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MEASUREMENTS AND SIMULATION OF GUIDING EFFECTS WITH FLAT BELT CONVEYORS

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Abstract - Flat conveyor belts supported and driven by cylindrical drums run in a state of instability because of lack of guiding forces. Faults such as asymmetry in the position or shape of pulleys and idlers, uneven load distribution or acting transverse forces such as those induced by friction will make the belt run out of true. On the other hand, some of these effects are used for guiding flat running belts.

This paper deals with the guiding effects of two significant features; the skewed cylindrical pulley and the conical pulley. In the first part the implemented measurements are described and in the second part a mechanical model is established for both features. Finally, in the third part measurements are compared with simulation results to verify the developed mechanical model.

Keywords: Belt Conveyor, Guiding Effects

1. INTRODUCTION

Flat conveyor belts are often used in a wide range of industrial fields both as machine components (process bands) or for conveying purposes (conveyor bands). Belts used are normally made of fabric inserts or, particularly for process belts metal, usually steel.

Flat-running belts driven by cylindrical drums and supported by carrying idlers or guide tracks do not display any systematic centring effects (Fig. 1). They run in an unstable condition. Small changes or inexactnesses in the position of the drums or carrying idlers, asymmetrical loading or laterally-acting frictional forces can cause lateral travel of the belt. This can result in damage to the belt, the transported goods or the supporting structure. In order to ensure the best possible availability of the plant, lateral travel of the belt must be prevented without fail.

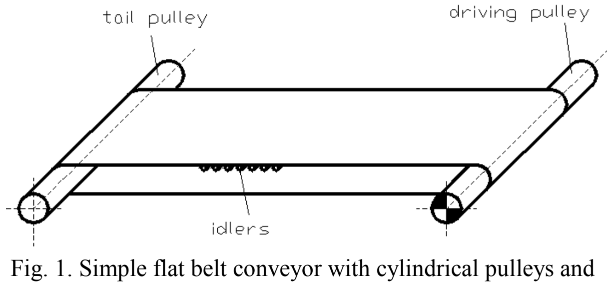

Fig. 1. Simple flat belt conveyor with cylindrical pulleys and idlers

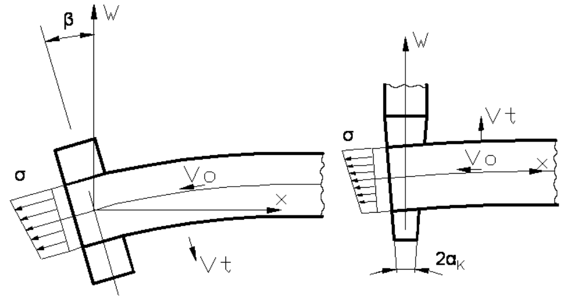

Fig. 2. Two influential guiding effects: the skewed cylindrical pulley and the conical pulley

Therefore a wide range of guiding systems have been developed to ensure satisfactory belt running. This paper investigates two significant cases:

- Skewed cylindrical pulley;
- Conical pulley.

The first can cause run-out of the belt with damaging consequences, but both are used for the guidance of flat belts.

The belt which is moving over a cylindrical pulley whose axis of rotation is not perpendicular to the centre line of the conveyor will run out of true in the direction of lower belt tensions whereas a non-skewed conical drum causes a lateral belt movement into the direction of the largest diameter of the pulley, resulting in higher belt tension (Fig. 2). Both effects are well known and some basic principles concerning this matter have been published to date, see [1] to [5].

In this paper firstly presents measurements and secondly discusses a mechanical model for simulation. Finally the results of simulation and measurements are compared in order to evaluate the relevance of the model.

2. MEASUREMENTS

Measurements were carried out on a test bench at the laboratory of Vienna University of Technology’s Institute for Design Engineering and Transport,- Handling and Conveying Systems [4].

Theoretical investigations show that the shape of the centre line of the belt at the point where it makes contact with the drum is responsible for the lateral running behaviour.

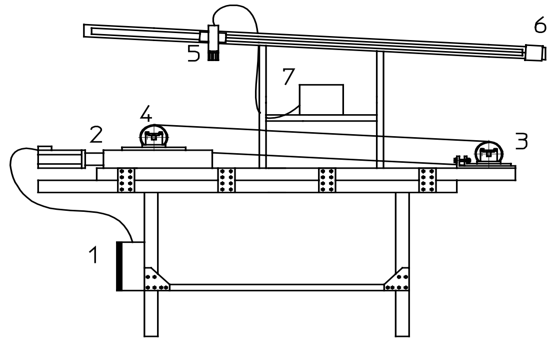

Fig. 3: Test bench - 1.Control unit; 2. Driving device to control the position of the tail pulley; 3. Driving pulley; 4. Tail pulley; 5. CCD camera; 6. Driving unit for CCD camera; 7. CCD camera-linked evaluation unit.

