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# Performance Improvement of Flow Rate of Spiral Chip Feeder in domestic cattle manure monitor making machine

**Abstract:** The abstract outlines a study focused on the stability and effectiveness of a screw feeding mechanism designed for the outlet of pulping material in a screw reactor. This reactor functions as a continuous system where material is transported and mixed by a screw (augur). The study emphasizes the importance of operational conditions in influencing the process outcomes. To efficiently understand and optimize the system, the researchers employed modelling techniques, which are often quicker and more cost-effective than conducting experiments. The paper provides a comprehensive list of modelling approaches, both validated by experiments and theoretical, that is applicable to various aspects of screw reactor operation.

Additionally, the study delves into new product development, specifically shaping a conical screw feeding reactor along with its shaft and flights design. A crucial aspect analyzed is the radial force effect on the flight surface during spiral rotation. Structural engineering techniques were employed to ensure the sustainability of the design, with validation results confirming its effectiveness.

**Keywords:** Screw, Radial Force, Pulping Material

## INTRODUCTION

Screw conveyors, also referred to as auger conveyors, are integral components in various industries, primarily in bulk handling applications. Consisting of a rotating helical screw blade enclosed in a tube, they efficiently transport liquid or granular materials. These conveyors find extensive use in handling diverse materials, such as food waste, aggregates, wood chips, cereal grains, animal feed, boiler ash, meat and bone meal, municipal solid waste, and more.

The existing machine components of a typical screw conveyor include:

1. Screw Blade (Fighting): The helical blade responsible for moving materials along the conveyor. Itis designed to suit the specific material being transported.

2. Tube: A cylindrical enclosure that houses the screw blade. It ensures containment and controlled movement of materials along the conveyor.

3. Drive Unit: This component provides the power to rotate the screw blade. It typically includes anelectric motor, gearbox, and coupling assembly.

4. Hanger Bearings: Bearings positioned along the length of the conveyor to support the rotating shaft.They prevent excessive deflection and ensure smooth operation.

5. Inlet and Outlet: Entry and exit points for materials into and out of the conveyor system. These aredesigned to facilitate efficient loading and unloading processes.

6. Cover: Some screw conveyors feature covers to prevent spillage and dust emissions. These coverscan be removable for maintenance and cleaning purposes.

7. Support Structure: Provides structural integrity and stability to the conveyor system. It includesframes, legs, and supports for mounting and positioning the conveyor.

Fig 1. Straight Screw Feeder

These components work in tandem to facilitate the smooth and reliable transportation of materials in bulk handling industries. Their design and configuration may vary depending on the specific requirements and environmental conditions of the application.

## LITERATURE REVIEW

Indeed, numerous analytical, research, and experimental studies, as well as patented innovations, have been undertaken to comprehensively analyze the characteristics and functionalities of screw conveyors. These studies have been instrumental in understanding and optimizing the performance of screw conveyors across various industries and applications.

Analytical studies often involve mathematical modelling and simulation to predict the behaviour of screw conveyors under different operating conditions. These models help in optimizing design parameters such as screw geometry, speed, and material properties to achieve desired performance outcomes.

Research studies delve into fundamental aspects of screw conveyor operation, including material flow dynamics, power consumption, and wear characteristics. By conducting experiments and collecting empirical data, researchers gain insights into the complex interactions between the screw, material, and conveyor components.

Experimental studies involve practical testing of screw conveyor prototypes or existing systems to validate theoretical predictions and evaluate performance metrics. These studies may include field trials in real-world operating environments to assess reliability, efficiency, and safety aspects.

Additionally, patented studies highlight innovative designs, mechanisms, and technologies aimed at improving the functionality, efficiency, and versatility of screw conveyors. These patented inventions often introduce novel features or configurations that address specific challenges or requirements in material handling applications.

Overall, the culmination of this analytical, research, experimental, and patented studies contributes toa deeper understanding of screw conveyor systems and facilitates the development of more efficient, reliable, and cost-effective solutions for transporting various materials from one location to another.

The works cited provide valuable insights into the design, sizing, and modification of screw conveyors, emphasizing their significance in industrial processes and the need for optimization to achieve efficient operation.

