BOOK REVIEW

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AERODYNAMICS AND HEAT TRANSFER IN ELECTRIC MACHINES*

Reviewed by P. M. Kolesnikov

Progress in electric-machinery manufacture is due not only to new electrical engineering materials, but even more to the efficiency of cooling systems.

In order to maintain admissible uniformly distributed temperatures in electric machines cooling streams must be distributed in them according to the heat sources. Therefore, even during the design stage reliable thermal and aerodynamic calculations must be made together with electromagnetic and mechanical calculations to determine the structural arrangements necessary to ensure adequate heat removal. Hence, aerodynamic and heat-transfer theories require refined scientifically based methods for making thermal calculations.

In books by the founders of our electric-machine manufacturing industry, A. E. Alekseev, M. P. Kostenko, and G. N. Petrov, cooling problems are presented in general form; special monographs by T. I. Al'per and T. G. Sergievskaya, P. N. Burkovskii, G. Gotter, A. I. Moskvitin, G. G. Schastlivyi, I. F. Filippov, et al. treat restricted problems as applied to certain types of electric machines; extensive material has accumulated, particularly during the last 20-25 years, in the form of journal articles. The time has evidently come to generalize all this material in the light of the contemporary experience of aerodynamicists and heat physicists in order to make it available to specialists.

The authors of Aerodynamics and Heat Transfer in Electric Machines have largely solved this problem by analyzing and critically reworking a large amount of material from the literature, including many results of their own investigations. The book treats a wide range of theoretical and experimental investigations with their analysis and gives specific examples and recommendations for designers.

The first five chapters are devoted to the theoretical bases of aerodynamics and heat transfer as applied to electric machines, and Chaps. 6-11 treat specific problems and methods for making heat and aerodynamic calculations for rotating electric machines.

Chapter 1 presents the physical principles and equations of aerohydrodynamics and heat transfer. The basic characteristics of electric machines are given; problems of heat losses and the relation between them and the geometric and electromagnetic parameters of machines are explained; systems of cooling electric machines and the construction of commercial and special use machines are discussed. The reasons for choosing the parameters characterizing the effectiveness of cooling systems are discussed briefly. This chapter gives clear notions of the problem and the objective of an electric machine from the point of view of aerodynamics and heat transfer.

Chapter 2 gives an account of the authors' research on the measurement of thermal conductivities of various insulators, magnetic and structural materials, and coolants which are important in practical electric-machine construction calculations; special attention is paid to equivalent thermal conductivities of slot and frontal parts of windings, various compositions of bundles of windings of enameled wire, and recommendations are made for calculating optimum windings. These results are given intables and graphs in appendices.

Problems of heat transfer for the free and forced motion of a fluid, flow and heat transfer in rotors and stators of electric machines, flow and heat transfer in the air gap between rotor and stator, and heat transfer in asymmetrically heated channels of electric machines comprise the content of Chaps. 3 and 4. Results of

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research on temperature distributions in the moving parts of full-scale machines and models, heat transfer of individual elements (rotor blades, frontal parts, windings of main and commutating poles, annular and axial channels in an air gap, etc.) are given here.

Chapter 5 is devoted to the choice of cooling surface of a finned and tubular design. Relations are found for determining the optimum parameters of the fins, and specific recommendations are given for choosing the fin parameters of totally enclosed machines in the design stage; one-dimensional and two-dimensional temperature distributions in cooling fins are discussed, taking account of variations in the heat-transfer coefficient over the length and height of an interfin channel, the nonuniformity of heat release, and the effect of heating of the air in its passage through the interfin channels. The results of calculations are compared with experiments. This chapter also presents methods for calculating compact and distributed heat exchangers of totally enclosed electric machines.

An aerodynamic calculation in chapter 6 is based on the method of equivalent circuits of ventillation systems of electric machines. Cooling systems are classified and methods are described for devising equivalent circuits and determining the hydraulic resistance of machines, the air flow rate, and its distribution over parallel branches. A great deal of attention is paid to investigating the flow structure in machines. Calculational methods are illustrated by examples.

Chapter 7 gives general information on thermal calculations for large asynchronous machines; thermal parameter methods, equivalent thermal circuits, and the temperature distribution method are developed.

Chapters 8, 9, and 10 describe methods for making thermal calculations of fully enclosed and protected direct current synchronous machines of intermediate power with various cooling systems. Electric motors similar in their thermal and ventillating circuits are discussed. The thermal calculations for these are performed by the method of equivalent thermal circuits and analytically.

The methods of calculating machines of intermediate power are based on the theory of similitude using relations obtained with experimental models. This necessitated performing careful experiments on the temperature distribution, heat and air flows, and studies of heat transfer of individual structural elements coupled with the study of ventillation systems, fans, and heat losses.

Chapters 9 and 10 describe thermal calculations for medium high-power machines, temperature distributions in the moving parts of large direct current motors, in electric traction motors and generators, hydraulic generators, and turbogenerators. A method is presented for calculating temperature distributions based on the solution of the differential equations of heat conduction.

We regard material on the selection and calculation of blowers for cooling systems as very important, and its absence leaves the impression of incompleteness in the solution of the problem; the operation of this apparently well-studied device under electric-machine conditions has a number of distinctive features requiring attention and consistency with the machine design, frequency control, heat exchangers, etc.

At the same time the sections on heat transfer in large-scale electric machines (turbogenerators) are of a somewhat "tacked on" nature; the specifics of this type of machine probably should be treated in greater detail in a separate monograph based on the book under review.

These comments do not lessen the value and originality of the book, which is written from a common point of view at a high scientific and technical level. It is one of the first domestic monographs devoted to the complex study of aerodynamics and heat transfer in electric machines. Its publication will without doubt be of great use to students, engineers, and scientific workers; it certainly will contribute to the further progress of electric-machinery construction.