# INTRODUCTION

Heat exchangers – the devices intended for the transfer of heat from one heat carrier to another or to the environment – are most widely used units in all types of energy plants and engines. This equipment makes up the bulk of the production in many branches of industry: power engineering, machine construction, aviation and rocket-space engineering, chemical, petroleum refining, and food processing industries, and also refrigerating and cryogenic technology, systems of heating, ventilation, air-conditioning, and others. In an overwhelming majority of heat exchangers used in all these fields, heat is transferred from a hot heat carrier to a cooler one through a solid body (wall). In this case, a heating agent transfers the heat to one surface, whereas a coolant takes it from the other surface of the wall, i. e., in all cases heat transfer takes place between the heat carrier and the heat transfer surface. Therefore, technical and economical characteristics of heat exchangers of all types and purposes are determined by the soundness in the design and construction of the macro- and microstructure of the heat transfer surfaces.

The theory of heat and mass transfer gives the scientific basis for the selection and design of surfaces in heat exchangers for various purposes. The boundary layer theory, which defines transport processes in the liquid at the boundary with a stable heat-transfer surface, is the basic component of the theory. As applied to a wide class of new problems, especially in nuclear power, aviation, and rocket-space technologies, where high densities of heat fluxes, velocity, and temperature of heat agents can occur, the heat transfer surface acquires an active role in its interaction with the liquid and cannot be considered as a passive, stable, nonvariable medium. In many cases, we observe physico-chemical, thermomechanical, radiative-chemical, and other types of interaction between the liquid and the surface. Without regard for these processes we cannot gain the complete idea of the heat transfer process, i. e., the boundary layer theory is inadequate for describing the mechanism of hydrodynamics and heat transfer under these conditions.

Correlation of various experimental data on heat and mass transfer and hydrodynamics under these conditions with account for achievements in the study of solid surfaces and surface phenomena at the laboratories of universities and companies worldwide, indicates the necessity for qualitatively new modeling and theoretical approach to such problems. The study of multi-layer models of the boundary region of heat transfer forms the basis for the developed theory as applied to the models of the Prandtl boundary layers. In the simplest case the boundary region includes three plane layers: a boundary layer of liquid, an intermediate layer with nonuniformities of the microstructure of the heat transfer surface, and a surface layer of the solid body which involves nonuniform and unsteady structures of the heat transfer surface. In the models studied, the boundary region of heat transfer realizes all nonuniformities of various processes of heat and mass transfer.

If the Prandtl theory explains the processes in the liquid, then the modern theory of a crystalline structure of a solid body does not present a unique description of its surface, since the mere presence of the surface (the boundary) is a "defect" of a three-dimensional structure of a crystalline matter. This defect – a break of a periodic crystal lattice – leads to the appearance of geometric, thermal, chemical, and other nonuniformities of the surface. With allowance for the diversity of these nonuniformities and inhomogeneity of physico-chemical properties of the surfaces interacting with different heat agents that are determined by them, under real conditions we deal with complex systems involving many uncertainties. These objective difficulties of the consideration of the problem of the heat transfer surface are complemented by the diversity of the methods of investigation of surfaces of solid bodies, technological processes of the formation of surfaces and their changes under real conditions (deposition and other contaminations, formation of oxide films on the surface, etc.).

All these various and very complex processes are extensively studied by specialists who design heat exchangers. Many works are concerned with the search for the ways to improve the surfaces and the methods of heat transfer enhancement. A large part of these works are devoted to partial problems, the results of many works are contradictory, and the methods suggested in them are not always effective and adaptable to streamlined manufacture. In a number of cases, the choice of the method of enhancement is not substantiated and has a random character. This situation makes a substantiated selection of effective heat transfer surfaces extremely difficult. Certain results of the studies reveal some conservatism as a result of which the possibilities for improvement of heat transfer surfaces for many fields of technology are not realized. In a number of cases use of traditional heat transfer surfaces leads to the substantially overestimated areas of heat transfer surfaces.

One of the special features of the present work is an attempt of applying the methodology of the system approach to the analysis of the role of the surface in the efficiency of heat transfer. The need for this approach is determined by a complex consideration of all factors governing the properties and structure of both the surface itself and the entire boundary surface area where these properties manifest themselves on the available micro- and macrolevels. At present, the methodology of system-structural analysis are actively introduced to various fields of modern science. As applied to the considered problem, the main advantage of this approach is the disclosure of the feasibilities of controlling the quality of the surface and the attainment of the required efficiency of heat transfer.

The advances of science in the investigation of the surfaces of solid bodies, disclosure of interrelation between micro- and macrostructure of surfaces, their behavior in the interaction with flows of liquids and gases, advances in mastering new technological processes of the formation of heat transfer surfaces and the methodology of complex optimization on the basis of a systematic approach, opened the possibilities for the formulation and solution of the problems of optimization of heat transfer surfaces. Nowadays these problems are formulated as comprehensive justification of macro- and microstructure of heat transfer surfaces providing most efficient technical and economic characteristics of heat exchanging equipment that is the most important stage of its design and production.

The problem of enhancement of heat transfer through the effect of the structure of the surface is of decisive importance in nuclear and thermonuclear power engineering, aviation and space technology, and also in solving the problems of transportation engineering, machine construction, environmental protection, electronics, etc. The variety of the methods of investigation, experimental equipment, and traditions of different branches results, in many cases, in unjustified duplication of expensive experimental studies, multiplicity and incoherence of recurrent design recommendations.

A complex general-science approach to an urgent scientific-engineering problem on the basis of use of achievements in different disciplines and technological processes, which is undertaken by the authors, is not only the summary of advances in the considered problem. A comprehensive analysis makes it possible to justifiably define perspectives of the considered new trend in the theory of heat and mass transfer, to facilitate widening and deepening of research and development, hastening of introduction of the results of fundamental and applied studies into practice.