Simulation and optimization of realized traction factor of belt conveyor

Simulation et optimisation de facteur de traction réel du convoyeur à bande

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ملخص

إن الخصائص الديناميكية للأحزمة الناقلة مرتبطة بعامل المرونة ولزوجة التخميد.هذه الورقة تعالج تقييم احتياطات الشد للأحزمة الناقلة من اجل تحسين قدرتها في التشغيل الأمن، حيث تم التعبير عن العلاقة بين قوى الشد عند مدخل ومخرج البكرة المحركة بمعدلات رياضية مع الأخذ بعين الاعتبار الخصائص التقنية للحزام، وتركيبة الناقل واستخداماته (ميلان، طبيعة الشحنة، التركيبة)
النموذج الذي تم تطويره في هذا العمل يمكن استخدامه كأداة لمراقبةحدود مرونة الحزام من اجل تجنب الانزلاق بين الحزام وبكرة القيادة حيث قمنا بمحاكاة عملية نقل الجهد الحركي للحزام والتصاقه مع بكرة المحرك ممايسمح لنا بالسيطرة الكاملة على قدرة الناقل وعامل الشد. وهذا سيمكن من تقييم وتقدير احتياطيات الالتصاق والتنبؤ بالمخاطر المرتبطة به.
هذه المنهجية تمكن من حماية الحزام الناقل من التمزق ومن الالتصاق حول بكرة المحركوالاستعمال السليم

الكلمات المفتاحية *الحزام الناقل، المراقبة، التحكم، عامل الجر، نقل الحركة*

Résumé

Le présent papier traite de l'estimation des réserves de traction du convoyeur à bande afin d'optimiser ses capacités pour un fonctionnement sans risques. La relation entre les forces de traction à l'entrée et à la sortie du tambour d'entraînement est mise en équation mathématique qui prend en considération les caractéristiques techniques de la bande, la configuration du convoyeur et son utilisation (relief, type de charge et construction). Le modèle développé dans ce travail peut être utilisé comme outil de contrôle des limites d'élasticité de la bande pour éviter son glissement sur le tambour d'entraînement.
La simulation du processus de transmission de l'effort moteur à la bande et de son adhérence avec le tambour d'entraînement nous permet une exploitation contrôlée des capacités de traction du convoyeur. Ceci permet d'évaluer et d'estimer les réserves d'adhérence et de prévoir les risques de glissement. Cette approche peut assurer un contrôle et une surveillance du convoyeur à bande afin d'éviter une usure excessive de la bande et par la même un bon fonctionnement.

Mots clés: *convoyeur à bande, surveillance, contrôle, facteur de traction, transmission par bande*

Abstract

The present paper discusses the estimation of belt conveyor tensile reserves to optimize its capacity in order to obtain a safe operation. The relation between traction forces at the input and the output of the drive drum is mathematically expressed taking into account the technical characteristics of the belt, the conveyor configuration and its use (inclination, load type and design). Moreover the model developed in this work can be used as a tool to control the elasticity limits of the belt to prevent it from slipping on the drive drum.
The simulation of transmission process of the motor force on the belt and its adhesion with the drive drum allows a controlled exploitation of the conveyor traction capacity. This makes possible the evaluation and the estimation of the adherence reserves and predicts the risks of slipping. This approach can insure conveyor control and monitoring to prevent the belt from excessive wear and thus good operation can be obtained.

Key words: *Conveyor Belt, Monitoring, Optimization, Traction factor, Belt Transmission*

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1. INTRODUCTION

Belts conveyors are used for many decades for handling bulk material mass flows over short and medium conveying distances. They showed their effectiveness world wide[1] and can be adapted to suit any local conditions. Actually belt conveyors are considered as continuous transporting means in mining and industrial plants. They continue to be largely used because of their economical effectiveness and operating safety. The rising demand in flow with more important transporting distances require an adequate technical development of belt conveyor as it becomes a serious competitor to railway and truck transport.The increased economical requirement needs to use conveyors with large belt and important flow for long distances, in certain cases the distance can reach 100 km (i.e. conveyor installed in New Caledonia).

