Design and Structural behavior Analysis of Pressurized Conical Screw Feeding System with Development of Shaftless Optimization

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Abstract— Squeezing and feeding in common machine is very unique system in process industry where thick wet material of specific density is processed inline. Here, we found a solution to make common feeding with squeezing the wooden pulp in pulping industry to make sufficient fiber separation while transferring material to the screening machine. Shaft less feeder makes lightweight and useful mechanical parameters to prove its working behavior in real life. Instead of typical feeder here going to design the screw structure without shaft, it delivered more volume of material to out let, also it is more efficient in productivity. Conical screw is the assembly of multiple shape and sizes flights which are assembled together with weldment technology. Work involves majorly with reducing diameter of flight and reducing pitch screw. Its validations are to be done on multiple variants of screw flights.

Key words: Pressurized Conical Screw, Shaft Less Optimization

I. INTRODUCTION

Instead of typical feeder here going to design the screw structure without shaft, shaft less screw will deliver more volume of material to out let, and more efficient in productivity. This project comes with the lightweight screw solution and innovation in material handling and feeding machineries.

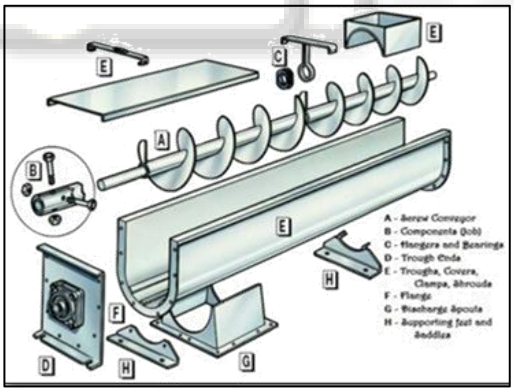

Fig. 1: Typical view of screw conveyor

A. Screw Conveyors

1) Are compact and easily adapted to congested locations.
2) Can be used to control the material flow in processing operations which depend upon accurate batching.
3) It can be employed in horizontal, inclined and vertical installations.
4) Can be used as agitator to blend dry or fluid ingredients, provide crystallization or coagulant action or is maintain solutions in suspension.
5) It prevent the escape of dust from inside the conveyor or keep dust or moisture from entering from outside the conveyor.
6) It serve as a drier or cooler by running hot or cold water through the jacket.
7) Can be made out of a variety of materials to resist corrosion, abrasion or heat, depending upon the product being conveyed.
8) It outfitted with multiple discharge points.

II. LITERATURE REVIEW

A. A. Ramesh, P. Karunaker and L. Ramesh, "Design and Analysis of Discharging of Dust in Pneumatic Conveying System by a Screw Conveyor Shafts"

In this paper Ansys software is used to do the analysis on the Screw Conveyor Shaft. According to ANSYS results, the stress and displacement values for hollow shaft assembly are little bit higher than solid shaft but the values are within the minimum strength of the material. So hollow shaft is better to used assembly instead of solid shaft. By this we can reduce the cost by reducing material quantity and can increase the mechanical efficiency by reducing weight.

1) Screw Conveyor components & design.

In this manual, Screw conveyor is designed according to 7 important design steps like, Establish conveying requirements; Identify the material and the corresponding material code; It determines Calculate required horsepower—select motor size; conveying capacity, conveyor size and speed; Determine the recommended size of components; Check the torsional ratings of components; deflection, thermal expansion and abrasion.

B. Jones, David D. and Kocher, Michael F., "Auger design for uniform unloading of granular material: I. rectangular cross-section containers".

In this paper, design equations were developed for two auger configurations that for practical purposes generate uniform vertical flow of granular material through containers or boxes having a rectangular cross-section. The configurations have uniform OD so the simple geometry of the conventional U-trough housings could be used with these augers. One configuration had a uniform pitch for the it and decreasing inside diameter. The other had a uniform inside diameter and a decreasing pitch of the flighting with distance from the outlet end of the auger. Both configurations dramatically improved the uniformity of flow over the conventional auger. However, confidence intervals (a = 0.01) generally indicated that flows were significantly different from an "ideal" uniform flow along the length of the augers.

C. Kocher, Michael F. and Jones, David D., "Auger design for uniform unloading of granular material: ii. Cylindrical containers".

