MAIN TOPICS, ABSTRACTS & KEY WORDS

Microstructure and mechanical properties of CMT + P welding process on G115 steel XU Lianyong[1,2,3], PANG Hongning[1], ZHAO Lei[1,2], HAN Yongdian[1,2], CHI Dazhao[3] (1. Tianjin University, Tianjin, 300072, China; 2. Tianjin Key Laboratory of Advanced Joining Technology, Tianjin, 300072, China; 3. State Key Laboratory of Advanced Welding and Joining, Harbin Institute of Technology, Habin, 150001, China). pp 1-5

Abstract: Based on cold metal transfer + pulse welding (CMT + P) welding method, the weldability of G115, a novel tempered martensitic heat resisting steel, microstructures and mechanical properties of welding joint were studied. The results showed that the microstructure of the welding joint was tempered martensite after welding and heat treatment. Two different grains were found in the weld metal, while both the weld heat affected zone and the base metal were equiaxed grains. Compared with manual arc welding (SMAW), CMT + P welding method reduces the heat input effectively, diminishing the size of the heat-affected area prominently, improving the tensile performance of the welded joint and the impact toughness of the heat-affected area, weakening the impact toughness of the welded joint slightly. The tensile fracture mechanism of welded joints at room and high temperature is ductile fracture. A certain amount of precipitate exists in the dimples of tensile fracture at room temperature.

Key words: novel tempered martensitic heat resisting steel; microstructures; mechanical properties; cold metal transition

Microstructure and mechanical properties of 18 Ni maraging steel deposited by gas metal arc additive manufacturing YANG Dongqing, WANG Xiaowei, HUANG Yong, LI Xiaopeng, WANG Kehong (Key Laboratory of Controlled Arc Intelligent Additive Manufacturing Technology, Ministry of Industry and Information Technology, Nanjing, 210094, China). pp 6-9,21

Abstract: A well formed 18Ni maraging steel thin-walled part was prepared by the gas metal arc additive manufactring. The microstructure and mechanical properties of the as-deposited and heat treated component were studied. The results showed that the microstructure of the component was mainly cellular dendrite, and the microstructure and mechanical properties of the as-built component in different positions were various: the top of the thin-wall was martensite, and the average hardness was 360 HV. The hardness of the middle part was 468 HV, slightly higher than that of the bottom part (437 HV). The tensile strength of the component (1 375 MPa) in the vertical direction was about 28.3% higher than it in the horizontal direction (1 072 MPa), and the corresponding elongation was 1.1% and 0.8% respectively. After the solution heat treatment at 825 ℃ for 1 h, the precipitates of the part were remelted into austenite and the hardness decreased (the average value was 328 HV) with little variation. The tensile strength in the vertical direction (1 025 MPa) were equivalent the horizontal direction (1 034 MPa) and the elongation was 6% and 14%, respectively.

Key words: gas metal arc additive manufacturing; maraging steel; solution treatment; mechanical properties

Multi-pass welding angle distortion prediction for QTT antenna track considering the bending moment of gravity XU Qian[1,2], HU Guangxu[3], DONG Zhibo[4], XU Hongxiang[4], FANG Hongyuan[4] (1. Xinjiang Astronomical Observation, Chinese Academy of Sciences, Urumqi, 830001, China; 2. Key Laboratory of Radio Astronomy, Chinese Academy of Sciences, Urumqi, 830011, China; 3. Harbin University of Commerce, Harbin, 150028, China; 4. State Key Laboratory of Advancd Welding and Joining, Harbin Institute of Technology, Harbin, 150001, China). pp 10-13

Abstract: Each block for assembling QTT antenna track is about 4 000 mm × 600 mm × 200 mm. To fabricate the track with multi-pass welding technology, it needs large groove dimension and a great amount of deposited metals, resulting large welding angle distortions. To validly predict and control the deformation, a thermal-elastic-plastic finite element model

was used to simulating a scaling experiment plate considering gravity boundary condition at first. Then, another welding simulation for the actual track block structure was computed to compare with the modified formula for the welding angle distortion adding the bending moment of Gravity. The result shows that the effecting of gravity for QTT multi-pass welding was ineligible, which make the formula more accuracy.

