Canadian Delegate Report to CCIIW

International Forum on Green Material and Processing Technology for Circular Economy (IFMP Beijing 2017)

Abstract

The forum was sponsored by the Beijing Natural Science Foundation and hosted by the Beijing University of Technology (BJUT), which is also International Institute of Welding (IIW) C-VIII Pre-Assembly Seminar jointly organized by IIW Committee VIII-Health, Safety and Environment. The forum contained four themes, i.e. New green welding materials, Health and safety in welding and allied processes, Advanced welding technology, and Advanced remanufacturing technology.

More than 30 world known experts delivered invited lectures, exchanged and discussed the latest achievements and development trends of green material and processing technology for circular economy. The forum's aim was to create an open atmosphere to exchange and discuss the latest achievements and development trends for green material and processing technology for the modern open economy.
Many of the speakers, whether national or foreign came from Chinese origin and while the conference was advertised as being held in English, many of the presentations were given in Chinese as several speakers felt more comfortable in that language.
This document is an accumulation of my notes, meeting handouts, and pictures that were supplied by Assoc. Prof. Hong Li of BJUT. Any errors or omissions are solely my responsibility.

David Hisey
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International Forum on Green Material and Processing Technology for Circular Economy (IFMP Beijing 2017)
June 23rd, 2017, Friday 8:30 a.m.

Meeting Venue: Grand Gongda Jianguo Hotel Beijing, China

Chairman of this section**: Zhuoxin Li**

Each section of the conference had one or two chair person(s) assigned which had the responsibility of introducing each speaker as well as controlling the time schedule which was 30 minutes per speaker the first day and 25 minutes on the 2nd day. The foreign speakers as well as some of the resident speakers were members of various International Institute of Welding Commissions, which were to meet the following week in Shanghai for the annual IIW conference. All speakers were invited guests of the Beijing University of Technology and were treated as such with much care and attention.
The chair(s) had the responsibility of introducing, timing and presenting the speaker with an award certificate and a gift following his/her presentation.

8:30-8:35
Opening Ceremony
Welcome speech - Prof. Zhuoxin Li, Professor of College of Materials Science and Engineering, BJUT
Prof. Zhuoxin Li introduced himself and welcomed all to the conference.

8:35-8:40
1st Welcome speech – Geoff Melton TWI UK
Geoff welcomed everyone on behalf of IIW Commission VIII HSE. Geoff acknowledged that Dr. Wolfgang Zschiesche had been involved in the planning but was unable to be here due to a medical condition. Geoff identified that welding processes were hazardous to both humans as well as the environment, but with the efforts of International Institute of Welding, Commission VIII we are working to improve both the safety of our work force as well as the impact welding has on the world environment.

Thank-you speech - Zhiling Tian from the China Iron & Steel Research Institute Group
Zhiling Tian from the China Iron & Steel Research Institute Group provided a brief speech directed to Dr. Zhuoxin Li, Headmaster of Beijing University of Technology thanking Prof. Zhuoxin Li for the conference and congratulating him, that the conference was now open.

2nd Welcome Speech from Beijing Natural Science Committee and the Beijing Natural Science Foundation.
As this organization was one of the sponsors and benefactors of the conference, they also provided a welcome message to all attendees.

8:40-9:00 Group photo
Professor Hong Li who had organized the conference arranged for a photographer to take a group photo which we were given assigned seating.

Professor Hong Li (1st person, 2nd row left and Professor Zhuoxin Li standing next to her) organizers of the conference. Seating was assigned, in front row, IIW C VIII members Geoff Melton (4th from right); Dave Hisey (3rd from left); 2nd row, Steve Hedrick (7th from right); Nicolas Floros (8th from left).

Chairman of this conference section**: Wolfgang Tillmann**

9:00-9:30
Remanufacturing Engineering for Ecological Civilization Construction, Binshi Xu. National Key Lab for Remanufacturing, China
Binshi Xu, is 80 plus years of age. Chairman of European Remanufacturing Network awarded him for his outstanding achievements to global development of remanufactured products.

Introduction

The important characteristics of RM Engineering is that the quality of the remanufactured products is non-inferior to the new ones, and the cost is only a half of the new one, saving 60% energy, saving 70% materials, and decreasing the bad influence on environments.

Whole life cycle theory provides foundation for RE progress. The traditional product life cycle, R&D -Use -Waste, is an open logistics system. RM makes it a green system as, R&D -Use Waste -RM.

China's remanufacturing developed from maintenance engineering and surface engineering, and mainly include size restoration and performance improvement methods. Remanufacturing rate increased significantly, consumption of resources and energy reduce significantly; Energy saving benefits is outstanding.

Looking to the future, China's remanufacturing should be the focus of a breakthrough in four aspects, "To study the scientific basis of remanufacturing quality control, to innovate the key technology of remanufacturing forming process, to establish the industry standard of remanufacture, to explore the cross integration of strengthening the domestic and foreign remanufacturing technology".

1) To study the scientific basis of remanufacturing quality control.
2) To innovate the key technology of remanufacturing forming process.
3) To establish the industry standard of remanufacture.
4) Learn from foreign remanufacturing industry development mode, accelerate the development of domestic remanufacturing industry.

Conclusions

The National Economy and Social Development of 13th Five-Years Program Outline had decided that taking the scientific development as theme, taking rapid changing the mode of economic development as principal line. The remanufacturing industry has become the strategic rising industry.

