出國報告(出國類別:國際會議)

出席第二屆摩擦攪拌銲接製程國際會議
FSWP2012 心得報告

服務機關: 國立中正大學機械工程學系
職稱姓名: 教授 敖仲寧
派赴國家: 法國 德國
出國期間: 101 年 1 月 21 日至 101 年 2 月 1 日
報告日期: 101 年 2 月 28 日

摘要

敖仲寧教授至法國 Saint Etienne 國立工程學院主辦參加 2012 第二屆摩擦攪拌銲接製程國際會議(Friction Stir Welding and Processing, FSWP 2012)並發表論文。該會議是針對應用先進製造科技--摩擦攪拌銲接製程的專業國際會議。該會議由法國聖艾蒂安 Saint Etienne 國立礦業工程大學材料系主辦，共舉行兩天 1/26-1/27。藉由觀摩摩擦攪拌銲研究之最新發展，了解中正大學機械系與 AIM-Hi 在摩擦攪拌銲接技術與國際最新技術之接軌情形，並結識各國學者與工業界人士可與 AIM-Hi 在精密機械製程方面建立互訪機制與合作研究管道。本次會議之前並前往德國 Stuttgart 之 University of Applied Science Esslingen 之 Department of Automotive Engineering 拜訪 Prof. Martin Greitmann。希望與該校建立 NSC/DFG 雙邊合作關係建立利用精密工具機發展摩擦攪拌點銲之製程技術。並具體討論出了提案方向與工作項目，由 Prof. Greitmann 先向 DFG 提案後轉由國科會核准我方之合作，最終能建立國際合作計畫。

目次

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壹、會議目的

1. 赴法國 Saint Etienne 國立礦業工程大學參加 2012 第二屆摩擦攪拌銲接製程國際會議(Friction Stir Welding and Processing, FSWP 2012，2012 1/26-1/27)發表論文。觀摩摩擦攪拌銲研究之最新發展，了解中正大學機械系 AIM-Hi 中心在摩擦攪拌銲接技術與國際最新技術之接軌情形，結識各國學者與工業界人士可與 AIM-Hi 在精密機械製程方面建立互訪機制與合作研究管道。

2. 前往德國 Stuttgart 附近之 University of Applied Science Esslingen 之車輛工程學系與 Prof. Martin Greitmann (2012 1/23-1/25)。洽談建立雙邊合作計劃，題目方向為利用精密工具機發展摩擦攪拌點銲之製程技術並探討刀具與材料之間攪拌之流動機理。打算利用我國國科會 NSC 與德國研究基金會 DFG 雙邊合作架構下之機制，建立國際合作研究計畫。

貳、會議過程

一、赴德國 Stuttgart 之 University of Applied Science Esslingen 之車輛工程學系與 Prof. Martin Greitmann 洽談建立雙邊合作計劃。

本人於 1/21 出發前往德國 Stuttgart，1/22 抵達 Stuttgart，適逢星期日故無行程。1/23(一)先至 Stuttgart 市郊之 University of Applied Science Esslingen(德文名稱為 Hochschule Esslingen)之 Department of Automotive Engineering (Fachbereich Fahrzeugtechnik) 拜訪 Prof. Martin Greitmann。Prof. Martin Greitmann 是本人昔日在 University Stuttgart 的國家材料試驗研究所 (Staatliche Materialpruefungsanstalt, MPA) 的同門師弟。他在 MPA 擔任研究員 15 年後於 2007 年獲聘 University of Applied Science Esslingen 擔任教授。他的研究專長在特殊銲接製程，包括摩擦攪拌銲、銅點銲製程、硬質金屬與陶瓷銲接、雷射銲接等，與工業界合作甚為密切，擁有設備完整之接合製程實驗室以及先進且完整之材料分析設備。

圖為 University of Applied Science Esslingen Department of Automotive Engineering 大樓

該校在德國屬科技大學體系(Hochschule)，在工業應用導向的研究非常先進，尤其與 Stuttgart 週邊之汽車工業如 Daimler-Benz，Porsche， Bosch 均有極密切之合作關係。此次拜訪之車輛工程學系暨研究所尤其在汽車工業相關之先進製造科技之研究尤享盛名。

此行之主要目的為希望與 Prof. Martin Greitmann 及該校建立我國國科會與德國德意志研究基金會之 NSC/DFG 雙邊合作架構下的雙邊合作關係。建立利用精密工具機發展摩擦攪拌銲接與點銲之製程技術與基礎研究計畫。事前已先將我方(我與林派臣副教授)所擬之研究計畫議題架構書寄給 Prof. Greitmann，1/23 全日參訪該系實驗室以及 Prof. Greitmann 之研究設施並深入了解其研究能量與成果，具體就計畫議題架構書內容討論出了提案方向與議題及工作項目，按照 NSC/DFG 的機制，由 Prof. Greitmann 先向 DFG 提案核准後由 DFG 轉我方國科會，先建立國際合作互訪計畫達到人員交流；下一步則為更深入建立國際合作計畫。Prof. Greitmann 並具體建議可以在本計畫內共同合作之德方研究單位與可以提供製程設備之工業界。

這項研究計畫由我方提出之計畫議題架構書內容經兩天之討論已擬出一份英文的研究計畫草案如下 (必須以英文呈現，標題重點則輔以中文):

本計劃草案已經具體訂出德方可能之合作對象以及可應用之資源以及可能之工作分配項目等。

Friction stir welding (FSW) & friction stir spot welding (FSSW) on surface clad Alclad® aluminum alloy sheets