Numerous works have been reported on dynamic performance parameters of the belt [2, 3].The study performed on the relationship between traction and slip in a wheel-driven belt conveyor showed that the belt speed has little effect on traction [4]Other works conducted on dynamic modeling, feedback and switching control for conveyors belt demonstrated that a proportional-integral controller (PI) is suitable to control the contentin conveyor belt whereas, fuzzy-immune PID controller help to start the belt conveyor softly and the output speed follows the preset speed with only small fluctuations [1, 5, 6, 7.8,9,10]. The mathematical model was developed and critical financial parameters as well as transport simulation technology were determined for belt conveyor [11].

In practice, the improvement of belt conveyors efficiency is achieved mainly by introducing highly efficient equipment such as energy-efficient motors, and variable speed drives (VSDs) [12],[13],[14].Transmission management of drive pulley traction effort to the belt is the key for rational and optimum exploitation of conveyor traction capacity taking into account motor power, belt characteristics, conveying distance and transporter productivity.Transporting belt is the main element of the system and must resist to numerous and different constraints. Moreover, each belt conveyor installation has its specific problem and requires a rigorous planning and computation in order to reach transport optimum capacity with high efficiency by optimizing the economical, security and environmental criterions.[14]

The present paper focuses on the design traction factor ($\mathbf{e^{f\alpha}}$ coefficient)in order to increase machine efficiency, transporting belt life time, and controlling and monitoring with high accuracy slipping phenomena. The purpose is to show the importance of real traction factor **(a)** which is the ratio between input and out put drive pulley tensile enabling to act on parameters directly related to exploitation conditions such as the flow, minimal tensile at drive pulley out put and wrap angle(angle between the belt and the drive pulley).

Simulating tests of the developed equation of forces acting on the belt by changing operating conditions (inclination angle, load to vary input tenseness and output tenseness) were performed in Matlab Simulink environment.

The presented approach deals with the management of machine efficiency, control and monitoring of different and essential parts which leads to the improvement of system reliability to prevent system failure. In addition this will serves as experience return to program other systems (installations). It is also important to change inclination angle of belt conveyor β to show the effect of moving masses gravity (load, belt, etc…) and utilization rate of real traction factor of belt conveyor.

2. MATHEMATICAL MODEL DEVELOPMENT

Traction transmission effort of drive pulley to the belt is realized by adhesionasa result of friction produced in superficial areas of two corps maintained in contact accomplishing a motion in respect to each other in absence of lubricant.

Supposing, the elastic traction device is in motion on pulley surface, thus tensile in any separate section of the belt (dx) can be determined by the following equation:

$$\frac{dT}{dx} = F \times N \qquad (1)$$

Where,
dT-Tensile strength required for a section of the belt dx
F- Friction factor of the belt on the pulley
N- Normal specific pressure of the pulley on the belt daN/m.

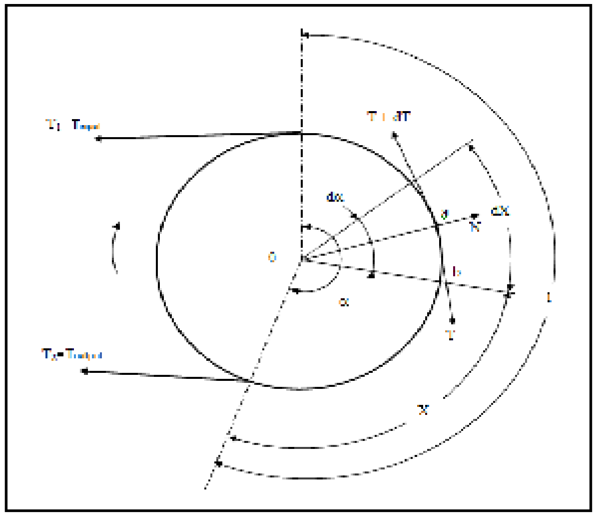

Figure.1.Belt drive pulley scheme

Normal specific force N can be determined by considering a small part of the belt dx, in front of angle dα as illustrated in Figure1.

$$\frac{T_1}{T_2} = \frac{T_{inp}}{T_{out}} = e^{f\alpha} \qquad (2)$$

This equation is obtained on the basis of Euler theory considering wire passing around the pulley where the ends are subjected to tensile T_1 and T_2.The wire mass is negligible, not extendible and doesn't present any resistance on the pulley and rotates in the opposite direction [13].The wrap angle(α) is the angle the belt making with drive pulley. When the traction factor design $e^{f\alpha}$ is equal to the ratio of input and output tensile, the operation is called operational regime at the boundary.

$$\frac{T_{inp}}{T_{out}} = e^{f\alpha} \qquad (3)$$

The presence of rest angle which corresponds to the belt when is not subjected to any effort, representing the normal operational regime. In Euler theory the boundary regime is when $\alpha_{rest} = 0$, thus in practice the existence of such angle is necessary to obtain an efficient transmission effort.
In the area where this angle exists, the tensile on the belt is usually constant in spite the variation of tensile at belt input as illustrated in Figure.2.

