Thursday July 20, 2023

11:00-12:30 Session 1 Keynote and Invited (Session Chairs: Stephan Egerland, Wei Zhou)

1. 11:00-11:10 Opening Addresses:
   YuMing Zhang, University of Kentucky
   Stephan Egerland, Fronius

2. 11:10-11:50 Keynote: Hybrid Intelligence Problems in Intelligentized Welding Manufacturing Systems.
   Shanben Chen, Shanghai Jiao Tong University

   Abstract: This speech investigates an intelligent science problem produced by the compound application of various AI technologies in the intelligentized welding manufacturing systems (IWMS), i.e., the hybrid intelligence (HI) problem in the IWMS, it is a commonly neglected, confusing and basic intelligent science problem in research and application of the IWMS, how to evaluate the intelligent performance of the IWMS, and with what standards and indicators to evaluate an IWMS, especially it contains a variety of AI technologies, methods and algorithms of composite application. Based on the technological constitution of the IWMS, this speech discusses the hybrid or compound, multiple and mixed effects of different intelligent methods and technologies applied in IWMS, which includes the HI problems existing in multi-source information sensing, knowledge modeling of arc welding process and intelligent control methodology for welding dynamic process; and the HI problems existing in intelligentized robotic welding process and systems.

   Bio: Shan-Ben CHEN received his Ph.D. degree in 1991 from Harbin Institute of Technology, P. R. China. He was awarded the Distinguished Professor position, Cheung Kong Scholar Program* of Ministry of Education of P. R. China & Li Ka Shing Foundation, Hong Kong, and engaged in Shanghai Jiao Tong University, P. R. China from 2000. He is currently the director of Intellgentized Robotic Welding Technology Laboratory, School of Material Science and Engineering, Shanghai Jiao Tong University.

   Prof. CHEN's research interests include intelligentized technologies for welding robot, intelligent control of welding dynamical process, modeling and control of complex systems, robust control of uncertain systems, and relevant ranging in welding automation and advanced welding manufacturing. He is the author or co-author of 10 academic books and more than 300 journal papers.

   Prof. CHEN is the former Chair of Robotics & Automation Committee of Chinese Welding Society (CWS) from 1996 to 2022. As the Initiator, Prof. CHEN organized and presided over a series of the International Workshop on Intelligentized Welding Manufacturing (IWIWM) every two years from 2017; and organized and presided over a series of International Conference on Robotic Welding, Intelligence and Automation (RWIA) every four years from 2002. As one of Editors in Chief of the TIWM, Prof. CHEN founded "Transactions on Intelligent Welding Manufacturing" (TIWM) at Springer in 2017. He is a Senior member of IEEE from 1995.

   Homepage: http://rwlab.sjtu.edu.cn/Article?ID=297

3. 11:50-12:10 Invited: Driving Towards Flexible and Automated Robotic Multi-Pass Arc Welding. Charalampos Loukas, University of Strathclyde

Charalampos Loukas[1], Veronica Warner[2], Richard Jones[2], Charles N. MacLeod[1], Gordon Dobie[1], Jim Sibson[2], Stephen G. Pierce[1] and Anthony Gachagan[1]
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Abstract: There is a need for automated intelligent welding systems in multiple industrial manufacturing and repair scenarios, especially for Small to Medium Enterprises (SMEs) where production flexibility is required. Although welding robots are an important enabler for intelligent welding systems, traditional manual teaching of robot paths and allocation of welding parameters for multi-pass robotic welding is still a cumbersome and time-consuming task, which decreases the flexibility, adaptability, and the potential of such systems.
The developments of a compact, autonomous, and flexible robotic welding system are presented herein, consisting of a small (500 mm reach) 6-DoF robot with a flexible mounting arrangement for varying weld applications deployment. Optical and tactile sensing are utilized to identify, adapt, and autonomously extract the feature characteristics of single-sided V-groove geometries while robotic motion is purely sensor-driven in real-time allowing the generation and adaption of the welding paths to varying V-groove geometries and random poses of the joint configuration.
To fulfil the need for automated robotic welding, a new adaptive fill sequencing framework is presented, enabling automatic planning of multi-pass welding for single-sided V-groove geometries. Driven with commercial aspects in mind, a novel cost-function concept has been permutated to identify the optimum welding parameters for each welding layer through a user-driven weighting, delivering the optimum combination of the number of passes, filler material and welding arc time based on application requirements.
The concept methodology and framework were verified experimentally, through automated robotically deployed Gas Metal Arc Welding (GMAW) developed system. For a given representative joint, the arc welding time and filler wire requirement were found to be 32.9% and 26.2% lower respectively, than the worst-case available welding parameter combination, delivering a corresponding decrease in direct manufacturing costs. An ultrasonic inspection was also undertaken to verify the consistent quality of the weldments and validate the framework outcomes for enabling future successful exploitation.
Keywords: Robotic welding, Sensor-enabled, Automation, Manufacturing, Real-time systems
Bio: Dr Charalampos Loukas is an Electrical & Computer Engineer and currently a Research Associate for the Sensor Enabled Automation Robotics & Control Hub at the University of Strathclyde, holding a PhD in Holistic & Adaptive Robotic Welding with Babcock International Group PLC. Having built a strong skillset in sensor-enabled high-integrity welding and real-time robotic control for metrology inspection, looking forward to shaping the growth of the heavy manufacturing sector. His research interests include sensor-enabled robotic automation for metrology inspection of high value manufacturing assets, computer vision, arc-welding processes, and applied machine learning techniques for industrial automation.

4. 12:10-12:30 Invited: Augmented Virtuality Human-robot Interactive Welding: Principles and Applications.
   Wenhua Jiao, University of Kentucky

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1. Nanjing Tech University, Nanjing, Jiangsu, China
2. Zhejiang Shuren University, Hangzhou, Zhejiang, China
3. University of Kentucky, Lexington, Kentucky, USA
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Abstract: This work develops a new human-robot interactive welding system. In this system, a human operates a virtual torch in a virtual reality (VR) based welding environment, away from the welding site. Its movement is captured by VR sensors as the basis to operate a robot to perform the actual welding. The robot is installed with weld sensors to capture the actual welding process so that the human can react similarly as at the actual welding site. In addition, raw signals from the weld sensors are processed by machine intelligence/deep learning to extract critical information. Such extraction is beyond the limits of human capabilities. An augmented virtuality welding environment with enhancement from machine intelligence is thus provided to allow the human to better react to the process. As the human is not directly operating the robot but through a robot controller, human operation imperfections such as torch shaking and seam tracking errors may be filtered out/corrected. This provides a shared control between humans and robots to combine their strengths while overcoming weaknesses. Unique novel capabilities provided include reduced requirements on welder's training/skill/physical strengths, improved protection of welders, and eased robotization for complex welding tasks that currently rely on human interaction with the process. This paper details the novel system and its three novel applications.
Bio: Dr. Wenhua Jiao received his BS and PhD degree in electrical engineering at the University of Kentucky in 2015 and 2020, respectively. He joined the faculty of College of Electrical Engineering and Control Science, Nanjing Tech University, China in 2021. His research focuses on learning of complex human welder intelligence from big data generated from augmented and virtual reality welding systems and has brought over 10 journal publications. Dr. Wenhua Jiao won the IIW Henry Grangon Prize Category D in 2023 on behalf of the USA/University of Kentucky.