Remanufacturing is the industrialization of high technology repair and reformation to the waste productions. The important character of remanufacturing engineering is that the quality of the remanufactured productions is as same as or superior to those of the new productions, and the cost is only a half of the new one, saving energy 60%, saving materials 70%, and decreasing the bad influence on environments.

The replacing-repair method and size-repair method have been used abroad. Meanwhile a new remanufacturing mode with Chinese character, namely size-resuming and performance-improving, has been establishing in China.

Product quality is the life of remanufacturing. The advanced technologies, such as surface engineering, nano surface engineering, automatic surface engineering, and the strict non-destroy test and residual life evaluation technology provide strong support to the quality of remanufactured products.

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9:30-10:00

Welding Safety - the Canadian Perspective, David Hisey, Canadian Standards Association, Standard, Chair, W117.2 Safety in welding cutting and allied processes, Canada. Sponsored by the CWB Group

This presentation presented CSA Standard W117.2-12 Annex G Welding services provided from vehicles, why it was developed and how it was developed. Regulations were developed and installed into law because of the work which was done for this paper.

A summary of other welding safety development work now under way at the University of Alberta, through Nicola Cherry MD PhD, Tripartite Chair of Occupational Health, Division of Preventive Medicine was also provided.

Dave Hisey presenting Welding Safety - the Canadian Perspective

10:00-10:20 Coffee break and Poster Session

Posters had been created on several engineering topics, these were set up in the break area and available for viewing. At the Welcome Dinner, later in the evening awards wee presented to the student who created the posters.

Chairman of this conference section: **Sindo Kou**

10:20-10:50

Driving Green Manufacturing and Assisting Industries Upgrading, Tianhu Song, Chinese Mechanical Engineering Society, China

In the next 10 years china will develop and improve the advanced forming technology.

Green manufacturing emphasizes the sustainable use of resources through comprehensive utilization and circular using of resources, the substitution of scarce resources, and energy-saving; At the same time, the production and discharge of waste materials and pollutants will be reduced, and the compatibility of production and consumption process with environment can be improved. Finally, the optimization of economic and environmental benefits will be achieved. The green life cycle of the mechanical products is an important direction of mechanical engineering technology development in the future.

10:50-11:20

Friction Stir Extrusion (FSE)-a Green and Energy Efficient Process to Recycle Al Alloys, Zhili Feng, Oak Ridge National Lab, USA

Friction stir extrusion (FSE) is a novel solid-state process for synthesis and recycling of metals and alloys. The novelty of FSE is that it utilizes the intrinsic frictional heating and extensive plastic deformation inherent in the process to stir, mechanically alloy, consolidate and convert powders, chips and other recyclable feedstock metals in to usable product form of highly engineered materials in a single step. Being a solid-state process, FSE eliminates the energy intensive melting and solidification steps, which are necessary in the conventional metal synthesis processes. Therefore, FSE is highly energy-efficient, practically zero emissions, and economically competitive. It represents a potentially transformational and pervasive sustainable manufacturing technology for metal recycling and synthesis. Estimated energy savings for aluminum and steel recycling by FSE are 94% and 79%, respectively. Or stated another way, recycling of aluminum saves approximately 250 kwh/kg to 0.33 kwh/kg of energy, or about 7 times saving over producing new aluminum. Similarly, with steel, the saving is approximately 5 times in energy saving when steel is recycled versus creating new.
In this paper, the concept and configuration of FSE are introduced, the advantage of FSE on energy saving is analyzed, the feasibility of FSE is demonstrated, and some preliminary metallographic and mechanical properties study results are presented. For metal producers recycling scraped materials is of prominent importance. In 2000, 48.5% of aluminum was recycled. Friction stir extrusion process has close to a zero-emission level.

11:20-11:50

Status Quo of HSLA in China Zhiling Tian, China Iron & Steel Research Institute Group, China

China is a dominant steel production country in the world, with a proportion of over 50% of global production since 2014. This report firstly reviews the evolution of steel production and product structure in the past decade, which has shown a trend towards better flat/long product ratio and higher steel grades. In the second part, the progress in R&D, production and application of High Strength Low Alloy (HSLA) steels are introduced, ranging from construction steels to micro alloyed steels, auto steels, pipeline steels, railway steels, shipbuilding steels and high strength steels for engineering machineries. In general, China is 99% self-sufficiency of steels, including almost all the high steel grades. In prospective to the future, the major task will focus on overcoming overcapacity problem, stabilizing product quality, reducing environment burden and efforts towards intelligent manufacturing.

In 2015 steel consumption in the world peaked and world consumption of steel is decreasing slightly, China realizes that they need to adjust as they are currently in an overproduction state. This presentation placed China’s 2015 production of steel at .8 billion tons and recognized they are in an over production situation. New construction is by far the largest consumer of steel in China consuming 54 % of China’s steel production.

Rebar is being produced in high strength steel, so that much lower quantities are required when high strength steel spec rebar is used. China is also the largest producer of automobiles in the world, they are also the largest consumer of automobiles. 60.8% of their auto framework is HSS.

They have a coal gas pipeline which traverses the country from west to east. The coal gas contains a high percentage of hydrogen which causes hydrogen embrittlement so both pipeline steel and weld procedures must deal with this issue. Before creating this pipeline, China developed a test pipe line which they experimented with to fully understand the problems which might arise on an actual coal gas pipeline.
China also acquires natural gas from Russia through a pipeline of 1.4 metres in diameter. From discussion, they claimed most field pipeline welds were automatic, others said they were semi-automatic welds. They also claimed that quality check inspectors are in place for all pipeline welds.

