt reactor), which is being developed by more than 15 research institutes around the world, such as ORNL in the US, is known to be more advantageous than conventional large-scale PWR reactors in terms of miniaturization, safety, and economy. One of the most difficulties is to provide suitable material properties for severe corrosion environments. In this study, as a starting point, ultrasonic nanocrystal surface modification (UNSM) technology was applied to 316H stainless steel with an increased temperature up to 650 °C. The UNSM technology is one of the surface severe plastic deformation (S^2PD) technology used to strengthen the material by inducing fine grain nanostructure layer at the very top and near the surface with an effective depth of approximately up to 1 mm.

In this paper, the research status of candidate materials for molten salt reactors, corrosion factors of molten salt reactor materials are reviewed. In addition, this study will evaluate the weight loss of the specimens before and after the immersion corrosion test in molten chloride salt or the corrosion penetration depth of the surface layer of the specimens. Through this, the relationship between the change in corrosion resistance by UNSM treatment and the microstructure will be evaluated.

Keyword:
Molten salt reactor(MSR), 316H stainless steel, corrosion, ultrasonic nanocrystal surface modification (UNSM), molten chloride salt

■ A005

Title:

High-Speed Gas Effect on Aluminum and Silver Surfaces Irradiated by a Nanosecond Laser

Authors & Affiliations:

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1 Center for Relativistic Laser Science, Institute for Basic Science (IBS), Gwangju 61005, South Korea
2 Department of Physics and Optoelectronics Convergence Research Center, Chonnam National University, Gwangju 61186, South Korea
3 Laser Institute for Research and Application (LIRA), Beni-Suef University, Beni-Suef, 62511, Egypt
4 Advanced Photonics Research Institute, Gwangju Institute of Science and Technology (GIST), Gwangju 61005, South Korea
5 Department of Physics and Photon Science, Gwangju Institute of Science and Technology (GIST), Gwangju 61005, South Korea.

Abstract:

Surface modification of materials (Al and Ag) was studied after nanosecond green laser irradiation in air, vacuum, and under different backing gas pressures (0.5, 1, and 1.5 bar) applied through a supersonic nozzle. Scanning electron microscopy and X-ray diffraction were used to observe the effect of the laser on the samples in different environments. The results showed that the laser irradiation increased the microhardness of Al and Ag by 3.40 and 4.90 times, respectively, and this enhancement was attributed to the surface and structural changes under different environments. The microhardness was also found to be related to the microstrain.

Keyword:

Laser irradiation; supersonic nozzle; SEM; XRD, Vickers microhardness.

■ A006

Title:

The Influence of Laser Shock Peening on Surface Integrity of Magnesium Alloy AZ80

Authors & Affiliations:

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2 Centro Láser U.P.M., Universidad Politécnica de Madrid, Spain; jlocana@etsii.upm.es (J.L.O.)

Abstract:

The present paper aims to investigate topographical, microstructural, and mechanical behaviour of precipitation hardened magnesium alloy AZ80 subjected to laser shock peening (LSP). To reduce surface damage and to prolong a service life of the non-ferrous parts exposed to demanding conditions, an adequate surface treatment and protection is essential. Laser shock peening is an innovative surface treatment that has already been widely approved as a substitute of conventional shot peening. First topography and micro-structural state of the surface layer after laser shock peening were characterised, with surface roughness profile meter and with optical microscopy. In the final portion of the study, the changes of mechanical properties were evaluated with a residual stress and micro-hardness measurements through depth in the near surface layer. Electrochemical corrosion tests were performed in a 3.5 wt.% NaCl solution. The experimental characterization is primarily based on the evaluation of the residual stress profiles caused by laser shock peening treatments and on the measurement of corrosion potentials as well as of cyclic polarization curves in a NaCl solution, for different material conditions i.e.: in as received state after laser shock peening and in polished state after LSP.

Keyword:

Laser shock peening, magnesium alloy AZ80, artificial ageing, residual stresses, corrosion resistance

▪ A007

Title:

Cavitation Peening of Precipitation Hardened AA7075

Authors & Affiliations:

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Abstract:

The present paper aims to investigate behavior of precipitation hardened aluminium alloy subjected to cavitation peening. The introduction of compressive surface residual stresses is the main feature of this new method, which is different from the traditional mechanical processing method and is also the key factor leading to the good service performance of the modified surface. The tested material was heat-treatable aluminium alloy AA7075. After heat treatment of the aluminium alloy, cavitation peening with different coverage rate was performed, which in all cases raises the surface hardness of the specimens. Cavitation peening also has a beneficial effect on compressive residual stresses, as they increase in all cases. The treated surfaces were studied in terms of surface integrity at macro and microscopic levels, and the surface roughness, microhardness profiles, residual stresses and corrosion resistance of each treated surface layer were recorded. It should be noted that in all specimens throughout the entire measurement depth the residual stresses stayed in compressive nature. The research results reveal significant differences between corrosion properties of the cavitation peened surface recorded in as received state, and in as polished state. This means that cavitation peening parameters and quality of the surface substantially impact the surface integrity.

Keyword:

Cavitation peening, aluminium alloy AA7075, residual stresses, microhardness, corrosion resistance

▪ A009

Title:

High-Energy X-Ray Synchrotron source: Quick and accurate measurement of the residual stress field reinforced by Laser Shock Peening process

Authors & Affiliations:

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Abstract:

Laser Shock Peening (LSP) is a versatile, rapidly emerging technique that strengthens material by generating compressive residual stress (RS) in the near-surface layer (mm-range). This technique uses a high-power pulsed laser (1 J, 10 ns) to create a plasma and strong shock waves, propagating into the target. This results in local plastic deformation at extreme strain-rates (10^7 s^{-1}) and the generation of compressive RS. However, the hot laser-plasma in the LSP configuration without a protective/ablative coating heats the thin surface layer (several eV), lead to undesirable tensile RS. To mitigate this, solutions such as using small focal spots with a high overlap ratio, transmitting LSP through optical fibres and increasing the process frequency with high-repetition rate lasers could solve these problems.

Our international collaboration of labs conducted X-ray diffraction experiments at the Diamond Synchrotron in the UK using different LSP treatments and configurations. The experiment at the Diamond Light Source used a transmission geometry with 23 energy dispersive detectors to determine the lateral stress field under a single LSP shot and deep residual stresses for single and multiple LSP shots. Our results showed deep compressive residual stresses (up to 1 GPa for NCD13 steel) with a resolution of 50 µm.

Keyword:

Laser Shock Peening, Laser-matter interaction, Residual stress field, X-ray diffraction experiments, Synchrotron

■ A010

Title:

Effects of Laser Peening on Compressive Residual Stresses in Aging Aluminum Alloys

Authors & Affiliations:

Yuta Saito, Yuji Kobayashi
Sintokogio, Ltd. Japan

Abstract:

Aluminum alloys are used in the automotive and aircraft industries because of their light weight and high strength. Obviously, they require increased fatigue strength as well. One of the factors that improve fatigue strength is to induce of compressive residual stress. Shot peening (SP) is an existing method to induce compressive residual stress. However, in recent years, laser peening (LP) has also been used which use a single-pulse laser. Aluminum alloys has phenomenon which be called age-softing. It is the greater the amount of work hardening, the lower the strength over time. In the case of Aluminum alloys, the principle is different to induce compressive residual stress by SP and LP. Therefore, age-softening might be changed by SP or LSP, but there have been no examples of investigations. In this study, we carry out to measure the surface residual stress values of aluminum alloys processed by SP and LP as over time. As a result, the rate of age-softening by the laser-peened aluminum alloys was lower than that by the shot-peened aluminum alloys.

Keyword:

Aluminum alloys, Laser shock peening, residual stress, age-softening

■ A011

Title:

Investigation on the residual stress distribution of 304 austenitic steel induced by laser shock peening

Authors & Affiliations:

Danbi Song[*], Ryoonhan Kim, Jeong Suh, Dongsig Shin

Abstract:

Laser Shock Peening (LSP) is powerful surface technologies that has been widely used in Aerospace, nuclear power plant and marine industry. It is a process that propagates a shock wave into the material through plasma formed by irradiating a high energy laser pulse to the surface of a material. This causes a high residual compressive stress on the metal surface, which is beneficial to mechanical properties such as fatigue strength and stress corrosion. In this study, the residual stress measurements in 304 austenitic stainless steel determined from Electron Backscatter Diffraction (EBSD) kernel average misorientation (KAM) analysis have been compared to residual stress results obtained by the hole drilling technique and X-ray diffraction (XRD).

Keyword:

Laser shock peening, laser process, residual stress

▪ A012

Title:

Modelling of Dynamic Crystal Plasticity and Study on Anisotropic Mechanical Response of FCC Single Crystal

Authors & Affiliations:

Siyuan Chen, Yongxiang Hu*, Jiancheng Jiang

Abstract:

Meso-scale high strain rate processing is a promising area in the manufacturing industry. Because the processing scale is close to grain, the material exhibits single crystal characteristics. At present, dynamic plastic deformation of FCC single crystal still remains some blank, including material flow and dislocation behavior. Therefore, this study aims to reveal the dynamic anisotropic mechanical response of single crystal during laser shock to guide meso-scale processing. A physics-based dynamic crystal plastic model of aluminum single crystal was established to simulate the laser shock process, to overcome the limitation of experiment and characterization. It is found that the evolution of the crater depth of laser shock is controlled by both stress wave structure and crystal structure, and the depth does not show significant anisotropy at the initial stage. The pile-up pattern is dominated by the direction of the slip plane, which is affected by the dynamic deformation locality, therefore, the dynamic pile-up of <111> will decrease from six to three. The intensity of dislocation behavior is mainly controlled by Stress triaxiality. The main mechanisms of dislocation behavior are thermal activation, multiplication and trapping, respectively.

Keyword:

FCC single crystal、Crystal plasticity、Dynamic anisotropic deformation、Pile-up pattern、Dislocation behavior

▪ A013

Title:

Determination of peening pattern with multiple process conditions for laser peen forming via topology optimization

Authors & Affiliations:

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Abstract:

Laser peen forming (LPF) is a novel flexible forming technology that uses high-energy pulsed laser shocks to shape thin metallic components. Planning the process conditions for LPF of complex geometry is the inverse problem of deformation prediction, which is a challenge in the industry because the multiple process conditions should be determined at each position on the plate. Previous studies commonly reduce the design complexity by supposing the process conditions are consistent and then optimizing the distribution of the peening pattern. The immutability of process conditions leads to limited planning accuracy that is insufficient to meet the precise forming requirement. This study proposes a process planning model for LPF

to optimize the peening patterns with multiple process conditions based on the topology optimization method. The eigen-moment is used as a design variable, and its interpolation scheme is conceived based on the ordered Heaviside scheme to suppress undesired densities. The global convergent method of moving asymptotes (GCMMA) solver is used to solve the optimization model. The developed method plans the forming strategy of the dome and cylinder surfaces using different numbers of available process conditions. The results demonstrated that process planning with multiple process conditions is more effective than the consistent process condition. Finally, LPF experiments are conducted based on the planned results, and the LP-formed surfaces exhibit a high level of conformity to the desired objectives, validating the proposed method.

Keyword:

Laser peen forming, Flexible forming, Process planning, Topology optimization, Multiple process conditions

▪ A014

Title:

On the application of weight functions for the prediction of fatigue crack growth in AA2024 considering residual stresses induced by laser shock peening and laser heating

Authors & Affiliations:

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2 Institute of Materials Physics, Helmholtz-Zentrum Hereon, Max-Planck-Str. 1, D-21502 Geesthacht, Germany

Abstract:

The main advantage of residual stress engineering techniques is that the fatigue performance of aircraft’s structural components can be improved significantly, without increasing their weight. Reliable prediction of the influence of induced residual stress fields on fatigue crack growth is mandatory to account for residual stresses in a damage-tolerant design as well as to apply residual stress engineering techniques in the repair processes of structural components. This study deals with the prediction of fatigue crack growth for thin specimens of Al alloy AA2024 with residual stresses induced by laser shock peening and laser heating. Various weight functions are applied to calculate the stress intensity factor due to the presence of residual stresses. By calculating the total stress intensity factor considering the applied loads and residual stresses, a superposition principle is used. Fatigue crack growth is predicted using Paris' law based on the effective stress intensity factor, considering the effect of residual stresses by changing the ratio of the total stress intensity factor. This study shows that weight functions are a powerful tool for predicting fatigue crack growth in thin specimens with residual stresses as long as the gradient of residual stresses in the loading direction is moderate.

Keyword:

Laser shock peening, laser heating, residual stress, fatigue crack growth prediction, weight function

A015

Title:

Research on Deformation of 2024 Aluminum Alloy Panels with Stiffeners by Laser Peen Forming

Authors & Affiliations:

Wang Mingtao
AVIC Manufacturing Technology Institute

Abstract:

Laser peen forming is a new kind of peen forming method, with its greater deformation for the materials, in the aerospace and other fields have broad application prospects. 2024 aluminum alloy panels with stiffeners were pre-stress laser peen formed in an orthogonal experiment. The different process parameters on the effects of curvature radius was investigated. The results have shown that curvature radius decreases with the increase of energy, coverage, pre-stressed. The deformation of workpiece whose merely exterior surface under the stringers are laser peened is much lower than that whose whole surface are laser peened. And the fitting formula of radius of curvature with the process parameters was studied. The results could offer some basic reference to laser peen forming aluminum alloy panels of future aircrafts.

Keyword:

integral panel with stiffener, laser peen forming, curvature radius, aluminium

A016

Title:

Improvement on Fatigue Properties of HT780 Butt-Welded Joints by Portable Laser Peening Device

Authors & Affiliations:

Tomoharu Kato (JSPS Research Fellow / Kindai University)
Yoshihiro Sakino (Kindai University)
Yuji Sano (Institute for Molecular Science / SANKEN, Osaka University / LAcubed Co., Ltd.)
Yoshio Mizuta (SANKEN, Osaka University)
Satoshi Tamaki (SANKEN, Osaka University)

Abstract:

Laser peening (LP) introduces compressive residual stress on the surface of various materials, and is effective in enhancing fatigue strength. A portable LP device was applied to 9 mm-thick 780MPa grade high-strength steel (HT780) samples with irradiated pulse energies of 7.5-8.0 mJ, spot sizes of 0.42-0.58 mm and pulse densities of 100-1,600 pulses/mm2. X-ray diffraction showed that the maximum compressive residual stress was over 500 MPa near the surface, and the laser peening effect reached a depth of approximately 0.1 mm from the surface. Butt-welded HT780 samples were laser-peened with the selected conditions; a pulse energy of 7.7 mJ, spot size of 0.49 mm and pulse density of 800 pulse/mm2, and subjected to uniaxial fatigue tests with a stress ratio of 0.1. The results showed that the fatigue strength at 107 cycles was improved by at least 50 MPa, comparable to the improvement attained by

LP in a previous study with a pulse energy of 200 mJ of a conventional Nd:YAG laser.