13:30-15:00 Session 2 (Session Chairs: Yonghua Shi, Charalampos Loukas)

1. 13:30-13:45: Fuzzy Control of Backside Weld Width in Cold Metal Transfer Welding of X65 Pipeline at The Vertical-up Position.
   Zhijiang Wang, Tianjin University

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Abstract: Reasonable backside weld geometry of the root-pass welding is the basic guarantee for good fatigue performance of the weld joints. At the vertical-up (3G) position, the change in the force direction of the molten pool makes the degree of penetration reduced, such that a small disturbance in the welding process will lead to uneven weld shaping and discontinuous weld penetration states. In order to obtain a good weld penetration state for root pass by cold metal transfer (CMT) welding in the vertical-up position, a control strategy applicable to CMT root-pass welding was proposed. The backside weld width (Wb) was related to the welding heat input (HI) and the peak current time ratio (PTR). As per that base current almost did not affect the long period and the long period tended to disappear in the range with small peak current or wire feed speed, a welding program with a stable PTR was designed, and the Wb prediction model was simplified to be only related to HI. Based on the simplified model, a fuzzy controller was designed and its control effects for the Wb in the CMT root-pass welding were tested. The experimental results proved the validity of the control strategy under normal fit-up conditions and the condition with varying misalignments.
Keywords: Heat input, Peak current time ratio, Backside weld width, Fuzzy control, Vertical-up (3G) position, CMT root-pass welding

2. 13:45-14:00: Robotizing Flexible Double-electrode GMAW Process through Machine Vision and Deep Learning.
   YuMing Zhang, University of Kentucky

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Abstract: The double-electrode gas metal arc welding (DE-GMAW) process is complex but promises separate controls of deposition rate and heat input. Past success in operating this process relies on fixing the relative position between the two electrodes. However, the needed relative position varies with the welding conditions. The relative position thus must be adjusted in real-time to sustain the bypass arc so that DE-GMAW requires an adaptive flexible robotic system to operate. As it is challenging to decide how the bypass electrode should be adjusted, we propose to learn from human welders. This talk presents our first results in learning from huma welders and deep learning-based monitoring of the DE-GMAW to decide if the process operates in the

desired state. The research is funded by the National Science Foundation under Grant 2024614 "NRI: FND: Intelligent Co-robots for Complex Welding Manufacturing through Learning and Generalization of Welders Capabilities".

3. 14:00-14:15: A Machine Vision-based System for Weld Bead Profile Extraction During Multi-layer Multi-pass Welding Process.
   OR-12-0067
   Van Doi Truong, Hanyang University, Korea

Van Doi Truong[1,3], Hyunkyo Lim [1,3], Seungbeom Jang [1,3], Wonjoo Lee [1,3], Seong-Je Kim [1,3], Jangwook Lee[4] and Jonghun Yoon [2,3,*]
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Abstract: Multi-layer multi-pass welding plays an important role in shipping-building, nuclear power plant, pressure vessel manufacturing. The inspection of welding bead is necessary to automatically control the path planning, evaluate the quality of welding process. In this paper, we proposed the real-time visual monitoring of the weld bead in welding process based on structured light system. The combination of segmentation and RANSAC method is developed to find weld bead profile of each layer. As a result, the weld bead parameters including weld width, height and layer profile are extracted. Besides that, the seam line tracking algorithm is applied to determine the misalignment of weld path. Finally, a series of validated experiments are conducted to demonstrate the efficiency of proposed method with high accuracy.
Keywords: Multi-layer multi-pass welding, Seam tracking, Computer vision, Feature extraction

4. 14:15-14:30: Weld Localization and Defect Identification Based on Deep Learning.
   OR-12-0086
   Xiaoteng Zhu, Beijing Institute of Petrochemical Technology

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Abstract: The most crucial technique for joining different metal parts is welding, and the effectiveness of the welding process directly determines how long welded constructions will last. Some welding errors will unavoidably happen throughout the welding process due to technical restrictions. The automatic recognition model of typical weld defect is built through the automatic learning of features using deep learning technology to improve the precision, effectiveness, and level of automation of detection. The defect recognition technology based on deep learning can achieve real-time processing and has the properties of automatic learning of complex deep features in images, and has strong practicability when compared to the traditional physical detection technology and machine vision detection technology. The lightweight Ghost network is used in place of the original model's backbone feature network based on the YOLOv5 model. In parallel, the original data set is expanded using the Mosaic+Mixup data augmentation approach, which enables the detection of laser welding flaws such bite-edge, stomata, weld-tumors, and burn-through. It is contrasted with various network architectures through a vast number of trials. Precision (P), recall (R), average precision (AP), mean average precision (mAP), and frames per second (FPS) were all thoroughly evaluated. The model's internal network structure was adjusted, and deep learning's potential for detecting weld image defects was investigated. The test findings demonstrate that the deep convolution network has a significant capacity for characteristic learning, and that the suggested network has a high degree of computational efficiency and classification accuracy.

Keywords: Deep learning, Defect detection, Convolutional neural network, Precision

5. 14:30-14:45 A Real-time Modified Analytical Weld Pool Model to Measure The Penetration in GTAW Based on 3D Weld Pool Surface.
   OR-12-0349
   Shaojie Wu, Tianjin University

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Abstract: The shape underneath the weld pool surface cannot be measured directly or routinely during the welding process, which limits the development of welding automation. To address this challenge, the authors proposed a method to indirectly obtain the shape underneath the weld pool surface in GTAW by using the in-situ modified analytical weld pool model. This analytical model which can calculate time-varying process parameters (time-varying current or time-varying welding speed) was first established, and was mathematically converted into a recursive analytical model to improve the computational speed by reducing the computational effort. Then, a dot-matrix structured light based 3D vision sensing system was built to reconstruct the 3D weld pool surface based on LSTM network. The deformation of the top of the weld pool due to the increased arc pressure was also considered. Finally, a calibration algorithm established according to the correspondence between the heat source parameters of analytical model and the information of the 3D weld pool to modify the analytical weld pool model in real-time, which further realized the real-time calibration of the analytical model.

