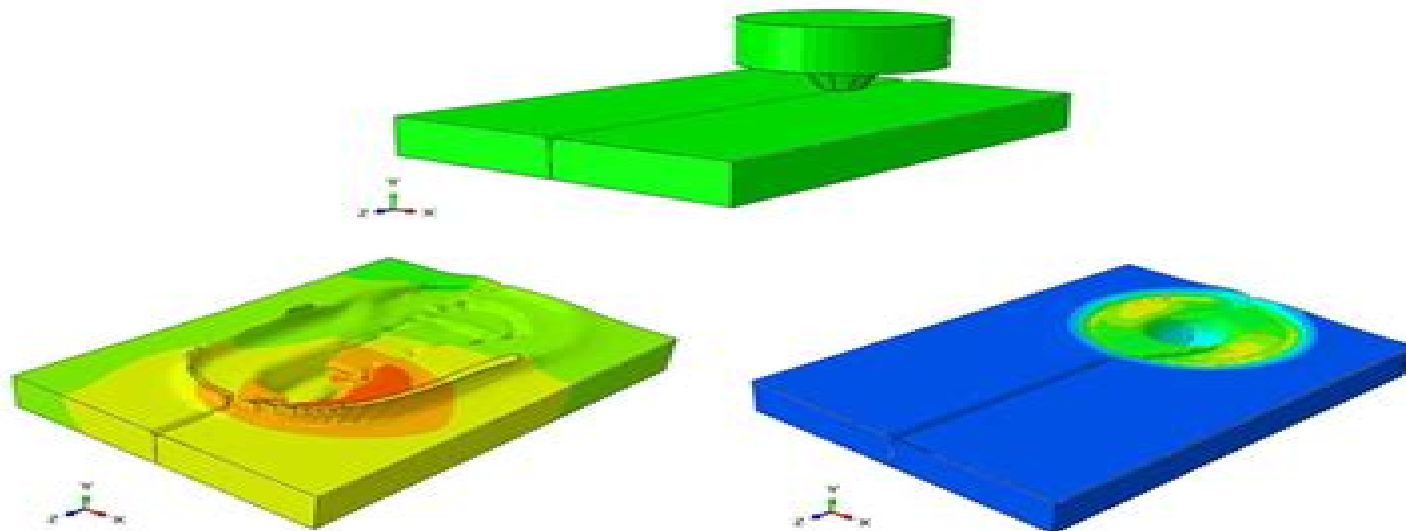




Friction Stir Welding Simulation

(Advanced level)



Abaqus Friction Stir Welding Tutorial

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



Abaqus Friction Stir Welding Tutorial:

Welding Simulations Using ABAQUS Bahman Meyghani, Mokhtar Awang, 2022-03-21 This book presents the use of ABAQUS software in a simplified manner for use in welding related issues. Increasing human needs leads to the creation of complicated scientific problems. In the majority of these problems it is necessary to join different parts and geometries together. Classical methods such as elasticity theory of stress distribution and governing equations of temperature distribution are not appropriate for solving these complicated problems. To overcome these challenges, finite element methods are proposed in order to solve different processes using differential equation. ABAQUS is a user friendly commercial finite element software for modeling different processes in mechanical, civil, aerospace and other engineering fields. This book contains unified and detailed tutorials for professionals and students who are interested in simulating different welding processes using the ABAQUS finite element software. Advances in Material Science and Engineering Mokhtar

Awang, Hussain H. Al-Kayiem, Ton C. Bor, Seyed Sattar Emamian, 2023-10-17 This book highlights the recent research works on mechanical manufacturing and plant engineering presented during the 8th International Conference on Mechanical Manufacturing and Plant Engineering ICMMP 2022 held on November 24, 2022 in Kuala Lumpur, Malaysia. It highlights the latest advances in the emerging areas, brings together researchers and professionals in the field and provides a valuable platform for exchanging ideas and fostering collaboration. Addressing real world problems concerning joining technologies that are at the heart of various manufacturing sectors, the respective papers present the outcomes of the latest experimental and numerical work on problems in soldering, arc welding and solid state joining technologies. **Proceedings of the 6th**

