DESIGN OF A SCREW PRESS FOR DEWATERING OF CATTLE DUNG SLURRY

[1]Kataria Mahendra B, [2]Hardik Khunt, [3]Pankit Kondhiya

Assistant Professor
Department of Mechanical Engineering
[1]Aditya Silver Oak Institute of Technology, [2,3]V.V.P Engineering College
[1]Ahmedabad, [2,3]Rajkot, India

***Abstract*—Screw presses have been used for various industrial applications, including material handling in the content of cattle dung slurry or biomass slurry (sludge) is fed in to overhead screw, which in turn pushes between the screw and a strainer and the water is drained out and the solid waste is collected at the screw thread. This is later dried to produce briskets. The brisket used as a solid fuel and its calorific value is comparable or better than that of any solid fuel like coal, wood, etc.**

Screw presses for oil crushing is quite common and design of manufacturing of a low cost screw press for separation of solid waste from sludge of the biogas plants is a requirement for rural India, in order to produce briskets to be used as fired, which is a good substitute for fire wood. Cutting of trees for fire wood affect the environment and hence to be minimized. In order to understand the process and its parameters, experiments have been conditioned on a hydraulic press to identify the screen considering screen of different hole size. The hole size tested are Ø 2.00mm, 2.5mm, 3.00mm, 3.5mm. And 4.00mm. It has been inferred from these experiments that Ø 3.00mm is the best screen hole size for filtering, with about 40% solid waste being collected.

***Keywords*: - Cattle dung slurry, Screw press, Screen, Total Solids**

INTRODUCTION

The Screw-Press is a horizontal continuous operation screw that is designed for dewatering/ solid-liquid separation of a wide range of food and other products. Materials that tend to pack or are otherwise considered unpressable are frequently processed successfully by this screw press.Screw presses have been used for various industrial applications – food processing, paper & pulp, starch & sorbitol - including material handling in the context of dung slurry on large animal farms like dairy or piggery. Raw material fed into a screw press in turn pushes between the screw and a screen or strainer and the water is drained out and the solid waste is collected at the screw head. This is later dried to produce briquettes. The briquettes are used as solid fuel and its calorific value is comparable or better than that of any solid fuel like coal, wood, etc.
Liquid is extracted from three areas of the screw press to maximize output and recovery. Free liquid is drained immediately to reduce the imposed hydraulic load. The screw press is equipped with separate main drive and cone motors for independent control of speed and retention time within the press. This design with its unique screw action represents the latest refinement in screw press which has served food processors successfully for many years.

A. OBJECTIVES OF THE PRESENT STUDY

Digested cattle dung slurry is a low solid, pumpable mixture of solids and liquids. The solids are fibrous in nature and hence for the separation of solid and liquid fractions, physical filtration process would not be sufficient but shear forces may prove to be effective. A screw press combines two separating devices: a screen and a press, as shown in the figure 1.5 below.

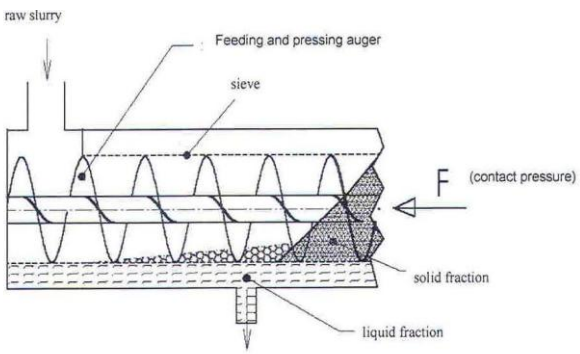


Figure 1.5 Solid- liquid separations in screw press

Various attempts have been made to develop digested slurry dewatering machine by different agencies, but an effective machine which would give around 35 % TSC have not yet been developed. If such a machine is developed, the thin liquid

fraction would be more homogeneous than the slurry and could be easily spread over the farm land and solid fraction recovered could be composted faster. The solid fraction could be directly used as mulch or raw material for Refuse Derived Fuel (RDF).
Such machines developed in western countries are of large capacity (10-30 m^3/hr) and may have limited application ifadopted directly. If a smaller capacity machine, suitable for slurry generated by 80-100 cu m community biogas plants is fabricated indigenously, it would have better acceptance.
Hence, the objective of this study is to develop and evaluate digested slurry dewatering machine which can produce solid residues with TSC around 35%, which would be suitable for large capacity biogas plants.

