MAIN TOPICS, ABSTRACTS & KEY WORDS

A multifunctional monocular visual sensor based on combined laser structured lights GUO Jichang[1,2], ZHU Zhiming[1], SUN Bowen[1] (1. Department of Mechanical Engineering, Key Laboratory of Advanced Materials Processing Technology, Ministry of Education, Tsinghua University, Beijing 100084, China; 2. Tiandi Science & Technology Co., Ltd., Beijing 100013, China). pp 1-7

Abstract: A novel multifunctional monocular visual sensor based on combined laser structured lights is proposed and designed; its research and development ideas and structural design process are detailed. The proposed visual sensor can realize multi-functions of detection such as the cross-sectional sizes of welding groove, the height, space position and posture of welding torch by using monocular vision and single image processing. The calibration of the sensor makes full use of its intrinsic parameters, and there is no need to re-calibrate the sensor when the position and posture of welding torch changes, which effectively improves the adaptability of the sensor in the welding process of complex structural workpiece and welding trajectory. With the use of combined laser structured lights, the problem of information loss in the depth direction existing in usual monocular visual sensor is solved effectively. Finally, the corresponding detection algorithms for the cross-sectional sizes of the V-type groove and the height of welding torch are derived, and the experiments are carried out to verify them. The experimental results show that the maximum relative detection error is not more than 2.1%.

Key words: visual sensor; laser structured light; detection of welding groove; welding seam tracking; detection of welding torch height

Electric simulation inertia friction welding technology DU Suigeng[1], ZHAO Xinzhe[1,2], LI Zhiyuan[1] (1. Key Laboratory of High Performance Manufacturing for Aero Engine (Northwestern Polytechnical University), Ministry of Industry and Information Technology, Xi′an 710072, China; 2. State Owned Assets Supervision and Administration Commission of Zhangjiakou, Zhangjiakou 075000, China). pp 8-14

Abstract: In order to adapt to the current development of friction welding equipment and reduce the manufacturing cost, the electro-simulated inertia friction welding technology and equipment are developed, based on the analysis of the kinematics equation of inertia friction welding process and the electric simulation inertia technology. The result shows that the regularity of the change of parameters over time and the influence of inertia size on welding parameters are in accordance with the general law of inertia friction welding during the electric simulation. The rotational speed curve of inertial friction welding is consistent with that of mechanical inertia friction welding process under the same inertia. The inertia can be set to be larger than the basic inertia of the system, and can be set to equal or lower than the basic inertia of the system by electric simulation inertial friction welding technology. The effect of friction resistance of spindle on the parameters of welding process can be compensated by electro-simulated inertial friction welding technique.

Key words: inertia friction welding; electrical inertia simulation; friction welding

Effect of TiN on microstructure and wear resistance of Fe-Cr-C hardfacing alloy LIU Zhengjun, LI Dongrui, WANG Wenxin, SU Yunhai (Shenyang University of Technology, Shenyang110870, China). pp 15-19

Abstract: Fe-Cr-C-Ti-N and Fe-Cr-C Surfacing layers were prepared by flux cored wires. The effect of TiN on the wear resistance and microstructure of the surfacing layer was discussed. The rockwell hardness tester was used to test the macrohardness of the surfacing layer. The abrasive wear test of the surfacing layer is carried out by the wet grinding wheel wear tester. Using X ray diffractometer (XRD), scanning electron microscope (SEM), energy dispersive spectrometer (EDS), transmission electron microscopy (TEM) and other equipment for testing and analysis. The results showed that the primary M_7C_3 in the surfacing layer containing TiN was significantly smaller than that without TiN and the hardness and wear resistance of the surfacing layer were also improved. Through thermodynamic calculation, TiN is prior to precipitation of M_7C_3 in molten pool cooling process. According to the dynamics calculations, the two-dimensional misfit of TiN/M_7C_3 is 8.43%. TiN can be used as a heterogeneous nucleation site for primary M_7C_3, which refines the M_7C_3 grains.

