MAIN TOPICS, ABSTRACTS & KEY WORDS

Microstructure and mechanical properties of EBW-brazed titanium to aluminum joint using AlSi5 filler wire

WANG Ting[1], LI Hongjian[1], JIANG Siyuan[1], ZHANG Binggang[2], FENG Jicai[1,2] (1. Shandong Provincial Key Laboratory of Special Welding Technology, Harbin Institute of Technology at Weihai, Weihai 264209, China; 2. State Key Laboratory of Advanced Welding and Joining, Harbin Institute of Technology, Harbin 150001, China). pp 1 – 4

Abstract: Electron beam welding-brazing experiments of titanium to aluminum using AlSi5 filler wire were carried out in present paper. Microstructure and mechanical properties of welding joints were examined. The results showed that it was possible to join aluminum to titanium by electron beam welding with filler wire. Tensile strength reached 98.8 MPa, up to 96.7% of that of aluminum. The joint took on a typical welding-brazing characteristic, which was composed of brazing joint at titanium side and welding joint at aluminum side. There was a Ti-Al intermetallic layer in the brazing joint with a thickness less than 2 μm, having weak impact on mechanical properties. Aluminum weld can be strengthened by dispersedly distributed IMCs. The lowest hardness value was in the HAZ, where fracture occurred during tensile test.

Key words: titanium; aluminum; EBW-brazing using filler wire; microstructure; mechanical properties

Modeling of ultrasonic metal welding of Cu-Al joints

LI Huan, CAO Biao, YANG Jingwei, CUI Xiaoyu (School of Mechanical & Automotive Engineering, South China University of Technology, Guangzhou 510640, China). pp 5 – 9

Abstract: A 3-D thermal-mechanical coupled finite element model of ultrasonic metal welding of dissimilar alloys is developed. The friction heat flux and the deformation heat flux are related to different level of coupon's vibration amplitude. The effects of ultrasonic softening on temperature distribution, stress distribution and tool indentation depths are included in the analysis of the welding process. The results show that the bulk temperature is lower than the melting temperature of the metals, the maximum temperature occurred at the center of the contact interface between the sonotrode tip and the upper copper specimen and the peak level of the welding interface temperature occurred at the center area. It is also shown that the sonotrode tip completely sinks into copper in welding, while the anvil tip's indentation depths do not reach its maximum. The proposed model is validated and verified by comparing with welding cross-section and a point temperature using experimental physical test. The presented model is capable of predicting and explaining the relationship between ultrasound soften, mechanical field and thermal field during welding process.

Key words: ultrasonic metal welding; finite element method; ultrasound softening; dissimilar metal

Investigation on wear resistance of in-situ (Ti, V)C reinforced Fe-based composite material

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Abstract: A series of Fe-Ti-V-C hardfacing alloys with different vadium contents were prepared by laser cladding. The microstructure and carbides morphology were investigated by means of optical microscope (OM) scanning electron microscopy (SEM) and X-ray diffraction (XRD). The results shows that the matrix transforms from ferrite to ferrite plus martensite, the volume fraction of primary (Ti, V)C complex carbides increase as the V content increase, the morphology of primary (Ti, V)C changes from globular to exploded shape when the V content is higher than 13.3%. In addition, the results of wet sand rubber wear tests indicate that proper V content significantly improves the abrasion resistance of hardfacing alloys. when V content is 13.3%, the microstructure characteristic with a high volume fraction of globular (Ti, V)C complex carbides are distributed uniformly and dispersly in the ferrite and lath martensite matrix, which suggests that the cladding layer has a excellent wear resistance.

Key words: wear resistance; microstructure; Fe-Ti-V-C alloy system

Effects of titanium powder addition on thermal stability of grain structure in friction stir welds of aluminum alloy

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Abstract: By adding a groove inside nugget zone, titanium-aluminum mix powder can be introduced into friction stir welding (FSW). Intermetallic particles can be produced in situ due to high heat input and severe plastic deformation during FSW. The relationship between the thermal stability of grain structure and the second phase particles in the welds was studied and discussed. The results show that abnormal grain growth (AGG) region of heat-treated samples decreased significantly with titanium powder addition as compared with that without titanium powder addition. The results further suggest that AGG after heat treatment can be restrained by introducing second phase particles into the nuggets zone. Meanwhile, it is found that with the increase of FSW passes, titanium powders are dispersed more homogeneously and the AGG region deceases, thus the thermal stability of grain structure in weld nugget is improved.

