

Optimal Design Parameters for an Inclined Conveyor

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Abstract - High demands indicate faster supply chains in Industries. And by far the most apt high-demand fulfilling model is the Automated Plant model. Which includes motorized conveyor belts and robots, which are operated by individual or integrated electronic units. This paper talks about the types of Conveyors used in an Automated Plant model. With a specific focus on Inclined Conveyor designs. Further the reader would be easily able to design the type of system to be used after going through this paper. Some 3D models of Conveyor systems are developed, which are prepared after reviewing various research publications. These designs are based on the operation-specific of some predefined designing constraints and objectives.

Key Words: Inclined Conveyor; Special Purpose Machine; Automation; Screw Conveyor; Belt Conveyor; Bucket Conveyor.

1. INTRODUCTION

Conveyors are special purpose machines (SPM) which are designed for transferring and delivering of material. With the increase in the Entrepreneurial scenario all over the world, and specifically in a country like India, SPM Conveyors are easily seen in every second Food based industry. However, the packing and storage-based Industries (plants) tops the list of number of conveyors used in Industry based operations.

1.1 Types of Conveyors

Screw Conveyor

Screw conveyor is a kind of machine which is used for continuous transportation wherein is no traction force is needed. It consists of a normal rotating screw in between the frame but with a U-shaped Frame hence giving a top opening flat platform along with the desired and necessary curvature provision for the spiral screw to experience rotary motion about its axis.

Tube Chain Conveyor

Tube chain conveyors are used for transport and delivery of solids in huge quantities i.e., as Bulk Volumes. These are classified as a sub category of continuous mechanical conveyors like the Screw Conveyors. Further, they are capable of transporting bulk volumes up to 60m³/hr, consume less power and can bear high temperatures up to 200°C. They mainly consist of Steel disks as their internal

parts and Sprocket Wheel as the external part, connected via a chain type arrangement. [6]

Belt Conveyor

Belt conveyor is a machine which is capable of transportation of items from one point to another. Further classification of the same are on the basis of type of belt; i.e., Rubber belt, Chain belt, Modular belt etc. Typically, modular belts are used more in number; as it serves the following advantages: [1]

- Easy part replacements.
- Ability to transport and operate in a curvilinear motion.
- Easy maintenance.
- Pertains good amount of mechanical strength.

2. LITERATURE REVIEW

The following section presents a brief literature review summary of various researches done on Conveyor designs -

Renfeng Zhao et al. in their research article performed structure optimization on the basic Screw Conveyor. Firstly, they simulated the screw conveyor model, and then they studied the result parameters based on 3 pivots, namely the screw blade pitch (S); screw inner diameter (d), and; the speed of the screw shaft (n). Then the conclusion of their research was made using Tabulated result entries; velocity diagrams and; transport time-quality diagrams based on the simulation. Further, it was noted that as the speed of the screw conveyor was increased; the conveying capacity was better than before. However, when the speed was extremely high; due to the action of centrifugal force, particle extrusion and accumulation were seen, resulting in instability. Finally, it was seen that the 80(mm)-35(mm)-100 (rpm) parameter configuration for the Screw Conveyor was the winner among the chosen and simulated options. [8]

C. Silverman and J.Kold theoretically examined the Belt Conveyors used in the Food Industries. In their research paper they briefly explain, how the use of Conveyors has increased production costs as well as the Hygiene standards of the industries; while reducing the quantity of food waste, the need for subsequent disinfections, the utilization of the water resource, and the need for highly expensive skilled labour. However, the chances of contaminations present on the Conveyor Belts need to be taken care of [10].

S.H. Masood et al. investigated various designs of mechanical conveyor systems used in the food industries. They further made a test conveyor for the labelling of plastic bottles. This was done after a proper investigation of the previous designs of the same. Here, the first theoretically studied the designing process and then performed a cost analysis of the same. Then the areas of improvement were found; which include the Leg design of the conveyor system, Side frame Support channel design improvements, etc. In this, the material along with the design was modified. And finally, the testing concluded as the improved plastic bottle labelling conveyor proved to be more effective in terms of lesser lead times and less material usage when operated upon [5].