題目： 表面披覆純鋁之鋁合金薄板 Alclad®材料之摩擦攪拌銲接

(FSW)與摩擦攪拌點銲(FSSW)研究

1. Materials (實驗材料)

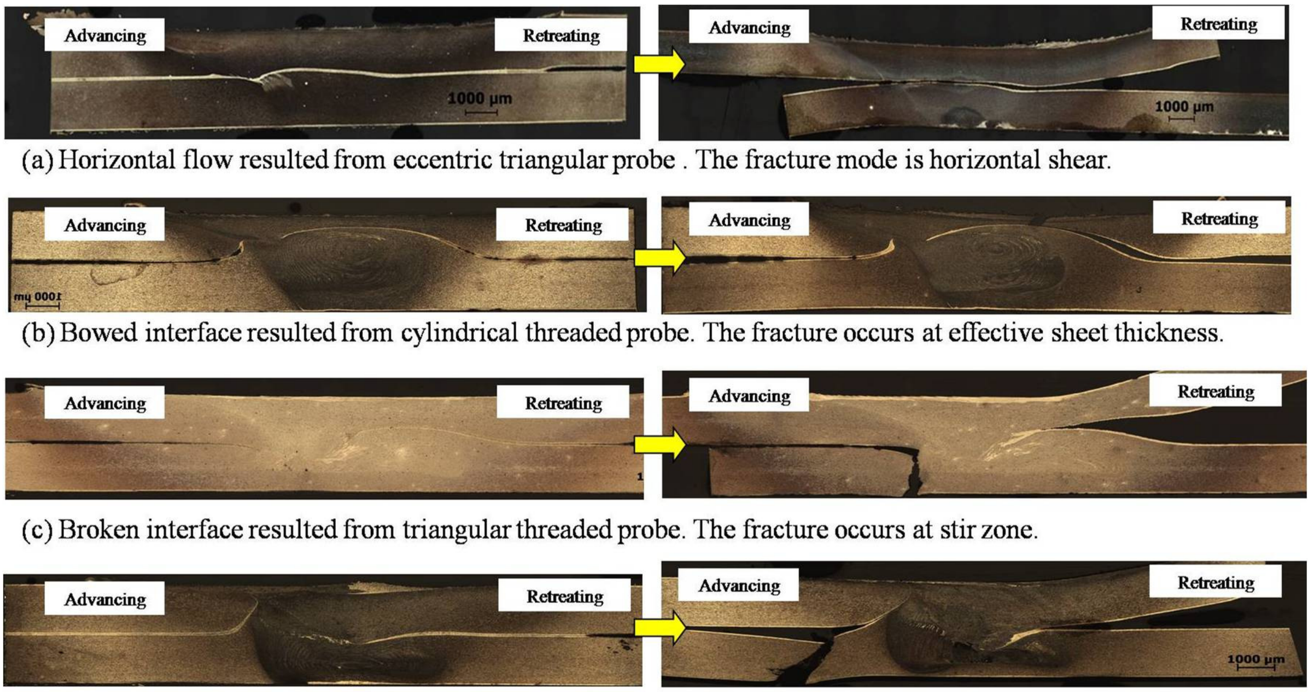
Alclad® aluminum is an aluminum alloy sheet laminated with an extremely thin layer of pure aluminum onto each side for corrosion resistance. Typical application of Alclad is aircraft skin or components. Friction stir lap welding has been developed for the manufacturing of sheet metal parts in aerospace industry.

2. Status of research: Material flow in friction stir weld of Alclad® aluminum alloy sheets

研究現況：表面披覆純鋁之鋁合金板在 FSW 銲道內之材料流動現象

The material flow patterns in the friction stir lap joint and especially the flow patterns of the thin pure aluminum layer coated on the surface of the aluminum alloy sheets are crucial to the quality and strength of the weld. We found that the thin aluminum layer was a relative intractable layer to some probe shapes. It remained a horizontal layer in the stir zone despite the penetration of the stir probe into sheets and a sound friction stir lap weld was achieved when using a cylindrical threaded or an eccentric triangular probe as shown in fig.1. Welding parameters had insignificant influence on the flow patterns. By using tools of triangular threaded or partial cylindrical threaded probes was it then possible to cause material flow in the stir zone having vertical movement and to stir the thin aluminum layer into distorted or broken shapes. Threaded cylindrical or triangular Probes caused the thin aluminum layer became a bowed layer.

Corresponding to the material flow modes, four types of failure modes were observed after tensile test. The fracture occurring at the narrowest effective thickness on the upper sheet due to bowed aluminum layer revealed a lowest strength while the horizontal flow of aluminum layer caused a horizontal shear with improved strength. The distorted or broken interface resulted in a fracture at stir zone. Well stirred aluminum layer achieved by using a partial cylindrical threaded probe corresponded to a tensile fracture at base metal. The latter two modes enjoyed a substantial higher strength.



(a) Horizontal flow resulted from eccentric triangular probe . The fracture mode is horizontal shear.

(b) Bowed interface resulted from cylindrical threaded probe. The fracture occurs at effective sheet thickness.

(c) Broken interface resulted from triangular threaded probe. The fracture occurs at stir zone.

(d) Well stirred zone resulted from partial cylindrical threaded probe. The fracture occurs at base metal.

Materials flow types at interface and the corresponding fracture modes resulted from different probe types

Fig.1 Material flow of Alclad layer at interface of FSW and the fracture types

圖一　表面披覆純鋁之鋁合金薄板 Alclad®材料之摩擦攪拌銲道與材料流動模式。

Similar to FSW, the pure aluminum Alclad layer at the cross section of an Alclad 2024-T3 FSSW weld cannot be stirred into the weld nugget as shown in figure 2. The Swept-FSSW process, fig.3, is a potential way to overcome this problem. The clad bonded on the surfaces of 2024-T3 sheets can be uniformly stirred and distributed inside the stir zone due to the circular tool path of Swept-FSSW. However, the Al-clad layer still extends a bit distance beyond the crack tip and disappeared inside the stir zone as well, as shown in fig.4.

