YOUNG PROFESSIONALS INTERNATIONAL CONFERENCE ON WELDING AND RELATED TECHNOLOGIES 2021

(DIGITAL)

ABSTRACTS

26 October 2021

Kyiv, Ukraine

ORGANIZERS

PROGRAMME COMMITTEE

Igor Krivtsun (Ukraine) – chairman, Serhii Akhonin (Ukraine), Levente Bakos (Hungary), Luca Costa (Italy), Bojan Gligorijevic (Serbia), Aleksey Kovalevsky (Israel), Oleksiy Slyvinskyy (Ukraine), Ernest Levert (USA), Sergiy Maksymov (Ukraine), Shun Tokita (Japan)

ORGANIZING COMMITTEE

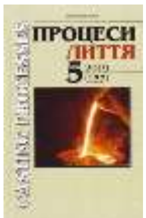
Serhiy Schwab (chairman), Ilya Klochkov, Alina Vashchuk, Roman Selin, Maksym Khokhlov, Sviatoslav Motrunich, Taras Maydanchuk, Liudmyla Lisova, Vitalii Porokhonko, Marianna Dyman

INFORMATIONAL PARTNERS

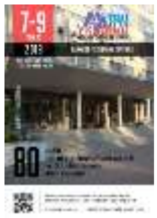
The Paton Welding Journal

Electrometallurgy Today

Casting processes



Metal and casting of Ukraine



Publication of PEWI NASU

SECTION I

ADVANCED WELDING AND JOINING TECHNOLOGIES

RESEARCH OF THERMAL DEFORMATIONS AND METALLURGICAL PROCESSES, FEATURED BY FLASH-BUTT WELDING FORMATION OF JOINTS IN MODERN RAILWAY STEELS, WELDING TECHNOLOGY DEVELOPMENT AND IMPLEMENTATION

B. Cherednychok[1], O. Didkivskyi[2], Y. Antipin[2], O. Kavunichenko[2], Y. Chvertko[1], R. Didkivskyi[1]

[1]National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine

[2]E.O. Paton Electric Welding Institute of the NAS of Ukraine, Kyiv, Ukraine

In recent years in Ukraine, using of high-strength rails has significantly increased, for the reason of improving the durability and reliability of railway tracks. At present, the most common national grade of high-strength steels is K65F. Railway track consists of individual rail strings, which are manufactured at specialized factories. However, when welding on standard modes & parameters the quality of welded joints, particularly ductility and strength, appears to be below standard requirement. Therefore, a number of research are being performed to identify causes of deterioration in quality. From the end of 2010, the production of a metallurgical enterprises, in particular, the plant of OJSC MK «Azovstal», oxygen converter rails P65 of the KF brand began. At the beginning of 2011, new railways of the K65F steel grade (converter production) began to arrive at Ukrzaliznytsia's rail welding enterprises. In the course of the works, it was found that the contact-butt welding regimes adopted for the open-hearth rails did not provide stable quality. As a result of metallographic research of K65F steel it appears that main causes of poor quality of welded rail joints are numerous non-metallic inclusions, mostly complex oxides of Si, Al, V and Ti elements. During setting up welding parameters and modes for K65F steel rails it was revealed that flash-butt welding method with preheating did not provide satisfactory quality characteristics of rail welded joints. Also, quite long time of welding cycle leads to widening of heat affected zone (HAZ) of the joint. On the contrary, lack of heat in the area close to fusion line at the time of upset (process stage on which the welding joint is formed) causes a significant drop in the quality of welding joints. Using pulsed flashing for welding gave a positive result. The high concentration of heat made it possible to significantly reduce heat affected zone (HAZ) and to provide a required temperature prior upset stage. This problem was solved by the application of pulsed flash-butt welding process the core principal of which is the actual speed of reduction of parts Va at all periods of melting being significantly different from the specified speed of movement of the moving part Vm. The melting process is a sequential melting of the adjacent metal layers. After melting of each primary layer, the temperature of the contact sections of the metal increases and the melting rate Va tends to rise, if the voltage and, accordingly, the power that is invested remain constant. Lowering the voltage allows to reduce the melting rate Va , so it does not exceed the pre-set values Va, and always remains below Vm (Va < Vm).

WELDING-BRAZING CMT AND PLASMA ARC BRAZING OF THIN SHEET GALVANIZED STEEL WITH ALUMINUM SOLDERS

V. Strashko, N.Strelenko, V.Kovalenko, V.Polischuk

National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine

In this work, a series of experimental studies of MIG / CMT welding-brazing and Plasma arc brazing of thin-sheet galvanized steel with Al-5Si, Al-12Si and Al-6Cu-Mn-Zr-Ti solders were carried out. The obtained samples were tested for strength and corrosion resistance. The results showed that the samples obtained using MIG / CMT welding-brazing were characterized by the absence of adhesive bonding between galvanized steel and aluminum solder. In turn to brazing by plasma arc allowed obtaining joints with a strength of 110–270 MPa and high anti-corrosion properties. To further improve the joining process of galvanized steel with aluminum solders, recommendations were given on the composition of the filler material and joining methods.

THE EFFECT OF ELECTROMAGNETIC FIELDS ON FLAT STEEL BILLET IN CASTING TECHNOLOGIES OF RECEIVING TWO- AND THREE-LAYER PRODUCTS

A. Tymoshenko, O. Shmatko, O. Goncharova

Physico-technological institute of metals and alloys of the NAS of Ukraine, Kyiv, Ukraine

The use of induction heating in foundry technologies for producing bimetallic and three-layer products is justified. The influence of the electromagnetic field on a flat billet thought the different inductors configuration using is studied. The billet-in-motion temperature distribution in continuous production of a bimetallic strip by casting is investigated.