Keywords: GTAW; Analytical calculation of thermal processes; Weld pool measurements; Temperature distribution calibration; Measurements of GTAW penetration

6. 14:45-15:00 Development of Machine Learning Model for Trajectory Deviation Detection in Multi-pass TIG Welding in A Narrow Gap.
   OR-12-0058
   Theo Boutin, University of Montpellie, France

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Abstract: For many years, fusion welding has been one of the most used processes in many industries for assembly of small or large components. To guarantee the safety level of the assemblies, the weld must be flawless. Today, quality control of operations is carried out during manufacture or afterwards by non-destructive methods (X-rays, ultrasound, dye penetrant testing etc.). These methods are costly, time-consuming, require the expertise of the inspector and are carried out after the assembly has been completed.
To improve in-situ welding control, the present work develops a new method to detect a deviation in the welding trajectory based on a Machine Learning model to anticipate the occurrence of defects in a narrow gap. A regression model is developed and is fed with experimental data from several synchronized sensors implemented around the TIG process with material input. We identify two main sources of data. On the one hand, the monitoring of the process parameters is performed (voltage, current, etc.). On the other hand, the evolution of the dynamics is monitored by two cameras (behind and front of the weld pool). An image processing algorithm is developed to extract the weld pool contour and its associated characteristics (length, width, area, etc.). All these data are ordered, stored, and labelled in a database for quick and easy processing. In addition, the database is created to train, test and validate the ML model. To test the ability of the ML model to predict the welding trajectory deviation, artificial deviations are introduced during welding. Different training models are tested to analyze their predictive character in a well-defined parametric domain in order to anticipate the defects appearance.
Keywords: Welding, Welding physics, Image processing, Machine learning

15:30-17:20 Session 3 (Session Chairs: Zhijiang Wang, Wenhua Jiao)

1. 15:30-15:50: Invited: ISTM: A Robust and Semi-supervised Seam Tracking Model Using An Interactive Segmentation Model.
   Yonghua Shi, South China University of Technology

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   Abstract: Weld path recognition and seam tracking are of great importance in automatic welding. The former instructs welding robot to locate the start welding point(SWP) and the latter guarantees that the robot will not deviate from the welding seam. Currently, laser tracking algorithm has been fully developed so that some are available in market, for example, the TH6D laser vision sensor from company Scansonic. However, although laser sensor has an advantage of high accuracy, the laser products stay in high prices, more than labor cost. That is the main reason why laser tracking has not been generalized in welding industry yet. By contrast, passive vision based tracking algorithm can retrench the spending with sacrificing accuracy and robustness. Therefore, an accurate&robust but semi-automatic passive vision based welding path recognition and tracking model was proposed in this paper, called Interactive Seam Tracking Model (ISTM). The ISTM consists of an interactive segmentation model which must be fed the guiding information from operators, like a point specifically. Then the model will recognize the zone to be weld with a simple pixel scanning algorithm extracting the center line and width. The result of 11 offline and online experiments, including different materials, various thickness and distinct types of groove, showed that the maximum error of ISTM is 1.1789mm and 1.9621mm in offline and online deviation detection respectively. Among the data from those experiments, only four groups of them make up the training dataset and three are validation dataset while the rest is testing set, which verify the robustness of the proposed model.
   Keywords: Weld path recognition, Seam tracking, Interactive seam tracking, Model, Interactive segmentation, Model robustness
   Bio: Dr. Yonghua Shi is a Full Professor in the School of Mechanical and Automotive Engineering at the South China University of Technology and the head of the Department of Mechatronic Engineering. His areas of research cover underwater welding, robotic welding, sensing and control technology in manufacturing, and additive manufacturing. Currently, his research focuses on deployment of intelligent algorithm on welding industry and underwater welding quality monitoring. He has published more than 70 research articles in reputed international journals and conference proceedings, and attained more than 15 authorized invention patents.

2. 15:50-16:05 Monitoring The Forming Dimensions of Arc Directional Energy Deposited Components Based on The Geometric Characteristics of Molten Pool.
   Shengfu Yu, Huazhong University of Science and Technology

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Abstract: To monitor the real-time size of components formed by arc directed energy deposition (ADED), a deposition size monitoring method based on the molten-pool geometric characteristics was established, including molten-pool image calibration, molten-pool contour extraction, contour coordinate calculation, and deposition size modeling. Image calibration was firstly performed using the molten-pool imaging transformation matrix to accurately correspond the pixels of the image to the actual spatial position. Then, an adaptive threshold segmentation algorithm was adopted to extract the contour of the calibrated molten-pool image, and the contour was further completed using breakpoint coordinates and their gradient information. The minimum bounding rectangle algorithm was adopted to fit the contour coordinates to obtain the width and height of single-pass deposition, and a mathematical model of multi-pass and multi-layer depositional size was established through the parabolic model and the equal volume algorithm, thus realizing the deposition size monitoring based on the molten-pool image. Finally, the rocket engine shell was manufactured by ADED and the depositional forming size was monitored in real-time. The overall average size deviation of the component was within ± 2.41mm, indicating a high forming accuracy.
Keywords: Arc directed energy deposition; Molten-pool monitoring; Image processing; Forming size

3. 16:05-1620: Synergetic Effect of Feedforward and Feedback Control for Deposition Height in WAAM Based on Visual Sensing.
   Jun Xiong, Southwest Jiao Tong University

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Abstract: Wire and arc additive manufacturing (WAAM) has been demonstrated to be a powerful technology to produce large-scale metal parts with low cost. However, techniques to achieve accurate geometry control and high process stability are yet to be perfectly developed. Although implementing vision sensing and feedback control contributes to promoting the levels of process automation and stability, it is difficult to markedly improve the geometry precision of parts by only performing the current layer detection due to a large detection lag with vision-based sensors. To deal with this issue, this research proposes a novel collaborative strategy of feedforward and feedback control for deposition height in WAAM. A novel multi-channel monocular vision sensor is developed to monitor different geometrical sizes, i.e., current layer to nozzle distance (CLND) and previous layer to nozzle distance (PLND). The CLND and PLND features are extracted by image processing algorithms mainly including edge detection, threshold division, and line fitting. Deviations in deposition height are automatically compensated via controlling the wire feed speed.

Compared with the feedback control using only the CLND detection, the deposition height of thin-walled parts can be excellently controlled by the proposed control strategy using the visual sensing of PLND and CLND, significantly increasing the process stability and achieving accurate height control in WAAM.

4. 16:20-16:35: Predicting Porosity in Wire-Arc Additive Manufacutring (WAAM) Using Wavelet-Scattering Networks and Sparse Principal Component Analysis.
OR-12-0042
Joselito Yam II Alcaraz, KU Leuven

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Abstract: WAAM or Wire-arc Additive Manufacturing is getting a lot of research attention because of its cost-effectiveness in large-part metallic production of complex parts. In pursuit of best-quality products and minimizing material loss, multimodal process monitoring methods is key. This paper presents the use of acoustic signals (both airborne and structural) in identifying one of the critical defects in WAAM, i.e. porosity. Unalloyed steel and aluminium was deposited in a controlled environment which developed different amounts of porosity alongside measurements from current and gas sensors. Feature reduction of the signals was carried out by using a combination of wavelet scattering networks and sparse-Principal Component Analysis (sPCA). While the models predict the porosity reasonably, the dominant features that are learned by the model are also investigated and reported.
Keywords: Additive manufacturing; Wire-arc additive manufacturing; Wire direct energy deposition; Process monitoring; Defect detection; Signal processing; Feature extraction; Wavelet scattering; Principal component analysis

5. 16:35-16:50: Welding Methodologies for Autonomous Robotic Arc Welding Using Computer Vision and Machine Learning
OR-12-0216
Mahyar Asadi, Novarc Technologies

