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Friction's Force Modelling of Belt Conveyors

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Abstract: In this study we expose an adaptive control method based on the estimate and distribution of the friction forces and the localization of the reserves zones adherences of the belt conveyors. The distribution of the friction force is modelled by the continuity and the derivation of mathematical functions. The essence of this study consists of the comparison between the mathematical method and summary of the experimental results carried out in laboratory.

Key words: Effects of the slip, behaviour of the force of friction, zone of adaptive friction, control

INTRODUCTION

The presence of the mechanical defects in belt conveyors and the complexity of electromechanical mechanism in question make it difficult the control of the system of regulation in loop closed.

The prevalent phenomenon in this type of mechanism remains ice-skating between band and its driving drum especially during the transitory process; this last influences negatively on the transmission effort to the body of work and takes part in the wear acceleration. Slip of the electromechanical system generates a difference in speed between elements in contact (band drum).

During the transitory process evolution totality of the force of friction varies according to speed control, slip which makes it possible to reduce the ice-skating effect, this spot can be concretized either by mechanical solutions or a control ensured by an automatic system of regulation.

The mechanical solutions remain in our opinion too much expensive and their repercussions is the lead of several parameters related to opera tings conditions and the type of mechanisms; therefore that control consists to minimize the effect of ice-skating by using one law of the control which takes account of the zone reserves of adherence.

Some work has been completed with an aim to improve the performances of these installation KOUSNITSOV which presents a theory[1] according to which exploitation of belt conveyors is characterized by zones of operation dependent on the site topography of exploitation and the transmission of the effort to the band zone with guaranteed reserves, where the capacities of traction are consumed and in the end strong possibilities of ice-skating.

The zone of operation thus obtained is limited by the angle of inclination of the installation. More of that this excluded not the risk from ice-skating in transient state. Mechanical solutions suggested by Vidal[2] based on the installation of tensioners, improvement of the quality of the garnishing of the driving drum, improvement of the angle of wrap of bandage on the driving drums do not bring always the solutions to the processes transients.

Dynamic analysis of the mechanism let us adopt a strategy of control for the reduction of the effect of ice-skating so to improve the coefficient of friction and the performances of operation of belt conveyors during the different ones modes.

Description of the test bench: The conveyor used for the experiment is Kpl-400 Fig. 1 type and is intended for the transport of materials into horizontal and with variable slope; for the needs of the experiment and in order to increase the practical repercussions at ends of simulations we were driven the machine by two different engines (synchronous and with D.C. current) Fig. 3.

The no-load test of the machine with the engine with D.C. current enabled us to record at the same time using sensors; rate of travel of the band, number of revolutions of the driving drum and the current used by the engine Fig. 4 to 6.

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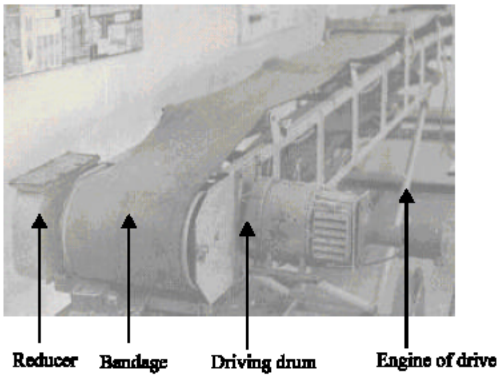

Fig. 1: General sight of the belt conveyor

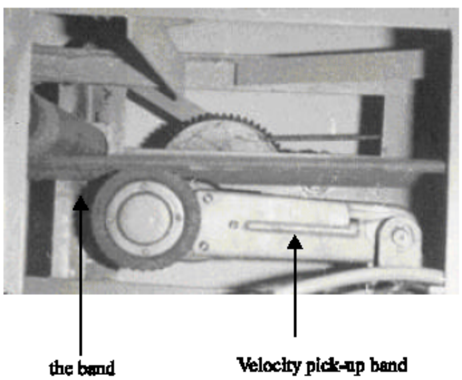

Fig. 2: Control speed belt

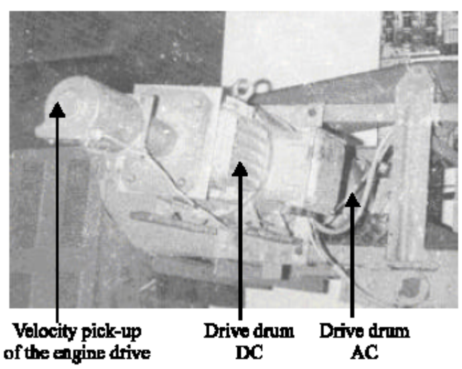

Fig. 3: Control speed drum

Curves thus obtained with acceleration variable ($\delta = \delta_{min}$, $\delta = \delta_{moy}$, $\delta = \delta_{max}$). Allowed us to make an assessment dynamics of the belt conveyor in which one determines the force of friction in function of the slip. Treatment and reading of the results of experiments made it possible to plot the curves

F = f(G).