Key words: friction stir welding; second phase particle; thermal stability; abnormal grain growth

Microstructures and mechanical properties of underwater friction stitch weld of DH36 steel

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Abstract: Using the hydraulically powered welding equip-

ment developed by Tianjin University, underwater friction stitch welding of DH36 steel was conducted. The microstructures and mechanical properties (hardness and tensile property) of the weld have been investigated. The microstructure of the weld and the hardness distribution were heterogeneous. The overall microstructure of the weld metal consisted of a volume of lath martensite and bainite. The highest hardness value was 489.3 HV10, which located at the upper part of friction stitch weld. The hardness levels of the upper region of the stitch weld were higher than those of the lower region, and hardness levels of the last weld in the stitch sequence were higher than those of the first two welds. Stitch welds with higher welding axis forces showed better ultimate tensile strength than those with lower ones when the other conditions kept constant. And the tensile strength of welds in air was better than that of welds in water.

Key words: microstructure; tensile property; underwater friction stitch welding; DH36 steel

Research on dynamic resistance in resistance microwelding of insulated copper wire MO Binghua[1], LI Yuanbo[2], GUO Zhongning[2], ZHANG Yongjun[2] (1. Guangdong Mechanical & Electrical Polytechnic, Guangzhou 510550, China; 2. College of Mechanical and Electrical Engineering, Guangdong University of Technology, Guangzhou 510006, China). pp 23 – 27

Abstract: A measuring system of dynamic resistance was developed to research on the resistance microwelding (RMW) process of insulated copper wire. The testing system is mainly composed of a PC, data acquisition card, digital trigger circuit and current sensor. The change regulation is concluded by measuring the dynamic resistance combining the analysis of faying surface by scanning electron microscopy and energy dispersive spectroscopy. The results show that the dynamic resistance is a monotonously decreasing curve due to lack of metal liquid or nugget formation; dynamic resistance manifests as disappearance of film resistance, decrease of constriction resistance and increase of bulk resistance. the dynamic resistance finally reaches an equilibrium state and shows an approximate level. A wave crest will appear when surface splash occurred. This peak characteristic can be used as the basis of weld quality monitoring.

Key words: resistance microwelding; dynamic resistance; insulated copper wire

Investigation on microstructural homogeneity in laser beam welding joint superplastic deformation JIANG Xunyan, CHEN Yiping, WANG Ming, CHENG Donghai (Nanchang Hangkong University, Nanchang 330063, China). pp 28 – 32

Abstract: In this paper, TC4 alloy is welded by laser beam welding. Through the technology of hydrogenation treatment to analyze the structural homogeneity of the welding joint superplastic deformation. The effect of different hydrogen content on the deformation uniformity and deformation uniformity of TC4 titanium alloy laser welding joint was studied. The coefficient structural inhomogeneity of deformation is adopted to express the microstructural homogeneity. The test shows that with the technology of hydrogenation treatment, the phase composition is able to be adjusted and the homogeneity of the welding joint superplastic deformation is able to improved. With increasing hydrogen content, the coefficient structural homogeneity is decreased and the structural becomes more evenly. With the same hydrogen content, the decrease deformation temperature and the reduce initial strain rate both can improve the level of structural homogeneity. With the hydrogen content (1.30% H), the deformation temperature (920 ℃), and the initial strain rate (1×10^{-4} s^{-1}), the coefficient microstructural homogeneity runs up to 95%.

Key words: hydrogenation; uniformity coefficient; superplasticity

Wavy interface and mechanical properties of explosive welded Ti/Al/Mg cladded plate ZHANG Tingting[1,2], WANG Wenxian[1,2], WEI Yi[1,2], CAO Xiaoqing[1,2] (1. College of Materials Science and Engineering, Taiyuan University of Technology, Taiyuan 030024, China; 2. Shanxi Key Laboratory of Advanced Magnesium-based Materials, Taiyuan University of Technology, Taiyuan 030024, China). pp 33 – 36

Abstract: In this study, within the transition layer of aluminum plate, Ti/Al/Mg explosion cladded plate were well fabricated by explosive welding. The Ti/Al, Al/Mg bonding interface and the whole Ti/Al/Mg composite plate's mechanical properties were investigated. The OM and SEM result revealed that both bonding interface of Ti/Al and Al/Mg interface show periodic wave morphology, and partial melting zone was appeared in the Al/Mg bonding interface. The interface wave sizes of Ti/Al interface wave show a small size with 160 μm in amplitude and 26 μm in wavelength, and the Al/Mg interface wave presents a large size, measured the length of 1 740 μm and the mean amplitude of 406 μm. The fracture position after tensile-shear testing test was along Al/Mg bonding interface. The three-point bending testing strength of Ti/Al/Mg composite plate was found to be higher under the condition of Mg alloy layer in pressure, and the crack propagation begins at the Al/Mg bonding interface and then fracture failure at the base metal magnesium alloy plate.