**Bortolamasi and Fottner's study (2001)** highlights the critical importance of proper design and sizing of screw feeders. They underscore that a non-optimal design or selection can lead to poor performance, increased power consumption, wear of equipment, and degradation of conveyed materials. The complexity of designing and sizing screw feeders necessitates a comprehensive understanding of system parameters. While standard procedures are essential, they advocate for integrating lab tests to accurately predict and optimize system behaviour, especially considering the inherent variability in phenomena associated with screw conveyors.

**Jigar N. Patel's work (2013)** focuses on improving the productivity of screw conveyors through modified designs. By reducing the size and power consumption while maintaining output, the modified screw conveyor offers enhanced efficiency. The study acknowledges the widespread use of screw conveyors across various industries for transporting and elevating particulate materials at controlled rates. Additionally, it highlights their versatility in applications such as measuring flow rates from storage bins and adding trace materials to granular substances or powders.

Both studies contribute to advancing the understanding and optimization of screw conveyor systems, addressing critical aspects such as design criteria, performance improvement, and application versatility. These insights are valuable for industries seeking to enhance material handling processes, optimize energy consumption, and improve overall efficiency.

## PROBLEM IDENTIFICATION

### A. Insufficient Flow Output:

The current augur screw flights are not providing adequate flow output for the pulp material. This issue could be attributed to various factors such as the design of the flights, the speed of rotation, or the properties of the material being conveyed. To address this, it may be necessary to redesign the flights to improve their efficiency in moving the pulp material or adjust the operational parameters to enhance flow output.

**B. Flights Bending:**

The flights on the existing machine are prone to bending during operation. This could be due to excessive stress or insufficient strength of the flight material. One potential solution could involve using thicker sheets for the flights to increase their durability and resistance to bending. Additionally, optimizing the design of the flights to distribute stress more evenly along their length may help mitigate bending issues.

**C. Welding of Spiral Flights:**

The spiral flights are welded onto the main shaft, and improper welding design may result in load- bearing failures. Ensuring proper welding techniques and material selection is crucial to prevent failures in the welded joints. Additionally, considering alternative attachment methods or reinforcing the welded joints may help improve the structural integrity of the flights.

## PROPOSED SOLUTION

Introducing a conical shape to the outer casing of the screw conveyor represents a significant design modification aimed at increasing the flow rate of pulp in the paper industry. This alteration not only affects the outer casing but also necessitates adjustments to the shape of the flights to accommodate the new conical configuration.

The change in the outer casing from cylindrical to conical inherently alters the trajectory and flow dynamics of the conveyed material, affecting the design requirements for the flights. Since the flights are directly responsible for moving the material along the conveyor, their shape and configuration must align with the new conical casing to optimize material flow and throughput.

With the outer casing now conical in shape, the flights will also need to vary in shape accordingly, referencing the diameter of the outer casing at different points along its length. This variation in flight shape ensures efficient material handling and flow throughout the conical screw conveyor system.

Designing the flights to match the changing diameter of the conical outer casing requires careful consideration of factors such as material properties, flight geometry, pitch, and spacing. Computational modeling and simulation can aid in optimizing the flight design to maximize material flow while minimizing energy consumption and wear.

Additionally, prototype testing and validation in real-world operating conditions will be essential to fine-tune the conical screw conveyor design and ensure its effectiveness in increasing the flow rate of pulp in the paper industry. Continuous monitoring and iterative improvements may be necessary to achieve optimal performance and reliability in the new conical screw conveyor configuration.