In this paper, the analysis presented can be used to determine the design equations for augers that produce uniform vertical flow of granular material through containers with cylindrical cross-sections. The augers so designed have a constant outside diameter and a variable root or shaft diameter. They could be used to convert a batch-in-bin dryer to a continuous flow dryer. The analysis is an extension of the work of Jones and Kocher (/995) who designed and tested such an auger for containers of rectangular cross-section, and determined flow to be uniform for practical purposes. The analysis follows the same concept used by Shivvers (1973) to develop augers with variable outside diameter to provide uniform vertical flow of granular material through containers with cylindrical cross-section.

D. GEC NO. 8, "Design and Construction of Continuous Flight Auger (CFA) Piles".

This document is to develop a state-of-the-practice manual for the design and construction of continuous flight auger (CFA) piles, including those piles commonly referred to as augered cast-in-place (ACIP) piles, drilled displacement (DD) piles, and screw piles. In this document allowable stress design procedure is presented as resistance factors have not yet been calibrated for CFA piles for a Load Resistance Factored Design approach. The intended audience for this document is engineers and construction specialists involved in the design, construction, and contracting of foundation elements for transportation structures.

E. Marco Bortolamasi, Johannes Fottner, "Design and sizing of screw feeders".

This paper describes the screw feeders are devices suitable for handling a wide variety of materials that have good flowability characteristics. The screw feeder has a helicoidal surface fitted on a shaft that rotates inside a fixed tube. The material comes out of the silo is pushed by the helicoid flight in the direction of transport. The advantages of the screw feeder include the possibility of having different openings, each with its own shut-off organ for unloading the material.

F. Alan W. Roberts, Emeritus Professor and Director, "Design considerations and performance evaluation of screw conveyors".

This paper describes 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. The flow properties of the bulk material being conveyed are shown to have a significant influence on the performance.

III. PROBLEM STATEMENT

Making of plug screw with one piece is manufacturability difficult process.

Now nonstandard and multidimensional screws required to obtain various output in various requirements. So full feel these, we need to design new conical screw with flights weldment assembly and shaftless work, to helping out reducing weight and reducing unwanted load parameters.

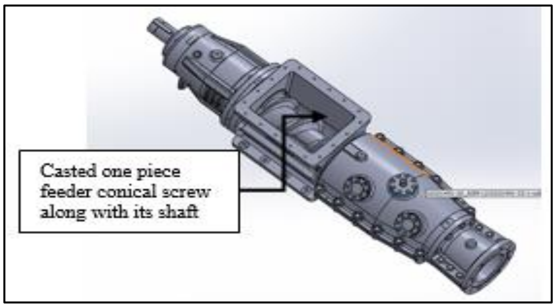

Fig. 2: Housing and previous screw assembly of plug screw

IV. OBJECTIVE AND SCOPE

A. Objectives

- To find out the solution and feasibility in application as to transfer the thick wet material from one station to another.
- Design of screw conveying system by its flights parameters.
- Main innovation on shaftless screw design to be developed to get maximum volume.
- Design and development of flights and moderate geometry to fulfill the work flow.
- Validate the results by engineering calculations.
- Find out the boundary conditions after torque and rotary calculations.
- Validation to be proved by analysis results stress, bending behavior etc.

B. Scope of Work

- Product inputs and application theories
- Concept modeling with shaft less screw
- 3D modeling (solid works), design calculations
- Comparison with other feeding mechanisms and future scope
- Stresses behaviour on flights of screw. (Ansys)
- Bending behaviour while working with boundary conditions. (Ansys)
- Modal analysis and validation (Ansys)
- Testing will be carried to validate analysis results
- Validation

C. Scope in Design

- Redesign of screw with newly weldment joints instead casting components.
- Volume of screw housing to be increased by removing shaft design instead flights strength to be made high to make perfect bonding in real working.

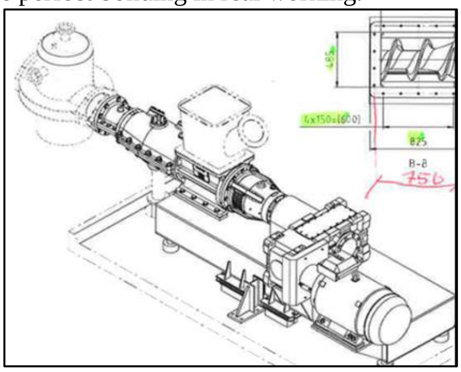

Fig. 3: Machine where plug screw feeder is installed.