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Abstract: The integration of artificial intelligence in welding is rapidly increasing, with smart vision systems being a popular front line for data collection in arc welding processes. These systems are designed to learn and improve over time, and continuously enhance the welding process from its current state. Autonomy is a requirement in the current welding industry for eliminating human risk factors and controlling the fabrication process to adapt the relative welding parameters to the weldment's condition. In response to this demand, this work focuses on the development and implementation of vision-based AI models for real-time understanding of weldment conditions

under the welding pool. The system is integrated into a pipe welding robot with gas metal arc welding (GMAW) and enables the robot to adaptively react to the pipe's variation. Our main implementation of the system is demonstrated on groove and fillet welding of pipe at 1G position, but the method can adapt to other weld configurations through optimizations and machine learning techniques such as transfer learning. In this paper, we provide examples of successful transfer learning to articulated robots for other weld configurations, demonstrating the versatility and potential of the approach. We also present a platform that collects welding experience globally and provides actionable insights through the analysis of vast amounts of data. Our solution demonstrates the potential of incorporating the perception and cognition of welders into the machine for improving the consistency, throughput, and quality of arc welding processes.
Keywords: Robotic arc welding, AI in welding, Vision system, Adaptive control, GMAW, Transfer learning

6. 16:50-17:05 A Study on Development of Weld Penetration Estimation Method using Weld Pool Images and Deep Learning Approaches in Gas Tungsten Arc Welding.
OR-12-0308
Daehyun Baek, Korea Institute of Industrial Technology

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Abstract: Gas tungsten arc welding (GTAW) is one of the most popular welding technologies for joining metal parts. Due to its stability and high quality, GTAW has been playing an important role in applications such as shipbuilding, pipe and pressure vessel welding. However, a lot of GTAW processes are still performed manually in many construction fields. The manual welding is time-consuming and inefficient, and the welding quality is completely dependent on welder's skill. While various automatic welding methods without user intervention have been developed, it is still challenging to control weld quality due to the difficulties in in-process prediction of the weld penetration depth.

This study proposes an effective and highly accurate in-process prediction approaches for weld penetration depth using topside weld pool images and deep learning approaches. The topside weld pool image is closely related to the welding quality such as penetration depth and back bead shape. In this study, two deep learning-based methods for weld penetration prediction were proposed, a weld penetration prediction model based on ResNet-50-based semantic segmentation [1] and an end-to-end prediction model that directly predicts quantitative penetration depth from the weld pool images using convolutional neural network (CNN) architecture. Through these proposed methods, the weld penetration was able to be accurately and efficiently predicted using only weld pool image. Also, accurate prediction of penetration depth can be applied to real time weld quality control to guarantee the sound weld back bead.
[1] In-process prediction of weld penetration depth using machine learning-based molten pool extraction technique in tungsten arc welding, Journal of Intelligent Manufacturing, https://doi.org/10.1007/s10845-022-02013-z

7. 17:05-17:20: Video Enhancement for Visual Assessment of Welding.
   Mahyar Asadi, University of British Columbia

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Abstract: Welder's visual assessment and control of welding are major factors in ensuring high-quality welding in various types of welding, including Gas Metal Arc Welding (GMAW). However, this visual monitoring is less effective in defect monitoring and detection because the formation of defects may not have a clear indication for visual assessment by welders. On the other hand, human visual monitoring represents a significant portion of the total labor costs for industrial products, accounting for over 10% [1], and is therefore critical for automation.

To address this limitation toward better automation, we propose using Eulerian Video Magnification (EVM) [2] to enhance the video of the weld pool during GMAW. EVM is a video processing technique that magnifies temporal subtle movements of molten metal, making changes easier to detect through visual monitoring during welding. The EVM method [2] estimates the motion signal by using the first-order Taylor expansion of two consecutive video frames and generates magnified video by adding the magnified motion signal to the original frames.

By magnifying the movements of the melt pool, EVM provides more effective visual monitoring of melt flow behavior resulting in better porosity detection during the welding. To assess the effectiveness of our proposed approach, we conducted a subjective video quality test, reporting mean opinion score (MOS) to evaluate the visibility of melt flow behavior in the enhanced videos compared to the original ones.

In summary, our study demonstrates the potential application of the EVM method [2] to improve the welding quality by enhancing the visual monitoring of the weld pool toward more precise defect detection.

Keywords: Defect detection, Motion magnification, Video enhancement, Eulerian video magnification method

Friday July 21, 2023

09:00-10:35 Session 4 (Session Chairs: Zengxi Pan, Abhay Sharma)

1. 09:00-09:20: Invited: In-situ Detection of Weld Quality Using Laser Ultrasonics toward Intelligent Welding Manufacturing.
   Satoru Asai, Osaka University

   Satoru Asai*, Kazufumi Nomura**, Keiji Kadota*
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   Abstract: To realize intelligent manufacturing, we are developing a monitoring system that in-situ detects welding quality using laser ultrasonics. The advantage of the laser ultrasonic method is that ultrasonic waves can be generated and detected remotely without contact, making it possible to measure high-temperature fields during welding. As for the basic configuration of the laser ultrasonic system, a YAG laser with a wavelength of 1064 nm, a pulse width of 8 nm, a repetition rate of 100 Hz, and an average output of 90mJ was used as the generation laser, and a laser interferometer was used as the detection laser. This paper describes the effectiveness of in-situ detection technology for welding defects such as solidification cracks and incomplete fusion in MAG thick plate welding using laser ultrasonic method with the synthetic aperture method as an in-process monitoring of welding quality. In addition, it was clarified that the development of a new algorithm enables in-situ detection of blowholes in lap fillet welding of galvanized steel sheets. As a practical system, we developed a robot system using a small and light microchip laser with a weight of 1 kg as a generation laser. The microchip laser has a pulse energy of 20 mJ, a pulse width of 1 ns, and a repetition rate of 100 Hz. It is mounted on the robot with a small galvanomirror box and a focusing system, and can be scanned in the direction perpendicular to the weld bead. Furthermore, we are promoting the application of this technique to Laser welding and Additive manufacturing.
   Bio: Satoru Asai has worked for Toshiba Corporation and carried out the development of high efficiency welding process and automatic welding system with sensors in power generation field since 1980. In 2015, he was a Professor at Dept. of Materials and Manufacturing Science, Graduated School of Engineering, Osaka University. He researches about sensing technology for welding control, monitoring method for arc process and quality control based on arc physics. After retiring in 2015, he continues to research the implementation of laser ultrasonic technology as a Specially Appointed Professor of Joining and Welding Research Institute in Osaka University. Also, he has contributed as a chairman of Commission-XII "Arc Welding Processes and Production Systems" for International Institute of Welding.