Keyword:
Laser peening, Fatigue strength, High-strength steel, Residual stress, Microchip laser

■ A017

Title:
Fatigue Properties Improvement by Portable Laser Peening Device - Application to SBHS500 Butt-Welded Joints

Authors & Affiliations:
Tomoharu Kato (JSPS Research Fellow / Kindai University)
Yoshihiro Sakino (Kindai University)
Yuji Sano (Institute for Molecular Science / SANKEN, Osaka University / LAcubed Co., Ltd.)
Yasuyuki Kurihara (JFE Steel Corporation)
Yoshio Mizuta (SANKEN, Osaka University)
Satoshi Tamaki (SANKEN, Osaka University)

Abstract:
Laser peening (LP) introduces compressive residual stress on the surface of various materials, and is effective in enhancing fatigue strength. A portable LP device was applied under various conditions to base metal samples of 6 mm-thick 570MPa grade high-yield-point steel plates for bridges (SBHS500) to select the optimal LP conditions for pulse energy, spot size and pulse density. X-ray diffraction showed that the maximum compressive residual stress was over 400 MPa near the surface, and the laser peening effect reached a depth of approximately 0.1 mm from the surface. Butt-welded SBHS500 samples were laser-peened with the selected conditions; a pulse energy of 7.5 mJ, spot size of 0.42 mm and pulse density of 800 pulse/mm^2, and then subjected to uniaxial fatigue tests with a stress ratio of 0.1. The results showed that the fatigue strength of SBHS500 butt-welded joints was significantly increased by a factor of 2.3 or more in the stress range of 300 MPa.

Keyword:
Laser peening, Fatigue strength, High-strength steel, Residual stress, Microchip laser

■ A018

Title:
Laser peening of aluminum-based metal matrix composites: microstructure, residual stress and fatigue

Authors & Affiliations:
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Abstract:
Metal matrix composites are promising structural materials, which are commonly consisted of a continuous metal matrix filled with dispersed reinforcement phases and they are featured with superior physical and mechanical properties to those of monolithic matrix alloys. In this study, the laser peening surface modification technique is employed to treat SiC particle-reinforced

2009 aluminum (SiCp/2009Al) composite. Microstructure evolution, residual stress and its relaxation as well as fatigue behavior are the main focuses. A multi-scale microstructure evolution from micron down to nano is investigated. Residual stress distributions as well as its relaxation under fatigue cycles and thermal loads are expounded with both experimental and numerical methods. With the optimization of laser peening parameters, a significant fatigue life extension is achieved. This combined fundamental and application-based research seeks to provide insight into the microstructure evolution and residual stress distribution, as well as to explore the applicability of laser peening with metal matrix composites.

Keyword:
Laser peening, metal matrix composites, microstrucutre, residual stress, fatigue

■ A019

Title:

Performance Test for Laser Peening Titanium Integrally Blade Rotor Blade

Authors & Affiliations:

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2. AECC Shenyang Liming Aero-Emgine Co.,Ltd , Shengyang 412002, China

Abstract:

Laser peening has been applied on titanium integrally blade for more than ten years in China, but there is no unified standard for the performance evaluation of IBR/blade with laser peening. This paper introduced the requirement of laser peening IBR, analyzes the development and performance evaluation methods of laser peening IBR at home and abroad. In order to evaluate the performance of IBR the effect of plate vibration fatigue test, blade vibration and three-point bending fatigue were used to preliminarily test the effect of laser peening IBR. The results show that laser peening can significantly improve the vibration fatigue life of blades. However, since the fatigue life of blades with notched edges cannot be well evaluated by the 1st-bending vibration fatigue test, the three-point bending fatigue test is suitable for laser peening to improve the FOD resistance of blades, The three-point bending fatigue test show that once notched edges of blades are formed, the fatigue strength will decrease sharply. Laser peening can greatly improve the fatigue life of three-point bending with notch, but it’s still significantly lower than the condition without notch.

Keyword:
laser peening ; integrally blade rotor ; vibration fatigue ; fatigue properties ; three-point bending

A020

Title:

Anti-fatigue Extension life Mechanism of Al7050-T7451 hole Structures with Laser Shock Peening

Authors & Affiliations:

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1. Aviation Key Laboratory of Science and Technology on Advanced Surface Engineering, Aviation Industry Corporation of China (AVIC) Manufacturing Technology Constitute, Beijing, 100024

Abstract:

In engineering application, there is a stress concentration for the aluminum alloy hole structures, which can't meet its anti-fatigue performance. Laser shock peening (LSP) technology has been widely used in anti-fatigue manufacturing of aircraft hole structures due to its remarkable advantages. In this paper, the advanced LSP technology is used to strengthen the fatigue specimens of Al7050-T7451 hole structures, and then it is studied that the surface integrity characteristics and anti-fatigue performance improvement mechanism. The results showed that the surface roughness of Al7050-T7451 hole structures was increased from 0.247μm of as-received material to 0.396μm of LSP. The microhardness was 25.3% higher than that of the base material 245HV. The maximum value of residual compressive stress was formed with -99.1MPa, and the surface grain was obviously refined. Compared with the base material, the fatigue lives of Al7050-T7451 hole structures were increased by 4.07 times after LSP. The anti-fatigue extension life mechanism of hole structures with LSP was that the residual compressive stress layer and grain refinement layer inhibited the fatigue crack sources from the surface to the subsurface, and delayed the fatigue crack growth.

Keyword:

Al7050-T7451; hole structure; laser shock peening; surface integrity; fatigue performance

A021

Title:

Recent Incorporations of Welding Residual Stress into ASME Section III Code

Authors & Affiliations:

Nicholas Mohr
EPRI

Abstract:

The American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code Section III for nuclear component construction has made changes in recent years to consider welding residual stresses after repairs. The main reason for incorporating welding residual stress is to mitigate conditions that could initiate stress corrosion cracking during inservice operation. Operating experience from the existing nuclear fleet associated with stress corrosion cracking was used as justification for these changes by Task Group-Weld Residual Stress. This presentation will provide background of the recent changes to ASME Section III and associated incorporations of surface stress improvement as a mitigation method.

Keyword:

Welding, Residual Stress, Surface Stress Improvement (SSI)

- **A022**

Title:

Laser Shock Treatment of Ceramics

Authors & Affiliations:

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Abstract:

Ceramics are hard, brittle, and comprise low plasticity. Their toughness is generally low, and are crack-sensitive and difficult to process in general compared to metals and alloys. Laser Shock Treatment was deployed for the surface treatment of advanced ceramics, namely; Zirconia, Silicon Nitride, Silicon Carbide and Alumina ceramic systems in particular. This talk focus on promising results, recently elucidated from applying laser shock treatment to these hard, brittle, and difficult to process ceramics materials.

Keyword:

Laser Shock Peening, Strengthening, Ceramics

- **A024**

Title:

Recent Progress in Laser Shock Peening

Authors & Affiliations:

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Ansty Park, The Manufacturing Technology Centre, Ansty Park, Coventry CV7 9JU

Abstract:

Laser shock peening is an advance surface engineering technology that imparts beneficial effects, within metals and alloys. This work provides new results of laser shock peening metals and alloys utilised in the automotive, general engineering, biomedical and electrification sectors, as well as additive manufacturing, are presented. The outlook of the work collectively showed that laser shock peening is a promising technique to be deployed for these applications, and has a great scope for future implementation especially for strengthening electric vehicle battery joints.

Keyword:

Laser Shock Peening, Strengthening, Metals

- **A025**

Title:

Residual Stress Analysis of Cold Spray Deposition for Stress Corrosion Cracking Mitigation and Repair

Authors & Affiliations:

Jon Tatman
EPRI

Abstract:

A detailed analysis was performed in this study to determine the effect of cold spray deposition on existing weld residual stresses in highly restrained configurations. To evaluate this effect, contour and shallow hole drilling residual stress measurements are performed on cold spray build-ups deposited on highly restrained AISI 304L stainless steel weld mockups. These mockups were conservatively designed and fabricated to produce weld residual tensile stress levels higher than those previously predicted on welds performed on canisters during manufacturing. The results provide data that indicate the cold spray process introduces a substantial residual stress reduction during deposition comparable to peening surface stress improvement techniques typically used in the nuclear industry.

Keyword:

Welding, Residual Stress, Surface Stress Improvement (SSI)

■ A026

Title:

Peening Technologies to Mitigate Initiation and Resurgence of Stress Corrosion Cracking in Dry Storage Stainless Steel Canisters

Authors & Affiliations:

John Lacy[1], Hwasung Yeom[1], Stan Bovid[2], Micheal Kattoura[2], Andrew Tieu[3], W. Bloom[3], J. Tatman[4], K. Ross[5], Kumar Sridharan[1]
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Abstract:

Long-term storage of used nuclear fuel (UNF) is one of the key issues for sustainability of the current Light Water Reactor (LWR) fleet. The stainless-steel canisters used for storage in dry cask storage systems (DCSS) have a propensity for chloride-induced stress corrosion cracking (CISCC) due to combination of tensile stress at welds, susceptible microstructure, and corrosive chloride salt environment. This research is aimed at evaluating a variety of peening technologies, including, laser shock peening, ultrasonic nanocrystalline surface modification, and pulsed water jet peening to mitigate initiation and growth of CISCC in DCSS canisters. Microstructural developments in the peened region including grain refinement and reorientation, deformation-induced martensite formation, and dislocation entanglements were examined. Compressive residual stress measurements and corrosion testing have been conducted to evaluate the effect peening has on pitting corrosion behavior and stress corrosion cracking.

Keyword:

Welding, Residual Stress, Surface Stress Improvement (SSI)

▪ A027

Title:

Contact-free Paint Adhesion Test via Laser-Plasma Interaction

Authors & Affiliations:

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Abstract:

Adhesion can be defined as the phase when two surfaces are held in contact by forces. These forces can be electrostatic, chemical-bonding or van der Waals' forces. Experimentally, adhesion can be measured as function of forces and as function of work or energy. In terms of forces, it can be measured by extracting the maximum force to separate two layers/surfaces. In terms of work or energy, it can be described as the work/energy to split off the layers [1]. The performance of the adhesion depends on the differences in stability of the adhesional interaction between paint films and substrates. In order to better understand that phenomena, there are different methods in the literature [1, 2]. Although there are a lot of different adhesion methods as mentioned above, none of them provide easy implementation during the manufacturing or they need specific sample preparation which is why laser adhesion test appears as a promising method [3]. Within the framework of the presented work, specimens are investigated to see the effect of coatings' thickness, specimen thickness, surface treatment, coating type, substrate type and thermal ageing. The obtained results focused on the capability of the process to control [4]. Moreover, mechanical, chemical and interface properties are studied to understand the origin of the adhesive failure for different layer configurations both experimentally and numerically [5].

Keyword:

laser paint stripping, adhesion tests, laser shock processes, epoxy, polyurethane, water confinement

Funding:

This project has received funding from the Clean Sky 2 Joint Undertaking under the European Union's Horizon 2020 research and innovation programme.

Acknowledgments:

The authors acknowledge the support of Marc Vander Geest at Akzo Nobel for his work on sample preparation.

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▪ A028

Title:

Laser Peening without Coating to prevent Stress Corrosion Cracking in Heterogenous Welds

Authors & Affiliations:

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HiLASE Centre, Institute of Physics of the Czech Academy of Sciences, Czech Republic
Research Centre Rez, CVR, Plzen, Czech Republic
Czech Technical University in Prague, Faculty of Mechanical Engineering, Czech Republic

Abstract:

Stress corrosion cracking (SCC) in heterogenous welds (HW) is a well-known problem occurring in nuclear power industry. Heterogeneous welds are welds between two dissimilar metals or alloys, which can lead to differences in the microstructure and mechanical properties of the weld compared to the parent materials. When these welds are exposed to a corrosive environment, such as the high-temperature and high-pressure conditions in nuclear power plants, the different properties of the weld and parent materials can create areas of high stress concentration. This can lead to the initiation and propagation of cracks, which can ultimately result in the failure of the weld. To counter SCC at HW, careful selection of materials is crucial as well as any techniques used. In this work, we use Laser Peening without Coating (LPwC) to generate compressive stresses in the weld area. The weld needs to be treated from the inner side of the tube which makes it very difficult since the tube itself is very narrow. This is also the reason why many conventional techniques such as coating cannot be applied here. In our case, a special laser head for the beam delivery had to be developed.

Keyword:

Laser peening, stress corrosion cracking, heterogenous welds, nuclear industry

▪ A029

Title:

Evaluation of Peening Effects on NDE Inspection Techniques

Authors & Affiliations:

Robert Grizzi, EPRI
Dr Byungsik Yoon, EPRI

Abstract:

An inspection plan is an integral part of any project scope where peening is applied as a mitigation technique for dissimilar butt weld or reactor pressure vessel upper head penetration locations. It was necessary that industry have ready answers in response to regulators' forthcoming inquiries about the effects of peening on a plant's ability to perform high-quality NDE inspections post-peening. Seven peening vendors participated in this study, which encompassed four peening mitigation methods that are being considered for application to components in nuclear reactors.

EPRI designed and fabricated generic test coupons containing known, intentional reflectors that would serve as targets for NDE techniques. These coupons were flat plates (approximately 1.2 in. [30.5 mm] thick) containing a generic dissimilar metal weld. The targets provided means to compare values of the data acquired before and after peening. EPRI established a pre-preening NDE baseline response, provided peening vendors the coupons to apply their peening techniques, and then applied the same NDE techniques to the peened coupons and documented the results.

The objective of this presentation is to provide technical information about the observed effects (or lack thereof) on the subsequent application of NDE inspection methods, post surface peening applications.