Key words: QTT antenna track; thick plate; multi-pass welding; welding angle distortion

TCP calibration method based on spherical uniform distribution for welding robot HONG Lei, YANG Xiaolan, WANG Baosheng, LV Dongsheng (School of Automotive and Rail Transit, Nanjing, 211167, China). pp 14-21

Abstract: In the current fixed reference point method for calibration of welding robot tool center point (TCP), there are problems of randomness of robot posture selection and non-uniformity of distribution. For this reason, a method of TCP calibration based on spherical uniform distribution is proposed. Based on the "six-point method", the initial measurement configuration is created at first. Then, in the off-line simulation environment, the mechanical repulsion iteration method is used to construct the virtual points with spherical uniform distribution with the fixed reference point as the center of the sphere. The end center of the virtual robot sixth axis was located at each virtual point by group calculation, and the situations of joint angle over limit and link collision are eliminated. Finally, the actual robot is adjusted to the selected measurement configurations for the final TCP calibration, and the result is solved by the least square spherical fitting method. The results show that this method can make the robot posture evenly distributed around the fixed reference point at each measuring point, and maximize the difference degree of robot posture, it is verified that this method can effectively improve the calibration accuracy.

Key words: welding robot; tool center point(TCP)calibration; spherical uniform distribution; mechanical repulsion iteration method

Effect of Fe particles on the structure and properties of SnBi/Cu joint during aging LI Zhengbing, HU Dean, CHEN Yiping, CHENG Donghai, HE Kai, GUO Yile (Nanchang Hangkong Uiniversity, Nanchang, 330036, China). pp 22-28

Abstract: To solve the problem of poor tissue stability of SnBi alloys during servicing, the microstructure of Sn35Bi-1Fe/Cu joints before and after aging was observed by scanning electron microscope (SEM), combined with energy spectrum analysis (EDS) and XRD, to analyzed the tissue changes of joint, and the mechanical properties of joints were analyzed by universal testing machine. The influence of Fe particles on SnBi/Cu joint structure and properties during aging was studied. The results show that with the increasing of contents of Fe particles, the shear strength of Sn35Bi-*x*Fe/Cu (x = 0%, 0.3%, 0.7%, 1.0% and 1.5%) joints increases first and then decreases. When the Fe particle content is 1% (wt.%), the maximum value is 50.23 MPa, and the mechanical properties of Sn35Bi-1.5Fe/Cu joints are always better than those of Sn35Bi/Cu joints; during the constant temperature aging stage, Fe particles in the Sn35Bi-1Fe/Cu joint through pinning the Bi phase, and grain boundary energy was consumed by reacting with Sn to form $FeSn_2$ compound to decreased Bi phase migration rate, lead to Bi phase coarsening was inhibited, at the same time, growth rate of interface IMC layer was decreased, the generation of interface Cu_3Sn was suppressed, the mechanical properties of the joints in the aging stage was improved.

Key words: brazing filler metal of Sn35Bi; Fe particles; aging; microstructure; mechanical properties

Feasibility analysis of image signal replaced by sound pressure in wet welding under depth water environment LI Zhigang[1], YANG Liting[1], HUANG Wei[1], YE Jianxiong[2] (1. Key Laboratory of Vehicle Tools and Equipment, Ministry of Education, East China Jiaotong University, Nanchang, 330013, China; 2. Nanchang Institute of Technology, Nanchang, 330099, China). pp 29-33

Abstract: Under water deep environment, underwater wet flux cored wire welding (FCAW) welding is affected by the growth of the surrounding arc bubbles, and its state needs to be collected through signal. The article first builds an underwater wet welding test platform to conduct a wet flux-cored wire welding experiment. The bubble sound pressure signal, high-speed camera signal, and arc current and voltage signal in the welding process are collected synchronously; then,

the arc ignition stage is compared. The dynamic evolution images of bubbles in shallow water and 20 m depth and their sound pressure signals, combined with the 20 m depth arc stabilization phase signal, it is found that the bubble pulse sound signal and the bubble image have a good corresponding relationship in the evolution details such as bubble size, blasting period, etc. As the water depth increases, soot causes the image signal to become more blurred. Finally, a comparative analysis of the acousto-electric signals from the arc starting to the arc stabilization stage obtained in the environment of 20 and 40 m underwater, shows that the bubble sound pressure signal can clearly reflect the changing state of the bubble, and the deep underwater sound pressure signal It is feasible to replace high-speed cameras.