They are currently developing a X90 pipe.

They produce high strength, high wear resistance steel rail which is 100 metres for each section.

12:00-13:00 Lunch

13:30-14:00
Development of Flux cored Brazing Filler Metal for Reducing the Consumption of Raw Materials and Energy,
Weimin Long, Zheng Zhou Research Institute of Mechanical Engineering, China

Brazing is a widely applied key fundamental technology of industrial manufacturing. Traditional brazing is long regarded as a barrier in the way of upgrading manufacturing to a higher level of eco-friendly, efficiency and quality. Thus, green brazing is one of the key tasks of developing cyclic economy.

In this presentation the classification, development, key manufacturing technologies, capability of material saving and emission reduction and some typical applications of the flux cored brazing filler metals are discussed. The flux-cored brazing filler metals is capable for flux and filler metal application during brazing, with accurate position, temperature, dosage and time. Thus, the waste of filler metal during manual brazing is avoid, the efficiency and activity of oxide layer removing process is improved and the emission of rinsing water and hazardous pollution is reduced. The flux-cored brazing filler metal largely ease the pressure that industrial manufacturing has put on the environment, and is recognized as a green industrial product with considerable developing potential and promising future.

Chairman of this conference section: **David Hisey, Anming Hu**
14:00-14:30

Solidification Cracking in Welds of Aluminum Alloys, Sindo Kou, University of Wisconsin, Madison, USA

Cracking can occur during solidification of AI alloys in both welding and casting. Key aspects of solidification cracking in AI welds will be presented in two parts. The first part is the introduction to solidification cracking in AI welds, including the characteristics of cracks, crack susceptibility tests and reduction of cracking. The second part is the prediction of crack susceptibility. An index for predicting the crack susceptibility of AI welds recently proposed by UW Madison will be discussed. The index is the maximum IdT/d(fS)1/21 of an AI alloy -the higher the maximum value is, the greater the tendency to crack. Curves of T vs. *(fS)1 /2* of AI alloys can be plotted to find the maximum steepness IdT/d(fS)1/21 using commercial thermodynamic software package Pandat and AI database PanAluminum.

14:30- 15:00

High efficiency in the high-current welding of newly developed metal-based flux cored wire, Daisuke Ohmura, Nippon Steel & Sumikin Welding Co. Ltd Japan

This study is a metal-based flux cored wire (FCW) that welding performance is high efficiency under high welding current, high heat input and high inter-pass temperature. In the construction industry in Japan, C02 gas shielded arc welding with a solid wire is the main by semi-automatic arc welding and robot welding. As a background, most welds are applied in the flat position and the horizontal position of high efficiency under the planning that is decided procedure and method of assembly. And the heat input is applied 3.0-4.0kJ/mm, the inter-pass temperature is applied 250-450°C. When general FCW is used under these welding conditions, mechanical properties of weld metal are not only decreased, but the slag removability is decreased also. However, welding with the solid wire has had many spatters and the working time of the post welding treatment is regarded as a problem. In this time, the metal-based FCW is developed low spatters, good arc stability, depth of penetration and fine mechanical properties of weld metal under high heat input and high inter-pass temperature that are commonly used in the construction industry in Japan. The amount of slag that becomes industrial waste is reduced compared to general FCW and is same as solid wire

15:00-15:30
Wire Arc Additive Manufacturing (WAAM) at University of Wollongong, Huijun Li, University of Wollongong, Australia

1. introduction: Additive manufacturing (AM) builds up a component through the deposition of materials layer by-layer instead of starting with an over dimensioned raw block and removing unwanted materials, as practised in conventional subtractive manufacturing. With the development of AM technology, the current focus has shifted to producing functional metal components of complex shape that can meet the demanding requirements of aerospace, defence, and automotive industries [1.] Wire and Arc Additive Manufacturing (WAAM) is by definition a wire-feed and arc-based additive manufacturing that uses either the gas tungsten arc welding (GTAW) or the gas metal arc welding (GMAW) process has drawn the interest of the research community in recent years due to its high deposition rate [2-5]. This technique has been presented to the aerospace manufacturing industry as a unique low-cost solution for manufacturing large thin-walled structures through significantly reducing both product development time and "buy-to-fly" ratios [6].

2. Experiments: A typical robotic WAAM system is developed at the University of Wollongong. A computer interface is used to program the processes from CAD modelling to robot code generation. The robot controller is used to coordinate both the robot motions and welding processes. A programmable GMAW power source is used to control the welding process. A large industrial robot implements the movement of the GMAW torch for metal deposition. Subsequently an example of fabricated component is shown. Note that GTAW torch could also be used to complement the deposition process by robotic WAAM system while different power source instead of is required.

As generating deposition motions for a given work piece is the most labour-r-intensive and time-consuming task in the robotic WAAM system, an automated programming system is developed. As shown in Fig.2, the programming system, which generates robot code directly from CAD models, consists of several modules (CAD Modelling, Slicing, Path Planning, and Robot Code Generation). During programming, a CAD model is analysed and processed by the different modules. The geometrical complexity of the input CAD model determines the build directions. In the Slicing module, the CAD model is sliced along the build direction (normally in vertical direction). The sliced layers are processed by the Path Planning module, which generate the deposition path for each layer to guide the movement of the torch. The Robot Code Generation module then creates an integrated file, in which both the trajectory of the robot motion and the welding parameters such as welding speed, wire-feed rate, and welding voltage for each weld path are included.