ELECTRIC ARC AND PLASMA ARC BRAZING OF THIN SHEET GALVANIZED STEEL

N. Strelenko, V. Kovalenko., V. Polishchuk

National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine

Most of galvanized steel produced today is used for the manufacture of transportation vehicles, ventilation, air conditioning and cooling systems. One of the ways to joint these materials is CMT (Cold Metal Transfer) welding using copper-based wire. In this work, the possibility of using filler material based on aluminum for joining galvanized steel was studied. Therefore, the present work carried out a series of experimental studies of MIG / CMT welding-brazing and Plasma arc brazing of thin-sheet galvanized steel by Al-12Si and Al-6Cu-Mn-Zr-Ti wires. The research tested samples for strength and corrosion resistance. The results showed that during the MIG / CMT welding-brazing process, the thermal impact of the electric arc was sufficient to damage the zinc coating, which caused poor wetting and spreading of the aluminum filler metal over the surface of the plates. For the reason, the obtained joints are brittle in the contact area between the base metal and the filler metal and are not able to withstand the tensile load. In turn to micro-plasma brazing is significantly different from welding-braing MIG / CMT in the nature of heat input. Experiments have shown that the use of a plasma arc allows to more uniformly heat the surface of the base metal. This helps to preserve enough layer the zinc coating and, as a consequence, results in better spreading and wetting of galvanized steel with aluminum filler metal. The mechanical properties of the joints made by plasma soldering have a tensile strength in the range of 90-120 MPa. The joints also have high anti-corrosion properties both in the seam zone and in the heat affected zone.

A USER'S GUIDE: PHYSICAL COMPARISON OF THE BEAM ABSORPTION BETWEEN FIBER AND DIODE LASERS USING CALORIMETRY

A. Aurin, J. Brozek, S. Keitel

SLV Halle GmbH, Halle (Saale), Germany

The diode laser went through a tremendous power evolution over the past few years. Nowadays this laser type is able to deliver up to 100 kW of laser power for the wide field of application in the macro processing. Above all stands the welding of thick walled steel. In earlier days this task was solved by the use of CO2- and fiber lasers which significantly differ from the diode lasers concerning the beam quality. The fundamental interaction between a laser beam and the material is characterized by the absorption coefficient A, which depends on a lot of parameters like: material composition, wavelength λ, angle of incidence, beam quality and power density, surface condition and temperature A comparison between different laser types needs the practical determination of the absorption coefficient by using calorimetry. The current piece of work will describe the selection of the fitting calorimetric principle and the measuring equipment. Furthermore the preparation of the material samples and the whole measuring process including the mathematical evaluation will be explained. The procedure will be illustrated by the real implementation of the comparison between a fiber laser (IPG Photonics) and a diode laser (Laserline) welding mild steel S355J2 (1.0577).

ACTUALITY OF DEVELOPMENT OF UNDERWATER WELDING TECHNOLOGY OF HIGH-ALLOY CORROSION-RESISTANT STEELS IN SALT WATER

M. Kakhovskyi

E.O. Paton Electric Welding Institute of the NAS of Ukraine, Kyiv, Ukraine

High-alloy corrosion-resistant steels are increasingly used for the manufacture and repair of elements of offshore oil and gas platforms, pipelines, port and hydraulic structures. Due to its high corrosion resistance properties, this type of steels has significant advantages over low-alloy structural steels. Due to the almost total absence of welding materials for underwater welding of corrosion-resistant steels in seawater, repair works at sea is almost impossible, and the wider introduction of this class of steel as a material for metal structures by these factors is much more difficult. Electric wind turbines, which are located in the coastal zone at a depth of up to 30 meters, have been selected as the object of underwater welding of high-alloy corrosion-resistant steels in sea salt water. They are manufactured in the factory and transported on large vessels to the place of further exploitation. Despite the fact that they are made of high-alloy corrosion-resistant steel, after some time, or under certain conditions, they will need repair. Repair works consists of dismantling, transporting and welding repair works in the factory, which is not much rational as a technical and economic decision. A much more rational solution is to ensure the possibility of underwater welding and repair work directly at the exploitation place. To this end, it is necessary to investigate the features of physical and metallurgical processes that occur during wet underwater welding of high-alloy corrosion-resistant steels in salty seawater and set requirements for welding materials that provide welding at depths up to 30 meters. To achieve this goal it is necessary to solve the following scientific problems: • to choose a system of alloying the weld metal, which will ensure the resistance of the welded joint to corrosion caused by salt water; • to study the physicochemical properties of the gas-slag-forming system and optimize it for the possibility of welding at increased depth; • to investigate the stability of the underwater welding arc burning process in sea salt water under conditions of high hydrostatic pressure. The results of these studies will provide a basis for further development of welding materials and technology for underwater welding of high-alloy corrosion resistance steels in sea salt water.

TIG WELDING OF COPPER TIRES WITH COLLECTOR PLATES MOTOR ARMATURE

T.B. Maydanchuk, A.N. Bondarenko, E.P. Lukianchenko, D.M. Stepchenko

E.O. Paton Electric Welding Institute of the NAS of Ukraine, Kyiv, Ukraine

Today, the time for connecting the armature windings with the collector plates in the manufacture of electric motors instead of soldering is widely used electric arc welding. In this work, a set of works on TIG welding in the environment of argon of copper tires with collector plates of the collector of the starter-generator DKS18-8 is performed. The conditions for the assembly of the starter-generator are defined, which allow to obtain a high-quality welded connection in the automatic mode. As a result of the experimental work, a cyclogram of the welding process was constructed, which includes: gas purge time, current rise time, welding time, current drop time and gas purge time after the completion of the welding process in automatic mode. It is established that in order to obtain high-quality connections, the welding process is carried out without moving the welding torch, with oscillations with a frequency of 80… 120 sec-1 and an oscillation step of 2… 4 mm. Thus, the developed technology is quite rational in the manufacture of starter-generators type DKS18-8.

CHEMICAL WELDING OF NOVEL EPOXY/GRAPHENE OXIDE COMPOSITES

A. Vashchuk[1], S. Motrunich[1], V. Demchenko[1], P. Lishchuk[2], M. Iurzhenko[1]

[1]*E.O. Paton Electric Welding Institute of the NAS of Ukraine, Kyiv, Ukraine*

[2]*Faculty of Physics, Taras Shevchenko National University of Kyiv*

Graphene oxide (GO) is a research hotspot of materials science since it was discovered in 2004 due to its excellent physical and chemical properties. The incorporation of GO delivers desired engineering properties such as high modulus and strength, thermal conductivity, the toughness of epoxy resins, which are extensively used in the production of composite materials. In particular, with the increasing demand for the development of new materials for electronic devices, sensors, intelligent clothes new joining technologies have been attracted great scientific interest.