Therefore the deformations of the belt in this area were recorded by an CCD camera as well as by conventional potentiometer distance sensors. This data made it possible to determine the position of the belt on the drum, the angle between the drum and the running direction, as well as the curvature of the belt at the point where it meet the pulley. The test bench (Fig. 3) was equipped with two electrical linear drive devices to control the position of the tail pulley. Belt feed was detected by an optical sensor fixed near the speed control driving pulley. Experiments can be carried out with automatic monitoring by a PC as well as data acquisition of the position and shape of the belt edge, the belt feed and the resultant forces exerted on the bearings of the pulleys.

2. 1. Technical Data of the Test Bench and of the Belt

Distance between centres:	2000 mm
Conveying speed:	0 – 1,4 m/s
Belt width max:	500 mm
Belt tension max:	5000 N
Pulley diameter (cylindical):	163 mm
Pulley diameter (conical):	155,3/150mm
Belt Type:	Habasit SAB 8EV
Young modulus:	1113 N/mm
Shear modulus:	56,7 N/mm

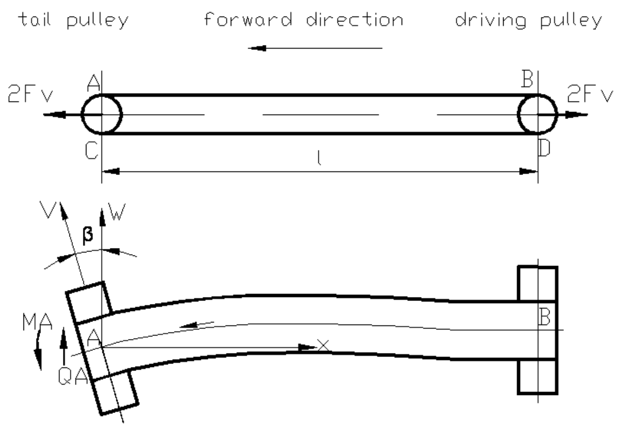

Fig. 4. Belt conveyor with a skewed cylindrical tail pulley

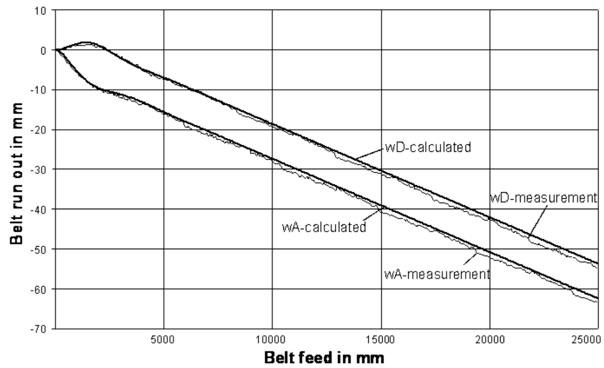

Fig. 5. Belt run-out on a skewed, cylindrical tail pulley, belt 125 mm, skewing angle: 0,5°

2.2. Skewed, cylindrical tail pulley

The first case studied deals with the lateral belt movement influenced by a skewed, cylindrical tail pulley (Fig. 4).

Fig. 5 depicts the lateral belt movement using a skewed cylindrical tail pulley. It shows an immediate run-out of the belt to lower belt tensions at point A where the belt approaches the skewed tail pulley whereas at point D, where the belt approaches the drive pulley, initially the belt moves slightly in the reverse direction. After several revolutions of the pulleys the belt reaches a quasi-static moving condition. The lateral velocity of each point of the belt is equal, hence its deformation is constant.

Fig. 6 shows the changing of the bending lines of the belt from the starting situation after skewing in standstill (line a) to the quasi-static condition after 25000mm of belt feed (line b).

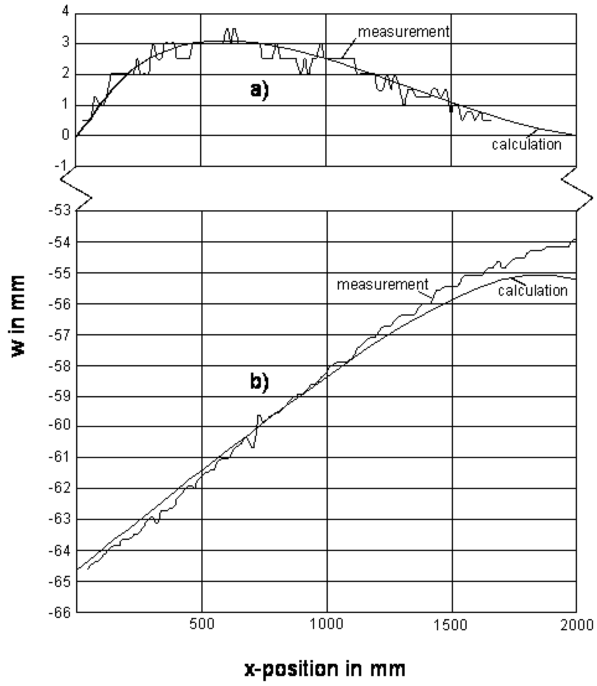

Fig. 6. Deformation of the top strand, belt 125 mm, skewing angle 0,5°
Line a: After skewing the tail pulley
Line b: After 25000 mm of belt feed