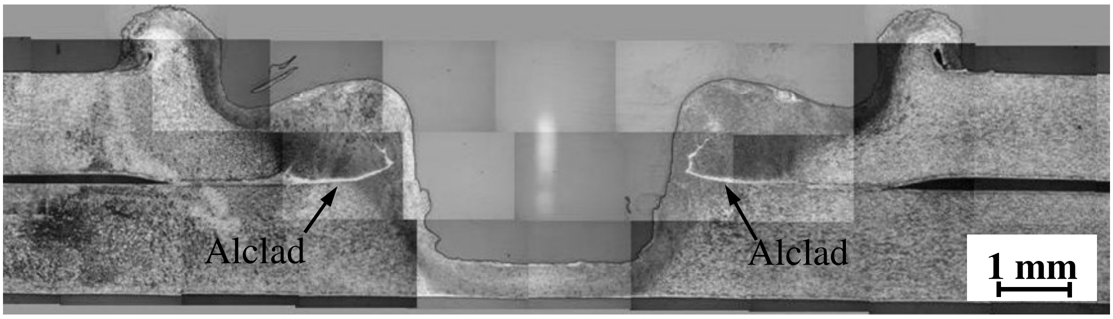
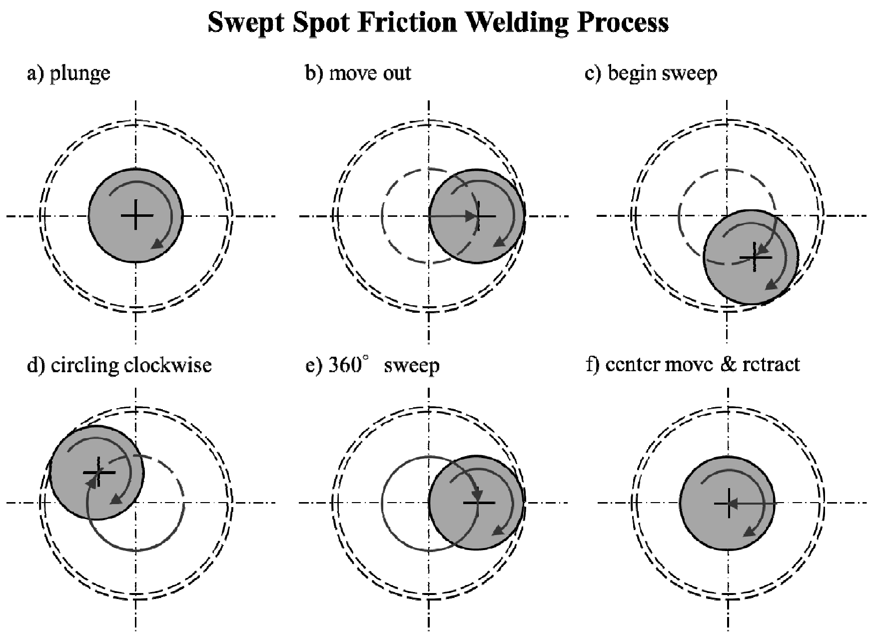


Fig. 2 The cross section of an Alclad 2024-T3 friction stir spot weld showing the intractable Alclad layer after FSSW.

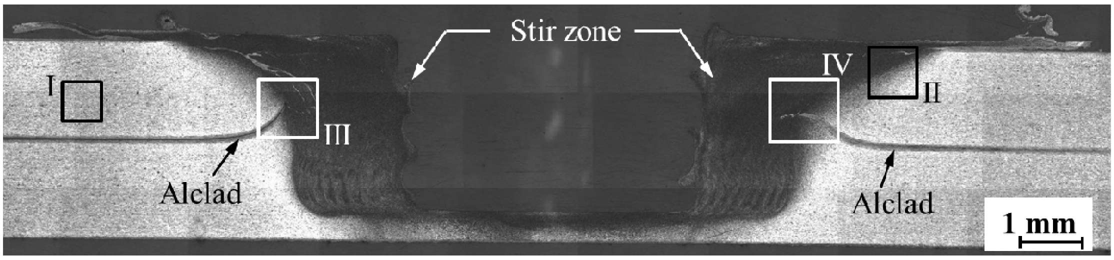
圖二 表面披覆純鋁之 2024 鋁合金薄板之摩擦攪拌銲點截面材料流動模式。



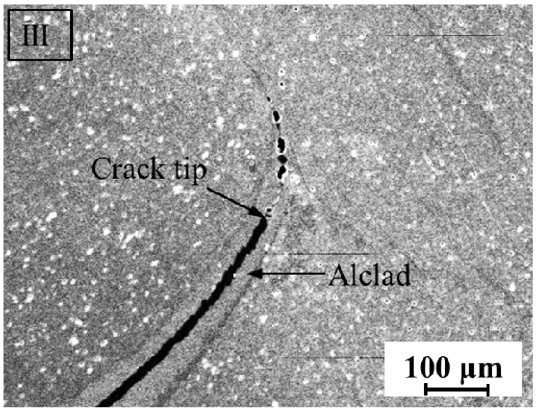
(FSSW)

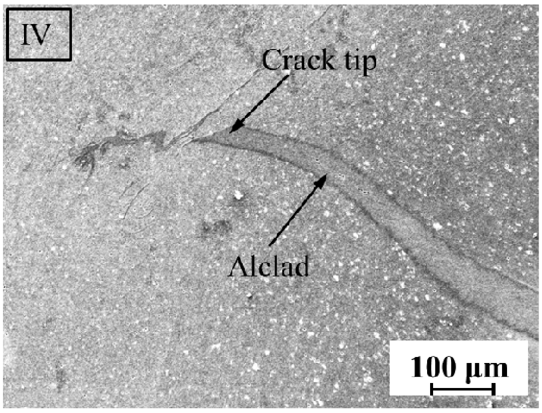
Fig. 3 Schematic illustration of a swept-FSSW process.

