DETERMINATION OF THE AMOUNT OF HEAT TRANSFERRED THROUGH THE WALLS OF A SYMMETRIC CHANNEL FOR USE AS THE BLADES OF WIND TURBINES WITH A VERTICAL AXIS OF ROTATION

Manatbayev Rustem, Kalassov Nurdaulet, Abdieva Zeine, Zhailauhan Ardak, Shaimardan Riza
Physico-technical Faculty, al-Farabi Kazakh National University, Almaty, Kazakhstan

Abstract

The Republic of Kazakhstan in terms of geography is in a wind zone of the northern hemisphere, and large parts of Kazakhstan there are enough strong air currents, especially the north-east, south-west directions. In some areas of Kazakhstan annual average wind speed is greater than 6 m/s, making these areas attractive for wind power development.

In times of greatest need for heat and power generation of wind turbines can be damaged due to wet snow drifts, followed by a sharp decrease in air temperature and the formation of heavy ice on them.

One possible way to protect the outer surface of the operating wind turbines from sticking of wet snow is heated by warm air flowing through the internal channels of the device. Thermal protection is a more radical way. This paper discusses the method of calculating the flow of heat through the wall of the air of the real device. Using this methodology, complete consumption were determined amount of heat to the walls of a specific channel.

Key words: *a wind turbine, the Reynolds number, the total amount of heat, warm air, the wind speed, the blade.*

INTRODUCTION

The scheme of movement of warm air cavity of the wind turbine carousel type is as follows. Air at a flow rate Q_0 through the annular channel extends a rotary shaft, and then an equal proportion ($Q_0/2$) supplied to Mach 2, suitable for working vanes and splits again here - one half rate ($Q_0/4$) moves along the upper half of the blade and released to the atmosphere, and half rate ($Q_0/4$) extends along the lower half and is also vented to atmosphere. [1] The heat is removed from the outer surfaces of the shaft rotation, the strides and working blades. For flow in the blades and mach problem is symmetrical relative to the rotational axis, so that it suffices to consider the flow and heat transfer in one of the Mach and one half of the blade.

As for the rotation of the shaft, there is the problem reduces to the case of cross-flow around a circular tube. Initially conduct heat transfer calculation of one of the halves of the blade, as You can set the temperature of the air flowing into the atmosphere from the hole at the end of the channel (T_{1b}) and thus try to determine the temperature of the warm air at the entrance of his blade into maha (T_{0b}) or, equivalently to find the temperature of the air at the end of the maha ($T_{0b}=T_{1M}$). Since the shape and size of the blade and the maha channels are the same, then it is easy to calculate the heat transfer maha similar manner, and to determine the temperature of the warm air at the inlet of the annular channel (T_{0M}) into the channel maha, knowing the temperature of the air at the end of the annular channel ($T_{0M}=T_{1M}$). Thus, one can calculate the air temperature at the inlet to the annular channel and thereby determine the amount of heat required for thermal protection windmill.

This paper discusses the method of calculating the flow of heat through the wall of the air of the real device.

DESIGN PROCEDURE

Method of calculation as follows. You must first determine the flow of warm air inside the maha. To calculate the heat loss through the wall of the channel is defined by desired to move the masses of warm air in the duct Mach. Mass flow ρQm root (where air flow rate Qm inside Mach per unit time), and has a dimension ρQm (kg/s)

If the mass flow rate multiplied by the sredneraskhodnuyu ρQmusrm, we get the driving force that moves the weight of an average speed of ucp and has a dimension of force [H], dividing by the area of the channel will find air buoyancy force per unit area $\frac{\rho Q_M u_{av M}}{S_M}$ with the dimensions of (Н/м^2). This force must be equal to the weight acting on the centrifugal force minus the force of viscous resistance of the channel, ie

$\frac{\rho\omega^2 l_м^2}{2} - \frac{\zeta_м l_м \rho u_{avм}^2}{2d_{eм}} = \frac{\rho Q_м u_{avм}}{S_м}$,

where ρ - density of air, ω-angular speed of rotation of the turbine, ζ_m coefficient of hydraulic resistance of the channel [2], l_m - length maha d_{em} - the equivalent diameter of the channel S_m - cross-section of the channel, Q_m - volume flow of heated air mass u_{avrm} - wind speed.

