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A Review on Design Analysis & Optimization of Screw Conveyor

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ABSTRACT: Screw (Auger) conveyors are widely used for transporting and/or elevating particulates at controlled and steady rates. They are used in many bulk material applications in industries ranging from industrial minerals, agriculture, chemicals, pigments, plastics, cement, sand, salt and food processing. They are also used for metering (measuring the flow rate) from storage bins and adding small controlled amounts of trace materials such as pigments to granular materials or powders. Many studies on screw conveyors were conducted to examine performance and to develop new types [1]. Most of these studies were experimental in nature. The purpose of this paper is to present a critical review of current explanations on the working concept of a screw conveyor. Although many experimental and numerical studies on the screw conveyor have been made. In this paper, design and analysis of screw conveyor for different material is discussed. Some researcher used a DEM method to predict the performance of screw conveyor is also discussed. This discussion will be helpful for future research.

Keywords: Screw conveyor, DEM, Auger

1. INTRODUCTION:

A screw conveyor consists essentially of a shaftmounted screw rotating in a trough and a drive unit for running the shaft. The material is moved forward along the axis of the trough by the thrust of screw thread or flight. The trough is usually of the U-shape. The basic principles of operation may be explained with reference to Fig.1.1. A helical blade is attached to a drive shaft which is coupled to a drive unit. The shaft is supported by end bearings, and intermediate bearing.

The U-shaped trough has a cover plate with an opening for loading the conveyor. A discharge opening is provided at bottom of the rough. The loading and discharge points can be located anywhere along the trough. More than one feed hopper and discharge hopper may be fitted according to the necessity. The basic principle of material along the trough is similar to the sliding motion of a nut along a rotating screw when the nut is not allowed to rotate.

The weight of material and the friction of the material against the wall present the load from rotating with the screw.

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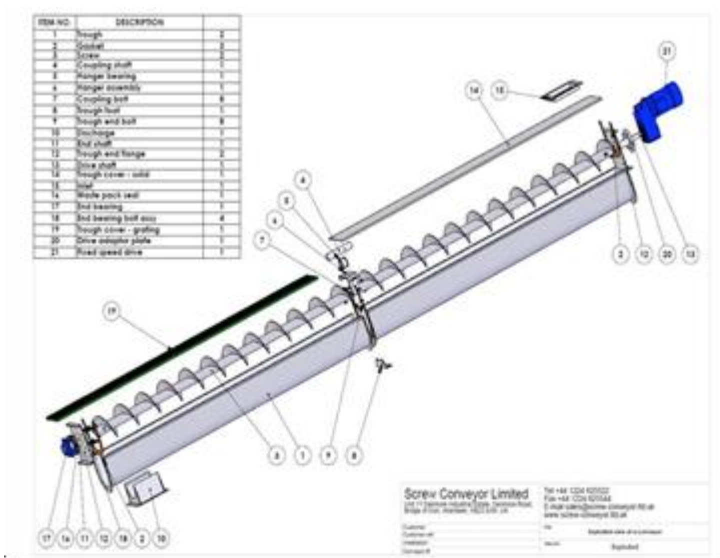

Fig. 1 Screw Conveyer Drawing

The physical characteristics of the material to be handled should be considered before selecting an appropriate conveying device. In particular, the following properties should be considered: average weight per unit volume, angle of repose, and particle size. Material flow rate, distance, environment, and economics influence conveyor design and operating parameters.

2. MATERIALS AND METHODS:

2.1 DESIGN CONSIDERATION :-

Factors considered in the design of this machine were cost, availability of the materials, rigidity and

vibration stability, durability and strength of the metallic material
selected to ensure corrosion and wear resistance, portability of the machine and the techno-economic status of the intended users. Also, the necessary properties of material to be conveyed were: the physical and thermal properties.

2.2 DESCRIPTION OF THE MACHINE :

The motorized screw conveyor consists of a Screw, U-trough, Hanger, hopper, coupling shafts, power source clamp and motor for power transmission. The discharge point is at the other end of the system where the materials conveyed are discharged.