2. 09:20-09:35: Adaptive Threshold Optimization based Incremental Learning Strategy for Online Monitoring of Pipeline Weld Crack Leakage.
   Zhifen Zhang, Xi’an Jiaotong University

   Jing Huang, Zhifen Zhang*, Rui Qin, Guangrui Wen, Wei Cheng and Xuefeng Chen

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Abstract: The leakage of pressure pipe weld cracks formed under the action of high-stress concentration and external alternating loads is a major hidden danger in the safe service of nuclear power ships. The micro structure difference and macro dynamic expansion of weld cracks cause the leakage state to drift continuously with the change of time and environment. To address the above problems, this paper proposes an incremental learning strategy with adaptive threshold optimization ability. Firstly, an affinity threshold is introduced to improve its stability when separating overlapping clusters and facing different acoustic emission input signals. Secondly, a depth-first search algorithm is used to label the category of neurons identified by the Enhanced self-organizing incremental neural network. On this basis, the RBF neural network is trained to obtain the class labels of the states, so as to realize online increment learning. Finally, the validity of the proposed method is verified by three well-thought-out circumferential, axial and curvilinear pipeline weld cracks. In addition, the effect of parameters such as the number of connected edges of neurons, the insertion period and the threshold value of the deletion operation on the accuracy of the labelling results are also discussed in detail. The proposed method outperforms the other three state-of-the-art methods for all four performance indicators, enabling automatic and adaptive updating of the pipeline weld crack leakage monitoring model based on new data.
Keywords: Weld crack; Leakage; Threshold optimization; Acoustic emission; Self-organizing incremental neural network; Online monitoring

3. 0935-09:50: Development of Electron Optical Capabilities for Manufacturing of Complex Components by Electron Beam Welding.
Thomas Dutilleul, University of Sheffield

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Abstract: Electron beam welding (EBW) is a fast process that shows promise to use for high productivity welding of thick section components in the nuclear Industry. Nuclear AMRC has been working for many years on proving the use of EBW for SMR applications. The major strength of EB is the single pass process that can radically reduce fabrication times. This is also one of the major issues with EB. The stress on the welding operator is high as any error generally means failure. In the pro-beam K2000, once the chamber is closed the only interaction between the operator and the work piece is through a camera or the electron beam. Tracking features of the material or the joint line is important to gather as much information on the situation as possible. Nuclear AMRC have used the functions of the Pro-beam multimode to their limit to gain reliability during welding. The team has demonstrated that the beam can be setup to high precision, assess whether a work piece has been correctly installed, a large joint can be fully seam tracked and features can be extracted from the data giving indication whether a joint can be safely welded or not. The system can automatically warn the operator if some situations are reached i.e., too large joint gap, too

high magnetism and can correct itself. It is found that the electron optic system is very reliable and an essential tool during electron beam welding of large-scale components.

Keywords: EBW; Electron optics; Reliability

4. 09:50-10:05 Detection of Reinforcement of Multi-Bead and Multi-Layer Weld in Additive Manufacturing Based on On-line Visual Information of Weld Pool.

Jun Lu, Nanjing University of Science and Technology

Abstract: In the multi-bead and multi-layer arc additive manufacturing process, the information of cladding reinforcement reflects the welding quality to a certain extent, so it is of great significance to monitor the reinforcement of cladding layers in real time. In this report, a point cloud density search method is used to segment the point cloud of a single weld bead in the multi bead weld seam, and then the reinforcement of each cladding bead of multibead and multi-layer weld is extracted separately when the bottom plate is deformed due to high temperature, and a residual-based prediction model is constructed for quantitative forecasting of the transient reinforcement before solidification of block cladding layer in real time. The following work is completed to prove the accuracy and effectiveness of the proposed model, two different strategies are used to predict the reinforcement of multibead and multi-layer welds. Through the experiment, we can see the mean forecast error of the reinforcement of multi-bead and multi-layer welds is less than 0.3mm, while the time for the model to dealing with the molten pool image is 18ms, and the optimal strategy can make the average error better than 0.15mm, which proves that the model constructed in this report has great generalization performance and realizes the real-time and high-precision prediction of cladding reinforcement in the case of small deformation. The study of this report supplies a necessary basis for the online monitoring and control of morphological defects in the process of weld processing.

5. 10:05-10:20: Time Shift Effects of Input Images in Weld Depth Estimation Model using CNN through Molten Pool Monitoring in GMAW.

Kazufumi Nomura, Osaka University
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Abstract: Welding monitoring methods using machine learning have been studied extensively in recent years, and their effectiveness has been confirmed. Our previous study showed that the penetration depth could be estimated using a CN N (convolutional neural network) model whose input is only the molten pool image in a single groove welding with gap fluctuation. In this study, we considered that the penetration depth is determined not only directly below the aiming position as a physical phenomenon and attempted to shift the combination of input molten pool image and output penetration depth. As a result, it was found that linking the molten pool image and the penetration depth after 1 second provided better estimation accuracy. Furthermore, the longitudinal cross sectional macro shape immediately after arc extinguishing helped explain the shift effect in the weld penetration estimation model.

6. 10:20-10:35: An Algorithm for Path Distribution and Scheduling for Multi-Robot Cooperative Wire and Arc Additive Manufacturing of Large-Scale Parts.
   Yongzhe Li, Southeast University

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Abstract: With the merits of being cost-competitive and time-efficient, wire and arc additive manufacturing (WAAM) is a typical directed-energy deposition solution, which has been adopted in the industry to fabricate parts with large-scale geometries and moderate structural complexity. However, concerning the deposition efficiency of WAAM, a meter-scale part usually takes weeks or more to be manufactured using a single robot. To facilitate deposition efficiency, multi-robot cooperative (MRC-) WAAM has been developed that requires multiple robotic WAAM systems to work simultaneously. A fundamental challenge is properly distributing deposition paths to robots and scheduling tasks for robots individually before the actual deposition process can be executed. The difficulty comes from the factorial computational complexity of treating hundreds of deposition paths when optimizing the time, amount, and order of deposition.

In this work, a novel algorithm is proposed for automatic path distribution and scheduling for the scenario of MRC-WAAM. The algorithm first creates a task warehouse for every robot that stores all deposition paths that the robot can reach and orders the deposition paths according to the path-robot distances. An iterative computation is then performed to distribute the top 1/K number of paths from the warehouse to the robot having the least total time of deposition, where K is a coefficient depending on the statistical distribution of path lengths. A significant benefit of the proposed algorithm is that the paths selected in a loop naturally form a block, reducing the complexity of scheduling when considering the block as the basic unit of arrangement. On the validation side, multiple large-scale parts were concerned with approving the algorithmic efficiency. Validation results suggest that the proposed algorithm achieved the logarithmic time complexity of computation. In addition, the algorithm can enhance the adjacency of paths distributed to a robot, avoiding the collision caused by the interleaving of the deposition path of different robots.