Or

$$\frac{\omega^2 l_м^2}{2} = \frac{\zeta_м l_м Q_м^2}{2d_{эм} S_м^2} + \frac{Q_м^2}{S_м^2}. \quad (1)$$

Given that $\omega^2 l_v^2 = V^2$, $\frac{Q_м^2}{S_м^2} = u_{avм}^2 \zeta = 4{,}62 Re_{uм}^{-0.488}$,

where $Re_{um} = \frac{u_{српм} d_{эм}}{\nu} = \frac{4Q_м}{\nu \Phi_м}$,

$$Re_u^2 + 2{,}31 \frac{l_м}{d_{eм}} Re_u^{1.512} - \frac{d_{eм}^2}{2\Phi_м^2} Re_v^2 = 0 \quad (2)$$

decision, which will give the flow rate of the warm air inside the maha through natural ventilation [3]. This hot air flow is distributed in equal amounts on the two halves of the working blades that enables to determine the value in the working Reul blade. Since the air must be ejected from the two holes at the ends of the blades, the air flow in each half of the blade is reduced by half

$$Q_л = \frac{Q_м}{2} \quad (3)$$

correspondingly change values of quantities usrl and ζ_l in the blade.

When constructing method of thermal design necessary to borne in mind that F_{3in}-F_{3ex}=Δ - wall thickness, $T_{w2}=T_{w1}-q\Delta/\lambda_k$, q - the amount of heat transferred through the wall of to the environment as, λ_k - coefficient of thermal conductivity of the wall material.

As a consequence a linear change in temperature of the warm air in the channel temperature of the inner surface of the last T_{w1} lead to the constancy of the difference of $T-T_{win} = \overline{T} - \overline{T}_{win} = k$. Obviously, if a constant wall thickness channel and uniformity of the material (λ_k = const), which is made from the blade surface temperature will differ from T_{wex} T_{win} by a constant $T_{win}-T_{wex}$ = const. Thus, all three function $T(\overline{\overline{z}})$, $T_{win}(\overline{\overline{z}})$, $T_{wex}(\overline{\overline{z}})$ parallel to each other. Equations (1) and (2) determine the total amount of heat given from the channel as a whole. With regard to equation (3), the heat from the outer wall of the blade to the incident flow varies along the channel so as T_{wex} reduced, and T_∞ = const. Therefore, this equation should be written as

$$q_{bex}(\overline{z}) = \alpha_{bex} F_{bex} (T_{wex}(\overline{z}) - T_\infty).$$

To find the total amount of heat given off the outer surface of the blade flow, we must integrate this equation over the length of the blade

$$q_{bex} = \int_0^1 q_{ex}(\overline{z})\, d\overline{z} = \alpha_{bex} F_{bex} \int_0^1 (T_{bex}(\overline{z}) - T_\infty)\, d\overline{z} = \alpha_{bex} F_{bex} (\overline{T}_{wex} - T_\infty), \quad (4)$$

where q_{bex} - the amount of heat given off the outer surface of the blade, T_∞ - ambient temperature, F_{bex} - the surface area of the channel, $\overline{T}_{wex}$ - the average temperature of the outer surface of the channel, T_{bex} - the temperature of the outer surface of the blade, α_{bex} - heat transfer coefficient.

The process of moving blades of the incoming heat from a flood is described by the following system of equations T_{bex}

$$q_b = \rho QAv(T_{0b} - T_{1b})$$
$$q_{bin} = q_{0b} = \alpha_{bin}F_{bin}(\overline{T}_b - \overline{T}_{wb}) = \tau_{bin}Av\frac{F_{bin}}{u_{av}}(\overline{T}_b - \overline{T}_{win}) \quad (5)$$
$$\overline{T}_{wb} = \overline{T}_{wb} - \frac{q_{b0}\Delta}{\lambda_b F_b}$$
$$q_{bex} = \alpha_{bex}F_{bex}(\overline{T}_{wex} - \overline{T}_\infty) = \tau_{bex}Cp\frac{F_{bex}}{u_{av}}(\overline{T}_{wex} - \overline{T}_\infty),$$

where T_{0b} - initial temperature of the gas entering the channel, T_{1b}- the temperature of the exhaust gas duct, τ_{bex} - shear stress, λ_b - thermal conductivity of the wall material, Δ - the thickness of the wall.

Indexes, in - refers to the internal problem, ex - refers to an external task, 0 - inlet temperature in the channel, 1 - temperature at the outlet of the channel, win - the inner wall surface of the channel, wex - outer wall surface of the channel.