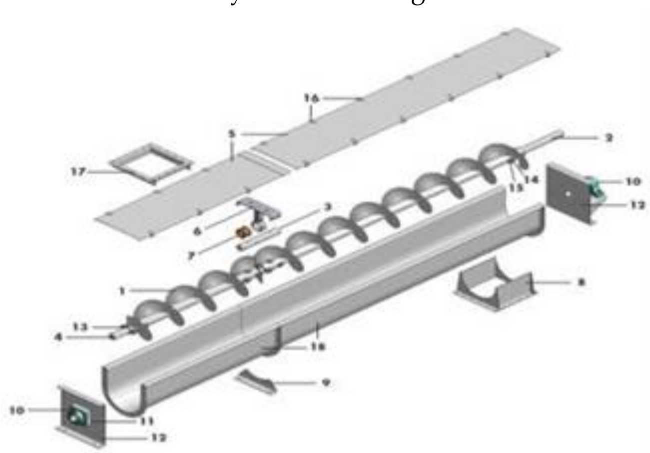

Fig. 2 Screw Conveyer component details

1.Screw	2. Screw shaft	3. Coupling shaft
4.End shaft	5. Covers	6. Hanger
7.Hanger bearing	8. Discharge	9. Flange foot
10.End bearing	11. Shaft seal	12. End plates
13.Internal collars	14. Coupling bolt	15. Bolt pads
16.Cover clamps	17. Inlet	18. U-trough

2.3 PRINCIPLE OF OPERATION :-

The granular materials to be conveyed (usually coal & limestone) are fed into the hopper at the lower end, the materials are then moved through the driven transmission via an electric motor positioned at the feeding end by the rotational effect of the auger and discharge the materials at the upper end through the outlet port. An adequate clearance between the auger blade and the housing (Barrel) was considered in the design to avoid clogging and breakage of grain kernels.

The priority of this project is to maintain the highest TPH (tons per hour) as possible. Hence to increase the TPH of the project appropriate screw flight thickness is selected, so that highest TPH is achieved and maximum life cycle of the auger is obtained; further by increasing the diameter of auger exponentially increases the total output of the setup.

3. METHODOLOGY:

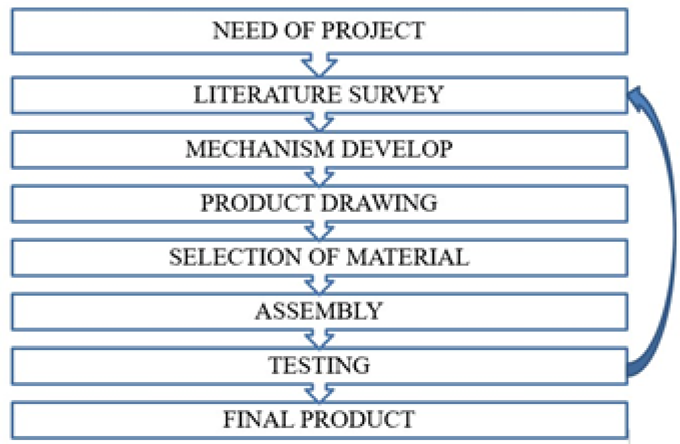

Fig. 2 Methodology

Following steps are followed,

- Study of present Screw Conveyor Designs.
- Take practical input from industry.
- Literature survey.
- Design of Screw Conveyor using SOLIDWORKS.

4. PROBLEM STATEMENT:

In initial design of screw conveyor the trough was overweight which needs to be reduced by FOS optimization and Material Selection by Strength vs density graph.

- Extreme vibrations were observed in bottom chassis which needs to be reduced by selecting proper profiles for chassis .
- Working cycles of screw shaft was only 3lakh which has to be increased upto 4.5lakh by selecting material based on S-N curve.

5. DESIGN CALCULATION:

Essential design calculations were done in order to determine and select the strength and size of the conveyor components. This was done with the aid of the results and established formulae in the design analysis.

5.1SCREW CONVEYOR DATA:

Thickness of flight=6mm

O.D of screw=300mm=pitch
I.D of screw=O.D of screw shaft=60.3mm
screw/conveyor length=5000mm
I.D of screw shaft=52.5mm

5.2VOLUMETRIC THROUGHPUT CALCULATIONS

Effective radius -
Ro-Outside radius of screw flight
Ri-Inner radius of shaft
Re=102.606mm

Helix angle of screw flight
D=2*Ro
α =24.97^0

Helix angle of the path
λ= 90o-(α+φs)
φs= friction angle =25^0
λ=40. 03^0

Conveying Efficiency (Nvr)
Nvr= 86.05%

Volumetric efficiency (Nv)
Nv= Nvr*Nf
Nv= 97.52%
T=1/8[(1+2*C/D)2-(Dc/D)2]*[(P/D)-(ts/D)]
T=0.15135

