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Design And Energy Optimization Of Z-Type Chain Conveyor

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ABSTRACT

Conveyor equipment selection is a complex, and sometimes, tedious task since there are literally hundreds of equipment types and manufacturers to choose from. From the variety of conveyors the selection of ZCs is because it provides fast, efficient, convenient and safe access to/from mezzanines, balconies, basements, and between levels in multiple story buildings. They can be installed for through-floor, interior or exterior applications. In this paper the design and energy efficiency of Z Conveyor is done. The improvement of the energy efficiency of chain conveyor systems can be achieved at equipment and operation levels. This paper intends to take a model based optimization approach to improve the efficiency of chain conveyors at the operational level. An analytical energy model, originating from ISO 5048, is firstly proposed, which lumps all the parameters into four coefficients. Subsequently, both an off-line and an on-line parameter estimation schemes are applied to identify the new energy model, respectively.

Keywords – Energy model, Energy optimization, Material plough, Resistance model.

1. INTRODUCTION

Conveyors are defined as fixed and portable devices used for transporting materials between two fixed points, through intermittent or continuous movement. They are usually employed where the workflow is relatively constant. If the path for the flow of material is fixed then the provision of the conveyors at suitable level eliminates a good deal of lifting and lowering of material. Conveyors are continuous in operation, in this operation the transportation of materials is effected by friction between materials being transported by the chain. These conveyors have the advantage that they largely save labour cost, but have disadvantage that take up considerable space, are relatively fixed and in most cases the investment cost is high.

Material handling is an important sector of industry, which is consuming a considerable proportion of the total power supply. For instance, material handling contributes about 10% of the total Maximum demand in South Africa [1]. Chain conveyors are being employed to form the most important parts of material handling systems because of their high efficiency of transportation. It is significant to reduce the energy consumption or energy cost of material handling sector. This task accordingly depends on the improvement of the energy efficiency of chain conveyors, for they are the main energy consuming components of material handling systems. Consequently, energy efficiency becomes one of the development focuses of the chain conveyor technology [2].

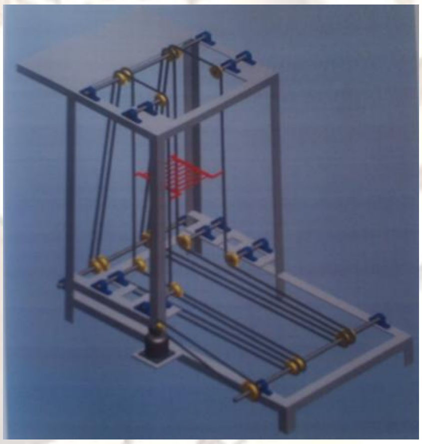

Fig.1

A chain conveyor is a typical energy conversion system from electrical energy to mechanical energy. Its energy efficiency can generally be improved at four levels: performance, operation, equipment, and technology [3]. However, the majority of the technical literature concerning the energy efficiency of chain conveyors focuses on the operational level and the equipment level. In practice, the improvement of equipment efficiency of chain conveyors is achieved mainly by introducing highly efficient equipment. The idler, chain and drive system are the main targets. In [4], the influences on idlers from design, assembly, lubrication, bearing seals, and maintenance are reviewed. Energy saving idlers is proposed and tested in [5, 6]. Energy optimized chains are developed in [7] by improving the structure of the chains.

2. DESIGN AND ASSEMBLY OF Z-TYPE CHAIN CONVEYOR:

Stage1: Selection of Motor and Shaft:
Material of the shaft is Mild Steel, MS C-45 and $d_s =$ dia of shaft

Load of motor W

Linear velocity (v) = πDN/60

D = Dia of sprocket = P/sin (180/z_1)

$Z_1 =$ No. of teeth on sprocket

P = Pitch

Design load (wd) = w × s.f

Power of motor (PM) = wd×v/60×η

Assume: η = 85% = 0.85

Selecting std motor power (PM) = 1hp,110 rpm and single phase A.C.motor.