11:00-12:25 Session 5 (Session Chairs: Kazufumi Nomura, Shaojie Wu)

1. 11:00-11:20: Invited: Application of Deep Learning on Welding Anomaly Detection.
   Xinghua Yu, Beijing Institute of Technology

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Abstract: Current study designed experiments to simulate anomalies in the welding process. Multiple sensors were used to collect welding process data and machine learning models were built to detect welding anomaly based on the process data. X-ray nondestructive testing was used to detect welding defects after welding processes. This paper applied the mainstream deep learning models in the field of computer vision, and compared the accuracy and recall rate of different models on the performance of detecting welding defects. In addition, attention mechanism and post-processing algorithm was applied to further improve the accuracy of defect detection.
Keywords: Welding anomaly detection; Machine Learning; Deep learning; Transformer; Attention Mechanism.
Bio: Xinghua Yu is a professor in the department of Materials Science and Engineering at the Beijing Institute of Technology (BIT). Prior to join BIT, he held a research staff position at Oak Ridge National Laboratory in the U.S. Dr. Yu's research interest includes physical metallurgy, advanced manufacturing, additive manufacturing, computational materials modeling, as well as non-destructive testing. He received IIW Henry Granjon Prize in 2013 and R&D100 award in 2017. He has published more than 70 papers relevant to material science and manufacturing.

2. 11:20-11:40: Invited: Deep Learning-Based Surface Reconstruction Model of Wire-Arc Additively Manufactured Surface.
   Abhay Sharma, KU Leuven

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Abstract: Among the additive manufacturing process, arc-based additive manufacturing is unique for its very high deposition rates. However, higher deposition rates also generate a highly irregular surface that requires extensive post-machining efforts leading to a considerable waste of critical raw materials and energy. With an aim to optimize the process to minimize the post-processing, it is essential to develop the ability to predict the surface topography as a function of the process parameters like wire feed speed and travel speed. The surface topography model is developed in this investigation, which reconstructs the surface, taking wire feed speed, travel speed, and inter-pass temperature as inputs. The first step in model development is to determine the appropriate

surface topography features, which collectively express the surface so that a random surface with the same value of those features resembles the original surface. Of the 14 surface features studied, seven are identified as representative attributes: spatial average roughness, spatial peak height, spatial maximum valley depth, spatial skewness, spatial kurtosis, maximum flatness, and waviness. The surface reconstruction model is developed using discrete cosine transform (DCT). The wire-arc surface is found to be reconstructed using a minimum of 30 DCT parameters. A deep learning model is developed to predict the DCT parameters with wire feed speed, travel speed, and inter-pass temperature as inputs. The model has been developed and validated for the 309L stainless steel test material. The high accuracy in predicting the DCT parameters made it possible to accurately predict the overall topography of the surface and the machining allowance. The model paves the way for the simulation-based design of the additive-subtractive process by identifying the optimum deposition conditions and the respective machining parameters. The model also facilitates the integration of a realistic surface into the computational models for additive process simulation.

Bio: Abhay Sharma has been an Associate Professor at the Department of Materials Engineering, KU Leuven, Belgium, since 2019. He heads the Additive and Welding Process research subdivision at the De Nayer Campus of KU Leuven. His publication record consists of more than 100 articles (co-) authored in peer-reviewed journals and conferences of international repute. Over the last one and half decades, several post-doctoral researchers and PhD students have been (co-) supervised by him. Abhay has mentored more than 40 individuals as a researcher and project staff. Grants and international collaborative research projects with universities in Europe and Asia have continuously supported his research. He has been involved in several industrial research projects as a principal investigator for Belgian, Japanese and Indian manufacturers such as Hitachi Zosen Japan, Boeing and DRDL. His current research focuses on Multi-material Additive Manufacturing, wherein he is the principal investigator of four ongoing research projects. He has a long history of collaboration with the Joining and Welding Research Institute, JWRI, Osaka University, Japan, on different welding and additive manufacturing topics. Before joining KU, Leuven Abhay served the Indian Institute of Technology Hyderabad in India for a decade. Abhay received his master's degree in 2003 from the Indian Institute of Technology (IIT) Roorkee, India 2003. Abhay was a visiting scholar at Purdue University, USA (2012) and Osaka University, Japan (2016,2020).

3. 11:40-11:55: Real-time Sensing and Control of GTAW Penetration Using Deep Learning and Model Predictive Control.
Zhifei Xu, Beijing University of Technology

Jun Xiao1*, Zhifei Xu, Yongchao Cheng, Shengnan Gai, Shunjun Chen
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Abstract: The sensing and control of weld pool penetration state in gas tungsten arc welding (GTAW) are crucial for assuring high weld quality. In the manufacturing process, the variation of cooling conditions, and adjustment of welding parameters would induce the weld pool to varying penetration state, so that keeping the uniformity of backside bead width characterizing the weld penetration is the key demand for high-quality welds. In the traditional welding process, the experienced welder observes the topside surface of weld pool to estimate the backside bead

width. Sensing and control the backside weld width like a human welder would be both challenging. Previous research has proved that the convolutional neural network (CNN) model can predict the backside width using active vision with a single stripe laser pattern. To simulate the welding process accompanied by the variation of heat input and cooling conditions, experiments changing the weld current and speed in a certain range to satisfy the full penetration are conducted. The model identification and design of the model-predictive controller are implemented. The simulation and online control experiments show the same trend of the backside bead width, and thus the effectiveness of the close-loop control is proved.

4. 11:55-12:10: Intelligent Prediction of the Keyhole/Penetration Status Based on Deep Learning Algorithms in Plasma Arc Welding.
   Chuanbao Jia, Shandong University

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Abstract: Keyhole Plasma Arc Welding (K-PAW) can join medium-thick metal workpieces with full penetration in a single pass. Because the keyhole is vulnerable due to the fragile force balance on the liquid metal around the keyhole, burn-through or lack of fusion might happen. However, it is difficult to predict the keyhole status based on conventional methods due to the complicated, coupled, and non-linear processes. Since the visually captured weld pool images from topside can provide sufficient information of the liquid metal as well as keyhole behaviors, the weld pool, plasma arc as well as keyhole entrance could be clearly recognized reflecting the different features during different keyholing stages. It was proposed to extract the image features automatically based on deep learning algorithms rather than manually selecting characteristic parameters. A well-trained Deep CNN (Convolutional Neural Network) model was employed and fine-tuned model using the acquired data to extract the K-PAW image features. The model training took weld pool images as input and penetration/ keyhole status (partial penetration with a blind keyhole or full penetration with a through keyhole) as output. For further verifying the effectiveness and reliability of the trained model, experiments were designed acquiring typical slow keyholing under constant welding current and rapid keyhole switching under pulse welding current. The verified 90% accuracy was achieved for correctly predicting the keyhole/penetration status. The visualization of the convolutional layers was carried out to clearly displayed the features for understanding the internal mechanisms. For higher accuracy prediction, a novel prediction method has been proposed based on eight classical CNNs trained, compared, and fused. For these single models, the prediction accuracy is higher than 95%, with the speed of faster than 10 frames per second (FPS). The model visualization by the Grad-CAM method was performed to show the focused feature regions clearly. A voting ensemble decision model (called KeyholeVot) was established based on the selected three robust models (i.e., InceptionNetV3, InceptionResNetV2, and XceptionNet) and achieved 96.62% evaluation accuracy.