Maximum theoretical volumetric throughput (Qt)
Qt = T*W*D3
Qt = 0.05991

Volumetric throughput (Q)
Q= Qt * Nv
Q= 5.8431

Mass throughput (TPH)
TPH= (Material Density/1000)*Q
TPH=5.8431

5.3Screw flight development

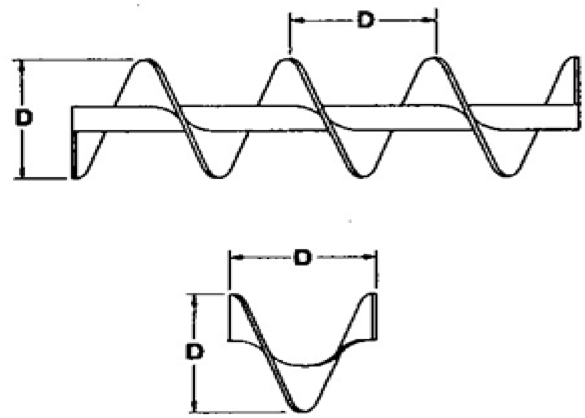

Fig. 3 Screw profile

We selected sectional flight screw.
The diameter of screw = 250mm
The inside diameter of the screw = 60.3mm
Development of outside diameter
A =$\sqrt{(3.1415 * D)^2 + (P)^2}$
=$\sqrt{(3.1415 * 250)^2 + (250)^2}$ A
= 824.2mm
Development of inside diameter
B =$\sqrt{(3.1415 * d)^2 + (P)^2}$
=$\sqrt{(3.1415 * 60.3)^2 + (60.3)^2}$
= 313.66 mm
The developed inside radius of the flight will be
= 313.792mm
No. of flights = screw length/pitch = 5000/250
= 20
Thickness of flight = 5mm
Material = Mild steel(MS)

5.4 CALCULATION OF VARIOUS LOADS ACTING ON SCREW CONVEYOR:

Load due to coal :
Coal bulk density = 61 * 16.018
= 977.098 kg/m3
Let
V = **volume in which coal loads acts downwards** (i.e. on the center pipe)

V = [(width of trough) * (height of end plate above center pipe)*L/2] – (0.5* volume of hollow pipe)

Width of trough = 260.2mm = 0.26m

Height of end plate above center pipe = 193.4mm = 0.1934m

Volume of hollow pipe = 0.785[(60.3)2 – (52.5)2]*417

= 288011 mm3 = 2.88*10-4 m3

V = (0.260*0.1934*2500) – (0.5*2.88*10-4)

= 125305994mm3

= 0.125m3

We know that

Bulk density = Mass / volume

Mass = 0.125*977.098 = 122.1372kg

The weight of coal = 122.137*10

W1= 1221.3725N

Load due to flights:

Volume of one flight

=3.142/4 * (D0*D0 – Di*Di) *thickness

=0.785(0.250*0.250 – 0.0603*0.0603)* 0.005

= 0.785(0.0625 -0.0036) * 0.005

= 2.311825*10-4m3

Mass of flight = 3.4 * density * volume

= 3.4*7800*2.3118*10^{-4}

= 10.76712kg/m

W2 = 107.6712 N/m

Adding 1 & 2

Total UDL on 1m length = 489.9+72.128

= 562.028 N/m

Taking 50% overload to be on safer side

UDL = 843.042 N/m

Load fluctuations may come due to dynamic loading

Therefore increasing UDL say = 900 N/m

Load due to each solid shaft :

Drive end shaft diameter = 48mm

Length of drive end shaft =325mm

= 0.7853*0.0482*0.325

= 5.88*10-4 m3

Density = Mass / volume

Mass = 5.88*10-4 * 7800 = 4.58 kg

W3 = 45.8 N

Coupling shaft diameter = 48mm

= 0.785*0.0482*0.417

= 7.54*10-4m3

Mass = 7800*7.54*10^{-4} = 5.88kg

W4 = 58.5 N

Load due to hollow pipe:

Mass = volume * density

= 2.88*10-4*7800

= 2.2464kg

Taking 60% overload to be on safer side

M = 3.59424kg

Considering this also as UDL of 36 N/m

Total UDL = 900 + 36 = 936 N/m

5.4 BEARING SELECTION (END BEARING)

We select SKF 6210 deep groove ball bearing is selected based on the shaft diameter 48 mm from the PSG data book