Key words: hardfacing alloy; wear resistance; thermodynamics; two-dimensional misfit

Fatigue design and prediction on cruciform joint of 7N01 aluminum alloy WANG Ping[1,3], MI Liyan[2], YU Yifei[1], DONG Pingsha[3] (1. State Key Laboratory of Advanced

Welding and Joining, Harbin Institute of Technology, Harbin 150001, China; 2. Technology Resaerch Center CRRC Tangshan Co., Ltd., Tangshan 064000, China; 3. School of Naval Architecture and Ocean Engineering, Harbin Insitute of Technology, Weihai 264209, China). pp 20-24

Abstract: The fatigue failure mode of aluminum alloy cruciform joint was carried out for the first time. By using the finite element analysis and fatigue test, the stress concentration factor s (SCF) of weld toe based on the traditional hot spot stress (HSS) and the equilibrium equivalent structural stress(EETS) were compared, the latter was mesh-insentive and shows high consistency. Besides, the influence of the Continuous member thickness of the joint, the penetration depth of the joint and the loading span on the EETS at the weld toe and the weld root are analyzed. And the effective traction stress was used to calculate the root cracking angle. It is found that, the equivalent structural stress at the weld toe keeps the constant, while the EETS at weld root changes with different continuous plate, the loading span and the penetration depth. The fatigue test shows that the root cracking angle is not 45°, which is consistent with the analytical prediction. The fatigue design of the cruciform joint needs to consider both the joint geometry and welding quality, which should meet the equivalent structural stress at the weld toe ($S_{s,\ toe}$) is higher than the equivalent structural stress ($S_{s,\ toe}$) at the root of the weld.

Key words: cruciform joint; fatigue design; traction stress; failure mode

Sensitivity analysis of process parameters of self-shielded flux cored wire GU Yufen, XIE Jinlong, ZHANG Hengming, SHI Yu (State Key Laboratory of Advanced Processing and Recycling of Nonferrous Metals, Lanzhou University of Technology, Lanzhou 730050, China). pp 25-30

Abstract: Self-shielded flux cored wire is a kind of welding material suitable for field project, which is widely used in welding and repair of field project such as ships, drilling platforms, oil pipelines and containers. Single-layer single-bead welding was carried out on the surface of Q235 steel by self-shielded flux cored wire, and quadratic regression mathematical model between arc voltage, wire feeding speed, welding speed and melting width, reinforcement, melting height was established by quadratic regression universal rotating combination design method. The relationship between process parameters and deposited geometries is analyzed, the results show that the model can predict the influence of process parameter variation on the geometry of the deposited layer in the stable process interval. The wire feeding speed is the main factor affecting the melting width and reinforcement at low voltage, while the welding speed is the main factor affecting the melting width and reinforcement at high voltage.

Key words: self-shielded flux cored wire; quadratic regression mathematical model; process parameters; deposited geometries

Effect of cooling rate on the microstructure and mechanical properties of high nitrogen stainless steel weld metal MING Zhu[1,2], WANG Kehong[1], WANG Wei[2], WANG Youqi[2] (1. Nanjing University of Science and Technology, Nanjing 210094, China; 2. Ningbo Branch of China Academy of Ordnance Science, Ningbo 315103, China). pp 31-35

Abstract: The micro-structure and mechanical properties of high nitrogen stainless steel weld metals prepared under air and water cooling conditions were investigated and the effect of cooling rate on the micro-structure and mechanical properties of high nitrogen stainless steel weld metal was discussed in this study. The results indicated that an increase in the cooling rate would significantly increase the nitrogen content in the high nitrogen stainless steel weld metal, especially for the one with nitrogen content of 0.85%. Increasing cooling rate could result in the increase in the tensile strength of high nitrogen stainless steel weld metal, which was found to be strongly dependent on the nitrogen content in high nitrogen stainless steel weld wire. For the lower nitrogen content of high nitrogen austenitic stainless steel welding wire, increasing cooling rate could significantly improve the tensile strength of weld metal, but had no influence on the one of weld metal when the nitrogen content beyond 0.58% in the welding wire. The tensile strength of the joint reached 850 MPa finally.

Key words: high nitrogen stainless steel; welding; cooling rate; microstructure; mechanical properties

Effect of workpiece inclination on weld pool shape and weld forming in pulsed MAG welding ZHANG Yang[1], LV Xiaoqing[1,2], XU Lianyong[1,2], JING Hongyang[1,2] (1. Tianjin University, Tianjin 300350, China; 2. Tianjin Key Laboratory of Advanced Joining Technology, Tianjin 300350, China). pp 36-42

Abstract: In this paper, the uphill welding and downhill welding tests were carried out on workpieces with different dip angles under the same MAG welding parameters by single factor test method. The characteristic parameters such as edge and size of the molten pool were extracted by High speed camera and image processing technology and the area and rear drag angle of the molten pool was corrected. The influence of workpiece dip angle on weld pool width, length, area, rear drag angle and weld forming was analyzed. The results show that when the dip angle of the workpiece exceeds

30°, the obliquity of the workpiece has obvious influence on the morphological characteristic parameters and the size of molten pool and it is different in uphill and downhill welding. It is of great significance to reduce welding defects and improve welding process in non-horizontal position welding.