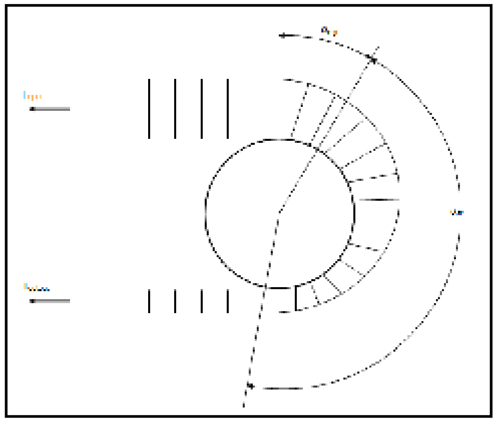

Figure.2. Tensile distribution on belt drive pulley

α_{ad} is the adhesion angle enabling to realize the real belt traction factor. The presence of rest angle (α_{rest}) (tensile is constant) means that the design traction factor is less than the ratio of input and output tensile leading to the following equation:

$$\frac{T_{inp}}{T_{out}} \langle \; e^{f\alpha} \qquad (4)$$

In general the belt conveyor is operating as follows:
As motor (belt conveyor in rising conditions)

$$\frac{T_{inp}}{T_{out}} \leq e^{f\alpha} \qquad (5)$$

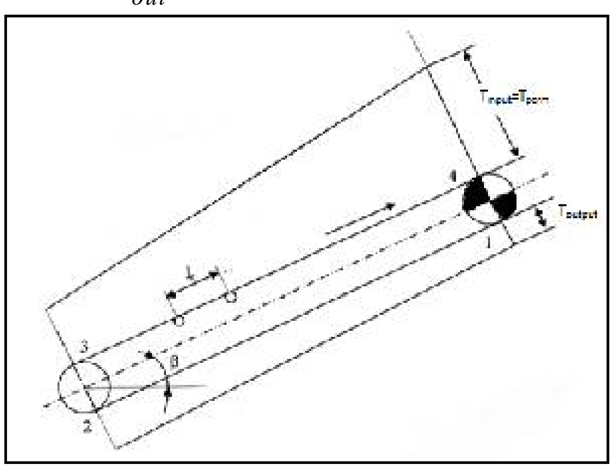

Figure.3. Belt conveyor tensile diagram

In these conditions, the load increase on the belt conveyor is limited by the design traction factor $e^{f\alpha}$ and when the input tensile increases for a given value, this equality will not be respected. Therefore, the belt will start slipping on the drive pulley.

In real operational conditions, the ratio (T_{inp}/T_{out}) as shown in Figure.3 represents the realization degree of traction capacity of the machine in respect to design characteristics. Thus, real traction factor depends on the resistance tomotion of carrying and return side, load, belt, bearing roller and transport distance. This factor is compared to the design factor which depends on the quality of pulley coating and wrap angle.
The relation representing braking regime is as follows:

$$\frac{T_{out}}{T_{inp}} \leq e^{f\alpha} \qquad (6)$$

During the braking regime, the belt becomes the driving element and any load increase will produce a decrease in the input tensile of belt conveyor and its use will always depend on the design traction factor $e^{f\alpha}$.

3. CONVEYOR TRACTION FORCE CAPACITIES ANALYSIS

On the basis of this theory, the possible traction factor to be realized can be determined for ascendant conveyors (a), to be compared to the design traction factor$e^{f\alpha}$. The pulley conveyor installed with inclination angle β, as illustrated in Figure.3 where:
L- The distance between carrying rollers; m
T_{min}- Minimal (input) tensile on the belt; daN
T_{perm}-Permissible tensile of the belt daN
The conveyor real traction factor is determined by considering the entire belt break, thus at point 4 Figure.3, the tensile is similar to the permissible tension (T_{adm}) as illustrated in the equation below.