## DESIGN STARTEGY

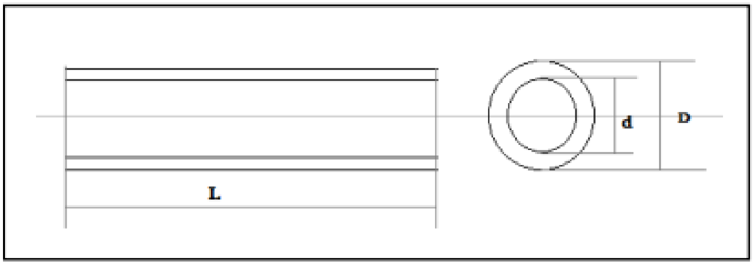

Fig 3. Spool nomenclature

According to amercian society of mechanical engineering code for the design of transmission shaftthe maximum permissible bending stress (σ) may be taken as

σ = 0.6 and 0.36

take smaller value from design data book$\sigma_{el}$ =

190 Mpa

$\sigma_{ut}$= 510 Mpa

hence σ = 0.6 x 190 = 140 Mpa

and σ = 0.36 x 510 = 183.6 Mpatake

whichever is small.

hence σ = 114 Mpa

we have flexure formula

$$\frac{M}{I} = \frac{\sigma}{y}$$

Where

M= bending moment

W = 1.5 N/mm (as an input standard)M =

$Wl^2/2$

= 1.4 x $10^6$ N-mm

I = moment of inertia

$$I = \frac{\pi}{64}(Do4 - Di4)$$

We have

$D_0$ = 80 mm L = 1350

mm

Y = $D_0/2$ = 40 mm

So we have

$\sigma = 114$ N/mm$^2$

by putting above value in equation we get$D_i = 74.5$

mm = 75 mm

Now according to Americian Society of Mechanical Engineering code for the design of transmission shaft that the maximum permissible shear stress ($\tau$) may be taken as 18 % of ultimate tensile strength ($\sigma_{ut}$)

In other words$\tau = 0.18$

$\sigma_{ut}$

Maximum permissible shear stress$\tau = 0.18$

$\sigma_{ut}$

$^{=}$0.18 x 510

= 91.8 Mpa

From torsional equation we have

$\frac{T}{J} = \frac{c}{R}$

Where

T = torque acting on the shaftJ = polar

moment of inertia

$\tau$ = torsional shear stress

R = distance from neutral axis to outermost fibre

= $D_0/2$ = 40 mm

We know that for solid circular shaft polar moment inertia J is given by

J = $\frac{\pi}{32}\,(Do4 - Di4)$

J = 1.0 x $10^6$ $_{mm}{}^4$

Now shear stress is

$\tau = 0.3\ \sigma d$Type equation here.

= 0.3 x 190

= 57 Mpa

Hence torque acting on shaft

T = 1.425 x 10 $^6$ N-mm

Twisting moment

According to maximum shear stress theory

Maximum shear stress

T max = $\frac{16\ Do}{\pi\,(D04 - di4)}\ x\,Te$

Where

$Te = \sqrt{(M2 + T2)}$

By putting values of M and T in equationTe =

$1.713 \text{ x } 10^{3}$ N/mm2

Hence maximum shear stresst max =

68.7 N/mm$^2$

According to Macaulay method maximum deflection Is given by

$y = \frac{wL4}{8EI}$

hence maximum deflection is y = 6 mm

## 2. Flight Design

Flight diameter is taken 420mm means at least 60% of pitch must be considered to give easy spiral bend to the sheet metal flight bending. Hence maximum possible pitch considering i.e. 250mm. Pitch we will take 150 mm for each flight. We get total 6 flights over the length of spool.

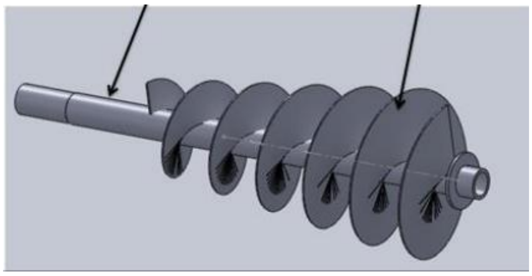

Fig 4: flights welded on a shaft

## 3. Design of Anti Bending beam for flight

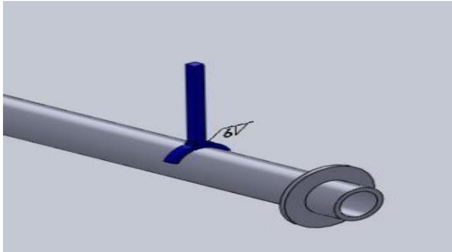

Fig 5: Anti bending beam on shaft

T shaped bracket designed for circular mounting and flights are welded with this structure. This bracket holds all the radial loads coming on flights and sustaining all the bending stresses which may affect flight shape and size with failures. For preventing the bending of flights I designed the this new beam.