Andrezej et al. presented a research article on the design process of a conveyor (technological) line for vegetable packing. For this, they made use of CAD tools like SolidWorks. In the process of the same they first defined their workspace for the proposed conveyor system. Then by the use of the CAD software, they generated an employee-workspace visualization. After this the machine performance/ delivery rate was defined; which was near about 60 to 150 pieces per minute. Followed by the safety concerns of the system. And finally, the material was selected for the same; which includes an optimum and cost-effective selection of Bearings, Motors, Variable Frequency Drives, and Belt material for the Conveyor system, in this case, it was a modular belt lineup. After which the manufacturing process was done [1].

A. Katterfeld and K. Williams published an article, titled Functional Analysis of Tube Chain Conveyors; in which they gave a full theoretical intext of the Tube Conveyors. Their paper contains all the necessary formulas. I.E., for the different forces acting while the Tube Conveyor is operated upon. The different friction forces, gravitational forces, tension forces, and viscous forces. Furthermore, they also talk about how these conveyors are suited for medium to low transportation rates and can bear temperatures up to 200oC; alongside the limitations like chain break, etc. of the same are found in the paper [6].

Dario Friso presented a mathematical model in his research article, which claims to be useful for designing a special-purpose Conveyor Belt Dryer. His model seems to be useful for the preservative food product industry; which revolves around the preservation of the nutritive content of dried products or foods. His design aims to use a concurrent flow direction dryer or dehumidifier; which will operate alongside the special purpose conveyor belt, and will be able to dehumidify the moisture content of the food items like kiwi, rice, potato, and other generic foods; till a point that is less than the respective critical points of the same. The critical point is the temperature for any food item until which its nutritive value remains or is maintained, whilst its moisture content is minimum. Further, the author compares his mathematically modeled conveyor belt dryer with the cross-flow dryers being used otherwise; based on different

temperature gradients of the respective food product corresponding to different air flow rates; for which the heat rejection rates were mathematically calculated. The tabulated results and plots for the same are also found in his research article [2].

Ghazi Abu Taher et al. designed and manufactured a special-purpose machine, which was made by combining a Belt conveyor mechanism and a Bucket elevator mechanism. The main aim of their experiment was to make the conveying of Bulky material, an easy task. For this they started by making a preliminary sketch of the same, then the inclination angle was selected i.e., 45o. Further, the material to be used for manufacturing was decided based on mathematical formulas. Which include the Load handling capacity of the Buckets, Maximum static tension capacity of the Bucket, Motor power needed, Belt tension, Belt load acting when the machine is in Idle i.e., non-loaded state, Belt breaking strength, etc. Finally, after combining all the efforts, a compact model for the same, governed by an electronic control system was prepared; which was claimed to be a cost-effective and highly useful method of transportation in material handling industries [3].

Sanjay G. Sakharwade and Shubharata Nagpal published a research paper on the Analysis of Conveyor Belt elongation/stretch. In the claim that mostly 30 to 40% of the cost of a conveyor system is associated with the Belt. And the failure of the same causes Belt damage as well as structural damage. So, they modelled a mathematical-mechanical control system for the same; in which a series of vibratory masses were considered such that they represent the conveyor belt system. Further, the spring-damper-mass vibratory analysis was worked upon. For this, they used the Lagrange Approach of estimation. And finally, an elongation of 1.16% was found for the fabric belt, by plotting velocity-time (response) graphs for the experimental/ computational results [9].

Jigar Patel et al. optimized the design of a simple screw conveyor with the main aim being to increase the productivity of the system; whilst reducing power consumption, stress induction, and screw deformation. In their approach they made use of Computational Finite element analysis wherein, they first modeled a simple screw conveyor that was made for conveying 2 tons/hr of cement, and then after doing the analysis, it was found that the induced stress was near 150MPa, while the deformation was nearly 1.9mm. Now, they modified the diameter of the screw conveyor for a Shaftless type Screw Conveyor, and performed the analysis; surprisingly the stress was nearly 1/2 i.e., 70MPa and the deformation was comparatively negligible i.e., 0.2mm. Also, the power consumption as found for the shaftless conveyor was 16% less [4].

Olanrewaju T.O. et al. published a paper on the design and fabrication of a screw conveyor, wherein they reviewed some research articles suggesting the use of a screw-based auger conveyor for the transportation of agricultural produce. Their

main aim was to prosper the conveyance of agricultural produce in an upward inclination; i.e., from the Hopper (ground) to the trailer. They used CAD tools to design the screw conveyor, the testing of which was done for different sets of inclination angles. I.E., 0°, 15°, 30°, 45°, 60°; A delivery rate of 10.72m³/hr was chosen by the authors, as the preliminary design parameter. And after considering the bending effect that would occur at the screw shaft, considering a uniform distribution of load, the authors finally claimed to achieve a 99.95 % efficiency [7].