$$T_{perm} = \frac{T_{rup}}{m} = \frac{\sigma_r \, i \, B}{m} \qquad (7)$$

T_{rup} -Belt tensile break, daN.
σ_r -Break specific strength, daN,
i- Beltp lies number,
m- Safety factor
B - Belt width, m
The output(minimal) tensile on point 3 is determined according the condition of the belt being tight.Thus, the following equation is obtained [13]:

$$T_{min} = T_3 = ((5 \div 10)(q_l + q_b)L_r \qquad (8)$$

q_l -load metric mass, Kg/m.
q_b -Belt metric mass, Kg/m.
L_r– distance between two carrying rollers, m
The coefficient taking in account operating conditions is ranging from 5 to 10 (opencast and underground mine) respectively.Thus, from Euler theory the real traction factor is as follows:

$$a = \frac{T_{inp}}{T_{out}} = \frac{T_4}{T_1} = \frac{T_{perm}}{T_{out}} \qquad (9)$$

If the permissible tensile is known, the tensile at the output (point 1) can be determined from the equations presented below.

$$T_i = T_{i-1} + W_{i \div i-1} \qquad (10)$$

$$T_2 = T_1 + W_{2-1} \Rightarrow T_1 = T_2 - W_{2-1} \qquad (11)$$

Similarly the same equation can be applied for carrying blade:

$$T_4 = T_{perm} = T_3 + W_{4-3}$$

$$T_3 = T_{min} = T_4 - W_{4-3} \qquad (12)$$

Equation (5) represents the equation of belt break point on the carrying side

$$W_{2\text{-}1} = W_{empty} = \omega_{empty} L \qquad (13)$$
$$W_{4\text{-}3} = W_{load} = \omega_{load} L \qquad (14)$$

Where, $W_{2\text{-}1}$ and $W_{4\text{-}3}$ (daN) - represent motion strength of return side and carrying side respectively; ω_{empty} and ω_{load} (daN/m)- specific strength corresponding to themotion. From equation (12), conveyor permissible length is deduced (L_{adm}) and can be written as follows:

$$L_{adm} = \frac{T_{perm} - T_{\min}}{\omega_{load}} \qquad (15)$$

Moreover, the difference in tensile between point 2 and 3 is expressed by the coefficient K [13] which takes in account the strength to movement of the belt on the return pulley

$$T_2 = T_3 / K = T_{\min} / K \qquad (16)$$

The tensile at the output (point 1) will be:

$$T_{out} = T_1 = T_{\min} / K - \frac{T_{perm} - T_{\min}}{\omega_{load}} \qquad (17)$$

The final equation of realized traction factor is written as follows:

$$a = \frac{T_{perm}\,\omega_{\text{load}}\,\text{K}}{\text{T}_{\min}\left(\omega_{load} + \text{K}\,\omega_{empty}\right) - \text{K}\,\omega_{\text{empty}}\,\text{T}_{\text{perm}}} \qquad (18)$$

It can be noticed that the parameters of this equation are constant excepting motion specific strengths (ω_{empty} and ω_{load}) which depend on belt metric mass, load, rollers and conveyor inclination angle.
Specific strengths to movement are expressed as follows:

$$\omega_{emptyv} = q_b\left[\left(C_2\ \text{W} \cos\beta \pm \sin\beta\right) + \text{C}_2\ \text{W}\ \text{q}_\text{r}''\right] \qquad (19)$$

$$\omega_{load} = \left(q_b + q_{load}\right)\left[\left(C_2\ \text{W} \cos\beta \pm \sin\beta\right) + \text{C}_2\ \text{W}\ \text{q}_\text{r}'\right] \qquad (20)$$

Where,

q'_r And q''_r : upper and lower rollers metric mass respectively, (kg/m)

C_2 : coefficient taking in account local strengths at any point

The coefficient ω expresses the strength to motion of conveyor carrying and return sides. In the equations (19), (20) the sign + is used for ascendant side and – is used for descendant side. Thus, it can be deduced that the dependence of specific strengths to motion is essentially related to conveyor load variation and its inclination angle β,whereas other parameters depend only on its design.
The inclination favors the gravity effect of moving masses (load, belt), giving directly the used rate of conveyor traction factor. To illustrate these hypotheses, considering a conveyor with nominal load, variable inclination (β = 0÷ 18°), break permissible force of the belt (belt designed with steel wire RTL-400) T_{perm} = 360 daN and a minimal tensile T_{min} = 65 daN.
The computation is carried out from the equations 18, 19, 20 and the curve of traction factor variation is plotted according to conveyor inclination angle, a=f (β) as illustrated in Figure.4.

