Ол сонымен қатар электр энергиясының әр түрлі көздерін пайдаланудың салыстырмалы талдауын ұсынады. Қазақстанның энергетикалық секторының егжей -тегжейлі талдауы мен Қазақстанда жаңартылатын энергияны пайдаланудың болашағы қарастырылды.

Түйінді сөздер: жел турбинасы, энергия ресурстары, электр энергиясы, электр энергиясын пайдалану болжамы, жаңартылатын көздер, дәстүрлі көздер

ОЦЕНКА ПЕРСПЕКТИВЫ ИСПОЛЬЗОВАНИЯ ВОЗОБНОВЛЯЕМЫХ ИСТОЧНИКОВ ЭНЕРГИИ В МИРЕ И КАЗАХСТАНЕ

Фазылова Алина Ринатовна, докторант, университет Сатпаева, Алматы, Казахстан, sharf_06@inbox.ru

Аннотация. Мировая энергетика сегодня находится на новом этапе развития, который характеризуется усилением интеграционных процессов, освоением новых

технологии в области добычи и производства энергоресурсов. Энергетический сектор Казахстана создавался с учетом того, что он был частью энергетического сектора Советского Союза. Сегодня Казахстан следует мировым тенденциям развития в сфере энергетики. Чтобы сделать достоверный прогноз развития казахстанской энергетики, необходимо взглянуть на глобальные процессы в развитии мировой энергетики. Есть несколько организаций, у которых есть эта информация. Это Международное энергетическое агентство (МЭА), ООН, Всемирный банк, крупные международные компании и др. При прогнозировании энергопотребления в Казахстане в рамках Евразийского экономического союза (ЕАЭС) важно учитывать прогнозы для стран-членов ЕАЭС. В данной статье представлена основная информация по прогнозированию роста потребления электроэнергии в мире и в Казахстане, основанная на различных источниках. Также дается сравнительный анализ использования различных источников электроэнергии. Рассмотрены подробный анализ энергетического сектора Казахстана и перспективы использования возобновляемых источников энергии в Казахстане.

Ключевые слова: ветряная турбина, энергоресурсы, электроэнергия, прогноз использования электроэнергии, возобновляемые источники, традиционные источники.

The Bulletin of Kazakh Academy of Transport and Communications named after M. Tynyshpayev, ISSN 1609-1817, DOI 10.52167/1609-1817, Vol. 118, No.3 (2021) pp.134-141

УДК 62-9 **DOI 10.52167/1609-1817-2021-118-3-134-141**

A.R. Fazylova
Satbayev University

CALCULATION OF THE PARAMETERS OF THE WIND TURBINE ROTOR EDDY CURRENT SENSOR

Annotation. Eddy current sensors are used to measure shaft clearance in wind turbines and to check that there is a thin film of oil in the clearance. In this case, the oil is usually applied under pressure. Because the eddy current sensors are resistant to oil, pressure and temperature, this allows them to operate reliably in these hostile environments. When the gap becomes too large, a maintenance warning is generated. Eddy current sensors help detect axial and radial deflection of the turbine shaft. Radial movement occurs when the shaft is off-center. Axial movement indicates that the shaft is tilted relative to the central axis. Both cannot be eliminated completely. However, with significant deviations, increased bearing wear occurs. If such situations are detected, the turbine should be shut down as soon as possible for maintenance, even before an accident occurs. Finally, eddy current sensors are used to measure forces or torques applied to the nacelle. These influences can be caused by vibration, wind loads or other factors that, over time, can lead to the destruction of the entire structure. Eddy current sensors can also be used to measure axial, radial or tangential deflection of clutch discs, which ensure the safety of the rotor in the event of strong winds. This article provides a method for calculating an inductive sensor. This calculation will allow you to correctly develop a wind turbine eddy current sensor.

Keywords: Sensor, eddy currents, wind turbine, gap, inductance, reliability.

Sensors are elements of many automation systems, with their help they receive information about the parameters of the monitored system or device. A sensor is an element of a measuring, signaling, regulating or control device that converts a controlled value (temperature, pressure, frequency, luminous intensity, electric voltage, current, etc.) into a signal convenient for measuring, transferring, storing, processing, recording , and sometimes to influence them on the controlled processes [1]. An inductive sensor is a parametric-type converter, the principle of which is based on a change in the inductance L or the mutual inductance of the winding with the core, due to a change in the magnetic resistance RM of the magnetic circuit of the sensor, into which the core enters. Inductive sensors are widely used in the industry for measuring displacements and cover the range from 1 μm to 20 mm [2].