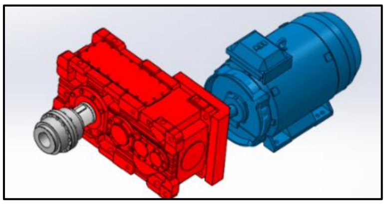

Fig. 4: Drive unit: 700 Nm torques producing with 20 rpm

V. METHODOLOGY

A. CAD Strategy

To make this CAD model practically, we have used helix command Pitch we took 150 mm for each flight.

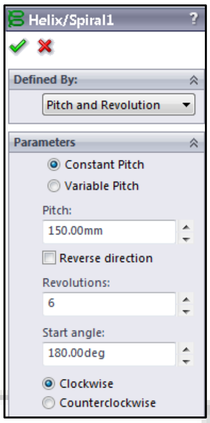

Fig. 5: CAD Strategy

1) Stages forming flight in CAD

Using sweep command,

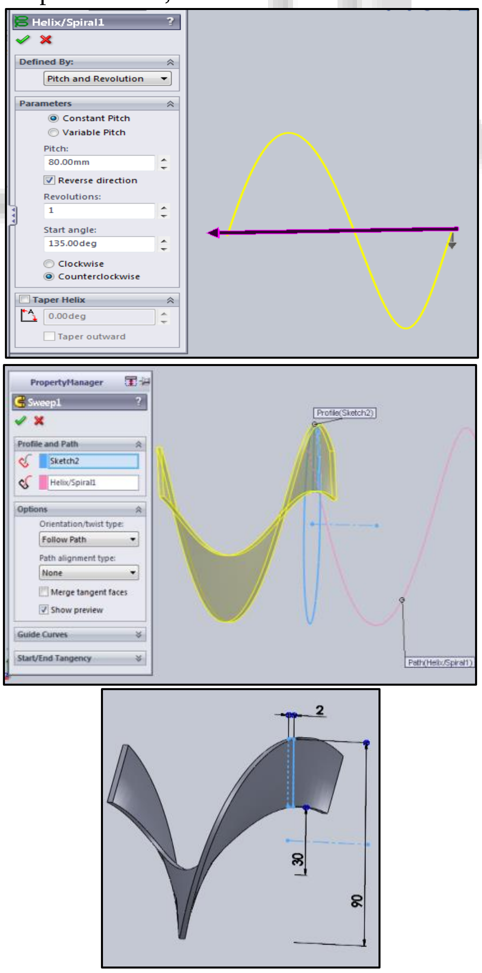

Fig. 6: Sheet metal swept flight

One by one flights assembly weldment can be formed.

Pitch of each flight will be same and axle insertion will be collinear. Only outer diameter will change in each flight comparison to formed conical shape.

B. Flight design

Flight diameter 420 means at least 60% pitch must be taken to give easy spiral bend to the sheet metal flight bending. Hence maximum possible pitch considering i.e. 250mm.

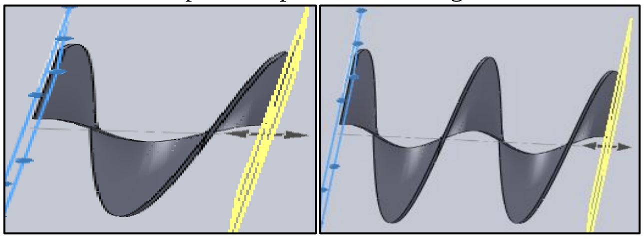

Fig. 7: Flight, joining of 1&2

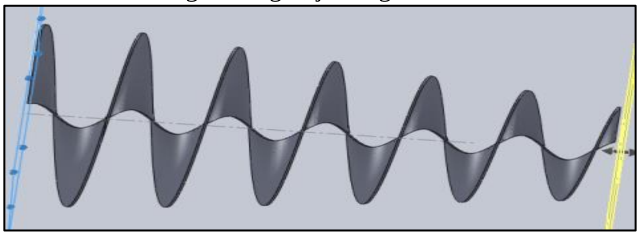

Fig. 8: Similarly 1, 2, 3, 4, 5 & 6 joined which are smallest in size.

