To Design a Spiral Aerator System for the Earthen Making Process to Increase Output

Mr. Nandkishor P. Karwande[1], Prof. M. A. Mohite[2]
[1, 2] Department of Mechanical Engineering
[1, 2] Sinhgad Institute of Technology, Lonavala.

Abstract- *Work is the new innovation in existing vertical aerating system. To make feasible combination of aerating and feeding in common machine, it's a bigger subassembly in this process which gives simplest but effective machine work for the application. Design work including optimized concept development giving work in mechanical component action to put outcomes in the form for productivity improvement. Work validation will be with structural bending and material behavior calculations with comparing virtual results to be formed from advance simulation tools. Work development will be considered with the different application use of this product which will help to make standardized product.*

Keywords*- Spiral Aerator, Transmission Shaft, FEM, ANSYS11*

I. INTRODUCTION

In chemical and pulping industry waste water (effluent) is generated in various processes. Aeration is an important process in waste water treatment. There are different types of aerators used for aeration such as surface floating aerators, faucet aerator,

Generally in traditional system vertical operated aerators are used. These are of fixed structure or floating types. The vertical mounted aerator structure gives limited output. It is bulky and not getting proper mixing of air and effluents. Also it takes more time for mixing process. So, it is required to design the light weighted aerator which will give more output and proper mixing within less time.

It is proposed to replace vertical aerator with horizontal one which will give more output with more input entry to the system.

STUDY FORMAT

This paper is divided in following sections. Section II will explain the literature survey which highlights the problems occurring in existing system and related solution. Section III will give information about methodology and design of spiral aerator assembly. Section IV will explore implementation of proposed system and calculations whereas validation of system is done in Section V. Finally the conclusion of the paper is presented.

II. LITERATURE SURVEY

The existing technology uses vertical operated aerators for waste water treatment process. In this system for aeration vertical structure assembly is connected with vertical axle rotating shaft shown in fig.1. It also requires separate screw feeder for feeding the materials which is installed in cylindrical gable. As this is installed in a cylindrical gable the material near to the surfaces is taking more time for mixing. Thus, the heavy structure is used to operate the aerators for proper air and MDF mixing. Apart from this, there are many other issues in vertical aerator system like sealing & leakages in joints. It also requires heavy maintenance and it has bulky structure. The more time is required to complete the process and hence less output is getting in vertical aerator system.

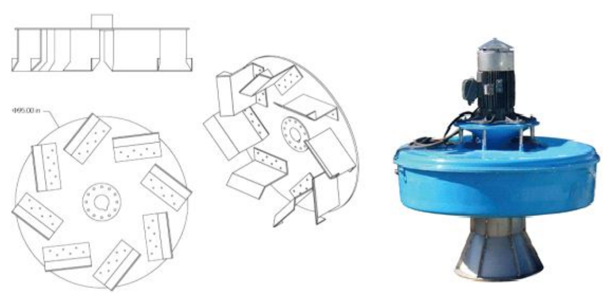

Fig. 1 Verical Spiral Aerator System

Jeevarathinam et al. [1] proposed analysis and design of optimization of tillage tool i.e. rotavator blade using FEM and simulation is done by using CAD, ProE software. Philip et al. [2] focused on performance of screw conveyor by comparing discrete element modelling with laboratory experiment. Alan et al. [4] has presented the procedure for computing the throughput, torque and power of screw conveyors. They have also illustrated the influence of the flow properties of the bulk material on the conveyor performance. Also they have proved that the efficiency of conveyor can be improved by employing a positive feed system to increase the fullness of the screw.

Scope of project:

Spiral aerator is the mechanism, which can be used in many industries. The present work has the following scope:

- Concept design : aerator hub, flights, housing and mounting.
- CAD modelling 3D modelling, assemblies BOM, Sheet metal Development GA drawings.
- Fixing Boundary conditions.
- Feasibility checking for manufacturing.
- Stress and deflection assessment.
- Validation review with theoretical and virtual analysis

III. DESIGN METHODOLOGY

By knowing the material properties and the loading conditions, the FEM using ANSYS11 is used to get the optimum design of the geometrical parameters of the spiral structure elements and to validate the advantages of the spiral aerator to give a high aerator performance.