B. DESIGN OF SCREW PRESS

a. POWER REQUIREMENT OF SCREW PRESS

Factors for Power Requirement Determination

Power requirement of screw conveyor basically depends on the length of screw conveyor, capacity and a factor for total apparent resistance. This resistance varies with respect to type of material conveyed that is its nature, abrasiveness, grain size, internal resistance, etc, and many also depend upon the degree of filling. There are various factors with quite a few variables involves for determination of power requirement of screw conveyor depends, are as follows:
a. Friction between the casing and the transported material.
b. Friction between the screw and the transported material.
c. Friction in the intermediate and in the end bearing and hence on type of bearings installed.
d. Friction in the axial bearing owing to axial force.
e. Additional resistance due to partial compensation of thermal expansion of the screw supported between the material or when the temperature difference between winter and summer is too high and the screw conveyor is comparatively long.
f. Additional resistance owing to accumulation of transport material at the intermediate bearings, mixing and rolling of the transport material.
g. Additional resistance for friction of the screw edge with the transport material when a grain is wedged between the grain between the screw and the casing.
h. Additional resistance fir upward conveying in case of inclined screw conveyors. The various factors mentioned shall apply basically to horizontal and slightly inclined screw conveyor. For vertical screw conveyor there may be some other factors also.
b. Effect of lump size
The size of lump indicates the maximum dimension of the particle. Usually there are three types of lumps sizes which are considered for selection of screw size. These are:
❖ A mixture of lumps and fines in which not more than 10% are lumps ranging from maximum size to one half of the maximum; and 90% are lumps smaller than one of the maximum size.
❖ A mixture of lumps and fines in which not more than 25% are lumps ranging from maximum size to one half of the maximum; and 75% are lumps smaller than one of the maximum size.
A mixture of lump only in which 95% or more are lumps ranging from maximum size to one half of the maximum size; and 5% or less are lumps less than one tenth of maximum size. The allowable size of a lump in a screw conveyor is a function of the radial clearance between the outside diameter of the central pipe and the radius of the inside of the screw trough, as well as the proportion of the lumps in mixture. Figure 3.1 shows the relationship.

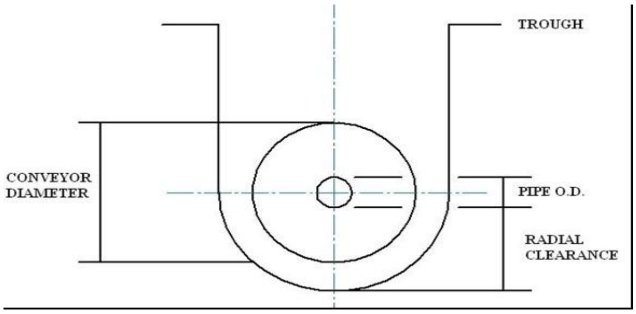
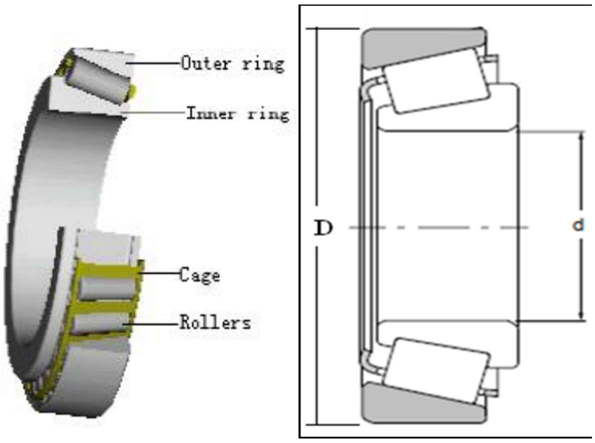


Figure 3.1: Radial Clearance

c. Bearing section
Rolling bearings come in a wide variety of types, shapes and dimensions. The most important factor to consider in bearing selection is a bearing that will enable the machine or part in which it is installed to satisfactorily perform as expected. Shaft assemblies generally require two bearings to support and locate the shaft both radially and axially relative to the stationary housing. These two bearings are called the fixed and floating bearings. The fixed bearing takes both radial and axial loads and \locates" or aligns the shaft axially in relation to the housing. Being axially \free", the floating bearing relieves stress caused by expansion and contraction of the shaft due to actuations in temperature, and can also allow for misalignment caused by fitting errors.