Keywords: Plasma arc welding; Penetration prediction; Deep learning; Keyhole; Weld pool; Majority voting

5. 12:10-12:25: Empirical Case Study and Results for the Training of Welders using VWTS (Virtual Welding Training Systems) and the Traditional Welding Training Methodology.
OR-12-0155
Antonio Fernandez Perez, Seabery Augmented Training

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Abstract: It is well documented that training in the welding industry is a critical and often costly endeavor. This study examines the training potential, team learning, material consumption, and cost implications of using the latest simulation technology of Augmented Reality as a major part of weld training, in comparison with the traditional methodology of welding training. The research was conducted by experiment. Two groups of ten participants were trained under equal conditions in different ways for two months at Pintor Pedro Gómez Vocational College. The first way (Group A) was training with the Virtual Welding Training Systems powered by Augmented Reality and a digital E-Learning platform (60% of the training time) followed by training in a workshop on the welding equipment (40% of the training time). The second way (Group B) was training only in a workshop on welding equipment and the use of paper media (100% of the training time). Results show that the combination of VWTS and Real Welding Training reduces the training time by 45% while reducing the cost of welding consumables by 64%. This study also analyses the qualitative outputs from both welding students and instructors related to the training quality, motivation, engagement and safety, including a comprehensive estimation of the positive impact to the environment from the usage of simulation technologies.
Keywords: Welding training; Virtual welding training systems; Simulation; Augmented reality; Psychomotor domain; e-Learning

14:00-15:00 Session 6 (Session Chairs: Zhifen Zhang, Jun Xiong)

1. 14:00-14:15 Optimization of Mild Steel MIG Welding Penetration Depth via Reinforcement Learning using Stochastic Policy Pptimization (SPO).
   OR-12-0341
   Giulio Mattera, University of Naples Federico II, Italy

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Abstract: Welding optimization is a significant task that contributes to enhancing the final welding quality. However, the selection of an optimal combination of various process parameters poses different challenges. The welding geometry and quality are influenced differently by several process parameters, with some exhibiting opposite effects. Consequently, multiple experiments are typically required to obtain an optimal welding procedure specification (WPS), resulting in the waste of material and costs. To address this challenge, we developed a machine learning model that correlates the process parameters with the final bead geometry, utilizing experimental data. Additionally, we employed a reinforcement learning algorithm, namely stochastic policy optimization, to solve the optimization process. Specifically, we designed a reward system aimed at identifying an optimal set of process parameters that minimize the amount of deposited material while achieving the desired minimum level of penetration depth. The proposed Artificial Intelligence-based method offers a viable means of reducing the number of experiments necessary to develop a WPS, consequently reducing costs and emissions. Notably, the proposed approach achieves an error rate of less than 1%.
Keywords: Process optimization, Arc welding, Reinforcement learning, Neural networks

2. 14:15-14:30: Study of The Influence of Al Element on The Arc and Molten Pool Behavior During Flux Bands Constricting Arc Welding (FBCA) Process.
   Jisen Qiao, Lanzhou University of Technology

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Abstract: This study examined the addition of 0.2%–1% Al element in the flux bands using a high-speed camera and side glass observation system on the flux bands constricting arc (FBCA) welding arc shape changes and molten pool fluctuations in the regulatory mechanism. The study was based on the FBCA welding of depth dynamic control challenges of ultra-narrow gap groove sidewall melt for the specific alloy composition in the flux bands on the regulation of the real-time

welding process. Moreover, the mechanism of the influence of Al elements on weld formation was analysed using the post-weld molten pool depth-to-width ratio. Results show that as the Al content increases, the welding arc shifts from a dispersive circular sphere to a contracted ellipsoidal shape, and the combustion position is compressed to the middle and lower parts of the welding channel. In addition, the molten pool flow changes from a shallow concave shape to a deep V shape, accelerating the molten pool flow accompanied by the appearance of a hump molten pool. As the Al element in the flux bands changes the molten pool Marangoni convection mode, the weld formation is significantly affected: with Al up to 0.80%, the weld depth to the width ratio reaches a maximum of 1.32, the best welding quality. Moreover, with 0.92% Al, the weld depth-to-width ratio fluctuations become larger, there are pores slag and the welding quality decreases. At this time, Al3+ vapour is preferentially ionised, deoxygenation within the arc induces further contraction of the arc down, the arc force impact on the bottom of the molten pool increased, Al2O3 is generated back into the molten pool and gathered on the surface and the flow and solidification of the molten pool reach the best. However, excessive Al was added to cause the molten pool reaction to be intense, resulting in the deterioration of the weld.
Keywords: Ultra narrow gap welding; Flux bands; Al element; Arc shape; Molten pool behavior; Weld formation

3. 14:30-14:45: Strategies Against the Shortage of Skilled Welders.
OR-12-0121
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Abstract: The global welder shortage is threatening industries worldwide, resuming in loss of revenue. Various research shows a range of approaches where the industry needs to improve, in order to attract and retain skilled welders.
Researches were conducted amongst apprentices, welders and HR managers, in order to understand the current status and the future needs of the work force as well as the issues the industry currently facing.
The study shows that there is a need for a holistic approach in order to solve the problem. Starting with introducing working with metal already in primary school, attract young people to the welding industry through new educational methods, such as digital welding; showing the importance of our industry, show the career opportunities. Implementing educational workshops where companies can re-educate unskilled workforce to their proper needs contributing to the lifelong learning process of adults.
The industry needs to implement new work methods also in production, to be an attractive employer to skilled welders. This also includes agile working teams, well trained leaders that are giving trust and thus enabling creative freedom, seeing the employee as a human being with his or her personality and individual needs, creating flexible and future-oriented work structures.

Another approach lies in increasing the diversity within the industry. The share of women among skilled workers in the active labour market is far too low. Yet there is great potential lying dormant here. A company that is committed to diversity will also be able to attract more skilled workers.

Keywords: Education & training, New work, Lifelong learning, Train the trainer, Working time models, Diversity

4. 14:45-15:00: An Adaptive Welding Method for Grooves with Position and Size Errors.
OR-12-0343
Wenkai Wang, Lanzhou University of Technology

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Abstract: For the mass production of workpieces represented by the steel structure node ball in construction, it is difficult to keep the position and size of the groove assembly within the standard size range due to the influence of upstream processing technology level, which leads to the inability to use the same process parameters and welding strategies to complete all groove welding. For workpieces with large groove size errors as mentioned above, a laser vision detection system was built, which uses digital image processing technology to extract the assembly size of the groove and input it into a pre-established linear regression model to achieve adaptive output of welding process parameters. Finally, the experimental plan was verified on actual workpieces. The range of height changes for reinforcement of steel structure node ball ring welds is within 2 mm, there are no unfused defects, and the entire welding process takes 20 minutes, which meets industrial production requirements.