For designing spiral aerator system horizontally, the hub mounted drum with weldment sheet metal flights are needed to be design with screw flight design methodology. The proposed flight mounted shaft screw is shown in fig. 2.

Fig 2 Spiral Screw sheet

This spiral shaft screw will be mounted on horizontal drum for its structural validation. This horizontal Drum is shown in figure 3. The top side opening will be inlet on MDF and crush soil with air mixture and one side bottom will be the outlet dry sludge.

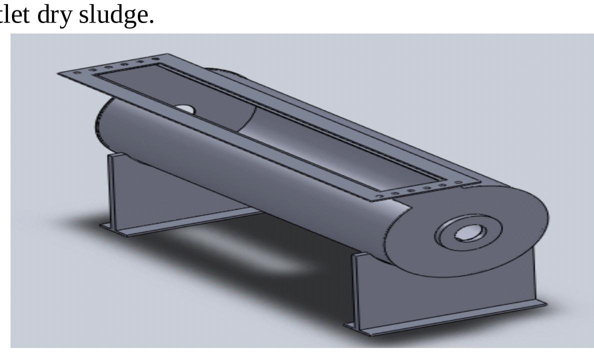

Fig 3 Horizontal drum

Expected view

The work is carried out to achieve the objectives of proposed model shown the fig. 4

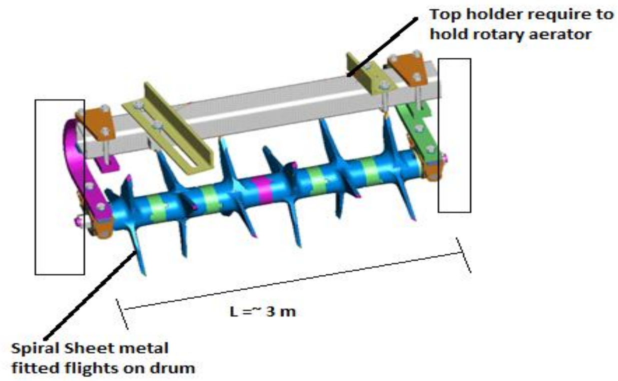

Fig.4 Expected view of spiral aerator

Material Used:

Comparison of mechanical properties for stainless steel and carbon steel is given in table 1.

Table 1 Mechanical properties of material selected

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

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

IV. IMPLEMETATION

Axel:

The axel is a stationary shaft, subjected to Bending Moment. IT just acts as a support. The axel is made up of hallow metal shaft with supporting bearing ends in Drum. Spiral flight is mounted on the shaft which is driven by external motor with Gear Box. The selection of motor and Gear box is depending on the load inside the drum.

The optimized hallow axel shaft with its dimensions is shown in following fig.5.

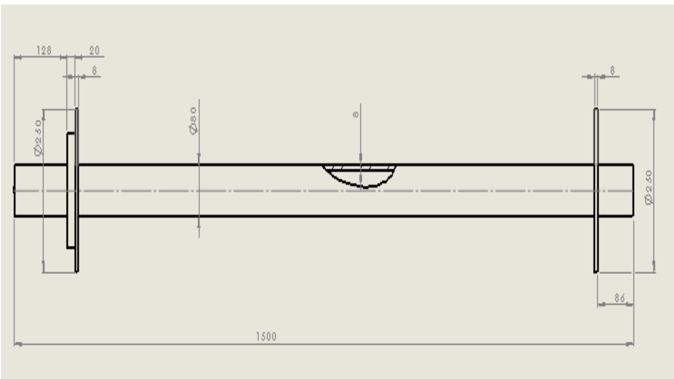

Fig. 5 Optimized model of hollow axel shaft

Flights:

The assembly of flights in vessel is performed in two stages as below.

