

Experimental Analysis And Optimization Of Inclined Belt Conveyor

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ABSTRACT: Conveyor belt is an equipment for material handling which is widely used in industrial and domestic application. The experimental setup of inclined belt conveyor is made with the help of lead screw mechanism. Effective belt pull can be determined by simple equations and from that the transmitted power and power for different angle of belt can also determined. optimization of the belt conveyor is done with three different cases.

KEYWORDS: optimization, effective belt pull of conveyor belt

I. INTRODUCTION

Material handling is the art and science of involving the movements, packaging and storing the substances in any form. Material handling is concerned with:

- (i) Movement: material handling involves movements of material manually or mechanically in batches or one by one within the plant. Movement may be horizontal or verticals. Primary concern of engineer is to find out most efficient manner how to reach materials to operator.
- (ii) Time: materials must arrive at its place at right time. Material handling must ensure that no production process is hampered due to late or early arrival of materials.
- (iii) Quantity: material handling must ensure that each location continually receives that right quantity of materials or finished products.
- (iv) Space: space requirements are influenced by material handling flow pattern. Space is required for storage of raw materials.

Primitive conveyor belts were used since the 19th century. In 1892, Thomas Robins began a series of inventions which led to the development of a conveyor belt used for carrying coal, ores and other products. In 1901, Sandvik invented and started the production of steel conveyor belts. In 1905 Richard Sutcliffe invented the first conveyor belts for use in coal mines which revolutionized the mining industry. In 1913, Henry Ford introduced conveyor-belt assembly lines at Ford Motor Company's Highland Park, Michigan factory [2]. In 1972, the French society REI created in New Caledonia the then longest straight-belt conveyor in the world, at a length of 13.8 km. Hyacinthe Marcel Bocchetti was the concept designer. In 1957, the B. F. Goodrich Company patented a conveyor belt that it went on to produce as the Turnover Conveyor Belt System. Incorporating a half-twist, it had the advantage over conventional belts of a longer life because it could expose all of its surface area to wear and tear. Mobius strip belts are no longer manufactured because untwisted modern belts can be made more durable by constructing them from several layers of different materials. In 1970, Intralox, a Louisiana based company, registered the first patent for all plastic, modular belting.

Belt conveyors are the most common form of material handling equipment system used in manufacturing and mining industry, thermal plants and in construction projects. Heavy industries like steel, fertilizer, chemical and cement etc. cannot function without belt conveyor [4]. In construction projects the belt conveyors are used for handling the materials in asphalt plants. Crushing and screening plants, aggregate mixing plants etc. In coal mining and other mining industries, these are used for handling of coal of other raw material. The belt conveyors are capable of conveying large quantities of material continuously over considerably long distances at a fast speed.

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A belt conveyor is a typical energy conversion system from electrical energy to mechanical energy. Its energy efficiency can be divided into four components: performance efficiency, operation efficiency, equipment efficiency, and technology efficiency. The improvement of energy efficiency can easily put to the operation efficiency and equipment efficiency for most energy systems [3]. It holds true for belt conveyors. It is also noted that equipment efficiency, and consequently operation efficiency, decides performance efficiency which is usually reflected by various external indicators, such as energy consumption, energy cost, or emission of greenhouse gas. On the other hand, a performance indicator can drive an operation in the optimal efficiency mode [5].

II. MATERIALS AND METHODS

The material used for belts and ropes must be strong, flexible, and durable. It must have a high coefficient of friction. The belts, according to the material used, are classified as follows:

1. Leather belts. The most important material for flat belt is leather. The best leather belts are made from 1.2 meters to 1.5 meters long strips cut from either side of the back bone of the top grade steer hides. The hair side of the leather is smoother and harder than the flesh side, but the flesh side is stronger. The fibers on the hair side are perpendicular to the surface, while those on the flesh side are interwoven and parallel to the surface. Therefore for these reasons the hair side of a belt should be in contact with the pulley surface. This gives a more intimate contact between belt and pulley and places the greatest tensile strength of the belt section on the outside, where the tension is maximum as the belt passes over the pulley. The leather may be either oak-tanned or mineral salt-tanned e.g. chrome-tanned. In order to increase the thickness of belt, the strips are cemented together. The belts are specified according to the number of layers. The leather belts must be periodically cleaned and dressed or treated with a compound or Dressing containing neat foot or other suitable oils so that the belt will remain soft and flexible [4].