China Aeronautical Science and Technology Conference Chinese Soc. of Aeronautics & Astronautics, 2023-12-20 This book contains the original peer reviewed research papers presented at the 6th China Aeronautical Science and Technology Conference held in Wuzhen, Zhejiang Province, China, in September 2023. Topics covered include but are not limited to: Navigation, Guidance and Control Technology; Aircraft Design and Overall Optimisation of Key Technologies; Aviation Testing Technology; Airborne Systems; Electromechanical Technology; Structural Design; Aerodynamics and Flight Mechanics; Advanced Aviation Materials and Manufacturing Technology; Advanced Aviation Propulsion Technology; and Civil Aviation Transportation. The papers presented here share the latest findings in aviation science and technology, making the book a valuable resource for researchers, engineers and students in related fields. *Nanomaterials for Defense, Aeronautical and*

Aerospace Applications Visakh P. M., 2025-08-24 This book provides a comprehensive overview about the numerous modern research accomplishments in the area of nanomaterials for defense, aeronautical and aerospace applications. It covers coatings for aerospace and defense applications; spray coating process of multi-walled carbon nanotubes (MWCNT) for aerospace applications; process and optimization of functionalized MWCNT rheological percolation behaviour and fracture properties of MWCNTs; and a highly crosslinked aerospace grade epoxy resin system and metal nanoparticles for

aeronautical engineering applications The book provides a wealth of information for scientists students and engineers in industry

Proceedings of International Conference on Intelligent Manufacturing and Automation Hari Vasudevan, Vijaya Kumar N. Kottur, Amool A. Raina, 2020-06-30 This book gathers selected papers presented at the Second International Conference on Intelligent Manufacturing and Automation ICIMA 2020 which was jointly organized by the Departments of Mechanical Engineering and Production Engineering at Dwarkadas J Sanghvi College of Engineering DJSCE Mumbai and by the Indian Society of Manufacturing Engineers ISME Covering a range of topics in intelligent manufacturing automation advanced materials and design it focuses on the latest advances in e g CAD CAM CAE CIM FMS in manufacturing artificial intelligence in manufacturing IoT in manufacturing product design development DFM DFA FMEA MEMS nanotechnology rapid prototyping computational techniques nano micro machining sustainable manufacturing industrial engineering manufacturing process management modelling optimization techniques CRM MRP ERP green lean agile manufacturing logistics supply chain management quality assurance environmental protection advanced material processing characterization of composite smart materials The book is intended as a reference guide for future researchers and as a valuable resource for students in graduate and doctoral programmes