3. Results and discussions: Two sample components, a turbine blade and an impeller structure, are fabricated using the proposed robotic WAAM system as shown in Fig.3. For the turbine blade, the wire-feed rate is 2.5 *m/min,* and the welding speed is 0.4 m/min. Each layer is deposited in around 30 s and has the average thickness of 1.3 mm. With the deposition of 150 layers, the blade has a height of 195 mm as shown in Fig. 3a. During the deposition, a waiting time of 60s is used between each layer to avoid the large distortion and poor surface finish due to the over heat of the structure. The whole deposition process takes around 4 hours. Minimum distortion is found with the usage of 8 mm thickness of mild steel plate as the substrate.

For the impeller structure, 5 *m/min* wire-feed rate and 0.8 m/min welding speed are chosen. Each layer has an average thickness of 1.8 mm. With the deposition of 40 layers, the impeller has a total height of 70 mm.

4. Conclusions: The control of residual stresses and distortions especially for large-scale WAAM process is one of the major concerns, as it not only affects the part tolerances, but it also causes quality issues such as premature failure. Due to the nature of the welding process, the accuracy of the process is limited by the wire diameter and light machining after deposition is necessary for good surface finish and high position accuracy. The future work will integrate a machining capability within the robotic system to be able to generate a final part using a single machine.

References

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15:30-15:50 Coffee break & Poster Session

Chairman of this section: **Geoff Melton, Huijun Li**

15:50-16:20
Flux on or Flux within-Aluminum Brazing Materials Advances, Dusan P Sekulic, University of Kentucky, USA
This presentation provided a visual demonstration of brazing of clad and double clad aluminum with and without flux. Over 100 joint formations were processed to provide this data. This was a demonstration of the Trillium flux product which has a powder flux embedded within the brazing foil. Embedding the flux as a powder into the brazing metal does work.

Issues of sustainability in the context of a control of resources use and protection of environment in manufacturing are at the forefront of scientific inquiries at a global and multiple lower scales. Novel materials processing requires a particular attention. This keynote lecture will address one approach to potentially better control of the efficient but less environmentally demanding use of flux for brazing. An interesting approach to CAB brazing without external addition of flux will be reviewed. The results of comparative studies of a traditional and novel flux use in terms of braze ability of aluminum will be presented. An in situ, in real time monitoring of the process of flux action during brazing will be presented.

16:20-16:50
Factors that Influence Welding Fume and Gas Emissions in Gas Metal Arc Welding, Nicolas Floros**,** Air Liquide-Paris Saclay Research center，France

During welding, fumes and gas are generated, predominantly by the welding consumable and to a lesser extent by the base metal. The amount of fumes and gases greatly depends on the welding process. Even for a same welding process, fume and gases emissions are influenced by several factors. These emissions can be minimized by adjusting welding parameters and selecting appropriate shielding gas.

In this work, we have studied the influence of shielding gas composition and arc transfer mode in Gas Metal Arc Welding (GMAW).

Four 1.2mm solid wires have been selected: 2 aluminum wires (G2 Sil70S-3, SAl 4043/S AI 5754), one low alloyed steel wire (G2 Sil70S-3) and one stainless steel wire (G19 9 L Si/308LSi). Wires have been tested in a fume-box where fume and gas emissions rates generated have been monitored.

For each alloy, several suitable shielding gases have been selected and tested in different arc transfer modes. For each configuration, Fume Emission Rate (FER) as well as NOx, CO, and 03 emissions rates have been measured on a laboratory test bench.

2. Experiments: The test bench consists on a fume-box in which a welding torch and a circular base metal plate are positioned. An extraction system is connected to the fume-box. Emitted fumes are trapped on it, while gases pass trough and are analyzed thereafter (see Figure 1 a). A welding time of 30s or 60s is sufficient to measure fume emission rates. However, considering response time of gas analyzers and gas contents variations during welding, it appeared that no reliable gas emission rates could be obtain for such short welding times.

Therefore, the fume box was modified to have a "spiral" welding instead of a circular one (Figure 1b), allowing to significantly increase welding time up to 360s.

Base metal plates have been weighed before and after FER measurements in order to express the results in g of fumes per kg of weld metal (g/kg) in addition to FER in mg/s.

3. Results and Discussion: The complete results will be presented during forum session. An illustration of the results is presented here for low alloyed steel. The tests conducted with G2 *Sil70S-3* show that FER greatly depend on both C02 content in shielding gas and arc transfer mode.

The comparison of FERs between pulsed and globular arc transfer mode at the same deposit rate (wire feed speed: 6m/min) illustrates these results. FERs in pulsed mode are lower by a factor 4 to 5 in comparison with FERs in globular mode.

CO emission rate depends also on both arc transfer mode and shielding gas composition. However, it can be highlighted that in all cases, CO emissions with 100%C02 shielding gas is significantly higher than all the other argon based shielding gases.

Conclusions: In GMAW, fume and gases emissions depend on both arc transfer mode and shielding gas composition. Optimized operating conditions can be set to minimize GMAW emissions: For low alloyed steel, low oxidizing gas (Ar-C02 mix) can be recommended. Additional improvement can be reached for lower thicknesses working in pulsed mode with optimized shielding gas such as Ar-3%C02%02; while for higher thicknesses, ternary mixtures such as Ar5%C02-4%02 or Ar-12%C02-2%02 are preferred.

For stainless steel, pulsed mode transfer with low oxidizing gas such as Ar-2%C02 leads to the lowest emissions.

For aluminum alloys, it can be underlined that alloy composition strongly influence fume emission. Pulsed mode transfer with argon or argon/helium mix is the best combination.