C. Analytical Method

Over-torque failures almost always occur in the feed section, which makes sense because that is screw section most susceptible to torque. Torque failures have characteristics that are easy to identify. They always initiate from the outermost portion of the screw—the flight surface and crack toward the centre. As a result you'll see radial cracks in the flight surface around the break. Additionally the screw will "wind up" like a spring, and the flight pitch around the break will be permanently reduced (see illustration). As the screw winds up and cracks it also grows in diameter, making it very difficult to remove from the barrel.

The root diameter carries the torque load, even though the flight adds to the screw's torsional strength.

It is found that a design of safe can be calculated using simple torque formulas and assuming a maximum allowable shear stress of 50,000 psi. That's a little over half the yield strength of 4140 heat-treated steel, from which the majority of feed screws are made in the U.S.

The formula is,

$$Ss=16T/\pi D^3$$

Where,

T= (hp x 63025)/max screw rpm (in.lb)

D= Diameter of feed-section root (in.)

Ss= Shear stress (<50,000) (lb/in.^{2})

This formula applies to a screw without a cooling bore. If a cooling bore is used the following formula works,

$$Ss=16\ TD/\pi(D4-d4)\ (d=\text{bore diameter}).$$

The cooling bores have almost no effect on torsional strength because the stress is max. at the outer surface and zero at the neutral axis where the cooling bore is located.

The screw fatigue failures are not typically show radial cracks. These failures reveals themselves by a single crack that goes all the way through the screw. In addition, these failures don't result in the "wind-up" effect or a pitch reduction.

Bending occured either from the side forces of the polymer exerts on the screw, or from misalignment of the barrel. Bending by either mechanism is termed "reversed bending." Think of the rapid failure caused when you break a wire between your fingers by flexing it back and forth.

In order for the internal barrel pressures to cause a screw break, the screw/barrel must first be worn enough to provide the clearance necessary for the bending to occur. This may take a long time, but once sufficient clearance is present, breakage quickly follows. I have covered this type of localized wear, called wedging, in previous columns .The screw is also under torsional load from the drive, adding to the overall stress, since both bending and torsional stresses are at their maximum on the outer surface of the screw. With the combination of the reversible bending stress and torsional stress, failure will occur in very few cycles after the critical stress is reached at the surface. That is typically at about 40% of the normal tensile strength, meaning reversed bending reduces the strength to about half the steel's specification.

Bending failures due to barrel alignment are similar but can occur sooner because it's not necessary to wait for the screw and barrel to wear. Interestingly, bending failures usually occur in the strongest sections of the screw, because that's where it takes the highest force to bend it, with the resulting highest stress at the flight surface. When a screw breaks in one of its thickest or strongest sections, it's extremely unlikely that it was an over-torque situation alone.

Considering bending beam installed on flights surface to save thickens of the sheet metal.

Beam is the main support against bending pushing forces coming by flowing material.

1) Design of Anti bending beam on flight

Need of the component: anti bending stiffness for sheet metal body of flight is majorly can be considered at joint forming at two flight assembly , so to make feasible weldment joint between two flights its effective solution to install beam structure .

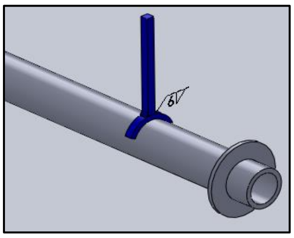

Fig. 9: T-Shaped bracket

T shaped bracket designed as per the circular mounting and flights welding behaviour with this.

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.

Applying loads to see behaviour of this beam,

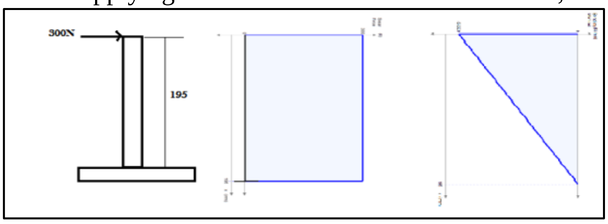

Fig. 10: SFD BMD

Maximum Shear load = V = 300N,
Maximum Bending Moment = M = 58500 N-mm,
We have from flexure formula,