3. METHODOLOGY

3.1 Selection of Suitable Conveyor

The method of selection of a conveyor is as follows [11]:

1. Material to be transported is classified into suitable category.
2. On the basis of the above classification the type of conveyor is chosen:
 - For Belt type conveyor, the type of belt is chosen as per the conveying material weight and volume.
 - For Screw type conveyor, the diameter of the screw is estimated with respect to the volume of material to be transported.
 - For a Scoop type conveyor, the dimensions of the Bucket are calculated with respect to the surface area of the part or item to be conveyed.
3. Further on the Motor and transmission drive is selected; with respect to the velocity of conveying.
 - Power need also plays an important role in the same.

3.2 Aligned Conveyor Designing

Here a 3D model/ assembly for an Aligned Conveyor is prepared, which is aimed to transport Rice Fakes (Poha/ Chidwa) from 2 quality approving machines separated by a distance. And further take this in-feed poha from a lower height to some aligned distance at a relatively greater height directly to an X-Ray Scanner machine, which will then scan the quality (size/shape approved) poha lot.

For this machine/ conveyor system design, the dimensions are taken according to the space available and the height of the preinstalled machines in between which this was to be installed was used. Further, the Angles of Inclinations that would exist corresponding to the optimum working arrangement/ configuration of the conveyor system was decided. And then all this designing was to be done taking in mind that there would be no backfall or back motion of the material to be carried by the conveyor belts (Poha).

Now, as this poha infeed was to be transported in an inclined motion, the belt used for these machines (conveyors)

was inclusive of a Clit (thin Plate) at the desired pitch or distance. This machine was ordered by a Namkeen-making company; for their lite poha namkeen production line. Further, this poha would be then transported via inter-floored channels which would pull the X-ray scanned and approved poha from the basement level where the Aligned Conveyors were to be installed up to the 1st floor where all the baking and frying were to take place for the making of the lite poha mix. So, these are the 2D designs/ Layout which was prepared by me, which were further presented by the company to the client company; which was also approved by them at that time. The preliminary design for the conveyor setup is as follows:

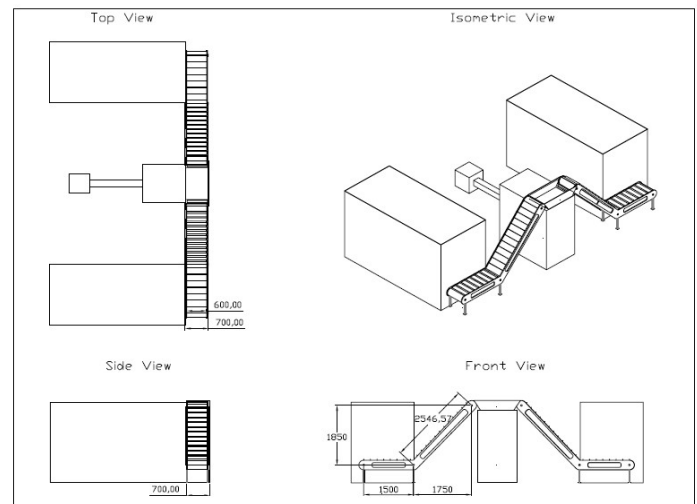


Fig -1: Preliminary Design for the Conveyor Setup

The dimensions in the above drawing are taken in mm.

Now, as it is seen in many cases, the secondary and final design of the conveyor setup based on the changes in the namkeen plant setup a second design is prepared, which is as follows:

