CONDITION ANALYSIS OF BELT CONVEYORS ROLLER BEARINGS AND DRUMS ON THE BASIS OF MATHEMATICAL MODEL OF STARTING MODES

Kondratenko M. N.

Diagnostics method of the rollers and drums state is proposed in order to detect and replace worn roller bearings to reduce the repair and maintenance costs. It is based on the research of power costs and dynamic processes, which appear when rollers and drums are found to be defective. Evaluation of the conveyor dynamic characteristics is carried out by modeling of dependencies connecting the speed, the way of the belt traveling on the head and auxiliary drums and rollers. It connects the dynamic force in the tape with the size and nature of the change of the driving force, which is developed by the electric drive during the diagnostics and benchmarking. Diagnostics by the proposed method is made in the period of time when the rollers of the load branch of the conveyor are alternately involved in rotation. At the starting moment of the rotation the complete picture of the state of the rotating load branch elements will be obtained by the tail drum belt, and the possibility of diagnostics by this method will stop.

Метод диагностики состояния роликов и барабанов предложен для своевременного обнаружения и замены изношенных роликоопор, а также с целью уменьшения затрат на ремонты и межремонтное обслуживание конвейеров. Он основан на исследовании затрат электроэнергии на динамические процессы, возникающие при неисправности роликов или барабанов. Оценка динамических характеристик конвейера производится путем моделирования зависимостей, связывающих скорости, путь перемещения ленты на головных и вспомогательных барабанах, роликах, динамическое усилие в ленте с величиной и характером изменения движущего усилия, развиваемого электроприводом во время диагностики и при эталонных испытаниях. Диагностика по предложенному методу производится в период времени, когда поочередно вовлекаются во вращение ролики грузовой ветви конвейера. В момент начала вращения лентой хвостового барабана будет получена полная информационная картина состояния вращающихся элементов грузовой ветви, а возможность диагностики по данному методу прекратится.

Метод діагностики стану роликів і барабанів запропонований для своєчасного виявлення і заміни зношених роликоопор, а також з метою зменшення витрат на ремонти та міжремонтне обслуговування конвеєрів. Він ґрунтований на дослідженні витрат електроенергії на динамічні процеси, що виникають при несправності роликів або барабанів. Оцінка динамічних характеристик конвеєра виконується шляхом моделювання залежностей, що зв'язують швидкості, шлях переміщення стрічки на головних і допоміжних барабанах, роликах, динамічне зусилля в стрічці з величиною і характером зміни рушійного зусилля, що розвивається електроприводом під час діагностики і при еталонних випробуваннях. Діагностика по запропонованому методу виконується в період часу, коли по черзі залучаються до обертання ролики вантажної гілки конвеєра. У момент початку обертання стрічкою хвостового барабана буде отримана повна інформаційна картина стану елементів вантажної гілки, що обертаються, а можливість діагностики за цим методом припиниться.

Кондратенко М. Н. ассист. ГВУЗ «КНУ»
miriama@online.ua

ГВУЗ «КНУ» – Государственное высшее учебное заведение Криворожский национальный университет, г. Кривой Рог.

UDC 622.647.2: 681.518.54

Kondratenko M. N.

CONDITION ANALYSIS OF BELT CONVEYORS ROLLER-CARRIAGES AND DRUMS ON MATHEMATICAL MODEL OF OPERATION STARTING MODES BASIS

It is known that the cost of repair and machinery TBO on average per year ranges from 10…15 to 25% of the equipment cost [1]. For the machines operating in the most severe conditions such as in mining, coal and construction industries, the cost only on the heavy overhaul reach up to 50% of their value.

For the timely detection and replacement of worn rollers their constant diagnostics is required [2, 3].

At belt conveyors operation it is possible to perform the express analysis of the rollers and drums state on the basis of analysis of dynamic loads encountered in the electric drive at starting mode, and estimates of energy consumption for this process [4, 5].

Therefore, using the known methods of conveyor starting modeling [6–8], by some changing of basic assumptions and approaches, we can create a model for the starting processes considering the masses of rollers and their state (rotated or fixed).

The electric drive of belt conveyors of big length and performance is mainly carried out on the basis of asynchronous motors with slip-ring motors, the start of which is carried out using the stepwise introduction of additional resistances into the rotor circuit. In recent years, the electric drives with the devices, performing a smooth start with a quasi-permanent moment became widespread.

The evaluation of the dynamic characteristics of the conveyor can be achieved by modeling of the dependencies connecting the velocity, the path of belt traveling on the head and auxiliary drums, rollers, the dynamic force in the belt with the size and nature of the change of the driving force developed by the electric drive during the diagnostics and reference tests.

To account the concentrated masses of drive drums and the belts and rollers masses distributed along the length of the conveyor let's use the method of piecewise linear approximation and assumption used in the work [9].

The block diagram on the example of multiple drum belt conveyor is shown in Fig. 1.