$$\frac{M}{I} = \frac{\sigma}{y} \qquad (1)$$

Where,
M = bending moment = 58500 N-mm,
I = Moment of Inertia = $bd^3 / 12 = 15 \times 15^3 / 12 = 4218.75\ mm^4$

$$y = d/2 = 7.5\ mm,$$

Hence bending stress,

$$\sigma = 104\ N/mm^2$$

Hence Deflection,

$$y = \frac{wL^3}{3EI}$$

$$y = 0.8\ mm$$

2) Spool design for rotation of screw

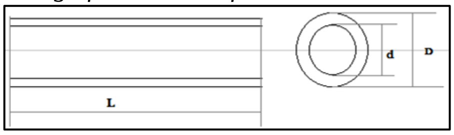

Fig. 11: Spool design for rotation of screw

When the shaft is subjected to bending and twisting moment simultaneously, it is designed on the basis of two moments.

The design of transmission shaft the maximum permissible bending stress (σ) may be taken as per American Society of Mechanical Engineers,

$\sigma = 0.6\sigma_{el}$ or $0.36\sigma_{ut}$ whichever is less
Hence σ = 0.6 x 190 = 114 MPa
Or
σ = 0.36 x 510 = 183.6 MPa whichever is small
Hence σ = 114 MPa
We have from flexure formula,

$$\frac{M}{I} = \frac{\sigma}{y} \qquad (2)$$

Where,
M = bending moment
M = $wL^2 / 2 = 1.4 \times 10^6$ N-mm
I = moment of inertia = $\frac{\pi}{64}(D_0{}^4 - D_i{}^4)$
We have
D_o = 80 mm,
L = 1350mm (distance between two ends is also considered as shaft is not long enough there will be gap between the two ends and rotary holder shaft will be there for cylindrical support)

$$Y = D_o / 2 = 40mm,$$

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

By putting in equation (i), we get

$$D_i = 74.5\ mm$$

Now, design of transmission shaft the maximum permissible shear stress (τ) may be taken as 18% of ultimate tensile strength (σ_{ut}) according to American Society of Mechanical Engineers,

In other words,

$$\tau = 0.18\ \sigma_{ut}$$

Max. permissible shear stress,

$$\tau = 0.18\ \sigma_{ut} = 0.18 \times 520 = 93.6\ MPa$$

From torsional equation we have,

$$\frac{T}{j} = \frac{\tau}{R}$$

Where,
τ = torsional shear stress

T = torque acting on the shaft
j = polar moment of inertia
R = Distance from neutral axis to outermost fibre = $D_0/2$....

Where D is diameter of the shaft = 40 mm

We know that, for solid circular shaft, polar moment inertia (j) is given by,

$$j = \frac{\pi}{32}\left(D_0{}^4 - D_i{}^4\right)$$

J = 1.0 x 10^6 mm^4

Now, the Shear stress is

$\tau = 0.3\ \sigma_{el} = 0.3 \times 205 = 61.5$ MPa

Hence,

Torque acting on shaft

T= 1.533 x 10^6 Nmm

According to maximum shear stress theory,

$$\tau_{max} = \frac{16D_0}{\pi(D_0{}^4 - D_i{}^4)} T_e$$

Where,

$T_e = 1.713 \times 10^3\ N/mm^2$

$T_e = \sqrt{(M^2+T^2)}$

Hence Maximum shear stress,

$\tau_{max} = 68.7\ N/m^2$

According to Macaulay's Method, Maximum Deflection is given by,

$$y = \frac{wL^2}{8EI}$$

Hence, Maximum Deflection is

Y = 3.42 x 10^3

D. Assembly features

Antibending beam installed as requirement in machine is given.

One by one flights assembly weldment can be formed.

Pitch of each flight will be same and axle insertion will be collinear. Only outer diameter will change in each flight comparison to formed conical shape.

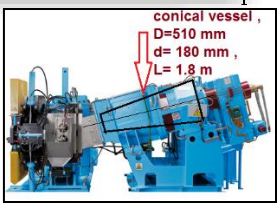

Fig. 12: Actual conical vessel

Assembled in linear pattern with pitch dimensions maintained now it will get cut in shape after welded all the beams in line along with every flight joint. Reducing flight sizes, to accommodate into conical shape vessel.