The static load,

C0 = 2120kgf

The dynamic load,

C = 2750kgf

Maximum permissible speed (rpm) = 5000rpm

Assume life required to be 10,000hrs for 90% probability of survival

Life in million revolution = L*60*N/ 1000000

= 10000*60*53.29/1000000

= 31.974 million revolution

The equivalent load,

P = [X.Fr+Y.Fa]*S

Where X = radial factor

Y = Thrust factor

S = Service factor

Fa/ Co = 635/4550 = 0.1395

From the PSG data book e = 0.31

Fa/Fr= 635/345 = 1.840 > e

The radial factor X = 0.56

Thrust factor Y = 1.4

P = [0.56(345) +1.4(635)]*1.2

= (193.2+88.9)*1.2

= 1298.64N = 129.86kgf

The ratio c/p in the graph from PSG data book

C/P = 3.36

C = 3.36*1298.64

= 4363.43 N

= 436.34 kgf

The bearing SKF6216 is selected because in our case dynamic capacity is 436.34kgf.It be lesser than permissible dynamic capacity. So, bearing is very well safe.

5.5 DEFLECTION CALCULATION:

The deflection of the screw is given by

$$D = 5\,wL^{3} / 384*E*I$$

Where W -Total weight of screw in pounds

L - Screw length inches

E - Modulus of elasticity

I - Moment of inertia (in)4

Here w =189 lbs

L = 132 in

E = 29,000,000 for low carbon steel
I = 4.788in4

For schedule 40 pipe

= 5∗189∗132³/384∗29000000∗4.788
= 0.040 in = 1.1016mm

It is lesser than the allowable deflection 6.35mm.

For schedule 80 pipe

= 5 ∗ 189 ∗ 1323/384 ∗ 29000000 ∗ 6.28
= 0.0310in =0.787mm

As comparing the both schedule 40 & 80 pipe, the deflection is less than allowable deflection 6.35mm

5.6TORQUE CALCULATION:

Torque acting on the screw conveyor is given by the relation

= 63025 * motor horse power / N (rpm of the screw)
= 63025* 3 / 54
= 3501.38 lbs. in
= 3501.38*4.44*2.54
T = 395.60*103 N.mm

From the **CEMA** correspond to shaft diameter 3″ = 76.2 mm. The calculated torque is less than the maximum allowable torque 15435 lbs. in under 2 bolts in shear and bearing.

The screw flight diameter = 12″ = 304.8 mm
The shaft diameter = 3″ = 76.2mm
Pipe outer diameter = 4″ = 101.6mm

6. RESULT:

Volumetric Throughput Calculations					
Re (Effective Radius)	mm	86.37052	102.60638	110.76711	118.94928
Helix angle of Screw Flight (α)	Deg	24.75	24.97	25.04	25.10
Helix Angle of the Path(λ)	Deg	40.25	40.03	39.96	39.90
Conveying Efficiency (Nvr)	%	61.94	86.05	93.08	98.03
Fullness efficiency (Nf)	%	1.54	1.1333333	1.0615385	0.9857143
Volumetric Efficiency (Nv)	%	95.38539	97.526043	98.809741	96.633915
T		0.122314	0.1513586	0.1230407	0.1234588
Max.Theoriotical Volumetric Throughput (Qt) factor		0.028019	0.0599139	0.0619235	0.0831469
Capacity		2.67261	5.8431654	6.1186444	8.0348106
Speed Calculations Ns	RPM	27.3896	32.867524	35.606484	44.019005
Mass Throughput	TPH	2.6726	5.84317	6.11864	8.03481

