Global R&D – Hamilton
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July 31, 2017

M. Nicholls

TRIP REPORT
IIW Annual Assembly & International Conference, Shanghai, China
June 25-30, 2017

OBJECTIVES

1. To participate in Commission III (Resistance Welding and Allied Processes) and SC-Auto at IIW.
2. To increase the recognition of Canada within the world welding community
3. Increase presence of ArcelorMittal within IIW Commission III and SC-Auto

BACKGROUND

From June 25-30, the International Institute of Welding (IIW) held its 70th Annual Assembly and Conference in Shanghai, China. The IIW gathers the welding community from around the world to discuss a wide range of topics concerning welding ranging from processes and weld properties to welding regulation and education. The IIW is the foremost organization concerned with welding as a whole. In 2017, the Canadian Council of the International Institute of Welding (CCIIW) gave me a bursary for the registration fee for the IIW Annual Assembly on the understanding that I would give a report on the proceedings of Commission III and SC-Auto.

SUMMARY

In Commission III and SC-Auto many papers were presented on topics of interest. The main topics discussed this year were: liquid metal embrittlement (LME), and dissimilar joining.

- It was shown that LME has no effect on mechanical properties and one presentation showed that LME may be avoided using long hold times after the welding cycle is complete.
- The work on dissimilar welding showed that Al to steel welding may be accomplished by controlling the growth of the Fe_2Al_5 intermetallic layer. Unfortunately, the main presentations of interest on these two topics did not have associated papers.
- There were also presentations of interest on laser welding Al-Si coated Usibor, using multiple pulses to improve spot weld strength and softening of the fusion boundary in Usibor spot welds.

I discussed the lack of Canadian award winners with Doug Luciani. I proposed that every year at least one paper should be submitted for the Henry Granjon Prize to increase Canada's visibility with IIW.

ACTIONS

1. Form a committee to solicit and write Canadian applications for the Henry Granjon Prize.

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CONTACTS OF NOTE

Stephanie Michaut- Welding Engineer	GRD - Maizières
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REPORT

Commission III and SC-Auto

Many presentations were given on a variety of topics including: spot welding, friction welding, dissimilar welding for automobile applications, laser welding, friction stir welding, liquid metal embrittlement (LME), and magnetic pulse welding. Below is a summary of the general business of the Welding Commission, and the topics of interested. A full list of the presentations may be found in the Appendix (please contact for available papers and abstracts).

General Business

The terms of the chairs for both Commission III and SC-Auto have ended. It was decided to extend Jorge dos Santos position as chair of Commission III for another term, however, Michael Rethmeier decided not to run for a further term as chair of SC-Auto. Michael was not replaced. A temporary chair will be assigned to SC-Auto for the coming year, then an election of a permanent chair will occur at the 2018 annual assembly.

Liquid Metal Embrittlement

Two talks were given on LME. The first was from M. Rethmeier's group in BAM (J. Frei), which again discussed that LME had no effect on joint strength, and they also showed that LME is not dependent on electrode life. The second paper from JFE (K.Taniguchi) used a modelling approach to suppress LME at the notch of a spot weld when electrode misalignment was applied during welding. The authors used FEA to show that during spot welding there was no tensile stresses until the electrodes were released. The authors increased the electrode hold time until the sheet surface temperature cooled below 420°C (melting temperature of Zn), which eliminated surface LME. Unfortunately, the authors neither revealed the material strength or the alloy family, and no paper was submitted.

Dissimilar Joining

There were many presentations on welding dissimilar joints between steel and Al. Most of these papers focused on increased joint strength by controlling the thickness of the Fe_2Al_5 intermetallic that grows between the steel and Al interfaces. From the presentations, strength may be maximized if there is a thin <2-4 μm intermetallic layer (depending on the presentation). When the thickness of this layer grows above this, the intermetallic grains align along the (001) direction

creating a brittle interface. Various papers showed how growth of this interface could be controlled using common welding parameter development techniques, such as pulsing. B. Carlson from GM showed that dissimilar joining could be further improved using dimpled electrodes (GM patent) to break up the surface oxide and a rapid pulse to break up the oxide at the faying surface. A paper was presented (M. Iyota) showing that when Al is spot welded to mild steel, the interface temperature can be controlled by using a typical truncated cone electrode with a radiused face on the Al side of the stackup, and wide electrode with a concave face (300 mm radius) on the steel side of the electrode. This mismatched electrode set will increase current density on the Al side of the joint, while minimizing it on the steel side of the joint; thus, allowing for controlled growth of the Fe_2Al_5 interface, without letting it grow too thick.

