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ISSN 0543-5846
METABK 60(1-2) 145-148 (2021)
UDC – UDK 621.165.822:621.72:621.56/.59:536.5:620.18=111

RESEARCH AND MODELING OF THE COOLING SYSTEM IN STEAM TURBINE BEARINGS

Received – Primljeno: 2020-08-28
Accepted – Prihvaćeno: 2020-10-30
Preliminary Note – Prethodno priopćenje

A new porous cooling system in which coolant supply is produced by the combined action of capillary and gravitational forces, is proposed and studied for various technical devices and systems developed by the authors. Cooling surface is made of stainless steel, brass, copper, bronze, nickel, glass and alundum. The wall thickness was $(0,05 - 2) \cdot 10^{-3}$m. Visual observations were carried out by using high-speed cameras filming using SCS-IM. Experiments are carried out with water at pressures (0,01 - 10) MPa, sub cooling (0 - 20) K, excess liquid (1 - 14) of steam flow, thermal load $(1 - 60) \cdot 104$ W / m^2, temperature pressure (1 - 60) K and the system orientation (±0 ±90) degrees. The influence of liquid flow on heat exchange in porous materials has been studied. Calculated formulas for optimal fluid flow depending on the heat load and the type of porous structure are obtained. The design principles porous structures of evaporators are constructed. The mechanism of the vaporization process in the proposed porous cooling system using internal boiling characteristics is described.

Keywords: Bearings turbines, modeling, cooling system, temperature, capillary-porous structure

INTRODUCTION

The operation of the bearing must be reliable, eliminating limited oil heating and liner wear out. When the liner runs out the vibration characteristics of the entire shaft line change and intense vibration may be started. The oil in the bearing is heated by frictional forces between the oil layers in the film and due to heat entering the shaft from the hot turbine parts. Typically, the amount of heat going on shaft takes up 10 – 12 % of the heat generated in the oil layer. Therefore, to maintain the temperature level of the bearing all operating instructions stipulate tough oil temperature at the inlet (35 - 45 °C), normal outlet temperature (about 65 °C) and the limiting temperature (about 70 °C), and immediate stop of the turbine is needed. Babbitt pouring temperature controlled by resistance thermometers should not exceed 100 °C. Porous systems that are deprived of limitations currently used by heaters is suggested to be used as a heater.

They can be heated by gas or electricity. The advantages of the heat systems are uniform heating of pins to a predetermined temperature, eliminating the need for the selection mode of the primary coolant in the process of heating, heat may be transferred to only non-threaded portion of the stud, heating deaf studs is allowed, simplicity and reliability of the device, long service life, satisfy special requirements: transportable, fire and explosion-proof, any special storage conditions are not required [1]. The main advantages of support systems are high intensity, high heat transfer capacity, reliability, ease of manufacture and operation; they improve performance and technical indicators and have high capital and operating costs [2].

MATERIALS AND METHODS

Figure 1 shows the bearing with a capillary-porous structure developed by us to cool the oil flowing to the thrust bearings with a central location of the liner support, made in one unit with the two thrust bearing housing. The oil flows to the bearing capacity from the emergency (not shown) along a vertical channel 8 into the annular cavity where it extends to the neck of the shaft to drilling 1 through holes and one hole in the mounting ring 4,12 and the spacer 11 to each individual thrust segment. Plane thrust segments sealed with Babbitt fills. Thrust bearings with a rotating shaft comb and continuous feed and oil drain is a complex hydrodynamic system, in some areas negative pressure may occur and oil consumption drops to zero, and the film is thinned down to break. Installation of the porous structure provides a reliable heat transfer and stabilizes temperature of the wall even in case of momentary cessation of oil flow. Heat flow q_e, under the influence of which coolant, impregnating capillary-porous body 18, is applied to the evaporation zone of the porous system, evaporates or boils. In this case, the heat is absorbed, equal to the heat of transformation. Further perceived heat $q_к$ is transferred by vapor stream mainly by mole the molar by to the con-