Experimentelle und numerische Untersuchungen des Rührreibschweißens von Aluminium- und Aluminium-Stahl-Verbindungen zur Verbesserung der mechanischen Eigenschaften Martin Werz, 2020-08-04 Die Reduktion des Fahrzeuggewichtes durch Leichtbau stellt eine effektive Möglichkeit zur Vergrößerung der Reichweite von E-Mobilen sowie zur Verringerung der Emissionen bei konventionellen Kraftfahrzeugen dar Sowohl beim konstruktiven als auch beim Werkstoff Leichtbau kommt dabei der Fertigungstechnologie eine entscheidende Rolle zu Das hochfeste schweißtechnische Fertigen niederlegierter ferritischer Stähle wie sie im Karosseriebau eingesetzt werden wird heute mit verschiedenen Schmelz- und Pressschweißverfahren wie z B dem Laser oder Widerstandspunktschweißen beherrscht Beim Verschweißen von hochfesten Aluminiumwerkstoffen mit heutigen Schweißprozessen kann es jedoch an der Fertigungstelle zu signifikanten Einbußen der Festigkeit kommen Die Festigkeitssteigernden Mechanismen im Aluminium werden durch die hohe Wärmeeinbringung beim Aufschmelzen reduziert bzw gehen verloren Bei der mit der Erstarrung einhergehenden Gefügeumbildung können diese Mechanismen nicht mehr oder nur noch in geringerem Maße aktiviert werden Darüber hinaus stellen je nach chemischer Zusammensetzung der Aluminiumlegierung Heißrisse sowie im speziellen Fall des Widerstandspunktschweißens der hohe Elektrodenverschleiß generelle Probleme dar Um diese mit dem Aufschmelzen bzw Erstarren der hochfesten Aluminiumlegierungen zusammenhängenden Probleme zu lösen bzw vielmehr zu umgehen wurde 1991 am The Welding Institute GB das Rührreibschweißen entwickelt Dabei handelt es sich um ein spezielles Pressschweißverfahren bei dem der Werkstoff vollständig in fester Phase verbleibt Im Gegensatz zu herkömmlichen Reibschweißprozessen wie z B dem Linear- oder Rotationsreibschweißen wird dabei allerdings keine Relativbewegung zwischen den zu fugehenden Bauteilen oder Werkstoffen benötigt Vielmehr wird die

Reibarbeit durch ein rotierendes Schweißwerkzeug eingebracht das in den Fugespalt eingepresst und entlang desselben verfahren wird. Durch den Materialtransport um das rotierende Werkzeug bzw. dessen Pin wird die Schweißnaht hergestellt. Aufgrund dieser Besonderheit, dass der Werkstoff in fester Phase verbleibt, sind neben hochfesten Aluminiumverbindungen auch Mischverbindungen möglich. Solche Mischverbindungen sind schmelzmetallurgisch nicht oder nur eingeschränkt möglich. Hierzu zählen insbesondere stoffschlüssige Aluminium-Stahl-Mischverbindungen, die für den konomischen Hybrid-Leichtbau der Karosserie von besonderem Interesse sind. Die Festigkeit solcher Verbindungen kann allerdings durch spröde intermetallische Verbindungen stark begrenzt werden. Dies stellt eine der technologischen Grundherausforderungen dieser Arbeit dar. Daher soll diese Arbeit dazu beitragen, den Reibschweißprozess als industrielles Fertigungsverfahren für hochfeste Aluminium- und Aluminium-Stahl-Hybridverbindungen, besonders für den Karosseriebau mit seinen spezifischen Anforderungen, zu etablieren. Um den Prozess besser zu verstehen und die Auswirkungen auf die resultierenden Festigkeitseigenschaften quantifizieren zu können, werden in dieser Arbeit vorrangig experimentelle, aber auch numerische Ansätze entwickelt. Des Weiteren ist es das Ziel, die gewonnenen Erkenntnisse in Form von Prozessweiterungen, Verbesserungen oder Abwandlungen für industrielle Prozesse nutzbar zu machen. Da die in diesem Zusammenhang entwickelten Lösungen teilweise deutlich über den aktuellen Stand der Technik hinausgehen, wurden während dieser Arbeit eine hohe Zahl an Erfindungen mit nachfolgenden Patentanmeldungen gemacht (siehe Tabelle 8.1). Grundlage des ersten Teils der Arbeit ist die Entwicklung geometrisch neuartiger Schweißnahtkonfigurationen samt zugehörigem Herstellungsprozess um Aluminium- und Stahlbleche unterschiedlichster Dicke hochfest fügen zu können. Hierbei wird explizit auf die Anforderungen für eine spätere Nutzung der Mischverbindungen in hybriden Tailor Welded Blanks (TWB) eingegangen. Hierzu gehört besonders die Anforderung, die Schweißnaht als Stumpfstoß und einseitig eben auszuführen. Ein weiteres Erfordernis besteht darin, dass die Tailor Welded Blanks in Tiefziehprozessen umformbar sind und dabei nicht im Bereich der Schweißnaht aufreißten. Zwei unterschiedliche Lösungen wurden hierzu entwickelt. Bei der ersten Ausführung wird das härteste, aber dünnere Stahlblech entlang der Schweißnaht umgebördelt, um so eine Vergrößerung des Anbindungsquerschnittes zu realisieren. Da dies einen zusätzlichen Bearbeitungsschritt erfordert und insbesondere hochfeste Stähle nicht rissfrei aufeinander umgelegt werden können, wurde im Verlauf dieser Arbeit eine zweite Lösung entwickelt. Hierbei wird ein Reibschweißwerkzeug mit abgestuftem Schweißstift verwendet, um eine kombinierte Überlapp- und Stumpfstoßverbindung herzustellen. Dabei führt der untere zylindrische Abschnitt des Schweißstiftes eine Stumpfverschweißung zwischen Stahl und Aluminium aus. Der stirnseitige Abschnitt der Stufe des Schweißstifts erzeugt gleichzeitig eine Überlappverbindung zwischen den beiden Werkstoffen. Der Vergleich beider entwickelten Lösungen mit dem Stand der Technik wurde anhand der automobiltypischen Werkstoffkombination EN AW 6016 T4 2,0 mm Aluminium-Magnesium-Silizium-Legierung HC340LAD 1,0 mm mikrolegierter Feinkornstahl durchgeführt. Dabei zeigt sich besonders in den Schwingfestigkeitsuntersuchungen eine signifikante