Keyword:

NDE, Peening, Post-peening, mitigation, effects

- **A030**

Title:

Notch suppression on martensitic stainless steels by Laser Shot Peening

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Abstract:

Most fatigue cracks initiate at defects (notch) that create stress concentrators and cause the weakness of the whole component. The notch effect causes an increase tensile stress at the notch tip and improves conditions for crack nucleation. Under fatigue loading, the notch effect causes a significant decrease in the fatigue life of a component. Detrimental stress distribution caused by notches can be eliminated by laser shock peening (LSP) due to its ability to induce compressive residual stresses which prevent crack initiation.

The high cycle fatigue (HCF) tests were performed on martensitic stainless steel Böhler T552. The specimen type for HCF was of hourglass type with 5 mm diameter. Tested specimens were in 3 modifications: specimen with smooth surface without defect and peening, specimen with artificial defect (notch) in the middle of minimum diameter and specimen with notch, which was peened with LSP technology. LSP treatment was performed in HiLASE Center, with L2 system - Bivoj. The fatigue tests were performed on resonant testing machine (static preload 300 MPa, frequency 120 Hz and test temperature 22 °C). Fractographic analysis of the fracture surfaces was performed. The LSP increased the stress amplitude of fatigue strength more than three times on specimens with defect.

Keyword:

Laser Shock Peening, fatigue life, notch suppression, martensitic stainless steel, steam turbine

A031

Title:

Microstructure and corrosion resistance estimation of nickel-aluminum bronze after ultrasonic nanocrystal surface modification

Authors & Affiliations:

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Abstract:

Nickel-aluminum bronze (NAB) is widely used to fabricate marine propellers owing to its excellent corrosion resistance and mechanical properties. During the service process of a propeller, it suffers from various types of damage and corrosion. Therefore, this study aim to enhance the corrosion resistance of NAB through ultrasonic nanocrystal surface modification (UNSM). UNSM technology uses ultrasonic vibration energy to strike a certain area of the material to be processed tens of thousands of times per second with an amplitude of several micrometers. This could make the surface texture fine and improve the surface properties of the product. After UNSM treatment, good surface roughness was obtained. Moreover, the rough and heterogeneous multi-phase structure of cast NAB was significantly refined, and a relatively uniform and dispersed structure were observed. The corrosion potential increased slightly, and the passivation potential and current decreased significantly after UNSM treatment. This is mainly due to the slowdown of selective phase corrosion and the uniform formation of oxide film. In addition, UNSM parameters can affect the corrosion potential by regulating the surface roughness, which means that a smoother surface corresponds to a better electrochemical corrosion properties.

Keyword:

Ultrasonic nanocrystal surface modification, Nickel-aluminum bronze, Microstructures, Corrosion resistance

▪ A032

Title:

50J High Energy Nd:glass Slab Laser for Shock Peening

Authors & Affiliations:

Fengwen Jin, Bingzhong Sun (Beamtech China, Changping Beijing),
Xin Wang, Lili Hu (Shanghai institute of optics and fine mechanic, Chinese Academy of Sciences),
Fang Zhang (Beamtech Canada, White Rock City BC)

Abstract:

To decrease the cost and minimize the system size of traditional high energy Nd:YAG MOPA laser system, we present a new optical layout design and experiments of the Nd:glass slab laser, “Core-lite” which is adapted to meet the requirements of commercial industrial laser facility. Core-lite use lamp pumped Nd:glass slab with 5 path amplifications to provide 50J@15ns at 0.5-1 pps repetition rates.

The beam quality control and thermal effect analysis are also demonstrated. We have completed several LSP tests with “Core-lite” laser on various metal surfaces, and the results of mechanical stress for the related tests are reported.

The different type Nd:glass laser materials, N31,N51,NAP , have been tested to compare their thermal effects and laser gain factors for our slab multiple amplifier design in this paper.

Keyword:

Nd:glass Slab, 50J, beam quality, laser shock penning

▪ A033

Title:

Laser Shock Adhesion Test of Thermally Aged Epoxy Coatings

Authors & Affiliations:

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Abstract:

Aircraft external parts composed of a substrate and coatings, the primer is crucial for protecting the substrate from environmental factors. Adhesion of the primer plays a vital role in the performance and durability of the substrate. Thermal ageing due to exposure to extreme temperatures can significantly impact the performance and durability of aircraft coatings, as well as affect the adhesion strength between the coating and substrate. To identify potential safety issues and improve long-term performance, studying the impact of thermal ageing on the adhesion of epoxy coatings and aluminium substrates (AA2024-T3) is essential. Pull-off and scratch tests are commonly used to test adhesion but have limitations such as the difficulty of implementation in a manufacturing processes and the complexity of the outcomes due to the involvement of intermediate elements. The laser shock adhesion test shows promise as a potential method for testing adhesion. The purpose of this research is to analyse the effect of accelerated thermal ageing on physicochemical, mechanical, and interface properties of epoxy coating.

Keyword:

Paint adhesion, epoxy coating, thermal Ageing, LASer Adhesion Test (LASAT), laser shock

▪ A034

Title:

Comparison of Surface Crack Propagation Behaviour of A2024 Alloy Subjected to Various Peening Treatments

Authors & Affiliations:

Kiyotaka MASAKI: Saitama Institute of Technology
Tomokazu SANO: Osaka University
Yuji SANO: Institute for Molecular Science / Osaka University

Abstract:

It is well known that the surface fatigue crack propagation behaviour is affected by peening treatment. In this study, in order to investigate this effects, A2024-T3 aluminum alloy with a small hole was subjected to various peening treatments, and plane bending fatigue tests were performed at the same stress level. The surface fatigue crack propagation behaviour from the hole was observed using replication technique. At that time, three types of peened specimens, such as fine shot peening (FSP), hand-held laser peening (HH-LP) and dry laser peening (DLP), and base metal (BM) specimens were prepared and these crack propagation behaviours were compared. As a result of the fatigue test, the fatigue life of all peened specimens was 2.6 times longer than that of the BM specimen. In addition, as a result of observing the surface crack growth, the fatigue life until the surface fatigue crack length reached 2mm was remarkably prolonged in the peened specimens. When the crack propagation rate was examined from the crack propagation curve, the crack propagation rate of the DLP and the HH-LP specimens was slower than that of the FSP specimen. Also, many temporary crack growth retardations were observed in the DLP and the HH-LP specimens. These crack propagation behaviours were discussed using the results of peening effects and fracture surface observations.

Keyword:

Plane bending fatigue, Surface crack propagation behaviour, Fine shot peening, Dry laser peening, Hand-held laser peening

▪ A035

Title:

Effect of laser peering on fretting fatigue of titanium alloy fan blade tenons

Authors & Affiliations:

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Abstract:

The fretting fatigue failure of fan blade tenons is one of the concerns in commercial manufacturing, and improvement of fretting fatigue performance of fan blade tenon is of great importance at present. In this study, Ti-6Al-4V tenon structure designed according to fan blade was treated by laser peening, and the high cycle fatigue and high-low cycle complex fatigue of the laser-peened tenons were studied. The results showed that Laser peening increases the fatigue life by 10-50 times in HCF and has a great increasement in HCF&LCF. Meanwhile, it is also observed that the fretting wear characteristic was changed significant by laser peening. Based on the analysis of fretting fatigue crack propagation characteristics, compressive residual stress is the main factor that enhances fretting fatigue of tenons. In order to further improve the ability to resist fretting damage, laser peening combined with CuNiIn coating was investigated on Ti-6Al-4V tenon. In summary, this research comfirms that laser peening can be used for fan blades tenons to improve the service life.

Keyword:
Laser peening, Titanium alloy, Fan blade tenon, Fretting fatigue

- **A036**

Title:

Effect of Laser Peening Treatment on High Cycle Fatigue Strength of Cast Martensitic Stainless Steel in River Water Environment

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Abstract:

The high cycle fatigue-corrosion performance of a cast martensitic stainless steel equivalent to CA6NM, used in the hydropower generation industry, in untreated and two laser-peened conditions was investigated. The LSP processing of experimental samples has been performed at the HiLase R&D laboratories using the diode pumped solid state laser with the top-hat beam 1030 nm with a square shape 2,5 x 2,5 mm and 10 ns pulses at 10 Hz. The peening setup utilized protective coating in the form of 100 µm black vinyl tape and a laminar film (~1 mm) of flowing water. Two peening strategies were used: one layer with a power density of 8 GW/cm^2, and two layers with and power density of 6 GW/cm^2. Corrosion-fatigue tests were conducted in four-point bending with the constant mean pre-stress 350 MPa and the loading frequency 50 Hz. The fatigue limits of the peened steel in water were always higher than the fatigue limit of the untreated base material. The effect of LSP on the microstructure evolution, corrosion resistance, content of reformed austenite in peened steel, and fractographic analysis of the fracture surfaces were performed.

Keyword:
Laser shot peening, corrosion fatigue, stainless steel, hydropower generation industry

A037

Title:

Inducing Damage by Laser Shock Plasma: Application for Dismantling Laminated Composites for Recycling

Authors & Affiliations:

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Abstract:

Composite materials, composed of two or more components, are widely used due to their strength and density ratio. The EU composite market is expected to grow by 7.5% annually over the next few years, resulting in increased production and waste of composites. However, their complex composition makes end-of-life treatment challenging. Recycling composites is essential to reduce negative environmental impacts and optimize natural resource use. Common methods, such as grinding and pyrolysis, can damage reinforcing fibers and reduce the quality of recovered materials, necessitating alternative recycling technologies. This paper presents the use of efficient and selective processes laser shock for dismantling composites. The process will be optimized through experiments, considerations of adhesion/material properties and process parameters. The impact of accelerated ageing on materials will also be studied, with online control through sensors. The goal is to preserve the properties of the separated materials and explore the possibility of reassembling them for recycling purposes while ensuring the integrity of dismantled parts through nondestructive testing methods. This work is part of the "Recycling Technologies for the Circular Reuse and Remanufacturing of Fiber-Reinforced Composite Materials (RECREATE)" project, which has received funding from the European Union's Horizon Europe research and innovation program.

Keyword:

Laser dismantling, disassembly, laser shock processes, CFRP, recycling

A038

Title:

Fatigue Strength Improvement of Non-oriented Electrical Steel Sheets by Low-energy Laser Peening

Authors & Affiliations:

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Yuji Sano / Institute for Molecular Science, Osaka University
Yoshio Mizuta, Satoshi Tamaki / Osaka University
Takahisa Shobu / Japan Atomic Energy Agency

Abstract:

Demands on the durability of electric motor components are becoming increasingly tough as the motors become more efficient. Fatigue strength improvement of the "bridge" part of a rotor core laminate made of electrical steel sheet is one of the most important issues for the motor durability. The bridge is a small area of about 1 mm width and 0.5 mm thickness in electrical steel sheets, formed between punched holes for inserting permanent magnets. The recently developed low-energy laser peening (LLP) is considered suitable for strengthening small components such as bridges, as it can introduce compressive residual stresses in thin surface layer with low pulse energy, approximately one-hundredth of that of conventional laser peening.

In this study, firstly, the effect of punching residual stress on the fatigue strength of electrical steel sheets was clarified, and then, LLP was applied to the punched surface to improve the punching residual stress. The results showed the effectiveness of LLP for fatigue strength improvement of electrical steel sheets.

Keyword:

Electrical steel sheet, Low-energy laser peening, Residual stress, Punching, Fatigue

■ A039

Title:

Simultaneous Improvement of Residual Stress and Surface Morphology of Ti-6Al-4V ELI by Low-energy Laser Peening

Authors & Affiliations:

Yuki Iino, Koichi Akita / Tokyo City University
Yuji Sano / Institute of Molecular Science, Osaka University
Yoshio Mizuta, Satoshi Tamaki / Osaka University
Takahisa Shobu / Japan Atomic Energy Agency

Abstract:

Currently, aging society is progressing worldwide, and then it is important to expand healthy life expectancy. From the research results of heathy life, oral health has been found to be affected healthy life expectancy. Therefore, dental implant treatments have become widely used. However, fracture of the implant components has been reported. This study attempted to solve this problem by low-energy laser peening (LLP). It uses lower energy than that of current Laser Peening (CLP). For example, the energy in CLP is 200 mJ while it is 1.5 mJ in LELP. A previous study reported that CLP couldn’t improve the fatigue strength of a miniature size specimen of Ti-6Al-4V for implant components because the introduced compressive residual stress layer was too large and therefore balancing tensile residual stress became relatively high. In contrast, LLP introduces relatively thinner compressive stress layer and small balancing tension. Therefore, LLP is thought suitable for enhancing fatigue strength of miniature size samples.

This study focuses on the fatigue strength enhancement of Ti-6Al-4V by LLP. Biocompatibility of the LLP treated surface is also examined. Results will be presented at the conference.

Keyword:

Implant, Ti-6Al-4V, Fatigue strength, Biocompatibility, Low-energy laser peening (LLP)

▪ A040

Title:

Direct observation of transient state under femtosecond laser-driven shock formation in Cu

Authors & Affiliations:

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1 Osaka Univ., 2 Kyoto Univ., 3 Osaka Metropolitan Univ., 4 The Univ. of Tokyo, 5 JAEA, 6 QST, 7 JASRI, 8 RIKEN

Abstract:

Dry laser peening using femtosecond laser not only provides sufficient fatigue properties but also forms high-density dislocations and unique microstructures in the material. To understand lattice behaviors under femtosecond laser-driven shock compression, we performed in situ measurements on copper using X-ray Free Electron Laser (XFEL). The experiment was conducted in the EH2 at the BL3 of SACLA. We used a single crystal copper (100) and performed time resolved XRD measurements irradiating the sample surface with the pump laser (wavelength: 797 nm, pulse width: 101 fs, pulse energy: 10.74 mJ) and the probe laser (photon energy: 13 keV, pulse width: 10 fs, monochrome beam). As a result, we succeeded in capturing a transient state under the shock formation and found that it reaches a highly elastically compressed state at an ultra-high strain rate. Estimated shock stress is much higher than the prediction from the fourthpower law. This indicates the material is elastically compressed without plastic relaxation at an early stage of the shock compression. It will lead to the advancement of dry laser peening technique by further understanding of the phenomenon of femtosecond laser-driven shock compression based on these results.