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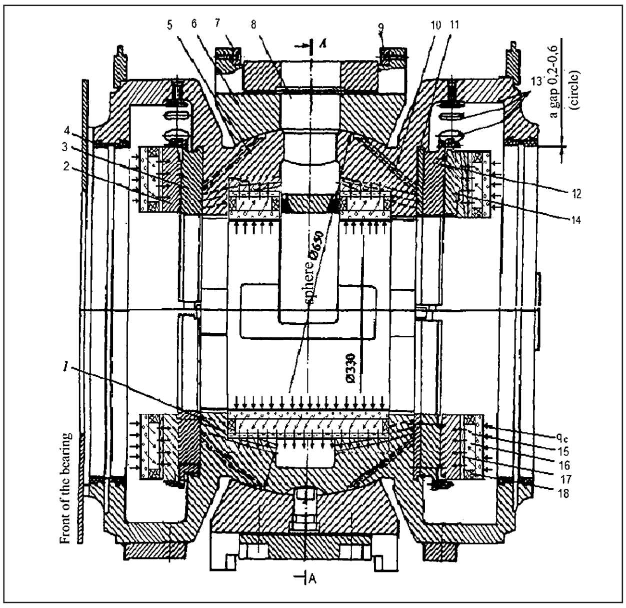

1-drilling; **2, 4, 12**-setting rings; **3**-resistant segment; **5**-liner; **6**-holder; **7,9**-rings; **8**-channel; **10**-drilling; **11**-spacer; **12**-plate; **13**-vent; **14**-feather; **15**-vapor stream; **16**-adiabatic zone; **17**-fluid flow; **18**-capillary-porous structure; q_e, q_c - heat flow in the evaporator and condenser.

Figure 1 Thrust bearing turbine T-250 / 300-23,5 TMZ

densation zone through the adiabatic zone 16. Due to condensation heat removal q_c occurs. The condensate in the form of 17 returns to the evaporation zone through the capillary-porous structure and then the operation process repeats itself. In emergency situations related to the termination of the oil supply in an emergency capacity, the oil is not supplied in the bearing via channel 8. After disconnecting the generator from the network during the run-shafting oil through emergency feeding tube is supplied to the lubrication of the bearing via channel, and via channel and inclined drilling 10 to lubricate the thrust segments. In case of emergency turbine components can be destroyed (rotor and stator). Therefore, when using a porous cooling system self-tuning of the distribution of coolant to the tap of a desired amount of heat takes place on account of the action of capillary forces. In this case, the turbine components keep operating and are not destroyed. Calculation of the porous system consists of calculating the vaporization and condensation zone [3]. When choosing a coolant it is necessary that the steam temperature t_s satisfies the inequality:

$$t_{wc} < t_s = t_s = f(P_s) < t_{we}$$

where P_s, t_s - pressure and saturation temperature;
t_{we}, t_{wc} - wall temperature of the evaporator and condenser.

Typically, the temperature difference in the evaporator, as well as in the capacitor does not exceed 5 - 10 °C, so t_s as well as t_{we} 5 - 10 °C can be selected in advance, it is necessary to further refine the calculation [4]. Calculations show that for a porous net system with selected geometry wall temperature in zones of evaporation and condensation is within the allowable range.

EXPERIMENTAL METHOD

A new porous cooling system has been developed for highly accelerated and highly cost-effective processes in such installations, in which the heat transfer processes are realized by vaporization of the liquid in porous structures, and the coolant supply is realized by the combined action of capillary and gravitational potential. Experiments were carried out with the water for the pressure (0,01 - 10) MPa, and with dilute solution of foam compound in water type PO-1. Fluid velocity assumes values $(1,1 \cdot 10^3 - 0,1)$ m / s, sub cooling (0 - 20) K, excess liquid m_l was (1 - 14) (1 - 14) m_s from the steam flow m_s. Thermal load $(1 - 60) \cdot 10^4$ W / m^2, temperature difference (1 - 60) K, relative to the vertical orientation of the system (±0 ± 90) degrees.