berlegenheit der kombinierten Stumpf und berlappverbindung gegen ber dem Stand der Technik Kombinationen von Aluminium und Stahl bei denen das Produkt von Blechdicke und Festigkeit seitens des Aluminiums etwas gr er ist als das des Stahlblechs zeigen in Napfziehversuchen Umformergebnisse ohne Aufrei en der Schwei naht Kombinationen bei denen das Produkt von Blechdicke und Festigkeit seitens des Stahls gr er war zeigen auch nach Optimierung der Schwei parameter eine signifi kante Dehnungslokalisierung mit nachfolgender Rissbildung in der WEZ des Aluminiums F r diesen Fall der Dehnungslokalisierung in der Schwei naht wird f r aush rtbare Legierungen basierend auf dem Aluminium Magnesium Silizium Dreistoffsystem 6000er eine neuartige W rmebehandlungsmethode entwickelt Ausgangspunkt da f r sind systematische Untersuchungen des Auslagerungsverhaltens des Grund werkstoffs bei unterschiedlichen Auslagerungstemperaturen dauern und Zwischen auslagerungszeiten Ferner werden die Grenzen f r das Auftreten von Rekristallisation f r den Grund werkstoff vorgedehnten Werkstoff und gleichartigen Schwei verbindungen ex perimentell untersucht berdies werden sowohl das Wachstum der intermetalli schen Phasen in Gl hversuchen von Aluminium Stahl R hrreibschwei verbindungen als auch die Auswirkung auf die Verbindungsfestigkeit untersucht Es zeigt sich dass der dickenabh ngige festigkeitslimitierende Effekt dieser Grenzschicht sehr gut mit der von Weibull entwickelten Theorie erkl rt werden kann Die quantitative Beschreibung dieses Zusammenhangs ergibt dass herk mmliche L sungsgl h prozesse aufgrund der zur Erw rmung der Bauteile ben tigten Zeiten nicht ziel f hrend sind Die neu entwickelte W rmebehandlungsmethode nutzt daher den Schwei prozess selbst als lokalen L sungsgl hprozess Grundvoraussetzung hierf r ist dass der Schwei prozess ausreichend schnell ausgef hrt wird sodass es w hrenddessen nicht zu einer beralterung der festigkeits steigern den Ausschei dungen kommt Durch die deutlich l ngere logistisch bedingte Raumtemperatur Zwischenauslagerung des Grund werk stoffs im Vergleich zur Schwei naht spricht dieser deutlich langsamer auf eine Warmauslagerung bei vergleichsweise niederen Temperaturen an Dies bedeutet dass mit dieser Methode die Festigkeit der Schwei naht durch Warmauslagerung gesteigert werden kann ohne dass der Grundwerkstoff eine signifikante Festigkeits steigerung erf hrt F r die Legierung EN AW 6016 werden Prozessdiagramme zur Ermittlung der minimal notwendigen Warmauslagerungsdauer entwickelt Die Diagramme ber ck sichtigen dabei die Auslagerungstemperatur die Dauer der Kaltauslagerung der Schwei naht sowie den Nahtunterhang der R hrreibschwei n hte Die Diagramme werden mittels gleichartiger Aluminium Schwei n hte und Aluminium Stahl Mischverbindungen validiert Der dritte und abschlie ende Teil dieser Arbeit besch ftigt sich mit der numerischen Modellierung des R hrreibschwei prozesses um zuk nftig numerische Prozess optimierungen zur weiteren Steigerung der Festigkeit durchf hren zu k nnen Anhand einer Literaturrecherche wird gezeigt dass ein wesentliches Steigerungs potential hinsichtlich der Aussagekraft der Prozesssimulationen in den hierzu verwendeten Materialmodellen liegt Hierzu werden die bislang in der Literatur bekannten Werkstoffmodelle daraufhin analysiert wie gut diese die Flie spannung ber die breiten Dehnraten Temperatur und Dehnungsbereiche abbilden die beim R hrreibschwei en auftreten k nnen Da bekannte