Dissimiliar joining between Al and steel was also successfully done using gas metal arc welding. During this process, welds were made in a lap fillet joint orientation where the steel was the bottom material and the Al was placed on top. Welds were made using an AA4043 Al filler wire which was welded to the Al sheet and brazed to the GI coating on the steel sheet. Failures in these joints occurred in the Al base material.

A study was presented to show how to maximize the strength between friction stir welds joining cast Mg and steel parts. The researchers showed that joint strength may be maximized by having the tool insert skim the steel surface during welding and by adding Al to the cast Mg. The researchers found that joint strength increased with increasing Al alloy content in the Mg as the Al formed a Fe_2Al_5 layer between the steel surface and the Mg casting that acted as interlayer in the joint.

Laser Welding Al-Si coated 22MnB5

A Chinese group (L. Wenhu) is investigating how the effect of Al on creating δ-ferrite during laser welding of AlSi coated 22MnB5. The group found that Al in the stabilized ferrite during both solidification and heat treating, increasing the ferrite content of the weld. During tensile testing the heat-treated material, the ferrite promotes failure through the fusion zone. This is consistent with literature. They concluded their presentation by announcing that they plan to promote austenite formation without the use of ablation, although the methods were not disclosed. It is unknown how far along in this research they are. No paper was submitted for publication.

Double Pulse Welding to Improve

Work was presented (P. Eftekharimilani) on the use of a double pulse during RSW to improve CTS. Like the previous literature, this work showed that the double pulse improved fracture morphology by reducing P segregation, however, they also claimed that the structure after welding with a double pulse was more equiaxed. When the welds were subjected to a paint bake cycle the CTS of all joints increased. The paint baked welds made with a single pulse all failed in partial interfacial mode and the double pulse welds all failed in full button pullout. The improvement in strength was claimed to be due to the formation of ε carbides found on electron images. However, there was no change in hardness. No paper was submitted for this presentation.

Fusion Boundary Softening in RSW UHSS

Work was presented (O. Sherepenko) that showed when high carbon steel (Usibor) is spot welded using long weld times softening occurs at the nugget periphery. The softened fusion boundary will change fracture morphology, as during CTS testing, in welds with a softened fusion boundary,

the fracture path will follow the nugget boundary as opposed to travelling through the interface, which occurs in a nugget without fusion boundary softening. The softening is due to C diffusing from the fusion boundary to the fusion zone during welding. This only occurs at long hold times as the nugget grows to its maximum width before the end of the welding cycle. The researcher believes that when the fusion zone is stationary at the end of the welding cycle, C from the fusion boundary diffuses to the liquid steel, where the C solubility is much higher than the surrounding δ ferrite.

Conversations of Note

Doug Luciani (CWB)

I discussed with Doug that we need to try to submit more Canadian applications for IIW awards to increase Canada's visibility. I volunteered to strike a committee to solicit and submit applications for the Henry Granjon Prize, with the objective of making one Canadian submission each year.

APPENDIX

Table A1. Commission III and SC-Auto program agenda

Time Start	Time End	Title and Authors	Manuscript / Abstract	IIW Doc Number
08:30	08:45	**Plenary Session Commission III** **Chairman: Dr. Jorge F. dos Santos**	–	
Monday, 26th June				
Seminar on the Application of Resistance and Friction Processes for Dissimilar Joints Chair: Dr. J.F. dos Santos, Co-Chair: Prof. H.S. Chang				
08:45	09:10	A novel friction-based welding process to join Al/Cu bimetal composite tubes: Formation mechanism and bonding characterizations, by W. Li, W. Yansong, Q. Wen, X. Yang and Q. Chu (China)		III-1804-17
09:10	09:35	Realization of different aluminium/steel-hybrid joints through ultrasound enhanced friction stir welding (USE-FSW), by M. Thomä and G. Wagner (Germany)		III-1802-17
09:35	10:00	Mechanical properties and microstructural characteristics of friction-spot welded Al-Cu dissimilar joints, by J. Shen, M.E.B. Cardillo, J.F. dos Santos (Germany)		III-1785-17
10:00	10:25	Study on interfacial morphologies of the joint between AA1060 and SS321 in magnetic pulse welding, by S. Su, S. Chen, J. Xiao, P. Wei, C. Kan, L. Wang (China)		III-1809-17
10:25	10:45	**Coffee Break**		

