ANALYSIS OF BELT TENSIONS AT VARIOUS POINTS ALONG CONVEYOR PATH AND POWER REQUIREMENT FOR BELT CONVEYOR

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Abstract: In the process or manufacturing industry, raw materials and products need to be transported from one manufacturing stage to another. Material handling equipment are designed such that they facilitate easy, cheap, fast and safe loading and unloading with least human interference. For instance, belt conveyor system can be employed for easy handling of materials beyond human capacity in terms of weight and height. Belt conveyor has high load carrying capacity, large length of conveying path, simple design, easy maintenance and high reliability of operation. Belt Conveyor system is also used in material transport in foundry shop like supply and distribution of molding sand, molds and removal of waste. Analysis of belt tensions ensures system reliability and operators safety. This paper discuss about analysis of belt tensions at various points along conveyor path and power requirement for belt conveyor. This designed structure can be used for failure analysis of belt conveyor system. The successful completion of this research work has generated design data for industrial uses in the development of an automated belt conveyor system which is fast, safe and efficient.
Index Terms—Material handling, Belt conveyor, Belt tension Analysis, Safety

I. INTRODUCTION

Material handling equipments are used to move loads in industries or plants, ports, construction sites, mines, stones etc. It is important to understand that, transferring of load is not only to shift the load from one place to another but also includes loading and unloading. Conveyor system is a mechanical system used in moving materials from one place to another and finds application in most processing and manufacturing industries such as: chemical, mechanical, automotive, mineral, pharmaceutical, electronics etc.

All lifting and conveying machines can be divided by their operating principles into two large groups: (i) Intermittent motion, (ii) Continuous motion Intermittent motion includes all types of cranes, lifts; surface transport means (trucks, loaders, prime movers), aerial tramways and cable ways, scrappers and the like. Continuous motion includes conveyors, pneumatic and hydraulic transport means etc. which may generally called continuous transport machines or conveying machines. It is easier, safer, faster, more efficient and cheaper to transport materials from one processing stage to another with the aid of material handling equipment devoid of manual handling. Handling of materials which is an important factor in manufacturing is an integral part of facilities design and the efficiency of material handling equipment add to the performance level of a firm. Conveyor systems are durable and reliable in materials transportation and warehousing. Based on different principles of operation, there are different conveyor systems namely: gravity, belt, screw, bucket, vibrating, pneumatic/hydraulic, chain, spiral, grain conveyor systems etc. The choice however depends on the volume to be transported, speed of transportation, size and weight of materials to be transported, height or distance of transportation, nature of material, method of production employed. Material handling equipment ranges from those that are operated manually to semi-automatic systems and to the ones with high degree of automation. The degree of automation however depends on handling requirements. Material handling involves movement of material in a manufacturing section. It includes loading, moving and unloading of materials from one stage of manufacturing process to another. A belt conveyor consists of an endless and flexible belt of high strength with two end pulleys (driver and driven) at fixed positions supported by rollers. The peculiarities of a belt conveyor is that it is easy and cheap to maintain, it has high loading and unloading capacity and can transport dense materials economically and at very high efficiency over long distance allowing relative movement of material. Belt conveyor can also be used for diverse materials: abrasive, wet, dry, sticky or dirty material. Only a single roller needs to be powered by driver pulley and the roller will constantly spin causing the materials to be propelled by the driving roller. Material handling equipment such as belt conveyors are designed to load and unload materials from one stage of processing to another in the fastest, smoothest, most judicious, safest, and most economical way with minimum spillage. Belt conveyors are employed for conveying various bulk and unit loads along horizontal or slightly inclined paths and for transporting articles between various operations in production flow lines.

Terminology Of Belt Conveyor System

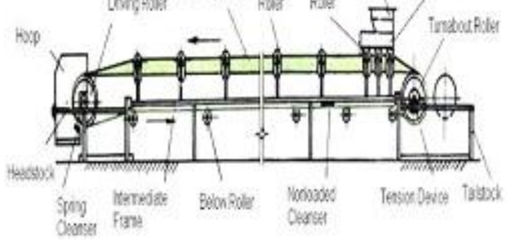

Fig 1: Belt Conveyor System

Belt: it is a flexible band placed around two or more pulleys for the purpose of transmitting motion, power or materials from one point to another.

Belt scraper: it is blade or brush caused to bear against the moving conveyor belt for the purpose of removing material sticking to the conveyor belt.

Crowned pulley: it is a pulley which tapers equally from both ends towards the centre, the diameter being greatest at center.

Feeder: It is a conveyor adapted to control the rate of delivery of packages or objects.

Flow: It is a device positioned across the path of a conveyor at the correct angle to discharge or deflect objects.

Return idler: it is roller which supports return run of belt.
Roller: It is round part free to revolute about its outer surface.

Snub pulley: It is a roller or pulley used to increase the arc of contact between a belt and drive pulley.

Angle of surcharge: It is the angle measured with respect to the horizontal plane of the surface of material being conveyed by moving a belt. It is normally between 5^0 to 20^0.

Angle of repose: It is the angle which the surface of a normal freely formed pile of the material makes with the horizontal.

Take-up or tension device: It is the assembly of the necessary structural and mechanical parts which provide the means to adjust the length of belt and chain to compensate for stretch, shrinkage or wear and to maintain proper tension.