RESULTS AND DISCUSSION

Figure 2 shows the effect of the thermal load on the heat transfer coefficient depending on the kind of the porous structure and an excess coolant. From the analysis of the experimental data the following was revealed: heat flux $q = (l - 8)_* 10^4$ W / m^2 boiling point is transitive. A significant effect of fluid flow of liquid refrigerating agent and a type of the structure were found for this mode. This is especially pronounced in nets with large mesh size. According to its characteristics they are close to a thin film evaporator. Later boiling liquid in comparison with heat pipes is deterministic due to the redistribution of heat flow and drain the boil. Some reduction in heat transfer coefficient with increasing q associated with the emerging steam bubbles reaches a certain size, increasing thermal resistance of the boundary layer.

Developed for nucleate boiling region ($q > 8_* 10^4$ W / m^2) up to the critical loads with a wall destruction, appreciable effect within the fluid flow changes its MF = m_l = (1 - 7,5) m_s is not detected. Viable option may be a single layer structure 0,14 or two-layer 0,28 and 0,42, but we should expect more overheating of the wall is shown in Figure 3. Large cell sizes allow reducing the requirements for cleaning fluid. Structures having invariable normal pore size showed a high efficiency in the gravitational forces as opposed to the heat pipes when the emergency mode of operation occurred. Transferring q_{max} the benefits of anisotropic mesh structures over isotropic is not seen as it is the case in heat pipes. This is due to the improved circulation of liquid and vapor in the structure created by the excess liquid. There are other possible contributions to the mechanism of the processes: the presence of inertial effects and partial condensation of vapor bubbles. In the nucleate boiling liquid flow impact on the value of α is insignificant. However, at relatively low cost of fluid flow reliable heat is provided by maintaining a pulsating liquid film stability that distinguishes the system from the thin film evaporator, in which the falling film rupture occurs and there is a need for a substantial increase of flow (in 100

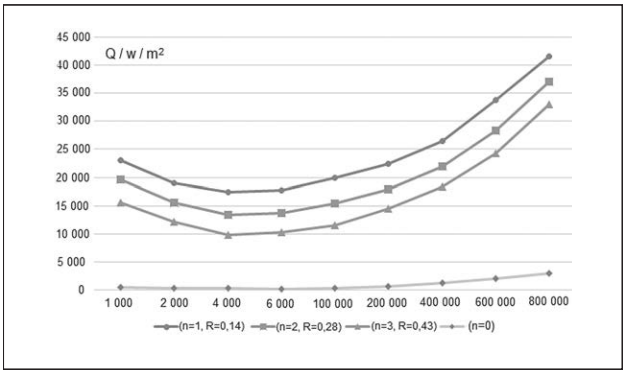

Figure 2 Dependence of the removed heat flux Q / W / m² on the heat flux density q / W / m² at different layers.

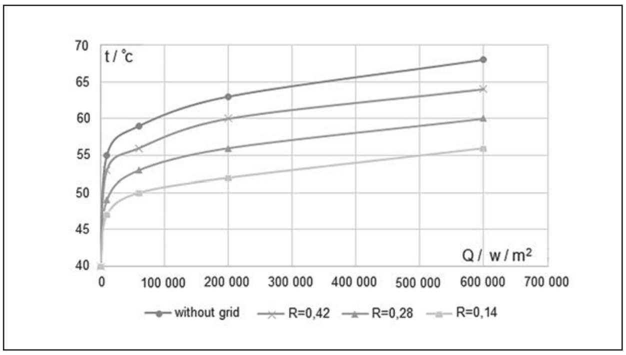

Figure 4 Dependence of the oil temperature t / ^{0}C from the heat flux density q / W / m² for pressure P = 0,1 MPa for one layer.