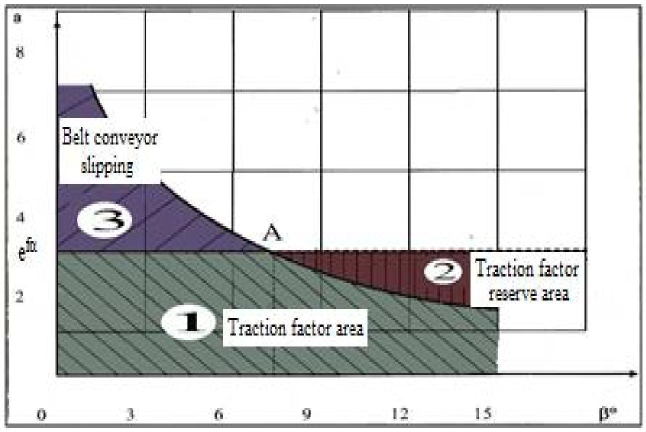

Figure.4. Real traction factor distribution

1. Traction factor area
2. Traction factor reserve area
3. Belt conveyor slip
   A. Optimum traction factor

From Figure.4, it can be observed that the ideal traction factor is obtained at the point A, representing the intersection of realized (a) and designed ($e^{f\alpha}$) traction factors. This corresponds to the ideal adhesion of the belt on the pulley. The area on the left of point A represents the traction factor when is fully used, beyond this slipping risk become higher (limits depend on design parameters). In contrast, on the right of point A, the limit is due to system adhesion parameters, where the gravity effect on the transported load is very important and in this case the slip risk is avoided.
In order to validate the developed model and show its effectiveness, computer simulation tests were conducted on two belt conveyors with different parameters as shown in table 1 and table 2.

4. COMPUTER SIMULATION AND EXPERIMENTS

Experimental tests were carried out to validate the developed model using computer simulation. In this part the traction factor variation in real conditions is observed with the entire rupture of the belt (T_{perm}=T_{max}) for two belt conveyors. A program of traction factor calculation is programmed according to conveyors inclination.
The main elements of this program are the equations of specific resistances of return side (empty) and carrying side (loaded) motion in which the effect of βon real traction factor (a) is introduced and considered as the most important element.This program enables to obtain curves of traction factor in relation to inclination angle with a possibility of varying the minimal tension, load and both simultaneously in order to simulate the conveyor real working conditions.
The developed program can be applied for any conveyor type under any conditions to test the machine in situ to improve its efficiency without the risk of damaging any element of the system (belt rupture, motor overheating).[14]

This program can also be applied to find reel traction factor of any system regardless the number of belt conveyor. Two belt conveying systems were taken as a case study with parameters illustrated in table 1 and table 2 presented below.

Table.1. Conveyors characteristics

Parameters	conveyor1	conveyor 2
Belt width (m)	1000	1200
Safety factor	4	4
Production (m^3/min)	13,7	25
Calculated production (t/h)	500	1200
Maximal transporting distance(m)	1140	2300
belt Speed (m/s)	2	2,5
Maximum motor power(KW)	500	500
Motor drum number	1	2
Belt permissible tension(Kg)	13000	18000
Belt metric mass (Kg/m)	16	30

Table.2.Conveyors parameters obtained by calculation

Parameters	conveyor 1	conveyor 2
Load metric mass(Kg/m)	69,44	133,33
Minimal tension (daN)	512,64	979,98
Metric mass of upper rollers (Kg/m)	24	27,06
Metric mass of lower rollers (Kg/m)	7,33	8,26

5. RESULTS AND DISCUSSION

Tests were conducted on three different operating conditions as illustrated in the curves below. The results of the first tested belt conveyor

- The obtained results of the first tested belt conveyors when the minimal tension is varied are plotted in Figure.5.a

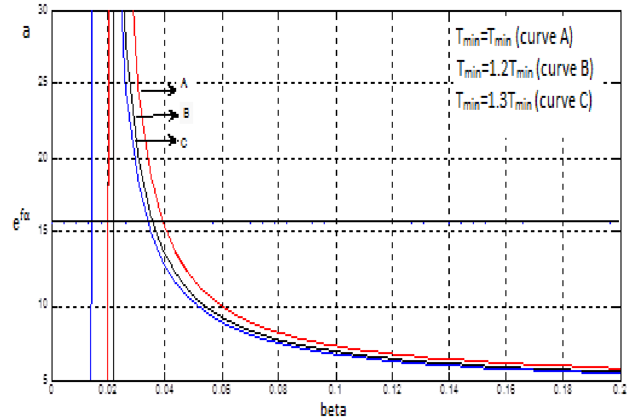

Figure.5.a. Curves obtained when minimal (output) tensile is varied

- The obtained results of the belt conveyors with loadvariation are plotted in Figure.5.b

