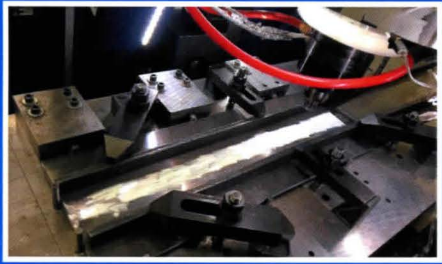
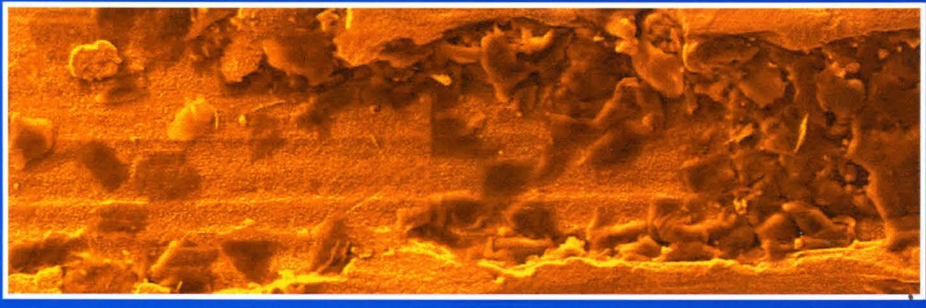
FRICTION STIR WELDING AND PROCESSING XI





Edited by
Yuri Hovanski • Yutaka Sato • Piyush Upadhyay
Anton A. Naumov • Nilesh Kumar

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Editors
Yuri Hovanski
Brigham Young University
Provo, UT, USA

Yutaka Sato
Tohoku University
Sendai, Japan

Piyush Upadhyay
Pacific Northwest National Laboratory
Richland, WA, USA

Anton A. Naumov
Peter the Great St. Petersburg Polytechnic University
Saint Petersburg, Russia

Nilesh Kumar
The University of Alabama
Tuscaloosa, AL, USA

ISSN 2367-1181 ISSN 2367-1696 (electronic)
The Minerals, Metals & Materials Series
ISBN 978-3-030-65264-7 ISBN 978-3-030-65265-4 (eBook)
https://doi.org/10.1007/978-3-030-65265-4

Cover Illustration: Top left: From Chapter "Preliminary Investigation of the Effect of Temperature Control in Friction Stir Welding", Johnathon B. Hunt et al., Figure 2: Is an example of the weld setup for all temperature control welds. https://doi.org/10.1007/978-3-030-65265-4_8. Top right: From Chapter "Process Robustness of Friction Stir Dovetailing of AA7099 to Steel with In Situ AA6061 Interlayer Linking", Md Reza-E-Rabby et al., Figure 2: **a** Lap shear tensile strength as a function of applied forge force during FSD process, **b** example of FSD joint produced solely by mechanical interlocking, and **c** failed FSD tools (tips of WC inserts broken) at process force of 75 kN or more. https://doi.org/10.1007/978-3-030-65265-4_14. Bottom: From Chapter "Characterization and Analysis of Effective Wear Mechanisms on FSW Tools", Michael Hasieber et al., Figure 8: SEM analysis of the FSW tool in the initial state at the probe (**a**) and the shoulder (**b**) https://doi.org/10.1007/978-3-030-65265-4_3.

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The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

These proceedings represent the 11th symposium on Friction Stir Welding and Processing (FSW/P) held under the auspices of The Minerals, Metals & Materials Society. These historic proceedings represent 30 years of study, research, and implementation since the initial FSW patent was filed in 1991. The continued interest and participation in this symposium and the associated proceedings are an indirect testimony of the growth of this field.

For 2021, a total of 61 abstracts were submitted, which include 8 oral sessions. There are 20 papers included in this volume, which when combined with the previous 10 proceedings' publications represent more than 325 papers over a 22-year period. These submissions cover all aspects of friction stir technologies including FSW of high melting temperature materials, FSW of lightweight materials, FSW of dissimilar materials, simulation of FSW/P, controls and inspection of FSW/P, and derivative technologies like friction stir processing, friction stir spot welding, additive friction stir, and friction stir extrusion.