Key words: Ti/Al/Mg explosion cladded plate; bonding interface; mechanical properties

Predictive modeling of mechanical properties of welded joints based on generalized dynamic fuzzy RBF neural network ZHANG Yongzhi[1,2], DONG Junhui[1], HOU Jijun[1] (1. School of Materials Science and Engineering, Inner Mongolia University of Technology, Hohhot 010051, China; 2. College of Mechanical and Electrical Engineering, Inner Mongolia Agricultural University, Hohhot 010018, China). pp 37 – 40

Abstract: Generalized dynamic fuzzy neural network model was established to predict the mechanical properties of welded joints. Structure of the model is no longer in default modeling, but on a sample-by dynamically adaptive learning process. By introducing elliptic basis functions to expand the receive domain to function, increased fuzzy rules was based on the systematic error and fuzzy rules ε completeness, and the RBF unit width determination criterion was based on fuzzy rules ε completeness. The fuzzy rule of model pruning was based on their importance which was evaluated by error reduction rate. By using three different thicknesses and different process TC4 titanium alloy TIG welding test group, 17 sets and 5 sets of training and simulation sample data were obtained for modeling and simulation. The results showed that the model can accurate prediction on the mechanical properties of welded joints.

Key words: generalized dynamic fuzzy RBF neural network; prediction; welding; modeling; mechanical properties

Laser welding-brazing characteristics of magnesium alloy to copper with AZ91 Mg based filler MENG Shenghao[1], TAN Caiwang[2], CHEN Bo[1], Deng Fengyu[1], LIU Duo[1], FENG Jicai[2] (1. Shandong Provincial Key Laboratory of Special Welding Technology, Harbin Institute of Technology at Weihai, Weihai 264209, China; 2. State Key Laboratory of Advanced

Welding and Joining, Harbin Institute of Technology, Harbin 150001, China). pp 41 – 44, 67

Abstract: Laser welding-brazing of AZ31B Mg alloy to T2 pure copper with filler was carried out in a lap configuration. The influence of heat input on microstructure, the phase structure, microhardness and mechanical properties were investigated. The results indicated that joint with good appearance and strength were obtained using proper welding parameters. The maximum shear strength can be 164.2 MPa, which was 64% of the magnesium alloy. When the heat input was low, the thin Mg-Cu eutectic structure was formed at the Mg/Cu interface, while the structure was varied into α-Mg + $(Mg、Al)_2Cu$ eutectic structure/$Mg_2Cu + Cu_2Mg$ intermetallic compound/Mg-Al-Cu ternary compound/$Mg_2Cu + Cu_2Mg$ intermetallic compound from fusion zone to Cu side with the increase of heat input. The variation of hardness value from fusion zone to Cu side increased first followed by sharp decrease, and then went up slowly, with the maximum value of 165 HV. The presence of Mg-Cu intermetallic compound near the interface influenced the joint strength, where fracture occurred.

Key words: magnesium alloy; copper; laser welding-brazing; interfacial microstructure; lap joint

Optimization on welding procedure of T-joint based on orthogonal test FANG Yuanbin[1,2], ZONG Xuemei[1,2], ZHANG Huaqing[2], YIN Xianqing[3], ZHNAG Linjie[3] (1. Jiangsu Xuzhou Engineering Machinery Research Institute, Xuzhou 221004, China; 2. State Key Laboratory of Intelligent Manufacturing of Advanced Construction Machinery, XCMG Construction Machinery Co., Ltd, Xuzhou 221004, China; 3. Xi'an Jiaotong University, Xi'an 710049, China). pp 45 – 49

Abstract: Welding deformation can be seen visually, and many methods are used to control welding deformation. Residual stress distribution is complex, and it has a great influence on production. In this research, the design method of welding numerical simulation and experimental method is used to optimize the process parameters. Residual stress distribution of T-joint is obtained by using single factor and multi factor orthogonal test. The results show that when the gap is 2 mm, the macro morphology can meet the requirements. Welding speed is the most significant, followed by wire speed and welding gap. The research is to optimize the welding parameters and reduce the peak value of residual stress by using the method of numerical simulation and experiment. It achieves the purpose of reducing the experiment times and saving the cost.