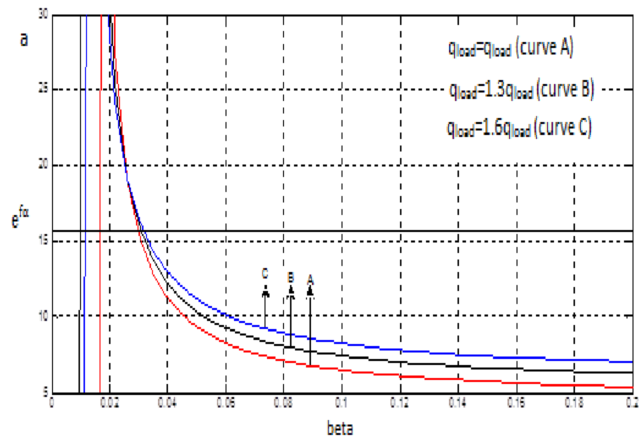

Figure.5.b. Curves obtained when the load is varied

The obtained results of the belt conveyors when the minimal (output) tensile and the load are varied simultaneously are plotted in Figure.5.c.

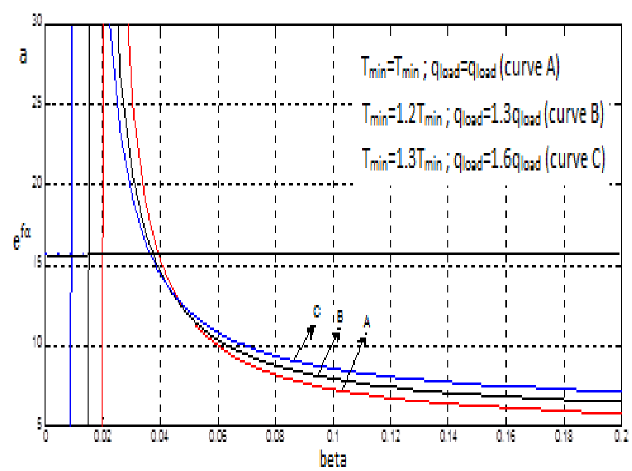

Figure.5.c. Curves obtained when the load and minimal (output) tensile are varied simultaneously

The results of the second tested belt conveyor

- The obtained results of the second tested belt conveyors when the minimal (output) tensile is varied are plotted in Figure.6.a

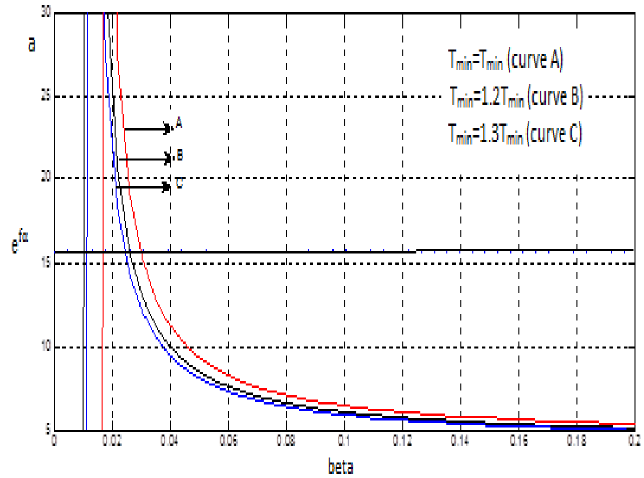

Figure.6.a. Curves obtained when minimal (output) tensile is varied

- The obtained results of the belt conveyors with load variation are plotted in Figure.6.b.