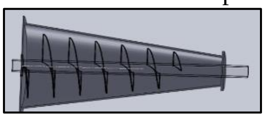

Fig. 13: Screw assembly installed inside vessel

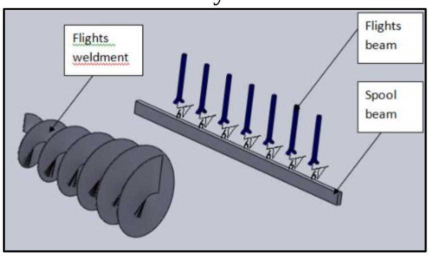

Fig. 14: Screw assembly

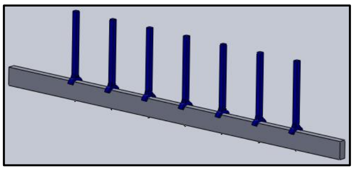

Fig. 15: Beams welded on spool beam

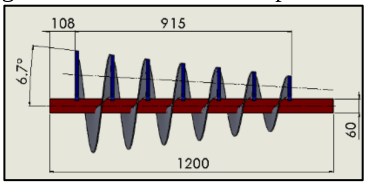

Fig. 16: Screw assembly overall dimensions

E. Numerical / Computational Method

1) Assembly simulation on CAE

- Applying all boundary condition on all flights simultaneously,
- Analysis on stress and deformation results to validate design ,
- If deflection found positive (beyond zero value) structure of flights joints will get changed.
- Again analysis on rework will be included.

Validation on spool less flighting will evaluated which will help to get conclusion.