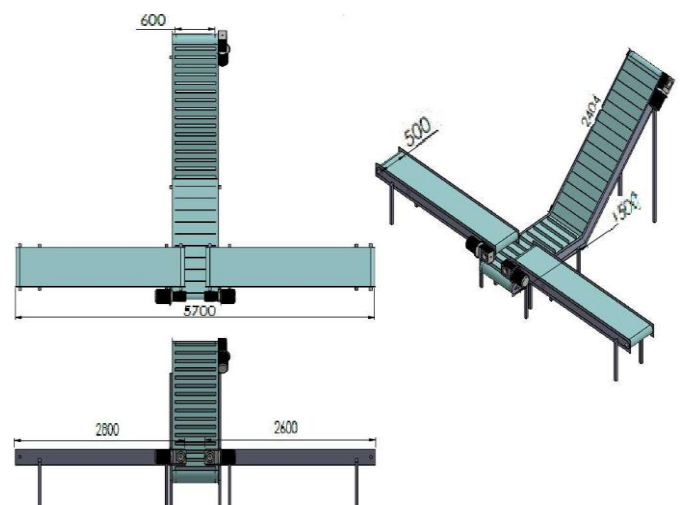


Fig -2: Final 3D Model for the Conveyor Setup

3.3 U-Type Screw Conveyor Designing

The First designed long length-small cross-section U-Type Screw Conveyor is as follows:

This Conveyor has a U-Frame Cross Section of 150mm and a Screw pipe of 50mm OD, with a Spiral Screw of pitch 100 mm, screw cross-section (face) length of 50 mm and 55.3 revolutions length. And the Length, Height and Angle of the same are specified below:

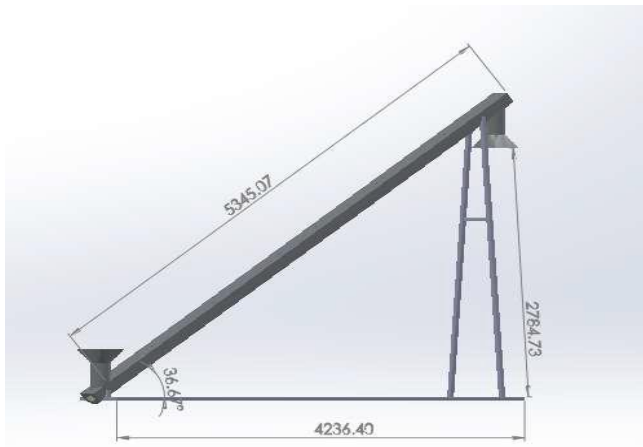


Fig -3: Design for Long Length-Small Cross-Section U-Type Screw Conveyor

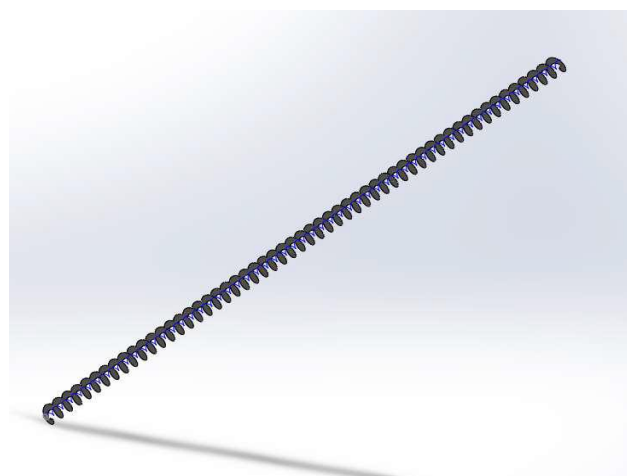


Fig -4: Helix Screw for Long Length-Small Cross-Section U-Type Screw Conveyor

The Second designed short length-big cross-section U-Type Screw Conveyor is as follows:

This Conveyor has a U-Frame Cross Section of 400 mm and a Screw pipe of 100mm OD, with a Spiral Screw of pitch 100 mm, screw cross-section (face) length of 100 mm and 34.181 revolutions length. Also, this U-Type Screw Conveyor had a Hopper type inlet at its back (inlet portion) and a round circular pipe at its outlet.

And all the necessary dimensions of all the Accessories of this second U-Type Screw Conveyor are included / specified in the following image.