Flight stage 1 – Spiral wide flights with weldment bracket

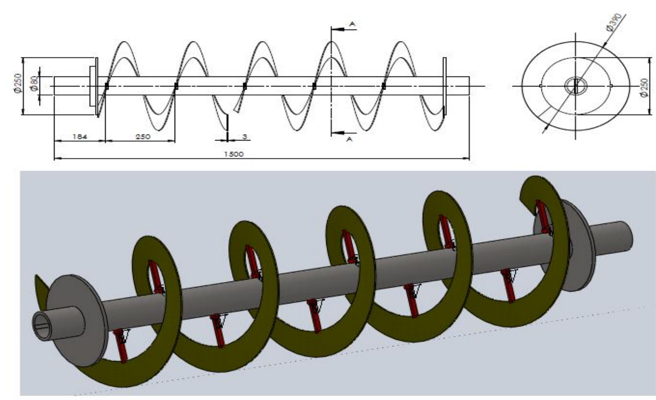

Fig.6 Flight stage 1– Spiral wide flights with weldment bracket

Flight stage 2 – Thin flight Weldment

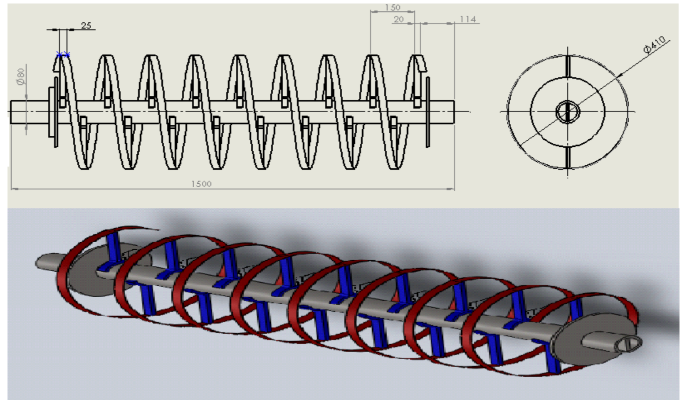

Fig.7 Flight stage 2 – Thin flight weldment

CAD implementation:

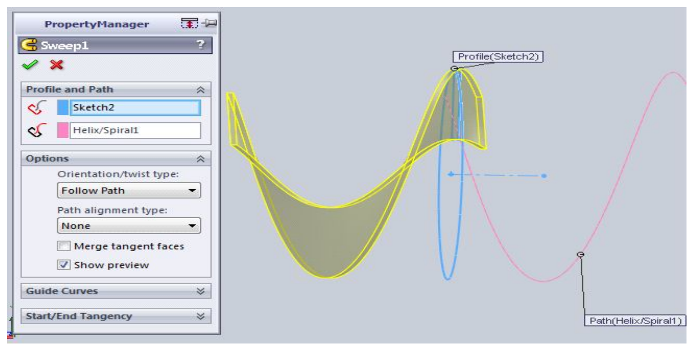

Fig. 8 Sheet metal

Forces acting on flight:

In this present work we have designed spiral aerator by considering 200 Litre drum size. Hence, we have taken length of drum L = 1350 mm. and diameter = 450 mm.

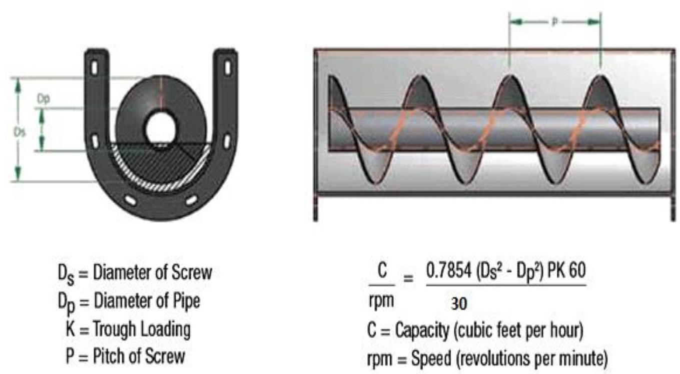

Fig. 9 Shaft screw assembly in vessel

The following design data is considered for calculating forces acting on flights

Length of shaft, L = 1350 mm
Diameter of screw, Ds = 450 mm

Diameter of shaft or Pipe, Dp = 250 mm
Trough loading factor, K = 50 %
Pitch of Screw, P = 250 mm.

Therefore, number of flights required to the decided length
= 1350 /250 = **5.5 units**

Now, Volume of total inner tubular vessel,
V = π r2 h
Radius of vessel, r = 450/2 = 225 mm,
Length of vessel, h = 1350 mm

Therefore,
Volume of inner tubular vessel is
V= 214794642.85mm3 = 0.21479 m3
= 215 litre.