In the present work, film materials (s=0,5 mm) of novel vitrimer epoxy nanocomposites generated by thiol-epoxy click reaction *in situ* of different amounts of GO (0.1, 0.5, 1.0 wt.%) have been developed and characterized. The size of GO particles and their distribution in the polymer matrix was examined using a JEM-1230 transmission electron microscope (JEOL, Japan) at the resolution of 0.2 nm. The structure of the nanocomposites has been investigated by wide-angle X-ray diffraction using DRON-4-07 diffractometer, which X-ray optical scheme was used at a “pass” primary-beam radiation through samples. Photoacoustic method with gas-microphone registration was chosen to characterize the thermal properties of the obtained composites. Chemical welding of the synthesized nanocomposite films was carried out by assembling two specimens at 150 °C for 60 min. In order to evaluate the network structure of the welding seam and further propose a chemical welding mechanism, FTIR analysis was performed. The stress-strain behavior of the nanocomposites at room temperature was evaluated by using tension tests on the 2054 P–5 machine. It was found, that welded assembly of nanocomposite containing 1.0 wt.% GO has tensile strength near 20 MPa and was ruptured directly in the bulk material far from the welding seam. Thus, the mechanical properties of lap welded joints were nearly equivalent to the basic material.

Funding: This research was funded by the National Academy of Sciences of Ukraine under program No 6541230 for Young Scientist Laboratories (agreement No11/01-2021(2)).

IMPROVEMENT OF HEATING ELEMENTS EFFICIENCY FOR RESISTANCE WELDING OF THERMOPLASTICS

R. Kolisnyk, M. Iurzhenko, M. Korab, O. Masiuchok, M. Kovalchuk,

S. Voynarovich, Y. Mamunya

E.O. Paton Electric Welding Institute of the NAS of Ukraine, Kyiv, Ukraine

Resistance welding is a simple way of joining thermoplastic polymers. In this process, a conductive heating element, commonly made of stainless-steel mesh, is placed between the adherends interface to be welded. When voltage is applied to the heating element, the Joule effect heats it up, which leads the adjacent polymer to melt. Weld strength is defined by the contact area of a polymer through mesh gaps and adhesion between the polymer and metal. However, adhesion between thermoplastic polymer and metal mesh heating element is poor. There are two possible ways of solving this problem. The first is concerned with improving adhesion by surface modification. The second is an application of heating elements, which have the same properties as polymer material to be welded. Electroconductive polymer composites meet this criterion. So, the aim of this study is to improve the adhesion of metal mesh heating elements and a completely novel approach of using conductive polymer composites as heating elements.

In this research, we used a metal mesh heating element made of stainless-steel and titanium, since it was reported better adhesion between polyetherimide, from which the parts to be welded were made, and TiO2. For surface modification of metal mesh heating elements, the method of microplasma spraying was used. This method provides the formation of the surface with a high specific contact area. Coatings of titanium and nichrome were deposited on a metal mesh. It is established that surface modification of the heating element leads to an increase in the area of interaction with the polymer material in the contact zone of the weld. Moreover, stainless steel heating element with nichrome coating has more uniform temperature distribution, compared with uncovered one.

Composite heating elements were made of polyethylene matrix and were filled with carbon black, carbon fiber, and their mixture. It is established that composite heating elements on the basis of high-density polyethylene/carbon black with carbon black content 30% from the volume provide the most uniform heating in the area and the least impact of the effect of a positive temperature coefficient of resistance in comparison with composites high-density polyethylene/carbon fiber and high-density polyethylene/carbon black/carbon fiber.

Welding was carried out in two modes, namely in “hard”, characterized by a high welding power and short welding time, and “soft” with stepwise regime of the applied power and longer heating time. It is established that stainless steel heating element with nichrome coating increases the strength of welded joints by 10-13% at a specific power of the welding process P = 60 - 100 W/cm2. For composite heating element it is determined that welding modes with parameters: welding time of 120 s, equivalent electric power of welding process within 20… 30 W/cm2, and clamping welding force of 1 MPa provide formation of butt and overlap welds with strength at the level of 98% and 100%, respectively, relative to the strength of the base material.

SECTION II

FRACTURE AND FATIGUE BEHAVIOR OF WELDED COMPONENTS AND STRUCTURES

NEW FORMULAS TO DETERMINE STRESS CONCENTRATION FACTOR IN THE ROOT AREA OF BUTT-WELDED JOINT

M. Dyman, A. Moltasov, P. Tkach

E.O. Paton Electric Welding Institute of the NAS of Ukraine, Kyiv, Ukraine

Until recent time Stakanov's-Korostelev's-Rybin's formula has been applied to determine the stress concentration factor (SCF) both for face side and for root side of butt-welded joints with asymmetrical reinforcement. However, this formula cannot be used for SCF calculation in the root area because the cross section in the root reinforcement area contain the face reinforcement as its height is bigger than the nominal one. Besides, bending stresses in the area of asymmetrical reinforcement is applied with eccentricity. It results in additional bending stress in this section. This is why development of complex approach to stress calculation in the vicinity of root reinforcement which takes into account both cross section size and bending stress is a topical scientific and practical problem in the scientific field of strength, reliability and life time of welded structure elements. Based on the broken section hypothesis a method for stress calculation in the butt-welded joint's transition zone (from the root reinforcement to the base metal) was developed and new analytical formulas for SCF determination in transition zones was proposed. For the AMg6M thin-sheet butt-welded joint aluminium alloy, made by TIG, following one of the proposed formulas the SCF calculated value equaled 2.4. While following Stakanov's-Korostelev's-Rybin's formula it equals only 1.66. Validity of the proposed formula is confirmed by the results of stresses evaluation which was made for the joint under study using the finite element method (FEM). The deviation of the calculated value is less than 3%.