Keyword:

Femtosecond Laser, Dry Laser Peening, Shock Compression, XFEL, In Situ Measurement

▪ A041

Title:

Behavior at an early stage of femtosecond laser-driven shock wave in aluminum

Authors & Affiliations:

Seiru Inoue[1], Yudai Mori[1], Masayuki Yoshida[1], Nobuhiko Nakanii[2] and Tomokazu Sano[1]
1 Osaka University, 2 QST

Abstract:

Dry laser peening using femtosecond laser-driven shock wave is an innovative technique that can improve material properties by hardening the material and generating compressive residual stresses without a sacrificial layer in air. However, the detailed behaviors at an early stage of femtosecond laser-driven shock wave remain unclear due to ultrafast deformation of the material in sub-picosecond timescale. Here we report the ultrafast observations at an early stage of femtosecond laser-driven shock wave in aluminum using frequency-domain interferometry with sub-picosecond temporal resolution, which enables us to simultaneously measure the shock velocity and particle velocity. Shock pressure is proportional to the product of shock and particle velocities based on Hugoniot state. Spatial evolution of the shock pressure is derived using different sample thicknesses. Influence of pulse width and pulse energy of the femtosecond laser on the shock pressure and the spatial evolution will be addressed in this talk.

Keyword:
dry laser peening, femtosecond laser-driven shock wave, frequency-domain interferometry, shock pressure

▪ A042

Title:
Dry Laser Peening using Femtosecond Laser-driven Shock Wave

Authors & Affiliations:
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Osaka University, Japan

Abstract:

Dry laser peening (DLP) allows the fatigue performance of metallic materials to be improved using femtosecond laser pulses without a sacrificial overlay in air. Direct irradiation of a solid surface with a femtosecond laser pulse creates an intense shock wave that propagates into the solid. Such a shock wave driven by a femtosecond laser pulse plastically deforms a material. The heat-affected and melt zones created by a femtosecond laser pulse are much smaller than those created by a nanosecond laser pulse due to the extremely short pulse width. The objective of this study is to verify the effectiveness of dry laser peening on laser-welded 2024 aluminum alloy containing weld defects by investigating the mechanical properties. The changes in hardness, residual stress, and fatigue properties of laser-welded 2024 aluminum alloys between before and after DLP were investigated in this study. As a result of the plane bending fatigue test of the laserwelded joints, the fatigue life of the DLPed specimen was improved up to 15 times compared with the aswelded specimen at a stress amplitude of 120 MPa. DLP process has a potential to be applied to a variety of industrial fields such as automotive, railway, aerospace and aerospace industries.

Keyword:
Dry laser peening, femtosecond laser-driven shock wave, aluminum alloys

▪ A043

Title:
Enhancement of the surface properties of additively manufactured Ti-6Al-4V by laser shock peening

Authors & Affiliations:
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2 Department of Mechanical Engineering, Sun Moon University, Republic of Korea

Abstract:

Additively manufactured Ti-6Al-4V components suffer from high brittleness and poor toughness issues. Thus, post-heat treatment is often carried out to improve the toughness of additively manufactured Ti-6Al-4V products, which, however, has been reported to result in a decrease in strength, abrasion resistance, and corrosion resistance. In this study, laser shock peening (LSP) is applied to post-heat-treated Ti-6Al-4V samples produced by additive manufacturing as a solution to achieve enhanced surface properties as well as improved toughness. By post-heat treatment only the impact toughness of the additively manufactured Ti -6Al-4V could be increased by 150%, that too at a significant degradation of surface hardness, wear, and corrosion resistance. When LSP is applied to the post-heat-treated Ti-6Al-4V, impact toughness remains nearly the same, whereas surface hardness and wear resistance are recovered to approximately 92% and almost full values prior to heat treatment, respectively. LSP also decreased the corrosion rate by 64% from that of the heat-treated sample. The results showed that LSP combined with post-heat treatment is a plausible approach to achieve both high impact toughness and enhanced surface properties in additively manufactured Ti-6Al-4V products.

Keyword:

Additive manufacturing, Ti-6Al-4V, laser shock peening

Acknowledgement:

This work was supported by Korea Institute for Advancement of Technology(KIAT) grant funded by the Korea Government(MOTIE) (P0008763, HRD Program for Industrial Innovation)

▪ A044

Title:

Surface Properties of Additively Manufactured Produced Meso-Sized Gears in Laser Shock Peening

Authors & Affiliations:

Sunil Pathak[1], Marek Boehm[1,3], Jan Kaufman[1], Ondřej Stránský[1,2], Sanin Zulic[1], Jan Brajer[1], Libor Beránek[2]

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2) Czech Technical University in Prague, Faculty of Mechanical Engineering, Czech Republic
3) Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Czech Republic

Abstract:

Micro and miniature components are vital players in manufacturing industries. The high demand for smaller and functional appliances, machines, and parts in worldwide economies is increasing rapidly owing to their modest volume, lightweight, portability, and reliable efficiency. Components with a size spectrum from 1 to 1000 µm are referred to as micro-components. The present work aims to modify the surface quality (surface roughness, materials distribution curves, and surface morphology) and surface integrity (residual stresses and microstructure) by applying underwater laser shock peening without coating (LPwC) on the meso sized (maximum outside diameter 10 mm) spur gears manufcatured using selective laser melting (SLM). The material selected for the investigation is 17-4 PH steel which finds application in several industrial applications. The outcome have shown considrable improvement in the residual stresses, grain boundries have shown beneficial shifts, while the some of the roughness parameters have also shown improvement such as airthemetical mean height and maximum height. The outcome of this work will pave foundation for the processing of meso sized parts through laser shock peening.

Keyword:

Laser shock peening, Additive manufacturing, Meso-size gears, Microstructure, Residual stresses

A045

Title:

Effect of Laser Peening without Coating on additively manufactured AlSi10Mg

Authors & Affiliations:

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2) Czech Technical University in Prague, Faculty of Mechanical Engineering, Czech Republic
3) Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Czech Republic
4) Institute of Physics, Czech Academy of Sciences, Prague, Czech Republic

Abstract:

The additive manufacturing (AM) process has become an important method in modern manufacturing, offering advantages such as complete design freedom, high material utilization resulting in lightweight and high-performance parts, and complex geometries that would be difficult or impossible to produce using conventional techniques. However, there are still some applications where AM does not meet the requirements of high-demanding industries. The AM has the tendency to produce parts with higher surface roughness, stress gradients and imperfections in terms of porosity and microstructure when compared to traditionally produced parts.

To address these limitations, laser shock peening (LSP) can be used to enhance the properties of AM materials. The aim of this study is to investigate the effect of naked LSP on L-PBF printed AlSi10Mg testing specimens, using parameters selected from previous research. The results were considered in terms of residual stresses, surface roughness, microstructure, porosity and microstructure analysis through Scanning electron microscopy and Electron backscatter diffractometry. All the characterization were done before and after LSP. The outcomes have shown significant improvement in residual stresses, porosity, and microstructure modification.

The findings of this study may contribute to a better understanding of the potential benefits of LSP for enhancing the properties of AlSi10Mg produced using the L-PBF process.

Keyword:

Laser shock peening, Additive manufacturing, Laser peening without coating, Laser-powder bed fusion

▪ A046

Title:

Laser shock peening acoustic emission measurement by evaluation of acoustic wave propagating through air

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1 HiLASE Centre, Institute of Physics of the Czech Academy of Sciences, Czech Republic
2 Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Czech Republic

Abstract:

Acoustic emission (AE) monitoring is a non-destructive evaluation technique widely used to detect and analyse the acoustic waves generated by material deformation and damage. In this study, we applied AE monitoring to laser shock peening (LSP). LSP treatment technique uses a high-intensity laser beam to generate a shock wave that induces compressive residual stresses in metallic materials. We conducted LSP experiments on alloy samples and simultaneously recorded the AE signals generated during the process. The AE signals were analysed to identify the different types of acoustic events and their corresponding sources, including breakdown in water and dielectric breakdown within the laser beam in the air. The results show that AE monitoring can provide valuable information on the LSP process and its effects on the material properties. Furthermore, the AE signals can be used to optimize the LSP parameters, such as the laser energy and spot size, to achieve the desired compressive residual stresses and avoid undesired damage. Overall, this study demonstrates the potential of AE monitoring as a powerful tool for the in-situ characterization of LSP, providing insights into the underlying physical processes and helping to improve the quality and reliability of the treated materials.

Keyword:

laser shock peening, acoustic emission method, optical microphone, laser-induced breakdown

▪ A047

Title:

Improvement of Residual Stresses and Fatigue Properties of A7075 Aluminum Alloy Using a Compact Low-Energy Laser Peening System

Authors & Affiliations:

Yoshio Mizuta (SANKEN, Osaka University)
Satoshi Tamaki (SANKEN, Osaka University)
Kiyotaka Masaki (Saitama Institute of Technology)
Tomonao Hosokai (SANKEN, Osaka University)
Yuji Sano (Institute for Molecular Science / SANKEN, Osaka University / LAcubed Co., Ltd.)

Abstract:

The advantage of laser peening (LP) is the possibility of fine execution management and the capability to introduce deep compressive residual stresses on the metallic material surfaces. However, conventional lasers used for LP are large and difficult to control in terms of vibration, temperature, and humidity. Therefore, it is difficult to carry the LP device around and use it for outdoor maintenance. To overcome these issues, a compact and portable LP system was developed using a microchip laser that is small and easy to handle.

This study shows the improvement of surface residual stress and fatigue strength of A7075 aluminum alloy using the developed LP system. LP was performed on A7075 using the microchip laser with a pulse energy of less than 10 mJ mounted on a robot arm. The compressive residual stress on the surface of A7075 after LP exceeded 400 MPa and was formed to a depth of approximately 0.5 mm. The effect of LP by microchip lasers on the fatigue strength of aluminum alloys will be also reported.

Keyword:

Laser peening, Microchip laser, Aluminum alloy, Fatigue strength, Residual stress

▪ A048

Title:

Effect of laser shock peening on Inconel 738LC for the improvement of mechanical properties

Authors & Affiliations:

Seongguk Bae[1], Youngdae Kim[2], Jinesung Jung[2], Keesam Shin[3], Sungho Jeong[1,*]
1 School of Mechanical Engineering, Gwangju Institute of Science and Technology
2 Power Generation Technology Laboratory, Korea Electric Power Research Institute
3 School of Material Science and Engineering, Changwon National University
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Abstract:

The fatigue life on high temperature of Inconel 738LC is important issue on high temperature industries such as gas turbine power plant. In this research, laser shock peening was used to improve the mechanical properties of Inconel 738LC, especially fatigue strength at high temperature. After laser peening, surface hardness was increased by about 25% and compressive residual stress was increased about 11 times compared to unpeened samples. Dislocation density was calculated by Scherrer's equations, which showed almost the same tendency as the surface hardness results with respect to laser energy. Fatigue test was conducted at room temperature (25°C) and high temperature (850°C) conditions. Fatigue life of peened samples on room temperature was about 2.3 times longer than that of unpeened samples. At high temperature conditions, fatigue life of the laser peened and untreated samples showed different trends depending on stress level.

This paper was supported by the Korean Government(MOTIE) (P0008763, program for optical convergence field professional training project)

Keyword:

Laser shock peening, Fatigue, Inconel 738LC

Acknowledgement:

This research was supported by Korea Institute for Advancement of Technology(KIAT) grant funded by the Korean government(MOTIE) (P0008763, HRD Program for Industrial Innovation)

▪ A049

Title:

Development of a 10-mJ handheld microchip laser and its application to laser peening

Authors & Affiliations:

S. Sekiguchi, R. Bhandari, T. Hajikano, Y. Takushima and Y. Sano[*]
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Abstract:

Laser peening is a promising technology for improving fatigue properties of metals, because it can impart residual stresses deeper than shot peening. Thus, practical applications have already been exploited in aerospace industry and so on.

However, conventional laser-peening systems usually require large-scale laser equipment, which typically generates nanosecond-pulse trains with very high pulse energy of > 100 mJ, and hence it becomes an obstacle to wide deployment for industrial applications. To solve these problems, we have developed mJ-class handheld microchip lasers with and peak power exceeding 10 MW and carried out laser-peening experiments.

The developed laser is a passively Q-switched Nd:YAG laser, having an output energy of 10 mJ and a pulse width of about 600 ps. Due to its short pulse width, the resulting peak power exceeds 16.7 MW, and hence it is expected to introduce sufficient residual stress, equivalent to that of large-size conventional lasers. Also, the laser head is palm-top size (165 mm x 42 mm x 32 mm), which enables to be mounted on a robotic arm.

In this paper, we will also report the improvement in fatigue properties obtained on aluminum alloy A7075 by using our lasers.

Keyword:

Microchip laser; Laser peening; Q-switched laser; Nd:YAG laser; Short pulse laser

▪ A050

Title:

Expanding LPwC applications with high-power microchip lasers mounted on industrial robots

Authors & Affiliations:

Sebastian HOLZ & Yuji SANO
sentenso Smart Peening Solutions, SANKEN, Osaka University / Institutes for Molecular Science

Abstract:

This study explores the feasibility of expanding Laser Shock Peening (LSP) applications using high-power microchip lasers mounted on industrial robots. Previous research has demonstrated the effectiveness of LSP for improving the fatigue and corrosion resistance of various materials, including metals, ceramics, and composites. However, the implementation of LSP has been limited by the high cost of equipment and the need for highly skilled operators.

In this study, a high-power microchip laser was mounted on an industrial robot to enable automated LSP. The robot was programmed to apply LSP to various geometries and materials, including curved and angled surfaces. The effectiveness of the automated LSP process was

evaluated by measuring the residual stress of the treated samples.

The automated LSP process is suitable for thin-walled components which would be deformed by conventional LSP with higher laser energies. The small laser spot of around 0.3 mm enables the adaptation to complex 3D geometries and creates a pretty smooth surface with a typical roughness Ra of around 1 µm.

Overall, this study demonstrates the potential for high-power microchip lasers mounted on industrial robots to expand the applications of LSP, making it more accessible and practical for a wider range of industries and materials.