2. Cotton or fabric belts. Most of the fabric belts are made by folding canvass or cotton duck to three or more layers and stitching together. These belts are woven also into a strip of the desired width and thickness. They are impregnated with some filler like linseed oil in order to make the belt water-proof and to prevent injury to the fibres. The cotton belts are cheaper and suitable in warm climates, in damp atmospheres and in exposed positions [4]. Since the cotton belts require little attention, therefore these belts are mostly used in farm machinery, belt conveyor etc.

3. Rubber belt. The rubber belts are made of layers of fabric impregnated with rubber composition and have a thin layer of rubber on the faces. These belts are very flexible but are quickly destroyed if allowed to come into contact with heat, oil or grease. One of the principle advantages of these belts is that they may be easily made endless. These belts are found suitable for saw mills, paper mills where they are exposed to moisture [4].

Experimental analysis of inclined belt conveyor can be carried out by using the experimental setup which is shown in fig. 1. In this paper, theoretical calculation also carried out for determining various parameters such as effective belt pull . Optimization of inclined belt conveyor is done in this paper. optimization is an act, process, or methodology of making something (as a design, system, or decision) as fully perfect, functional, or effective as possible; specifically the mathematical procedures. Optimization is about determining an alternative with the most effective or highest achievable performance under the given constraints, by maximizing desired factors and minimizing undesired ones. In the simplest case, an optimization problem consists of maximizing or minimizing a real function by systematically choosing input values from within an allowed set and computing the value of the function. The generalization of optimization theory and techniques to other formulations comprises a large area of applied mathematics. More generally, optimization includes finding best available values of some objective function given a defined a set of constraints.

III. EXPERIMENTAL ANALYSIS

The experimental setup of inclined belt conveyor is shown in fig. 1. Material used for making this inclined belt conveyor frame is iron. Leather belt is used to carry the load at different angle by changing the angle with the help of lead screw mechanism. The leather belt is kept tight with the help of idlers.

Procedure of making this particular inclined belt conveyor as shown in fig.1 is as follows:

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- i) Different sheets of iron according to requirement are taken.
- ii) Now at the both end driving and driven rollers are attached by welding with the help of bearing.
- iii) Attach idlers for tightening the belt.
- iv) For changing the angle, provide the mechanism of lead screw with sprocket and connect it to the sheet.
- v) Fix the leather belt of 195 cm long and 22.5 cm wide.
- vi) Fastened the driving roller shaft with the gear motor shaft.



Fig. 1. Experimental setup of belt conveyer

Abbreviations used for calculation of power of inclined belt conveyer:

m = mass of material conveyed on belt (kg)

m_b = mass of the belt

m_r = mass of roller except drive roller

c_1, c_2 = calculation constant

F_1 = maximum belt pull (N)

F_2 = minimum belt pull (N)

F_U = effective belt pull (N)

P = Power required for conveyor belt

$$F_U = \mu_r \cdot g(m + m_b + m_r) + g \cdot m \sin \alpha$$

$$= 0.2611 \cdot 9.81 (0.3 + 0.49 + 0.196 \cdot 3) + (9.81 \cdot 0.3 \cdot 0.3472)$$

$$= 4.55 \text{ N}$$

$$F_1 = F_U \cdot c_1 = 4.55 \cdot 1.5 = 6.827 \text{ N}$$

$$c_2 = \frac{F_1}{b_0} = \frac{6.827}{0.225} = 30.34 \text{ N/m}$$

$$F_2 = F_1 - F_U = 6.827 - 4.55 = 2.277 \text{ N}$$

$$P = F_U \cdot V$$

$$= 4.55 \cdot 2.5 \cdot 10^{-3}$$

$$= 11.38 \text{ mW}$$

Now,

Power of motor = Voltage * Current ; where, voltage = 1.5 V and current = 0.022 A