Finally, it should be underlined that these results have been obtained in laboratory conditions. In operation, in addition to optimized shielding gas and welding parameters, extraction systems are usually necessary to trap or evacuate the emitted pollutants off the working areas in order to decrease their exposure as low as possible and fulfill national regulations.

Nicolas Floros (left) receiving his gift and award certificate from Geoff Melton who chaired this session

16:50-17:20

Structural Characterization of SnAgCu Solder Joint Interface with Bi and In Additions, Hodúlová Erika, Slovak University of Technology, Slovak

The design and production of lead free solder. To reduce or eliminate the silver in solder to satisfy the requests to lower the cost of lead free solders. 3 new solders were created, one without any silver, all had very similar melting points of approximately 218 degrees C.

Properties of lead-free solder alloys and microstructural characterization of soldered joints made from SnAgCu solder with Cu-plate have been widely studied in this work. Influence of Bi and In additions in these solder alloys were studied. The melting temperatures, diffluence and wetting properties, microstructures were observed and evaluated. The solder joints reliability were carried out for thermal cycling test. Optical microscopy, scanning electron microscopy (EDX microanalysis) and shear strength test were used for the evolution of microstructure, structural integrity and mechanical strength of thermal cycled solder joints.

17:20-17:50

Fabrication and Characterization of Scandate Cathode Sheet Beam for Terahertz Devices, Jinshu Wang, Beijing University of Technology, China

Introduction Vacuum electron devices have received considerable attention as one important kind of terahertz (THz) source. The generation of high-current-density sheet electron beams is a critical component among the challenging technologies which must be mastered to enable the realization of such devices. Among all the thermionic cathodes, scandate cathode is considered as the next generation high emission cathode which has attracted great interest. In recent years, we developed a new kind of scandate cathodes, submicron Sc203-W matrix dispenser cathodes by Sol-Gel method in the cathode matrix [2 3]. In this work, the scandia doped tungsten powder was fabricated in a new way of spray drying method. Based on the obtained scandate cathode, the sheet beams were fabricated.

2. Experiments The scandia doped tungsten powders were pressed and sintered into porous matrices of about 3mm in diameter and 1 mm in thickness. The matrices were impregnated with (411) barium calcium aluminates at temperatures of 1500 degrees Cb-1700 degrees Cb. Then, the cathodes were washed with deionized water in order to remove impregnate residues at the surface of the matrices. Then the cathode surface was coated with a tens of microns thick non-emission layer composed of molybdenum prepared by magnetron sputtering method. Several rectangle and square beams in dimension of several micrometers, have been generated by precision finishing. A heater was assembled to the cathode by welding method for measuring the emission property at different temperatures.

3. Results and Discussion The scanning electron microscope micrographs of the surface of scandia doped tungsten matrix cathode. The cathode has submicron microstructure and the pores distribute uniformly in the cathode. The micrograph of the cross-section of the cathode show that the cathode consists of sub-micrometer spherical grains with barium-calcium aluminates distributing at the interface of these grains.

A typical pulsed Lgl-LgU characteristic as a function of temperature from 850 degrees Cb to 900 degrees Cb tested in pulse conditions together with relative slopes and Jdiv is indicated. Pulse emission was measured with pulse width of 25 IJs and frequency of 100 Hz. The emission capability of the cathodes was measured after being activated at 1150 degrees Cb for about 2h before testing. The scandia doped impregnated cathode exhibits good emission properties, i.e., the current density of this cathode reaches 71.86A/cm2 at 900 degrees Cb with the slope of 1.46, indicating its good emission uniformity. Using the obtained cathode, the sheet beam was prepared by coating the cathode surface with a tens of microns thick non-emission layer followed by film etching method. Before etching, computer simulation was used to design and correlate the structures of cathode assemblies. One of the approaches to obtain sheet beam from cathode is to cover the round cathode with a tens of microns thick non-emission Mo layer, leaving a defined area for electron emission.

The precision finishing and metallic-membrane plating were used to prepare the orifice and emission suppressor layer. In this way, normal thermionic cathode can be applied in Terahertz (THz) electron gun easily. Several rectangle and square beams in dimension of several micrometers, such as 6001Jmx1001Jm, have been generated by the technique.

The emission properties of the sheet beam electron sources have been studied. Covering cathode with thick layer with taper edges of proper angles is possible approach to eliminate the beam crossing in front of the cathode. Anti-emission films were coated by magnetron sputtering to suppress the noise-emission caused by Ba oxide on anti-emission layer which was diffused from internal during the operating time. The 600jJm x 1OOjJm sheet beam obtained by such a structure loaded with current densities of above 50 *Alcm2* operated for more than 500 hundred hours at 950 degrees Cb. This sheet beam source can be applied in THz electron gun easily.

Conclusions The submicron Sc203-W matrix dispenser cathodes has been prepared using the scandia doped tungsten powder prepared by spray drying method. The space charge limited current density could reach *71.86A1cm2* with the slope of 1.46 at the operation temperature of 900 degrees C. Based on the obtained cathode, the sheet beam was fabricated by coating the cathode surface with a tens of microns thick non-emission layer followed by film-etching method. The 600jJm x 1OOjJm sheet beam obtained by such a structure loaded with current densities of above 50 *Alcm2* operated for more than 500 hundred hours at 950 degrees Cb

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18:30-20:30 Welcome dinner

We provided with a table served smorgasbord Chinese meal which in typical Chinese fashion well over fed. We were assigned seating which paired us with the individuals we had worked or introduced during our time of chair throughout the day. At the dinner, the University of Beijing students who had participated in the poster contest or who had participated caring for guests and in other ways helped with the conference were remembered. Dave Hisey and Geoff Melton, representing the IIW Commission VIII were on the platform to hand out certificates and awards to the participants and contest winners. It was a great evening and certainly one which will be remembered by all.