Key words: welding parameters; orthogonal test; residual stress distribution; welding numerical simulation

Numerical simulation of diffusion behavior of Cu_3Sn/Cu interface based on molecular dynamics YU Bo, LI Xiaoyan, YAO Peng, ZHU Yongxin (School of Material Science and Engineering, Beijing University of Technology, Beijing 100124, China). pp 50 – 54

Abstract: In this paper, the diffusion process of Cu_3Sn/Cu interface in lead-free solder joints was investigated using molecular dynamics (MD) technique with the modified embedded atomic method (MEAM) potentials. The diffusion behavior of different atoms was analyzed and the diffusion activation energies was obtained. In addition, the thickness of diffusion transition zone was acquired based on the empirical equation of diffusion. The simulation results indicate that the Cu atoms predominantly diffuse into the Cu_3Sn side in the process of diffusion. The Cu atoms diffuse slowly but deeply diffuse into the interior of Cu_3Sn, whereas the atoms of Cu_3Sn diffuse with high rate but hardly diffuse into the interior of Cu. Based on the Arrhenius relation and equation of Einstein, the diffusion activation energies of Cu lattice atoms at interface is 172.76 kJ/mol, and the Cu and Sn atoms in Cu_3Sn lattice are 52.48 and 77.86 kJ/mol, respectively.

Key words: microelectronic packaging; diffusion process; Cu_3Sn/Cu interface; molecular dynamics

SSCC properties of welded joints to weld nickel-based alloy LI Jiexiang[1], LI Yuntao[1], HAN Yongdian[2], ZHAO Yingxin[1] (1. School of Materials Science Engineering, Tianjin University of Technology, Tianjin 300384, China; 2. School of Materials Science Engineering, Tianjin University, Tianjin 300072, China). pp 55 – 58

Abstract: X65 pipeline steel was welded by Tungsten Inert Gas Welding TIG using nickel base alloys (Arc625). For the welded joints, through the observation of microstructure, electrochemical test, hydrogen permeation test, four point bending and spectrum analysis of the H_2S sulfide stress corrosion cracking (SSCC) behavior. The results showed that there were hard and brittle carbides in the fusion line. The electrochemical corrosion behavior of weld and HAZ was quite different, the self-corrosion current density of welding seam is one order of magnitude smaller than that of HAZ. This kind of welded joint had strong hydrogen permeation resistance. After the SSCC test, the crack appeared at the fusion line, which was caused by the double effect of anodic dissolution and hydrogen permeation. The aggregation of C and the segregation of Ni and Cr at the fusion line had a great influence on the SSCC performance of the welded joint.

Key words: nickel-based alloy welding consumables; pipeline welded joints; H_2S stress corrosion; cracking

Numerical simulation of wind characteristics in local dry welding chamber and its influence on welding arc GAO Yanfeng, HU Ao (School of Aeronautic Manufacturing Engineering, Nanchang Hangkong University, Nanchang 330063, China). pp 59 – 62, 72

Abstract: Underwater welding technology has been widely applied in the building and repairing of underwater construction in recent years. In the underwater welding technologies, local dry welding method which adopts local dry chamber to prevent the effect of water on the welding process has some advantageous such as better joint quality and ease to realize automatic welding. However, in the process of local dry welding the high-pressure compress air need to be injected into the local dry chamber in order to prevent the water flow into it. In this paper, a numerical simulation method is adopted to study the structure of the wind field in the local dry chamber firstly. Based on the simulation results, the structure of local dry chamber is optimized. And then the impacts of the wind field in the local chamber to the welding process and arc characteristics such as the arc temperatures, velocities and pressures are analyzed. The simulation results show that the lateral wind has a great influence on the welding arc column, and the declination of arc column displays a linear relationship with the increasing of lateral wind speed. Finally, a high-speed camera is used in the welding experiments to photograph the arc shape under different lateral wind. It is found that the experimental results are consistent with the simulation results.

Key words: local dry welding; arc plasma; wind field structure; simulation

Effect of heat input on crack growth behavior of CGHAZ of Q890 high-performance steel CUI Bing[1,2], PENG Yun[2],

PENG Mengdu[2], JIANG Zhuojun[2] (1. College of Materials Science and Engineering, Anhui University of Technology, Maanshan 243000, China; 2. State Key Laboratory of Advanced Steel Processes and Products Central Iron and Steel Research Institute, Beijing 100081, China). pp 63 – 67

Abstract: The present study focuses on the relationship between microstructure and toughness property in the coarse grain heat affected zone (CGHAZ) of Q890 high-performance steel. The result show that, with the heat input increasing microstructure changes from martensite to martensite and bainitic ferrite and then to bainitic ferrite and granular bainite. The Charpy impact test results show that impact energy as high as 83 J attained in the CGHAZ with 19.7 kJ/cm, which related to the contribution of pre-phase bainitic ferrite segment martensite and leading to maximum density of high angle boundaries, which can improve toughness. When the heat input is 34.1 and 44 kJ/cm, the impact energy reasons for the decline is due to catenulate distribution of embrittlement M-A constituents and local stress concentration, resulting in rapid crack initiation and propagation via the massive martensite – austenite (M-A) constituent.

