IRSTI 73.41.19

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Methodology of justification and calculation of rational and constructive parameters of a tube belt conveyor

Abstract. The article considers the methodology of justification and calculation of rational and constructive parameters of a tube belt conveyor (TBC), which allows to transport bulk cargo safely.
At the same time, there was noted the need for a harmless impact on the environment, especially when transporting routes with vertical and horizontal bends over long distances.
The considered TBC design, unlike the existing ones, is formed with a closed belt tray due to support devices placed along the perimeter of the bulk cargo transportation line.
It is revealed that the main advantages of conveyor transport are a high level of labor productivity achieved by automating the operation of equipment and low production costs. And the problems inherent in them are the need for crushing the transported cargo, precise alignment of transition sections, coordination of drives and synchronization of movements, easily adjustable during operation, subject to certain initial design conditions.
Keywords: bulk cargo transportation, conveyor belt, tube belt conveyor, roller supports, design parameters.

DOI: doi.org/10.32523/2616-7263-2022-140-3-134-140

Introduction

Currently, at some foreign processing plants and chemical plants, there is carried out the movement of materials of environmentally harmful goods mainly by transporting tube belt conveyors (hereinafter TBC). The tube belt conveyor has advantages over the belt conveyor of the traditional design. It is environmentally safer due to the tightness of the belt closed in the pipe throughout the entire route of cargo transportation, prevents dust from entering the environment without the construction of complex shelters, protecting the transported cargo from the effects of various natural factors such as precipitation and wind; there are excluded spills of the transported cargo, and therefore, there are reduced operating costs associated with cleaning spills. From the station on various sections of the route, it is possible to create a spatial route with vertical and horizontal bends. Thus, there are eliminated additional transshipment points that reduce the reliability of conveyor lines; the contact of the sides of the belt with the supporting metal structure is eliminated and the service life of the belt increases; due to less sagging of the belt between the roller supports, dynamic effects on the transported cargo are reduced and its grinding is reduced. TBC allows you to implement the shortest transportation routes that do not depend much on the terrain, and also provides the possibility of simultaneous transportation of goods on the upper and lower branches (Figure 1).

Figure 1. Tube belt conveyors

Determination of the main components of the total force of resistance to movement for various design and design parameters of the TBC and justification of the method of calculating the distributed forces of resistance to movement on the cargo and empty branches.

To achieve this goal, it is necessary to establish the values of the main components of the total resistance force to the movement of the belt, namely, the resistance force to movement from deformation of the load and the belt, from rotation and pressing of the rollers into the belt of the tubular conveyor.

The article considers the components of the total resistance force to the movement of the TBC belt on single roller support.

The calculation of the TBC proposed by us is carried out by the contour bypass method as for traditional conveyors. Due to changes in the structures of the staves, the distributed forces of resistance to movement arising on the cargo and empty branches of the linear part of the TBC differ significantly from similar forces arising on traditional belt conveyors, where the belt rests on grooved roller supports.

The traction calculation is based on the contour bypass method as for classical conveyors, but taking into account the forces of resistance to movement from the rotation of the rollers by the belt, their forces of resistance to movement from the pressing of the rollers into the lower lining, the forces of resistance to movement from the deformation of the load and the belt between the rollers. The belt with the load is deformed when moving inside the annular roller supports, which leads to the appearance of a force of resistance to movement and vice versa. Analytically, it is extremely difficult to solve the problem of deformation of a tube-shaped belt with sides connected by an overlap and loaded with an uneven load along and across. There is also a second task to determine the force of resistance to movement from the indentation of the supporting rollers into the lower lining of the tube-shaped belt and vice versa, because this is due to finding the contact line of the tube-shaped belt. The force of resistance to the movement of the belt:

$$W_x = (a + bv) \cdot \acute{v}(0) + c_p \cdot P + c_f \cdot F_0, \text{ N} \quad (1)$$

where P and F – radial and axial loads, N;

c_p, c_f – radial and axial load coefficients, $c_p = 16 \cdot 10^{-5}$, $c_f = 1,5 \cdot 10^{-5}$ (c_f the minimum value is not taken into account in further calculations);

$\acute{v}(0)$ – ambient temperature coefficient when rotating the rollers;

a, b – coefficients that consider the design of the sealing unit and the amount of lubrication [1].