June 24st, 2017, Saturday   8:30 a.m.

Venue: Grand Gongda Jianguo Hotel（Meeting room on the third floor）

On this the 2nd day of the International Forum on Green Material and Processing Technology for Circular Economy (IFMP Beijing 2017), the time limit was 25 minutes, which was maintained for a while and then we ran over into our lunch time so that all speakers had sufficient time.

Chairman of this section: Dusan P Sekulic

8:30-8:55

Near Net Shaped Thermally Sprayed Coatings Achieved by Means of Industrial Robots, Wolfgang Tillmann, Dortmund University of Technology, Germany

The importance of using a 90-degree spray format was demonstrated. Ensuring the programming of the robot provides for a 90-degree spray gun pattern is vital. Unless the program is optimized the spray, coating will not be consistent across an irregular object. The more complex the object design the more strategic the robot programming must be, re-positioning of the robot is often where time can be reduced, in this process the programming strategies drive the quality of the product. The robot must always work at a 90-degree angle to the surface of the object.

Industrial robots are well established as spray gun handling devices in the field of thermal spraying. Despite the widespread use of industrial robots, in many cases complex geometries are still coated utilizing hand-operated spray systems. But even when industrial robots are used, the coating results are often insufficient (e.g. coating thickness inhomogeneity). The potential of industrial robots is not fully used and the coating results are insufficient due to the same cause: the coating of complex geometries requires an elaborate offline path planning with special knowledge about robot kinematics and the influencing handling parameters. To solve these problems, the handling parameters must be specifically adapted to the critical surface areas. However, a simple optimization of the path planning often can already provide a much better coating result. In the present contribution, an overview of the main influence factors will be given and some problem-solving approaches will be introduced. The main aim is to produce near net-shaped coatings, which directly reduce the consumption of expensive feedstock powders. Furthermore, the effort of post-treatments such as grinding to obtain the determined coating thickness is reduced. Both directly lead to shorter process times and a higher cost efficiency which are crucial for up-to-date processes.

8:55- 9:20

Recent Progress on the Laser Micro- and Nano-Manufacturing, Anming Hu, The University of Tennessee, USA
This presentation reviewed the laser technology for nanosintering, nanobrazing, photonic reduction, carbonization, 20-30 printing with specially highlighting nanomaterials for microdevice fabrication. It focused on the latest progress on laser brazing of Ni-superalloys, laser 3D direct writing of flexible sensors and 3D printing of thin film batteries. The author also discussed the future developing trend and introduction of laser-based super-resolution manufacturing.

9:20 - 9:45

Exposure of Welders to Electromagnetic Fields from Welding Processes, Geoff Melton, The Welding Institute (TWI), UK

Society is becoming increasingly aware of the health aspects of welding processes. Recently, in Europe a law has been published, limiting workers exposure to Electromagnetic fields (EMF). The EMF Directive 2013/35/EU which came into force on 1 July 2016 will have a significant impact on the welding industry and resistance welding. The Directive sets out to limit workers exposure to EMF from industrial processes and it is known that resistance welding and some arc processes produce elevated levels of EMF.

Basic physics show that the high currents involved in welding will create a high level of magnetic fields, to which the welder may be exposed. Furthermore, high frequency components of the field, as produced by inverters, ac and pulsed welding processes, produce magnetic fields that are more significant than those at power frequencies. In particular equipment that is hand held or processes in which components are held close to the electrodes may be significantly affected.

Conclusions: The EMF Directive is likely to have a significant impact on the fabrication industries in Europe and in time, the rest of the world. Companies will, by law, need to carry out workplace assessments of workers' exposure and in some cases, the fields measured or calculated may be above the action levels (ALs). The EMFWELD software will help companies to make this assessment and in some cases, enable a comparison to the exposure limit values to be made, demonstrating the process complies with the Directive.

Although the EMF Directive is now in force, it is still uncertain how this will be implemented and enforced throughout Europe. It appears that there will be differences between countries and some equipment will not be able to be used manually, which may necessitate changes in design and working practices, such as the more widespread use of welding robots.

References

[1] Hamnerius Y and Nilsson T, "Method to Assess Magnetic Fields from Welding Against the EU Directive on Electromagnetic Fields" 8th Int. Seminar on Advances in Resistance Welding, 10-12 September 2014, Baveno, Italy.

9:45 - 10:10

From Energy Efficiency to Fume Reduction-Welding in the Fields of Workplace and Environment

Presented by **Geoff Melton** on behalf of **Wolfgang Zschiesche**. German Institute for Social Accident Insurance and Occupational Medicine, Germany,

Introduction: Welding is one of the most often applied joining technologies worldwide. Together with its allied processes such as thermal cutting, spraying and soldering/brazing, an estimated number of over 15 million workers does regular or part time welding.

Therefore, questions of environmental hazards due to energy consumption, material consumption, health hazards from fume emissions into the environment and the storage of fume filters playa significant role in the economy.

The work environment is an important part of the overall environment. The welders and bystanders are under risk of health hazards due to emissions of fumes and gases, optical radiation and ergonomic aspects such as posture and awkward positions, which all can lead to complaints and diseases of the working staff.