Key words: microstructure variation; M-A constituents; high angle grain boundaries; crack propagation; impact toughness

Growth behaviour of Al-Mg intermetallics during post weld annealing treatment JIN Yuhua[1], GAN Ruigen[1], SHAO Qingfeng[1], LI Changfeng[1] (State Key Laboratory of Advanced Processing and Recycling of Non-ferrous Metals, Lanzhou University of Technology, Lanzhou 730050, China). pp 68 – 72

Abstract: The paper investigated the microstructure of the friction stir lap welded dissimilar joint between 6061 aluminum alloy and AZ31B magnesium alloy and the growth kinetic of intermetallic compounds (IMC) during post weld annealing treatment. The results show that the IMC layer consisted of continuous β-Al_3Mg_2 (near Al side) and γ-$Al_{12}Mg_{17}$ phase (near Mg side). The thickness of the IMC layer increased with increasing the annealing time and/or annealing temperature. In addition, the β layer was observed to grow faster than the γ layer. The increase of the IMC layer thickness was found to obey a parabolic relationship with annealing time, which reveals diffusion-controlled mechanism during annealing. As the temperature increased from 300 ℃ to 400 ℃, the diffusion coefficient in the IMC layer increased from 2.88×10^{-14} m^2/s to 3.67×10^{-13} m^2/s. The growth activation energy for the growth of IMC was 82.5 kJ/mol.

Key words: friction stir lap welding; annealing; intermetallic compound; activation energy

Effect of annealing treatment on fatigue behavior of titanium alloy clinched joints ZHANG Yue, HE Xiaocong, XING Baoying, CHENG Qiang (Faculty of Mechanical and Electrical Engineering, Kunming University of Science and Technology, Kunming 650500, China). pp 73 – 76

Abstract: Clinching technology was used to connect titanium alloy sheet, one group of the specimens was untreated, and the other group was annealed. Quasi static mechanics performance experiment and fatigue tests were adopted to test the property of the two kinds of joints. It can be seen from experiments that the tensile-shear strength was 4 363.64 N, the displacement was 1.48 mm. And the tensile-shear strength and displacement of the annealed joints were respectively 3 879.74 N and 1.85 mm. It can be concluded that the untreated clinched joints has a superior fatigue performance than the annealed clinched joints. The cracks of the two kinds of joints were always appear at the first force bearing point of the button, and the stress concentered in that location and there exist several fatigue sources and the fracture had feature of brittle fatigue fracture. The fracture of the annealed joints at the minimum thickness of the neck had a feature of ductile fracture.

Key words: mechanical clinching; titanium alloy; annealing treatment; fatigue test

Distribution characteristics and parameters effects of MPLW arc WANG Angyang, HE Jianping, WANG Xiaoxia, LINYANG Shenlan (Shanghai University of Engineering Science, Shanghai 201620, China). pp 77 – 81, 86

Abstract: Temperature field distribution of the arc in micro-plasma arc welding was simulated by ANSYS software, and the calculation results was validated by the spectral measurement and the image processing of high-speed photography. The results showed that the axial maximum temperature of the arc in micro-plasma arc welding occurs in the area near the tungsten cathode, and the arc temperature decreases with the increasing of the distance from the tungsten tip. The maximum radial temperature of the arc in micro-plasma arc welding occurs at the center of the arc transverse, and the temperature decreases with the increasing of radial distance from the center of the arc transverse. With the increasing of welding current, the axial maximum temperature in the area near the tungsten tip and the radial maximum temperature at center of the arc transverse increase. With the decreasing of tungsten tip diameter, the axial maximum temperature in the area near the tungsten tip and the radial maximum temperature at center of the arc transverse increase. After normalizing, the numerical calculated radial and axial temperature distributions have high agreement with distribution results by using spectrum detection and image processing of high-speed photography, respectively.