Time Start	Time End	Title and Authors	Manuscript / Abstract	IIW Doc Number
10:45	11:10	Similar and dissimilar resistance spot weldability of multi-layer advanced high strength steels, by S. Wei, S. Lu (China)		III-1800-17
11:10	11:35	Texture Evolution and Plastic Deformation Mechanism in Magnetic Pulse Welding of Dissimilar Al and Mg Alloys, by X. Jiang and S. Chen (China)		III-1819-17
11:35	12:00	Magnetic Pulse Welding of dissimilar materials (i.e. Cu to steel and Al to Steel), Mahadev Shome (India)		III-1829-17
12:00	12:25	Fracture mechanisms of Al/steel resistance spot welds and effects of Fe_2Al_5 growth on mechanical property, by N. Chen, M. Wang, H. Ping Wang, Z. Wan, B. E Carlson (China)		III-1830-17
12:25	12:50	Dissimilar of FSW of Steel and Magnesium Alloys (Immiscible Combination), by H. Fujii, H. Kasai and Y. Morisada (Japan)		III-1836-17
12:50	14:00	**Lunch**		
III-A Resistance Welding and Allied Processes Chair: Prof. M. Kimchi, Co-Chair M. Tumuluru				
14:00	14:25	Effects of post-weld heat treatment on microstructure and mechanical properties of double pulse welded advanced high strength steel, by P. Eftekharimilani, E. van der Aa, M.J.M. Hermans, I.M. Richardson (Netherlands)		III-1823-17
14:25	14:50	Servo-controlled projection welding of vehicular air-condition control valve, by H.S. Chang (South Korea), H. Lin (China) and M. Raash (Mongolia).		III-1788-17
14:50	15:15	Transient softening at the fusion boundary in resistance spot welded ultra high strengths steel 22MNB5 and its impact on fracture processes, by O. Sherepenko, S. Jüttner (Germany)		III-1791-17

APPENDIX

Time Start	Time End	Title and Authors	Manuscript / Abstract	IIW Doc Number
15:15	15:40	Simulation of resistance spot welding process for the aluminum alloys 5182 and 6016 taking into account the surface layer, by S. Heilmann, D. Köberlin, M. Merx, J. Müller, J. Zschetzshe, S. Ihlenfeldt, U. Füssel (Germany)		III-1792-17
15:40	16:05	Comparison between fatigue properties of RSW and RSW-bonded joints for automotive applications, by M. Pedemonte, M. Palombo, G. L. Cosso and M. Rinosi (Italy)		III-1805-17
16:05	16:30	**Coffee Break**		
16:30	16:55	Heat development of the contact area during capacitor discharge welding, by M.-M. Ketzel, J. Zschetzshe (Germany)		III-1796-17
16:55	17:20	Life-time increase of resistance spot welding electrodes by using wear-dependent milling intervals and dispersion hardened copper, by D. Köberlin, C. Mathiszik, O. Sherepenko, S. Heilmann, J. Zschetzshe, S. Jüttner, U. Füssel (Germany)		III-1797-17
17:20	17:45	Influencing factors for NDT of spot welds by imaging analysis of the residual flux density, by C. Mathiszik, D. Köberlin. J. Zschetzshe, U. Füssel (Germany)		III-1798-17
17:45	18:10	The possibility of resistance welding on the design and manufacturing of modern railway passenger coach by A. Erdei, I. Borhy, (Hungary)		III-1795-17

Tuesday, 27th June				
SC-AUTO Chair: Prof. M. Rethmeier				
Time Start	**Time End**	**Title and Authors**	**Manuscript / Abstract**	**IIW Doc Number**
08:30	08:30	**General Matters** a. Opening of the meeting and welcome address b. Approval of the agenda c. Election of a new chairman d. Membership of SC-AUTO		SC-Auto-87-17
08:30	08:50	a. Mechanical Properties of Repair Welded Joints for Automobile Body Structures, by J. Ditter (Germany)		SC-Auto-88-17
08:50	09:10	Innovative Joining Technologies for Multi Material Applications with High-Manganese Steels in Lightweight Car Body Structures by M. Ivanjko (Germany)		SC-Auto-89-17
09:10	09:30	Susceptibility of electrolytically galvanized dual phase steel sheets to liquid metal embrittlement during resistance spot welding, by J. Frei (Germany)		SC-Auto-90-17
09:30	09:50	Al-Si coating influence on the solidification and properties of laser-welded 22MnB5 steel joints by L. Wenhu (China)		SC-Auto-91-17
09:50	10:10	Probing joint strength and distortion in an advanced gas metal arc joining of dissimilar materials between aluminium and steel sheets, by S. Goecke (Germany)		SC-Auto-92-17
10:10	10:20	Presentation Prof. Böllinghaus – Welding in the World		–
10:20	10:45	**Coffee Break**		
10:45	11:10	Developing Resistance Spot Welding Processes for Joining 6XXX Aluminum Alloys to Zinc Coated Steels, B. Carlson (USA)		III-1843-17
11:10	11:35	Modelling and Experimental Validation of Friction Self-Piercing Riveting Aluminum Alloy to Magnesium Alloy Y-W. Ma, M. Lou, Y.- B. Li, and Z.-Q. Lin (China)		III-1807-17