2. Overall Environment

2.1 Energy consumption: Welding processes need considerable amounts of energy, which is mainly provided by electric current, which must be produced by power plants that are still often run by fossil fuels. This means a waste of energy resources of the earth on the one hand, and emission of fumes and gases at the power plants including

C02 with its greenhouse activity. Therefore, a reduction of energy consumption per meter weld would be an essential contribution to the protection of the environment.
At present, in a variety of countries and organisations like the European Union, approaches are under discussion, how to minimize the energy consumption in welding. One of the appropriate means could be replacing transformers by more intelligent electronic devices such as inverters at the work place. Also within the "Econweld" project, there has been a tool developed to estimate and to optimize the energy needed for special purposes according to the requirements of the producer.

2.2 Material consumption: the production of base metals and polymers that must been processed by welding technologies also consumes material resources and energy for their production. From this point of view, it is wise to minimize the amount of metal or other sheets for a special purpose. Losing material by wastage (e. g. by excess length that must been cut and by grinding of the weld) should be reduced to a minimum. There have been intelligent software solutions developed with this approach, e. g. within the "Econweld" project.

2.3 1m mission of pollutants into the environment: The emission of fumes and gases from welding shops (like from any other enterprise) is regulated and limited in almost all countries. If emissions into the environment would exceed the allowed levels (e. g. mass per hour, mass/m^3), further action must be taken to reduce these emissions, e. g. by appropriate filtering devices. This is cost and energy consuming, therefore even the emissions from the welding source should be minimized from the very beginning.

2.4 Storage of waste and filters: Filters that have been used to collect fumes and gases from welding processes must be handled and stored separately from other waste (e. g. in particular waste disposals that can be a hazard to the environment, mainly to the groundwater). Welding fume components that are assessed carcinogenic are critical. Again, it is wise to minimize the amount of these filter by reduction of the fume and gas emission at the welding source with the aim of cost reduction and reducing space for waste disposals.

3. The working environment Exposures to welding fumes and gases, to optical radiation and unfavourable position of the body can lead to diseases of the work force with the result of increased costs for the manufacturer and the social systems. Therefore, these exposures should be reduced and optimized resp. as far as possible. At least, the national regulations (e. g. limit values) should be observed.
3.1 Fumes and gases: Welding fumes and gases mainly affect the airways and the lungs. Possible health hazards are: -Acute asthma (rare in welding; more often in soldering and polymer processing) -Toxic lung edema (mainly from nitrogen oxides) which is life threatening -Chronic bronchitis and chronic obstructive lung disease (COPO) -Lung fibrosis (rare) -Increased risk of bacterial pneumonia (mainly from pneumococcus) -Excess risk of lung cancer: The International Agency for Research on Cancer (IARC) 2017 has evaluated all kinds of welding fumes, irrespective of their components, as proven carcinogens to humans (group 1). Also, the central nervous system is under suspect of being affected by manganese (Mn) in welding fumes. In the past, also aluminium (AI) has been under discussion of being neurotoxic, but no clear evidence has been provided.
Cadmium (e. g. from brazing) may cause severe kidney damage.

3.1 .1 Approaches to reduction of fume and gas exposure: The primary step is to minimize the fumes emission by choosing welding technologies that provide only little fume emission. This can be reached by applying low energy technologies, pulsed arc techniques etc. The emission of carcinogenic chromates (CrVI) when welding high alloy steels can be significantly reduced by replacing welding with covered stick electrodes or self-shielded flux core wires by gas metal arc welding with solid wires (GMAW); TIG welding provides the lowest fume emissions.

An additional mean of protecting the welders and other staff in welding shops is the use of appropriate general ventilation and local fume extraction devices at the source of welding fumes and gases.
Another protective measure is the use of personal protection of the airways by filtering masks or by using helmets with fresh air supply.

3.2 Optical radiation Optical radiation from the arc and from the flame can cause severe burns of the skin and ocular damage. There has been some excess risk of malignant melanoma of the eyes found in several studies on arc welders. The International Agency for Research on Cancer (IARC) 2017 has evaluated ultraviolet radiation (UV) from the welding arc as proven carcinogenic to humans (group 1).
Therefore, appropriate personal protection of the eyes and the skin is always necessary. Staff other than welders should be protected by limitations of staying in the vicinity of welding activities and by appropriate protective devices such as radiation absorbing curtains.

3.3 Ergonomic aspects A significant part of sickness leaf of welders is due to diseases of the musculoskeletal system. Therefore, it is important that the welding position is being optimized and that unfavourable positions are being avoided. Respective approaches are adaptable welding tables and devices to keep the base metals in an optimum position.

4. Conclusions Welding and its emissions of fumes, gases and other exposures affect the overall environment as well as the work environment. Reducing the respective emissions in general and the exposure of the staff by appropriate means on various levels can lead to a reduction of energy consumption, consumption of material, protection of the environment and of the welders and reduces sickness leaf. All together, these approaches provide a benefit for the general environment and for the work force. Optimizing these approaches leads also to cost reduction.

10:10-10:30 **Coffee break**

Chairman of this section: **Dietrich Rehfeldt**

10:30-10:55
A New Technology of Air Pollution Control in Welding and Remanufacturing, Yanbin Wang, Aerospace Kaitian Environmental Technology Co., Ltd, China

This presentation described both China’s standards around air quality control as well as very high-quality air purifying equipment that they have installed. This presentation did not deal with the removal of gaseous material except through an air exchange process.