In this study the Eq of the force of friction calculated will be[3]:

$$F = cf_m W_{tam} - \delta_{driving\ engine} J - \delta_B J_{drum+ban}$$

Variation of the force of friction according to the slip

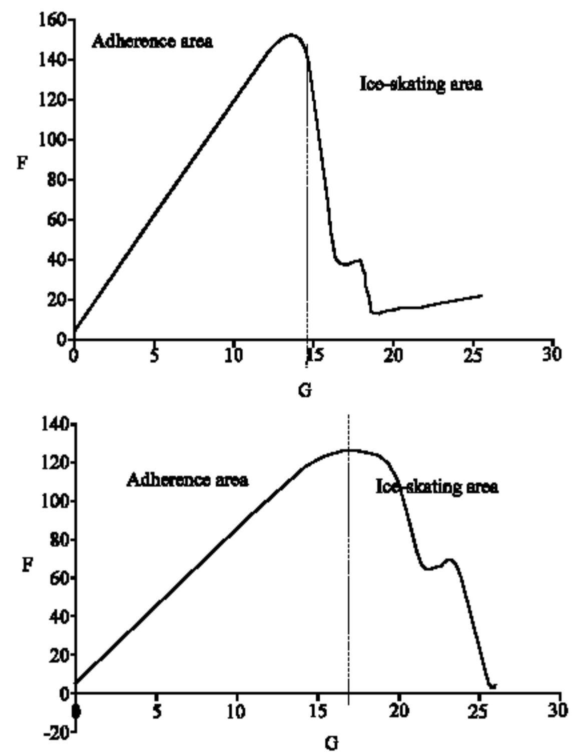

Fig. 4: For a starting with accelerated minimal $\delta = \delta_{min}$ (rd.s^{-2})

Or J_B J_m F_m: are successively the moments of inertia and the viscous friction of the engine and band-drum part. $'\Omega_m$ $'\Omega_b$ Ω_m Ω_b θ_m θ_b are successively accelerations, the angular velocities and the positions of the engine and the band.
C: is the turning moment.

Experimental results: The experiments carried out in laboratory enabled us to make a simultaneous recording of the essential sizes (speed of the band, number of

Variation of the force of friction according to the slip

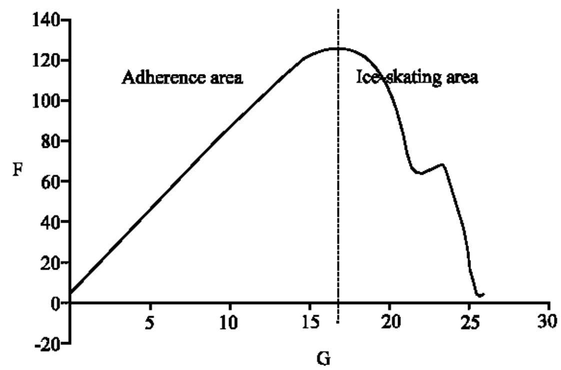

Fig. 5: For a starting with accelerated maximum $\delta = \delta_{max}$ (rd.s $^{-2}$)

Fig. 6: For a starting with accelerated average $\delta = \delta_{moy}$ (rd.s $^{-2}$). Variation of the force of friction according to the slip

revolutions of the driving drum and the load) Fig. 4 to 6, for the dynamic study of the belt conveyor which make it possible analysis of the behaviour of the force of friction during various accelerations.

The shape of the force of friction according to the slip remains the same one and present two zones of operation distinguish (zone of adherence and zone of slip) variation of the force of friction according to the slip

Dynamic modeling: In this section we present a simplifed diagram electromechanical system in question appears. The revolving parts are pulled by an engine with D.C. current which delivers one turning moment of mass relatively significant. On the part of reducer, the constant of the reduction is surroundings of 1; In this study one considers that the shaft of the engine is directly related to the driving drum Fig. 7. I.e., it is primarily about the detailed study of the model of the force of friction between the transaction tape with driving drum[5]. According to the results of experiment on the behaviour force of friction with the different ones accelerations; the existence of two zones is noted of operation: Zone with increasing adherence and zone with significant slip F = f(G) for Fig. 4 to 6[3].

It is consequently desirable, starting from this model to stop a strategy of control to make synthesis of a regulation adapted to the mode of given operation; Or the principal interest is reduction of the effect of the slip and the improvement of performances of the transmission[4].