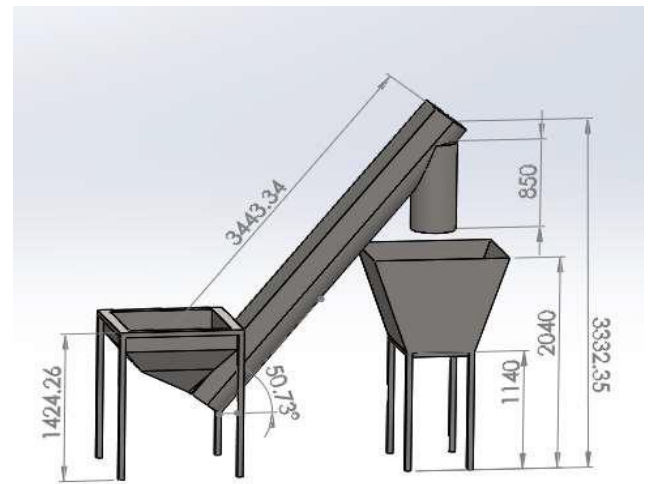


Fig -5: Design for Short Length-Big Cross-Section U-Type Screw Conveyor

3.4 Super Grip Conveyor Designing

A Super Grip Conveyor is a type of Belt Conveyor Machine which is similar to a normal belt conveyor machine but the only difference here is the use of a Super Grip Belt in this machine instead of a normal (plain) belt which is used in conventional conveyor machines. A Super Grip Belt is a special type of belt which as its name suggests has a property/ tendency to hold on to the items placed onto it (like boxes, bags, etc.). This Belt has special, small extrusion patterns/ textures on its surface hence enabling it to offer more or a high amount of static/ limiting frictional force or high coeff. of static or limiting friction. And these types of belts are used in conveyor machines generally to transport bulk or heavy items along an inclined or elevated plain or route (till 30o of maximum elevations).

A small, single inclined unit conveyor system, which also incorporated a Heat insulative boxed chamber in its above portion; and this conveyor was to go from a floor below its actual outlet delivery floor all through an sq. opening which was to be cut in the top wall of the place where this was to be installed and made for. So, its design is as follows:

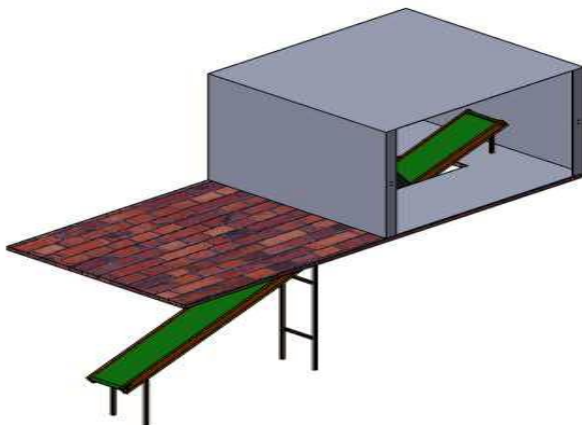


Fig -6: Isometric View for Super Grip Conveyor

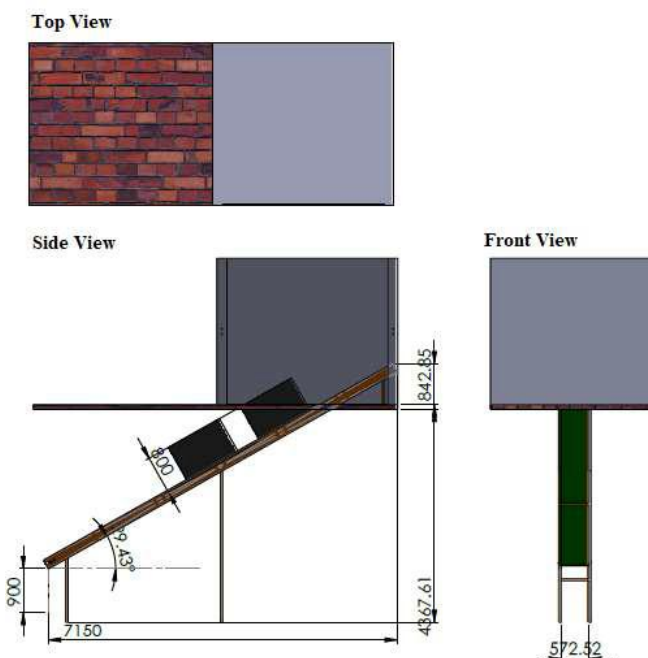


Fig -7: Top-Side-Front Views for Super Grip Conveyor

3.5 Inclined Scoop Conveyor Designing

Here is a design of a conveyor system for a plant where items were to be taken up to a high level (height) in a slant path like along the main body diagonal of a cube or a cuboid. Now, a scoop conveyor consists of scoop like buckets on its belt and this this of a conveyor is generally suitable for high angle elevation motions or paths. So, the design is as follows:

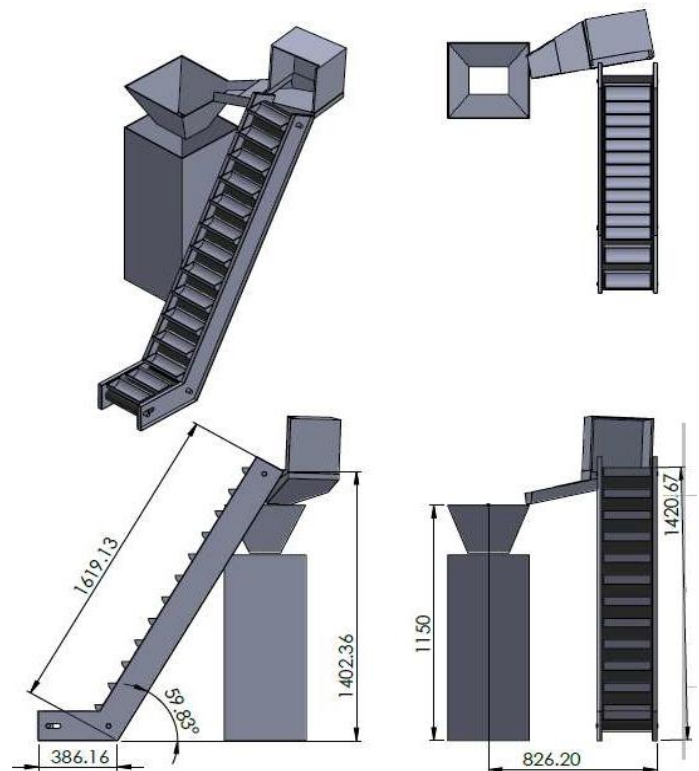


Fig -8: Drawing for Inclined Scoop Conveyor

Here, the items would go in a straight inclined path up till a certain height where then they would fall into the above shown hopper structure from which due to a downwards angular base, they would fall into the desired location through another catching hopper structure.

4. MATHEMATICAL FORMULAS

4.1 For Screw Conveyors

The relations for Discharge flow rate and Theoretical Outer Diameter are [8]: -

$$Q = 47\beta D^2 S n \psi \gamma$$

$$D = \sqrt{\frac{Q}{47\beta S n \psi \gamma}}$$

Where,

Q = Discharge flow rate($g \cdot h^{-1}$)

β = Inclined transport coefficient

D = Theoretical Outer Diameter of spiral blade (cm)

S = Screw blade pitch (cm)

n = Speed of the screw shaft ($r \cdot \min^{-1}$)

ψ = Filling coefficient of material

γ = Material capacity ($g \cdot cm^{-3}$)

The relation for Efficiency (ξ):

(Olanrewaju T. O., 2017)

$$\xi = \frac{\text{Total Quantity of Material Conveyed by the Screw (At Outlet)}}{\text{Total Quantity of Material into Hopper (At Inlet)}}$$

The relation for Bending Moment (σ_B):

(Olanrewaju T. O., 2017)

$$\sigma_B = \frac{32BMD_o}{\pi(D_o^4 - D_i^4)}$$

Where,

BM = Bending Moment

D_o = Outer diameter of the Screw Shaft

D_i = Inner diameter of the Screw Shaft

4.2 For Inclined Belt Conveyor

The relation for Belt Tractive Pull generated by Conveyor motor is [9]:

$$P = CfgL_h(m_c + m_r + m_m + 2m_b) + m_m H_m g$$

Where

C = Conveyor length coefficient

f = Conveying friction coefficient

L_h = Belt Horizontal run distance (m)

m_c = Carrying idler rotating mass (kg/m)

m_r = Return idler rotating mass (kg/m)

m_m = Bulk material mass (kg/m)

H_m = Total vertical lift of belt conveyor (m)

3. CONCLUSIONS

From the above-presented paper on Inclined Conveyors with a literature review and some designed CAD models, the utility, selection criteria, and designs are clear for the automated supply chains. The literature survey provided above makes substantial claims based on the findings of the referenced sources published by various authors in the Conveyor designing, analysis, and also in its lifecycle management cycle. Then some of my designs for a Screw Conveyor setup with and without a Hopper; for an Inclined Conveyor setup; a Super grip Conveyor and the Bucket Conveyor are also depicted with clear pictorial representations containing different views of the same, with dimensions specified in mm. Finally, the paper is concluded with the provision of some of the mathematical formulas, that were found during the literature survey; from some previously published research articles.

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BIOGRAPHIES

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