Key words: underwater wet welding; bubble sound pressure signal; arc voltage and current; high-speed camera; arc bubble

Evaluation on interfacial defect size of diffusion bonding based on ultrasonic non-destructive testing WANG Bin[1], LI Sheng[1], ZHU Fuhui[2], LI Xifeng[2] (1. Beijing Xinghang Electro-Mechanical Equipment Co., Ltd., Beijing 100074, China; 2. Shanghai Jiao Tong University, Shanghai 200030, China). pp 34-38

Abstract: Aiming at the non-destructive testing problems of interfacial defects of diffusion bonding, the water immersion ultrasonic testing was performed on the prepared specimen with artificial defects. An ultrasonic response model of interfacial defects of diffusion bonding was proposed. A measurement method was developed to evaluate the interfacial defect thickness by ultrasonic testing. The specimen with artificial defects was firstly prepared by the diffusion bonding process. It was later subjected to the water immersion ultrasonic testing through an incident wave frequency of 30 MHz. Based on the principle of ultrasonic non-destructive testing, an ultrasonic response model for unbonded defects was proposed. The interfacial stiffness coefficient (K) was introduced as a bridge to establish the relationship between the ultrasonic reflectivity and the interfacial defect size. At the specific measurement position, constants of the ultrasonic response model were determined by fitting the ultrasonic reflected wave data and actual micro defect size. Therefore, the interfacial defect thickness can be evaluated by the proposed model based on ultrasonic non-destructive testing. The results show that tradition ultrasonic C scanning usually determines qualitatively whether the defects exist or not. The proposed measurement method of interfacial defect thickness make a supplement for ultrasonic C scanning to some extent. It is helpful for measuring defect size quantitatively. The evaluation of defect risk level is achieved.

Key words: ultrasonic non-destructive testing; diffusion bonding; interfacial defect

Research on optimal heat input for blade repair of aero compressor GONG Miao[1,2], DAI Shijie[1], WANG Zhiping[2], WANG Liwen[2] (1. Hebei University of Technology, Tianjin, 300401, China; 2. Civil Aviation University of China, Tianjin, 300300, China). pp 39-47

Abstract: A heat transfer model for MPAW additive manufacturing repair of compressor blades was established. Firstly, the heat input range was calculated by analyzing the thermal properties of the alloy, and the temperature distribution of molten pool under different heat input was obtained. After that, the mathematical model of the additive manufacturing height and wire feeding speed was established, and the height under different wire feeding speed was solved. Through the numerical analysis of temperature distribution of weld cross-section, the heat input range was further reduced and the experimental parameters were obtained. Finally, with numerical analysis and experimental comparison, the evolution law of microstructure and heat input rate of the alloy repair zone was revealed, and the optimal heat input and welding parameters were obtained. The experimental results are in good agreement with the theoretical model, which verifies the effectiveness of the theoretical method. The results show that the optimal heat input rate can be achieved by using the welding parameters obtained, and the better additive manufacturing morphology and repair effect can be achieved.

Key words: additive manufacturing repair; compressor blades; heat input; heat transfer modeling; numerical analysis

Microstructure and mechanical properties of magnesium alloy welded joint under the combined effect of magnetic field and $NiCl_2$ activated flux ZHANG Guiqing, REN Yinglei, SU Yunhai (Liaoning Advanced Welding

Technology and Automation Laboratory, Shenyang University of Technology, Shenyang, 110870, China). pp 48-54