So, Power = 1.5 * 0.022 = 0.033 W

But, power = effective belt pull (N)*velocity of Belt (m/s); where, velocity of Belt (m/s) = $2.5 \cdot 10^{-3}$

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So, effective belt pull (F_U) = 13.2 N

IV. OPTIMIZATION OF INCLINED BELT CONVEYOR

A. Case –I:

Mass and power is constant and find out inclination angle:

Theoretically,

$$F_U = \mu_R \cdot g(m + m_b + m_r) + g \cdot m \sin \alpha$$

$$13.2 = 0.2611 \cdot 9.81 (1.8 + 0.490 + 0.588) + (9.81 \cdot 1.8 \cdot \sin \alpha)$$

$$\alpha = 19.27^\circ$$

Practically, By taking different angles for this case from 5° then increasing the angle up to when material is go down. Then at 17° when subjecting mass of 1.8 Kg ash it comes down. So 17° is the maximum inclination angle can be determined for this case.

By optimization method,

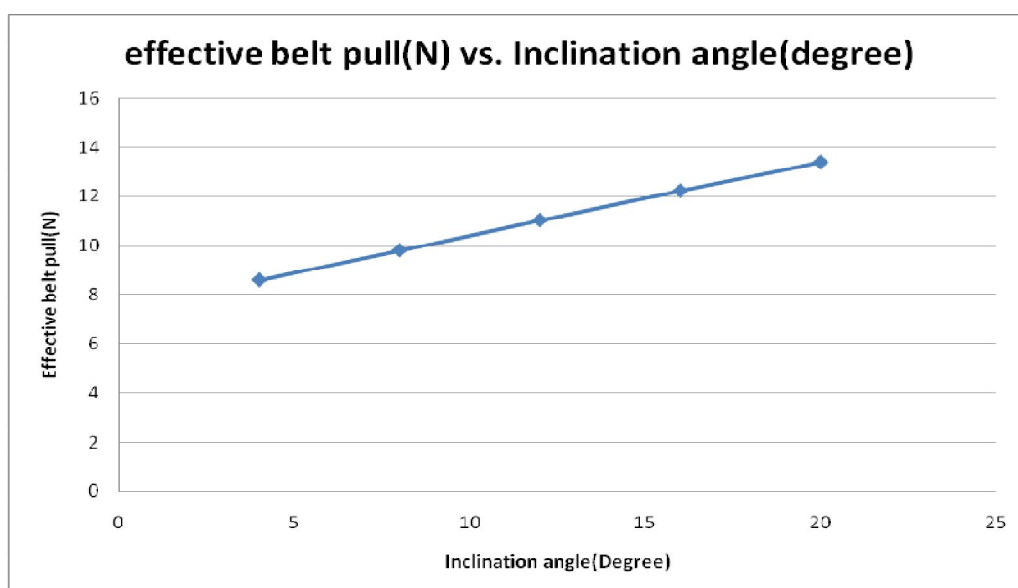
m = mass of material conveyed on belt (kg) = 1.8 Kg which remains constant.

TABLE I

Inclination angle (α)	4°	8°	12°	16°	20°
Effective belt pull(N)	8.59	9.81	11.03	12.22	13.40

TABLE 1 indicates the variation of effective belt pull (F_U) according to variation in inclination angle of belt with respect base of frame of setup. Actually, effective belt pull (F_U) increases with increasing value of inclination angle. From the TABLE I ,the following GRAPH I can be generated.

