of variation of τ_e = 9.0–9.1 s (relative change is equal to 1 %) and τ_g = 8.4–8.8 s (5 %). In the second case for the range of variation v_w = 0.5–1.0 cm/s changes of transportation lags are as follows: τ_e = 6.7–13.8 s (relative change of 78 %) and τ_g = 6.2–13.3 s (83 %). Thus, in the second case, the model of control object is a non-stationary dynamic system which requires more sophisticated control algorithms.

The proposed procedure of calculation of transportation lags in weld reinforcement formation ACS with feedback allows correct selection of time parameters and type of automatic regulator.

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THESIS FOR A SCIENTIFIC DEGREE

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On December 10, 2009, **A.V. Yarovitsyn** (PWI) defended his Candidate of Sciences Thesis on subject «Microplasma Powder Cladding of Heat-Resistant Nickel Alloy with 45–65 % γ-phase Content».

The thesis is dedicated to investigation of the energy, thermal and technological peculiarities of microplasma powder cladding with the aim of development of a commercial technology for repair of blades from heat-resistant nickel alloys.

The thesis substantiates requirements to a welding heat source for microplasma powder cladding. It shows that a combination of low specific heat inputs of 100–650 W, low heat power density in an equivalent heat spot equal to 150–1500 W/cm^2 and low speed of the microplasma arc provides slow cooling of the base metal in the brittle temperature intervals at a rate of 3–10 °C/s. In this case the strain growth rate does not exceed the critical values, and initiation of hot cracks is hardly possible in the most dangerous zone of the base metal. The microplasma arc stability at a current of 2–35 A with portioned feed of a powder to the arc column, depending on the level of constriction of the arc by plasma nozzles, was investigated. It was determined that destabilization of the microplasma arc at currents of less than 22–25 A is caused by the influence on the arc by the carrier gas dosing pulses moving in a flow-through gas-powder system at a speed of up to 60 m/s. Proportion of a carrier gas dosing pulse speed of 5–15 m/s and specific plasma gas flow rate of 2–4 m/s was experimentally found to provide the stable arc.

It was established, based on experimental calorimetry data, that at currents of 5–35 A the effective methods for control of the heat power density in the microplasma arc heating spot include the effective heat power of the arc equal to 100–600 W, constriction of the arc due to changes in diameters of the plasmatron nozzle channels and shielding gas types (Ar or a mixture of Ar + 10 % H_2), and concentrated powder feed. In microplasma powder cladding the heat power density in the equivalent heat spot is 100–250 W/cm^2, which is 3–8 times lower in comparison with the arc for the low-current TIG process. Such heat characteristics of the microplasma arc provide a more uniform metal cooling and, combined with its speed of about 1 m/h, efficiently limit the strain rate.

The thesis determines that in microplasma powder cladding of heat-resistant nickel alloys the oxygen content of the deposited metal varies in a range of 0.0068–0.0220 %, and the nitrogen content — in a range of 0.0026–0.0080 %. It was experimentally proved that it is necessary and efficient to limit the oxygen content in the deposited metal of heat-resistant nickel alloys to 0.006–0.009 % by providing the following process parameters: plasmatron-to-workpiece distance of 2.5–5.0 mm, using powders with a low oxygen content, and using a mixture of Ar + 10 % H_2 as a shielding gas.

The thesis established the feasibility of microplasma powder cladding at currents of 5–35 A on a narrow substrate, and at currents of 17–35 A on a wide substrate.

The technology was developed for repair of ends of band flanges of blades from heat-resistant nickel alloy JS32-VI for aircraft engine D18T. The technology is based on application of one-layer cladding at currents of 8–20 A using additive powder of JS32 alloy. The feasibility was proved of repair of polycrystalline blades by microplasma powder cladding using additives with a composition identical to that of the base metal of JS6U-VI alloy, as well as less heat-resistant additives with a specified level of properties for alloys JS6K-VI and ChS70-VI.

O.V. Makhnenko (PWI) defended thesis for a Doctor's degree on the subject «Prediction of Deformations in Welding and Thermal Straightening of Structures Based on Methods of Thermal Ductility and Functions of Shrinkage».

The thesis is devoted to development of general approach to prediction of deformations in welding (hard-facing, thermal straightening) of large-sized structures based on complex application of methods of thermal ductility and functions of shrinkage, and also development of appropriate calculation algorithms of realization of a combined approach.

