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MEASUREMENT OF THE ROTATIONAL RESISTANCE OF STEEL-CASE ROLLERS USED IN BELT CONVEYOR SYSTEMS OPERATING IN ACIDIC ENVIRONMENTS

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Abstract: To design a conveyor belt, data on conveyor bridges to span the terrain or existing structures is required, as well as calculations for belt tensions. The total belt tension consists of many force components; however, some of them are required to make experimental measurements, such as for various resistance forces. Our comparative tests were conducted on two pieces of rollers, the same in terms of bearing type, hub type and quality of craft. The research objects were 89-mm-diameter rollers, used in conveyor belt systems for bulk transportation. Measurement campaigns were conducted in phosphoric acid baths to save time. Neglecting maintenance can lead to breakdowns, causing unplanned downtime and productivity loss. Regular checks and repairs keep the system running smoothly and prevent costly interruptions.

Keywords: *conveyor belt, rotational resistance, belt tension, acid media*

1. INTRODUCTION

Various bulk materials can be efficiently and continuously transported in large quantities using conveyor systems in logistics operations. The continuous operation of conveyor systems often poses a challenge due to wear and tear on the numerous moving parts. The design parameters of conveyor belt systems can be derived from the properties of their components, such as the design of an idler set. The nominal role of the idler roll set is to provide load support with low resistance to movement.

Rolling resistance is influenced by several factors: seal properties, belt design, idler diameter, transporting mass, conveyor speed and the frequency at which the belt passes over the idler. Woźniak (2020) introduced a new small-scale method for testing indentation rolling resistance. Rotational or running resistance is independent of mass, in contrast to rolling resistance and breakaway mass, which are mass-dependent amounts of a friction force between the idlers and the conveyor belt. The most common issue on roller blockades is bearing damage. This study focuses on examining the characteristics of time-dependent damage processes related to steel-cased idlers in terms of rotational resistance, which are critical to the energy efficiency of the transport process.

Our investigation was about the idlers of long-distance conveyor systems transporting acid-containing material such as fertilizers that employed troughed belts which contain numerous idlers. In terms of limited running resistance, it is essential that idler roller sealing ensures that the bearings are protected from corrosion and contamination. Effective monitoring of idlers' condition is very important for the reliable operation of conveyor belt systems.

The slender structural design forming the arrangement of a conveyor unit inherently causes low natural frequencies, making such structures easily excitable and requiring regular monitoring. In frameworks exposed to excitations due to conveyor-belt motion, resonance catastrophe may occur if the excitation frequency matches any structure's natural frequency. Besides roller blockages, additional vibration-related problems may also arise from wear or failure of the conveyor belt rollers, acting as excitation sources. These effects are detected, as reported by Klimendaa et al. (2016). Such resonance can lead to failure, typically manifested as fractures in the weakest components, disrupting the mechanical transport system functionality. Due to the potential hazards of resonance catastrophes, vibration analyses are also conducted on various mining equipment, such as excavators, disc-cutting rock extraction machines and bridge frames for belt conveyors, where the structures are the same slender design, as reported by Popescu et al. (2020), Wijaya et al. (2022) and Szirbik et al. (2024).

2. IDLER RESISTANCES

An idler roll (Figure 1) design is, in principle, a compromise among the parameters of the rotating outer cylindrical surface and a pair of bearings mounted on a stationary shaft, taking into account the various forces exerted by the conveyor belts.