Friction stir welding was invented by TWI (formerly The Welding Institute), Cambridge, UK and patented in 1991, although the real growth in this field started several years later. In the last 30 years, FSW has seen significant growth in both technology implementation and scientific exploration. The original patent has led to hundreds of additional patents issued globally, as various solid-state processing techniques have derived from the original FSW concept. In addition to the tremendous number of derivative technologies that have been developed based on the concept of friction stirring, thousands of papers have been published characterizing and documenting the commercial and scientific benefits of the same.

The organizers would like to thank the Shaping and Forming Committee of the Materials Processing and Manufacturing Division for sponsoring this symposium.

Yuri Hovanski
Yutaka Sato
Piyush Upadhyay
Anton A. Naumov
Nilesh Kumar

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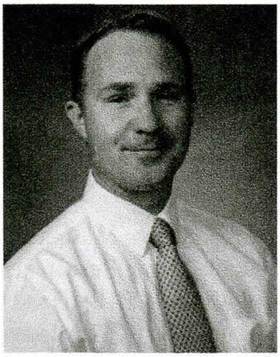
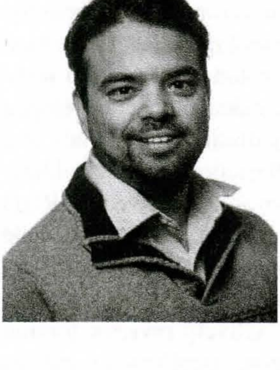
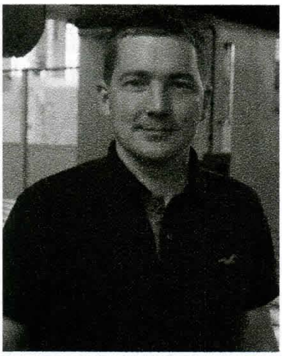


Yuri Hovanski is an Associate Professor of Manufacturing Engineering at Brigham Young University. He earned a B.S. degree in Mechanical Engineering at Brigham Young University, and then completed his masters and doctorate degrees at Washington State University. As a member of numerous professional societies, he actively participates in AWS, ASM, SME, and TMS serving in numerous leadership roles at the technical committee and division levels. He is the past chair of the TMS Shaping and Forming Committee, the chair of the ASM Joining of Advanced Specialty Materials Committee, and center director for the Center of Friction Stir Process, a retired NSF-IUCRC. He participated in research related to friction stir technologies for more than a decade as a senior research engineer at Pacific Northwest National Laboratory where he developed low-cost solutions for industrial implementation of friction stir technologies. Working with numerous industrial suppliers around the world, Dr. Hovanski has introduced cost-efficient solutions for thermal telemetry, demonstrated novel, low-cost tool materials for friction stir spot, implemented high volume production techniques for aluminum tailor-welded blanks, developed new methodologies for joining dissimilar materials, and reduced the cycle time for refill friction stir spot welding. As an active researcher, Dr. Hovanski received the R&D 100 award in 2011 and again in 2017, the DOE Vehicle Technologies Office Distinguished Achievement award in 2015, and a western region FLC award for technology transfer in 2015. He actively reviews friction stir related literature for numerous publications and has documented his work in more than 75 publications and proceedings and five U.S. patents.

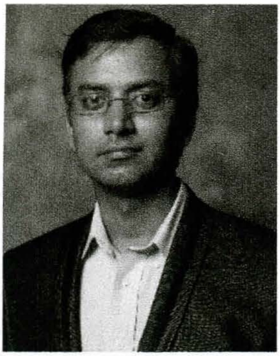
Yutaka Sato is a Professor in the Department of Materials Processing at Tohoku University, Japan. He earned a Ph.D. in Materials Processing at Tohoku University (2001). His Ph.D. thesis was titled "Microstructural Study on Friction Stir Welds of Aluminum Alloys." He participated in friction stir research of steels at Brigham Young University for a year in 2003. He was a member of Sub-commission III-B WG-B4 at IIW, which is a working group to build international standardization of friction stir spot welding. His work has focused on metallurgical studies of friction stir welding and processing for more than 20 years. He has obtained fundamental knowledge on development of grain structure, texture evolution, joining mechanism, behavior of oxide-layer on surface, and properties–microstructure relationship. He has received a number of awards including the Kihara Award from the Association for Weld Joining Technology Promotion (2008), Prof. Koichi Masubuchi Award from AWS (2009), Murakami Young Researcher Award from the Japan Institute of Metals (2010), Honda Memorial Young Researcher Award (2011), The Japan Institute of Metals and Materials Meritorious Award (2015), and Light Metal Breakthrough Award from the Japan Institute of Light Metals (2017). He has authored or co-authored more than 250 papers in peer-reviewed journals and proceedings.