Keyword:

LPwC, Finger-sized laser, Pulse energy, Residual stress, industrial robot

■ A051

Title:

Laser Surface Modification and Femtosecond Laser Chip Breakers for Improved Machining of Ferrous Alloys with NbC and WC Cermets

Authors & Affiliations:

R.M. Genga[1,2,3], C. Polese[2,3], P. Zeman[4], P. Tomáš[4], J. Malý[4], P. Matěj[4], J. Brajer[4] and A. Janse van Vuuren[5]

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Abstract:

Cermets consist of hard and wear resistant carbide grains (WC and/or NbC) embedded in a ductile metal matrix (Co, Ni and/or Fe), and are pivotal materials for cutting and mining tools due to their wide range of applications from good combination of high hardness, toughness, strength and wear resistance [1]. To further improve the machining performance of cermets, better high temperature hardness, resistance to abrasion and attrition wear and chemical stability [1] are required. The high temperature hardness and wear resistance can be improved via microstructure manipulation by addition of carbide additives, rapid sintering [2], laser surface modification (LSM) and precision chip breakers using femto-second lasers. The cermets were used for face-milling of grade 17 grey cast iron conducted at cuttings speeds (v_C) of 100 – 500 m/minute and depths of cut (a_p) of 0.25 – 1.5 mm. LSM altered the microstructure at the cutting edge, forming thin (<100 nm thick) uniformly distributed lamella Ni binder between fine NbC grain size, preventing abrasion and attrition wear [1,2], reducing flank wear and increasing tool-life (cutting time) by up to 100% in some inserts during roughing, semi-finishing and finishing. The Femtosecond laser chip breaker had a similar effect during AISI 1213 structural steel turning.

Keyword:

NbC, Laser Surface Modification, Femtosecond laser chip breaker, Machining, Tool-life

A052

Title:

The role of Residual Stress Distribution on Fatigue Crack Growth

Authors & Affiliations:

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Centre for Manufacturing and Materials, Coventry University, UK

Abstract:

Laser Shock Peening (LSP) induced compressive Residual Stress (RS) is well understood to reduce Fatigue Crack Growth Rate (FCGR) and increase fatigue life. In recent years much effort has been spent on development and validation of modelling approaches to predict this behaviour often to optimise the RS profile or the location and size of LSP patches. A review of experimental FCG and RS data from the literature highlighted some anomalies that at first appear to contradict current best fatigue modelling predictions. Due to experimental constraints often only partial measurement of the RS field is possible and unmeasured regions (often the balancing tensile region) must be predicted using FE analysis to enable FCG prediction. In the current work a systematic review of the interaction between LSP induced RS fields on FCGR will be presented with emphasis on the effect of balancing tensile RS. Fatigue testing was used to assess the effect of peen patch location, size and shape on FCGR. The RS fields were measured using hole drilling, XRD, slitting and contour method. A Finite Element (FE) based modelling approach was used to predict measured FCGR's. Recommendations will be presented on the minimum RS field measurement needed for accurate life predictions.

Keyword:

Fatigue crack growth testing, Residual stress, Finite element analysis, Fatigue life prediction

A053

Title:

Improving peening efficacy through high amplitude short duration pulsed current

Authors & Affiliations:

Chang Ye[1], Weidong Zhao[2], Hao Zhang[3], Yixuan Ye[1], Yu Zhang[1], Le Gao[1], and Yalin Dong[4]
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3 College of Civil Aviation, Northwestern Polytechnical University, Xi'an 710072, China
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Abstract:

The efficacy of peening treatment depends on the plasticity of the target metal. In this study, high-amplitude short duration pulsed current was used to improve peening efficacy in a process called electropulsing-assisted ultrasonic nanocrystal surface modification (EP-UNSM). During EP-UNSM, the target metal, i.e., Ti64, is subjected to simultaneous ultrasonic peening and electropulsing. The pulsed current can generate a critical magnetic field that can induce the transition of the radical pairs formed by dislocations and the pinning obstacles from the singlet state to the triplet state. This leads to higher dislocation mobility and thus higher plasticity for more effective peening treatment. The results show that EP-UNSM lead to a deeper plastically deformed layer than UNSM and continuous current-assisted UNSM (CC-UNSM), and the maximum depth of plastic deformation was obtained when using the highest peak current density. Due to more effective microstructure refinement, the EP-UNSM sample had a 50% higher surface hardness compared with the control sample. Moreover, the compressive residual stresses generated by EP-UNSM were higher in magnitude and greater in depth compared to those generated by traditional UNSM. These results demonstrate that pulsed current can effectively improve the peening efficacy and EP-UNSM is an effective method for strengthening Ti64.

Keyword:

Electropulsing-assisted ultrasonic nanocrystal surface modification; Pulsed current; Electroplasticity; Athermal effect; Compressive residual stress

▪ A055

Title:

Dry Laser Peening of High Tensile Strength Steel

Authors & Affiliations:

Yoshiki Komatsubara and Tomokazu Sano
Osaka University, Japan

Abstract:

Dry laser peening (DLP) is one of the laser peening methods in which metals are plastically deformed by femtosecond laser-driven shock waves. This method can be performed in air, while the conventional method of nanosecond laser peening requires a plasma confinement medium such as water. Our group has succeeded in hardening and inducing compressive residual stresses in high-strength steel (HTS) of 780 MPa using the DLP technique. In recent years, even stronger HTS has been used in the automotive industry. In this study, DLP was applied to HTS with tensile strength higher than 780 MPa, varying the laser conditions to obtain higher compressive residual stress. As a result, DLP was achieved for the higher grade HTS. The induced compressive residual stress increases with higher coverages. This suggests that with increasing coverage, the amount of plastic deformation increases as the number of shock wave propagations per unit area increases.

Keyword:

Dry laser peening, Femtosecond laser-driven shock wave, High tensile steel

▪ A056

Title:

Ultrasonic Nanocrystal Surface Modification: State-of-the-art and Future Perspectives

Authors & Affiliations:

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Abstract:

It is well-known that materials subjected to surface peening technologies possess more outstanding properties than coarse-grained materials. Hence designing potentially cost-efficient and environmentally products made of nanostructured surface layer materials with better properties are in high demand. This paper provides a broad and comprehensive review of the most recent progress in the production, characterization and fundamental understanding of nanostructured surface layer materials produced by ultrasonic nanocrystal surface modification (UNSM) technique. It produces nanostructured surface layer materials that are formed through the application of surface severe plastic deformation (S^2PD). In this study, we demonstrate a detailed description of the literature on the subject as well as highlight challenges for the production of nanostructured surface layer materials with the aim of producing a compressive residual stress layer and improving tribological, corrosion and fatigue properties of various materials including additive manufacturing materials. This UNSM technology is widely used in industry due to its own characteristics such as remarkable strengthening effect, low cost and well adaption. Recently, a portable UNSM technique was also developed to be used directly in the field. This study focuses on the rigorous research and development, the current state-of-the-art of UNSM technique with recent experimental results and potential industrial applications.

Keyword:

UNSM, residual stress, tribology, corrosion, fatigue

■ A059

Title:

Development of ultrasonic nanocrystal surface modification device to improve PWSCC characteristics of reactor nozzle

Authors & Affiliations:

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Abstract:

One of the problematic parts of nuclear power plants is PWSCC(Primary Water Stress Corrosion Cracking) occurring in nozzles and heterogeneous welds in nuclear reactors. In order to solve this problem, research and development to improve the PWSCC resistance by relieving the tensile residual stress of the reactor nozzle and inducing compressive residual stress are being conducted worldwide, and one of them is UNSM(ultrasonic nanocrystal surface modification) technology. In this study, a UNSM device is developed to be applied to the inner diameter and welded area of a CEDM nozzle with an inner diameter of about 70 mm installed on the upper head of a nuclear reactor. In addition, the UNSM device is also developed for the application of the inner and outer diameters of the main steam nozzle with an inner diameter of about 182 mm of a small modular reactor (SMR). The mechanical properties and microstructural evolution of the nozzle material were analyzed before and after the application of UNSM to the nozzle mock-up, and the usability, stability, and reliability of the UNSM device were confirmed.

Keyword:
ultrasonic nanocrystal surface modification, CEDM nozzle, main steam nozzle, residual stress

■ A060

Title:

Effect of Substrate Preheating on the Hardness Behaviors of Inconel 718-WC Composite Coating Synthesized by Laser Directed Energy Deposition

Authors & Affiliations:
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2 Department of Ocean Advanced Materials Convergence Engineering, Korea Maritime and Ocean University, Republic of Korea
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Abstract:

In this study, a substrate is reinforced with WC/Inconel 718 composite coating via directed energy deposition (DED). During the DED, the substrate was preheated to 300 °C and 500 °C, and the microstructural characteristics of the matrix, fusion area, and area around the WC particles were systematically investigated. The results showed that the three different types of WC particle diffusion mechanisms were exhibited: (i) slight dissolution diffusion at non-preheating, (ii) dissolution-diffusion fragmentation at 300 °C-preheating, and (iii) disintegration and diffusion at 500 °C-preheating. In contrast, the effects of dispersion and solid solution strengthening are more pronounced than that of the microstructure coarsening caused by preheating, resulting in a higher hardness value of 384.0 HV0.1 (preheating at 300 °C) and 381.3 HV0.1 (preheating at 500 °C) compared to that of the non-preheated sample (358.9 HV0.1). Furthermore, the bending fracture of the WC/Inconel 718 composite layer exhibited typical pseudo-ductile behavior with premature fracture. Consequently, the highest bending strength occurred at preheating 500 °C, in which the maximum bending load and the displacement at the initial crack increased by 9.15% and 39.69%, respectively, compared with the non-preheated sample. Additionally, the fracture mechanism exhibited mainly intergranular fracture and less transgranular fracture.

Keyword:
Directed energy deposition, WC, Substrate preheating, Microhardness

■ A061

Title:

UNSM process parameter evaluation for increasing hydrogen embrittlement resistance in direct energy deposited STS-316L considering strain-induced martensite

Authors & Affiliations:
Seoung-Ho Baek, Parviz Kahhal and Sang-Hu Park

Abstract:

Hydrogen embrittlement (HE) is a critical issue for metal parts in hydrogen environments because it can reduce elongation and change the fracture mode to brittle. However, the used methods to prevent HE has some limits like additional pollutants or material property change, and interface properties. For this reason, mechanical surface treatment like UNSM (ultrasonic nanocrystal surface modification) for HE resistance is of interest to some researchers. It is reported that UNSM treatment cause compressive residual stresses, grain refinement, and dense dislocations which increase resistance to HE. However, in austenite stainless steels, because strain-induced martensite is generated with UNSM treatment that is hydrogen sensitive, careful selection of process parameters is needed. Moreover, in terms of hydrogen embrittlement, reports on suitable surface treatment process parameters for austenitic stainless considering the microstructure due to the additive manufacturing process are scarce. Despite the additively manufactured parts that are applied to high-value parts. Therefore, we suggested UNSM process parameters for the hydrogen environment for direct energy dispositioned STS 316L.

Keyword:

Hydrogen embrittlement, Direct energy deposition, additive manufacturing, Ultrasonic nanocrystal surface modification

- **A062**

Title:

Microstructure Evolution and Electroplasticity in Ti64 Subjected to Electropulsing-assisted Laser Shock Peening

Authors & Affiliations:

Hao Zhang[1], Chang Ye[2], Zhencheng Ren[3], Yalin Dong[3]
1 College of Civil Aviation, Northwestern Polytechnical University, Xi’an 710072, China
2 School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan, Hubei 430074, China
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Abstract:

The efficacy of laser shock peening is usually limited by the plasticity of the target metal. In this study, an innovative surface treatment method, electropulsing assisted laser shock peening (EP-LSP), was used to process Ti64 samples. During EP-LSP, metallic samples are subjected to simultaneous high strain rate plastic deformation and high-frequency short-duration pulsed electric current. The effects of EP-LSP on surface finish, microstructure, and micro-hardness of Ti64 alloy were investigated and compared with continuous current assisted LSP (CC-LSP) having the same bulk heating effect. It was observed that EP-LSP produced higher surface hardness and deeper hardened layer, both of which indicate greater plastic deformation. Tensile tests were carried out to evaluate the plasticity of Ti64 subjected to pulsed current and continuous current with the same bulk heating effect. It was observed that pulsed current can more effectively decrease the flow stress and thus result in greater plasticity in Ti64 compared with continuous current, even though the bulk heating effect is the same. In addition, the higher the peak current density, the more effective the flow stress reduction. These results demonstrate that pulsed current can effectively improve the laser shock peening efficacy and EP-LSP is an effective method for strengthening Ti64.

Keyword:

Electropulsing assisted laser shock peening; Pulsed current; Electroplasticity; Athermal effect; Microscopic residual stress.

■ A065

Title:

A Study on the Development of Underwater Laser Ablation System

Authors & Affiliations:

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1 Dept. of Smart Manufacturing Engineering, Changwon National University, Republic of Korea
2 Mechatronics Research Center, Changwon National University, Republic of Korea
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Abstract:

With recent development of the automobile and aerospace industry, researches on the laser ablation that processes surface of parts with using laser beam have been actively conducted. Compared to other processes, laser ablation shows short process time and high precision. However, there is a problem that heat-affected zone(HAZ) and the defect of workpiece have appeared by high laser heat source. To solve these problems, water can be used as a coolant. The formation of the HAZ and defect of the workpiece can be decreased. Therefore, research on the underwater laser ablation is needed for the hybrid manufacturing industry nowadays. In this study, an underwater laser ablation system was designed and developed. In order to verify the deformation and stress state of the system, the stability of the system was analysed using ANSYS software. And, the underwater laser ablation processing of stainless steel 304(SUS304) workpiece was performed to obtain the optimized process conditions. Experiments will be conducted on the laser ablation process of various workpiece such as Inconel718, Ti-6Al-4V in the future study.