Density of flowing material, ρ = 2800 kg/m3
Volume = Mass / Density = m/ ρ,
Mass, m = v x ρ = 601 kg

Neglecting Coefficient of friction (Zero)
Total force F acting on inside of vessel,
F= m x g= 6010 N

Let's say load is to be divided into equal parts on flights,
Here we are using 5.5 flights.

So, **Force on each flights = 6010 / 5.5 = 1092 N**
Design of a Shaft:

A shaft is a rotation member usually with cylindrical shape which is used to transmit torque, power and motion between various elements such as electric or combustion motors and gear sets, wheels, cams, flywheels, pulleys, or turbines and electric generators.

As shaft is rotational there are bending and twisting forces acting on it. According to American Society of Mechanical Engineers (ASME) code for the design of transmission shaft the maximum permissible bending stress (σ) may be taken as
$\sigma = 0.6\sigma_{el}$ or $0.36\sigma_{ut}$ whichever is less
Therefore,
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,
M/I = σ/y .... (i)

Where,
M = Bending moment, $M = wL^2 / 2 = 1.4 \times 10^6$ N-mm
I = Moment of Inertia $I = \pi/64\ (D_o^4 - D_i^4)$
We have,
D_o = 80 mm
L = 1350 mm
y = D_o / 2 = 40 mm
So we have,
σ = 114 N/mm^2
By putting in equation (i), we get
D_i = 74.5 mm

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

In other words,
$\tau = 0.18\ \sigma_{ut}$

Maximum permissible shear stress,
$\tau = 0.18\ \sigma_{ut}$
= 0.18 x 520
= 93.6 MPa

From torsional equation we have,
(T/J)= (τ / R)

Where,
T = Torque acting on the shaft
J = Polar moment of inertia
τ = Torsional shear stress
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,
$J = \pi/32\ (D_o^4 - D_i^4)$
$J = 1.0 \times 10^6\ mm^4$

Now, the Shear stress is
$\tau = 0.3\ \sigma_{el}$
= 0.3 x 205
= 61.5 MPa
Hence,
Torque acting on shaft
$T = 1.533 \times 10^6$Nmm

Twisting moment, According to maximum shear stress theory, Maximum shear stress

$\tau_{max} = (16Do/\pi(Do4 - Di4))\ XTe$

Where,

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

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

Hence Maximum shear stress,

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

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

$y = wL^2/8EI$

Hence, Maximum Deflection is

$y = 3.42 \times 10^3$ mm

Support bracket design:

From share force and bending moment diagram we can get the value of maximum share force and maximum bending moment in supporting bracket. The SFD and BMD is given in fig.10 for support bracket.

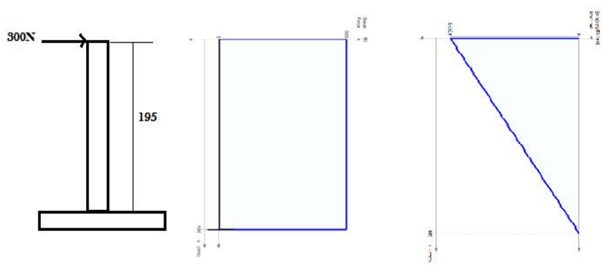

Fig.10 Share force Diagram and bending moment Diagram

Hence,

Maximum Shear load, V = 300N

Maximum Bending Moment, M = 58500N-mm

We have from flexure formula,

$M / I = \sigma / y$ ....(i)

Where,

M = bending moment = 58500 N-mm

I = Moment of Inertia, $I = bd^3 / 12$

$= 15 \times 15^3 / 12$

$= 833.33\ mm^4$

$y = d/2 = 7.5$ mm

Hence, bending stress

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

Then the deflection in supporting bracket is,

$y = wL^3 / 3EI$

Hence,

y = 0.8 mm

Connecting weldment bracket:-

The supporting connecting brackets of main flights are shown in figure 4.11.