Notation used
F_L= resistance at loading
K_{clean}= cleaning factor
F_{CL}= frictional resistance
$€_P$= snub factor
F_P= frictional resistance at pulley
M= capacity of conveyor
V= Belt Speed
$V_{i=}$ component of incoming material velocity
B= belt width
F_m= load resistance due to lifting of materials.
F_{cr}= frictional resistance due to carrying run idlers.
F_{rr}= frictional resistance due to return run idlers.
f_c= friction factor for idlers.
m_m= material carried by conveyor per unit belt length
m_b= mass of belt
m_{ci}= mass of carrying run idler
Z_c= Number of carrying run idlers
Z_r= Number of return run idlers
F_{slack}= tension in slack side
F_{tight}= tension in tight side

SELECTION OF IMPORTANT FACTORS BEFORE ANALYSIS;

SURCHARGE FACTOR

ANGLE OF REPOSE (Ψ)	SURCHAEGE FACTOR (C)	
15^0 to 20^0	0.067 to 0.09	Flat belt
15^0 to 20^0	0.125 to 0.15	2 Idler
15^0 to 20^0	0.13 to 0.16	3Idler
15^0 to 20^0	0.15 to 0.18	
15^0 to 20^0	0.16 to 0.185	5 Idler
15^0 to 20^0	0.165 to 0.19	

Table 1: Selection Of Surcharge Factor

II. FLOWABILITY FACTOR

Belt type	Inclination belt(ά)	Flowability Factor(k)* 10^{-4}
plain	10^0 to 15^0 16^0 to 20^0	2.65 2.5
cleated	21^0 to 25^0 $26\ ^0$ to 30^0	2.35 2.2

Table 2: Selection Of Flowability Factor

III. SNUB FACTOR

Contact angle θ	Snub Factor **€**
For $\theta < 90^0$	0.02 to 0.03
$90^0 < \theta < 180^0$	0.03 to 0.04
For $180^0 < \theta$	0.05 to 0.06

Table 3: Selection Of Snub Factor

Analysis of Belt Tensions At Various Points Along Conveyor Path.

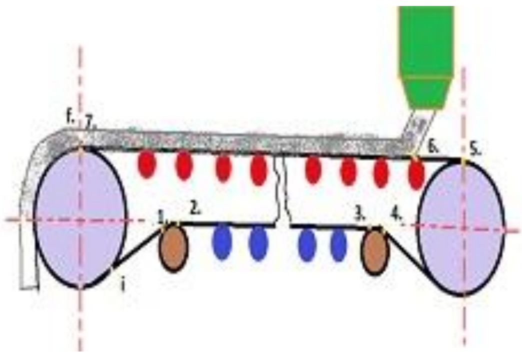

Fig 2: Analysis Of Belt Tension

The total resisting force acting on the conveyor belt and the belt tensions at various points along the conveyor path can be found by dividing the conveyor belt in to number of sections. Fig shows the layout of the typical belt conveyors. The belt tension at every succeeding point is equal to the belt tension at the preceding point plus the resisting force in that section between the two points.

The analysis starts from the point where belt leaves the drive pulley which is called as initial point. And ends at final point.
At initial point
$F_i = F_{slack}$

At point 1
$F_1 = F_{slack} + F_{CL}$
$F_1 = F_{slack} + K_{clean} * g * B$

At point 2
$F_2 = F_1 + F_{P1}$
$F_2 = F_1 + €_P * F_1$
$F_2 = F_{1*}(1 + €_P)$

At point 3
$F_3 = F_2 + F_{rr}$
Where,

$F_{rr} = f_c(m_b + ((m_b * Z_r)/l_r)) * g * l_r$

At point 4
$F_4 = F_3 + F_{P2}$
$F_4 = F_3 + €_P * F_3$
$F_4 = F_{3*}(1 + €_P)$

At point 5
$F_5 = F_4 + F_{P3}$
$F_5 = F_4 + €_P * F_4$
$F_5 = F_{4*}(1 + €_P)$

At point 6
$F_6 = F_5 + F_L$
$F_6 = F_5 + M(V - V_i)$

At point 7:
$F_7 = F_6 + F_{cr} + F_m$

Where,
$F_{cr} = f_c(m_m + m_b + ((m_{ci} * Z_c)/l)) * g * l$
$F_m = m_m * g * h$

At final point:
$F_{tight} = F_7 + F_{P4} + F_U$
$F_{tight} = F_7 + €_P * F_7 + 3.5 * m_m * g * B$

Note: Resistance due to unloading station will exist only when the unloading device is placed. For natural unloading $F_U = 0$.

Power requirement for belt conveyor
At final point we will get, the effective tension in tight side of drive pulley as,
$F_{tight} = X * F_{slack} + Y$
For drive pulley,
$F_{tight} / F_{slack} = e^{\mu\theta}$
Where,
μ= coefficient of friction between belt and drive pulley
θ= Angle of lap on drive pulley in radians.
Power required on drive pulley is,
$P_0 = (F_{tight} - F_{slack}) * V$, watts.
Input power to the conveyor belt is,
$P_i = P_0 / \dot{\eta}$
Where,
$\dot{\eta}$= Efficiency of the drive.

IV. CONCLUSION
The construction of a belt conveyor system requires high capital base. This is a major constraint that limits this work to design only and as such performance evaluation cannot be carried out on the belt conveyor system. However, the research work provides design data for development of belt conveyor system for industrial uses. The components like different types of pulleys namely drive pulley, tail pulley, pressure pulley, snub pulley and hold down pulley etc., carrying and return idlers, frame structures, and columns were manufactured successfully with the required dimensions and also from motor speed, power required, diameter of pulley, diameter of shaft the horizontal foot mounted PBL type geared motor and foot mounted Elecon type gear box was procured from manufacturer's organization. The above given process can be used for analysis of belt tensions at various points along conveyor path. And to find out the power requirement for conveyor system having particular material handling capacity.

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