The first equation determines the total amount of heat lost by warm air as it moves within the blade from the point of connection with a move to release into the atmosphere.

The second equation describes the amount of heat removed the channel walls.

Third - a temperature difference on the channel wall, averaged over the length of the blade.

Finally, the fourth equation allows you to find the total amount of heat given up the outer surface of the blade environment.

It should be borne in mind that

$$T_{bwex0} = \overline{T}_{bwex} + \frac{T_{bwex0} - T_{bwk1}}{2}.$$

Or

$$T_{bwex0} = 2\overline{T}_{bwex} - T_{bwex1},$$
$$T_{bwex1} = 2\overline{T}_{bwex} - T_{bwex0},$$
$$F_{bex} = F_{bin} - 2\Delta l_b.$$

Accordingly, the average temperature in the blade

$$\overline{T}_b = \frac{T_{0b} + T_{1b}}{2}.$$

Obviously, can also be represented as

$$\overline{T}_b = \frac{T_{0b} - T_{1b}}{2} + T_{1b}, \tag{6}$$

$$T_b = \overline{T}_{0b} - \frac{T_{0b} - T_{1b}}{2}. \tag{7}$$

Let us make the following operation: from equation (5) we have

$$\overline{T}_b - \overline{T}_{wbb} = \frac{q_{0b} u_{av}}{\tau_{лн} Av F_{bex}} = \Delta T_1^b .$$

Adding these two equations, we arrive at the equality

$$\overline{T}_b - T_\infty + \overline{T}_{wbb} - \overline{T}_{wbb} = \overline{T}_b - T_\infty - \frac{q_0 \Delta}{\lambda_b F_b} = \Delta T_1^b + \Delta T_2^b ,$$

or $\overline{T}_л = T_\infty + \frac{q_0 \Delta}{\lambda_л F_л} + \Delta T_1^л + \Delta T_2^л$.

We transform the average temperature of the warm air ($\overline{T}_b$) by (6) and write

$$\overline{T}_{1b} - T_\infty = \frac{q_0 \Delta}{\lambda_b F_b} + + \Delta T_1^b + \Delta T_2^b - + \Delta T_3^b, \tag{8}$$

$$\tau_{bin} = \frac{\zeta}{8} \rho u_{av}^2 .$$

For channel having a shape wing profile NASA - 0021 $\zeta = 4.62 Re^{-0.488}$
Accordingly, for the outer problem

$$\tau_{bex} = 0{,}0296 Re_V^{-0.2} \rho V^2.$$

Using expressions for τ_{bin} and τ_{bex}, we write

$$\Delta T_1^b = \frac{q_{0b}}{\frac{\zeta}{8} \rho u_{av} \frac{\lambda}{\mu} F_{bin}},$$

$$\Delta T_2^b = \frac{q_{0b}}{0.0296 Re_V^{-0.2} \rho V \frac{\lambda}{\mu} F_{bex}},$$

$$\Delta T_3^b = \frac{q_{0b}}{2 \rho Q \frac{\lambda}{\mu}} = \frac{2 q_{0b}}{Re_u \Phi \lambda}.$$

Here is the latest equality to convenient form for computations

$$\Delta T_1^b = \frac{32Sq_{0b}}{4.62Re_u^{0.512}\lambda\Phi^2 l_b},$$

$$\Delta T_2^b = \frac{q_{0b}}{0.0296Re_V^{0.8}\lambda l_b},$$

$$\Delta T_3^b = \frac{2q_{0b}}{Re_u\Phi\lambda}.$$

Put in (8) and get

$$T_{1b} - T_\infty = q_{0b}\left[\frac{6,93S}{Re_u^{0.512}\lambda\Phi^2 l_b} + \frac{33.8}{Re_V^{0.8}\lambda l_b} + \frac{\Delta}{\lambda\Phi_b l_b} - \frac{2}{Re_u\Phi\lambda}\right], \quad (9)$$

where T_{1b} - the temperature at the outlet of the channel, T_∞ - ambient temperature, q_{0b} - the total amount of heat released through the wall of the channel, F - wetted perimeter of the section, Re - Reynolds number.