HIGH CYCLIC FATIGUE BEHAVIOR UNDER CONSTANT AND VARIABLE AMPLITUDE LOADING OF 7XXX SERIES ALUMINUM ALLOYS JOINTS PRODUCED BY FLASH BUTT WELDING

S. Motrunich, A.Vashchuk, K. Guschin, I. Klochkov

E.O. Paton Electric Welding Institute of the NAS of Ukraine, Kyiv, Ukraine

High-strength thermally hardened aluminum alloys are widely used in the manufacture of various elements and structures in the aerospace industry. The alloys are strengthened by heat treatment while acquiring high mechanical properties and sufficient technological plasticity. Nowadays, for example, for the manufacture of power elements of the body of air- and spacecraft, alloys of 7XXX series which based on the Al-Zn-Mg(-Cu) doping system are widely used. They belong to the groups of hard-to-weld or non-weldable alloys. Moreover, a significant drawback of a riveted joint is an increase in the weight of the structure due to the appearance of auxiliary elements during the riveting of abutting elements. Riveting is a time-consuming, economically complex operation associated with difficult working conditions. Careful surface treatment of the rivet hole is required for a reliable connection of the product. During long-term operation, the riveted joint tends to weaken, which affects the service life of the products. An effective way to solve the problem of increasing the strength, quality of joints and improving the tactical and technical characteristics of aircraft (in particular, reducing the weight of the structure and, accordingly, increasing the payload of aircraft) is to use welding instead of riveting. One of the promising ways to obtain high-quality welded joints with high mechanical properties for these tasks is flash butt welding (FBW) which takes place in the solid-state and reduced heat transfer. In this regard, studies of the weldability of aluminum alloys of the 7XXX series with a high content of Zn were performed using FBW. In order to demonstrate the viability of this method, aluminum alloys were obtained. In this paper, we consider the formation of the microstructure, hardness measurements, and mechanical properties of aluminum alloys in a hardened state. The durability of the obtained butt joints was studied at constant and variable amplitude loading.

SECTION III

ADDITIVE MANUFACTURING, SURFACING AND CUTTING

CORRELATION BETWEEN ARC MODE AND MICROSTRUCTURE DURING WIRE ARC ADDITIVE MANUFACTURING OF TITANIUM ALLOYS

R. Selin, S. Schwab, M. Dyman

E.O. Paton Electric Welding Institute of the NAS of Ukraine, Kyiv, Ukraine

Titanium alloys are widely used for aerospace and biomaterial applications since their high specific strength, and high corrosion resistivity. Besides these properties, titanium is an excellent biocompatible material widely used for internal body implants. Because the products have complex geometries in both applications, Additive Manufacturing (AM) methods have been recently applied for production. AM methods can process a direct 3-D shape of the final product, decrease total production time and cost. Arc Direct Energy Deposition (DED-Arc), also known as Wire and Arc Additive Manufacturing (WAAM), is a technology for the manufacture of customized metal structures, layer-by-layer, using a solid wire as consumable for deposition. Parts produced by WAAM show a good structural integrity. WAAM manufactured components, due to the high heat generated by the arc, are subject to distortions, residual stress and structural inhomohenity. The latter can be minimized with additional techniques or custom deposition modes. The annealing of titanium alloys can also stabilize microstructure, reduce presence of undesirable metastable phases and therefore, such mechanical properties, as fracture toughness, ductility at room temperature, and creep resistance. In this work, we will investigate the effect of arc mode correlation and additional WAAM techniques on structure of obtained details.

A CONTRIBUTION TO THE HEAT MANAGEMENT IN WIRE ARC ADDITIVE MANUFACTURING WITH GAS FLOW BASED COOLING STRATEGIES

P. Gröninger, F. Koch, G. Trensch, S. Keitel

SLV Halle GmbH, Halle (Saale), Germany

This work examines the possibilities to reduce the cooling time for the Wire Arc Additive Manufacturing (WAAM) process. The WAAM generates near-net-shape metal objects. During the build-up process the heat transfer conditions are changing which results in excessive heat accumulation. The heat is controlled by pausing the build-up process in which the object is cooled down to a predefined temperature. To examine the most effective way to reduce this non-productive time a water-cooled base table, a vortex tube, an air amplifier, and a CO2-cooling system are compared with each other. With the purpose of assessing the heat dissipation, the temperature is recorded during the build-up and cooling process with an infrared camera and thermocouple elements. This leads to the conclusion that the effectiveness of the three used cooling systems depends on the geometry of the object. The rate of volume to surface determines the cooling down speed. Furthermore, the option of reducing the heat input through changing the tool path generation strategy and the characteristic curve are examined. The results show that the cooling time depends on many different elements and thus can be reduced in different phases of the whole process.

COMPARISON OF CARBON STEEL FILLER MATERIALS FOR WIRE AND ARC ADDITIVE MANUFACTURING (WAAM) APPLICATION: AN EVALUATION BASED ON FINANCIAL, OPERATIONAL AND MECHANICAL PROPERTIES

R. G. N. Silva, W. Verlinde, N. Vandermeiren, D. Boruah, W. De Waele

Belgian Welding Institute, Gent, Belgium

The additive manufacturing technology is changing the way we face production. Although able to deliver several clear advantages when compared with conventional manufacturing processes, there is still multiple questions and challenges to overcome in order to bring the technology to a real application. One of these questions is how to select the best filler material for each application. In this scenario, the present work proposes an empirical evaluation of five different commercial carbon steel filler materials. Among them, it was evaluated solid, tubular and AM specific filler materials, based on their price, printability, heat input, defect-free printing, tensile strength, and formation of spatters and fumes. The results here described proved themselves to be an important source for new applications for all industry sectors.