GRAPH I



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GRAPH I shows that as inclination angle increases, the effective belt pull also increases. As the value of effective belt pull is 13.2 N, so from the GRAPH I it can be seen that at 13.2 N, inclination angle is approximately 18°, which is the angle for material slide for this case.

B. Case-II:

Angle remains constant and mass is varying then power can be found.

Here, Inclination angle (α) = 10° and m = mass of material conveyed on belt = 100 gm

$$F_U = \mu_R \cdot g(m + m_b + m_r) + g \cdot m \sin \alpha$$

$$= 0.2611 \cdot 9.81 (0.100 + 0.49 + 0.588) + (9.81 \cdot 0.100 \cdot 0.1736)$$

$$F_U = 3.1876 \text{ N}$$

$$P = 3.1876 \cdot 0.0025 = 7.97 \text{ mW}$$

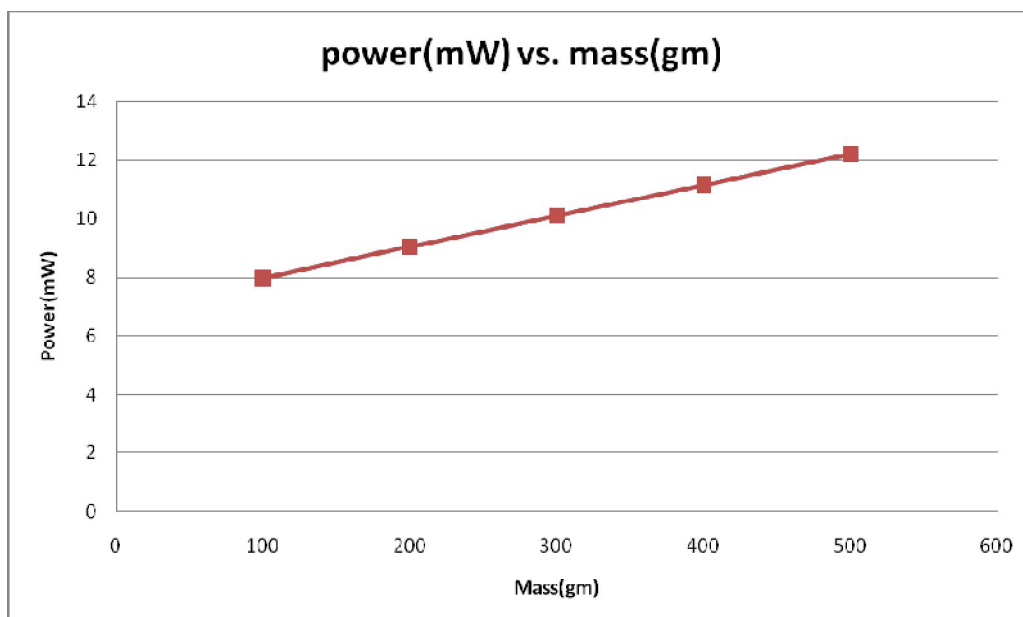
The different mass of loading material conveyed on belt can be taken as per TABLE II and by above equation, power can be calculated for each mass. Here, mass of conveyed material is vary from 100 gm to 500 gm with interval of 100. power for different mass at fix inclination angle is tabulated in TABLE II.

TABLE II

Mass(gm)	100	200	300	400	500
Power(mW)	7.97	9.034	10.10	11.17	12.23

From the TABLE II, the following graph II can be generated.

GRAPH II



GRAPH II shows that power required for handling the material increases as the mass of conveyed material increases. This GRAPH II helps to determine the selection of motor of required power by knowing the mass of conveyed material which is to be handled by the belt conveyor.