Inductance is an idealized element of an electrical circuit in which the energy of a magnetic field is stored. The storage of the energy of the electric field or the conversion of electrical energy into other types of energy does not occur in it.

The closest thing to an idealized element inductance is a real element of an electrical circuit an inductive coil. In contrast to inductance, an inductive coil also stores the energy of the electric field and converts electrical energy into other types of energy, in particular into heat. Quantitatively, the ability of real and idealized elements of an electric circuit to store the energy of a magnetic field is characterized by a parameter called inductance. Thus, the term "inductance" is used as the name of an idealized element of an electric circuit, as the name of a parameter that quantitatively characterizes the properties of this element, and as the name of the main parameter of an inductive coil.

The principle of operation is based on changes in the amplitude value of oscillations of the generating unit when an object of a certain size enters the active zone of the device. In the process of supplying power to the end switch of the equipment, a changing magnetic field is formed in the area of its sensitive part. It induces eddy currents in the material located in the working area of the sensor, leading to a change in the amplitude of electromagnetic oscillations.

As a result, an output signal will begin to be generated, which in the process may vary depending on the actual distance between the device and the object under control.

This article discusses a method for calculating an inductive sensor. The principle of operation of such a sensor is based on a change in the oscillation amplitude of the generator when a metal, magnetic, ferromagnetic or amorphous material of a certain size is introduced into the active zone of the sensor. The main performance characteristics of inductive position sensors are: response range, degree of protection, operating temperature and response frequency [3].

A single inductive sensor was taken (figure 1), the operation of which is based on the property of a choke with an air gap to change its inductance when the value of the air gap changes. The inductive sensor consists of a yoke 1, a winding 2, an armature 3 - held by springs. An alternating current supply voltage is supplied to winding 2 through the load resistance Rн. The current in the load circuit is defined as [4]:

$$I = \frac{U}{\sqrt{(R_н + r_d)^2 + (\omega L)^2}} \quad (1)$$

where r_d is the active resistance of the choke;

L is the inductance of the sensor.