Keywords: Steel structure node ball; Groove size measurement; Welding process parameter prediction; Adaptive welding

15:30-16:15 Session 7 (Session Chairs: YuMing Zhang, Aprilia)

1. 15:30-15:45 Optimization of Welding Parameters Based on Weld Bead Geometry in Gas Metal Arc Welding Using A 1.0-mm-Diameter Wire.
   OR-12-0159
   SolMi Lee, Korea Institute of Industrial Technology

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   Abstract: As the strength of steel used in automobile chassis parts increases, the thickness of the steel tends to become thinner. To adapt to this trend, the diameter of a welding wire needs to be reduced. This study focuses on welding characteristics of the effect of welding parameters when a 1.0-mm-diameter wire was applied to replace the 1.2-mm-diameter wire, which is mainly used for recently produced chassis parts, with a 1.0-mm-diameter wire. To investigate the welding characteristics, gas metal arc welding (GMAW) was conducted on a 590 MPa class hot-rolled steel sheet (SGAFH590) at a T-fillet joint. Weld bead geometry, as a weld quality metric, was observed using an optical microscope (OM). To extract weld bead from a cross-sectional OM image and measure the weld bead geometry, an image segmentation model was built for the weld area on the cross-sectional image, and an image detection model was built for the upper/lower plate beads on the cross-sectional image. The parts of weld bead, including leg length, penetration depth, and throat thickness, were measured using the coordinate information of the bead and weld area obtained through each model. The parts of the weld bead, as a quality metric, were evaluated based on AWS D1.1/D1.1M:2006. Response surface methodology (RSM) was used to derive optimal welding parameters based on the bead geometry that satisfied the quality specification. Optimal welding conditions and suitable welding range were derived based on the model estimated from GMAW of a high-strength steel sheet with a 1.0-mm-diameter wire. In addition, based on the estimated model, suitable welding conditions were selected and a welding experiment was conducted and verified. It was concluded that GMAW quality that satisfies welding quality specifications can be obtained using a 1.0-mm-diameter welding wire.
   Keywords: Gas metal arc welding; Weld quality; Image detection; Image segmentation

2. 15:45-16:00: Data Driven and Machine Learning based Design Framework for Self-Piercing Riveting Process.
   Li Huang, Nanjing Tech University

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Abstract: Due to its excellent performance, the self-piercing riveting (SPR) process has been widely used in auto body manufacturing in recent years. The need for efficient and reliable design of SPR process parameters is growing in industry. Traditional trial-and-error design methods rely on historical experience and can be limited by physical experimental materials and equipment. Data-driven methods rely on data accuracy and data volume, and data from a single source is often inadequate to meet design needs. To address these issues, a multi-fidelity data-driven optimization design framework is proposed. The most significant feature of this framework is the fusion of physical experiment data and simulation data to build surrogate models. In this framework, a modified optimal Latin hypercube sampling method and a multi-fidelity surrogate model based on transfer learning and neural networks are proposed for SPR process. This multi-fidelity surrogate model can use a very small amount of experiment data to modify the surrogate model built on simulation data, so that the model predictions can more closely match the physical experiment results at a lower modeling cost. Benefit from this method, the proposed framework can balance the contradiction between design accuracy and development cost compared to a single-fidelity data-driven framework. The application cases show that the prediction errors of the multi-fidelity models are less than 0.1 mm for the key geometric parameters of the SPR joint. As verified by physical experiments, the rivets and dies selected by the framework are the optimal solutions within the optional range. To the author' knowledge, this is the first time that a multi-fidelity modeling method has been introduced to the field of SPR process, to solve the process parameter optimization design problem. Further, the method is not limited to the use of SPR process but can be applied as a paradigm in other engineering optimization design problems, especially in joining process parameter design problems.
Keywords: Self-piercing riveting; Machine learning; Data driven

3. 16:00-16:15: A Comprehensive Review of Deep Learning for Predicting Remaining Fatigue-Corrosion life of TIG-dressed Welded Joints.
   Badr EL Hajouji, Hassan The First University of Settat, Morocco

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Abstract: Classic methods for the fatigue assessment of welded joints are very well known and enough data was gathered and verified in the last decade. The latest recommendations of the International Institute of Welding (IIW) explicitly explain these methods as e.g., the nominal stress method, Structural hot spot stress, Notch stress method, Fracture mechanics methods, and verification by component testing. Also, techniques for improvement of remaining fatigue life with post-weld treatments were widely studied and enhanced. These methods can be clustered into three types: geometry, shape, and residual stress.
Recently, Artificial Intelligences techniques were intensively used and honed to predict the remaining fatigue life for printed (additive manufacturing), molded, or welded parts. There are several different approaches to using AI for fatigue life prediction, including: Neural Networks,

Genetic Algorithms, Support Vector Machine, Random Forest, etc. In these algorithms, weight analysis is used to assign weights to each feature in the dataset, indicating their importance in predicting the output variable. The weights are usually learned during the training process, by minimizing a loss function that measures the difference between the predicted output and the actual output. These AI techniques can be used in combination with traditional fatigue analysis methods, such as finite element analysis, to improve the accuracy and reliability of fatigue life predictions.

Nevertheless, deep learning was rarely used to study post-welded joints and assess it effect on fatigue life extension. These sorts of models require using a larger dataset for training to optimize its architecture and parameters.

Keywords: Additive manufacturing; TIG dressing; Fatigue; Metal repair; Welded joints; Weight analysis; Deep learning, Artificial intelligence

4. 16:15-16:30: Weld Scoring Model for Virtual Welding Training System.

OR-12-0154

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Abstract: To conduct efficient welding training, it is necessary to summarize the welding experience of senior welders and efficiently communicate it to junior welders. At the same time, automated training can effectively reduce personnel costs in welding training, and the use of digital twin and virtual reality technologies can save junior welders from exposure to the hazards of welding at an immature stage of skills. Therefore, the ultimate objective of this research is to construct an VR-based automated welding training system that can effectively extract welding body knowledge and give feedbacks. However, based on the current station, the biggest difficulty in establishing an ideal arc welding training system is to come up with a reasonable welding scoring model, since welding results are affected by various aspects such as body posture, torch operation, and voltage and current levels. However, as the result of arc welding, the weld bead can basically reflect the body knowledge of the welders during welding. As the most direct factor affecting the weld bead, the weld pool is not only associated with body knowledge, but also has a stronger real-time nature, which can be evaluated to guide the welding process more effectively. Therefore, the objective of this research is to propose an effective weld pool scoring model for arc welding training.

5. 16:30-16:45: A Study on Machine Learning Algorithm Comparison for the Performance Evaluation of Manual Welding Process.

OR-12-0162

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Abstract: Unlike the past, There are many processes applied an automated welding technology in the shipbuilding industry by technologies development. Nevertheless, a manual welding still have demand and essential processes. Whereas, issue of neither high-skilled nor low-skilled manual welding labor supply have been taken a turn for the worse steadily since a decade ago. Furthermore, the professional manpower shortage of manual welding process is difficult issue to solve in a short time period. In order to provide efficient education for the non-skilled manual welding labor on time, a new strategy is needed. Therefore, in this paper, performance evaluation of welding trainee by two machine learning algorithms are conducted based on the collected dataset of manual welding process by high-skilled and low-skilled welder group. In order to find fitted algorithm, comparison study is conducted between two algorithms which are K-nearest neighbor(KNN) and support vector machine(SVM). As a result, positive and negative parameters in the training of the manual welding process are searched out to provide an effective education strategy for unskilled welding labor. In addition, the result of this paper provide to find the best algorithm with high accuracy.