Stage 2: Selection of Bearing:
Span of bearing = T hrs, Dia of shaft = ds,

Speed of shaft, N rpm

Life of bearing in Lmr:-

$Lmr= T×60×N/ 10^6$

Calculation of equivalent load on bearing, Pe:-

$Pe = (x× F_r + yF_a)\ s_{kt}$

e is eccentricity for deep groove ball bearing
As $Fa/F_r < e$

x =1, y = 0

Load life relationship,c

$C= (Lmr)^{1/k}×P_e$

Stage 3: Design of Tray:
Material of rod C-3

Let us select rod dia d= check for bending failure of rod w= load of tray

Now bending stress = bending moment on the tray/ polar moment of inertia * no.of rods

$\sigma_b= M_b/z×n$

$M_b = wl/4$ l= length of rod

Stage 4: Selection of Chain:
Power to be transmitted P1

Assuming service factor,s

Design power [P] = P1*s

Z1 No. of teeth on i/p input sprocket

Z2 No.of teeth on o/p sprocket

Stage 5: Selection of Pitch of Chain
Input sprocket diameter d1:-

$d_1 = \frac{P}{Sin180/z1}$ P- pitch of the chain

Output sprocket diameter d_2:-

$d_2 = \frac{P}{Sin\ 180/Z_2}$

Velocity of Chain:-
Avg velocity of chain is given by $V = P\ N_1\ Z_1 / 60,000$ and N1, input speed in rpm
Breaking load, Q is calculated as: -

$N = QV/102\ n*K_s$ n-allowable factor of safety and Ks is product of all different factors

2.1 Chain available R-940 R-957
Based on breaking load for safer side selecting R-957

. Table 1:- Chain Details

ISO/dim	Rolon	Pitch mm	Roller Dia mm	Bravery Area cm^2	Wt/m	Breaking load kgf
06B-1	R-957	9.525	6.35	0.28	0.41	910

3.RESISTANCE BASED ENERGY MODELS:

The existing energy calculation is based on the methodology of resistance energy models, in which energy consumption is mainly determined through the calculation of the resistances to the motion of chain conveyor. In this methodology, the motion resistances is divided into four groups: the main resistance, F_H, the secondary resistance, Fn, the slope resistance, Fst, and the special resistance, F_S.The peripheral driving force, F_U, required on the driving sprocket(s) of a chain conveyor is obtained by adding up the four groups as follows:

$F_U = F_H + Fn + Fst + Fs$
(1)

When F_U is obtained, the mechanical power of a chain conveyor is obtained by

$PT = F_U * V$
(2)

where V is the chain speed in meters per second. Then the power of the motor is PM = PT/η, where η is the overall efficiency of the driving system. Now, the energy calculation is cast to the calculation of the four groups of resistances. The main resistance is calculated by

$F_H = fLg[Q_{RO} + Q_{RU} + (2Q_B + Q_G)\cos\delta]$
(3)

where f is the artificial friction factor, L is the center-to-center distance(m), Q_{R0} is the unit mass of the rotating parts of carrying idler rollers (kg/m), as shown in Fig. 1, Q_{RU} is the unit mass of rotating parts of the return idler rollers (kg/m), Q_B is the unit mass of the chain(kg/m), d is the inclination angle (^{o}), and QG is the unit mass of the load (kg/m). Further, QG is determined by QG T/3.6V, where T is the feed rate of the chain conveyor (t/h). Eq. (3) is a simplified form of the main resistance suitable for engineering application, while proposes a non-linear model of the main resistance, which is more complicated. The secondary resistance, is further divided into four parts: the inertia and frictional resistance at the loading point and in the acceleration area between the material and the chain, F_{BA}, the frictional resistance between the skirt boards and the material in the accelerating area, F_F, the wrap resistance between the chain and sprocket and the sprocket, Fw, and the sprocket bearing resistance, Ft. Similarly, the special resistance is further divided into four parts: the resistance due to idler tilting, F_{FR}, the resistance due to friction between the material handled and the skirt boards, Fsb, the frictional resistance due to the chain cleaners, Fc, and the resistance from the material ploughs, Fp. Accordingly, provide the detailed equations for each part of the secondary resistance and the special resistance. The slope resistance is resulted from the elevation of the material on inclined conveyors. It can be accurately calculated by Fst = QGHg, where H is the net change in elevation (m).