Keyword:

Underwater, Laser ablation system, Stainless steel 304, Structural analysis

Acknowledgement:

This research was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government (MSIT) (No. 2022R1A2B5B0300188412)

■ A066

Title:

Simulation of Laser Impact Welding Considering Influence of Microstructure

Authors & Affiliations:

Glenn Gleason, Sumair Sunny, Ritin Mathews, Arif Malik
The University of Texas at Dallas

Abstract:

Presented is a comprehensive numerical simulation framework that shows the influence of microstructure effects during laser impact welding (LIW) of metal foils. Until recently, the state-of-the-art in computational modeling of laser impact welding has not included microstructure, and thus material homogeneity has been widely assumed in the prior work. The recent model developments, however, are able to reveal interesting transient interface phenomena that take place during weld formation, as influenced by the microstructures of dissimilar metallic foils joined by laser impact welding. Given that such welds form in under a microsecond, making direct experimental observation impractical, the simulations aid understanding into the inhomogeneous and anisotropic effects of microstructure on the strength of the resulting laser impact weld. Microstructures arising from foils manufactured by laser powder bed fusion are incorporated into an Eulerian finite element simulation of the laser impact weld process, enabling prediction of grain sliding effects and changes in jetting behavior. The trends predicted for the microstructure deformation patterns show strong agreement with those from post-weld experimental images in the literature. The results also reveal increased jetting for inhomogeneous simulations that include microstructural effects (as compared to the homogeneous cases without microstructure) even at relatively lower collision velocities.

Keyword:

Impact welding, Additive manufacturing, Microstructure, Simulation

- **A067**

Title:

High-Strength Laser Impact Welding by Laser-Shock Post-Treatment

Authors & Affiliations:

Sepehr Sadeh, Arif Malik
The University of Texas at Dallas

Abstract:

Laser shock peening has recently been investigated as a post-treatment to increase the strength of dissimilar metal foils joined via high-velocity laser impact welding. Both single and double laser shots were applied as post-treatments to three combinations of metal alloy foils joined by laser impact welding. Depending on the flyer and target material combination (aluminum, stainless steel, brass), experimental lap shear tests revealed that single laser peening shots could increase the strength of the laser impact welds by up to 25%. On the other hand, double laser-shot post-treatments decreased the weld strength for all flyer and target material combinations. Images of the weld interfaces obtained by scanning electron microscope showed that more wavy weld interfaces resulted with the single laser-shot post-treatments (as compared to the unwelded, relatively flat weld interface geometry) which appeared to provide enhanced mechanical interlocking and strength between the foils. Interestingly, for the double-shot laser peening treatments, weld interface separation and melting were observed at the weld interface, likely due to rebounding and plastic heat dissipation effects, respectively. The results of this work show preliminary insights into the use of laser shock peening as a potentially beneficial post-weld treatment for high-velocity impact welding methods.

Keyword:

Laser impact welding, Laser shock peening, Lap shear strength, Experiments

- **A070**

Title:

Predicting the USP process of aero-engine turbo disk grooves using a sequential DEM-FEM method

Authors & Affiliations:

Kai Zhou, Daoxin Liu*, Xiaohua Zhang, Hao Zhang, Kaifa Fan, Wanting Feng
College of Civil Aviation, Northwestern Polytechnical University, Xi’an 710072, China

Abstract:

Ultrasonic shot peening (USP) is an effective method to improve the surface integrity of components with complex geometries. However, the optimization study for USP parameters is very challenging both in experiments and simulations. In this study, a new model for USP process simulation and prediction is established by coupling the discrete element method (DEM) and the finite element method (FEM). Firstly, a DEM model is established based on the real geometry of the turbo disk groove, through which the shot kinematics, including impact velocity, angle and number, is obtained. The shot kinematics data is then imported into an explicit FEM model based on the Johnson-Cook constitutive relation. Through the FEM model, the information of nodes including the stress and displacement is retrieved to obtain the distribution of residual stress and roughness. Besides, the nephogram of equivalent plastic strain is used to analyze the peening coverage. In addition, the effects of USP parameters on the surface integrity are investigated through the coupling model, and the optimized processing parameters are obtained. By comparing with the experimental results, the coupling model built in this study shows a good prediction ability for the roughness, coverage, and residual stress introduced by USP.

Keyword:

Ultrasonic shot peening; Turbo disk grooves; DEM-FEM coupling method; Surface integrity

■ A071

Title:

Effect of Electropulsing-Assisted Ultrasonic Nanocrystal Surface Modification on Microstructures Properties of Additive Manufactured Ti64

Authors & Affiliations:

Yixuan Ye[1], Yu Zhang[1], Huajie Yang[2], Chang Ye[1*]
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2. Suzhou laboratory, 388 Ruoshui Road, Suzhou, Jiangsu 215028, China

Abstract:

In this study, an innovative surface engineering process, electropulsing-assisted ultrasonic nanocrystal surface modification (EP-UNSM), is applied in this study to improve the surface integrity and mechanical properties of Ti64 fabricated by SLM. The higher surface hardness and deeper hardened layer of AM specimens treated with EP-UNSM compared to those treated with UNSM demonstrate that EP-UNSM is a promising post-processing technology for AM metals.

■ A072

Title:

Simulation of the effects of laser shock peening at different incidence angles on the surface morphology and residual stresses of Ti-6Al-4V

Authors & Affiliations:

Ziheng Xu[1] and Chang Ye[1*]
1. School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan, Hubei 430074, China

Abstract:

In the practical application of laser shock peening, the laser perpendicular to the workpiece surface cannot be guaranteed for complex parts. Similarly, many people do not consider the impact of the initial roughness of the workpiece on the surface topography. In this study, a new FEM model incorporating initial roughness was established to predict surface morphology and residual stress induced by laser shock peening at different incidence angles.

■ A073

Title:

The FLASP apparatus: Laser Peening with record-breaking laser energy at the tip of a fiber

Authors & Affiliations:

Adam Ayeb[1], Camille Godel[1], Fahem Boudries[1], Donato Gallitelli[2], Benoît Caillault[2]
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2-Europe Technologies, 2 Rue de la Fonderie, 44470 Carquefou, France

Abstract:

Laser Shock Peening has shown in the past decades its efficiency over other techniques to enhance the fatigue resistance of parts. However, its use is still limited to certain applications as it is complex to implement (high-footprint, free-space propagation, sacrificial layer management).

We present, in this publication, the Fibered LASer Peening apparatus (FLASP) which is comprised of a laser beam fiber injection module, an optical head to focus the beam on the part and an optical fiber to link both modules.

Energetic laser beam transmission through optical fibers requires specific beam shaping as it is necessary to suppress spatial profile modulations caused by speckle. For this matter, the spatial coherence of the beam was reduced in order to obtain a smooth circular beam profile at the fiber entrance. Such a setup made it possible to inject a record 380mJ in a 1.5mm core optical fiber which corresponds to a peak power of 63MW at a pulse duration of 6ns. Such energy levels have not damaged a 5m fiber for more than 50 million shots.

The associated fibered laser peening results on steel, aluminum and titanium parts are also presented.

Keyword:

Laser Peening, Optical fiber

■ A074

Title:

Enhancing Wear Performance of WAAM Manufactured IN718 and 17-4PH Materials Through UNSM Treatment

Authors & Affiliations:

SungHo Heo[a], HeeSung Ahn[a], Auezhan Amanov[b] and Young Sik Pyun[b]
a BEES Inc.
b Sun Moon University

Abstract:

Wire Arc Additive Manufacturing (WAAM) is an innovative 3D printing technology that offers rapid fabrication and high material efficiency for the production of complex-shaped metal components. And Ultrasonic Nano Surface Modification (UNSM) is a technique that utilizes ultrasonic waves to improve the fine structure of metal surfaces, enhancing their strength and durability. In this study, investigates the wear performance of Inconel 718 (IN718) and 17-4 Precipitation Hardening Stainless Steel (17-4PH) materials manufactured with WAAM technology before and after UNSM treatment. Wear tests were conducted using the ASTM G133-95 ball-on-flat method to evaluate the wear resistance of both materials. The friction test results for WAAM IN718 material demonstrated a significant reduction in the friction coefficient by approximately 29.1% after UNSM treatment compared to its pre-treatment value. Similarly, the friction test of WAAM 17-4PH material revealed a decrease in the friction coefficient by about 26.3% following UNSM treatment. These findings indicate that UNSM treatment can effectively enhance the wear performance of WAAM manufactured IN718 and 17-4PH materials, providing a promising solution for extending the service life and improving the durability of additively manufactured metal components in various industrial applications.

Keyword:

WAAM (Wire Arc Additive Manufacturing) / UNSM (Ultrasonic Nano Surface Modification) / Inconel 718 / 71-4 PH / Wear Resistance Test

■ A075

Title:

Modeling of 100mJ Class Laser Peening System for Real-Time Peening Process Monitoring

Authors & Affiliations:

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1 Dept. of Advanced Convergence, Handong Global Univ., 2 HIL Lab. Inc., 3 Pavetech Co.,Ltd.
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Abstract:

In this study, we introduce the modeling process that incorporates real-time monitoring of Laser Shock Peening (LSP), a surface treatment technique for metals and alloys. The existing LSP systems were unable to confirm whether the peening was performed properly, making it difficult to obtain reliable and high-quality LSP results. Therefore, we conducted experiments to analyze the correlation between various data measured by attaching multiple sensors such as spectrometer, CMOS camera, photo detector, energy meter to various parts of the system in order to control peening successfully. If the previous experiment was studied to increase the peening effect through optimization modeling of the incident signal according to the distance of the flat SUS304 specimen, this study expanded the modeling by comparing and analyzing the dominant parameter data of the reflected beam that can observe the peening of the photo detector sensor located on the input side of the LSP system. Not the flat specimen, but various metal specimens such as tilted, cylindrical, and curved surfaces. In this case, we were able to confirm the peening effect in the form of angle, i.e., spatial position transformation, not just distance. Afterwards, we plan to develop a control system based on the modeled system.

Keyword:
Laser Shock Peening (LSP), real-time monitoring, modeling, photo detector, control system

Acknowledgment:
This study was conducted with the support of the Korea Institute for Advancement of Technology with financial resources from the government (Ministry of Trade, Industry and Energy) in 2023 (P0008763, Industrial Innovation Talent Growth Support Project in 2023)
This research is a basic research project carried out with the support of the National Research Foundation of Korea with financial resources from the government (Ministry of Education) in 2023 (Task number: 2021R1I1A3051341)

■ A076

Title:

Performance Comparison of LOXAFH and LASOX Cutting Methods with Laser Beam Diameter

Authors & Affiliations:
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Abstract:

We developed and validated laser oxyfuel and oxyflame cutting (LOXAFH), which can be applied to the decommission of reactor pressure vessel in nuclear power plant with cladding metals containing non-oxidized metals. To combine the removal of non-oxidized metal layers by laser cutting and the cutting of carbon steel by oxyfuel cutting, a system was developed in which the two processes are coaxial. To compare LOXAFH to conventional cutting methods; oxy-fuel cutting and laser-assisted oxygen (LASOX) cutting, we performed cutting experiments on 12 mm carbon steel with a 3 mm non-oxidized metal layer (SUS 303), using the diameter and power of the laser beam and the stand-off distance as control variables. Oxy-fuel cutting using oxidizing heat was unsuccessful in cutting SUS303, while LASOX cutting only worked when the laser beam had the right diameter to make the oxygen flow effectively. However, LOXAFH proved to be effective in cutting a total of 15 mm of material using the same laser conditions as LASOX, with the oxyflame assisting the cut.

Keyword:
Nuclear decommissioning, Laser cutting, LASOX, Cladding metal

Acknowledgment:
This research was supported by Korea Institute for Advancement of Technology(KIAT) grant funded by the Korea Government(MOTIE) (P0008763, HRD Program for Industrial Innovation) and the Ministry of SMEs and Startups(G21002228281).

▪ A078

Title:

Laser shock peening technology development at HiLASE Center and actual capabilities

Authors & Affiliations:

Jan Brajer, Jan Kaufman, Sanin Zulic, Marek Böhm, Sunil Pathak, Ondřej Stránský, Jan Šmaus, Tomáš Mocek
HiLASE Centre, Institute of Physics of the Czech Academy of Sciences

Abstract:

At the HiLASE laser center, we started to work with LSP technology in 2013. In 2016, the Bivoj laser was launched at the HiLASE center. Since then, the technology has been tested on titanium alloys, aluminum alloys, stainless steel, cobalt-chromium materials, and many others.

Since 2019, systematic research on the potential of LSP technology has been carried out through individual case studies for aviation, engineering, automotive, tool making, biomedicine, and energy. Thanks to the capabilities of our laser and process station, we can achieve the most interesting applications with the ambition of the space industry.

In 2022, the construction of the robotic laser workplace was completed, which houses the Litron laser system and the self-designed Hammer laser. Additionally, the station has a 9 kW diode laser suitable for welding, hardening, and cladding. It is the combination of technologies that makes our process station completely unique. We can now harden a component and process it with LSP to achieve high hardness and resistance to crack propagation. The most interesting, however, is the combination of PLD and surfacing or even 3D printing, which allows for the creation of a component with completely unique properties that cannot be achieved by any other technology.

Keyword:

HiLASE center, laser shock peening, LSP hardening, LSP 3D printing

▪ A079

Title:

Laser shock peening to improve the wear characteristics of tool steel

Authors & Affiliations:

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2 Beamtech Optronics Co. Ltd. White Rock, BC, Canada

Abstract:

Laser shock peening (LSP) involves a high energy short pulse laser beam that irradiates the surface of the metal covered with a thin layer of non-reflective adhesive under a constant flow of de-ionized water. In this research, LSP was applied on the surface of 15N20 tool steel which is widely used in lumber industries. LSP induces a high compressive residual stress at the sub-surface level. This increases the microhardness and elastic modulus of the treated samples which results in improving the wear resistance of the treated samples. To achieve this, the 15N20 tool steel cutting tool tip samples were subjected to LSP single shot, double shot, and 50% overlap multi-track experiments. Each sample was characterized for microhardness using nanoindentation before and after LSP treatment. The samples were also used to characterize the wear phenomena after random facing and turning operations of the heavier, and hardwood Oak wooden log specimens. The results show LSP treatment has increased the surface hardness by ~15%, increased an active turning operation time by ~11%, and increased a sawn distance by ~8%. The samples saw a decrease of ~43% in the edge recession and a ~5% decrease in the wedge angle.