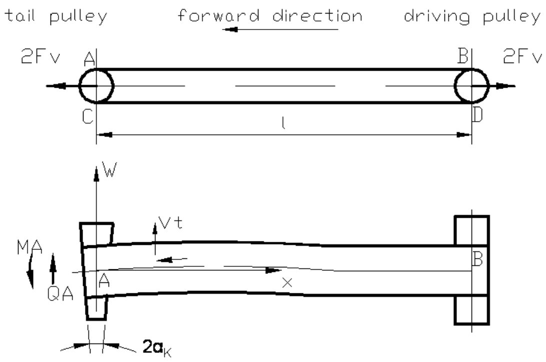

Fig. 7. Belt conveyor with a conical tail pulley

2.3. Conical tail pulley

Fig. 7 depicts the scheme of a simple conveyor equipped with a conical tail pulley. As mentioned above a conical drum causes lateral belt movement in the direction of the largest diameter of the cone, resulting in higher belt tensions.

Fig. 8 depicts lateral belt movement when using a conical tail pulley. It shows immediate run-out of the belt to lower belt tensions at point A where the belt approaches the conical tail pulley, whereas in point D where the belt approaches the drive pulley the belt run-out starts with a time delay. Also, in this case the belt reaches a quasi-static moving condition after several revolutions of the pulleys.

2.4. Transition from the cylindrical to the conical part of a tail pulley

Cylindrical drums with conical ends (Fig. 9) are widely used for independent centring of the running belt if the distance between the pulleys is relatively short. As soon as the belt edge reaches the conical part of the pulley, the lateral movement will be reversed and the running of the belt tends back to the centre of the pulley. Some theoretical and experimental investigations on this subject were carried out by Koster [2] and Spaans [3].

Determination of the guiding features of cylindrical drums with conical shaped ends requires investigation of the transition from the conical part to the cylindrical part

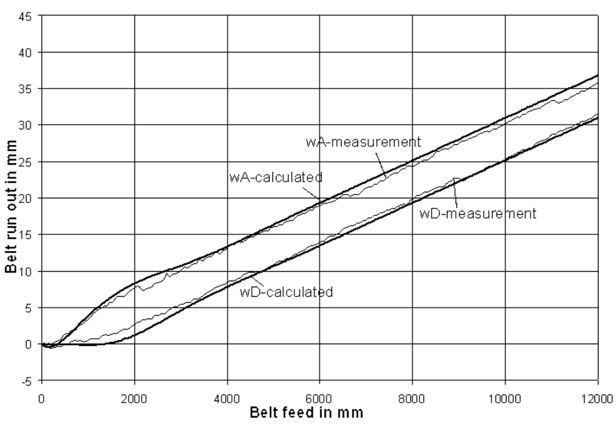

Fig. 8. Belt run-out on a conical tail pulley, α_K =0,61°, Belt 125 mm, Strain: 0,8%

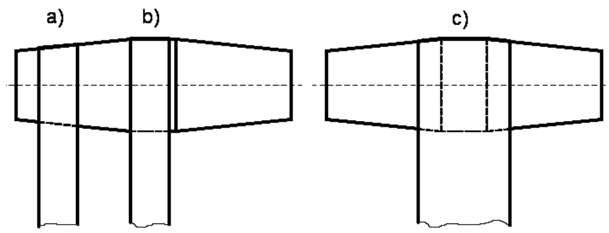

Fig. 9. Pulley with double-coned ends
a) Starting position of a narrow belt
b) End position
c) Starting position of a wide belt

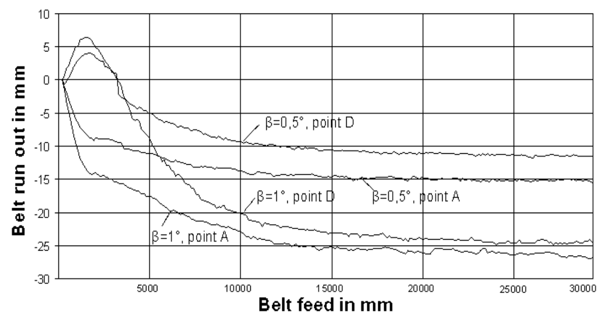

Fig. 10. Belt run-out on the transition between conical and cylindrical part of the tail pulley

of the drum. If the belt is positioned at the conical part of the pulley (position a, Fig. 9) it starts to move up to the cylindrical part. If the band width is smaller than the cylindrical part of the pulley and the skewing angle is absolutely zero, the band slowly reaches the end position (position b, Fig. 9).