The process of welding and remanufacturing will produce harmful gases, such as fume, dust, VOCs and oil mist, which are harmful to the operator. When the operator is working on a long-term operation under poorly environmental conditions, he might be infected with some occupational diseases. Therefore, installing an appropriate ventilation system to eliminate the harmful gases and dust is extremely important for operator's health conditions. The industrial ventilation system can separate in two types, one is the comprehensive ventilation, and another one is the partial ventilation. The comprehensive ventilation system can purify and eject the contaminated air to keep the factory environment in a good condition. The technology that we applied on this system is called whole plant stratified air supply, which include the functions of dedusting, dehumidification and temperature control. With the development and popularization of Internet, building environmental smart service platform, who achieves ventilation dust-removal system remote control, intelligent diagnosis, after sales service functions, can ensure reliable operation of our environmental protection equipment. Through environmental smart service platform large data and optimizing the operation parameters of equipment, it will make the ventilation dust-removal system becomes more efficient for purification of harmful gases.

10:55-11:20
Progress on Welding Safety Protection, Zebing (Mark) Ou, Group 3M China, China
Among the three elements of welding process, the welder is the first element and the most active factor. The level health determines how long the welder can efficiency serve the enterprise continuously. Although welder's safety awareness and protection equipment have great progress in recent years, there are still welding occupational injuries reports frequently. Welding safety education and protection are still insufficient. Management and employee's safety awareness, welders' safety and health education, welding safety standards and welding PPE standards become key factors affecting welding protection. Encourage welding occupation safety and health study, push universities, vocational colleges, welding training organization and enterprises to strengthen welding safety and health education, revise current welding safety and welding PPE standards to upgrade safety level and keep industry sustainable development. Vocational welding technical training colleges provide a 3-year training curriculum for welders. Data shows that as time progresses, injuries and illnesses are in the decline. A survey which included qualified welders and technical engineering graduates, indicated a lack of understanding for the correct use of PPE.

11:20-11:45
Advances on Global Green Arc Welding Materials, Zhuoxin Li, Beijing University of Technology, China

To meet the requirements of environment and automatic welding, arc welding consumables in the world need to be higher in strength and toughness, be cleaner, more energy-saving and environment-friendly, and highly efficient as well as automatic. In this presentation, the recent global research progress on green arc welding consumables was reviewed, especially environment-friendly copper free solid wires, metal-cored wires for high strength steels welding, stainless steel flux-cored wires of low Cr(VI) emission, and aluminium alloy wires with high performance.

12:45-13:00 **Closing Ceremony** Wolfgang Tillmann and Zhuoxin Li
13:00-14:00 **Lunch**

Round table conference

Venue: Grand Gongda Jianguo Furong Hall
Time: 2017, June 24th, 2:30-4:00

Host: Professor Wolfgang Tillmann, Professor Li Zhuoxin

Main topics: Environment and energy materials and green processing technology

Purpose: To give expert reviews and scientific suggestions on key issues and technical problems, to provide guidance, direction and show international cooperation to the to research project of the Green Material and Processing Technology for circular economy and sustainable development of Beijing Society and Economy.

Round Table conference getting underway

- Professor Tillman provided a summary and drew conclusions from the International Forum on Green Material and Processing Technology for the Circular Economy which had just concluded before lunch.
- We were split into 3 problem solving groups to complete our various assignments. The conveners had been given previous direction as to their responsibilities, which was to lead a 30-minute group discussion on their assigned topic

Group #1: Environment and energy materials and green processing technology

Convener: Prof. Jinshu Wang

Attendees: Prof. Wolfgang Tillman, Prof. Dusan Sekulic, Prof. Wenyi Wang, Prof, Guangfen, Assoc. Prof. Chenlu Bao, Assoc. Prof. Hong Li.

Group 5 hard at work: Prof Wolfgang Tillman in white shirt and Prof. Dusan Sekulic (grey suit) to the right.

Group #2: Green additive manufacturing and remanufacturing engineering technology.

Attendees: Prof. Shicheng Wei, Prof. Zhuoxin Li, Prof. Dietrich Rehfeldt, Dr. Chenfeng Zhao

Group 2: Assoc. Prof. Hong Li (leaning forward white jacket) leading the discussion with Prof. Zhuoxin Li

Group #3: Environmental and occupational safety and health during manufacturing processes

Convener: Mr. David Hisey and Mr Zebin (Mark) Ou

Attendees: Mr. Junjie Zhang, Mr. Tao Wang, Mr. Stephen Hedrick

Group 3 at work: seated L to R: Nicolas Floros, Steve Hedrick, Dave Hisey, Mark Ou, Tao Wang, Junjie Zhang

Steve Hedrick leading the discussion, Dave Hisey and Nicolas Floros look on intently

Group 3 Recommendations:

If you have a reasonable level of rules and regulations (we can always improve) around worker safety and excessive problems still exist, then the rules and regulations are not being followed by employers and their workers.

1. **Audit to ensure compliance.**
    a. **Auditing should be by the company/employer**
    b. **Follow-up compliance should confirm audit results.**
2. **Perform accident/incident follow-up as an education tool not an enforcement tool.**
    a. **Use external experts to understand accident/incident**
    b. **Create publication to share findings**

- **Responsibilities:** Provide a summary speech of the team discussions with the final agreement provided in both Chinese and English languages.

- Provide a formal document in English with all attendees' signatures.

- The Beijing Natural Science Foundation and Beijing Municipal Commission of Technology provided formal closing speeches in Chinese language only.

- Adjournment – 4:30 pm