Modeling of the force of friction: The mechanical model of the system is described according to the following form[6].

$$C = \frac{d\Omega_m}{dt} + \Omega_m f_m + K(\theta_m - \theta_b) \quad (1)$$

$$F + J_b = \frac{d\Omega_b}{dt} = K(\theta_m - \theta_b) \quad (2)$$

Or J_B J_m F_m: are successively the moments of inertia and the viscous friction of the engine and band-drum part. $'\Omega_m$ $'\Omega_b$ Ω_m Ω_b θ_m θ_b are successively accelerations, the angular velocities and the positions of the engine and the band.

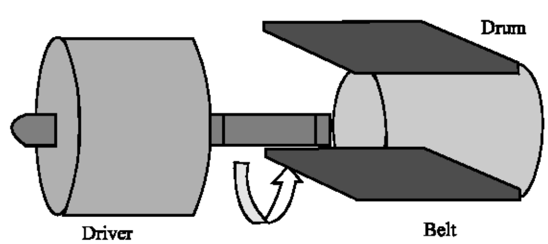

Fig. 7: diagram to simplify of the conveyor unit

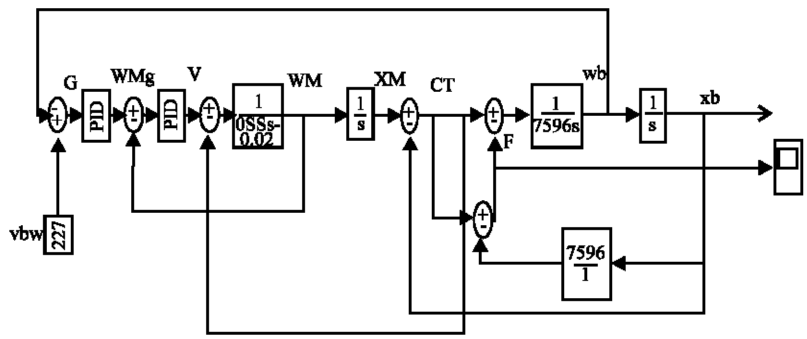

Fig. 8: diagram block of simulation

C: is the turning moment of writing in (1)
F: is the force of the total friction of the mechanical model. maintaining the system (1) could be expressed by the following expression

$$C = F + \frac{d\Omega_m}{dt} + \Omega_m f_m + J_b \frac{d\Omega_b}{dt}$$

Let put to us

$$\xi_s = \Omega_{bd} - \Omega_b$$
$$\xi_e = \Omega_{md} - \Omega_m$$
$$C_r = k(\theta_m - N\theta_b)$$

Or $\Omega_{bd,}$ Ω_{md} is successively the speed of the band, of the desired engine and N represents the constant of reduction

Digital simulation
Calculation the speed of the engine:

$$C - C_r = \frac{d\Omega_m}{dt} + \Omega_m f_m$$

$$C(P) - C_r(P) = J_m P\, \Omega_m(P) + \Omega_m(P) f_m$$
$$C(P) - C_r(P) = \Omega_m(P) [J_m P + f_m]$$

$$\Omega_m (P) = \frac{C(P) - C_r(P)}{[J_m P + f_m]}$$

$$\Omega_m (P) = \frac{1}{P} \theta_m (P)$$

$$\theta_m (P) = P\Omega_m (P)$$

calculation of the resistive torque

$$C_r = k(\theta_m - \theta_b)$$

$$C_r(P) = k(\theta_m - \theta_b)$$

Calculation the speed of the band

$$F + J_b \frac{d\Omega_b}{dt} = C_r$$

$$J_b \frac{d\Omega_b}{dt} = C_r - F$$

$$J_b P\, \Omega_b(P) = C_r(P) - F(P)$$

$$\Omega_m (P) = \frac{C_r(P) - F(P)}{J_b P}$$

$$\Omega_m (P) = \frac{1}{P} \theta_b (P)$$

$$\theta_b (P) = P\, \Omega_b (P)$$

Calculation mean velocity desired of the engine

$$\Omega_{md} = k_p (\Omega_{bd} - \Omega_b) + k_d (\Omega_{bd} - \Omega_b) + k_I \int \Omega (\Omega_{bd} - \Omega_b)$$

The force of total friction

$$F + J_b = \frac{d\Omega_m}{dt} = C_r$$

$$F = C_r - J_b = \frac{d\Omega_b}{dt}$$

$$F(P) = C_r(P) - J_b P\, \Omega_b(P)$$

Calculation of the couple of the engine

$$C = k_p (\Omega_{md} - \Omega_m) + k_d (\Omega_{md} - \Omega_m) + k_I \int \Omega (\Omega_{md} - \Omega_m$$

Diagram of the control of the electromechanical system: The diagram of the control of the electromechanical system is represented in Fig. 8. This diagram is represented by two loops, first is based on a standard regulator PID, the which deduced speed of wished entry, second is based on another standard regulator PID used for the estimate of the couple thus for deduced the signal from the control.