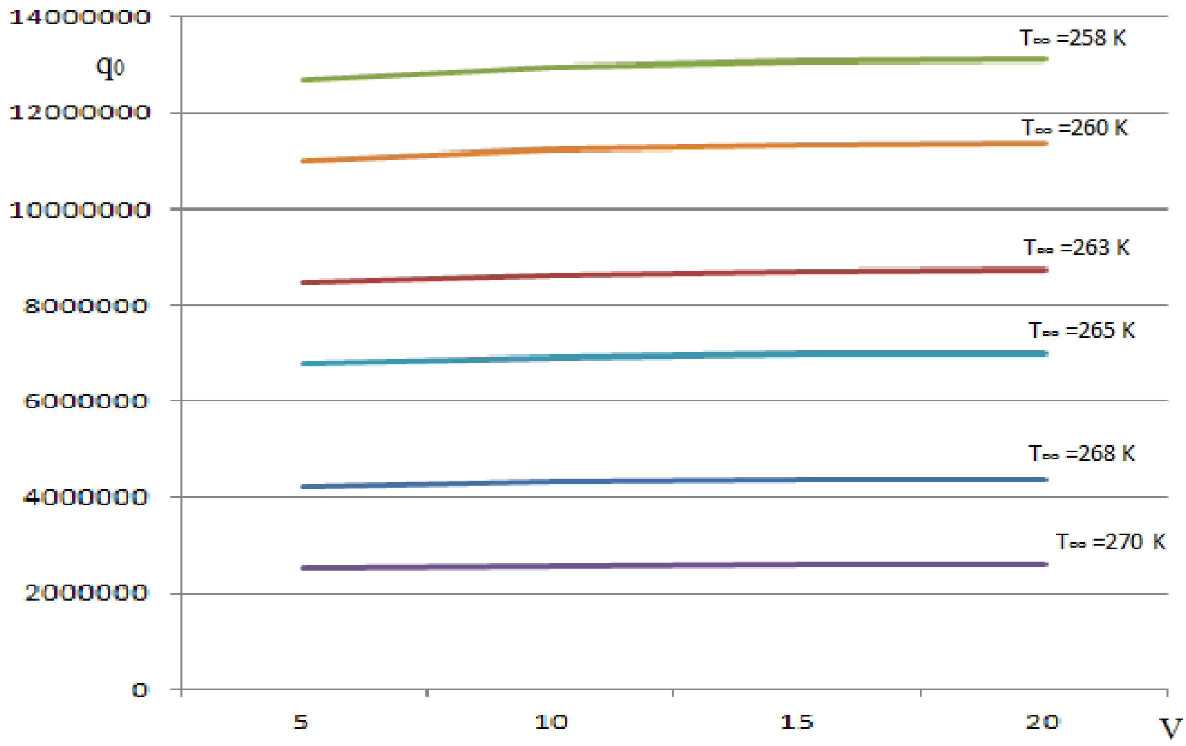

Figure1 Dependence total flow amount of heat released through the wall of the channel on the wind speed

CONCLUSION

The last equation makes it possible to determine the total amount of heat q_{0b}, gave the blade environment with a temperature of T_{∞} as T_{1b} we ask ourselves, all the values in the square brackets can be quantified for a given geometric and dynamic parameters of the problem.

It is easy to see the value in the square brackets is inversely proportional to the Reynolds number and for large values of their rather small, which leads to high values q_{0b}. Therefore, when carrying out calculations necessary to select values Re, or the same amount of pick Q_0.

Using the equation to determine the full posslednee surprising number of heat and got the dependence of flow total amount of heat released by the channel walls of the wind speed.

REFERENCES

Manatbayev R.K., Dauylbaev O., Elubaeva B.T., Sadikova L.A., Tulegenova A.T.Theoretical basis of natural ventilation inside Darrieus. International Journal of Mathematics and Physics V.3, N1, p.59-61.

Ershyna A.K., Manatbayev R.K. Opredeleniya gidravlicheskogo soprotivleniya simmetrichnogo krylovogo profilya NASA – 0021. Vestnik KazNU, seriya matematika, mehanika, informatika, 2006 g. №4 (51), S.56-58.

Ershyna A.K., Ershyn SH. A., Ershyn Ch. Sh., Manatbayev R.K. Sposob teplovoi zashity vetroenergoticheskoi ustanovki karusel’nogo tipa I konstruktivnoe oformlenie (varianty) dlya ego osushchestvleniya. Patent Rossiskoi Federacii. № 2447318, g.Moskva. byul. №10 ot 10.04.2012g.