Abstract: In order to analyze the evolution of microstructure and mechanical properties of magnesium alloy welded joints under the combined effect of magnetic field and activated flux, longitudinal AC magnetic field was used during A-TIG welding of AZ91 magnesium alloy. The formability, microstructure, phase composition and mechanical properties of welded joints with different coating amounts of activated flux were analyzed, the arc shape and crystallization nucleation characteristics under the combined action of magnetic field and activated flux were discussed. The experimental results show that the introduction of magnetic field has a negative effect on increasing penetration and improving welding efficiency, but it has a very obvious effect on improving the mechanical properties of welded joints. When the coating amount of activated flux is 3 mg/cm^2 under the selected magnetic field parameters, the forming state and microstructure performance of welded joints reach the best match. In this condition, the forming coefficient is 2.38, and the tensile strength and elongation of welded joints are 338 MPa and 13.3%, respectively. Under the combined action of magnetic field and activted flux, the arc moves downward spirally, and drives the molten pool to change the crystal crystallization conditions, promotes the formation of small equiaxed crystals and the appearance of twins, so that the mechanical properties of welded joints are improved. At the same time, the introduction of magnetic field can change the growth mode of the crystal, and the preferential growth phenomenon appears along the (0001) crystal plane.

Key words: longitudinal magnetic field; AZ91 magnesium alloy; $NiCl_2$ activated flux; grain refinement; mechanical properties

Numerical simulation of double-sided explosive welding of stainless steel/ordinary carbon steel MIAO Guanghong[1,2], AI Jiuying[2], MA Leiming[2], LI Xuejiao[2], MA Honghao[3], SHEN Zhaowu[3] (1. State Key Laboratory of Mining Response and Disaster Prevention and Control in Deep Coal Mines, Anhui University of Science and Technology, Huainan, 232001, China; 2. Anhui University of Science and Technology, Huainan, 232001, China; 3. Key Laboratory of Mechanical Behavior and Design of Materials, University of Science and Technology of China, Hefei, 230027, China). pp 55-62

Abstract: In order to improve the utilization rate of energy, two composite plates can be obtained at one time by using a double-sided explosive welding device. With the help of LS-DYNA software and smoothed particle hydrodynamics, SPH-FEM coupling algorithm was adopted. Three-dimensional numerical simulations were made for the double-sided explosive welding experiment of stainless steel/ordinary carbon steel by selecting 304 stainless steel with the thickness of 3 mm, Q235 steel with 16 mm and emulsion explosives. The explosive welding window was calculated and established. The vertical displacement, collision pressure and collision velocity were analyzed, and the simulation results were consisted with the experimental results. The simulation results show that the composite quality is better under the thickness of 7 mm, while the welding failure may be caused by the excessive collision energy under the thickness of 10 mm. The simulation results were in accordance with the experimental results. The Gurney formula was introduced to predict the experimental results. The calculation results show that the prediction results of the Gurney formula are in good agreement with the experimental results, indicating that the SPH-FEM coupling algorithm and Gurney formula are effective for double-sided explosive welding of stainless steel/ordinary carbon steel.

Key words: double-sided explosive welding; 304 steel; Q235 steel; numerical simulation

Effects of PWHT on the impact toughness and fracture toughness of the weld metal under restraint welding WANG Dongpo[1], LIU Kaiyue[1], DENG Caiyan[1], GONG Baoming[1], WU Shipin[2], XIAO Na[1] (1. Tianjin University, Tianjin, 300072, China; 2. Tianjin University of Technology and Education, Tianjin, 300222, China). pp 63-67,78

Abstract: The post-weld heat treatment (PWHT) was conducted on the thick-plate DH36 weld metal under restraint welding, and the impact toughness and fracture toughness of the weld metal before and after PWHT were tested. The differences between the effects of PWHT on the impact toughness and fracture toughness were compared and analyzed, and its toughening mechanisms were investigated. The results show that the weld metal has well impact toughness on as-

welded (AW) condition, but its fracture toughness is poor. After PWHT, there is no obvious change in the impact toughness of weld metal, but the fracture toughness increases significantly, with the average CTOD value rising from 0.123 mm to 0.707 mm. PWHT causes the improvement of toughness through the decrease of dislocation density, the significant reduction of dislocation tangles, and the precipitation and spheroidization of fine carbides. It can meanwhile eliminate the local embrittlement inside of the weld metal caused by the strain aging effects, thus improving the toughness. In addition, the results of the tested impact toughness of weld metal are quite different from those of the fracture toughness. Therefore, there may be risks in using single-temperature impact toughness as the only criterion to evaluate the toughness and the safety of the thick-plate weld metal under restraint welding.