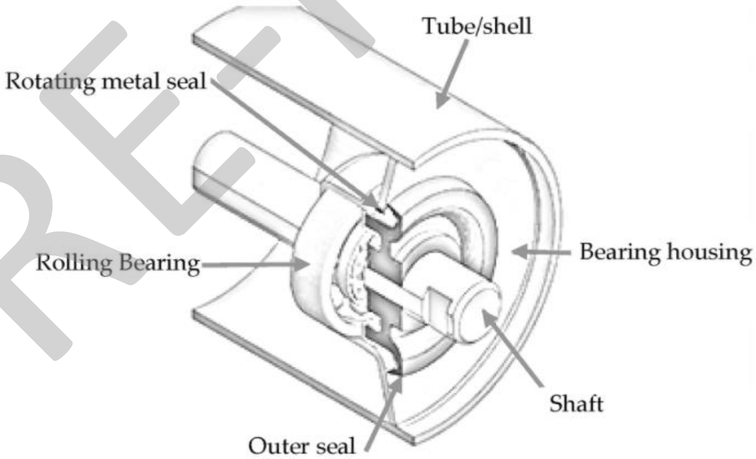

Figure 1
Structure of idler

To find the total belt tension is necessary to calculate the effective tension that is required to move the conveyor and the load material at a constant speed. The resistance components are important because their structure depends on the configuration of the conveyor. A portion of the total belt tension T is required to overcome the primary resistance, and this tension component is denoted by

$$T_g = T_k + T_e + T_r + T_f + T_s, \tag{1}$$

which contains the frictional resistance which overcomes the accessories as idler rotational resistance T_k and the belt sliding resistance T_s over the idler, furthermore, the tension T_e to overcome the rolling resistance related to pressing the roller into the rubber belt, the tension T_f in function of bulk density of phosphate, namely, ground fertilizer 0.8 t/m^3 to move with empty belt, load etc. and the belt bending resistance T_r on the roller sets. The secondary resistance concentrated at arbitrary points of the conveyor and grade resistance, which occurred only on inclined sections of the route, are also considered, as reported by Zhang et al. (2011) and Kulinowski et al. (2023). The two most important are the resistance deriving from the carrying and return idlers due to the friction in idler bearings and seals and belt advancement resistance resulting from the impression of the idlers in the belt, the recurrent flexing of the belt and of the material. In this way, the tension force and the required peripheral force on the driving pulley of the conveyor belt can be calculated step by step in Newtons, provided that the values of the friction coefficients can be determined from the corresponding measurements.

It is worth mentioning that the other key parameter to determine the quality of the idler is breakaway mass which means the amount of force needed to start a roller turning from standstill. It is important that the bearings are protected from water, dirt and bulk material, thereby ensuring that rotational resistance is kept to a minimum. Optional designs must also be compared in terms of price, load-bearing capacity, installation costs, as well as comparable mechanical properties.

Our testing of roller rotational resistance in corrosive media is essential in improving design solutions to reduce the energy consumption of belt transport. Laboratory tests on rotational resistance were conducted under simulated conditions in which the transported material has a highly corrosive effect on steel components, including bearings and tubes. For this purpose, a phosphoric acid bath was used to simulate the damage to the 89-mm-diameter test rollers in eight time periods to detect the rotational resistance in Newtons. After each period, the force measurements were taken.

3. EXPERIMENTAL AND RESULTS

Damage to the rollers caused by an acidic environment is a time-dependent process. To save time in our analysis, we conducted the measurement series on the same two rollers, which were kept in phosphoric acid baths between measurements. Our apparatus consists of a rotating shaft driven by a lathe, which rotates the roller shaft; a guide roller with a diameter of 89 millimeters, equipped with a rope that holds the guide roller's shell in place; and the measuring instrument required to perform the force measurements. Figure 2 illustrates the measurement system during the running-in phase.