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C. Case-III:

Inclination angle (α) and power is constant and find out mass:

Inclination angle (α) = 15° and power = 33mW

Theoretically,

$$F_U = \mu_R \cdot g(m + m_b + m_r) + g \cdot m \sin \alpha$$

$$13.2 = 0.2611 \cdot 9.81 (m + 0.49 + 0.588) + 9.81 \cdot m \cdot 0.2588$$

So, $m = 2.047$ Kg

Practically, Different masses is taken for this case which starts from 500 gm then increasing the mass up to critical mass when material is go down. when mass is subjecting 1.9 Kg of ash it comes down. So 1.9 Kg or above is the maximum mass for moving down for this case.

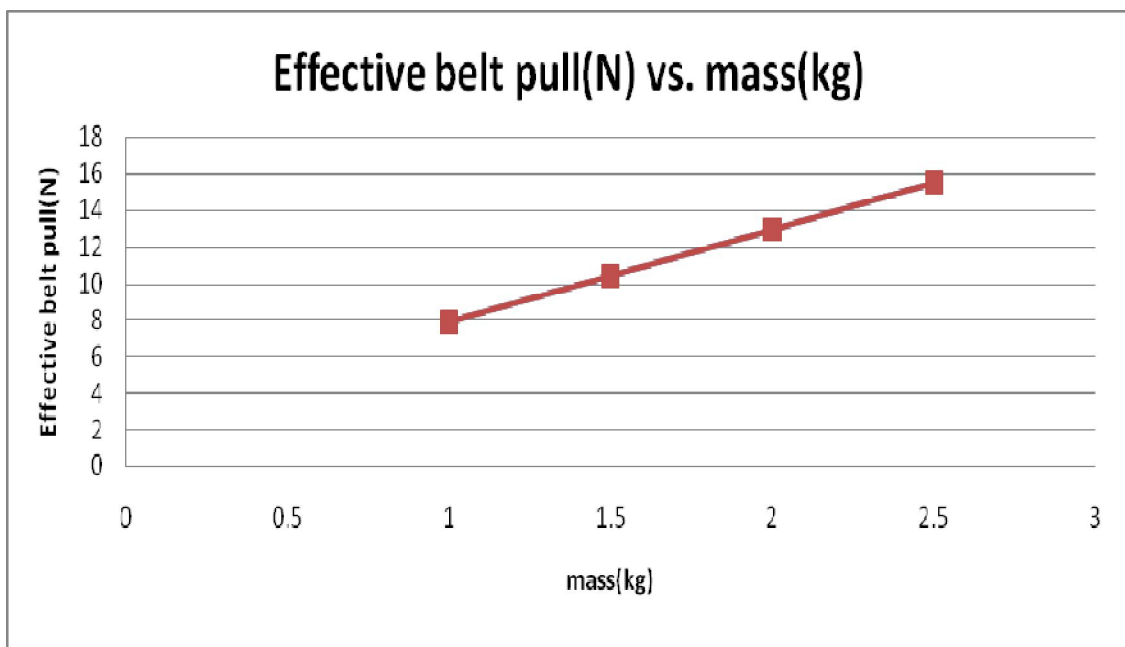
TABLE III

Mass(kg)	1	1.5	2	2.5
Effective belt pull(N)	7.849	10.40	12.94	15.50

Different mass of conveyed material is chosen for determining the critical mass , the mass which is maximum to go at one pass at inclined belt conveyor for fix angle. Effective belt pull variation can also be determined for each mass as shown in TABLE III.

From the TABLE III ,the following graph III can be generated.

GRAPH III



GRAPH III shows that as the mass of conveyed material increases, the effective belt pull of belt also increases. For this particular experimental setup of belt conveyor, effective belt pull is already determined which is 13.2 N.

Therefore, from the above GRAPH III it can be seen that at effective belt pull 13.2 N, mass of conveyed material is approximately 2 Kg.

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V. CONCLUSION

The critical angle of material slide and critical mass of conveyed material for inclined conveyor belt can be measured by using experimental analysis and by optimization method optimum parameter can be determined using optimization method.

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