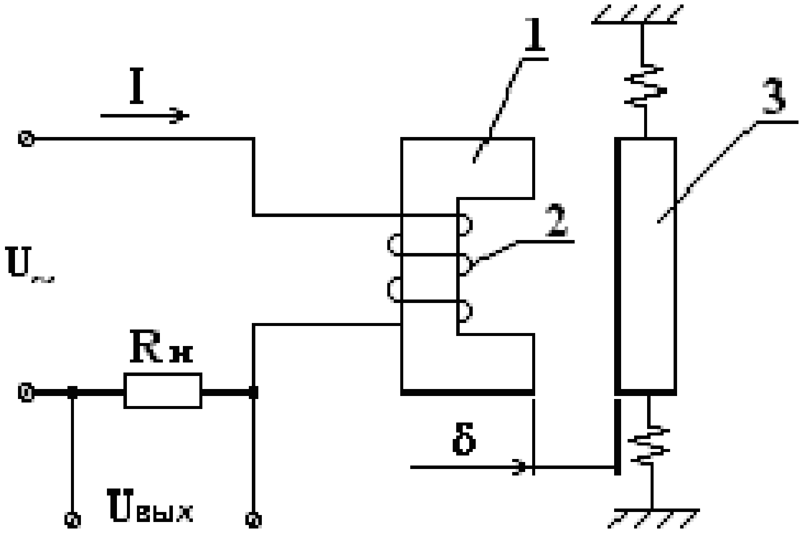


Figure 1 - Schematic of an inductive sensor

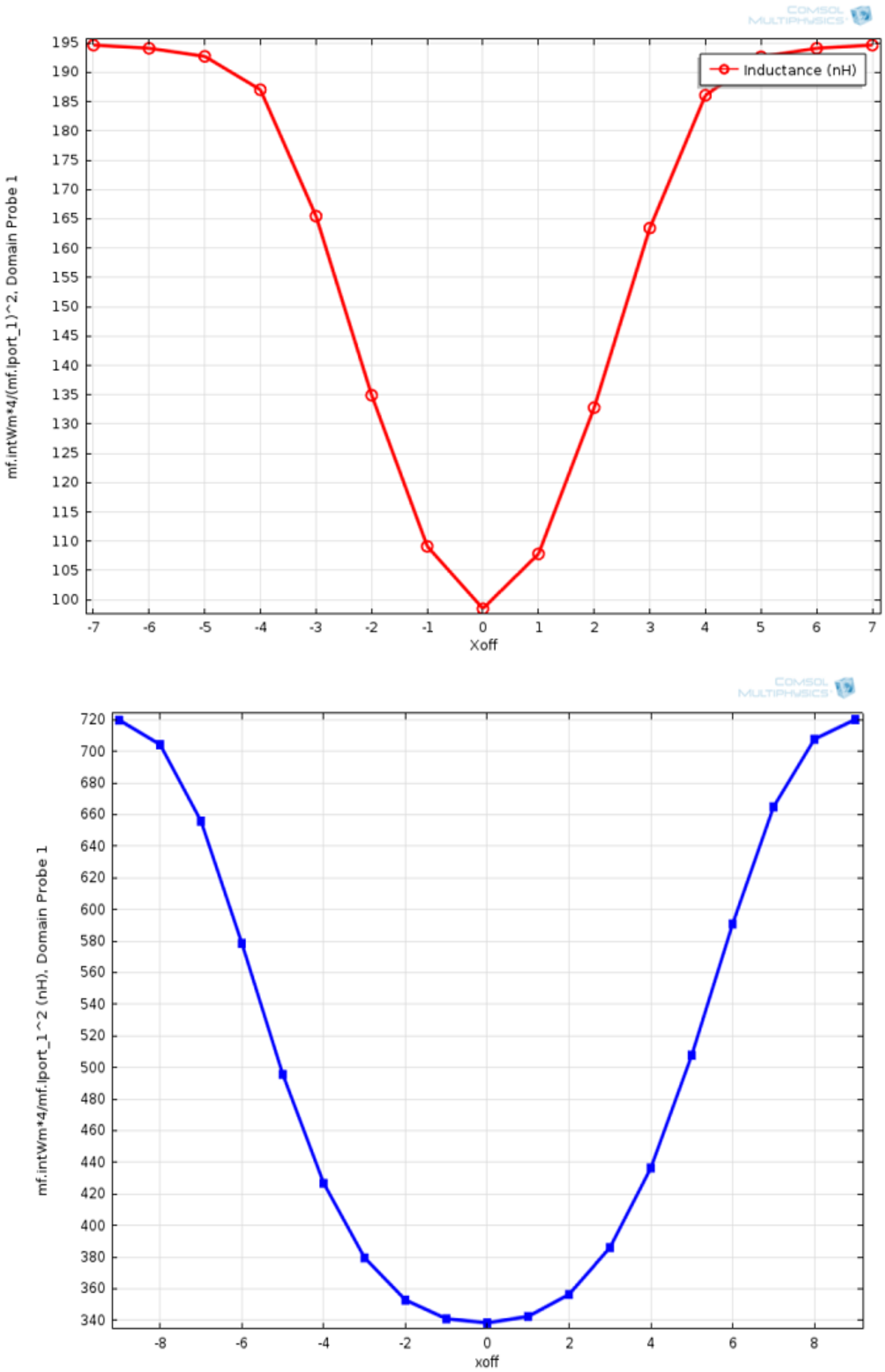
Because the active resistance of the circuit is constant, the change in current I can only occur due to a change in the inductive component XL = $IR_н$, which depends on the size of the air gap δ. Each value of δ corresponds to a certain value of I, which creates a voltage drop across the resistance $R_н$: $U_{out} = IR_н$ - is the output signal of the sensor. It is possible to derive the analytical dependence U_{out} = f (δ), provided that the gap is sufficiently small and the scattering fluxes can be neglected, and the magnetic resistance of iron R can be neglected in comparison with the magnetic resistance of the air gap R_m [4]

In order to analyze the operation of the inductive position sensor, the finite element analysis (FEA) software package of the COMSOL Multiphysics environment was used to create a frequency-dependent model of a planar inductor. In order to analyze the performance of the inductive sensor, the FEA software package of COMSOL Multiphysics was used to create a frequency-dependent model of a planar inductor. circuit board - PCB). Planar coils can be of different geometric shapes: square, rectangle or circle.The model also includes a sensor activator (in this case, in the form of a diamond), which is made from a thin copper plate and is located at a height of 0.2 to 0.3 millimeters above the plane of the coil. It can move, or slide, horizontally along the surface of the planar coils. It should be noted that although the activator is free to move horizontally, the vertical distance is fixed. When a copper activator approaches a planar coil, eddy currents generated in it reduce the inductance of this coil. In general, an inductive sensor can be thought of as a lossy transformer, or with loosely coupled primary and secondary windings, and an air gap.