Usually the band is wider than the middle part of the pulley. In this case, after a certain amount of belt feed the symmetric end position is reached (position c, Fig. 9). If the skewing angle does not equal zero, the belt is moving to a destined stationary position where the effects of the skewing angle and the angle of the cone are in equilibrium. Of course this position depends on a number of parameters, such as the skewing angle and the cone angle.

To study this centering effect the following experiments were carried out. Every experiment was started with a symmetrical position of the band (position c, Fig. 9). A lateral movement was caused by skewing the tail pulley and the belt run-out was measured. The belt moves to a state of equilibrium. To reach this state requires about 20000mm of belt feed (Fig. 10). According to this figure, similar behaviour is recognisable at the beginning of the movement as in the case of the skewed cylindrical pulley (Fig. 5).

3. SIMULATION

In this study a simplified model of a flat belt conveyor, consisting of a tail pulley, a drive pulley and an endless belt without idlers is used for the investigation of guiding effects.

Earlier investigations [5] show that the effects of both the scewing angle β as well as the angle of the cone α_K can be described in a common mechanical model. Two kinds of properties are responsible for the lateral running behaviour:

- Geometry of the pulleys;
- Inclination and curvature of the approaching belt.

This means that the belt's deformations at point A, where the upper strand approaches the tail pulley as well as the deformations at point D, where the lower strand approaches the drive pulley, are mainly responsible for the current lateral running.

The first part of the model belongs to the free strand of the belt. It can be assumed that the second order bending theory factoring in the tensile stresses descibes the shape of the centre line of the belt. The deflection is given by:

$$w(x) = C1 \cdot \sinh(\sqrt{\gamma} \cdot \alpha \cdot x) + C2 \cdot \cosh(\sqrt{\gamma} \cdot \alpha \cdot x) + \frac{M_A - Q_A \cdot x}{Fv} + w_A \quad (1)$$

with $\alpha = \sqrt{\frac{Fv}{E \cdot J}}$ and $\gamma = \frac{1}{1 + \frac{Fv}{G \cdot A}}$ (2), (3)

The constants $C1$, $C2$, M_A and Q_A depend on the current boundary conditions in Point A and Point B according to Figure 4 and 7. The lateral position of the approaching points A and B is:

$$w_A = w(x = 0)$$
$$w_B = w(x = l) \quad (4)$$

The angle of the belt's inclination at A and B is:

$$k_A = w'(x = 0)$$
$$k_B = w'(x = l) \quad (5)$$

The curvature at A and B is:

$$\rho_A = w''(x = 0)$$
$$\rho_B = w''(x = l) \quad (6)$$

Similar equations can be applied for the lower strand. Earlier investigations [4] show that it is normally not valid to assume the belt being clamped by the drums. Sliding friction occurs between belt and pulley, and this must also be taken into consideration. The action of the frictional forces can be modelled by areas of constant line loads acting between drum and belt. A more detailed explanation is given in [1], [5].

The inclination and the curvature at the approaching part of the upper strand (point A) and of the lower strand (point D) are derived from equation (1) considering the effects of friction forces and from the matching conditions between the belt deflection line and the position of the pulleys. The calculations show that the conditions of the leaving belt have only minimal influence on lateral movement. Based on this statement it is possible to correlate the calculations from one state to the next.

Successful simulation can only be achieved by an iteration process with very small increments. Further details can be found in [5].

4. COMPARISON

Figure 5 depicts an example of lateral belt movement in the case of a skewed cylindrical tail pulley. The simulation results are compared with measurements. Close correlation can be found between measurement results obtained from practical tests and the simulation according to the mechanical model described above. With reference to this experiment, the changing of the bending line of the belt from the starting situation after skewing in standstill (line a) to the quasi-static condition after 25000mm of belt feed (line b) is shown in Fig. 6. Finally the belt run-out in the case of the conical tail pulley is presented in Fig. 8. The same close correlation between measurements and calculation can be observed for all these described tests.

5. CONCLUSION

The obtained results presented in this paper can be applied to predict the run-out of the conveyor belt when considering certain configurations and also for assessing the influence of certain geometric and mechanical parameters relating to lateral running behaviour. The simulation model could be the theoretical basis for further investigations regarding the guiding effect of skewed and conical shaped pulleys and other guiding systems.

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