Key words: workpiece inclination angle; high speed photography; image processing; shape of molten pool; weld forming

Aluminum alloy thick plate laser scanning wire filling welding porosity suppression ZOU Jipeng[1], LI Liansheng[1], GONG Jianfeng[2], HUANG Ruisheng[1], LI Yubin[3] (1. Harbin Welding Institute Limited Compay, Harbin 150028, China; 2. State Key Laboratory of Advanced Welding and Joining, Harbin Institute of Technology, Harbin 150001, China; 3. China Academy of Engineering Physics, Mianyang 621054, China). pp 43-47,66

Abstract: To reduce big plate of 5A06 aluminum alloy laser welding defects, which enhances the stability of welding process, using a laser beam in a certain way of scanning new welding method, welding laser beam was studied different trajectories, amplitude, frequency of deep penetration laser welding aluminum alloy weld porosity, and the welding groove design optimization based on the application of narrow gap scanning laser wire filling welding technology for 130 mm thick 5A06 aluminum alloy welding test. The results show that when the scanning amplitude of the laser beam is greater than 1 mm and the scanning frequency is near the highest frequency, the porosity of the weld can be greatly reduced. The welding method of narrow gap laser scanning wire filling was adopted to obtain the high-quality welding joints of 130 mm 5A06 aluminum alloy with average porosity of 1%, no side wall non-fusion, interlayer non-fusion, crack and other welding defects.

Key words: laser scanning welding; aluminum alloy; thick plate; narrow gap

Microstructure to properties of coarse grained heat affected zone in deposited weld metal of metal cored wire E120C-K4 SU Xiaohu[1], LI Zhuoxin[1], LI Hong[1], JinKim Hee[2], MENG Bo[3] (1. Beijing University of Technology, Beijing 100124, China; 2. Advanced Joining Research Team, Korea Institute of Industrial Technology, Cheonan-si 330-825, Korea; 3. Shandong JuLi Welding Co., Ltd., Dezhou 253000, China). pp 48-53

Abstract: The effect of microstructure as a function of welding cooling time ($t_{8/5}$) from 800 °C to 500 °C on the impact toughness of coarse grained heat affected zone (CGHAZ) of deposited metal of metal cored wire E120C-K4 was investigated by welding thermal simulation. The results showed that the microstructure of CGHAZ was mainly composed of degenerate upper bainite (DUB) granular bainite (GB) and Acicular ferrite(AF) at $t_{8/5}$ from 6 s to 12 s, forming the interlace multiphase microstructure, then the optimal impact toughness was obtained. The microstructure of CGHAZ formed with granular bainite (GB) and Acicular ferrite(AF) and the impact toughness decreased when $t_{8/5}$ from 30 s to 120 s. The absorbed energy of CGHAZ was only 24 J at −40 °C at $t_{8/5}$ of 120 s, the worst impact toughness. The key of improving impact toughness at $t_{8/5}$ from 6 s to 12 s was: ① forming the interlace multiphase microstructure; ② refining grains; ③ more high-angle grain boundaries per unit distance.

Key words: welding thermal simulation; 800 °C to 500 °C welding cooling time; coarse grained heat affected zone; microstructure; impact toughness

Compression fatigue behavior of Fe-C-Cr-Nb alloys surfaced on 45 steel REN Zhen′an[1], ZHENG Siqiang[1,2], HUANG Fei[1,3], LIU Wumu[1] (1. Jilin University, Changchun 130022, China; 2. FAW Jiefang Automotive Co., Ltd., Changchun 130011, China; 3. Northeast Electric Power University, Jilin 132012, China). pp 54-59

Abstract: The compression fatigue behavior of six kinds of Fe-C-Cr-Nb surfacing alloys on the base metal of 45 steel was tested with self-designed dual-notch fatigue specimens according to the compression fatigue working condition of the cement squeeze roller. In-situ observation and laser confocal crack analyses were carried out on the surface of fatigue specimens. The stress-strain concentration of the notches accelerated the accumulation of slip lines at local HAZ just below the notches and plastic deformation zones formed there. At the same time, fatigue cracks were initiated at the bottom edge of the notches and propagated into HAZ through surfacing alloys. Fatigue cracks were initiated and propagated along the fusion line as well and eventually resulted in fatigue failure. The experimental results show that the a-N curves of fatigue specimens were approximately straight lines. When the matrix micro-structures of the surfacing alloys were mainly composed of martensite with high hardness, the fatigue crack propagation rate is big and the fatigue life is only 50,000 times. While the micro-structures were composed of soft ferrite or austenite, the propagation rate is small and the fatigue life is up to 540,000 times.