Key words: impact toughness; fracture toughness; post-weld heat treatment; restraint weld

Study on K-TIG welding process and properties of Q235 steel XU Liang[1], OUYANG Kai[2], YANG Haifeng[1] (1. Harbin Welding Institute Co., Ltd., Harbin, 150028, China; 2. CSCEC Installation Group Co., Ltd., Nanjing, 210023, China). pp 68-72

Abstract: The K-TIG welding technology was used to weld the 10 mm thick Q235 steel. The results showed that the welding process was stable, and the welded joint with good weld formation and no defects such as cracks and pores was obtained. The dynamic behavior of keyhole in the welding process was observed by high-speed photography test, and the microstructure and hardness of the welded joint were studied The mechanical properties such as tensile, impact and bending are tested. The results show that the stability of keyhole of K-TIG welding can be increased by improving the heat dissipation condition and reasonable assembly clearance; the Vickers hardness of weld area and heat affected area are higher than that of base metal; the tensile strength and impact toughness of welded joint are better than that of base metal; the weld area is mainly composed of fine acicular ferrite and a small amount of massive ferrite The K-TIG welding joint with excellent properties has been obtained, which has reference significance for the further study of K-TIG welding process of low carbon steel.

Key words: K-TIG welding; dynamic process; microstructure and properties

Microstructure and properties of electron beam welded joints of dissimilar high temperature titanium alloys GAO Fuyang[1,3], GAO Qi[1,3], HAN Linju[1,3], YU Wei[1,3], ZHU Lele[2,3], LIU Yinqi[2,3] (1. Luoyang Ship Material Research Institute, Luoyang, 471039, China; 2. Luoyang Shuangrui Precision Casting Titanium Industry Co., Ltd., Luoyang 471039, China; 3. National Local Joint Engineering Research Center of Advanced Titanium and Titanium Alloy Materials Technology, Luoyang, 471039, Cina). pp 73-78

Abstract: High temperature titanium alloy Ti60 plate and Ti700sr casting were welded by vacuum electron beam welding machine, and the microstructure and mechanical properties of the joint were studied. The results show that the high temperature titanium alloy Ti60 plate and Ti700sr casting have good weldability by electron beam welding, and high quality joint can be obtained. The welding seam in the joint is fine acicular martensite, and there are stacking faults and twins infusion zone of Ti700sr side. The α phasein the HAZ of Ti700sr grow a lot compared with the α phase in the base metal. There are rich rare earth Nd precipitates in the fusion zone and heat affected zone on the Ti60 side. The microhardness of the weld metal is similar to that of Ti60 and Ti700sr, which is about 360 HV. The highest hardness occurs in the heat affected zone of Ti60 side, and the maximum hardness reaches 418 HV. The tensile properties of the joints at 600 and 650 ℃ are 695 and 587 MPa respectively.

Key words: Ti60 alloy; Ti700sr alloy; electron beam welding; microstructure; mechanical properties

High entropy mechanism of nugget in Ta1/0Cr18Ni9 sheet energy storage welding ZHAI Qiuya[1], LIU Shuaibin[1], YANG Quanhu[1], YE Jianlin[2], XU Jinfeng[1] (1. Xi'an University of Technology, Xi'an, 710048, China; 2. Xi'an Younite Container Manufacturing Co., Ltd., Xi'an, 710201, China). pp 79-84