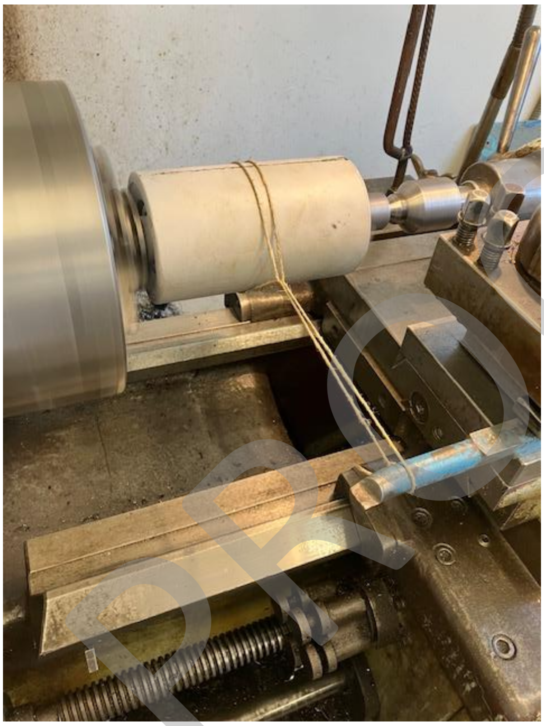

Figure 2
Measurement system

The roller's diameter is $d = 89$ mm and the relation between the rotational speed per minute (RPM) and peripheral velocity (Per. vel.) in meters per second can be expressed as follows:

$$v_p = s_r \cdot 2\pi \cdot \frac{d}{2} \cdot \frac{1}{60}. \tag{2}$$

In all cases, the measurements were taken after the initial run-in period. Since running resistance is primarily speed-dependent, the measurements were taken at various speeds. An average of two weeks elapsed between measurements, which is sufficient to demonstrate the corrosive effect of the acid. Selecting nine measurement points and using the measurement system shown in Figure 2, Tables 1 and 2 list the running forces corresponding to the circumferential speeds of the rollers used in the measurement. Tables 1 and 2 show that the force required to maintain a roller's rotation, namely, the rotational resistance, increases as the idlers remain in the acid bath for a longer period of time. This demonstrates that the acidic medium has a significant effect on the operation of the mechanism. The results show significant differences for idlers 1 and 2, demonstrating that the phenomenon depends on several parameters.

Table 1
Running forces [N] measurement for idler 1

s_r	v_p	Measurement No.							
1/min	m/s	1	2	3	4	5	6	7	8
530	2.47	0.9	1.0	0.8	1.1	1.1	1.0	1.2	1.5
750	3.50	1.1	1.2	1.0	1.3	1.3	1.2	1.3	1.8
1060	4.94	1.4	1.5	1.3	1.4	1.6	1.5	1.5	2.1

Table 2
Running forces [N] measurement for idler 2

s_r	v_p	Measurement No.							
1/min	m/s	1	2	3	4	5	6	7	8
530	2.47	0.7	0.7	0.6	0.6	0.6	0.7	1.1	1.5
750	3.50	0.9	0.9	0.8	0.8	0.8	0.9	1.4	1.6
1060	4.94	1.0	1.1	1.0	1.0	1.0	1.0	1.6	1.9

These key parameters, shown in Tables 1 and 2, determine the quality of idlers besides breakaway mass. Lower resistance results in energy savings in the conveyor belt system, which in turn leads to cost savings.

The effects of corrosion are clearly visible on the rollers. Discoloration can be observed on the surface of the steel shaft and housing. The roller seal has also sustained visible damage during the process. The effects of corrosion on the rollers are shown in Figure 3.

Figure 3
View of the idlers during testing

4. Conclusions

This article discusses the rollers used on conveyor belts for transporting fertilizers and focuses on the effect of transporting bulk materials containing such acidic substances on rotational resistance. This resistance represents the force required to maintain the roller's rotation and increases as the corrosive environment damages the rollers' structure.

Experimental investigation of the rotational resistance caused by fertilizer moving on the conveyor belt is essential, as it is crucial for preventing operational disruptions. An increase in rotational resistance leads to higher power requirements and, consequently, increased costs. This study provides a basis for addressing issues related to the resistance of roller assemblies. Without proactive planning and monitoring of the conveyor belt system, unexpected roller failures cause problems during the transport of acid-containing bulk materials.

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