Key words: compression fatigue; surfacing alloy; microstructure; fatigue life; squeeze roller

Quality evaluation of laser welds based on air-coupled ultrasound CHANG Junjie[1,2], LI Yuanyuan[1], HU Chen[1], Wu Ruifeng[3] (1. Key Lab of Nondestructive Testing, Ministry of Education, Nanchang Hangkong University, Nanchang

330063, China; 2. Japan probe Co., Ltd. Japan Yokohama 2320033, Japan; 3. CRRC Tangshan Co., Ltd., Tangshan 063035, China). pp 60-66

Abstract: With the wide application of laser welding technology in automobile and rail transit, the requirements for non-destructive testing of laser welds are getting higher and higher. For the laser welding of two-layer metal sheets below 3 mm, the air-coupled ultrasonic testing technology is discussed. The possibility of detecting the laser weld. Using numerical analysis and experimental analysis, the Lamb wave is excited on the aluminum plate in the air, and laser welding is analyzed by the propagation simulation of the Lamb wave in the laser weld test piece. By studying the propagation simulation of Lamb waves in laser weld specimens, The effect of the width of the laser weld and the quality of the weld on the reflectivity and transmittance are analyzed. The results show that the Lamb wave A0 mode can be used to evaluate the quality of the laser weld.

Key words: air coupling; lamb wave; thin plate; laser welding

Weld shape and microstructure of TC4 laser welding with activating flux of Na_2SiF_6 HOU Jijun[1], DONG Junhui[1], BAI Xueyu[1], HAN Xu[1], YANG Hu[2] (1. Inner Mongolia University of Technology, Hohhot 010051, China; 2. Ulanqab Bureau of Industry and Information Technology, Ulanqab 012000, China). pp 67-72

Abstract: Na_2SiF_6 was used as surface activating flux for laser welding of TC4 titanium alloy. The effect of Na_2SiF_6 on TC4 titanium alloy laser welding was determined by observing the weld surface. The morphological characteristics of the high temperature plasma above the workpiece was observed and analyzed by using high-speed digital camera system. The variation of weld depth,width and microstructure were analyzed by optical microscope. The experimental results show that laser weld of TC4 titanium alloy has good appearance with activating flux of Na_2SiF_6, weld penetration increases by about 0.8% ~ 12%, while weld surface width decrease by about 10% ~ 29%, the depth to width ratio is effectively improved. The inhomogeneity of weld microstructure was improved , and the crystallization direction of βcolumnar crystals on the upper part of the weld was changed, the grain size and microstructure of the weld were refined by Na_2SiF_6.

Key words: Na_2SiF_6; TC4 titanium alloy; plasma; weld shape; microstructure

Analysis of bending test characteristics of welded joints with same material SU Shijie[1], WANG Chao[1], LI Cunjun[2], LIU Jitao[1], YUAN Zhong[3] (1. Jiangsu University of Science and Technology, Zhenjiang 212003, China; 2. Zhoushan Institute of Calibration and Testing for Quality and Technology Supervision, Zhoushan 316021, China; 3. Jiangsu Yongfa Medical Equipment Co., Ltd., Suzhou 215621, China). pp 73-79

Abstract: Bending test can be used to assess the quality of welded joints, however, there are great differences in the different standards about how to select the proper bending diameter for the bending test. In this paper, firstly, the theoretical formula for bending elongation of the welded joint under ideal conditions is deduced, and the finite element method is used to analyze mechanical properties of the welded joint, and the correctness of the theoretical formula is verified. Further, the theoretical formula is modified according to the analysis results, and the formula for minimum bending diameter under the two bending methods is established respectively. Then the new formula is verified by carrying real bending test on welded joints of different specifications. Finally, calculation result of the formula for minimum bending diameter are compared with the standard of Chinese Classification Society. The results showed that the bending diameter recommended by the Chinese Classification Society is closer to the calculation result of three point bending, but when the bending diameter is small, it is more recommended to use the roller bending method.