THE EFFICIENCY INDUCTION SURFACING OF METAL DISCS

V. Havryliuk, Ch. Pulka

Ternopil Ivan Puluj National Technical University, Ternopil, Ukraine

Induction surfacing is the technological, highly productivity process, that subject to automation easily and it is effective in conditions of multi-series production. The main advantages of this process are a low thickness of fusion the basic metal and possibility to surfacing of thin metal layers. The disadvantages of induction surfacing are a low the energy conversion efficiency of technological process and the overheating of basic metal.

The key reason of a low the energy conversion efficiency of induction surfacing process are excessive losses of electrical energy, as surfaces are located in magnetic field of inductor and heating of them are undesirable occurrence or it don't provided of technology. Therefore are used electromagnetic screens to remove these disadvantages. These screens made to red cupper that have high properties of thermal and electrical conductivity.

The main condition that must executed to installation of screen are limited distance between screen and inductor. That must be more compare to distance between inductor and surface of detail that subject to surfacing. These screens could have different shape in depending to shape of detail that protect from undesirable heating.

Therefore, report's authors suggest use electromagnetic screens to induction surfacing of thin shaped discs that provide more even temperature by zone of surfacing. These screens are prevent the overheating of disc's edge and fusion metal too. More stability of temperature field are achieved if additional to use thermal screen together with inductor and electromagnetic screen that to allow decrease heat transfer in environment with lower surface which opposite to zone of surfacing and edges of disc. It allows decrease the time of surfacing with 32 sec to 22 sec and decrease losses of electrical energy per one detail to 0,293 kW/h.

The using electromagnetic and thermal screening allows increase energy efficiency the process of induction surfacing and geometrical stability of fused metal layers. This technology of induction surfacing with additional using electromagnetic and thermal screening allows increase the quality of fused metal.

SECTION IV

NEW STRUCTURAL AND FUNCTIONAL MATERIALS, NANOMATERIALS, COMPOSITES

ELECTRICALLY CONDUCTIVE POLYMER COMPOSITES WITH CONTROLLED MORPHOLOGY

O. Maruzhenko, Ye. Mamunya, S. Pusz, U. Szeluga

E.O. Paton Electric Welding Institute of the NAS of Ukraine, Kyiv, Ukraine

Recently, the electrically conductive polymer composites (CPC) are increasingly used in applications, in particular as antistatic or EMI shielding materials, sensor materials, conductive elements in microelectronics, electrodes in the current sources, heating elements, materials for medical equipment, etc. The main advantages of such systems are relative cheapness, lightweight, high producibility, corrosion resistance, and control of conductivity. CPC is a polymer matrix with randomly distributed conductive particles of filler, which when reaching a critical concentration (the so-called percolation threshold Pc), form conductive pathways in the polymer matrix and the composite abruptly transitions to a conductive state. However, to have high values of conductivity, CPCs with random filler distribution require a high concentration of the filler (i.e. characterized by high values of Pc), which leads to a deterioration of the mechanical properties of composites and their conditions of processing. This problem can be solved by arranging an ordered distribution of the conductive phase in the polymer matrix. Such a controlled change in the morphology of the composite can be achieved by a technological method, when the composite is formed by hot compaction of a mixture of polymer and filler powders with a particle size D and d, respectively, at D>d. In this case, the filler particles are placed on the surface of the polymer particles and during compacting are localized at the boundary between the polymer grains forming a framework structure in the polymer matrix (the so-called segregated structure). The local concentration of the filler in the walls of the framework is much higher than the average, associated with the total volume of the composite. It gives a low value of Pc and determines the electrophysical properties of the composite. CPC based on ultra-high molecular weight polyethylene (UHMWPE) with particles having an average size of 100 mcm was investigated. The fillers were heat-treated anthracite (A) with a fraction size of 4-9 mcm and graphene nanoplates (GNP) with a size of <10 mcm and a thickness of 1-3 layers. Also, a hybrid filler A/GNP in the ratio of 3/1 was used. Hot compaction was performed in steel form at a temperature of 180 oC and a pressure of 20 MPa. For comparison, PP-A composites with the random distribution of the anthracite particles were also formed by processing in an extruder. Measurement of electrical conductivity was performed by the two-electrode method using a teraohmmeter E6-13. Concentration dependences of electrical conductivity of composites show percolation behavior and obey the percolation equation S = Sm*(P - Pc)^t, where S is the conductivity of the composite, Sm is the conductivity of the filler, P is the volume content of the filler, t is the critical exponent. Percolation thresholds Pc for composites with segregated structures and fillers A, GNP, A/GNP have values of 2.95, 0.21, and 0.49 vol.%, respectively. At the same time, the composite with a random distribution of the anthracite has a percolation threshold of 24.8 vol.%, i.e. almost an order of magnitude higher than with the ordered structure of the conductive phase. The lowest value of the percolation threshold is observed for the composite with graphene nanofiller. The hybrid filler A/GNP shows a value of Pc =0.49 vol.%, which is close to GNP, although the content of anthracite in it is 3 times higher than GNP, i.e. in this case there is a synergistic effect due to the formation of a common conductive network. Thus, the controlled formation of the ordered structure of the conductive phase leads to conductivity in the composite with a much lower content of conductive filler. The use of filler hybridization also gives a great effect of lowering the percolation threshold, the replacement of 25% anthracite on GNP in the hybrid filler A/GNP leads to a decrease 6 times in the Pc value, from 2.95 vol.% for A to 0.49 vol.% for A/GNP. These data suggest that hybrid fillers have great potential for application in CPC for the use of cheaper fillers, which, however, provide high electrical performance.