圖三 偏心摩擦攪拌銲點技術示意圖



(a)





(b) (c)

Fig.4. The cross section of an Alclad 2024-T3 Swept-FSSW showing crack tip resulted from Alclad layer.

圖四 偏心摩擦攪拌銲點材料流動線與缺陷

3. Problematic (待進行之研究問題)

Although the Alclad layer on the 2024-T3 sheets could be well stirred and uniformly distributed inside the stir zone by the combination of appropriate probe shape and Swept-FSSW process, the geometric features of the Alclad interface is disadvantageous to the strength of FSWs and the failure strength and fatigue life of Swept-FSSWs.

4. Project investigators (計畫主持人)

NSC Project investigator:(國科會計畫主持人)

Prof. Dr.-Ing. Jong-Ning Aoh 敖仲寧教授

Department of Mechanical Engineering
National Chung Cheng University
Minhsiung, Chiayi, 621
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NSC Project co-investigator: (國科會計畫共同主持人)

Prof. Pai-Chen Lin, Ph.D. 林派臣教授

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Minhsiung, Chiayi, 621
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DFG Project Investigator (德國研究基金會計畫主持人)

Professor Martin Greitmann
Hochschule Esslingen
University of Applied Sciences
Fakultät Fahrzeugtechnik
Kanalstr. 33
D-73728 Esslingen
Germany E-Mail: Martin.Greitmann@hs-esslingen.de

5. Partner in Deutschland and participants 德國合作伙伴與參與人員

單位

1. Hochschule Esslingen:
Prof. Dr.-Ing. (IWE) Martin J. Greitmann
Labor-Ingenieur: Dipl.-Ing. (FH) Udo Merk
Hochschule Esslingen

University of Applied Sciences
Fakultät Fahrzeugtechnik
Kanalstr. 33
D-73728 Esslingen
Germany

- Joining / process development (friction stir spot welding = FSW with refill-tools)
  in cooperation with Harms und Wende GmbH & Co. KG
- Process analysis (high-speed measurement, thermography…)
- Quality assurance
- Metallography, SEM
- NDT (visual testing, ultrasonic testing…)
- Shear tests, fatigue tests (Testing)

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2. Universität Stuttgart (IMWF/MPA Stuttgart)

Prof. Dr. rer. nat. Siegfried Schmauder
Institut für Materialprüfung, Werkstoffkunde und Festigkeitslehre (IMWF)
Pfaffenwaldring 32
D-70569 Stuttgart
E-Mail: siegfried.schmauder@imwf.uni-stuttgart.de
Internet: http://www.imwf.uni-stuttgart.de

- Material science
- Experimental thermo-mechanical simulation (Gleeble 2000 A-A)
- Failure analysis
- Micro structure analysis
- Numerical modelling (micro mechanics….)
- Friction Stir welding (Equipment: ESAB Legio machine)

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3. Industry partners 工業界合作夥伴

Harms & Wende GmbH & Co KG
Manager/Director: Dipl.-Ing. Ralf Bothfeld
Grossmoorkehre 9
D-21079 Hamburg, Germany
Telephone: +49 (40) 766 904 – 0
Telefax +49 (40) 766 904 – 88
E-Mail: Ralf.Bothfeld@harms-wende.de
Internet: http://www.harms-wende.de

- Joining / process development (friction stir spot welding = FSW with refill-tools)
- Process control / Quality assurance

Helmholtz-Zentrum Geesthacht, GKSS
Instiutute of Materials Research
Max-Planck-Straße 1
21502 Geesthacht
Phone: +49 (0)4152 87-0
Fax: +49 (0)41 52 87-1403
- Joining / process development (friction stir welding robots)
- Basic research on material flow

二、赴法國聖艾蒂安參加 2012 摩擦攪拌銲接製程國際會議(FSWP 2012)發表論文

1/25(三)由 Stuttgart 搭乘法國國鐵 TGV 經 Strasbourg 及 Lyon 至 Saint Etienne 參加 2012 摩擦攪拌銲接製程國際會議(FSWP 2012)並發表論文。該會議是針對摩擦攪拌銲接製程技術的國際會議，由法國 Saint Etienne 國立工程學院主辦，共舉行兩天 1/26-1/27。有三項關於 FSW 的大議題分別為:

- Relationships between microstructure, mechanical and functional properties, (顯微結構與機械性質與功能特性)
- Modeling and numerical simulation, (數值模型與數值模擬)
- Process and Applications.(工業製程研究開發與應用領域)

各大議題之邀請演講者與題目為:

- Jorge F. dos Santos: "Precipitation Phenomena in AA7449 Friction Stir Welds: Results of an in-situ Study"
- Motomichi Yamamoto: "Improvement of Joint Strength Based on Material Flow during Friction Stir Spot Welding"
- Russel Steel: "Advancements in Friction Stir Welding of Thick Section Steels"

會議參加人數約 200 人。共有口頭發表論文 50 篇。包含擦攪拌銲接基礎機理研究、製程數值模擬分析、製程技術與機具刀具開發研究、製程技術應用研究以及工業發展現況報告等。國際知名學者包括日本廣島大學機械系之 Prof. Yamamoto，德國 Helmholz Geesthacht 研究所之 Prof. Santos，法國 Saint Etienne 國立工程學院之 Dr. Feulvarch，法

國 Nante 大學之 Prof. Marya 等。

會議排程如下 ：

ProgramI

Invited lectures

Russel Steel — *Megastir*

Advancements in Friction Stir Welding of Thick Section Steels

J. Dos Santos — *Helmholtz- Zentrum*

Precipitation Phenomena in AA7449 Friction Stir Welds: Results of an in-situ Study

Helmholtz- Zentrum

A 3D simple finite element strategy dedicated to FSW simulations for tools with complex geometry.