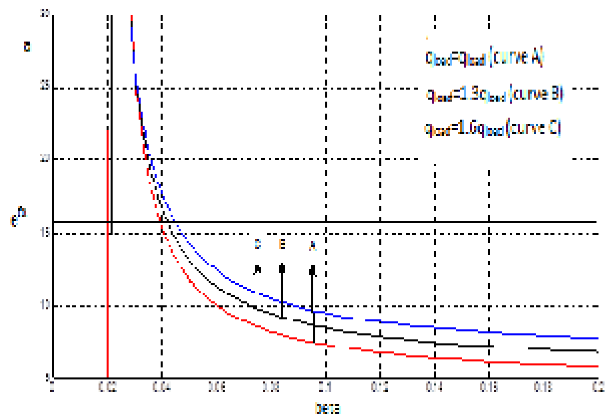

Figure.6.b. Curves obtained when the load is varied

- The obtained results of the belt conveyors when the minimal (output) tensile and the load are varied simultaneously are plotted in Figure.6.c.

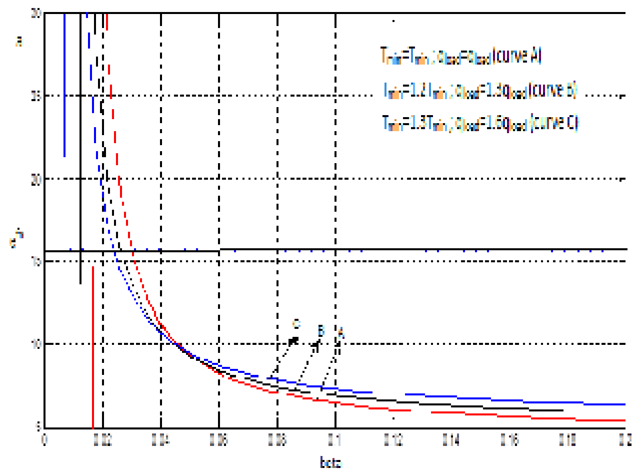

Figure.6.c. Curves obtained when the load and minimal (output) tensile are varied simultaneously

The minimal (output) tensile obtained in both cases by calculation have developed an important area of slipping risk Figure.5.a and Figure.6.a, with a possibility of belt rupture. Therefore, the increase in the minimal (output) tensile of conveyors has led to a significant increase in the reserve area of traction forces and a decrease in the area of slipping risk due to diminution of dynamic forces amplitudes which are the main cause of fatigue, wear and belt rupture.

Generally, when minimal (output) tensile at belt conveyors drive pulleys output increase, balance between the area of real traction factor and that of design traction factor is achieved.

Increasing by 20% the tensile at the output of the first conveyor drive pulley, more important dynamic amplitudes with higher slipping risk will appear on conveyor 1 because the permissible tensile of conveyor 2 is higher. Slipping risks always exist for conveyor 1 in contrast; they have disappeared in the case of conveyor 2.It can be concluded that the increase of output tensile affect essentially the slipping risk where a substantial reduction is noticed, its influence on consumed reserves still significant but at an acceptable level.

In the second series of tests, the load is varied and the minimal (output)tensile is maintained constant Figure.5.b and Figure.6.b.A slight increase in the reserve area of real traction factor is followed by a decrease the area representing conveyor designed traction factor. Thus, an improvement in the machine efficiency followed by a slight reduction in the slipping risk and belt rupture is observed for both cases. The conveyor 2 has a better response to load increase because its belt permissible tensile is higher.

In the final test, the minimal tension and the load are increased simultaneously Figure.5.c and Figure.6.c. The main objective of increasing progressively these two parameters is to enhance the machine exploitation limits (production improvement) and consume the belt elasticity limits.

From the obtained results the following conclusions can be drawn:

- Increasing the degree of real traction factor
- Progressive disappearance of slip risk zone for the two conveyors (a complete disappearance for the second conveyor is reached because the permissible tension can allow it).
- The physical process is respected when acting on load and minimal tension but it is impossible to increase the load beyond a certain limit because all parameters depend on machine design, belt dimensions and motor power.

6. CONCLUSION

The developed mathematical model of traction factor of belt conveyor is shown to be an important tool to carry out the simulation of the machine operation in various conditions related to its exploitation or elastic capacities and rigidity of its working elements. Minimal (output) tensile variation and control at the output of drive pulleyenables the machine to operate without any slip risk. The load capacity is limited by the

machine design and motor power. Therefore, any increase in the load within belt characteristics will improve the machine efficiency and company production.
When minimal (output)tensile is rising up, the slip risk decreases considerably, the area of traction reserves increases the real traction factor. Thus, increasing conveyor flow, the area of slip risk rises slightly but the real traction factor increases considerably.
In conclusion, it is necessary to adopt a mean that enabling the variation and the control of tensile and conveyor flow simultaneously in order to reduce slip risk, prevent failures, and increasing significantly traction capacities.