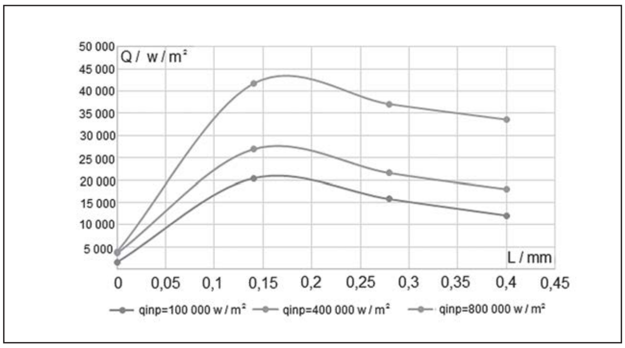

Figure 3 Dependence of the removed heat flux Q / W / m² on the cell size r, mm with one layer: m_w = (1 - 7,5) mn; **1**-structure 0,14; **2**-structure 0,28; **3**-structure 0,42

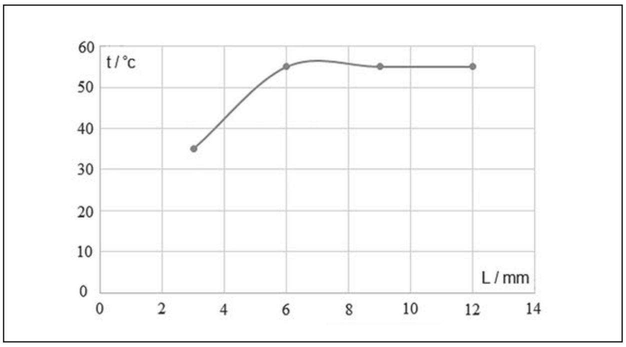

Figure 5 Dependence of oil temperature t / ^{0}C along the length of the bearing diameters L / mm

– 1 000 times). The thermal and hydrodynamic stability of the wall layer is determined by the presence of a pulsating liquid film under the vapor bubbles, through which heat is transmitted by thermal conductivity and transferred to the bubbles due to vaporization. The boundary layer is randomly turbulization by growing and bursting steam bubbles. The growth of turbulence in the boundary layer and increase the sustainability of a vibrant film of liquid leads to increase of heat transfer coefficient and the extension limit of the heat transfer capabilities of the system. Partially affects the hydrodynamic effect of the liquid flow on the mechanism of the vaporization process, facilitating the separation of steam bubbles before they reach the size of the separation diameter. Moreover, relatively "cold" portions of liquid from the core of the flowing stream, rushing to the wall, displace the two-phase mixture, reducing its thickness and thermal resistance. When certain superheats of the liquid are reached, the stability of the wall-mounted pulsating layer is lost, the grid cells are blocked by steam bubbles and the liquid access to the heated zone is stopped. A sharp increase in thermal resistance leads to overheating of the machine up to its burnout. At large angles of inclination relationships are pronounced, especially for structures with small capillary potential. This confirms the fact that the force of gravity is the main transport and capillary provides the uniform distribution of the liquid through the pores and capillaries of the structure and the more potential the capillary structure has, the uniform temperature distribution in the wall at different values of q. Comparison with heat pipes for q > 100 kW / m² indicates that the intensity of the heat pipes is lower by 40 %, or they are not efficient is shown in Figure 4. For q < 20 kW / m² heat pipes have a high intensity. In the field $(2 - 10)_* 10^4$ W / m² there is satisfactory agreement between the experimental data is shown in Figure 5. The combined operation of capillary and mass forces allows to control internal heat transfer characteristics and heat transfer in general [5], and analogy in the birth and death of steam bubbles with explosive processes to share the energy of heat and light phase.

CONCLUSION

The new porous cooling system in relation to bearings of turbines of power plants is offered and investigated. The originality of system consists in a joint supply of a cooler by capillary and mass forces. High- speed performance allowed to reveal the mechanism of the process of boiling from a variety of operational and design factors for two types of heat exchange. Experimental data were obtained for optimal fluid flow using high speed film shooting and holographic interferometry a model was constructed and the mechanism of heat exchange during vaporization was explained. The established type of porous structure, optimum consumption of liquid and the mechanism of a heat transfer allow to extend the received results to other scopes of porous system in turbine installations and to make their calculations with an accuracy of ± 20 %.

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Note: The responsible for England language is Aigerim Nauryzbayeva, Almaty, Kazakhstan