d. Bearing load

The magnitude of the load is the factor which usually determines the size of bearing to be used. Generally, roller bearings can carry heavier loads than ball bearings having the same external dimension. The load direction of bearings must be considered for selection bearing in addition to the magnitude of the load. When the bearings carry pure radial load, deep groove ball bearings, cylindrical roller bearings and needle roller bearings should be selected. When the bearings carry pure axial load, thrust ball bearings, cylindrical roller thrust bearings and needle roller thrust bearings should be selected. When bearings carry combined load which comprises a radial and an axial load acting simultaneously, angular contact ball bearings or tapered roller bearings are generally selected. If radial load in combined load is larger and axial load in combined load is smaller, deep groove ball bearings or cylindrical roller bearings with ribbed rings can be selected. If axial load is considered to be principle in combined load, angular contact ball bearings or spherical roller thrust bearings should be selected. When the load acts eccentrically on the bearing, tilting moments will arise. If moment load is not large, single row angular contact ball bearings in pair or tapered roller bearings arranged face-to-face or back-to-back are more suitable.



Selection of Bearing (As per ISO 32218)
Axial thrust on screw, p
P = q L μ, kgf (3.1)
= 5652.91 x 1 x 0.6
= 3391.74 kgf
Fa = 33273 N
Equivalent load:
P = xFr + yFa (3.2)
P = yFa
= 1.45 x 33273
= 48245 N
Loading calculation:
$L_{10} = (C/P)^{10/3}$ (3.3)
$L_{10} = 20000$
$200000 = (C/48245)^{10/3} \times 10^6/60/25$
= 666.66
C = 2.77 x 4825
= 133.63 KN < 200 KN so that Design is Safe.
As per ISO 32218 Std. Taper Roller Bearing is selected.

e. Design of the rotating shaft

The shaft on which the screw material was wound was designed based on the following assumptions:

1. Shaft is solid and made from austenitic steel with a yield stress 0f 280 M/N²
2. Density of shaft material is 1000 kg/m³.
3. Pitch of screw 286 mm.
4. Maximum angle of twist is 1˚ per 300 mm length.
5. Factor of safety FS is 2.5

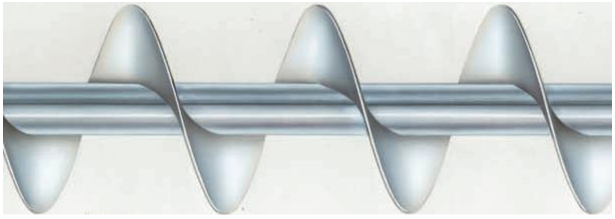


Figure 3.3 screw press shaft

f. SIZE OF SCREW PRESS

The size of screw conveyor depends on two factors:

a. The capacity of the conveyor

$Q = 15\ \pi\ D^2\ S\ n\ \Psi\ \rho\ C$

$= 15 \times 0.114 \times 0.286 \times 8 \times 0.1 \times 1000 \times 1$

= 1.2 tonne/hr

b. friction factor of the material on through,

0.1 for non- abrasive, free flowing materials.

g. Capacity of screw press

The capacity of screw conveyor depends on the screw diameter, screw pitch, speed of the screw and the loading efficiency of the cross sectional area of the screw.

Design data for the screw press

D = screw diameter 0.114 m.

S = pitch of screw 0.286 m.

n = rpm of screw, 8rpm.

Ψ = loading efficiency 0.1

ρ = density of material 1000 kg.

C = factor of inclination of screw 1.

The capacity of a screw press with a continuous screw may be expressed as:

$Q = A \times V$ (3.4)

$Q = 15\ \pi\ D^2\ S\ n\ \Psi \rho\ C$

$= 15 \times 0.114 \times 0.286 \times 8 \times 0.1 \times 1000 \times 1$

= 1.2 tonne/hr (3.5)

h. Screw pitch: (S)

Commonly the screw pitch is taken equal to the diameter of the screw D. however; it may range from 0.75 -1.0 times the diameter of the screw.

i. Loading efficiency :(Ψ)

The value of loading efficiency should be taken large for materials which are free owing and non-abrasive, while for materials which are not free owing and, or, are abrasive in nature, the value should be taken low:

= 0.12 to 0.15 for abrasive material.

= 0.25 for mildly abrasive material.

= 0.1 for non- abrasive, free flowing materials.