Key words: roller bending test; three-point bending test; welded joint; bending diameter calculate

Microstructure and properties of brazing joints with a Ti-based filler of TiAl/GH536 alloy LI Xiaoqiang[1], LOU Li[1], QU Shengguan[1], YANG Chao[1], LI Li[1,2] (1. National Engineering Research Center of Near-net-shape Forming for Metallic Materials, South China University of Technology, Guangzhou 510640, China; 2. East China Jiaotong University, Nanchang 330013, China). pp 80-85

Abstract: Vacuum brazing of TiAl alloy and GH536 alloy with Ti-Zr-Fe-Cu-Ni-Co-Mo filler as interlayer was investigated. The microstructure of the brazed joints was characterized by employing SEM, EDS and XRD, and shear strength of the joints was analyzed in detail. Results show that the typical microstructure of the joint is given below: TiAl/layer I /layer II /layer III /layer IV /GH536. Layer I is mainly composed of Ti_3Al, in which some TiAl phases are embedded. Layer II is constituted by Al_3NiTi_2. Layer III mainly contains $AlNi_2Ti$, the other phases are Cr-rich (Cr, Ni, Fe)$_{SS}$, Ni-rich (Cr, Ni, Fe)$_{SS}$ and (Ni)$_{SS}$ + $TiNi_3$. In Layer IV, there are still Cr-rich (Cr, Ni, Fe)$_{SS}$, but a small number of Ni-rich (Cr, Ni, Fe)$_{SS}$, $AlNi_2Ti$ and (Ni)$_{SS}$ + $TiNi_3$ can be observed. The shear strength first increases and then decreases in the brazing temperature range of 1 110 ~ 1 170 °C for 10

min. The diffusion of atoms and the formation of intermetallic compounds are closely related to the brazing temperature. Lower or higher brazing temperature will lead to lower joint strength. It obtains a maximum value of 183 MPa at temperature of 1 150 °C with a holding time of 10 min, and the joints are mainly fractured at layer II.

Key words: TiAl alloy; Ni-based alloy; brazing; interfacial microstructure; shear strength

Welding parameters optimization and mechanical properties analysis of PVPPA welded high-strength aluminum alloy LI Guowei[1,2], LIANG Yahong[1,2], CHEN Furong[1,2], HAN Yongquan[1,2] (1. Inner Mongolia University of Technology, Hohhot 010051, China; 2. Inner Mongolia Key Laboratory of Light Metal Materials, Hohhot 010051, China). pp 86-92

Abstract: The welding process of 7075 aluminum alloy with a thickness of 10mm was carried out by PVPPAW. The influence of welding current and plasma gas flow rate on weld forming coefficient was studied. The optimum welding parameters were determined and the well-formed welds were obtained. The mechanical properties of the well-formed welded joints were analyzed. The results shown that the weld forming coefficient initially decreased and then increased with the increase of welding current. While the plasma gas flow rate increased, the weld forming coefficient gradually decreased. The better weld forming coefficient range is 1.1 ~ 1.3. Compared with the plasma gas flow rate, the welding current has greater influence on weld formation. The satisfying weld appearance can be achieved under the pulse welding current of 250 A/290 A, the plasma gas flow rate of 2.0 L/min. The welding quality is good under the optimum welding parameters, and the tensile strength of the weld reached 397.9 MPa, which is nearly 67.5% of that of the base metal. The weld area exhibited the dendrite microstructure.

Key words: 7075 aluminum alloy; PVPPA; welding parameters; mechanical property

Thermo-mechanical coupling analysis of consumable-rod friction welding process JU Jianzhong[1], REN Zhaohui[1], LIU Dapeng[2], LIU Jialong[1] (1. Northeastern University, Shenyang 110819, China; 2. Minmetals Luzhong Mining Co., Ltd., Laiwu 271100, China). pp 93-99

Abstract: AA6061 aluminum alloy was taken as the test object, based on ABAQUS/Explicit, a three-dimensional fully thermo-mechanical coupling model for consumable-rod friction welding was established, and the temperature field, equivalent plastic deformation field, axial shortening and flash shape were analyzed. The results shown that the solid phase bonding was achieved because the welding temperature was lower than the melting point of the material, plastic metals were extruded in large quantities to form a mushroom head shape of flash with a temperature of about 480 °C during welding process. In the stable welding stage, the temperature of the advancing side was higher than that of the retreating side. In the direction perpendicular to the welding seam, the high temperature zone of the welding rod was larger than that of the welding plate, and the uneven temperature distribution made the bonding at the edge of the coating poor. The relation between axial shortening and time is nearly linear after the high temperature region tends to be stable, and the number of axial shortening was 7.5 mm at the end of welding. Both the high temperature zone and the plastic deformation zone were concentrated in the accumulation area near the friction interface.