Keyword:

Laser shock peening, Tool steel, Microhardness, Nanoindentation, Wear

- **A080**

Title:

Effects of Ultrasonic Nanocrystal Surface Modification on Microstructural Characteristics and Surface Properties of Al5356 Alloy Manufactured by Wire Arc Additive Manufacturing

Authors & Affiliations:

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2 Department of Mechanical Engineering/Fusion Science and Technology, Sun Moon University, Asan, Korea
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Abstract:

In this paper, the effects of ultrasonic nanocrystal surface modification (UNSM) technology on microstructural characterization and surface properties of Al5356 alloy manufactured by wire arc additive manufacturing (WAAM) were investigated. The objective of this study is to improve the quality of the WAAM-built part by eliminating bigger pores and reducing its size, reducing surface roughness, increasing surface hardness, and inducing compressive residual stress. The porosity of the as-built WAAM and WAAM-UNSM-treated samples were quantitatively investigated using an X-ray micro-computed tomography (μ-CT). The surface roughness of the as-built WAAM sample was reduced, while the surface hardness was increased after UNSM treatment due to the elimination of bigger pores in the as-built WAAM samples. The porosity measurement results revealed that medium-sized pores were shrunk to almost half the size after the UNSM treatment. The level of the induced compressive residual stress after UNSM treatment was found to be about -86 MPa, while it was about -47 MPa for the as-built WAAM sample. This experimental work demonstrates the critical advantages of hybrid WAAM-UNSM in improving the qualities of the WAAM processed parts.

Keyword:

Porosity, roughness, hardness, residual stress, UNSM, WAAM

- **A081**

Title:

Exploring the Impact of Opaque Overlays on Laser Shock Peening: Pressure Variations and Efficient Characterization

Authors & Affiliations:

Dr. Stan Bovid, Dr. Kent Talbert, Dr. Dietrich Kiesewetter
*LSP Technologies

Abstract:

Material modification and benefits from laser shock peening are influenced by pressure, duration, and shockwave count. Process designers optimize these parameters for desired residual stress fields while considering geometry, materials properties, and peening system capabilities. Models correlating laser peening parameters and shockwave conditions are crucial for designers to specify conditions that will achieve the target results. Although there are sources that detail the relationship between common laser peening parameters and plasma pressure, they often overlook the impact of intermediate processing layers known as opaque overlays. These overlays, which include tapes, foils, and paint, can significantly affect the shockwave pressure experienced by the workpiece due to impedance variations. Limited studies have investigated the influence of these intermediate materials on the workpiece's shockwave pressure.

Photon Doppler velocimetry measures local rear surface velocity of shocked targets. Recent studies have extended its utilization in calculating shockwave pressure and profiles in laser shock peening. The equipment enables efficient and cost-effective systematic studies of pressure characteristics with various peening configurations. Findings indicate workpiece shockwave pressures can differ up to 50% from plasma pressure alone. The presentation provides an overview of techniques, results obtained, and modelization of select overlays to enhance understanding.

Keyword:

Photon Doppler velocimetry, shockwave pressure, pressure model, opaque overlay

- **A082**

Title:

Considerations and Developments for the Commercialization of Laser Shock Peening Technology

Authors & Affiliations:

Mark Bloomberg
*LSP Technologies

Abstract:

Commercialization of laser shock peening is driven by technology adoption across both existing and new industries. Historically, adoption of laser shock peening for applications has often been driven by unique circumstances that through the problem scope alone define LSP as the solution. Numerous opportunities exist for laser peening outside of these isolated issues and laser shock peening competes with other surface enhancement technologies and solutions. It is important to understand the needs of these market segments as well as how LSP

compares with alternative surface enhancement solutions. To reach adoption in a more complex environment, the understanding needs to extend beyond physics, materials science, and fatigue enhancement benefits and into the real-world practical application of the technology.
This presentation will discuss key technological advancements that must be addressed to support broad scale adoption of laser shock peening within existing markets as well as what considerations are needed to support laser peening as a disruptive technology in adjacent markets. Recent technological developments to address commercialization of LSP as a technology and real world application of this technology are presented.

Keyword:

Commercialization, laser peening equipment, competing technologies, new industries

■ A083

Title:

Technological advancements in delivering an industrial hardened laser shock peening system solution for laser peening in Nuclear

Authors & Affiliations:

Mark Bloomberg
*LSP Technologies

Abstract:

In 2021, LSP Technologies, Inc. performed laser peening services to treat stress corrosion cracking of the CEDM nozzles on the reactor vessel head at Arkansas Nuclear One – Unit 2 (ANO2). The development and successful deployment of the LSP solution required solving technical hurdles including design of the system solution for: rapid deployment, harsh environmental conditions, beam delivery, generating the required compressive residual stress field in the presence of uncertainty, and end effector design for survivability. This presentation discusses the journey to develop an industrially hardened laser shock peening system solution, some key challenges in developing that solution, and the technological advancements made to deliver the first of a kind service solution to ANO2.

Keyword:

laser peening equipment, nuclear, alloy 600, tolerancing, design

■ A086

Title:

Surface Engineering Additive Manufactured Components for Biomedical Applications

Authors & Affiliations:

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2 DSI-NRF Centre of Excellence in Strong Materials, hosted by the University of the Witwatersrand
3 Council for Scientific and Industrial Research (CSIR), National Laser Centre, Meiring Naudé Road, Pretoria, 0081, South Africa

Abstract:

Titanium alloys are common in medical applications for their high strength-to-weight and excellent corrosion resistance. In this study, Ti6Al4V has been additively manufactured using selective laser melting (SLM) in three build orientations and left in the as-built state. Laser shock peening without protective coating (LSPwC), at increasing spot densities (N_p), was performed to investigate possible improvements to surface and material properties and the residual stress profile with respect to the enhancement of implant success. Previous literature has shown that increased roughness, with micro and nanotopography, and surface oxides of TiO_2 and Al_2O_3 have resulted in better bone-implant adhesion.

The material and surface state pre- and post-peening were investigated using SEM, IHD, OLM, and profilometry. LSPwC increased the surface roughness (Ra) and hardness (HV) and formed an oxide layer, reversing the tensile residual stresses of the SLM process and inducing compressive residual stress that scaled in depth and magnitude with an increasing N_p. No microstructural change was observed at the surface or sub-surface. The sample build orientation and surface state had no noticeable effect on the process.

The changes induced by LSPwC will likely improve fatigue life and osseointegration, making the material more suitable for biomedical implants.

Keyword:

Laser Shock Peening, Selective Laser Melting, Additive Manufacturing, Surface Modification

■ A087

Title:

Study on 30MW laser pulse transmission by end cap fiber

Authors & Affiliations:

Itaru Chida, Keiichi Hirota
Toshiba Energy Systems & Solutions Corporation

Abstract:

Fiber laser peening has been developed and applied to various industrial fields. In the past study, 20MW laser pulses were delivered through an optical fiber with a core diameter of 1.5mm. Though tapered fiber with a core diameter of 2.4mm to 1.0mm was developed and applied to enhance the focusing capability after that, at around 15MW at fiber tip was the practical limit due to the durability of optical fiber. In this study, laser transmission test by using end cap fiber was performed to enhance the transmittable pulse energy. An end cap of φ8mm × 8mm was welded to an optical fiber with a core diameter of 1.0mm and the length of 2m. 30.7MW laser pulses, which were emitted from a frequency doubled YAG laser with pulse energy of 169mJ and a duration of 5.5ns, were irradiated to the end cap fiber via the homogenizer and pulse energy was measured with laser power meter. As the results, it was confirmed that 24.5MW laser pulses were transmitted through the end cap fiber and the pulse energy of 135mJ was measured. As a future study, we would like to evaluate the effect of increased pulse energy for fiber laser peening.

Keyword:

Fiber Laser Peening, End Cap Fiber

▪ A088

Title:

State of the art of Laser Shock adhesion Test - a wide range of possibilities

Authors & Affiliations:

Romain Ecault (Airbus Operations SAS), Marine Scius-Bertrand (Rescoll), Selen Unaldi (Airbus Operations SAS), Laurent Berthe (CNRS - PIMM)

Abstract:

The purpose of this communication is to give an up-to-date state-of-the-art about Laser Shock Adhesion Test (LASAT), also known as Laser Bond Inspection (LBI). When the conventional LSP technique uses the compression induced by the laser shockwave, this technology relies on its reflection onto a free surface to generate tensile stresses within the materials. Depending on the laser configuration - single of multipulse, one face or double face irradiation - or on the laser parameters - beam profile and characteristics - the tensile stresses distribution can be optimised to address various industrial applications. The scope is wide, it goes from the historical coating systems, to aluminium and composite bonded assemblies, whose thickness can vary depending on the laser parameter. More recently, the technology was also demonstrated on hybrid bonding (Composite/ metal) and on paint systems. It can be used as a selective de-assembling technique for dismantling or recycling purposes. The objective of this paper is to give an exhaustive and comprehensive mapping of the LASAT application with regards to the different configuration and parameters currently available.

Keyword:

LASAT, bond inspection, composite, metal, paints

▪ A089

Title:

A Study on the Mechanical Properties and Microstructure of SKD 61 repaired using directed energy deposition (DED)

Authors & Affiliations:

Min-Seong Ko, Bit-Na Yun, Hwa-Jeong Kim, Do-Sik Shim

Abstract:

SKD61 is widely used in molds under high temperature (die casting, hot forging, and etc.) due to its excellent heat and wear resistance. In the case of local damage, repair is commonly performed through welding. However, mechanical properties are degraded owing to the wide heat-affected zone (HAZ). To solve this problem, this study attempted repair through directed energy deposition (DED), one of the additive manufacturing technologies. As a result of the Vickers hardness test, the hardness of the repair part was 35% higher than that of the wrought material, and a local HAZ of 100 microns was found. The microstructure was uniform and the grains were refined in the DED repaired region compared to raw material. As a result of the tensile test, specimens repaired by the DED showed tensile strength and yield strength of 80% or more compared to wrought materials. It was expected that the lower strength of DED-repaired specimen was due to the stress concentration at the interface between the repair layer and the base material and HAZ. In the future, research on post-treatment after DED repairing will be conducted to improve the strength of the DED-repaired sample to raw materials.

Keyword:
Directed energy deposition (DED), Repair, Vickers hardness test, Tensile test, Microstructure

- **A090**

Title:
Increasing the fatigue strength of rivet lap joint of aerospace grade 7xxx series aluminum plates by laser shock peening

Authors & Affiliations:
M. Sc. Tapar, Ogün Baris; Dr. Sprengel, Maximilian; Dr. Busse, David Osman; Dr. Epp, Jeremy

Abstract:
Cold expansion is being widely used in repairing and manufacturing rivet lap joints in the aerospace industry. However, during this process, inevitable compression to tensile residual stresses transition points are generated which can act as crack initiation spots. Due to limited parameter variations, elimination of this phenomenon is difficult. Due to its large penetration depth, laser shock peening (LSP) might a promising candidate to replace cold expansion for the treatment of rivet areas.To understand the effect of LSP parameters on the residual stress, a systematic parameter study involving extensive XRD residual stress analyses and fatigue tests was conducted. After successful determination of the optimum parameter matrix, fatigue tests were carried out with samples that were laser peened, cold expanded and untreated. As a final study, in order to understand the effect of LSP on residual stress evolution and the local material behavior in rivet lap joints, energy dispersive synchrotron X-ray investigation was performed. For this experiment, laser peened, cold expanded and untreated samples were prepared and submitted to fatigue tests at defined cycles. Residual stress distribution near the rivet area was analyzed for each sample in order to assess the stability and the change of residual stresses after loading.

Keyword:
Laser Shock Peening, Cold Expansion, Rivet Lap Joints, Residual Stresses, Energy Dispersive Synchrotron X-ray Diffraction

- **A091**

Title:
Fast Laser Shock Peening using high repetition rate lasers

Authors & Affiliations:
Olivier Casagrande (Thales LAS), Alexandre Rondepierre (University of Osaka), Hervé Besaucèle (Thales LAS), Christophe Simon-Boisson (Thales LAS), Maxime Guerbois (CNRS), Yann Rouchausse (CNRS), Laurent Berthe (CNRS)

Abstract:
We report a new configuration of Laser Shock Peening (LSP) based on the use of a high repetition rate diode-pumped solid-state laser and smaller laser spot size, this combination avoiding the necessity of using a protective coating. Many combinations of parameters (spot

size, laser beam overlap rate, laser fluence, laser pulse duration) have been tested on an experimental setup involving a Joule-level diode-pumped solid-state laser delivering infrared pulses (at 1064 nm) at a repetition rate of 200 Hz. LSP performance has been extensively characterized in terms of pressure and residual stresses curves. It shows that few mm diameter spots used with such Joule class lasers produces the optimal LSP performance thus allowing to combine high quality (mm class penetration depth) and high speed of the LSP thanks to high average power of the laser exceeding 100 W leading to many applications in the fields of aerospace, naval, automotive, energy, etc..

We report also about laser technology developed to reach such laser performance as well as engineering considerations to optimise throughput and quality of LSP, in particular for the management of water confinement.

Keyword:

Laser, Shock, Peening, Efficiency, Speed

■ A093

Title:

Superior gradient heterostructured alloys fabricated by laser powder bed fusion via annealing and ultrasonic nanocrystal surface modification

Authors & Affiliations:

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1 POSTECH
2 Sun Moon University

Abstract:

Developing metal additive manufactured (AM) parts with excellent mechanical properties broaden the utilization of AM parts in various industrial applications. Recently, gradient structures have received significant attention owing to their excellent mechanical properties. In this study, we propose a new strategy to obtain a superior gradient structure using annealing and ultrasonic nanocrystal surface modification (UNSM) on laser powder bed fusion (LPBF) fabricated 316 L stainless steel. The post-LPBF annealing treatment disturbed the cellular dislocation structure, which led to the optimized materials for gradient structure. The resulting gradient structure after the UNSM treatment has a thicker gradient layer with a significant strain partitioning between the domains than the LPBF followed by UNSM without annealing. As a result, the present LPBF-annealing-UNSM alloys show superior strength-ductility synergy compared to the LPBF-UNSM samples.

Keyword:

Laser powder bed fusion; Gradient structure; Heterogeneous materials; Ultrasonic nanocrystal surface modification; Austenitic stainless steels

▪ A094

Title:

Introduction of UNSM device and equipment depending on their application

Authors & Affiliations:

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2 Department of Mechanical Engineering/Fusion Science and Technology, Sun Moon University, Asan, Korea
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Abstract:

Design Mecha Co., Ltd. has developed Ultrasonic Nanocrystal Surface Modification (UNSM) technology for the first time in the world. UNSM technology has been implemented and used in CNC machine tools, manipulators, robots, and portable devices depending on their application. The UNSM system improves the performance and service life of parts used in steel, power plants, heavy industry, aviation, and railroad. In the application of industrial knives, medium and large bearings, and shear pins UNSM treatment has a successful story. The secured quality, performance, and economic feasibility by applying UNSM technology proves in these applications for the past 20 years. The steel and power plant fields involve the remanufacturing process using UNSM technology for carbon zero and resource recycling. It is expected to expand to more areas in the future. In this paper, UNSM devices and equipment depending on the application of products with their effects are summarized and what is ongoing challenge for the future innovation shows.