Key words: micro plasma arc; numerical simulation; temperature distribution characteristics; detection validation

Microstructure of laser-welded Hastelloy X and laser-welded Haynes 230 LIU Yue[1,2], XIONG Jiankun[1,2,3], ZHAO Haiyan[1,2], ZHONG Jie[3] (1. Department of Mechanical Engineering, Tsinghua University, Beijing 100084, China; 2. State Key Laboratory of Tribology, Tsinghua University, Beijing 100084, China; 3. Department of Process Dong Fang Turbine CO., LTD, Deyang 618000, China). pp 82 – 86

Abstract: Hastelloy X and Haynes 230 are nickel based alloy used for combustion chamber tube of F class and G/H class gas turbine respectively. The alloys are processed into plates with thickness of 2 mm and fiber laser are adopted for the welding. Welded joints as welded and solution heat treated are taken into comparison and analysis. Results show that, As to Hastelloy X as welded, it's of high hardness and weak toughness with network carbides precipitated in weld beam. While after solution heat treatment, palisade tissues and brittle Fe_2W phase are present in weld beam. As for Haynes 230 as welded, it's of smaller grain size than Hastelloy X as welded. Besides, carbides are discontinuously precipitated along dendrite grain boundary. After solution heat treatment, straight grain boundary transferred to zigzag one and creep property gets improved.

Key words: nickel base alloy; laser welding; microstructure analysis

FEM analysis of distribution of thermal stresses at sapphire/kovar alloy brazed joint DU Jinsong[1], YAN Jiazhen[1], CAO Jianguo[1], YANG Deyong[2], XIN Chenlai[1] (1. School of

Manufacturing Science & Engineering, Sichuan University, Chengdu 610065, China; 2. GuoGuang Electric Company of Chengdu, Chengdu 610065, China). pp 87 – 90

Abstract: Using ANSYS finite element software, the stress field and temperature field of brazed joint which brazing filler metal is Ag-Cu-Ti8 was simulated between Sapphire and kovar alloy by the means of elastic-plastic analysis. It is simulated that the different positions temperature has changed and filler metal thickness has effect on residual stress and its distribution. It is concluded that the best radial tensile stress of sapphire is 538 MPa in peripheral surface and extends to the border. The calculation results suggested that the real fracture pattern was consistent with the analysis of the finite element method. When the filler metal thickness is 150 μm, this would be lowest stress. Brazing parameters were optimized so that the reality brazing process can be operated.

Key words: sapphire; numerical simulation; brazing; stress

Feature extraction and analysis of weld seam stripe line on slope analysis method HONG Lei[1], YANG Xiaolan[2], ZHONG Dongping[3] (1. School of Automotive and Rail Transit, Nanjing Institute of Technology, Nanjing 211167, China; 2. School of Mechanical Electrical Engineering, Nanjing Institute of Technology, Nanjing 211167, China; 3. Nanjing China Construction Chemical Equipment Manufacturing Co. Ltd, Nanjing 210034, China). pp 91 – 94

Abstract: For extracting the weld seam feature lines in line structured light stripe, a slope analysis method based on linear fitting is proposed. In this method, all the n pixels in the light stripe are arranged in the order of the coordinates, progressive from the starting point, linear fittings are performed for each consecutive points, and total n_0 values of the slope are recorded. The number distribution of the points in each stripe line is calculated by the change characteristics of the slope and point set division is completed. According to the division of the point set, linear fitting are performed and these fitted lines are taken as the weld seam feature lines. Finally, the influence of parameter n_0 on the fitting lines is discussed. The experiment results indicate that this method can efficiently extract the feature lines in corner butt welding, overlap butt welding and V-groove welding seam and meets actual field requirements.

Key words: weld seam detection; feature extraction; slope analysis method; linear fitting; line structured light

Research on radial gap of 304L stainless steel piping with socket weld under vibration fatigue XIU Junjie, LI Yang, ZHANG Xiaoyu (School of Environment and Materials Engineering, Yantai University, Yantai 264005, China). pp 95 – 98

Abstract: Based on fatigue experiment and finite element method (FEM), the effect of radial gap on the vibration fatigue was researched. The test results show that crack with a higher stress tend to originate at the weld toe while for the case of lower stress failures tend to occur at the root. The root failure is that the crack originates at the inside of weld roots and propagates to the outside surface of specimen on the socket side of the weld, the crack of toe failure initiates at the outside surface of the specimen near the pipe side toe of the weld and propagates to the inside surface. The radial gap of runout is higher than that of failure. The effects of radial gap on weld root and weld toe were also investigated by FEM. Results show that the radial gap can significantly reduce the stresses of weld root and weld toe, which decrease 14% and 1.4% with the width of radial gap from 0.1 mm to 0.4 mm. Further, the radial gap can redistribute the stress in the weld root and weld toe, which is beneficial to the fatigue life.