INFLUENCE OF COPPER CONTENT IN HIGH-ENTROPY ALLOYS Co-Cr-Fe-Ni-Cu SYSTEM ON THEM DISSIPATIVE PROPERTIES

A. Ustinov[1], V. Skorodzievskii[2], O. Kremenchutskiy[1]., S. Demchenkov[1], T. Melnychenko[1]

[1]*E.O. Paton Electric Welding Institute of the NAS of Ukraine, Kyiv, Ukraine*

[2]*G. V. Kurdyumov Institute for Metal Physics of the NAS of Ukraine, Kyiv, Ukraine*

A number of high-entropy alloys (HEA), in particular alloys of Co-Cr-Fe-Ni-Cu system, have higher strength and acceptable ductility in the high-temperature region. However, their dissipative properties have been little studied. Therefore, it is rational to study the damping properties of such alloys for assessment of the prospects of their application in devices operating under the conditions of intensive vibrations. It was shown earlier that Co-Cr-Fe-Ni-Cu alloys demonstrate higher characteristics of mechanical energy dissipation in the range of 290…670 K. In order to develop damping products alloys of this system, it is necessary to study the nature of copper influence on their dissipative properties, in order to optimize the alloy composition and its structural properties. (CoCrFeNi)1-xCux alloys, where x = 0…3, were produced as self-standing foils, as well as in the form 40 – 60 μm coatings for flat titanium rods, using the technology of vapour-phase deposition of the condensate. Mechanical properties of the alloys were studied on foils by indentation method, and their dissipative properties – on coated rods, supported in cantilever, by the method of damped bending vibrations of 120…140 Hz frequency. Microstructural characteristics of the alloy foils were studied using scanning electron microscopy and X-ray diffractometry. It is shown that foils of (CoCrFeNi)1-xCux alloys form in the single-phase or two-phase states, depending on their deposition temperature. Formation of a two-phase state of the foils is observed at deposition temperatures above 930 K, and it is due to solid solution decomposition with precipitation of copper-enriched FCC-phase. Two-phase structure of the coatings was produced from the single-phase structure by its annealing at temperatures above 930 K. It is found that the damping capacity of the coatings in the single-phase and two-phase structural states increases with higher concentration of copper in the alloy. Here, coatings with a two-phase structure are characterized by higher damping ability than those with a single-phase structure of the same chemical composition. Irrespective of the structural state and chemical composition of the coatings, the "rod-coating" oscillatory system was characterized by a linear amplitude dependence of the measured damping characteristic, the logarithmic damping decrement. With increase of sample temperature in the range of 290…670 K, their level damping increased almost linearly for all the measured amplitudes of coating deformation, right up to ε = 10-3. Proceeding from investigation of (CoCrFeNi)1-xCux alloy microstructure in the two-phase state and dependence of the alloy damping ability on vibration temperature and amplitude, the mechanisms of vibration energy dissipation are considered, which are due to the processes of grain-boundary diffusion of copper atoms and shifting of the coherent interfaces between the grains of FCC phase, differing by the lattice parameter. The possibility of using such coatings to lower the level of resonance vibrations in elements of mechanical systems, exposed to vibration loading in service, is analyzed.

CHANGING OF THE PROPERTIES OF CARBON NANOTUBES UNDER EXTERNAL INFLUENCE

H. Mykhailova, Yu. Bozbey, B. Kovalchuk

G. V. Kurdyumov Institute for Metal Physics of the NAS of Ukraine, Kyiv, Ukraine

Carbon nanotubes are interesting because they have unusual properties: they combine high strength and elasticity, thermal and electrical conductivity. Mechanical deformation and defects affect the electronic structure, the concentration of charge carriers, electrical, emission and other properties. Defects can occur both in the process of synthesis (growth and gas impurities) of CNTs, and under external influences, in particular, during radiation exposure. They deviate the shape of the CNT from rectilinear, change the conditions of current flow, affect the concentration of charge carriers, Fermi energy and electrical conductivity. The need to study radiation defects is due to the possibility of using nanotubes in space and nuclear reactors, as well as to use high-energy radiation as a technological tool to create radiation defects and obtain material with fundamentally new properties. It is shown that each of the defects of different genesis deviates the shape of the MUNT from rectilinear and forms a topological disorder, which changes the electrical conductivity and increases the thermo-EMF coefficient, but their combined action (or large doses of radiation) reduces this disorder as a result of defect interaction. leads to the annihilation of defects of different signs and / or their "healing" as a result of recombination of knocked out carbon atoms with vacancies. The nature of the high radiation resistance of CNTs is explained by their small size, compared with the path length of the knocked out atoms, their rapid migration between graphene layers, and recombination with vacancies.

FUNCTIONAL POLYMER COMPOSITES FOR FDM 3D PRINTING

O. Masiuchok, M. Iurzhenko, V. Demchenko, R. Kolisnyk

E.O. Paton Electric Welding Institute of the NAS of Ukraine, Kyiv, Ukraine

FDM (Fusing Deposition Modeling) 3D printing technology is widely used in all spheres of human life and at the same time is one of the most interesting and promising areas for further development and improvement. At present, there is a shortage of consumables with unique functional properties on the market, which makes it impossible to form special-purpose 3D products needed by industry. That is why the development of functional consumable composite materials for 3D printing by adding to the material matrix of various fillers and thus improving 3D technology by significantly expanding its field of practical application, is an urgent task.

The work aimed to develop electroactive polymer composites based on thermoplastics with the addition of conductive fillers and creation of the filaments with the necessary set of technological and electrical properties for 3D printing processing. Another task was to develop filaments and 3D products from them, with antimicrobial and antiviral properties. For this purpose polylactide (PLA) was used as a matrix. PLA is known for its environmental friendliness, biocompatibility, low shrinkage, high strength. It is the most popular consumable for additive manufacturing of 3D products using FDM 3D printing technology. As a filler for obtaining filaments with antimicrobial and antiviral properties, we used nanosized Ag (4% of the mass) and particles of the electrically conductive disperse microfiller (particle size 30 μm) of carbon black (CB) of different volume concentrations (1%vol; 2.5%vol; 5%vol and 7%vol) for obtaining electroactive filaments.

It is determined that when the CB content is within φ = 2.5… 5% vol, it is formed a continuous framework of the electrically conductive CB phase in microcomposites and, accordingly, their electrical conductivity σDC passes the percolation threshold, which is accompanied by a sharp increase in its values σDC = 6.5 × 10 -10 .... 3.33 × 10-3 S/cm. Also, with the increase of CB content in microcomposites there is a change in their structure and thermophysical properties, in particular the general increase in the glass transition temperature of the amorphous phase PLA Tgt = 62.02… 67.86 °C, cold crystallization temperatures Tcc = 114.59… 127.71 °C and melting of the crystalline phase PLA Tm = 169.04… 173.82 ° C, which indicates phase changes in the polylactide matrix with the addition and increase the concentration of CB from φ = 1% vol to φ = 7%vol.