Key words: consumable-rod friction welding; thermal coupling; temperature field; plastic deformation field

Forming method and technology of arc additive manufacturing for thick wall structural parts YANG Zhuang, WANG Tianqi, LI Liangyu, LI Tianxu (Advanced Mechatronics Equipment Technology Tianjin Area Laboratory, Tianjin Polytechnic University, Tianjin 300387, China). pp 100-105

Abstract: Arc welding robot is used for arc additive manufacturing, and the welding technology of additive manufacturing of thick-walled structural parts is studied. Based on the traditional stratification theory, the prediction and analysis of the molding dimension of the thick wall structure are carried out with the algorithm optimization. On the basis of this algorithm, the prediction model of the single weld shape size neural network is introduced to improve the precision of the preform model and the optimum selection of the actual welding parameters; In view of the collapse of the weld edge in the forming process of thick wall structures with inner holes and other features, the "boundary constraint" welding method was proposed and the interlayer welding trajectory was planned to improve the quality of the surface of the preform. Finally, the welding method has an illustrative physical component verification prediction algorithm and the accuracy of trajectory planning. The test results show that the structure is well formed and the size error is less than 1 mm.

Key words: arc welding robot; additive manufacturing; thick wall structure; trajectory planning; size prediction

Bonding strength and plasticity of multiscale composite nanosilver paste for low temperature sintering LI Zhao, LIU Yang, ZHANG Hao, SUN Fenglian (Harbin University of Science and Technology, Harbin 150040, China). pp 106-110

Abstract: Nano silver paste for low temperature sintering bonding was studied. The optimal ratio of nano silver particles to micro silver particles in the silver paste was calculated and then was made into composite silver paste. The effect of different solvents on the porosity of the sintering joint was investigated. Meanwhile, the hardness, elastic modulus, and plasticity of the sintered joints by nano silver paste and micro silver paste were studied. The results indicated that the composite silver paste using the mixed organic solvent improved the quality of the sintered joints under 250°C. The porosity in the joints was significantly lower using the mixed organic solvent than that using glycol. Compared with nano silver sintered joints, the sintered joints using composite silver paste showed larger indentation area but lower hardness and elastic modulus. When the sintering time ranged from 10min to 30min, the plasticity of the composite silver joints was higher than that of the nano silver sintered joints.

Key words: low temperature sintering; composite silver paste; hardness; elastic modulus; plasticity

Numerical simulation on in-serve welding of natural gas pipeline LIU Yongbin[1], FENG Lide[2], ZHANG Jina[1], XU Zhiwu[3], LI Zhengwei[3] (1. Gas Technology Institute of Petrochina KunLun Gas Co., Ltd., Harbin 150010, China; 2. Kunlun Energy Company Limited, Beijing 100101, China; 3. State Key Laboratory of Advanced Welding and Joining, Harbin Institute of Technology, Harbin 150001, China). pp 111-115,120

Abstract: During the in-service welding of natural gas pipeline, large depth of molten pool can result into low strength of the un-melted material at the bottom of the molten pool. The pipeline will fail if it cannot bear the inner gas pressure. To avoid this, this work used MSC.Marc software to simulate the in-service welding of natural gas pipeline. Tungsten Inert Gas (TIG) Welding was employed. The simulation result of the temperature field showed that the peak temperature of the inner wall of the pipe was 1 131 °C under a welding current of 220 A and did not exceed the melting point of the pipe material. Under this temperature, the yield strength of the material was 19 MPa, which was higher than the gas pressure inside the pipe. Burnthrough easily appeared when the welding currents ranged from 240-260 A. The surrounding of the cover plate was a closed ring weld. The stress field was more complicated than that of the straight weld. The results showed that the residual stress distribution was asymmetrical and its peak value was 212.3 MPa under the welding current of 220 A. The maximum deformation of the cover was 1.79 mm.