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REFERENCES

[1] Suweken G., VanHorssen W. T., 2003 On the Weakly Nonlinear, Transversal Vibrations of a Conveyor Belt with a Low and Time- Varying Velocity, Nonlinear Dynamics vol.31,197–223

[2] Dalgleish AZ., Grobler L., 2003.Measurement and verification of a motor sequencing controller on a conveyor belt, Energy, Elsevier, vol 28, 913–927.

[3] You-fu H., Meng Q., 2008. Dynamic characteristics of conveyor belts, Journal of china University of Mining and Technology, Elsevier, vol 18, 0629–0633.

[4] Nuttall A.J.G., Lodewijks G., 2006.Traction versus slip in a wheel-driven belt conveyor, Mechanism and Machine Theory, Elsevier, vol 41, 1336–1345.

[5] Zanoelo E.F., Abitante A., Meleiro L.A.C., 2008. Dynamic modeling and feedback control for conveyors-belt dryers of mate leaves, Journal of Food Engineering, Elsevier, Vol. 84,458–468.

[6] Fang-wei X., You-fu H.,Zhi-Peng X., Rui Z.,2009. Fuzzy-immune control strategy of a hydro-viscous soft start device of a belt conveyor, Mining Science and Technology, Elsevier, Vol.19 ,544–548.

[7] Kiranoudis C.T., Markatos N.C., 2000.Pareto design of conveyor-belt dryers, Journal of Food Engineering, Elsevier, Vol. 46,145-155.

[8] Kobayashi Y., Toya K., 2007. Effect of belt transport speed and other factors on belt mistracking, Microsystems Technologies, Springer, Vol. 13, 1325–1330.

[9] You-fu H., Fangwei X., Huang –F., 2011. Control strategy of disc braking systems for downward belt conveyors, Mining Science and Technology (China), Elsevier, Vol.21, 491–494.

[10] Shirong Z., Xiaohua X., 2010.Optimal control of operation efficiency of belt conveyor systems, Applied Energy, Elsevier, Vol 87, pp 1929–1937.

[11] Shirong Z., Xiaohua X., 2011 modeling and energy efficiency optimization of belt conveyors, Applied Energy, Elsevier, Vol. 88, 3061–3071.

[12] De Almeida T A., Fonseca P., 2003 Bertoldi P., 2003. Energy-efficient motor systems in the industrial and in the services sectors in the European Union: characterisation, potentials, barriers and policies, Energy, Elsevier, Vol. 28,673–690,

[13] Tchevonienko A., Razdolski A., Zabolotni Yu., 1983.Dynamics of belt conveyors, Ed, Naouka-Doumka, Kiev, Page 192 (In Rassian).

[14] Daiji. H, Yosong .P, Lodewijks .G. 2016. Speed control of belt conveyors during transient operation, powder Technology, Elsevier, Vol. 301, 622-631.

NOMENCLATURE

dT - traction force required for the considered dx element
F- Friction factor on the pulley
N- Normal specific pressure of the pulley on the belt, daN/m
T_1- Input tensile, daN
T_2- Ouput tensile, daN
α_{ad} - Adhesion, (degree)
α_{rest}- Rest angle, (degree)
L- The distance between carrying rollers, m
T_{min}- Minimal (input) tensile on the belt, daN
T_{perm}-Permissible tensile of the belt, daN
T_{rup} - Belt tensile break, daN.
σ_r - Break specific strength, daN.
i - Belt plies number
m - Safety factor
B - belt width, m
q_l - load metric mass, Kg/m
q_b -belt metric mass, Kg/m
L_r-distance between two carrying rollers, m
$W_{2\text{-}1}$- Motion of return side, daN
$W_{4\text{-}3}$ - Motion strength carrying side, daN
ω_{empty} - specific strength of return side, daN/m
ω_{load}- specific strength of carrying side, daN/m
L_{adm}- Admissible length, m
L_{perm} - Permissible length, m
q'_r, q''_r - Upper and lower rollers metric mass respectively, kg/m
C_2 - Coefficient taking in account local strengths at any point
ω - Coefficient expressing the strength to motion of conveyor carrying and return sides
a - Real traction factor
β - Inclination angle of belt conveyor, degree
$e^{f\alpha}$ - Design traction factor