Maximum Shear load = V = 300N

Maximum Bending Moment = M = 58500N-mm-We have

from flexure formula [7], From eqn (i

$$-\quad \frac{M}{I} = \frac{\sigma}{y}$$

Where

M = bending moment = 58500 N-m

I = Moment of inertia = $bd^3$ / 12 = $15x15^3$ / 12 = 833.33 $mm^4$y = d/2 =

7.5 mm

Hence bending moment stressσ = 104

$N/mm^2$

Deflection is given by

y = $\underline{wL}33EI$

y = 0.8 mm

## 4. Flow rate calculation

Cylindrical vessel volume is given by following formula. Volume of cylinder = $\pi r^2 h$
Volume = 368 litres with water content
There was no dewatering in this vessel due to gravity possibilities in cylindrical vessel. Volume of conical vessel is given by following formula
V = $\frac{\pi h}{3} * R2 + Rr + r2 +$
V = 181 Litres

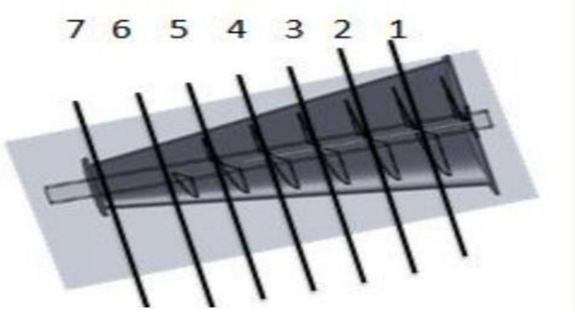

Fig 6: compartments formed on new proposed structure

It seems like you've provided calculations based on the volume of buckets or compartments in a screw feeding system and the rotational speed of the plug screw. Let's break down the calculations and ensure accuracy:

Total number of buckets: 7

Volume of buckets (compartments) derived from CAD data:

Bucket 1: 36 liters, Bucket 2: 35 liters, Bucket 3: 31 liters, Bucket 4: 23.5 liters, Bucket 5: 19 liters, Bucket 6: 18 liters, Bucket 7: 18 liters

Since 50% of water is removed from the perforated vessel sheet by squeezing the pulp in the screwfeeding system, the output volume from each bucket reduces by half.

Output volume in 7 rotations (assuming each rotation empties one bucket): 20/7 liters.The speed

of the plug screw is given as 20 rpm (rotations per minute).

Therefore, the total volume output per minute is calculated as:

Total volume output per minute: output in 7 rotations x rotations per minute

Let's compute the total volume output per minute: (20/7) x 20 = 57.14 litres per minuteExisting

model = 1000 lit/hour = 16.66 lit/min

New model = 57.14 lit/min.

## RESULT AND CONCLUSION

Comparison of flow rate of existing and new developed model.

| | Existing model | New Developed model |
|---|---|---|
| Flow rate | 16.66 lit/min | 57.14 lit/min |

## CONCLUSION

In conclusion, the load-sustaining parameters of the newly designed screw conveyor with a conical feeding vessel have been determined to be safe, with all stresses remaining below the yield strength value. The conical shape of the feeding vessel enables the system to achieve a 32% increase in efficiency compared to the previous design. This efficiency improvement is attributed to the flow benefits derived from the conical shape, where the larger diameter at the inlet and the smaller diameter at the outlet facilitate gravity flow.

In the previous design, which featured a simple cylindrical vessel, material flow relied solely on screwrotation. However, in the new design, material flow is enhanced by both the forces generated by the screw and the gravitational loads acting on the material. This combination of screw forces and gravity flow results in a more efficient and effective material handling process.

Overall, the adoption of a conical feeding vessel in the screw conveyor system has proven to be a successful design modification, leading to improved performance and throughput. The integration of gravity flow alongside screw forces has optimized material handling, contributing to the overall efficiency and reliability of the system.

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