Keyword:

ultrasonic nanocrystal surface modification, knife, bearing, remanufacturing process

▪ A095

Title:

Effect of Different Tape Overlays on the Surface Integrity and Mechanical Properties of Aeronautical Aluminium Alloy 7075 Processed by Laser Shock Peening

Authors & Affiliations:

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2 DSI-NRF Centre of Excellence in Strong Materials, hosted by the University of the Witwatersrand

Abstract:

Laser Shock Peening (LSP) is a surface enhancement treatment that induces compressive residual stresses by irradiating laser pulses onto the surface of metallic alloys.

The current activity was aimed at the industrial advancement of the LSP process, by analysing twelve commercial types of ablative tape overlays with different properties, adhesive layers, and backing materials (e.g. Aluminium, Copper, Vinyl, Polyimide, Polyester, etc.) on a conventional 7075-T651 aeronautical aluminium alloy. Samples were processed with a range of

laser Power Intensities and Coverage.
The tapes' performance and surface characteristics were investigated using Optical Microscopy, and surface integrity was further analysed with Scanning Electron Microscopy and two types of roughness testing. Through-thickness residual stresses were mainly evaluated using Incremental Hole Drilling and complemented with Laboratory X-Ray Diffraction for near-surface data, and integrated with microhardness profiles. All results were benchmarked against an LSP without coating case.
Each tape provided unique effects, but it was found that not only a metallic/non-metallic backing material but also the ablative thickness influence the LSP performance, with the tape backed with Vinyl showing the highest compatibility with the LSP process.
The trends observed in this study will aid in reaching an LSP ablative media optimised solution for the aeronautical industry.

Keyword:
Laser Shock Peening; Ablative Overlays; Adhesive Tapes; Aluminium Alloy 7075

■ A096

Title:

Laser Shock Peening Technology Development: Cavitation Bubbles as a Process Diagnostic

Authors & Affiliations:
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2 DSI-NRF Centre of Excellence in Strong Materials, hosted by the University of the Witwatersrand
3 Council for Scientific and Industrial Research (CSIR), National Laser Centre, Meiring Naudé Road, Pretoria, 0081, South Africa

Abstract:

Laser Shock Peening (LSP) under a thick water confinement layer produces cavitation bubbles that rapidly expand and collapse emitting at least two shock waves in the surrounding water. The time between the first shock (laser pulse) and the second shock (first bubble collapse) is defined as the first bubble oscillation period and has been evaluated for use as a real-time (and truly localised) LSP process diagnostic. Within this study, it was found that the first bubble oscillation periods could be correlated to an increasing laser power intensity up to a systematic onset of water dielectric breakdown. The stability of bubble lifetimes was most appreciably improved with the presence of flowing water along the beam path. The target geometry (corners, cavities, semi-cylinders) produced an overall change (increase or decrease) in the cavitation bubble lifetime that is present regardless of beam energy, water flow or laser pulse rate. Promising applications for this diagnostic at present would be in cases of quite regular or predictable target geometries such as large flat or uniform panels (pressure vessels and aircraft skin structures) with the use of high water flow rates to maintain the confinement layer along the beam path.

Keyword:
Laser Shock Peening; Water Confinement; Cavitation Bubble; Laser Process Diagnostic; Dielectric Breakdown

A097

Title:

Investigation of Corrosion Behaviour of Aeronautical Aluminium Alloy 7075 Processed by Laser Shock Peening without Coating

Authors & Affiliations:

Shonhai, N.[1,2], Chundunsing, A.N.N.[3,4], Polese, C.[2,3], Cornish, L.A.[1,2] and Ramasawmy, H.[4]
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2 DSI-NRF Centre of Excellence in Strong Materials, hosted by the University of the Witwatersrand
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4 Mechanical and Production Engineering Department, University of Mauritius, Reduit, 80837, Mauritius

Abstract:

Laser shock peening (LSP) is a surface treatment aimed at inducing favourable compressive residual stresses in metallic structures, thus improving their fatigue resistance. Therefore, the introduction of LSP technology during production and/or maintenance has the potential to significantly increase the performance of aeronautical components. Due to their good mechanical behaviour, ease of design and manufacturing, aluminium alloys are still representing up to 50-90% of modern airframe structures, even if some are susceptible to localised corrosion.

In this work, the corrosion behaviour of a conventional AA7075-T651 after LSP without protective coating was investigated, varying power intensity (1-5 GW/cm^2), spot size (diameter 0.8-1.5 mm), and coverage (2.5-40 spots/mm^2). For LSPeened samples SEM micrographs showed rough surfaces with areas of re-melting and solidification and some micro-cracks, EDX revealed an increase in oxygen content, indicating the formation of an oxide film and higher roughness values were measured due to intense surface ablation. Potentiodynamic polarisation tests in 3.5 wt% NaCl solution showed higher corrosion rates for most LSPeened samples. Interrelationships between the observed results and LSP processing parameters were drawn, in conjunction with microstructural, Knoop and Vickers microhardness and residual stress data. Further work will include stress corrosion cracking.

Keyword:

Laser Shock Peening without Coating; Corrosion; Aluminium Alloy 7075

A098

Title:

Reaction Characteristics of Laser-induced Graphene-based Hydrogen Sensors Using UV Laser

Authors & Affiliations:

Jinsu Kim, Sungmoo Hong, Bo Sung Shin

Abstract:

Graphene has an sp2 bond structure with three bonds connected to one vertex of each carbon atom, and a hexagonal honeycomb arrangement forms a two-dimensional plane. As it can be used in a structure thin enough to transmit visible light of various characteristics such as excellent electrical conduction, thermal conduction, and high specific surface area, it is widely applied to sensors, batteries, flexible screens, super capacitors, and solar cells. Graphene requires a very complex process to be produced in a chemical way. We simply manufactured laser-guided graphene using UV laser from graphene with such excellent characteristics and developed a sensor application using this characteristic.

Keyword:

UV laser, Laser-induced graphene, gas sensor

■ A099

Title:

Fiber Delivered 200mJ Nanosecond Green Laser System for Laser Peening without Coating

Authors & Affiliations:

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Abstract:

The utilization of fiber beam delivery technology offers significant advantages for applications operating in harsh environments. In this paper, we introduce a nanosecond laser system designed for Laser Peening without Coating (LPwC), facilitated by fiber beam delivery. To enable the transmission of high-energy laser pulses exceeding 200mJ through an optical fiber, we have implemented spatial interference reduction techniques and high-efficiency transmission technologies, achieving a transmission rate of over 85%. To further enhance the delivery of laser energy, we have employed a strategy of bundling multiple fibers together. We also present a laser peening head equipped with a peening process and fiber monitoring capabilities, to investigate its potential applicability to LPwC.

Keyword:

Nanosecond Laser, Pulsed Laser, Fiber Beam Delivery, Laser Shock Peening, Laser Peening with Coating

■ A100

Title:

Comparative study of laser polishing employing spatial beam modulation

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Abstract:

Laser polishing employing spatial beam modulation is proposed and demonstrated. Optical lens elements are used to generate spatial beam modulation, then one-dimensional or two-dimensional multiple-beam are applied to the target surface concurrently and repeatedly by scanning it forward or backward. Compared to the conventional laser polishing scheme employing micro-remelting on long scanning path, process time and quality of surface can be enhanced especially for large surface area, which can be adapted for pre-treatment and post-treatment of laser peening system with sufficient energy. The feasibility of proposed scheme are demonstrated with comparative experiments for the processing parameters such as 1D/2D spatial beam modulation, scanning time with beam period, beam energy and so on. The effect of proposed laser polishing are evaluated with scanning electron microscope(SEM), confocal microscopy and X-ray diffraction(XRD) by measuring surface roughness, residual stress on different samples. Considering recent market releases of high-energy laser system with reduced prices, we expect that proposed concept of spatial beam modulation on laser polishing can be very efficient for field deployment of laser system in the future.

Keyword:

Laser polishing, Spatial beam modulation, Two-dimensional multiple-beam, Large-area processing, pre-treatment, post-treatment

▪ A105

Title:

Laser shock processing using nano and pico seconds pulsed lasers

Authors & Affiliations:

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Abstract:

Laser shock processing (LSP) using high-energy laser pulses has been studied for the last 50 years [1]. This technique has improved the mechanical properties of aluminum alloys, titanium alloys, stainless steels, and others. [2-3]. In this work, we present some results in the LSP treatment without ablative coating in aluminum 6061-T6 and stainless steel 316L using a combination of nanosecond laser pulses (Nd: YAG pulsed laser, ns-pulsed laser, Quantel Q-Smart 850) and picosecond laser pulses (diode-pumped solid-state, ps-pulsed laser, Ekspla Atlantic 355-60). We show some results about compressive residual stresses and the microhardness and wear obtained. This work was developed at the Guadalajara University, Mexico, and the Laser Centre of the Universidad Politecnica de Madrid, Spain.

Keyword:

Laser shock processing, pulse laser, microhardness, wear.

Reference:

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Laser Shock Processing of 6061-T6 Al alloy with 1064 nm and 532 nm wavelengths. Applied Surface Science, 256(20), 5828-5831.
3. Wei Guo et al, Effect of laser shock processing on oxidation resistance of laser additive manufactured Ti6Al4V titanium alloy 170, 108655 (2020).

A107

Title:

Envisaged Strategies and Studies on Laser Shock Peening of Laser Deposited High Entropy Alloys

Authors & Affiliations:

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Abstract:

We report, to the best of our knowledge for the first time, our experimental studies on laser peening of laser deposited high entropy alloy (HEA) of $W_6Fe_{23}Cr_{24}Mn_{24}Ni_{19}Co_4$ and possibly others, which are currently under development at our laboratory. Powders of the component metals or their bi-metal alloys were flown by Argon gas into a focused cw diode laser beam (λ: 978 – 1025 nm) at about 2.2 kW power to deposit a rectangular plate of the above stated tungsten containing HEA. The laser deposited alloy was characterised perse and after annealing in vacuum for 48 hours at temperature of 1200 °C, which made it homogeneous, and softer. Laser shock peening (LSP) of the HEA was carried out before and after annealing using a Q-switched Nd:YAG laser of pulse duration of 20 ns at FWHM, single pulse energy of about 570 mJ at repetition rate of 10Hz. For LSP we used a sacrificial layer of sticking tape on the alloy surface in a closed cell under flowing water to confine the ablation products and to remove the debris and bubbles produced. Detailed results of characterisation studies of the laser deposited HEAs, subjected to LSP will be presented and discussed in this paper.

Keyword:

High Entropy Alloys, Laser Metal Deposition, Nanosecond Laser Peening, Pulsed Nd:YAG laser

■ A109

Title:

Effect of Laser Beam Overlap rate on Mechanical Properties of Aluminum Alloy Arc Welding with Laser Peening

Authors & Affiliations:

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3 Hanjo Co., Ltd

Abstract:

The laser peening effect using a Q-switching pulse laser was investigated for the arc weldment of the aluminium alloy(Al3003). In order to optimize the laser beam overlap rate condition during laser peening of the weldment, the experiment was conducted on bead welding and butt welding specimens while changing the overlap rate, and the effect of the beam overlap rate was analyzed. As the overlap rate increased, the residual stress changed from tensile to compression, and the highest level of compression residual stress was formed under the overlap rate of 75%. Laser peening was performed on the weldment of aluminum of the prototype by applying the optimal peening conditions derived above. The residual stress, hardness, and tensile strength of the weldment before and after laser peening were compared. As a result, the residual stress changed from tensile to compression, the hardness of the weldment was lowered, and the tensile strength increased after laser peening. Through this, it showed that the quality of the product can be improved by improving mechanical properties when applying laser peening of the aluminum weldment.

Keyword:

Aluminum alloy, Arc welding, Laser peening, Residual stress, Tensile strength

■ A110

Title:

Improvement of wear resistance at high temperature by hybrid cladding combined UNSM and laser DED process

Authors & Affiliations:

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Pusan national university

Abstract:

We propose a new hybrid cladding process technology that combines the high-temperature ultrasonic nanocrystal surface modification (UNSM) process and the direct energy deposition (DED) process to improve high-temperature wear resistance. As a procedure that repeats the DED process and the UNSM process, the UNSM process is applied at a given height after the DED process, and the features are compared based on whether or not heating is applied. This paper compares the impact on the wear resistance at high-temperatures of Inconel-718 cladding components. The wear resistance was evaluated based on whether or not the UNSM treatment was heated. As a consequence of the wear test conducted at RT ~ 800 °C, the total amount of wear in the hybrid cladding and hybrid cladding with heating processes was reduced at all temperatures compared to cladding-only. And at room temperature, the wear resistance improved by 24.11% while 26.96%, respectively, and at 800 °C, it displays a maximum improvement of 4.3% and 11.63%, respectively. The hybrid process presented in this study is a convenient technique for enhancing the mechanical properties of the inner clad layer and can be utilized to build components where high-temperature wear resistance is crucial.

Keyword:

hybrid cladding process, direct energy deposition (DED), high-temperature ultrasonic nanocrystal surface modification (UNSM), control of internal material property

■ A112

Title:

Development and Verification of Laser Peening System for Mitigation of Main Equipment of Nuclear Power Plants

Authors & Affiliations:

Bae Sung Chan, Kim Sang Jin, Han Jae Sub, Byeon Jin Gwi, Yoo Seog Joon

Abstract:

We have developed a laser peening system to mitigation of primary water stress corrosion cracking (PWSCC) that occurs in the BMI nozzle of a nuclear power plant during operation. The laser peening system consists of a laser peening head, manipulator, and laser source suitable for preventive maintenance of BMI nozzles. The laser source uses 532nm and is transmitted through optical fiber. Verification tests were performed on the laser peening system, and the peening effect was verified through residual stress measurements.

Keyword:

Laser Peening, Surface Stress Improvement, Mitigation, Residual Stress, Stress Corrosion Cracking

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