

DUAL-FREQUENCY POWER SUPPLY SYSTEM AND INDUCTORS FOR HEATING OF ROTATING DISKS IN AN ELECTROMAGNETIC FIELD

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I. INTRODUCTION

One of fields of induction heating is realization of thermal processes in rotation bodies for carrying out tests and processes of disks aviation gas turbine engines and power installations on spin and specialized rigs. The induction heating allows to provide high speeds of heating and to receive the set non-uniform temperature distribution on radius of the disk corresponding operational conditions at tests on the spin rigs. The dual-frequency power supply system and special inductors are developed for heating of rotating disks in an electromagnetic field.

II. DESCRIPTION OF THE PROBLEM

The disks of turbines of aviation gas turbine engines (GTE) and power installations under operating conditions are under influence of rather significant mechanical and thermal loadings. Thermal streams in a zone of blades are characterized by key parameters of a gas stream: gas temperature and heat transfer factors from gas to a surface of blades. The temperatures in rim part of disks on an operating conditions reach 550, 750 °C, in blades – 800, 1100°C and more. The average heating speeds of turbine disks of aircraft engines under operating conditions make $0,2\div 1$ K/c and the maximal speeds of heating of disks reach $2\div 5$ K/c. on separate heating regimes in the beginning of a flight cycle. Therefore the modelling of high-speed heating modes of rotating disks and rotors has the importance of in connection with increase in an operating time of GTE details at non-stationary modes. The isothermal and thermal cycle tests of turbine disks with reproduction of operational thermal and mechanical loadings are spent on spin rigs with use of induction heating [1]. One of fields of induction heating is realization of thermal processes in rotation bodies for carrying out thermocycle tests of gas turbine disks on spin and specialized rigs.

The calculated-experimental methods of accelerated thermal cycle tests are developed for realization of modelling of operational high-speed modes of heating and cyclic thermal loading of GTE disks in view of the lead analysis of the test equipment and spin rig is advanced with use of new frequency supply system for induction heating and new inductors and with new system of computer control of the electric drive of a direct current.

The usual system of induction heating for heating of turbine disks consists of several flat ring inductors, located on different radiuses of a disk. The specified heating system demands of use of several power supplies and accordingly raised power consumption. The lacks of the given system consist also that the inductors are located discretely on a surface of a disk and consequently there are local deviations (gradients) of temperatures $\pm 30\div 40^\circ\text{C}$ in a radial direction

The development of a heating systems and methods of rotating disks with maintenance of the set temperature field of disks is an actual problem. For the decision of the specified problem it is necessary to solve problems of modelling of heating regimes of rotating disks. The choice of the frequency power supply system and inductors of a various configuration is necessary for maintenance of the designed temperature field of a disk. At thermocycle tests the maximal frequency of rotation of disks makes 5000 - 80000 r.p.m. The heating is carried out with the designed thermal streams.

The development and application special frequency power supply systems and flat inductors allows to eliminate local gradients of temperatures which are peculiar to systems of heating with discretely located inductors and to provide demanded distribution of thermal streams and to raise accuracy of reproduction of the set temperature distribution of a disk.

For the decision of the specified tasks the regimes of induction heating and mathematical models in program complex ANSYS are developed for calculation of electric, power characteristics of system of induction heating and modelling of temperature distribution on a disk in view of rotation.

At the present time works by calculation of heating of cylindrical preparations and creation of corresponding devices due to rotation in a constant magnetic field [2] are known.

III. RESULTS AND DISCUSSION

Authors first considered the heating the rotating disks in an electromagnetic field in view of additional allocation of internal power sources at high frequencies of rotation 10000-80000 r.p.m. [3].

The control heating of a disk is considered in two channels: changing of the heating power and changing of the rotation frequency.

For this purpose mathematical models in program the complex ANSYS are developed for calculation of electric and power characteristics of induction heating system, development of new inductor designs, constant magnets and electromagnets and modelling of heating modes of disks in view of rotation [3].

The investigations of influence of rotation frequency on allocation of power of heat internal sources in a disk due to two components of electromotive force have been carried out with use inductors of the different form. The first component arises on average frequency of a current in a variable electromagnetic field. The second component electromotive force arises at a rotation disk in the variable electromagnetic field created of an inductor. The specified component is small on small rotation frequency. The speed of change of a magnetic stream in a disk increases at increase of rotation frequency and induced electromotive force (the second component) becomes significant. As a result the power of additional internal heat sources increases and the induction heating intensity raises of a rotating disk.

According to this methodology the three-dimensional finite-element models of induction heating system of, consisting of a ring and loop and other inductors for heating the turbine GTE disk variable thickness in the software package ANSYS were developed.

The new configurations flat inductors which allow to raise accuracy of reproduction of a temperature field in GTE turbine disks are developed and to receive the additional thermal energy. By means of computer model the parameters of loopback and ring inductors on a rim and a nave have been specified and calculated temperature distribution in a rotating disk which has well coincided with data of experiments is received.

The use of loop inductors designed using of the computer simulation and dual-frequency power supply system (Fig. 1) of loop inductors (from one thyristor frequency converter (TFC)) located on both sides of the disk allows for in an effective temperature regimes in thermal cycling tests of rotating disks in an electromagnetic field on the spin rig and improve the accuracy of modeling the experimental temperature distributions in disks in 2-3 times (with an accuracy of $\pm 10 \div 15^\circ \text{C}$) and reduce the number of inductors and power supplies in 1.5-2.0 times.

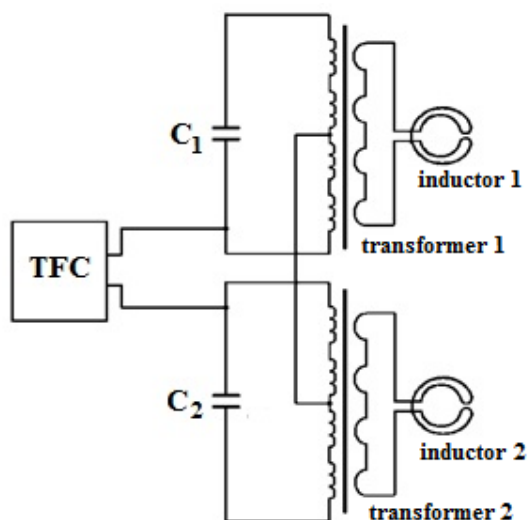


Fig. 1. The dual-frequency power supply system with loop inductors

The heating of the disk was provided by induction heating system with three TFC working at 2400-10000 Hz. The analysis of rapid heating also showed that with increasing heating rate in 5 times (from 2 K / s to 10 K / s) the performance-of the induction heating is increased in 2 times and the cost of electricity at the thermal cycling tests are reduced in 3 times.

Besides some results of researches of heating of a modelling disks with use of constant magnets are resulted.

The developed dual-frequency power supply system with loop inductors and heating regimes of the rotating disks in a electromagnetic field with allocation of additional power of heating due to rotation [3] were allowed to raise economy of the electric power and to reduce the established power of heating installations.

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