It is established that the developed filaments based on silver-filled nanocomposites, which were obtained by preliminary thermochemical reduction of silver ions in the volume of polymeric films and final 3D products from them show antimicrobial activity against strains of opportunistic pathogens

Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa and yeast-like fungi Candida albicans and antiviral activity to human adenovirus type 2 and influenza virus type A - H1N1, and therefore are promising materials for additive molding of products for use in various fields of medicine and food industry.

ANALYSIS OF GA DOPING EFFECT ON MG-AL AND MG-CD ALLOYS BY MICROINDENTATION

M. Khokhlov

E.O. Paton Electric Welding Institute of the NAS of Ukraine, Kyiv, Ukraine

A promising lightweight structural material that provides the specific strength of structures is magnesium, alloys of which are widely used for the manufacture of protective shells of microelectronics, laptops, photography equipment, as well as for the manufacture of temporary implants in surgery. Sufficiently high plasticity and relatively low corrosion resistance and modulus of elasticity, poor casting properties, the tendency to gas saturation, oxidation and ignition during their creation or processing stimulate research aimed at improving the functional properties of magnesium alloys. Mg-Ga binary system has several intermetallic phases that have significantly increased hardness and Young's modulus compared to pure Mg and its alloys, which opens up the possibility for improvement of existing Mg alloys and development of the new ones. Micromechanical testing (ISO 14577-1: 2015) is a convenient way to evaluate the influence of Ga diffusion on the gradient of Mg alloys properties.

Surface alloying of several basic Mg-Al and Mg-Cd systems alloys was done at different temperatures in the range of 0,3…0,7 of their melting point. Micromechanical test showed an average increase in microhardness from 1,2 to 2 GPa and in Young's modulus from 43 to 72 GPa in the diffusion zone of all the alloys. The temperature had an impact only on the depth of Ga diffusion.

Ingots of Mg-Al-Ga and Mg-Cd-Ga systems were obtained using induction remelting at temperatures 650…700°C for further investigations of Ga doping effect. Micro-X-ray spectral analysis (JEOL, INCA) confirmed chemical composition similar to the diffusion zones. Micromechanical propeties were at the same level as measured after surface alloying experiments. X-ray diffractographic analysis showed that stable Mg_5Ga_2 phase forms under these conditons and probably it is the main mechanism of strengthening in studied Mg alloys.

SECTION V

NUMERICAL SIMULATION AND MODELLING OF PROCESSES AND MATERIAL

DEVELOPMENT OF A MATHEMATICAL MODEL FOR PREDICTION RESIDUAL STRESSES AND STRAINS AT FSW

B. Tsaryk

E.O. Paton Electric Welding Institute of the NAS of Ukraine, Kyiv, Ukraine

To predict residual welding stresses and strains at friction stir welding (FSW) of flat elements made of aluminum alloys, the mathematical model was developed that takes into account the heat input due to the processes of intense friction of the tool with the material of the joint elements. One of the features of the model is the condition of rigid restraint of the welded elements along the length of the welded elements at a short distance from the weld during welding and subsequent cooling. Residual welding stresses and strains are determined as a result of elastic-plastic analysis at local welding heating in a 3D model of a butt joint of limited dimensions. The results on the characteristic distribution of residual stresses and plastic strains at FSW of a sample of 500x500x10mm in comparison with TIG arc welding of a butt joint from an aluminum alloy of the same thickness confirm that undesirable residual stresses and strains are formed during FSW of aluminum alloys, but they have a lower level than at traditional arc welding processes. The developed model can be effectively used for the operational prediction of residual stresses and plastic strains in the zone of welded joints made by FSW. To further improve the accuracy of the developed model, it is important to consider the dependence of the friction coefficient on the temperature of the material, additional heat input due to plastic deformations of the material and the process of stir the material, as well as the degradation of the mechanical properties (softening) of the aluminum alloy upon heating.

COLLISION DETECTION OF SPHERICAL PARTICLES ON GENERAL QUADRATIC SURFACE AS A LOW-COST COMPUTATIONAL ALTERNATIVE FOR REAL TIME SIMULATIONS

G. Domínguez-Rodríguez, O. Bilyy, G. Canto-Santana, J. J. Ku-Herrera

Universidad Autónoma de Campeche, Centro de Investigación en Corrosión, Campeche, Mexico

Due to the SARS-COV-2 pandemic, the access to laboratories has been drastically reduced for engineering students. Therefore, the use of simulated environments for carrying on practices can be an alternative to presential ones. However, some students and universities at developing countries do not have access to powerful computing equipment. When simulating physics by time-dependent integrations, such as Velocity Verlet, Leapfrog, etc., the simulation of collisions is one of the most computationally demanding processes. Especially for complex surfaces. In order to compensate this, and since it is possible to model complex shapes through general quadratic surfaces and their Boolean operations, an analytical methodology for predicting the interaction of spherical particles with a general quadratic surface is proposed here. However, finding the distance between an arbitrary point to a general quadratic can require a numerical approach. This methodology uses the fact, that the closest point on a quadratic surface to an arbitrary point is on the trajectory of a normal vector coming from the closest surface point toward the arbitrary one. Then, two candidates for the closest surface points to the center of the particle can be proposed, one is selected, and finally, it is accepted or rejected through the evaluation of the Boolean interactions with other quadratic surfaces.