RESULTS AND DISCUSSION

From the experimental installation we modelled from where we will retain a continuity in the variation of the force of friction.

Fig. 9: Variation of the force of friction for: v_{band} = 0 rd/s

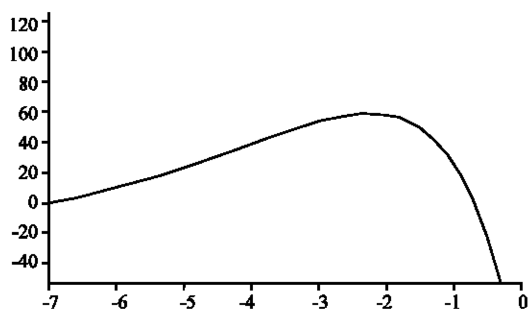

Fig. 10: Variation of the force of friction for: v_{band} = 9.56 rd/s

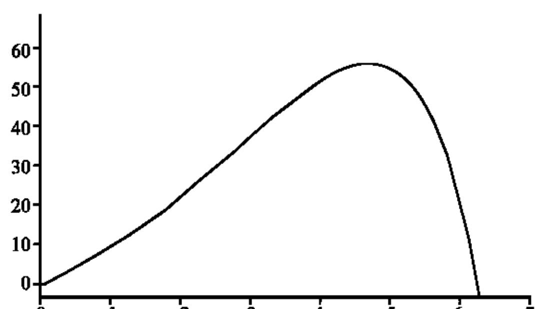

Fig. 11: Variation of the force of friction for: v_{band} = 9,27 rd/s

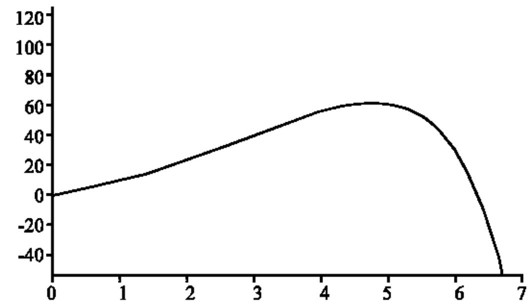

Fig. 12: Variation of the force of friction for: v_{band} = 9,85 rd/s

By imposing a set point speed of the band (desired speed) and with the characteristics of the model of simulation Fig. 9-12 we observe a continuation of announces evolution of the force of friction according to the relative value of the slip.

CONCLUSION

With the court of the transient process evolution of totality of the force of friction varies with speed except in the case of solid friction. At low speed the mechanical equipment (drum-band) has a linear variation of the viscous friction whose adherence passes by one maximum for weak slips; then decrease again to reach effective adherence available to the level of the contact the first part of the curve adherence where the reserves of

Characteristics of the model of simulation

Parameters of control		Parameters of the system	
K_{P1}	1	J_B	75.48
K_{P2}	10	J_m	0.055
K_{D1}	0.01	J_T	0.48
K_{D2}	10	F_m	0.024
K_{I1}	0.01	K1	
K_{I2}	0.5	N1	

traction are guaranteed; on the other hand in the second part called zone of slip there exists an increased possibility to develop an ice-skating. Then we propose an adapted control Fig. 8 which allows to reduce the slip and to improve the performances operation of the system.

NOTATION

v_{band}	linear velocity of the band (m/s)
N angular$_{drum}$	velocity of the drum (tr/min)
W angular$_{drum}$	velocity of the drum (rd/s)
$W_{bandages}$	angular velocity of the band (rd/s)
$\delta_{bandage}$	acceleration of the band (rd/s ^{2})

has $_{band}$	acceleration of the band (m/s ^{2})
δ_{drum}	acceleration of the drum (rd/s ^{2})
has $_{drum}$	acceleration of the drum (m/s ^{2})

G slip (m/s)

C couples (n.m)

I running of the engine (A)

J $_{bandages}$	moment of inertia of the band (kg.m ^{2})
J $_{drum}$	moment of inertia of the drum (kg.m ^{2})
J $_{driving}$	moment of inertia of the engine (kg.m ^{2})
F $_m$	coefficient of viscous friction (n.m/rd.s)
α_0	coefficient of solid friction (n.m)
α_1	constant of adherence
α_2	coefficient of viscous friction (n.m/rd.s)

F forces friction (n.m)

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