Suggested are the calculation methods of determination of parameters of shrinkage function for the characteristic cases of welding heating based on the geometric typification of object.

Designed are the calculation algorithms for girder structures and the investigation of kinetics of general deformations of welded girders in laser welding at multi-supporting fastening is carried out which allowed solution of problem of positioning the laser heat source in the process of welding with account for welding deformations. The distinctive feature of developed mathematical model is consideration of static indeterminateness connected with the sites of intermediate fastening of a girder in the process of welding performance, possibility of prediction of forces for maintaining of a girder on supports during welding and also providing the preliminary bending or mechanical straightening after welding.

Designed are the calculation algorithms for prediction of welding deformations of tube plates of heat exchangers in the process of welding-in of a big amount of heat exchanger tubes and new practical results were obtained based on carried out calculated investigations. The type of welded joint was defined for tube plate with the tubes of five considered ones providing the least deformation of a tube plate. It was established that application of austenite steel for tubes and fillers as compared to the variant of ferrite steel allows obtaining lower residual general stresses of the tube plate. It was defined that for the structures with two tube plates and short straight tubes the welding-in in a certain sequence of two tube ends simultaneously can considerably decrease deformations of tube plates especially at limited thicknesses of the latter. The estimation of risk of buckling at axial compression of tubes welded in the first turn was made.

Designed are the calculation algorithms for prediction of general deformations connected with multipass surfacing large-sized plates using wear-resistant alloy. It was established that the variant of surfacing along the long edge of a plate at the minimum heat input modes, providing necessary microstructure in HAZ metal is most favourable from the point of view of decrease of deformations. The significant effect of decrease of deformations (nearly by 3 times) was revealed in application of fastening in the surfacing area, i.e. pressing of this area against the plate with subsequent release after cooling.

Designed are the calculation algorithms for modelling the process of thermal straightening of thin-walled structures with buckling deformations using heating spots of different shape. Basing on the developed algorithms the study of possibility of increase of efficiency of thermal straightening process was carried out. It was established that due to optimisation of heating parameters it is possible to increase considerably the straightening efficiency that is connected with significant economy in power and labour consumption. The fundamental regularities of thermal straightening process of thin-walled structures with buckling deformations, defined by geometric parameters of buckling and arrangement of heating spots, were revealed for the first time. It was established that the process of thermal straightening of buckling deformations has a complete number of objective factors limiting the efficiency of this technological operation especially at large thicknesses of lining sheet.

On the basis of developed calculation algorithms the controlling software was created to automate the process of thermal straightening of thin-walled structures with buckling deformations, which found its application in automated complexes of equipment for laboratory tests and tests under conditions of manufacture of welded shipbuilding panels.

Designed are the calculation algorithms and methods of determination of optimal parameters of thermal straightening of distortion deformations of axis of cylindrical shell allowing in-process obtaining of solution on the selection of parameters of thermal effect in the real time mode. The experimental approbation of thermal straightening general distortion deformations of a long axis of cylindrical shell and long screw shafts showed a high efficiency of the developed method.

V.Yu. Skulsky (PWI) defended thesis for a Doctor's degree on the subject «Weldability of Heat-Resistant Chromium Steels for Boiler Units of High Parameters».

The thesis is devoted to investigation of regularities of formation of a structure, properties of welded joints of chromium heat-resistant steels, nature of formation of cold and tempered cracks in welded joints of these steels and development of scientifically-grounded approaches towards technology of producing quality joints of welded pipe systems of boiler units of new generation with supercritical parameters of a steam for power units of thermoelectric power stations.