Abstract: In this paper, in view of the difference of physical and chemical properties between tantalum and steel,which is easy to produce brittle intermetallic compounds during welding, resulting in poor performance and cracks of fusion welded joints. According to the idea of high entropy

technology of nugget metal, a new type of interlayer alloy $Ta_{20}Fe_{20}Ni_{20}Cr_{20}Co_{20}$ was designed based on the first principles of thermodynamics based on density functional theory. Combined with fusion ratio, the composition of intermediate layer alloy suitable for tantalum/steel energy storage welding is $Ta_7Ni_{32}Cr_{19}Co_{42}$. The button alloy ingot was melted by vacuum arc furnace, and then the middle alloy foil was prepared by single roll quenching method, which was used for energy storage welding connection of Ta1/0Cr18Ni9 sheet. The results show that under the condition of energy storage welding, Ta1/$Ta_7Ni_{32}Cr_{19}Co_{42}$/0Cr18Ni9 lap joint has formed a flat spherical nugget with regular and complete morphology and about 0.8 mm long diameter, and the nugget has shifted to the steel side as a whole. The nugget structure consists of simple FCC solid solution and no intermetallic compound precipitation. It has typical characteristics of high entropy alloy and realizes high entropy of nugget metal. The average strength of Ta/$Ta_7Ni_{32}Cr_{19}Co_{42}$/0Cr18Ni9 energy storage welding joint can reach 395 MPa under the welding voltage of 1 000 V, capacitance of 500 μF and electrode pressure of 30 N.

Key words: Ta1 tantalum; 0Cr18Ni9 stainless steel; CDW; nugget entropy

V-groove weld tracking model and simulation of rotating arc robot LI Xiangwen, WU Hongbao, HONG Bo, LUO Hua, CHEN Yu (Welding Robot and Its Application Key Laboratory of Hunan Province, Xiangtan University, Xiangtan, 411105, China). pp 85-89

Abstract: By establishing the mathematical model of the torch's spatial attitude when the rotary arc sensor scans the V-groove weld seam, extracting three-dimensional information of welding torch, combining the characteristics of V-groove weld, the transformation matrix between tool coordinate system and base coordinate system of ABB robot after correcting deviation of welding torch is derived. Combining the inverse kinematics of the robot, mathematical model of tracking and correcting deviation of V-groove weld by ABB robot is established, an Asymptotic Particle Swarm Optimization algorithm is proposed for solving the model. Last, the model is simulated and analyzed by using LABVIEW and the algorithm, the left and right tracking deviations and the high and low tracking deviations are obtained. The accuracy and validity of the model and the efficiency of the algorithm are verified, it provides a theoretical basis for the automatic welding of V-groove weld by the combination of rotating arc sensor and ABB robot.

Key words: rotating arc; ABB robot; mathematical model; asymptotic particle swarm optimization

Numerical analysis of weld pool fluctuation behavior induced by droplet transfer in twin-wire GMAW PAN Jiajing[1], HE Xixin[1], ZHAO Pengcheng[1], HU Yiteng[1], LIANG Ying[2] (1. Qingdao University of Science and Technology, Qingdao, 266061, China; 2. Shanghai University of Engineering Science, Shanghai, 201620, China). pp 90-96

Abstract: The dynamic fluctuation behavior of the free surface of molten pool during pulsed twin wire GMAW was studied. Based on the two-dimensional wave theory, the transient mathematical model of the shock vibration of molten pool surface and the two-dimensional wave behavior resulting from it are established. The governing differential equation is derived. The corresponding initial and boundary conditions are given, and the numerical analysis is carried out by programming. The displacement and vibration velocity distribution of the free surface of the molten pool, the instantaneous fluctuation of the free surface of the molten pool under different droplet transition conditions and the interference caused by the surface fluctuation during welding are obtained. The results show that the surface wave mainly originates near the center of the front wire and the back wire, resulting in a strong depression on the surface of the molten pool. The welding wire with diameter of 1.0 mm can reduce the surface fluctuation of molten pool and prevent the occurrence of coarse weld ripple; When the droplet transfer frequency is 1 000 Hz, defects such as rough welding ripple and undercut are easy to appear. The fluctuation interference decreases with the decrease of droplet transfer frequency. The work in this paper can provide basic data and theoretical guidance for the industrial production of pulsed twin wire GMAW and the optimization of welding parameters.

Key words: pulsed twin-wire GMAW; weld pool surface; wave behavior; droplet impingement