		INITIAL DESIG	Case 2	Case 3	Case 4
Inputs					
Screw O.D	mm	250	300	325	350
Core Shaft Diameter(screw I.D) (Dc)	mm	60.3	60.3	60.3	60.3
Pitch	mm	250.00	300.00	325.00	350.00
Radial Clearance (C)	mm	3	20	3	3
Flight Thickness	mm	3	8	6	6
Screw RPM	RPM	14	14	14	15
Inner Diameter of Screw Shaft	mm	52.5	52.5	52.5	52.5
Conveying Length	mm	5000	5000	5000	5000
Friction Angle	Deg	25	25	25	25
Average height of material on screw Surface	mm	3.85	3.4	3.45	3.45
Angular Velocity (w)	rad/sec	1.466077	1.4660766	1.4660766	1.5707963
Material		Limestone	Limestone	Limestone	Limestone
Mild steel density	kg/m3	7800	7800	7800	7800
Material Density	kg/M3	1000	1000	1000	1000
Feeder Efficiency	%	80	80	80	80
Coefficient of Friction		0.45	0.45	0.45	0.45
Bulk density	kg/m3	1217.368	1217.368	1217.368	1217.368
width of trough	mm	260	260	260	260
height of end plate above center pipe	mm	193.4	193.4	193.4	193.4
Inner radius of screw		30.15	30.15	30.15	30.15
Outer radius of screw		125	150	162.5	175
Mean radius	mm	47.425	59.925	66.175	72.425
Drive end shaft dia	mm	48	48	48	48
Drive end shaft length	mm	325	325	325	325
Coupling shaft diameter	mm	48	48	48	48
Coupling shaft length	mm	417	417	417	417
Bearing SKF6210 (Dynamic load)	kgf	2750	2750	2750	2750
Bearing SKF6210 (static load)	kgf	2120	2120	2120	2120
Max permissible speed	rpm	8000	8000	8000	8000
Axial load on bearing	Fa	842	842	842	842
Radial load on bearing	Fr	348	348	348	348
Bearing Service factor (S)		1.2	1.2	1.2	1.2
Screw length	inch	196.8504	196.85039	196.85039	196.85039
Modulus of elasticity	Psi	27992283	29732736	30457925	30458925
Moment of Inertia	in^4	0.7	0.7	0.7	0.7
Motor power	HP	3	3	3	3

Force Analysis					
Weight of Bulk Material retained in each pit	Kg	92.02	161.24	205.97	25
Axial Force	Kgf	1771.057	1610.3984	3065.1083	7605.
avg normal pressure on casing	kgf/m2	531.4049	119.97085	36.69257	4.138
Normal pressure due to bulk solid on shaft	Kgf/m2	955.3904	955.39041	955.39041	955.3
screw flight development					
Development of outside diameter (A)	mm	825.75360	990.90431	1073.47967	1156.0
Development of inside diameter (B)	mm	313.6633	354.80227	376.17769	397.9
Developed inside radius of flight©	mm	156.8316	177.40114	188.08884	198.9
no. of flights		20.00	16.67	15.38	1
calculation of various loads					
1.load due to limestone					
volume of hollow pipe	mm3	288011.22	288011.22	288011.22	2880
volume of limestone acting downward	mm3	1.26E+08	125565994	125565994	12556
Weight of limestone (W1)	N/m	1528.6	1528.6002	1528.6002	1528.
Volume of one flight	mm3	138624.51	542365.35	480367.77	55984
Weight due to flight per metre (W2)	N/m	36.76322	143.83529	127.39353	148.4
W1+W2	N/m	1565.363	1672.4355	1655.9938	1677.
10% overload of (W1+W2)	N/m	156.5363	167.24355	165.59938	167.7
Volume of drive end shaft	mm3	587808	587808	587808	58
Load due to drive end shaft(W3)	N	45.84902	45.849024	45.849024	45.84
volume of coupling shaft	mm3	754202.9	754202.88	754202.88	75420
load due to coupling shaft (W4)	N	58.82782	58.827825	58.827825	58.82
Load due to hollow pipe	N	22.46488	22.464876	22.464876	22.46
50% Load due to hollow pipe	N	33.69731	33.697313	33.697313	33.69
Total load	N	294.9105	305.61771	303.97354	306.0
BEARING SELECTION					
LMR	lmr	8.40000	8.40000	8.40000	9.00
Radial factor (X) from PSG databook		0.56	0.56	0.56	
Thrust factor (Y) from PSG databook		1.12	1.12	1.12	
Equivalent load on bearing(P)	N	2338.56	2338.56	2338.56	233
Deflection calculations					
Deflection of screw	inch	0.07235	0.32086	0.31154	0.3
		1.83773	8.14985	7.91301	7.9
Torque calculations					
Torque acting on screw	N.mm	13.50536	13.50536	13.50536	12.6
Material Resistance on Trough Side					
Material Vertical Pressure	kg/m2	125.00000	150.00000	162.50000	175.0
Rankine Failure for Side Pressure		2.49762	2.49762	2.49762	2.4
Material Side Pressure	kg/m2	312.20256	374.64307	405.86333	437.0

Fig. 4 results from CEMA

7. CONCLUSIONS:

The performance of screw conveyors is significantly influenced by the vortex motion of the bulk solid being conveyed. the vortex motion together with the degree of fill, govern the volumetric efficiency and hence the throughput. This in turn influences the torque, power and conveying efficiency.

7. ACKNOWLEDGMENT:

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