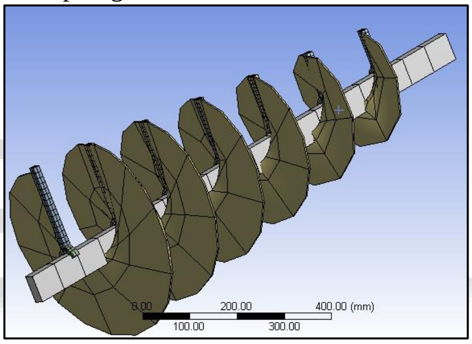

Fig. 17: Meshed model

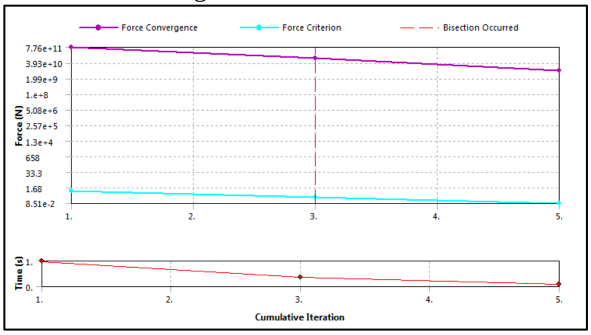

Fig. 18: Meshed model graph

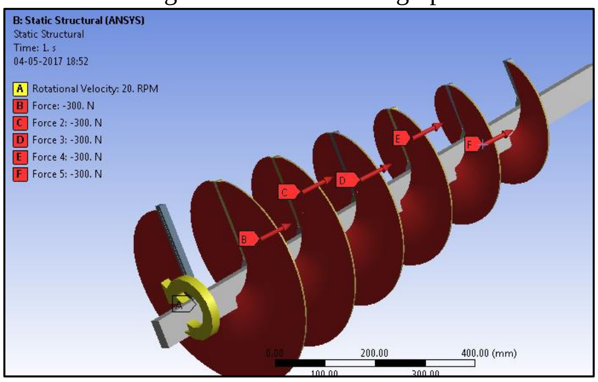

Fig. 19: 3D model

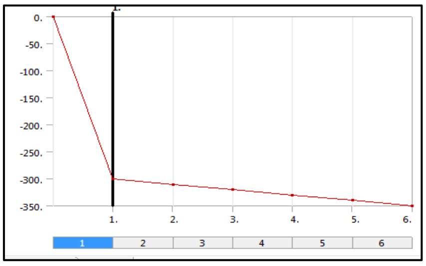

Fig. 20: 3D model graph

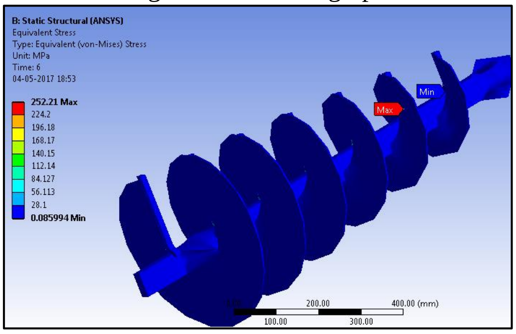

Fig. 21: Boundary conditions applied

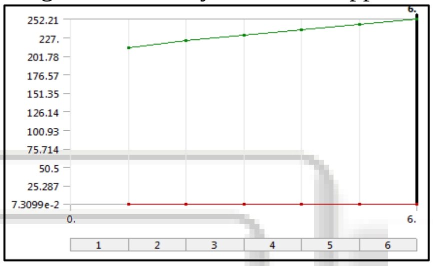

Fig. 22: Boundary conditions applied graph

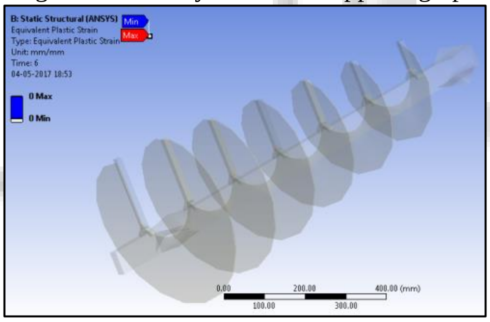

Fig. 23: Permanent deformation is negligible

VI. MATERIAL SELECTION

Material to be used is AISI316 as pressure vessel manufacturing and testing occurs in pulping and fluid medium so other special purpose machines and supporting machineries are also get contact with wet medium hence here anti corrosive material to be applied everywhere.

Grade	Design strength (N/mm^2)	Ultimate tensile strength (N/mm^2)	Young's Modulus (N/mm^2)	Elongation (%)
Stainless steel				
304 (1.4301)	210	520	200 000	45
316 (1.4401)	220	520	200 000	40
Carbon steel				
S275	275	410	205 000	22
S355	355	490	205 000	22

Table 1: AISI316 grade of stainless steel

No limitations on thickness in relation to brittle fracture apply to stainless steel; the limitations for carbon steel are not applicable due to the superior toughness of stainless steel. The austenitic stainless steel grades do not show a ductile-brittle impact strength transition as temperatures are lowered. Stainless steels can absorb considerable impact without fracturing due to their excellent ductility and their strain-hardening characteristics.

This type of plate has a thickness of specifically designed with high strength wear resistant material formed by a special deposition welding method over laying mild carbon steel.

VII. EXPERIMENTATION & VALIDATION

By putting strain gauges on the surface of this unique screw, external forces will be applied by hydro-pneumatic loads or actuators and equivalent strains and stresses will be the output of testing machine.

A. Experimental Setup

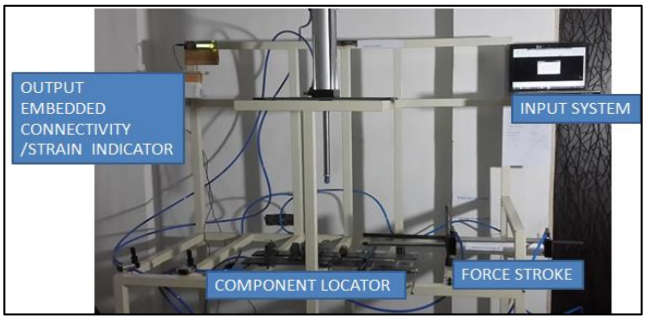

Fig. 24: Actual machine view

This is the on which actual testing is to be carried out. The name of machine is Semi Automated Strain Gauge Output Analogger. Strain gauges are fixed on testing specimen by soldering operation. After loading machine gives strain developed into the specimen. By using stress strain relation stress induced in component is calculated. Pneumatic or Hydraulic bar are used for loading.

Fig. 25: Blank machine setup

This is the photograph of blank machine setup. These are some fixtures are shown in photograph. After fixing our specimen into this fixture actual testing is done. The blue pipes are seen in this picture are pneumatic pipelines. The various types of fixtures are available in lab. According to our requirement fixtures can be manufactured also.