DESIGN OF SCREW PRESS

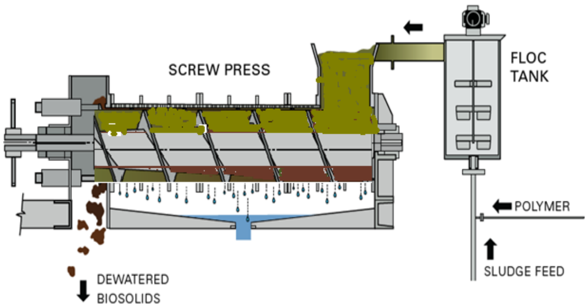


Figure 4.1 Design of Screw Press

Power required for driving the screw:

$N = \frac{QL}{367} [\underset{\circ}{w} + \sin\beta] \frac{1}{\eta}$

(3.6)

= 1000 x 2.6/367[4 ± 0.0174]

N = 0.4883 KW

1) Torque on screw shaft, M,

$M = 975 , \frac{N}{n}$ (3.7)

= 975 x 0.4883 /8

= 5777.8 N

2) Load propulsion speed

$V = \frac{sn}{60}$, m/s

(3.8)

= 0.285 x 8/60

= 0.0381 m/s

3) Load per meter length of screw, q

$q = \frac{Q}{3.6v}$

(3.9)

= 1000/3.6 x 0.0381

= 7290 kg

4) Axial thrust on screw, p

P = q L μ,

(3.10)

= 647.50 x 2.6 x 0.1

= 1.895 N

Q = capacity of conveyor, tone/hr

D = screw diameter, m

S = pitch of screw, m

n = rpm of screw shaft, table 1 below

Table 1 R.P.M. of Screw

Screw dia. D	**150**	**200**	**250**	**300**	**400**	**500**	**600**
rpm, min	23.6	23.6	23.6	19	19	19	15
Max	150	150	118	118	95	95	75

Ψ = loading efficiency,

= 0.125 for slow flow abrasive material

= 0.25 for slow flow abrasive Material

= 0.32 for free flow and mildly abrasive material

= 0.4 for free flow and non abrasive material

C = factor of inclination to horizontal

β = angle of inclination of screw shaft to horizontal

a. **Inclination factor: (C)**

The inclination factor C is determined by the angle of screw conveyor with the horizontal. Approximate values may be obtained from the following table 2

Table 2 Value of Inclination Factor C

β, deg.	0	5	10	15	20
C	1.0	0.9	0.8	0.7	0.65

N = power in kw

L = length of conveyor, m

H = L sin β

$\underset{\circ}{w}$ = material factor

= 2.5 for coal, rock salt

= 4.0 for fine dry clay, foundry sand, cement, sulfur, ash, etc.

η = efficiency of gear reducer.

μ = friction factor of the material on trough, 0.1

Helix angle

Helix angle defined as

$$\frac{\text{pitchdia.}}{\pi * \text{pitchsmalldia.}}$$

Bending stress of screen

Material mild steel

$\sigma t = 290$ N/mm², $\tau = 143$ N/mm², $\mu = 0.28$.

t = 3mm, L = 1521, D = 360 mm.

$$t = ri\frac{\sqrt{\sigma t+(1-\mu)p}}{\sigma t-(1+\mu)p} - 1$$

P = 4.850699457 N/M^2

b. Taper diameter

Variation of tapering shaft diameter along length for various tapering angles β is 22.76° shown in equ.3.9. It is obvious that for a shaft whose base diameter was 90mm and screw thread big diameter is 350mm and small diameter is 220mm.

c. Presures

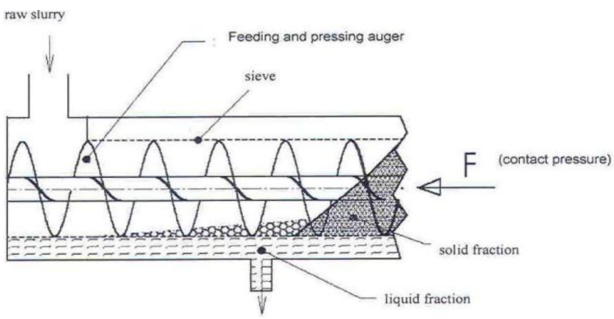
Adeeko and ajibola report that oil will only be expressed in peanut seed if the static pressure is not less than 20 MPa, this being the oil-point. For this work, a power transmission efficiency of 30% was assumed; hence a pressure, of not less than 50 MPA had to be made available at the pressing zone. For this pressure to be attained, a power source of 1.0 kw, at speed of not more than 8 rpm. For this work, a 1.5 kw variable speed motor was used with the speed varying between 75 and 95 rpm.