APPENDIX

Time Start	Time End	Title and Authors	Manuscript / Abstract	IIW Doc Number
11:35	12:00	Influence of acoustic softening on the process characteristics in ultrasonic vibration enhanced FSW, by C. S. Wu, L. Shi, Y. B. Zhong		III-1839-17
12:00	12:25	Effect of hook defects and residual stress on the fatigue behaviour of the friction spot welded 6061-T6 alloy, by J.Y. Cao, M. Wang, L. Kong, T. Yuan (China)		III-1831-17
12:25	12:50	Development of resistance spot welding process to suppress liquid metal embrittlment crack in zinc-coated ultra-high strength steel sheets, K. Taniguchi, C. Sawanshi, K. Takashima,.H. Matsuda, R. Ikeda (Japan)		III-1837-17
12:40	14:00	**Lunch**		
III-B Friction Based Processes Chair: Prof. P. Vilaça, Co-Chair Prof. Wenya Li				
14:00	14:25	Application of hybrid friction stir channeling (HFSC) technique to improve the cooling efficiency of electronic components, H. Karvinen, D. Nordal, P. Vilaça (Finland)		III-1799-17
14:25	14:50	Understanding the formation of 'kissing bond' defects in friction stir welds, by G. Chen, H. Li, S. Zhang, Y. Zhu and Q. Sh (China)		III-1813-17
14:50	15:15	Microstructures and mechanical properties of friction plug welds repairing for AA2219-T87 friction stir welded joints, by K. Liu, Z. Sun, X. Yang, B. Dua and J. Song (China)		III-1810-17
15:15	15:40	Effects of welding parameters on microstructure and mechanical properties of underwater wet friction taper plug welded API X52 pipeline steel, by J. Xiong, X. Yang, W. Lin and K. Liu (China)		III-1811-17
15:40	16:05	Effect of pin thread on the material flow behaviours during friction stir welding: a Computational Fluid Dynamics study, by G. Chen, S. Zhang, Y. Zhu, Q. Shi (China)		III-1812-17

Time Start	Time End	Title and Authors	Manuscript / Abstract	IIW Doc Number
16:05	16:30	**Coffee Break**		
16:30	16:55	Underwater friction stir welding of arc welded carbon steel J. P. Bergmann and J. Liefeith (Germany)		III-1822-17
16:55	17:20	Study on microstructure evolution of AISI 304 stainless steel joined by rotary friction welding, by Guilong Wang, Jinglong Li, Jiangtao Xiong, Wei Zhou, Fusheng Zhang (China)		III-1817-17
17:20	17:45	Increase of tool life of friction stir welding tools by laser implantation of ceramic particles into the boundary layer of the tool, by S. Schüddekopf, G. Mienert, S. Böhm (Germany)		III-1814-17
17:45	18:10	Discussion on questions of Friction Stir Welding, by Z. Wang (China)		III-1821-17