Éric Feulvarch[1] Jean-Christophe Roux[2] Jean-Michel Bergheau[1]

[1]*Univ Lyon, Enise, Umr 5513, Ltds,* [2]*Univ Lyon, Enise, Ea 3719, Dipi*

Thermo-mechanical Simulation and Experimental Verification of Linear Friction Welding Process of Ti6Al4V alloy

Dong-Ying Ju[1],

[1]*Saitama Institute Of Technology*

Modelling of fluid/solid couplings in high temperature assembly processes: application to the Friction Stir Spot Welding process

Thomas Heuzé[1] Jean-Baptiste Leblond[1] Jean-Michel Bergheau[2]

[1]*Institut Jean Le Rond D'Alembert/Université Pierre Et Marie Curie*

[2]*Ltds/Enise*

Predicting grain size distribution in friction stir welded 6061 aluminum

Mohamadreza Nourani[1] Abbas S. Milani[1] Claire Yan1 Spiro Yannacopoulos[1]

[1]University Of British Columbia, Okanagan Campus, School Of Engineering

Prediction of the Temperature Distribution in Friction Stir Welding Technique of AA 7020-T6 Aluminum Alloys

Adel Mahmoud[1]

[1]College Of Engineering - University Of Diyala

EXPERIMENTAL INVESTIGATION AND PREDICTION OF MECHANICAL PROPERTIES OF FRICTION STIR WELDED METAL MATRIX COMPOSITE PLATES

Yahya Bozkurt[1] Aykut Kentli[1] Serdar Salman[2]

[1]Marmara University, [2]Marmara Unv.

Precipitation Phenomena in AA7449 Friction Stir Welds: Results of an in-situ Study

J. Dos Santos[1]

[1]Helmholtz- Zentrum

Toward friction stir welding simulation

Abdelaziz Timesli[1] Bouaaza Braikat[2] Hamid Zahrouni[1] Abdelhadi Moufki[1] Hassane Lahmam[2]

[1]*Laboratoire D'Étude Des Microstructures Et De Mécanique Des [1]Matériaux (Lem3), Umr Cnrs 7239, Ile Du Saulcy 57045, Metz Cedex 01*

[2]*Laboratoire De Calcul Scientifique En Mécanique (Lcsm), Avenue Driss El Harti Bp 5579Sidi Othmane,Casablanca*

Program II

Improvement of Joint Strength Based on Material Flow during Friction Stir Spot Welding

Motomichi Yamamoto

Hiroshima University

Understanding material flow in FSW and its implications

Pedro Alvarez[1] Ekaitz Arruti[1] Egoitz Aldanondo[1] Alberto Echeverria[1]

[1]*Lortek-Ik4*

FSW of casting aluminium alloy AlSi12

Damjan Klobcar[1] Ladislav Kosec[2] Janez Tušek[1]

[1]*Faculty Of Mechanical Engineering, University Of Ljubljana*

[2]*Faculty Of Natural Sciencies, University Of Ljubljana*

Microstructure and mechanical properties of friction stir processed AISI D2 tool steel

Noushin Yasavo[1] Amir Abdollah-Zadeh[2] Dulce Rodrigues[1]

[1]*Cemuc, Mechanical Engineering Center From University Of Coimbra*

[2]*Department Of Materials Engineering, Tarbiat Modares University, Tehran*

Microstructure and mechanical properties of friction stir processed magnesium matrix composites reinforced with carbon fibres

Aude Simar[1] Anne Mertens[2] Montrieux Henri-Michel[2] Jacqueline Lecomte-Beckers[2] Halleux Jacques[3] Francis Delannay[1]

[1]*Université Catholique De Louvain, [2]Université De Liège, 3Sirris*

Identification of the heterogeneous elasto-plastic behaviour of FSW welds at high strain rates

Guillaume Le Louëdec[1] Michael A. Sutton[2] Fabrice Pierron[1] Anthony Reynolds[2]

[1]*Arts Et Métiers, Paristech*
[2]*University Of South Carolina*

Effect of welding parameters on the tesile strength of friction stir welded aluminum matrix composites

Adel Mahmood Hassan[1] Tarek Qasim[1] Ahmed Ghaithan[1]
[1]*Jordan University Of Science And Technology*

FSW of lap joints: process parameters and joint properties

Egoitz Aldanondo[1] Ekaitz Arruti[1] Pedro Alvarez[1] Alberto Echeverria[1]
[1]*Lortek-Ik4*

Microstructural issues and material flow in dissimilar friction stir welding of AA5086-AA6061

Hamed Jamshidi Aval[1] Siamak Serajzadeh[1] Altino Loureiro Amir[2] Hossein Kokabi[1]
[1]*Department Of Materials Science And Engineering, Sharif University Of Technology*
[2]*Cemuc, Department Of Mechanical Engineering, University Of Coimbra*