SCREW PRESS SCREEN DESIGN

The biogas plants based on cattle dung operate at 8-10 % Total Solids (TS) content. TS of raw cattle dung is 16-20% and hence water is used to prepare slurry of desired consistency. In case of large biogas plants handling tons of cattle dung on daily basis, the volume of water used and slurry to be handled is huge. Digested slurry coming out of the biogas plant contains 3-4% TS. Recycling and reusing of digested cattle dung slurry is gaining importance in the light

Of nutrient recovery, better resource management and alternative energy generation. Integral to a digested slurry management system is a unit to separate the liquid from the solids. Liquid thus separated could be recycled and solids could be used raw material for composting or for preparing solid fuel.

Equipment and processes for separating liquids and solids have been widely used in many industries. The unique characteristics of cattle dung slurry like no homogeneous, slimy, corrosive, abrasive, etc. require changes in equipment developed for other processes before they function acceptably in separating slurry solids. Several types of equipment or processes are used for manure liquid-solid separation. One such equipment is a screw press. Screw presses are composed of a screw-type conveyor in the center. The screw-type conveyor forces the manure slurry through a tube and past a cylindrical screen. Solids retained on the screen are pressed to the end and discharged. Rate of flow determines the solid removal from liquid manure. With most screw presses, the rate can be adjusted to control moisture content of the solids discharged. Conceptual view of a screw press is shown below fig-1



Sardar Patel Renewable Energy Research Institute (SPRERI) conducted some experiments on dewatering of digested cattle. Dung slurry from a biogas plant using a screw press. It was observed that even when effective separation of solid and liquid fraction of slurry was taking place, majority of solids (by weight) were going to the liquid fraction. This needed change in design of the screen. This paper presents the laboratory experiments conducted to collect data on dewatering of slurry for design of another screen for the existing screw.

CONCLUSION

A screw press has been design for separating the solid to produce briskets from the slurry of cow dung at a rate 1.2 tone/hr, with 8 rpm, with a factor of safety of 2.5. The requirement of maximum collection of the solid needs an effective screen and experimentally and it has been fond that a perforation size of Ø 3 mm is the optimal size. The optimum wire mesh size, fond experimentally is of 0.77 x 0.77 mm size. The press could be used for producing briskets from biomass slurry as well.

Experiments have been conducted on a hydraulic press to identify the screen considering screen of different hole size. The hole size tested are Ø 2.00 mm, 2.5 mm, 3.00 mm, 3.5 mm, And 4.00 mm. It has been inferred from these experiments that Ø 3.00 mm is the best screen hole size for filtering, with about 40% solid waste being collected.

Experiment using screens made up of wire mesh of sieve size of 3.35mm, 0.45mm, and 0.77 mm was performed, Experiments have been conducted on wire mesh screen size 3.35 mm and 0.77 mm, solid residues with 26% TS content were produced, but the filtration rate was so low that it was totally impractical to design of screw press with that type of screen. However, a large amount of solids were also present in the fraction 0.45 mm. The data helped in concluding that even if the sieve size was kept as fine as 0.45 mm, around 40% of the solids.

ACKNOWLEDGMENT

I am highly thankful to my guide Dr. P.M. George Head of Mechanical Department, B.V.M Engg. College V.V. Nagar, for providing constant guidance, encouragement.

I am grateful to Er. Himali Mehta, Head of Sardar Patel renewable energy research institute for allowing me to work on this project with timely guidance.

I would like to express a deep sense of gratitude and thanks profusely to my parents and fellow friends for constant support and motivation.

REFERENCES

[1] Marcy Ford and Ron Fleming, Mechanical Solid-Liquid Separation of Livestock Manure - Literature Review, Ridgetown College - University of Guelph, Canada

[2] M. Hjorth, K.V. Christensen, M.L. Christensen, S.G. Sommer, Solid–liquid separation of animal slurry in theory and practice - A review, Journal of Agron. Sustain. Dev. 30 (2010) 153–180.

[3] Richard K. White, The role of liquid - solid separation in today's livestock waste management systems, Journal of Animal Science (1980) 50:356-359.

[4] Thomas H. Manley and Robert B. Johnston, Screw presses in waste dewatering, Tappi Journal, Vol. 78, No. 12, 233-235.

[5] www.vincentcorp.com