MATHEMATICAL MODELING OF RESIDUAL STRESSES IN THE COMPOSITE WELDED CONNECTION OF THE COLLECTOR TO THE NOZZLE OF THE STEAM GENERATOR PGV-440

A.A.Makarenko [1], O.V.Makhnenko [2]

[1]*STC E.O. Paton Electric Welding Institute of the National Academy of Sciences of Ukraine*

[2]*E.O. Paton Electric Welding Institute of the National Academy of Sciences of Ukraine*

Composite welded joints (CWJ) of dissimilar materials, usually ferritic-perlite and austenitic steels, were widely used in the equipment and pipelines of existing NPPs. A significant difference in the chemical composition of the base and welding materials leads to chemical and structural inhomogeneity of the metal in the joint area, and due to the difference in the coefficients of thermal expansion of materials during welding and post-welding heat treatment high unrelaxed residual stresses. It is known that unrelaxed residual stresses significantly affect the strength, durability and corrosion resistance of equipment elements. Mathematical modeling by the method of finite elements of the kinetics of residual stresses during welding of the welding unit of the Du-1100 collector of stainless steel 08Cr18N10T to the nozzle of the steam generator body made of steel 22K VVER-440 nuclear power units, as well as in the process of post-welding heat treatment. The influence of preheating on microstructural phase transformations in HAZ of the main material of a branch pipe was investigated, the main features of distribution of residual stresses in CWJ after welding and heat treatment are defined.

SECTION VI

INNOVATIVE TECHNOLOGIES AND PROCESSES OF METALLURGY

PRODUCTION OF FINECRYSTALLINE AL-BASED MASTER-ALLOYS BY USING ELECTRON-BEAM CASTING TECHNOLOGY

M. Voron

Physico-technological institute of metals and alloys of the NAS of Ukraine, Kyiv, Ukraine

Electron-beam casting technology is relatively new and unique method of obtaining cast parts from refractory and active metals, such as titanium and zirconium. Technological features of this method cause some wide enough abilities to solve different and difficult tasks, connected with production of unique materials. The good instance is aluminum-based master-alloys with high concentration of Zr, V, Mo, Hf and some other metals. The experiments aim was to produce ingots with compositions of second component concentration on a level about 10-15 wt %. The main demand to structure was connected with obtaining finecrystalline structure, acceptable morphology and evenly deposited modifying phases.

OBTAINING THIN-WALLED TITANIUM CASTINGS IN CERAMIC MOLDS UNDER CONDITIONS OF ELECTRON BEAM TECHNOLOGY

P. Kaliuzhnyi, M. Voron, O. Mikhnian, O. Neima, A. Tymoshenko

Physico-technological institute of metals and alloys of the NAS of Ukraine, Kyiv, Ukraine

Today there is a tendency for the use of titanium products and their alloys in the most responsible industries, medicine and everyday life. However, most of titanium products have a fairly high cost, effective reduction of which is possible due to application of foundry technologies. Effective production of different parts made of titanium and its alloys, especially thin-walled and high-precision casting, is not a completely solved problem. An effective solution of this problem may be found in using of ceramic molds and specific casting technologies. The melting of titanium alloys today is carried out by the following vacuum-induction, vacuum-arc or argon-arc and electron-beam methods. Most of them are focused more on obtaining relatively thick-walled products with simple configuration and semi-finished products, using metallic or graphite molds. Ceramic molds are used in argon-arc scull technology, but the efficiency of this process and metal quality is often not enough. Electron beam foundry technology provides a possibility to obtain high quality metal. In addition, it may also realize the resource-saving aspect that is meant to use as a charge a variety of raw materials, including up to 100% of production waste. Thus, a combination of these technological solutions may ensure the creation of new effective scientific and technological approaches for solving a problems of obtaining high quality thin-wall titanium casting.

RESEARCH OF GRANULOMETRIC COMPOSITION AND SPEED OF MOTION OF DISPERSED PARTICLES OF ZIRCONIUM WIRE DURING MICROPLASMA SPRAYING

S. Kaliuzhnyi, A. Khozhanov

D. Serikbayev East Kazakhstan State Technical University, Ust-Kamenogorsk,

Republic of Kazakhstan

The paper shows the analysis the granulometric composition and speed of movement of dispersed particles in a plasma jet depending on the technological parameters of microplasma spraying of neutral zirconium wire made of KTC-110 alloy. Using optical digital devices, it was found that in these investigated ranges of operating parameters, the average velocity of the sprayed particles is from 7.7 to 28.5 m / s. It is shown that the average velocity of a particle in a microplasma jet is inversely proportional to its geometric dimensions. It was found that in the case of a combination of the minimum values of the current strength, the flow rate of the plasma-forming gas and the speed of the sprayed wire introduction (mode No. 8), the formation of particles with a maximum diameter of 310 μm is ensured.

ELECTROSLAG REMELTING (ESR) WITH PORTION INGOT FORMATION

V. Porokhonko, I. Protokovilov

E.O. Paton Electric Welding Institute of the NAS of Ukraine, Kyiv, Ukraine

Experimental studies of the features of forming the side surface and the crystallization structure of steel and 29NK precision alloy ingots, produced by the method of electroslag remelting with a portion formation were carried out. The ingots with diameters of 84...220 mm were produced by remelting consumable electrodes in a pulsed mode in the electroslag furnace, providing the periodicity of the processes of electrode melting and metal solidification. This was achieved due to a cyclic change of the slag pool voltage from operating values to the values, at which the electrode melting ceased, as well as due to a corresponding change in the electrode feed rate. It was found that layer-by-layer formation of the ingot allows reducing the volume of the liquid metal pool, equalizing the crystallization front and controlling the conditions of metal structure formation while maintaining a good quality of the side surface. At the same time, the ingots are characterized by a dense disordered structure, the absence of large columnar crystals and a zone of counter crystallization along the axis of the ingot. The dispersion of the structure of ingots melted with portion formation is significantly higher than that of ingots of traditional ESR. If the conditions of layer-by-layer formation are selected correctly, there are no defects in the fusion zones and the mechanical properties along and across the crystallization layers are equivalent. It was shown that The determining parameters of the ESR-L process are the duration of pulses and pauses of the melting of the electrode, the volume of a separate layer of melted metal, the electric modes of heating the slag pool during pauses of melting of the electrode and the nature of their change during the transition from a pause to the pulse of melting of the electrode. These characteristics must be selected based on the ingots size, the properties of the melted material, the cooling conditions of the liquid metal pool.

AUTHOR INDEX