For the 204 bearing: $a = 0,6 - 1,1$ N; $b = 0,2 - 0,8$ Ns/m. For the 205 bearing: $a = 0,6 - 10,7$ N; $b = 0,2$ Ns/m; For the 305 bearing: $a = 0,7 - 0,8$ N; $b = 0,2$ Ns/m.

The TBC support roller support consists of six rollers forming a ring. The roller bearing is affected by loads from the pressure of the transported soil, the weight of the rotating parts of the rollers, the weight of the belt and its bending on the roller support. The pressure from the load across the cross section is distributed as follows:

$$p'(\varphi, \alpha) = R \cdot \rho \cdot g \int C(\alpha) d\alpha, \text{ Pa} \quad (2)$$

Where function $C(\alpha) = (\cos 2\varphi + cos\alpha) \cdot (cos^2\alpha + \frac{sin^2\alpha}{m})$ – for passive pressure;

$C(\alpha) = (\cos 2\varphi + cos\alpha) \cdot (cos^2\alpha + m \cdot sin^2\alpha)$ – for active pressure;

φ – the angle characterizing the degree of filling of the cross section of the belt;

m – load mobility coefficient;

α – the current angle of inclination of the site in question to the horizontal;

ρ – bulk cargo density, kg/m^3;

R – radius of the tube-shaped belt, m.

Each pressure acts on half of the span l_p, so the specific pressure of the distributed load is equal to:

$$p_{passive}(\alpha) = p'_{passive} \frac{l'_p}{2} = \frac{1}{2} R\rho g l'_p \int C_{passive}(\alpha) d\alpha, \text{ N/m} \quad (3)$$

$$p_{active}(\alpha) = p'_{active} \frac{l'_p}{2} = \frac{1}{2} R\rho g l'_p \int C_{active}(\alpha) d\alpha, \text{ N/m} \quad (4)$$

Then the total load equation is:

$$P\sum(\alpha) = p_\Sigma(\alpha) = p_{passive}(\alpha) + p_{active}(\alpha) = \frac{1}{2} R\rho g l'_p \int (C_{passive}(\alpha) + C_{active}(\alpha)) d\alpha, \quad \text{N/m} \quad (5)$$

And an equivalent concentrated load acts on the roller from the load within the angle $\Delta\alpha$, which is on the section of the belt along the width $\Delta B = R\Delta\alpha$ (Figure 2), the force acts on the lower roller:

$$P_{p1} = 2 \cdot \frac{\pi}{6} \cdot R^2 \cdot \rho \cdot g \cdot \frac{l'_p}{2} \int_0^{\frac{\pi}{6}} (C_{passive}(\alpha) + C_{active}(\alpha)) d\alpha, N \quad (6)$$