thermomechanische Werkstoffmodelle für andere Anwendungen wie z.B. ballistische Impacts oder Warmumformung entwickelt wurden zeigt sich die Notwendigkeit für eine Neuentwicklung. Bei dieser Neuentwicklung wird bewusst ausschließlich auf Effekte eingegangen, die bereits in der Literatur bekannt sind und die für den Prozessbereich des Reibschweißens als relevant einzustufen sind. Das neu entwickelte Modell wird unter Berücksichtigung verschiedener Annahmen zum Werkstoffverhalten bei Temperaturwechseln als User Subroutine für Abaqus Explicit implementiert. Zur Bestimmung der benötigten Modellparameter werden mit einer Gleeble 2000 bei einem breiten Temperatur- und Dehnraten-Spektrum für die Werkstoffe Al 99.5 EN AW 5182 AlSi10Mg und EN AW 6016 Druckversuche durchgeführt. Das Materialmodell reduziert den Modellfehler bei der Anpassung der Versuchsergebnisse gegenüber bereits etablierten Materialmodellen erheblich. Hierdurch wird die Aussagekraft von Prozesssimulationen, die dieses Materialmodell gegenüber dem etablierten Johnson-Cook-Modell verwenden, erheblich gesteigert. *Government Reports Annual Index*, 1992

Friction Stir Welding and Processing VI
Rajiv S. Mishra, Murray W. Mahoney, Yutaka Sato, Yuri Hovanski, Ravi Verma, 2011-04-12
Friction stir welding has seen significant growth in both technology implementation and scientific exploration. This book covers all aspects of friction stir welding and processing from fundamentals to design and applications. It also includes an update on the current research issues in the field of friction stir welding and a guide for further research.