Piyush Upadhyay is a material scientist at Pacific Northwest National Laboratory. He earned his Ph.D. from the University of South Carolina in 2012 in "Boundary Condition Effects on Friction Stir Welding of Aluminum Alloys." For more than a decade he has been involved in research and development of FSW and allied technologies to join similar and dissimilar materials. Currently, he leads and contributes to projects on friction stir welding and joining of alloys in dissimilar thickness and dissimilar materials including combinations of aluminum, magnesium, steels, and polymers. He has received several awards and recognitions including Aid Nepal Scholarship for undergraduate study (2001), Happy House Foundation Research Fellowship at Kathmandu University (2007), the DOE Energy Efficiency & Renewable Energy Recognition for Innovation (2015), and the R&D 100 award (2018). He has authored or coauthored more than 35 papers in peer-reviewed journals and proceedings and is actively involved as a guest editor and reviewer for technical journals and conference committees.



Anton A. Naumov is an Associate Professor at the Institute of Mechanical Engineering, Materials and Transport at Peter the Great St. Petersburg Polytechnic University (SPbPU). He obtained B.S. (2003), masters (2005), and doctorate (2010) degrees in Metallurgy at SPbPU. In 2012, 2014, and 2016 he won the Grants of the President of Russian Federation for young Ph.D.s in technical field of science. The 2016 grant was focused on the microstructure and mechanical properties evolution of aluminum alloys during friction stir welding. Dr. Naumov was one of the organizers for the Laboratory of Lightweight Materials and Structures (LWMS) at SPbPU in 2014 in terms of Mega-Grant of Ministry of Science and Education of Russian Federation for attracting leading foreign scientists and opening R&D labs under their supervision. He has been working in R&D laboratory LWMS until the present time as a principal researcher in the field of friction stir welding and processing. Dr. Naumov is an active member of the professional societies TMS and AWS and reviews friction stir related articles for several journals. He has authored or coauthored more than 40 papers in peer-reviewed journals and proceedings and has three Russian Federation patents.



Nilesh Kumar has worked as an Assistant Professor in the Department of Metallurgical and Materials Engineering at The University of Alabama since August 2018. Prior to this, he was a post-doctoral research associate in the Department of Nuclear Engineering at North Carolina State University Raleigh and the University of North Texas Denton. He obtained his Ph.D. degree in Materials Science and Engineering from Missouri University of Science & Technology Rolla. A common theme which cuts across all the research work Dr. Kumar has carried out so far is establishing correlation among processing (thermo-mechanical, friction stir processing, and laser), microstructure (grain-size, dislocations, and precipitates), and mechanical properties (strength, ductility, creep, creep-fatigue, residual stress, and stress corrosion cracking) of metallic materials (aluminum alloys, magnesium alloys, austenitic stainless steels, titanium alloys, high-entropy alloys, advanced high strength steel) used primarily in transportation and power-generation industries. He has published 38 papers in peer-reviewed journals, co-authored three books, and contributed two handbook chapters. Dr. Kumar is a member of several scientific organizations and has been a reviewer for more than 20 scientific journals. He is also the recipient of the Kent D. Peaslee Junior Faculty Award by the Association for Iron & Steel Technology (AIST) Foundation for the year 2019–2020.

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Y. Hovanski et al. (eds.), *Friction Stir Welding and Processing XI*, The Minerals, Metals & Materials Series, https://doi.org/10.1007/978-3-030-65265-4

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Yuri Hovanski · Yutaka Sato · Piyush Upadhyay · Anton A. Naumov · Nilesh Kumar *Editors*

Friction Stir Welding and Processing XI

This collection presents fundamentals and the current status of friction stir welding (FSW) and solid-state friction stir processing of materials, and provides researchers and engineers with an opportunity to review the current status of the friction stir related processes and discuss the future possibilities. Contributions cover various aspects of friction stir welding and processing including their derivative technologies. Topics include but are not limited to:

- Derivative technologies
- High-temperature lightweight applications
- Industrial applications
- Dissimilar alloys and/or materials
- Controls and nondestructive examination
- Simulation
- Characterization

ISBN 978-3-030-65264-7

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