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MATHEMATICAL MODELING AND OPTIMIZATION OF THERMAL STRESSED STATE OF SHELL STRUCTURES IN POWER ENGINEERING

At present, power engineering is one of the priority industries [1-3]. Modern requirements to operational reliability and durability of power engineering facilities cause the need for both modernizations of existing equipment and development of new structures from advanced materials with enhanced performance properties [3-5]. Manufacturing of many elements of such structures, as a rule, is associated with technologies characterized by operations with high temperature conditions [6, 7]. Structural transformations of materials due to intensive thermal effects lead to the emergence of inhomogeneous high-gradient thermal stress states in the areas of technological influence [8, 9]. Thus, the development of methods for research and optimization of high-gradient thermal stress states of critical elements of power engineering structures taking into account the peculiarities of manufacturing processes is an urgent task. The most widespread structures of power engineering include shell-type structures, among which we can distinguish: fuel elements of nuclear engineering, pressure vessels of power apparatuses, hull structures of power plants, parts and units of technological equipment of metallurgical production. Typical for them is a complex structural form consisting of many articulated shell elements: shells, spherical bottoms, nozzles, fittings, pipelines, etc. [10-12]. The presence of unbreakable joint and mating parts significantly affects the strength and load-bearing capacity of the whole product.

From a large number of varieties of connections of separate units into a single structural form, welded joints formed by longitudinal, circular, meridional and many contour welds are widespread. Technological processes of their manufacturing are characterized by local inhomogeneous high-gradient thermal loading, volumetric deformation of metal in the zone of influence, concentration of elastic-plastic stresses in the vicinity of the welded joint, contributing to the formation of technological defects in the form of cracks and shrinkage porosity. The combination of negative factors of technological character and design features in certain conditions can lead to a decrease in operational properties and possible subsequent destruction of the structure.

It should be emphasized that technological processes of power engineering associated with high-temperature loading, such as welding, heat treatment, induction heating, are currently the main ones in the manufacture of load-bearing shell structures of power plants, the strength reliability of which significantly depends on the residual stress state. Concentration of local tensile thermal stresses in the joints of the mold contributes to the development of cracks during operation and can lead to loss of stability. The stringent requirements for such structures include, among other issues, ensuring minimum temperature deformations, dimensional stability and accuracy of fabrication of the main load-bearing elements. When the resources of optimal design are exhausted, manufacturing techniques that produce elastic-plastic deformations become of paramount importance in the creation of high-quality power equipment. To reduce dangerous levels of thermal stresses and deformations, it is necessary to develop methods for optimization of thermal stress states taking into account the choice of quality criteria, constraints and target function [11, 12].

The aim of the work is to develop adequate models and methods of research and optimization of high-gradient thermal stressed states of articulated shell-type structures taking into account the peculiarities of technological processes of power engineering.

Mathematical models for determining the parameters of the thermal stressed state of articulated structures of complex geometric shape with variable physical and mechanical properties experiencing local high-gradient thermal loading are developed.

Algorithms for optimization of thermal stressed states of articulated shell-type structures on the basis of the system of quality criteria, selection of the optimal design form and optimal control of the parameters of technological manufacturing processes have been developed. Structures of estimation weight functions is mathematically justified. The results of the study can be applied in the development of advanced power structures with enhanced performance properties.

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