The concepts of influence of alloyed elements on the peculiarities of high-temperature $\delta \rightarrow \gamma$ transformation and phase composition of martensite chromium steels were expanded. It was shown that exclusion of δ-ferrite formation and obtaining of one-phase martensite structure of complex-alloyed chromium steels (as conditions of providing their high technological properties and durable strength) is achieved at chromium content at the level of 8.15–9.75 % which is grounded by practicability of application of steels with 9 % Cr with alloying system 0.1C–9Cr–MoVNbNiN (type 10Kh9MFB). The peculiarities of phase transformations and formation of structure of welded joints of 9 % Cr steels under the conditions typical of arc welding are studied. It was established that increase in chromium content in heat-resistant steels (from 2.5 to 12 %) results in increase of stability of austensite in overcooling, decrease in temperature of martensite transformation (from ~450 up to ~280–230 °C) and increase in hardening level. The steels with 9 % Cr are prone to the formation of martensite (with hardness of ~450 *HV*) within wide range of cooling rates, which makes them hard-to-weld and prone to cold crack formation. The conditions of possible formation of δ-ferrite in welding of steels with 9 % Cr are established. It was shown that heterophase constitution of weld metal and fusion zone can arise in welding with increased heat input as a result of development of heterogeneous distribution of elements-ferritizers (Cr, Mo, V, Nb) and carbon (at liquation and high-temperature diffusion). The formation of δ-ferrite is caused by decrease in carbon content in welds (for example during its burning out in TIG welding), and also intensification of carbon diffusion from the base metal to a side of a weld with higher chromium content, that is typical of welding of joints of chromium and austenite steels by an austenite chromium-nickel weld. The latter phenomenon is excluded in use of nickel welding consumables. The principal approach to the technology of welding joints of martensite steels with 9 % Cr is the application of conditions with a decreased heat input. The regularities of formation of stress-strain state and formation of cold cracks in welded joints of hardening steels are studied. It was experimentally shown that main factor predetermining the tendency of martensite metal to cold crack formation is the degree of strengthening in hardening. Welding (shrinkage) stresses together with stresses from external loading is an additional factor initiating the fracture process. Using developed method the thermokinetic peculiarities of delayed fracture of welded joints were investigated. It was established that tendency to cold crack formation of welded joints of martensite steels is manifested at the temperature below ~140 °C; at 80–100 °C the joints have a minimal crack resistance that is determined by maximum rate of fracture process. Basing on dilatometric investigations of specimens of hardened steels (10/40Kh9MFB, 25Kh2NMFA, 38KhN3MFA) and determination of activation energy of development of deformations in the period of tests of crack resistance it is shown that revealed differences in resistance to cold cracks formation at different temperatures can be connected with different kinetics of development of low-temperature decay (tempering) of martensite. The appeared microstructural heterogeneity determines the nature of distribution of elastic-plastic deformations in volume of metal hardened in welding and probability of formation of microareas with high local stresses, density of dislocations and hydrogen concentration where fracture initiates and develops. At the high rate of decay (within the range of 80–100 °C) the conditions for local deformations in the zone of grain boundaries and rapid fracture are created. It is proved experimentally and theoretically that the high rate of martensite decay propagation in the volume of metal at increased temperatures and also evolution of diffusive hydrogen from a welded joint are the conditions of increase of resistance to a delayed fracture. It was shown that the presence of microstructural components (δ-ferrite), more tended to deformation, in initial hard martensite structure leads to decrease in crack resistance. The concepts of mechanism of tempering brittleness become more profound and factors are established defining the possibility of formation of cracks under conditions of high-temperature relaxation of stresses in welded joints of 9 % Cr steels. The effect of dispersion hardening within the range of ~400–550 °C is revealed, the reason of which can be the precipitation of chromium carbide M_7C_3. It was established that at the presence of δ-ferrite in the structure at tempering within the range of hardening the cracks can form. The condition of high resistance against cracks formation in tempering is the providing of homogeneous martensite structure. Basing on the study of kinetics of stress relaxation in the process of high-temperature tests it was established that to relieve inner stresses more completely the tempering of welded joints should be carried out at temperatures ~750–760 °C. The level of weld metal alloying by C, Mn, Ni was defined to provide its single-phase martensite structure and obtaining of required mechanical properties after tempering of welded joints. The recommendations to the conditions of submerged manual and automatic welding are experimentally and theoretically grounded. The conditions of achievement of high resistance of welded joints against delayed fracture using thermal influence on structural and hydrogen factors are determined (limit of cooling rate of HAZ metal of $w_{6/5} \leq 8$–10 °C/c, thermal relaxation at temperatures 160–200 °C) and providing of their required mechanical properties at heat treatment (high tempering at $T \approx 750$–760 °C during not less than 2 h). New welding electrodes ANL-8 are developed, the technical documentation on main technologies of welding of typical pipe joints is worked out. The pilot-industrial verification of welding technology was performed.