Key words: in-serve welding; numerical simulation; temperature field; residual stress; deformation

Prediction on thin plate welding buckling of TIG bead welding GUO Nan[1], YU Yongjian[1], YIN Xianqing[2], YANG Fang[1] (1. Henan Key Laboratory of Modern Mechanical Design and Transmission System, Henan University of Science and Technology, Luoyang 471049, China; 2. Xi'an Jiaotong University, Xi'an 710049, China). pp 116-120

Abstract: In view of the complex deformation of thin plate caused by TIG bead welding, a thermal-elasto-plastic finite element method was used to establish the prediction model of welding deformation. A non-contact detection method based on digital image correlation technology was proposed to verify the prediction model and a thin plate welding deformation test device was designed. The research shows that the non-contact deformation detection method based on digital image correlation technology can dynamically obtain welding deformation data in the whole field, and can fully verify the welding deformation finite element prediction model. The welding deformation prediction thermo-mechanical coupling model has high accuracy based on Gaussian heat source model, nonlinear transient heat conduction boundary conditions, and material high-temperature performance parameters. The welding deformation of thin plates is saddle-shaped after cooling. Combining the dynamic temperature field and stress field, it is great significance in revealing the mechanism of welding saddle-shaped buckling deformation.

Key words: bead welding; thermal-elasto-plasticity; buckling; digital image correlation

Microstructures and mechanical properties of Ti-6Al-3Nb-2Zr-Mo alloy fabricated by electron beam rapid manufacturing ZHANG Shuaifeng[1], JIANG Peng[1], YU Bingbing[1], GONG Shuili[2], YANG Guang[2] (1. Luoyang Ship Material Research Institute, Luoyang 471039, China; 2. Beijing Aeronautical Manufacturing Technology Research Institute, Beijing 100024, China). pp 121-126,155

Abstract: The Chemical compositions, microstructure, mechanical properties, toughness of Ti6321 alloy made by electron beam rapid manufacturing (EBRM) were studied. The 1% of Al in the solder wire was burned during the manufacturing process, and no element segregation was found. The as-built microstructures exhibit large columnar grains, which grew epitaxially along the height direction of deposits through many deposition layers. The columnar grain is mainly composed of α lamellae. As a result, the anisotropic coefficient of tensile strength is 2. 6%. Dimple are observed on fractured tensile specimens in both X and Z directions. The impact toughness of

X and Z direction is not less than 80J, and the anisotropic coefficient of toughness is 2.6%. The impact fracture is typical ductile fracture, which consists of a large number of dimples.

Key words: electron beam rapid manufacturing; microstructure; chemical content; mechanical property; anisotropy

Study on droplet transfer of CMT + P welding process in SAF2507 super duplex stainless steel HUANG Hanchuan[1], XU Lianyong[1,2], JIN Hongyang[1,2], LV Xiaoqing[1,2] (1. School of Materials Science and Engineering, Tianjin University, Tianjin 300072, China; 2. Tianjin Key Laboratory of Advanced Joining Technology, Tianjin 300072, China). pp 127-136

Abstract: In this paper, the high-speed camera and welding electrical signal collection system were applied to observe the metal transfer of CMT + P welding process in SAF2507 Super Duplex Stainless Steel. The metal transfer behaviors, change of waveforms and heat input characteristics with different WFS of CMT and CMT + P were analyzed. The droplet transfer characteristics were revealed. The results show that there are many differences between the actual waveforms and the theoretical waveforms. The shape and size of the droplet, transfer form, the wave state of molten pool, the distance from the wire tip to the workpiece and the spatter can all affect the fluctuation of the voltage. The voltage waveform diagram can be used to guide the analysis of the metal transfer behaviors. The pulse period plays a major role in heat input, and the control of heat input can be realized by adjusting pulse peak current, pulse base current and the number of pulses.

Key words: CMT; pulse; super duplex stainless steel; droplet transfer; heat input

Microstructure and high temperature mechanical properties of inertia friction welding joint of K447A + GH4169 ZHANG Chuanchen[1], ZHANG Tiancang[1], ZHAO Chunling[2] (1. AVIC Manufacturing Technology Institute, Aeronautical Key Laboratory for Welding and Joining Technologies, Beijing 100024, China; 2. AECC Hunan Aviation Powerplant Research institute, Zhuzhou 412002, China). pp 137-141

Abstract: The dissimilar materials of Ni-base cast superalloy K447A and Ni-base wrought superalloy GH4169 were welded by Inertia Friction Welding (IFW). The microstructure and high temperature mechanical properties of the joints were studied after heat treatment. The results show that good flash can be formed after IFW and no clear defects were found at the root of the flash. Fine recrystallization zone was formed in the weld zone (WZ) and fine γ" phase and γ' phase were precipitated in the WZ after heat processing. The recrystallization zone width of the K447A side is between 3μm and 10μm. The high temperature tensile strength and torsional strength of GH4169 + K447A IFW joints were equal to K447A base metal. The high cycle fatigue strength of the joint is 355 MPa at the temperature of 400 °C. Under the condition of 400 °C and 720 MPa, the low cycle fatigue life of all the joint samples exceeded 30 000 times.