Friction Stir Welding Simulation, Optimization and Design
Xingguo Zhou, 2013
Friction stir welding is an advanced welding technology mainly used to join aluminum alloys but with potential for other materials like steel, titanium and its alloys. The aim of this work is to provide a combination of numerical and experiment tools to understand the mechanisms of friction stir welding, optimizing the friction stir welds and characterizing the material properties for welds. The thesis is broadly divided into three themes. In the first theme, an automatic procedure to estimate friction stir welding model parameters, particularly those difficult to measure directly, is proposed and developed. The proposed methodology is seen to predict heat input, power from the welding tool and contact conductivity between the workpiece and its supporting plate in good agreement with experimental temperature history data. In the second theme, discontinuous and distributed cooling methods, which use periodical and non-uniformly distributed cooling medium flow to cool the welding workpieces, are proposed to reduce the residual stress of friction stir welds and investigated using multi-physics numerical simulation to predict transient temperature field, residual stress and mechanical performance of welds. The discontinuous cooling method is found to be more effective than conventional active cooling, leading to a lower drop in induced welding temperature and reduced residual stress. The distributed cooling provides another method to balance residual stress and welding temperature for butt welding. The effect of discontinuous cooling on microstructure is evaluated using the multi-physics model. The third part presents a small punch beam testing method to characterize material properties of base material, welded material and material property distribution. The small punch beam test utilizes miniaturized specimen and is therefore suited to measuring material properties in local regions of structure such

as the friction stir welding nugget *Friction Stir Welding* Daniela Lohwasser,Zhan Chen,2009-12-18 Friction stir welding FSW is a highly important and recently developed joining technology that produces a solid phase bond It uses a rotating tool to generate frictional heat that causes material of the components to be welded to soften without reaching the melting point and allows the tool to move along the weld line Plasticized material is transferred from the leading edge to trailing edge of the tool probe leaving a solid phase bond between the two parts Friction stir welding from basics to applications reviews the fundamentals of the process and how it is used in industrial applications Part one discusses general issues with chapters on topics such as basic process overview material deformation and joint formation in friction stir welding inspection and quality control and friction stir welding equipment requirements and machinery descriptions as well as industrial applications of friction stir welding A chapter giving an outlook on the future of friction stir welding is included in Part one Part two reviews the variables in friction stir welding including residual stresses in friction stir welding effects and defects of friction stir welds modelling thermal properties in friction stir welding and metallurgy and weld performance With its distinguished editors and international team of contributors Friction stir welding from basics to applications is a standard reference for mechanical welding and materials engineers in the aerospace automotive railway shipbuilding nuclear and other metal fabrication industries particularly those that use aluminium alloys Provides essential information on topics such as basic process overview materials deformation and joint formation in friction stir welding Inspection and quality control and friction stir welding equipment requirements are discussed as well as industrial applications of friction stir welding Reviews the variables involved in friction stir welding including residual stresses effects and defects of friction stir welds modelling thermal properties metallurgy and weld performance **Friction Stir Welding and Processing XIII** Yuri Hovanski,Yutaka Sato,Piyush Upadhyay,Nilesh Kumar,Anton A. Naumov,2025-02-20 This volume 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 Additive friction stir technologies Friction stir extrusion technologies High temperature applications Industrial applications Friction stir spot technologies Dissimilar alloys and materials Lightweight alloys Simulation characterization and non destructive examination techniques *Friction Stir Welding and Processing VII* Rajiv Mishra,Murray Mahoney,Yutaka Sato,Yuri Hovanski,Ravi Verma,2016-12-01 This collection focuses on all aspects of science and technology related to friction stir welding and processing *Friction Stir Welding and Processing VIII* Rajiv S. Mishra,Murray W. Mahoney,Yutaka Sato,Yuri Hovanski,2015-02-18 This symposium focuses on all aspects of science and technology related to friction stir welding and processing This is the eighth proceedings volume from this recurring TMS symposium **Friction Stir Welding and Processing XII** Yuri Hovanski,Yutaka Sato,Piyush Upadhyay,Anton A.