Key words: socket weld; vibration fatigue; radial gap

Wetting match properties of Sn2.5Ag0.7Cu0.1RExNi solder alloy on surface of copper wire with water-soluble flux WANG Yaoli[1,2], SONG Kexing[1,2], WANG Guangxin[3], ZHANG Keke[2] (1. College of Material Science & Engineering, Henan University of Science & Technology, Luoyang 471003, China; 2. Collaborative Innovation Center of Nonferrous Metals, Luoyang 471023, China; 3. Research Center for High Purity Materials, Henan University of Science & Technology, Luoyang 471003, China). pp 99 – 102, 123

Abstract: The wetting match properties of Sn2.5Ag0.7Cu0.1RE lead-free solder on the surface of copper wire with tiny Ni addition and different soldering parameters by adopting commercial water-soluble flux were investigated by means of wetting balance methods. The obtained results show that the microstructure of Sn2.5Ag0.7Cu0.1RExNi solder alloy can be refined with the addition of 0.05 % Ni; and it has better wetting match proprieties on the surface of $\phi 0.6 \times 30$ mm copper wire at soldering temperature of 255 ℃, soldering time of 5 s, impregnating speed of 20 mm/s and the impregnating depth of 3 mm, i.e. it has higher wetting force, smaller wetting angle and shorter wetting time. The wetting properties can fully accord with the standards of the wetting force, wetting time and wetting angle, and meet the standard to the lead-free solders of surface mount technology industry.

Key words: water-soluble flux; SnAgCuRExNi solder alloy; soldering parameters; wetting properties

Formation mechanism of micro-resistance spot welded joints of QBe2 with Ni interlayer MAO Jinrong[1], HUANG Yongde[1], Fuqiang[1], ZHANG Chengcong[2], HE Peng[3] (1. School of Aeronautical Manufacturing Engineering, Nanchang Hangkong University, Nanchang 330063, China; 2. Shanghai Spaceflight Manufacture (Group) Co., Ltd., Shanghai 200245, China; 3. State Key Laboratory of Advanced Welding And Joining, Harbin Institute of Technology, Harbin 150001, China). pp 103 – 106

Abstract: Lap welding of 0.1 mm-thick beryllium bronze with nickel interlayer was realized using micro-resistance spot welding. Tensile shear test, optical microscopy (OM) scan electric microscopy (SEM) and energy spectrum analysis (EDS) were used to study the influence of Ni interlayer on the dissimilar joint formation and the joints' shear strength. The results show that, mechanism of beryllium bronze with nickel interlayer joint formation were solder bonding and fusion-solder bonding; The formation of the joint has gone through four processes: copper alloy wetting and spreading, element diffusion, nickel-copper interface reaction and metal solidification. Under the two kinds of joint formation mechanism, the fracture mechanism of solder bonding is fracturing along the interface, and it's button fracture when fusion-solder welding. Their fractures present ductile fracture with a mixed characteristic of brittle fracture.

Key words: beryllium bronze sheets; micro-resistance spot welding; solder bonding; fusion-solder bonding; fracture

Study on inducement and equilibrium mechanism of pore defects in vacuum electron beam welding LUO Yi[1,2], HAN Jingtao[1,2], ZHU Liang[1,2], ZHANG Chengyang[1,2] (1. School of Materials and Engineering, Chongqing University of Technology, Chongqing 400054, China; 2. Chongqing Municipal Engineering Research Center of Institutions of Higher Educa-

tion for Special Welding Materials and Technology, Chongqing 400054, China). pp 107 – 110

Abstract: Pore defects are the major problem in vacuum electron beam welding. The inducement mechanism and thermodynamic equilibrium mechanism were analyzed from the perspective of force balance condition, and the minimum radius survival conditions for pores in molten pool were proposed. The results showed that the gasification nucleus is an important factor induced bubbles in molten pool from the perspective of bubble dynamics. The bubbles, which don't meet the minimum radius survival condition, do not satisfy the thermodynamic equilibrium condition and therefore can't develop into the pores. The size of the bubbles generated on the wall of middle part of weld depends largely on the gas density in bubble, surface tension of bubble, and overheating of gas-phase components in bubble. The overheating is not only a driving force for bubble stability, but also a main factor determining the bubble size.

Key words: vacuum electron beam welding; bubble; pore; equilibrium mechanism; survival condition

Effect of heat treatments on resistance spot weldability of TRIP 980 steel WEI Shitong, LU Shanping (Shenyang National Laboratory for Materials Sciences, Institute of Metal Research, Chinese Academy of Sciences, Shenyang 110016, China). pp 111 – 114

Abstract: Cold rolled TRIP 980 steel sheets were resistance spot welded by different welding procedures. The effects of welding current, preheating and postweld heat treatments on the resistance spot weldability were studied. The results show that the increasing welding current increases the nugget diameter and tensile shear strength of spot weld. However, when the welding current is large enough to cause spatter, the nugget diameter and tensile shear strength of spot weld decrease. The preheating process raises the spatter occurring current, which results in larger nugget diameter and tensile shear strength. Under the condition of adding postweld heat treatment to spot weld, when the cooling time between welding current and postweld heat treatment current was larger than 900 ms, the microstructure of weld nugget was improved significantly, which decreased the hardness of weld nugget and increased the tensile shear strength of spot weld.