Key words: dissimilar superalloys; inertia friction welding; microstructure; high temperature mechanical property

Structure and corrosion behavior of friction stir weld joint of 2195 Al-Li alloy MA Yunlong[1,2], YANG Ziqi[1], LI Jinfeng[1] (1. Central South University, Changsha 410083, China; 2. Beijing Institute of Aerospace Systems Engineering, Beijing 100076, China). pp 142-147

Abstract: Microstructures, electrochemical behavior and corrosion feature of different locations in 2195-T8 Al-Li alloy FSW joint were investigated. The parent metal possesses fiber-like grains, but the nugget zone is featured with fully recrystallized grains with size less than 10 μm. The strengthening precipitates of the parent metal are T1 (Al_2CuLi) and θ' (Al_2Cu). In the thermo-mechanically affected zone, most T1 and all θ' are re-dissolved, but all T1 and θ' are re-dissolved in the nugget zone. From the parent metal to the nugget zone, the potential increases. Accordingly, galvanic corrosion occurs on the FSW joint surface, the parent metal undertakes anodic current and the nugget zone undertakes cathodic current. In the intergranular corrosion medium, superficial corrosion occurs on the nugget zone surface, but corrosion penetrates inside the parent metal.

Key words: Al-Li alloy; friction stir weld; microstructure; corrosion; electrochemical behavior

Brazing process of TC4 titanium/ 304 stainless steel dissimilar materials honeycomb sandwich structure DENG Yunhua[1], YUE Xishan[1,2], LI Xiaohui[3], TAO Jun[1], ZHANG Sheng[1] (1. Aeronautical Key Laboratory for Welding and Joining Technologies, AVIC Manufacturing Technology Institute, Beijing 100024, China; 2. Northwestern Polytechnical University, Xi'an 710072, China; 3. Military Representative Office of Chinese People's Liberation Army Accredited in Chengfei Company, Chengdu 610092, China). pp 148-155

Abstract: TC4 titanium face sheet/304 stainless steel honeycomb core dissimilar materials honeycomb sandwich structures were brazed by Ti-37.5Zr-15Cu-10Ni and Ag-Cu28 brazing filler metals respectively. Microstructure of brazing interfaces and mechanical properties of honeycomb sandwich

structures brazed by both brazing filler metals were comparatively analyzed in details. Results show that the wettability between 304 stainless steel honeycomb core and Ti-based brazing filler metal is poor and the hardness of brazed interface is relatively high, which lead to the low strength of Ti-37.5Zr-15Cu-10Ni brazed interface. Significant reaction has taken place between 304 stainless steel honeycomb core and Ag-based brazing filler metal. Honeycomb sandwich structure with the tensile strength of 10.35 MPa is attained at the brazing temperature of 830°C with the bolding time of 10 min. Compared with Ti-based brazing filler metal, Ag-based brazing filler metal is suitable for brazing TC4 titanium /304 stainless steel dissimilar materials honeycomb sandwich structures.

Key words: dissimilar materials honeycomb sandwich structure; Ag-based brazing filler meta; Ti-based brazing filler metal; brazing interface; mechanical property

Effect of rotational speed on forming and tensile shear properties of 2060 Al-Li RFSSW joint LI Shuaizhen[1], XING Yanshuang[1], LIU Xuesong[2] (1. CSR Qingdao Sifang Co., Ltd., Qingdao 266111, China; 2. State Key Laboratory of Advanced Welding and Joining, Harbin Institute of Technology, Harbin 150001, China). pp 156-160

Abstract: This study chose 2060 Al-Li alloy as the objective to perform RFSSW experiments. The purpose is to investigate the rotational speed on interior form and tensile shear properties of RFSSW joint. The results show that the incomplete refilled defect, void and hook occur in the RFSSW joints under different rotational speeds. Furthermore, the incomplete refilled defect and void easily occur at low and high rotational speeds. Meanwhile, hook bends toward downward and its height first increases and then reduces. The tensile shear load of joint increases and then decreases with increasing rotational speed. The maximum value reaches to 9 800 N under 2 200 r/min. The fracture mode of RFSSW joint is shear fracture, and the fracture location includes three types. They are along the lap interface, along the bottom of the sleeve affected zone and along the above-mentioned mixture fracture.

Key words: 2060 Al-Li alloy; refill friction stir spot welding; defect; tensile shear load