The Tensile Properties of Friction Stir Welding joint of Al 2024 and Al7075

Kelimu Tulugan[1] Hojun Hwang[1] Hyeong Jo Kim[1] Wonjun Lee[2] Hyojae Lee Wonjo Park[1]
[1]*Department Of Mechanical And Precision Engineering, Graduate School, Gyeongsang*
[2]*National University, Tongyoung, Gyeongnam Emsco Inc. #209-1, Weujam-Ri, Dong-Eup, Changwon, Gyeongsangnam-Do*

Characterization of Friction Stir Welded 7042-T6 Extrusions through Differential Scanning Calorimetry

Carter Hamilton[1] Stanislaw Dymek[2] Oleg Senkov[3]
[1]*Miami University,* [2]*Agh University Of Science And Technology,* [3]*Ues, Inc.*

Influence of hexahedron tool pin profile on the mechanical properties of ST12 Friction Stir Welded butt joints

Afshin Emamikhah[1] Shirin Emamikhah[1] Alireza Abbasi[1]
[1]*Department Of Mechanical Engineering, Islamic Azad University Najafabad Branch*

Study of material flow in a surface hybrid composite fabricated via friction stir processing

Amir Abdollah-Zadeh[1] Sima Ahmad Alidokht[1] Soheyl Soleymani[1] Hadi Ghaseminanesa[2] Hamid Assadi[1]
[1]*Tarbiat Modares University,* [2]*University Of Tehran*

STUDY OF THE WELDING CONDITIONS DURING SIMILAR AND DISSIMILAR ALUMINIUM AND COPPER WELDING BASED ON TORQUE SENSITIVITY ANALYSIS

Ivan Galvão[1] Carlos Leitão[1] Dulce Rodrigues[1] Altino Loureiro[1]
[1]*Cemuc - University Of Coimbra*

Friction stir welding of SiCp/2009Al composite plate

Dong Wang[1] Bol V Xiao[1] Quan Zhao Wang[1] Zong Yi Ma[1]
[1]*Institute Of Metal Research*

Microstructure and mechanical properties of FSW extruded Al-Mg-Sc alloy

Yao Tao[1] Dingrui Ni[1] Bol V Xiao[1] Dong Wang[1] Zong Yi Ma[1]
[1]*Institute Of Metal Research*

Effects of FSP and Post-FSP Heat Treatment on Tensile Properties of Cast Al A206 Alloy

Ning Sun[1] Diran Apelian[1]
[1]*Worcester Polytechnic Institute*

Investigation of superplasticity in a friction stir processed AA 5054 alloy

Gelson Miori[1] Erika Prados[1] Gilmar Batalha[1]
[1]*University Of Sao Paulo*

Mechanical and Microstructural study of joints produced by Friction Stir Welding on ST12

Afshin Emamikhah[1] Shirin Emamikhah[1]
[1]*Department Of Mechanical Engineering, Islamic Azad University Najafabad Branch*

Program III

Characterization of friction stir welded joints of the aluminum alloy 2017

Bouzaiene Hassen[1] Ayadi Mahfoudh[1] Rezgui Mohamed Ali[1] Zghal Ali[1] Cherouat Abel[2]
[1]*Esstt,* [2]*Utt*

INFLUENCE OF TOOL SHOULDER GEOMETRY ON PROPERTIES OF F. S. WELDS IN THIN COPPER SHEETS

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Statistical Model of the tool/workpiece mechanical interaction in FSW

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Experimental investigation for measuring temperature FSW tool

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Study of material flow in a surface hybrid composite fabricated via friction stir processing

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Composite Fabrication via Friction Stir Processing

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Friction Stir Welding and Fabricating of Particulate reinforced Al6061/SiCp Metal Matrix Composites

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Chloride removal from the secondary source of zinc

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Dissimilar 2014T6-6061T6 welds: application, clamping device, non destructive examination.

Nicolas Legrand[1] Alban Geurten[1] Dorian Gioe[1] Kevin Deplus[1] Caroline Jonckheere[2] Bruno De Meester[2] Aude Simar[2]
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Advancements in Friction Stir Welding of Thick Section Steels

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本人於民國101年1月27日發表:

發表論文題目為 Friction Stir Welding and Fabricating of Particulate reinforced Al 6061/SiCp Metal Matrix Composites(顆粒強化鋁基複材 Al 6061/SiCp 之摩擦攪拌銲接製程研究)，是國科會計畫以及中正大學 Adavanced Institute of Manufacturing and High Tech with Innovations, AIM-HI 支持之研究項目之部分研究結果，並由中科院提供部分顆粒強化鋁基複材。本研究利用精密銑床及自行開發攪拌刀具對無法利用傳統銲接製程加工之顆粒強化鋁基複材 Al 6061/SiCp 成功以摩擦攪拌銲接銲合並達與母材接近之強度，而銲接後進行熱處理還可以將強度再次提升。並利用此製程以摩擦攪拌的方式製造局部顆粒強化鋁基複合材料，除此之外還開發了顆粒表面披覆金屬製程，目的是為了改善顆粒強化複合材料之顆粒與基地鍵結不佳的情況，期待以披覆金屬表面之顆粒可以與金屬基地鍵結良好，局部顆粒強化複合材料之延升性與強度能獲得提升，並探討摩擦攪拌銲接過程中顆粒流動行為所造成之影響與攪拌過程中的機制。

叄、會議心得與建議

本次藉參加 FSWP 2012 國際會議了解摩擦攪拌銲研究之最新發展，摩擦攪拌銲過程之固相材料流動性為相當困難及器帶探究之議題，近年來逐漸有學者利用塑性力學結合流體力學之流動性數值模型，建構模擬摩擦攪拌銲製程，但尚無太大進展。困難仍在於無法取得適切之材料在固相時之黏滯性係數、流變曲線等，因此數值模擬僅能模擬趨勢無法逼近實情。本人在此研究中利用實驗的解析，在定性探討上已有些突破。此次並結識日本廣島大學機械系之 Prof. Yamamoto 他在航空與車輛工業之 FSW 薄板銲接研究相當傑出,他所專精的摩擦攪拌點銲與本系林派臣教授領域接近，本人積極與 Prof. Yamamoto 建立交流管道,希望該校機械系有機會可與本系及 AIM-Hi 在精密機械製程方面建立互訪機制與合作研究管道。