Naumov, Nilesh Kumar, 2023-02-11 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 applications Industrial applications Dissimilar alloys and or materials Lightweight alloys Simulation Characterization Non destructive examination techniques Solid-State Welding: Friction and Friction Stir Welding Processes Esther Titilayo Akinlabi, Rasheedat Modupe Mahamood, 2020-01-06 This book presents critical information on the principles and operation of friction welding friction stir welding and friction stir processing enhanced with many robust illustrations It explains the application of these technologies and the current research efforts in the field The authors explain in detail the advantages offered by these welding processes in particular their ability to join dissimilar materials not possible to weld in the past Written for graduate students researchers and industrial professionals the book reinforces concepts presented with case studies on the experimental analysis of welding the dissimilar materials of copper and aluminum and on friction stir processing **Friction Stir Welding and Processing XI** Yuri Hovanski, Yutaka Sato, Piyush Upadhyay, Anton A. Naumov, Nilesh Kumar, 2021-02-16 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 Friction Stir Welding Technologies, Glass Materials and Applied Technologies Omar S. Es-Said, Nicușor Alin Sîrbu, Amjad Ali, Risa Suryana, 2024-11-01 Special topic volume with invited peer reviewed papers only Friction Stir Welding and Processing IX Yuri Hovanski, Rajiv Mishra, Yutaka Sato, Piyush Upadhyay, David Yan, 2017-02-06 This book presents a current look at friction stir welding technology from application to characterization and from modeling to R D It is a compilation of the recent progress relating to friction stir technologies including derivative technologies high temperature applications industrial applications dissimilar alloy materials lightweight alloys simulation and characterization With contributions from leaders and experts in industry and academia this will be a comprehensive source for the field of Friction Stir Welding and Processing *Friction Stir Welding and Processing* Sandeep Rathee, Manu Srivastava, J. Paulo Davim, 2024-03-25 A single source of information on the fundamental concepts and latest research applications of friction stir welding and processing Friction Stir Welding and Processing Fundamentals to Advancements provides concise yet comprehensive coverage of the field of friction stir welding with an eye toward future research directions and applications Throughout the book case studies

provide real world context and highlight applications for various engineering sectors With contributions from an array of leaders in the field Friction Stir Welding and Processing provides readers with a single source of information on all aspects of FSW and FSP After explaining the fundamentals of friction stir welding FSW and its variants the book discusses composite fabrication techniques using friction stir processing FSP Different types of friction techniques are covered as is the equipment used Detailed characterization of samples and composites are included Additional topics discussed include the impact of FSW on the economics of production methods for coupling FSW FSP with additive manufacturing composite fabrication and process property relationships Master the basic concepts of friction stir welding and its variants Discover the role of FSW in developing hybrid manufacturing techniques Follow case studies that connect theoretical concepts to real world experimental results Learn from contributions from an array of global thought leaders in the field This is a valuable compendium on the topic for engineers and designers who utilize welding and advanced manufacturing across industries as well as graduate students and post graduate researchers who are exploring new friction stir welding applications

Friction Stir Welding and Processing Rajiv S. Mishra, Murray W. Mahoney, 2007-01-01 This book covers the rapidly growing area of friction stir welding It also addresses the use of the technology for other types of materials processing including superplastic forming casting modification and surface treatments The book has been prepared to serve as the first general reference on friction stir technology Information is provided on tools machines process modeling material flow microstructural development and properties Materials addressed include aluminum alloys titanium alloys steels nickel base alloys and copper alloys The chapters have been written by the leading experts in this field representing leading industrial companies and university and government research insititutions

Abaqus Friction Stir Welding Tutorial Book Review: Unveiling the Magic of Language

In a digital era where connections and knowledge reign supreme, the enchanting power of language has become more apparent than ever. Its ability to stir emotions, provoke thought, and instigate transformation is truly remarkable. This extraordinary book, aptly titled "**Abaqus Friction Stir Welding Tutorial**," compiled by a highly acclaimed author, immerses readers in a captivating exploration of the significance of language and its profound effect on our existence. Throughout this critique, we shall delve into the book's central themes, evaluate its unique writing style, and assess its overall influence on its readership.

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Abaqus Friction Stir Welding Tutorial Introduction

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