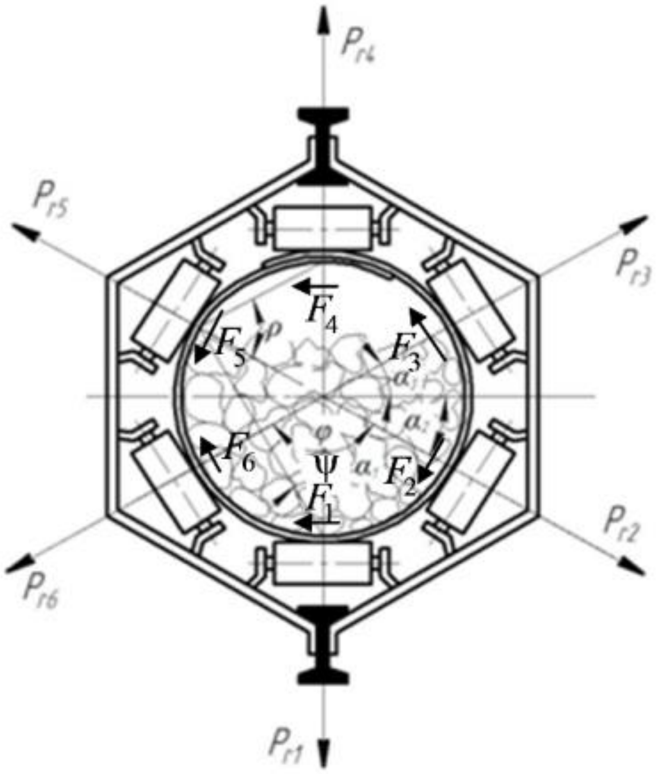

Figure 2. Cross section of loaded tubular belt with loads

$$P_{p1} = 2\frac{\pi}{6}\cdot R^2\rho\cdot g\cdot\frac{l_p'}{2}\cdot\frac{\pi}{6}\cdot 0{,}11^2\cdot 1{,}6 - 9{,}8\cdot\frac{0{,}08}{2} =$$

$$= 2\cdot\frac{\pi}{6}\cdot 0{,}0075\cdot\int_0^{\frac{\pi}{6}}\Big(C_{passive}(\alpha) + C_{active}(\alpha)\Big)d\alpha =$$

$$= 2\frac{\pi}{6}\cdot 0{,}0075\cdot\int_0^{\frac{\pi}{6}}(cos2\varphi + cos\alpha)\left(cos^2\alpha + \frac{sin\alpha}{m}\right) + (cos2\varphi + cos\alpha)(cos^2\alpha + msin^2\alpha) =$$

$$= \int_0^{\frac{\pi}{6}}\left(cos2\cdot\frac{\alpha}{2} + cos\alpha\right)\left(cos\alpha^2 + sin^2\frac{\alpha}{m}\right) + \left(cos2\alpha\frac{\alpha}{2} + cos\alpha\right)(cos^2\alpha + msin^2\alpha) =$$

$$= \int_0^{\frac{\pi}{6}}(\cos\alpha + \cos\alpha)\left(\cos^2\alpha + \frac{\sin\alpha}{m}\right) + (\cos\alpha + \cos\alpha)(\cos^2\alpha + m\sin^2\alpha) =$$

$$= \int_0^{\frac{\pi}{6}}(2\cos\alpha)\left(\cos^2\alpha + \frac{\sin\alpha}{m}\right) + (2\cos\alpha)(\cos^2\alpha + m\sin^2\alpha) =$$

$$= \int_0^{\frac{\pi}{6}}(2\cos\alpha)\left(\frac{1}{2} - \frac{1}{4}\sin 2\alpha + \frac{1}{2} + \frac{1}{4}\cos 2\alpha\cdot\ln m\right)(2\sin\alpha)\left(\frac{1}{2} - \frac{1}{4}\sin 2\alpha + \right.$$

$$\left. + \left(\frac{1}{2} + \frac{1}{4}cos2\alpha\right)\boldsymbol{m^2}\right) =$$

$$= \int_0^{\frac{\pi}{6}}(2\cos\alpha)\left(\frac{4 - \sin 2\alpha + \cos 2\alpha - \ln m}{4}\right) + (2\sin\alpha)\left(\frac{2 - \sin^2 2\alpha + 2m^2 + m^2\cos 2\alpha}{4}\right) =$$

$$= 2\sin 2\left(\frac{4 - \sin 2\alpha + \cos 2\alpha - \ln m + 2 - \sin^2 2\alpha + 2m^2 + m^2\cos 2\alpha}{4}\right) =$$

$$= \frac{\sin\alpha}{2}(6 - 2\sin 2\alpha + \cos 2\alpha\cdot\ln m + 2m^2 + m^2\cos 2\alpha) =$$

$$=\frac{\sin\pi/6}{2}\left(6-2\sin2\frac{\pi}{6}+\cos2\frac{\pi}{6}\cdot\ln m+2\cdot0{,}065^2\cdot\cos2\alpha\frac{\pi}{6}\right)=$$
$$=\frac{1}{4}\left(6-2\frac{\sqrt{3}}{2}+\frac{1}{2}\cdot(-0{,}43)+2\cdot0{,}4225\cdot\frac{1}{2}\right)=$$
$$=0{,}25(6-1{,}73-0{,}215+0{,}845+0{,}2112)=1{,}27$$
$$\int_0^{\frac{\pi}{6}}(cos2\varphi+cos\alpha)\left(cos\alpha^2+sin^2\frac{\alpha}{m}\right)+(cos2\varphi+cos\alpha)(cos^2\alpha+msin^2\alpha)=$$
$$=2P_1=2\cdot\frac{\pi}{6}\cdot0{,}0075\cdot1{,}27=0{,}00996\,kH=9{,}96\,H$$