The simulation helps to visualize the real functionality of the eddy current sensor by determining the change in inductance of the planar coils in relation to the movement of the copper activator over their surface. In the sensor, the change in the horizontal Xoff coordinate correlates with the physical change in the position of the copper activator relative to the coils. Usually, the Xoff position of the activator serves as a signal to suspend or completely stop the transmission (if we are talking about a wind turbine gearbox), but in this simulation this means only the maximum

 ISSN 1609-1817
DOI 10.52167/1609-1817

reduction in the inductance of the planar coil. In these graphs, Xoff = 0 represents the center of the planar coil. At this point, the inductance should be at its lowest value, because at the Xoff position, the maximum suppression of inductance occurs. Figure 2 illustrates how sliding a copper activator with a fixed vertical gap causes inductance changes at 10 MHz.



Top: Change in coil inductance (nH) versus horizontal position Xoff (mm) of a copper activator for a single-layer planar coil. Bottom: Change in coil inductance (nH) versus horizontal position Xoff (mm) of a copper activator for a two-layer planar coil.

Figure 2 – Change in coil inductance

In accordance with Figure 2, a sensor was selected, the initial data of which are presented in Table 1.

Table 1 - Initial data

$\delta_{в1}$, mm	$\delta_{в2}$, mm	$\delta_{в3}$, mm	S_m, mm^2	n
0,3	0,5	0,7	60	15500

The inductance of the sensor is calculated using formula 1.

$$L = 2/\delta_в * \pi * n^2 * S_m * 10^7 \qquad (2)$$

From formula 1 it follows that

$L_1 = (2/0{,}0003)*3{,}14*15500^2*0{,}06*10^7 = 30{,}2*10^{17}$ Гн

$L_2 = (2/0{,}0005)*3{,}14*15500^2*0{,}06*10^7 = 18{,}1*10^{17}$ Гн

$L_3 = (2/0{,}0007)*3{,}14*15500^2*0{,}06*10^7 = 12{,}9*10^{17}$ Гн

According to the calculation results, table 2 is filled.

Table 2 - Calculation results

L_1, 10^{17} Gn	L2, 10^{17}Gn	L3, 10^{17} Gn
30,2	18,1	12,9

Graph L = f (δв). This graph is shown in Figure 3.