APPENDIX

Wednesday, 28th June				
III-B Friction Based Processes Chair: Prof. P. Vilaça, Co-Chair Prof. Wenya Li				
Time Start	**Time End**	**Title and Authors**	**Manuscript / Abstract**	**IIW Doc Number**
08:30	08:55	Simultaneous Double Sided Friction Stir Welding of Thick Section Aluminium Alloys, J.P. Martin (UK)		III-1833-17
08:55	09:20	Friction Stir Welding of ODS Alloys and RAFM Steels, by Z. Feng, W. Tang, X. Yu, and D. Hoelzer (USA)		III-1832-17
09:20	09:45	Hybrid friction stir processing with active cooling approach to achieve low temperature superplasticity in AA7075 alloy, by V.V. Patel, V. Badheka (India)		III-1824-17
09:45	10:10	Effect of processing temperatures on the properties of high strength steel welded by FSW, by G. Sorger, T. Sarikka, P. Vilaça, T.G. Santos (Finland)		III-1825-17
10:10	10:35	Global and local constitutive behaviours of friction stir welded AA2024 joints, P. Niu, W. Li, Z. Zhang, X. Yang (China)		III-1828-17
10:35	11:00	**Coffee Break**		
11:00	11:25	The corona bond response to normal stress distribution during the process of rotary friction welding F. Jin, J. Li, H. Li, Z. Liao, X. Li, J. Xiong (China)		III-1826-17
11:25	11:50	Effect of rotation speed on friction behaviour of rotary friction welding of aluminium alloy, by X. Li, J. Li, Z. Liao, F. Jin, X. Nan, J. Xiong (China)		III-1827-17
III-A Resistance Welding and Allied Processes Chair: Prof. M. Kimchi, Co-Chair M. Tumuluru				
11:50	12:15	Wavelet Analysis based Splashing Identification in Electrode Pressure Sensing of Servo-torch Resistance Spot Welding, by N. Wu, J. Xiao, S. Chen (China)		III-1808-17

APPENDIX

Time Start	Time End	Title and Authors	Manuscript / Abstract	IIW Doc Number
12:15	12:40	An experimental study on contact resistance of coated galvanized steel sheet, by Bao Yefeng, Ren Ling, Yu Zhongtai, Jiang Yongfeng and Yangke (China)		III-1820-17
12:40	14:00	**Lunch**		
Joint Meeting with Commission XVI: "Seminar on Hybrid Metal-Polymer Joints" Chair: Prof. V. Schoeppner, Dr. J.F. dos Santos				
14:00	14:20	Evaluation of joint formation and mechanical performance of AA7075-T6/CFRP spot joints produced by frictional heat, by N. Manente, J. F. dos Santos, S.T. Amancio-Filho (Germany)		III-1803-17
14:20	14:40	Mechanism of ABS polymer and Steel/Aluminum Joining by Resistance Spot Welding, by C. Zhang, S. Jin, L. Yang, X. Liu (China)		III-1818-17
14:40	15:00	Durability of metal – composite friction spot joints under environmental conditions, by S.M. Goushegir, J.F. dos Santos, S.T. Amancio-Filho (Germany)		III-1816-17
15:00	15:20	The influence of the clamping pressure on the joint formation and mechanical performance of friction-riveted woven-reinforced polymer composite joints, by N. Z. Borba, J.F. dos Santos, S.T. Amancio-Filho (Germany)		III-1801-17
15:20	15:40	Investigations on bubble formation, flow field and melting/solidification process in laser-based joining of metals to plastics, by Schricker, K.; Bergmann, J. P. (Germany)		III-1840-17
15:40	16:00	Single side resistance spot joining of polymer-metal-hybrid structures, by Schricker, K.; Bielenin, M.; Szallies, K.; Bergmann, J. P. and Neudel, C. (Germany)		III-1841-17
16:00	16:20	**Coffee Break**		

Time Start	Time End	Title and Authors	Manuscript / Abstract	IIW Doc Number
16:20	16:40	Thermal joining of thermoplastics to metals: Surface preparation of steels based on laser radiation and tungsten inert gas arc, by Schricker, K.; Kohl, M.-L., Bergmann, J. P.; Lohse, M.; Hertel, M.; Füssel, U. (Germany)		III-1842-17
III-A Resistance Welding and Allied Processes Chair: Prof. M. Kimchi, Co-Chair M. Tumuluru				
16:40	17:00	Effect of electrode material on spot welding and electrode failure mechanism of hot-dip galvanized high strength steel, by J. Yaoyao, Z. Wu, C. Changjin, L. Yonggang (China)		III-1806-17
17:00	17:20	Effects of electrode shape on temperature distribution of resistance sport welds, M. Iyota, Y. Taguchi (Japan)		III-1838-17
III-WGS Standardisation Chair: Prof. K. Matsuyama				
17:20	17:30	Plenary Session WG III-S Standardisation Prof. K. Matsuyama		–
17:30	17:50	International standardisation works of C-III 2017, by K. Matsuyama (Japan)		III-1834-17
17:50	18:10	How to develop the Annex A of ISO 14273, by K. Matsuyama (Japan)		III-1835-17