The forces of resistance to movement depend on the deformations of the belt both on the roller supports and between them, therefore, the main task that was set during the development of the model was the possibility of determining the values of various deflections of the belt, the radius of curvature of the belt near the roller and the size of the contact area of the belt with the roller depending on the tension of the belt, the degree of filling of the cross section of the belt and the distance between roller supports for three sizes of conveyor belts. When the belt with the load moves immediately behind the roller support, due to some collapse of the belt, the relationship between the cargo particles and the belt decreases, and the transported cargo - conveyor belt system is in an active stressed state. Therefore, at high transport speeds, the active phase can be ignored.

The technical and economic advantages of this conveyor for closed bulk cargo transportation over the design of a traditional belt conveyor are obvious.

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Құбырлы таспалы конвейердің ұтымды және конструктивті параметрлерін негіздеу және есептеу әдістемесі

Аңдатпа. Мақалада сусымалы жүктерді сақтауға тасымалдауға мүмкіндік беретін құбырлы таспалы конвейердің ұтымды және конструктивті параметрлерін негіздеу және есептеу әдістемесі қарастырылған.

Бұл ретте, әсіресе тік және көлденең иілісі бар трассаларды алыс қашықтықтарға тасымалдау кезінде қоршаған ортаға зиянсыз әсер ету қажеттілігі атап өтілді.

Қарастырылып отырған құбырлы таспалы конвейердің конструкциясы, қолданыстағы құрылымдардан айырмашылығы, сусымалы жүктерді тасымалдау желісінің периметрі бойынша орналасқан тірек құрылғыларының арқасында таспаның жабық науасымен қалыптасады.

Конвейерлік көліктің басты артықшылығы - жабдықтың жұмысын автоматтандыру арқылы қол жеткізілетін еңбек өнімділігінің жоғары деңгейі және төмен өндірістік шығындар екендігі анықталды. Оларға тән проблемалар-тасымалданатын жүкті ұсақтау қажеттілігі, өтпелі учаскелерді дәл тексеру, жетектерді үйлестіру және кейбір бастапқы дизайн жағдайларын ескере отырып, жұмыс барысында оңай реттелетін қозғалыстарды синхрондау.

Кілт сөздер: сусымалы жүктерді тасымалдау, конвейер таспасы, құбырлы конвейер, роликті тіректер, құрылымдық параметрлер.

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Методика обоснования и расчета рациональных и конструктивных параметров трубчатого ленточного конвейера

Аннотация. В статье рассмотрена методика обоснования и расчета рациональных и конструктивных параметров трубчатого ленточного конвейера (ТЛК), позволяющего транспортировать сыпучие грузы в сохранности.

При этом отмечена необходимость безвредного воздействия на окружающую среду, особенно при транспортировке на большие расстояния трассы с вертикальными и горизонтальными изгибами.

Рассматриваемая конструкция ТЛК, в отличие от существующих, сформирована с замкнутым лотком ленты за счет опорных устройств, размещенных по периметру линии транспортирования сыпучих грузов.

Выявлено, что главные достоинства конвейерного транспорта - высокий уровень производительности труда, достигаемый путём автоматизации работы оборудования и низких производственных затрат. А проблемами, присущими им, являются необходимость дробления транспортируемого груза, точная выверка переходных участков, согласование приводов и синхронизация движений, легко регулируемые в процессе работы при соблюдении некоторых первоначальных конструктивных условий.

Ключевые слова: транспортировка сыпучих грузов, конвейерная лента, трубчатый ленточный конвейер, роликоопоры, конструктивные параметры.

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