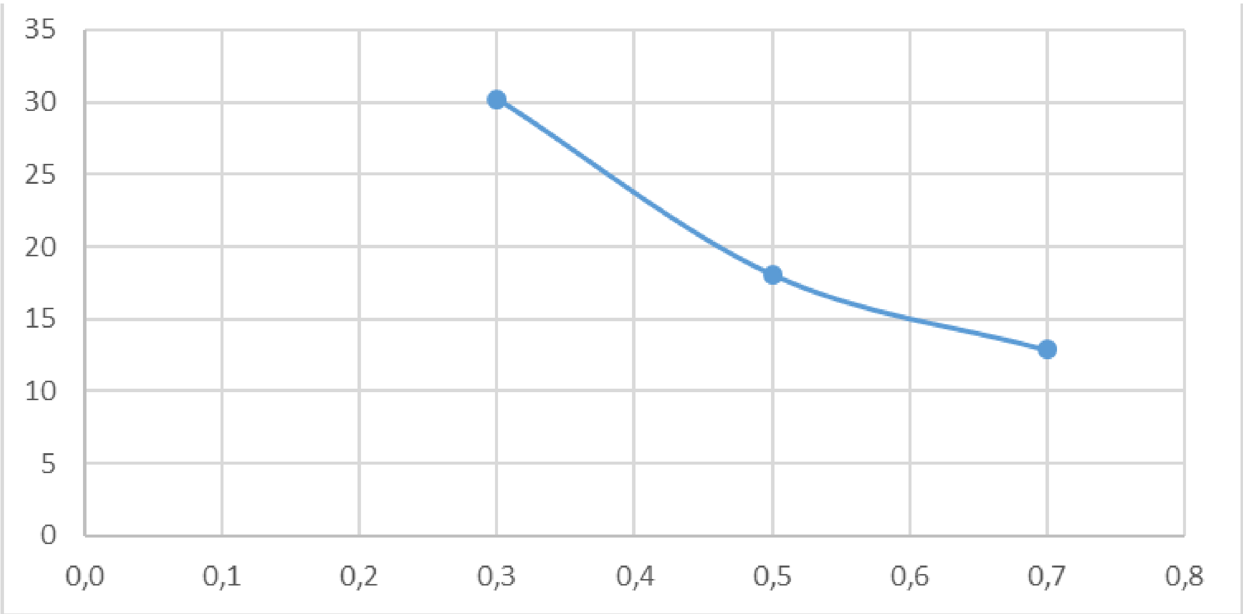


Figure 3 - Graph of the dependence of the inductive sensor on the air gap

According to the initial data presented in Table 3, it is necessary to find the angular frequency, sensor inductance, number of turns, wire diameter.

Table 3 - Initial data

Sm, mm^2	$\delta_в$, mm	I, mA	Δ, A/mm	U, V	f, Hz
400	3	20	3,5	220	400

The angular frequency of the alternating current is determined by formula 3.

$$w = 2*\pi*f \quad (3)$$

The inductance of the sensor is determined by the formula 4.

$$L = U\sim /(I\sim w) \quad (4)$$

The number of turns is determined by the formula 5.

$$n = \sqrt{}(L*\delta_в*10^7)/(2*\pi*S_m) \quad (5)$$

The wire diameter is determined by formula 6.

$$d = \sqrt{}4*I\sim/(\pi*\Delta) \quad (6)$$

Based on the above formulas, a calculation was made.

w = 2*3,14*400 = 2512 (1/s).
L = 220/(0,02*2512) = 4,4 Gn.
n = √(4,4*0,003*10^7)/(2*3,14*0,4) = 230.
d = √4*0,02/(3,14*3,5) = 0,007 mm.

The calculation results are presented in Table 4.

Table 4 - Calculation results

w, 1/sec	L, Gn	n	d, mm
2512	4,4	230	0,007

Thus, in accordance with the calculations, the optimal use of the sensor in a wind generator is the TL-W5MC1 end inductive sensor (Figure 4)

Figure 4 – Limit inductive sensor TL-W5MC1

Conclusion.

This article describes the principle of operation, the main characteristics of the inductive sensor. The parameter was calculated - inductance, inductive sensor. Based on the calculation results, a graph of the sensor inductance versus air gap was plotted. Also, according to the initial data, the parameters of the inductive sensor were calculated, such as inductance, number of turns, wire diameter, angular frequency of alternating current. According to the results of the study, it can be concluded that for measuring eddy currents, the selected sensor with the initial parameters is suitable for its use in a wind generator. When a metal object, in this case, a gear tooth, approaches the device, the magnetic field generated by the built-in permanent magnet increases, which leads to the induction of an alternating voltage in the coil.

REFERENCES

[1] Kelim Yu. M. Typical elements of the automatic control system. Textbook for students of institutions of secondary vocational education. - M .: FORUM: INFA-M, 2002. - 384 p .: ill. - (Series "Professional Education").

[2] V. V. Litvinenko, A. P. Maystruk. Automotive sensors, relays and switches. Quick reference. - Moscow: ZAO KZhI "Za rulem", 2004. - 176 p .: ill .: tab.

[3] Sosnin DA Autotronics. Electrical equipment and on-board automation systems for modern passenger cars: Textbook. M .: SOLON-R, 2001, 272 p.

[4] Turichin A.M., Electrical measurements of non-electrical quantities, 4th ed., Moscow - Leningrad, 1966.

CALCULATION OF THE PARAMETERS OF THE WIND TURBINE ROTOR EDDY CURRENT SENSOR

Fazylova Alina Rinatovna, doctoral student, Satbayev University, Almaty, Kazakhstan, sharf_06@inbox.ru

ЖЕЛДІК ТУРБИНА РОТОРЫНЫҢ ҚҰЙЫНДЫ ТОҚТАРЫНЫҢ ПАРАМЕТРЛЕРІН ЕСЕПТЕУ

Фазылова Алина Ринатовна, докторант, Сәтбаев университеті, Алматы, Қазақстан, sharf_06@inbox.ru