4. REMARKS ON THE EXISTING MODELS:

The resistance based models consider almost all the issues contributing to the energy consumption, thus they are believed to be more accurate. Correspondingly, complicated equations, along with many detailed parameters, are needed for the calculation of these issues. It leads to complexity of calculation. On the other hand, the energy conversion based models simplify the calculation by integrating the compensation length constant(s) into the models. Because these models use one or a few constants to compensate all the cases, their accuracy is usually compromised. Furthermore, all these existing models use the design parameters to calculate the power of chain conveyors. When they are applied to practical condition, large difference of energy calculation will be generated because the practical operation condition always deviates from the design one.

5. AN ANALYTICAL ENERGY MODEL:

An analytical energy model is proposed here to meet the requirement of energy optimization. It has its root in ISO 5048 [8], however, its analytical form makes it suitable for parameter estimation and energy optimization. According to ISO 5048 the secondary resistance of a chain conveyor is obtained from four parts as follows:

$Fn = F_{BA} + F_F + Fw + Ft$
(4)

Ft is relatively small, hence it can be omitted. Fw is also small and does not vary much, so it is taken as a constant, C_{ft}. If the initial speed of material in the direction of chain movement is taken as zero and the frictional factor between the material and the chain is taken as the same as that between the material and the skirt boards [9],F_{BA} and F_F can be obtained through the following two equations, respectively.

$F_{BA} = TV/3.6$
(5)

$F_F = T^2/6.48\ b_1^2\rho$
(6)

where ρ is the bulk density of material (kg/m3), and b_1 is the width between the skirt boards (m). Now, F_N can be rewritten as follows

$Fn = TV/3.6 + T^2/6.48\rho b_1^2 + C_{Ft}$
(7)

The special resistances, Fs, for an existing chain conveyor, including F_{FR}, Fsb, Fc and Fp has the following relation with T and V

$Fs = k_1T^2/V^2 + k_2\ T/V + k_3$
(8)

where k1, k2, and k3 are constant coefficients which relate to the structural parameters of the chain conveyor.

Combining (3), (7) and (8), and $F_{st} = Q_g\ H_g$ with (2), we get

$P_T = V^2T/3.6 + VT^2/6.28\rho b_1^2 +$ (9)

$\{gfQ[L\cos\delta + (1-\cos\delta)(1-2Q_B/Q)] + k_3 + C_{ft}\}V$

$+ k_1T^2/V + (gL\sin\delta + gfL\cos\delta/3.6 + k_2)V.$

Further, let

$\theta_1 = 1/6.48b_1^2\rho,$ (10)

$\theta_2 = gfQ[L\cos\delta + L(1-\cos\delta)(1-2Q_B/Q)] + k_3 + C_{Ft},$

$\theta_3 = k1,$

$\theta_4 = (gL\sin\delta + gfL\cos\delta)/3.6 + k_2,$

we get the analytical energy model of a chain conveyor as follows

$P_T - V^2T/3.6 = \theta_1T^2V + \theta_{2+}\theta_3T^2/V + \theta_4T$ (11)

θ_1, θ_2, θ_3 and θ_4 are determined by the structural parameters and components of a chain conveyor, by the operation circumstance and by the characteristic of the material handled; therefore, they are relatively constant for a certain chain conveyor. Because (11) originates from ISO 5048, it can be used for design purpose as well, where θ_1, θ_2, θ_3 and θ_4 are derived from design parameters.

6. CONCLUSION:

The Z type chain conveyor was designed successfully for a load of 50kg and energy efficiency model was developed based on resistance energy model from ISO 5048. The new model was formed by lumping all parameters into four coefficients and is suitable for parameter optimization and estimation. As chain conveyors consume considerable part of total energy supplied, this model guarantees accuaracy in energy model therby optimizing energy of chain conveyors. The four coefficients of the new model can be derived from the design parameters or be estimated through field experiments. The proposed energy model is used for operation efficiency optimization of a conveying system with a belt conveyor.

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