此次會議的 keynote 之一有提到摩擦攪拌已經發展多年，不論是在鋁合金的應用與刀具的開發，都已經到達相當的程度，與會者 Provo 在這場 keynote 發表了，他們配合攪拌刀具並且開發出 Orbital Pipe Welding 的銲接方式，此銲接方式的優勢在於結合了摩擦攪拌銲接的優點，攪拌銲接的優點有:銲後形變小、速度快、固相銲接等優點於管狀的銲接，並且克服攪拌銲的夾持固定不易的缺點，將 Orbital Pipe Welding 的銲接方式配合專用刀具而發表了厚管(>12mm)的銲接，所

銲的材料是鋼鐵類。此銲接技術針對於製管業或是民生工業有重要的突破，經濟效益極高，如果能將此技術導入台灣產業界，將可以提高台灣傳統產業產值。

在與會上有一篇利用 FSP 方式進行複合材料製備與本人此次發表的研究方向很接近，作者是使用鎂合金 AZ31 與 AZ91 為金屬基地，在兩片鎂合金中間放置碳纖維塊材，使其成為三明治的情況，最後透過摩擦攪拌的方式使攪拌區局部形成複合材料，並且在硬度趨勢可以發現形成局部複合材料的區域硬度明顯提升，這是由於碳纖維顆粒在攪拌區內與鎂基地中形成強化的效果，達到提升硬度，此篇研究非常值得聆聽與參考。對照本實驗室目前所進行的研究，可以確定本實驗室的研究方向很新穎，並且努力突破的方向正確。

而國際知名學者 Prof. Yamamoto 在本會上所發表的摩擦攪拌搭接論文與本實驗室團隊林派臣教授研究之輕金屬摩擦攪點銲主力研究方向相同，本實驗室是探討連續摩擦攪拌銲接的部分。此篇文章是探討轉速與刀具幾合形狀對於剪力破壞模式的影響。此研究議題意味著輕金屬於應用汽車工業的突破，傳統汽車工業都是藉由電阻點銲將車輛結構或車體零件接合，為了追求更高性能的表現或是車體輕量化之節能減碳需要，突破全鋁車或是鎂鋁合金的汽車工業應用是全球汽車工業的趨勢。在此次國際研討會上獲益良多，也更確定本實驗室未來

之研究目標與方向，並且期待能藉由此次研討會上的交流，往後可以與各國際知名學者交流合作。

作者發表之論文摘要

Friction Stir Welding and Fabricating of Parti-culate reinforced Al 6061/SiCp Metal Matrix Composites

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Abstract

This work demonstrated friction stir welding(FSW) of a particulate-reinforced aluminum matrix composite (AMC) Al6061/SiCp. The weld exhibited a defect-free stir zone with distinctive flow arm and onion-rings. The width of the stir zone (SZ) and the thermo-mechanical affected zone (TMAZ) decreased with increasing traverse speed. Lower traverse speed resulted in better grain refinement in the stir zone and thus redered higher hardness values. Tensile fracture in TMAZ implied a superior strength in the stir zone. Post-weld heat treatment (PWHT) effectively restored the strength of the welds to the level of the AMC base metal. A novel method was developed in producing a localized particulate-reinforced bulk AMC by adding 6μm SiC particles into Al6061 plates via friction stir process. Perfect stir zone with uniformly distributed SiC particles along the flow traces was obtained. The hardness in the stir zone remained similar to that of the base metal while PWHT restored the strength of the stir zone. Tensile fracture in the stir zone indicated that the expected reinforcement was not completely achieved despite the defect-free weld and uniform microstructure. However, the sucess of uniformly stirring SiC particles into Al6061 provided a new perspective for the fabrication of AMC.

Keywords:

Friction stir welding, SiC particulate reinforced AMCs, localized particulate-reinforcement

1 Materials and experimental highlights

As-extruded Al6061/SiCp AMC plates of 240x100x10mm containing 15 vol% SiC of 303m and (63m 5%+303m 10%) mesh sizes were applied. The tool made of SKD 61 modld steel has a shoulder of 20mm; and a LH threaded (pitch 1mm) probe of 6mm; and 5mm in length. FSW parameters including rotation speed 1000rpm CW, tilt angle 2o, and traverse speed : 1.18 to 7.11mm/s rendered successful results. Same parameters were applied to the frabrication of localized particulate-reinforced bulk AMC containing 63m SiC particles. The SiC particles were inserted into a groove at butt-surface of the plates. T-6 and T-5 post-weld heat treatment (PWHT) was conducted for both cases to restore the strength of the weldment.

2 Results and discussions

Fig.1 shows the cross-section of the Al6061/SiCp weld and the microstructures in onion rings and at the interface between SZ and TMAZ. It revealed a defect-free weld with uniformly distributed reinforced SiCs. With increasing traverse speed, there was a tendency in grain growth in SZ which brought about a slight decrease in hardness, yet the width of SZ decreased, fig.2. The macroscopic onion-ring feature became less distinctive at high traverse speed. The SZ exhibited higher hardness than base metal in the tested traverse speed range. Tensile strength reached 88% of the base metal. Fracture in TMAZ implied a superior strength in the stir zone. Post-weld heat treatment effectively restored the strength of the welds to 98% of the base metal shown in fig.3, yet the SZ suffered a lower ductility. Micrographs of localized particulated reinforced zone in fig. 4 demonstrated a preliminary sucess in stirring SiC particles into Al-plates with uniform particle distribution as shown in the micrograph. The hardness in the stir zone remained similar to that of Al6061 while the tensile strength reached 77% of the base metal. T5-PWHT restored the strength of the stir zone, fig.5. Tensile fracture occurred in the stir zone indicated that the expected reinforcement was not completely achieved despite the perfect stirring of SiC.