Аннотация. Құйынды ток датчиктері жел қондырғыларының білік саңылауын өлшеу үшін қолданылады және саңылауда жұқа майлы қабық бар -жоғын тексереді. Бұл жағдайда май әдетте қысыммен қолданылады. Құйынды ток сенсорлары майға, қысымға және температураға төзімді болғандықтан, бұл олардың коррозиялық ортада сенімді жұмыс істеуіне мүмкіндік береді. Саңылау тым үлкен болған кезде техникалық қызмет көрсету туралы ескерту беріледі. Тұрақты ток сенсорлары турбина білігінің осьтік және радиалды ауытқуын анықтауға көмектеседі. Радиалды қозғалыс білік орталықтан тыс болған кезде пайда болады. Осьтік қозғалыс біліктің орталық оське қисайғанын білдіреді. Екеуін де толық жою мүмкін емес. Алайда, елеулі ауытқулар кезінде мойынтіректердің тозуы пайда болады. Егер мұндай жағдайлар анықталса, турбинаны жөндеу үшін мүмкіндігінше тезірек, тіпті апат орын алғанға дейін де өшіру керек. Ақырында, құйынды ток сенсорлары насельге қолданылатын күштерді немесе моменттерді өлшеу үшін қолданылады. Бұл әсерлер діріл, жел жүктемесі немесе басқа факторлардың әсерінен болуы мүмкін, олар уақыт өте келе бүкіл құрылымның бұзылуына әкелуі мүмкін. Сондай - ақ, құйынды ток сенсорлары ілініс дискілерінің осьтік, радиалды немесе тангенциалды ауытқуын өлшеу үшін қолданылуы мүмкін, бұл қатты жел кезінде ротордың қауіпсіздігін қамтамасыз етеді. Бұл мақалада индуктивті сенсорды есептеу әдісі берілген. Бұл есептеу жел турбинасының құйынды ток датчигін дұрыс құруға мүмкіндік береді.

Негізгі сөздер: сенсор, құйынды токтар, жел турбинасы, саңылау, индуктивтілік, сенімділік.

РАСЧЕТ ПАРАМЕТРОВ ДАТЧИКА ВИХРЕВОГО ТОКА РОТОРА ВЕТРОВОЙ ТУРБИНЫ

Фазылова Алина Ринатовна, докторант, университет Сатпаева, Алматы, Казахстан, sharf_06@inbox.ru

Аннотация. Вихретоковые датчики используются для измерения зазора вала ветряных турбин и проверки наличия тонкой масляной пленки в зазоре. В этом случае масло обычно наносится под давлением. Поскольку вихретоковые датчики устойчивы к маслу, давлению и температуре, это позволяет им надежно работать в этих агрессивных средах. Когда зазор становится слишком большим, выдается предупреждение о техническом обслуживании. Датчики вихревых токов помогают обнаруживать осевое и радиальное отклонение вала турбины. Радиальное движение происходит, когда вал смещен по центру. Осевое перемещение означает, что вал наклонен относительно центральной оси. Оба не могут быть устранены полностью. Однако при значительных отклонениях происходит повышенный износ подшипников. Если такие ситуации обнаруживаются, турбину следует как можно скорее остановить для обслуживания, даже до того, как произойдет авария. Наконец, датчики вихревых токов используются для измерения сил или крутящих моментов, приложенных к гондоле. Эти воздействия могут быть вызваны вибрацией, ветровыми нагрузками или другими факторами, которые со временем могут привести к разрушению всей конструкции. Вихретоковые датчики также могут использоваться для измерения осевого, радиального или тангенциального прогиба дисков сцепления, что обеспечивает безопасность ротора в случае сильного ветра. В этой статье представлен метод расчета индуктивного датчика. Этот расчет позволит правильно разработать датчик вихревых токов ветряной турбины.

Ключевые слова: датчик, вихревые токи, ветряк, зазор, индуктивность, надежность.

The Bulletin of Kazakh Academy of Transport and Communications named after M. Tynyshpayev, ISSN 1609-1817, DOI 10.52167/1609-1817, Vol. 118, No.3 (2021) pp.141 - 149

УДК 681.2-5 **DOI 10.52167/1609-1817-2021-118-3-141-149**

A.R. Fazylova
Satbayev University

CALCULATION OF THE PARAMETERS OF THE WIND TURBINE ROTOR TEMPERATURE SENSOR

Annotation. Today, all the processes associated with technology, mainly operate in autonomous modes, so devices such as a temperature sensor are a must. Since technical progress is taking place in industry and production by leaps and bounds, all equipment most often used in various kinds of processes and work has an automatic principle of operation [1].