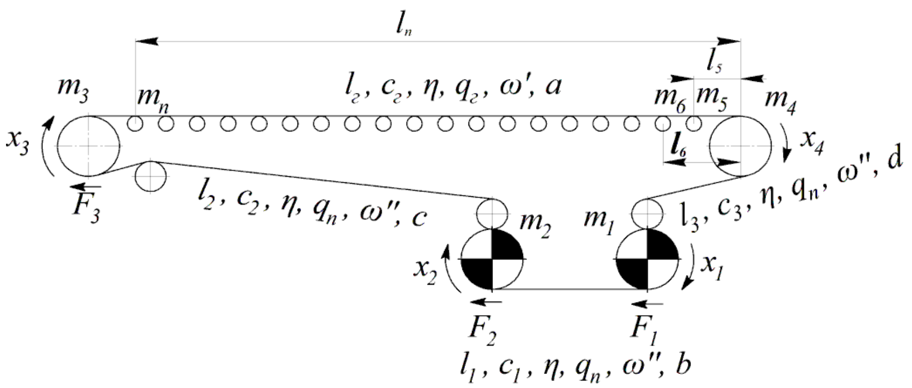

Fig. 1. Design scheme of a multiple drum belt conveyor

Here m_1, m_2, m_3, m_4, m_5, … , m_n – are the masses of the rotating parts of the drive, head and tail drums reduced to the circumference of the drive drums (considering couplings, gears and electric motors), kg; F_1, F_2 – are the driving forces developed by the drive electric motors on the respective driving drums, N; x_1, x_2, x_3, x_4 – are the belt traveling on respective drums, m; $l_г$, l_1, l_2, l_3, l_5, … , l_n – are the lengths of the respective portions of the belt between the drums and the rollers, m; ω', ω'' – are the coefficients of resistance to the belt movement on the upper and lower conveyor branches; c_1, c_2, c_3, $c_г$ – are the stiffness coefficients of corresponding portions of the belt,

$c_i = E_O / l_i$, N/m; E_0 – the dynamic stiffness of the belt, N, $E_O = z_T \cdot F_T \cdot E$; where z_T – is the number of ropes in the belt; F_T – the total cross sectional area of the rope wires, mm^2; E – is the elastic modulus per unit of wires cross section; η – is the damping coefficient of oscillations in the conveyor belt, kg/s; $q_г$, $q_п$ – are the distributed linear loads of the upper (cargo) and lower (weight empty) branches of the conveyor, kg/m; a, b, c, d – are the conditionally adopted structural coefficients of the conveyor, kg.

The distributed linear loads of the upper and lower belt branches are determined by the formulas:

$$q_г = q_л + q'_p; \quad q_п = q_л + q''_p, \tag{1}$$

where $q_л$, q'_p, q''_p – are the distributed linear loads from the belt respectively, belt idler rotating parts of the upper (cargo) and lower (weight empty) branches of the conveyor, kg/m.

$$q'_p = \frac{m'_p}{h'_p}; \; q''_p = \frac{m''_p}{h''_p}, \tag{2}$$

where m'_p, m''_p, – is the mass of the belt idler rotating parts of the upper and lower branches of the conveyor respectively, kg;

h'_p, h''_p, – is the step of belt idler of the upper and lower branches of the conveyor respectively, m.

Diagnostics by the proposed method is possible only in the time interval when the 1st, 2nd and 4th drums began to rotate, and the third (tail) drum is not rotating yet. Part of the belt, which slacks from the 2nd drum "is selected" by belt tensioner. Part of the belt, which slacks from the 4th drum is just starts to move gradually involving in it the load branch entering on this drum.

Thus, the first roller №5, then №6 etc. №n are involved in the rotation movement, until the moving part of load branch of the tape starts to rotate the third (trailing) drum.

In this case the complete picture of the state of the rotating load branch elements will be obtained and possibility of diagnostics by this method will stop.

Let's form the differential equations of the conveyor motion in the operator form considering the accepted assumptions. They link the belt traveling x_1, x_2, x_4 on the respective driving drums with driving forces F_1, F_2, which are created by the drive electromotors on the respective driving drums:

$$a_{11}(p) \cdot x_1(p) + a_{12}(p) \cdot x_2(p) + a_{14}(p) \cdot x_4(p) = F_1 - a_{1F}; \tag{3}$$

$$a_{21}(p) \cdot x_1(p) + a_{22}(p) \cdot x_2(p) + a_{24}(p) \cdot x_4(p) = F_2; \tag{4}$$

$$a_{31}(p) \cdot x_1(p) + a_{32}(p) \cdot x_2(p) + a_{34}(p) \cdot x_4(p) = -a_{3F}; \tag{5}$$

$$a_{41}(p) \cdot x_1(p) + a_{42}(p) \cdot x_2(p) + a_{44}(p) \cdot x_4(p) = -a_{4F}, \tag{6}$$