3 Conclusions

Defect-free joining of Particulate-reinforced Al6061/SiCp AMC was conducted using FSW. The elevated hardness and strength of the stir zone in as-welded state and after PWHT were interpreted with microstructure change. The success of stirring SiC particles into Al6061 provided a potential technique for the fabrication of localized particulate-strengthened AMC.

4 Figures

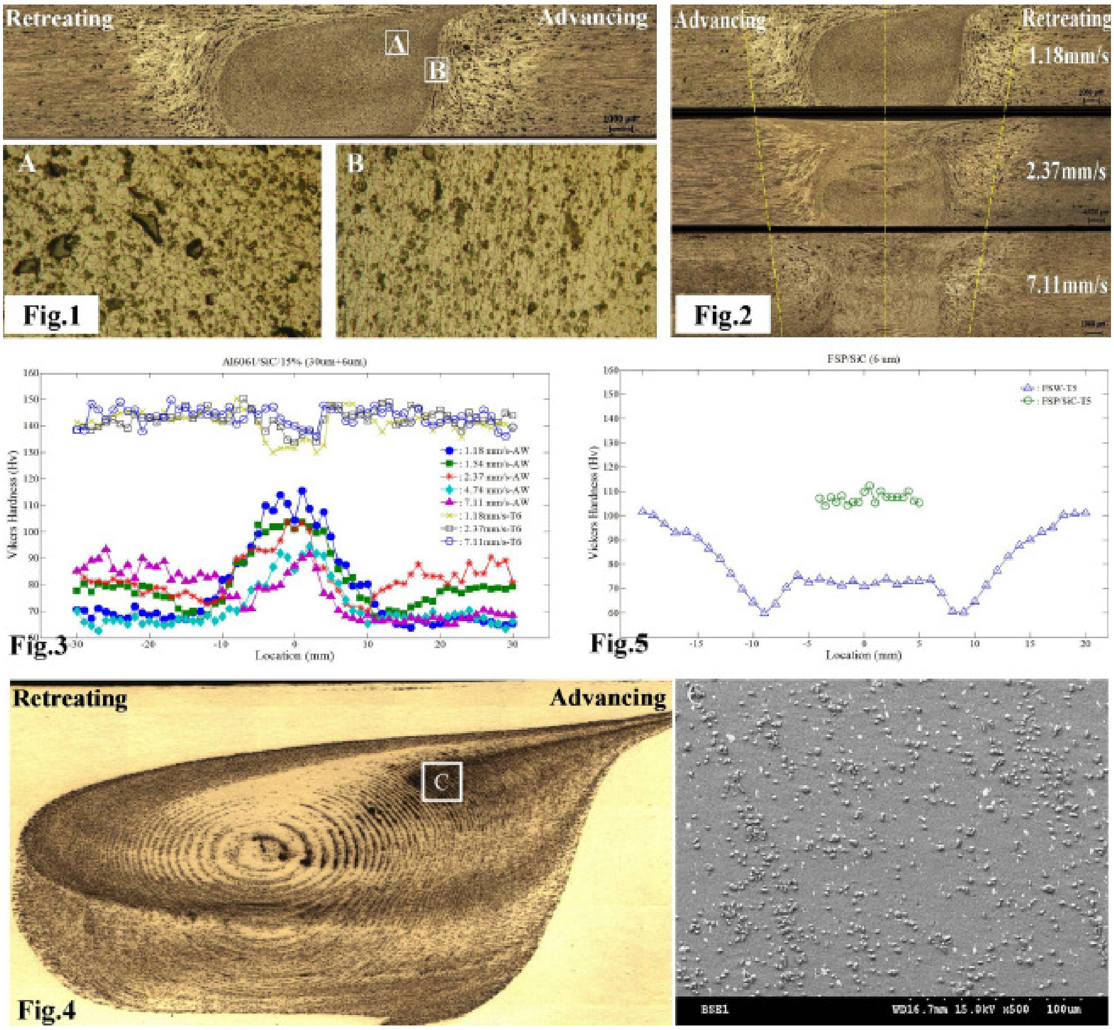

Figure 1. The cross-section of the Al6061/SiCp 15% weld and the microstructures. A, B in onion rings and in TMAZ, traverse speed: 1.18mm/s

Figure 2. The effect of traverse speed on the width of SZ and TMAZ.

Figure 3. Microhardness of Al6061/SiCp15%, as-welded and after PWHT.

Figure 4. Localized particulate-reinforced zone and microstructure revealing uniform SiC distribution.

Figure 5. Microhardness of localized SiC stirred zone, as-welded and after PWHT.

FSW2012 大會於 1/27 傍晚圓滿閉幕。本人於 1/28 日離開聖艾蒂安前往法國第二大城有小巴黎之稱的里昂(Lyon)。本次出國差旅適值國內春節期間，整整一週國人正在享受春節假期，而我則行程滿檔收穫豐富。1/28 至 1/30 三天為我在里昂之個人行程。1/31 日由里昂搭法國國鐵至巴黎戴高樂機場，次日由巴黎戴高樂機場飛荷蘭阿姆斯特丹機場轉機回國，於二月一日返抵國門。

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