B. Processing testing on component

Fig. 26: Component Loaded to Come Out with Strains Values

Fig. 27: Flights individual prototype

Strain gauges are fitted on blade by soldering operation. Strain gauge mounting is very important operation during experimental validation. If the strain gauges are not mounted properly then reading taken from display are not correct. For strain gauge mounting surface should be cleaned and well prepared. 4 strain gauges are mounted 2 are giving bending area output and other 2 are for maximum affected stresses area.

The display shows that the value of strain developed into flight component assembly. After getting strain readings by using calculation method find out stress value. Reading came out with four strain mounts zone after load applied on side surface of flight. These are readings come out from four strain gauges which are fixed on testing specimen two on front side and two on rear side.

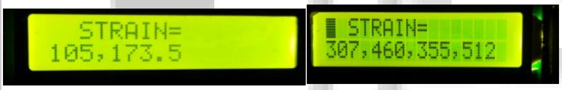

Fig. 28: Actual catched strain gauge readings

CHECK LIST AND INPUT

COMPONENT NAME: agitation section.			
CAD MODEL	YES ✓	NO	REMARK
MATERIAL SELECTED	YES ✓	NO	average wt. 35 kg. welding defect avoided.
MANUFACTURING	WELDMENT ✓	MACHINING ✓	
	CASTING	FORGING	
QC FOR PROTOTYPING	YES ✓	NO	
MFG DRAWING	YES ✓	NO	
FIXTURE NEEDED	YES ✓	NO	
GEOMETRY/SHAPE	CYLINDRICAL	FLAT ✓ (2)	
	COMPLEX ✓	SOLID	

15.1.17.

Table 2: Check list of experimental setup

Experiment carried out on 1. strain gauge meter SPS

pneumatic vertical loads are applied.

Parameters	Load 1 -	Load 2
σ stress (Mpa)	61.5, 92, 71, 102.5.	
μ Strain	307.5, 460, 355, 512	
Entity 1		
Entity 2		
Entity 3		

Report in DRP (Design Review process)

- No plugs, no clogs to prevent continuous operation.
- 50% higher filling proportion to the trough relative to conventional linkages.
- Removable wear Liner
- Stability Failure can be expected when more pushing loads incorporated material AISI304 is suitable and can be used Mild steel also.

15.7.17

Table 3: Lab Report

VIII. Results and Discussions

Flight bended sheet metal component			
Parameter		CAE	Testing
Stress mpa		17.3	17.9
Deformation mm		0.02	NA
Flight support beam			
Stress	104	168	102.5
Deflection mm	0.8	0.9	NA

Table 4: Result

IX. Conclusion

The shaftless spiral allows higher filling rates and lower rpm's resulting in less stress and consequently less maintenance and down time. Good for sludge and sticky substances.

References

[1] Coperin ktron industry for process equipment

[2] A. Ramesh, P. Karunaker and L. Ramesh, "Design and Analysis of Discharging of Dust in Pneumatic Conveying System by a Screw Conveyor Shafts", Advance Research and Innovations in Mechanical, Material Science, Industrial Engineering and Management - ICARMMIEM-2014

[3] Screw Conveyor components & design, CEMC Manual, Version 2.20, 2012

[4] Jones, David D. and Kocher, Michael F., "Auger Design For Uniform Unloading of Granular Material: I. Rectangular Cross-Section Containers" (1995). Biological Systems Engineering: Papers and Publications. Paper 148.

[5] Kocher, Michael F. and Jones, David D., "Auger Design For Uniform Unloading Of Granular Material: Ii. Cylindrical Containers" (1995). Biological Systems Engineering: Papers and Publications. Paper 149.

[6] GEC NO. 8, "Design and Construction of Continuous Flight Auger (CFA) Piles", Report No. FHWA-HIF-07-03, April 2007

[7] Marco Bortolamasi, Johannes Fottner, "DESIGN AND SIZING OF SCREW FEEDERS", International Congress for Particle Technology, Nuremberg, Germany, 27-29 March 2001

[8] Alan W. Roberts, Emeritus Professor and Director, "Design Considerations And Performance Evaluation Of Screw Conveyors", Centre for Bulk Solids and Particulate Technologies, The University of Newcastle, Australia.

[9] Coperin K-Tron Industry for Process Equipment- Screw Feeders Designed to Handle a Diverse Range of Bulk Materials http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1147&context=biosysengfacpub