Key words: resistance spot welding; welding parameter; heat treatment; tensile shear property; nugget diameter

Effect of microstructural inhomogeneity on mechanical properties of stationary shoulder friction stir welded joints for 6061-T6 aluminum alloy HE Fangzhou[1], YANG Xinqi[1], LI Dongxiao[2], CUI Lei[1] (1. Tianjin Key Laboratory of Advanced Joining Technology, Tianjin University, Tianjin 300072, China; 2. Beijing Satellite Manufacturing Factory, Beijing 100094, China). pp 115 – 118

Abstract: The relationship between microstructural inhomogeneity and mechanical properties of the stationary shoulder friction stir welded (SSFSW) joint for 6061-T6 aluminum alloy was investigated. Results show that there is existing obviously microstructural inhomogeneity in the SSFSW joints, which reflected in the different grain size and shape, morphology and distribution of precipitates. It should be noted that the different precipitates is the major factor of the mechanical properties variation. Resulting from the microstructural inhomogeneity, the HAZ which is closed to the NZ was softened seriously, and its hardness and tensile strength were the lowest in the joint, reaching at 60% and 72% of the base metal, respectively. The strength and plasticity of the NZ are the best in the joint because of the precipitation strengthening and fine-grain strengthening, and the tensile strength and elongation of the NZ reach at 88% and 215% of base metal, respectively. With the distance from NZ increasing, the ultimate tensile strength and yield strength of micro-tensile specimens increase, while the elongation of samples decreases.

Key words: 6061-T6 aluminum alloy; stationary shoulder friction stir welding; microstructural inhomogeneity; mechanical property

Effect of heat input on weld appearance for fiber laser welding 6A02 aluminum alloy XU Fei, CHEN Li, LU Wei, GUO Luyun (Science and Technology on Power Beam Processes Laboratory, Beijing Aeronautical Manufacturing Technology Research Institute, Beijing 100024, China). pp 119 – 123

Abstract: The fiber laser beam with high power density is used for welding 6A02 aluminum alloy with 1.0mm thickness. And the effects of heat input on weld macrography, structure and properties are studied. The results show that the stable fully penetration weld could be obtained when the heat input is controlled in the range of 8-12 J/mm and the welding speed is very high. The typical cross-section of the welds always presents near X shape. The characteristic of the welds could reduce the nonuniformity of welding temperature field. It also could reduce welding buckling and deformation. The columnar microstructure is formed near the fusion line. The mixed microstructures, including columnar grains and equiaxed grains, distribute in the center of the weld. The transition from columnar microstructure to mixed microstructures can be found from the fusion line to the weld center. With the heat input reduced, the microstructures of the weld zone are tendency to fine, the soften phenomenon near the fusion line is helpful to weak, the microhardness of the weld zone and the tensile strength of the joints are increasing slightly.

Key words: fiber laser welding; weld appearance; microstructure; microhardness; tensile properties

Impact on welding pool shape under combined effect of magnetic field and active agent LIU Zhengjun, WANG Xiaohui, SU Yunhai (Materials Science and Engineering, Shenyang University of Technology, Shenyang 110870, China). pp 124 – 128

Abstract: In order to study the combined effect of magnetic field and active welding influence on the welding pool of liquid metal flow pattern, the paper established the moving heat source under the action of three-dimensional transient mathematical model of magnesium alloy TIG welding. By using fluent software and its secondary development function to simulate the welding pool temperature field and velocity field under the effect of single magnetic field, single active welding and the combined effect of both. The simulation results show that liquid metal in the welding pool was directed clockwise rotation under the effect of single magnetic field, velocity field presented asymmetrical bimodal distribution, maximum speed biased the pool side. Under the effect of single active welding liquid metal in the welding pool formed outside-in convection mode, which scour the bottom of the pool to increase penetration. The fluid flow is more complex under the combined effect of magnetic field and active agent. The liquid metal flow near the pool surface is mainly affected by surface tension. The liquid metal flow inside the pool is mainly affected by external electromagnetic force.

Key words: electromagnetic force; surface tension; temperature field distribution; velocity field distribution