where

$$a_{11} = A_1 p^2 + 4\eta p + (c_1 + c_3);$$

$$a_{22} = A_2 p^2 + 4\eta p + (c_1 + c_2);$$

$$a_{44} = A_4 p^2 + 4\eta p + (c_3 + c_г);$$

$$a_{12} = a_{21} = bp^2 - 2\eta p - c_1;$$

$$a_{14} = a_{41} = dp^2 - 2\eta p - c_3;$$

$$a_{23} = a_{32} = cp^2 - 2\eta p - c_2;$$

$$a_{34} = a_{43} = ap^2 - 2\eta p - c_г;$$

$$a_{24} = a_{31} = a_{42} = a.$$

$$\begin{cases} a_{1F} = 0{,}5 \cdot q_п \cdot l_3 \cdot g \cdot \omega''; \\ a_{3F} = 0{,}5 \cdot q_г \cdot l_5 \cdot \omega' \cdot g; \\ a_{4F} = 0{,}5 \cdot (q_г \cdot l_5 \cdot \omega' + q_п \cdot l_3 \cdot \omega'') \cdot g. \end{cases} \tag{7}$$

where g – is the gravitational acceleration, m/s^2;

i. e. the coefficient matrix

a_{11}	a_{12}	a_{14}
a_{21}	a_{22}	a_{24}
a_{31}	a_{32}	a_{34}
a_{41}	a_{42}	a_{44}

becomes a matrix

$A_1 p^2 + 4\eta p + (c_1 + c_3)$	$bp^2 - 2\eta p - c_1$	$dp^2 - 2\eta p - c_3$
$bp^2 - 2\eta p - c_1$	$A_2 p^2 + 4\eta p + (c_1 + c_2)$	a
a	$cp^2 - 2\eta p - c_2$	$ap^2 - 2\eta p - c_г$
$dp^2 - 2\eta p - c_3$	a	$A_4 p^2 + 4\eta p + (c_3 + c_г)$

.

By measuring the current of I_d in the frequency converter DC link and knowing that it is proportional to the driving force the resistance to the belt movement of ω' can be certain by its value. Depending on the increase of the current the state of roller can be determined by solving a system of equations (3–7) relative to ω' and F. The number of roller (i.e. the distance l_i) can be calculated using distometer.

To develop a methodology for state analysis of the drums and rollers of load branch, which is most susceptible to deformation, it is necessary to reduce the 1st, 2nd and 4th drums to a single and to consider each after each the interaction of this reduced drum and each roller of load branch. Further studies will be conducted on this model by using any research package, for example, Matlab.

In addition to the above requirements for the drive during the tests, the optimal combination of system parameters control laws formation is necessary: the flux linkage and speed [10] in order to reduce the losses in asynchronous motor and for more accurate diagnostics of rollers and drums.

CONCLUSIONS

To test the results reproducibility the curves obtained by mathematical modeling should be compared with real curves of change of the conveyor belt motion parameters, obtained experimentally. The divergence of results may be explained by the following factors:

– inhomogeneity of the conveyor belt,

– method's error of piecewise linear approximation of transfer functions of higher order by transfer functions of the second order.

REFERENCES

1.Shenderov A.I. The reliability and performance of complex mining equipment / A.I. Shenderov, O.A. Emelyanov, I.M. Odin. – M.: Nedra, 1976. – 247 p.

2.Kondratenko M.N. Evaluation of the technical state of the traction rollers of belt conveyors / M.N. Kondratenko // Collected scientific works of the National Mining Academy of Ukraine. – 2001. –№11. – V 2. – P. 99–102.

3.Nazarenko V.M. Overview of diagnostics rolykoopor belt conveyors / V.M. Nazarenko, M.N. Kondratenko // Bulletin of Kryvyi Rih Technical University. Collected Works. – 2004. – №4. – P. 77–79.

4.Kondratenko M.N. Review of the systems of diagnostics of conveyor rollers / M.N. Kondratenko // Development of ore deposits. – Kryvyi Rih, 2003. – No 83. – P.143–149.

5.Kondratenko M.N. Automated control of conveyor rollers / M.N. Kondratenko, A.I. Savitskyi // Bulletin of Kryvyi Rih Technical University. Collected Works. Kryvyi Rih. 2006. –№15. – P.147–150.

6.Sokotnyuk Yu.A. The automatic control system sloping conveyor belt: the Dissertation of the candidate of technical sciences: 05.13.07/DGI – Dnepropetrovsk, 1987. – 16 p.

7.Zapenin I.V. Transient Simulation of belt conveyors / I.V. Zapenin, V.E. Belfer, Yu.A. Selishchev. – M.: Nedra, 1969. – 56 p.

8.Nazarenko V.M. Modes of operation of automated conveyor belts preparatory ore production: the Dissertation of the doctor of technical sciences: 05.13.07, 05.05.06 / IGTM. – Dnepropetrovsk, 1990. – 455 p.

9.Nazarenko V.M. The transfer functions of the conveyor belt as the object of regulation / V.M. Nazarenko, Yu.A. Sokotnyuk // Proceedings of the universities. Electromechanics – 1986. – №1. – P. 110–114.

10.Economic evaluation of efficiency of investments into energy-saving controlled electric drives of conveyers of mining and processing works / Krutov, G., Savitskyi, A.I. // Metallurgical and Mining Industry. – 2014. – No.6. – P. 78–81.

Статья поступила в редакцию 20.04.2017 г.