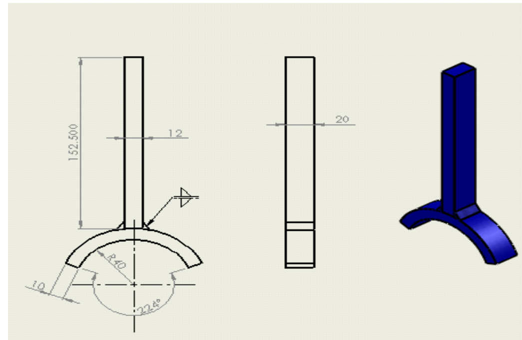

Fig. 11 Weldment bracket for flight type 2

V. RESULTS AND DISSCUSSION

Project outcomes are validated and checked through analysis using ANSYS 11.0 software; validated results are shown in fig.12, fig. 13, fig. 14, fig 15, fig. 16 and fig 17, the aerator flights are capable to hold loads coming on its surface, by selecting stainless steel grade as a material for construction it is very feasible to perform required things done in project.

1) Analytical values in full body

- Shear stress in body = 24 MPa
- Equivalent stress is found 47.78 MPa

2) Mechanical components Shaft

- 138 MPa equivalent stresses where we found 93 MPa theoretical
- 103 MPa shear stress

3) Bigger spiral Flight

- 0.93 MPa stress max found

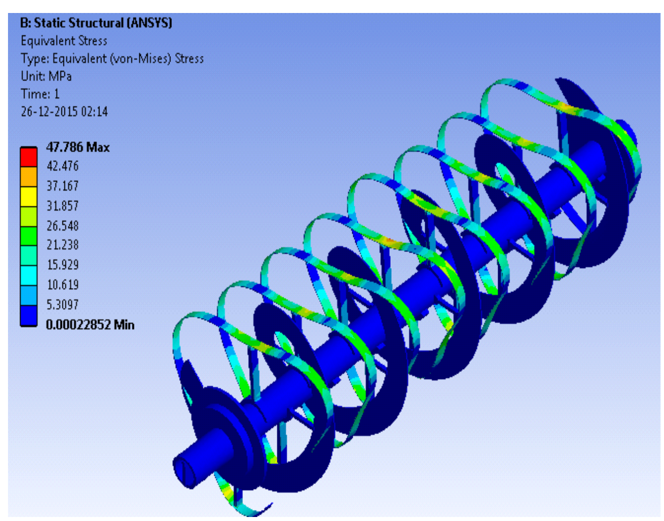

Fig. 12 Von-Mises (Equivalent) Stress in aerator body

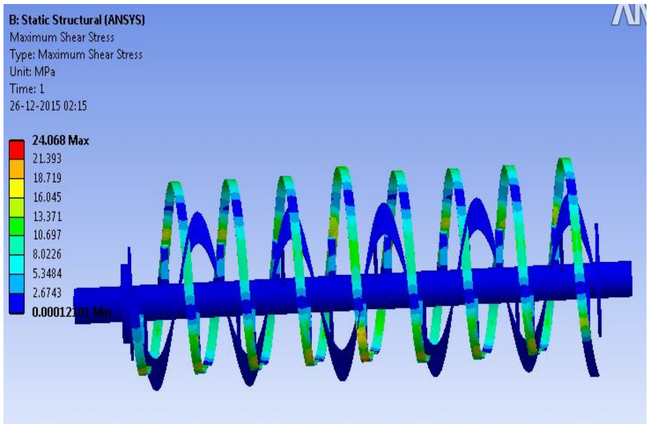

Fig. 13 Maximum shear stress in aerator

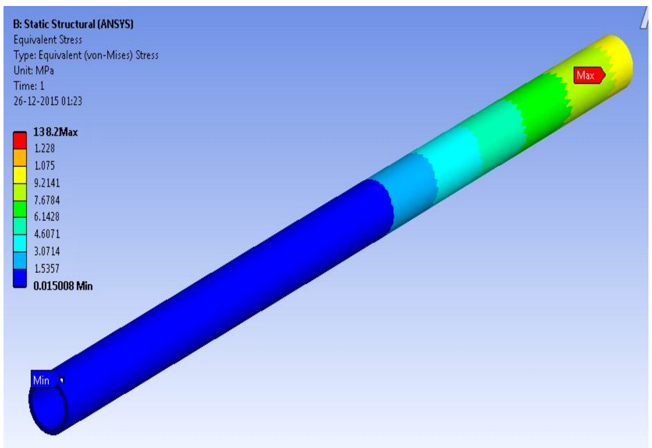

Fig. 14 Von-Mises (Equivalent) stress in component shaft

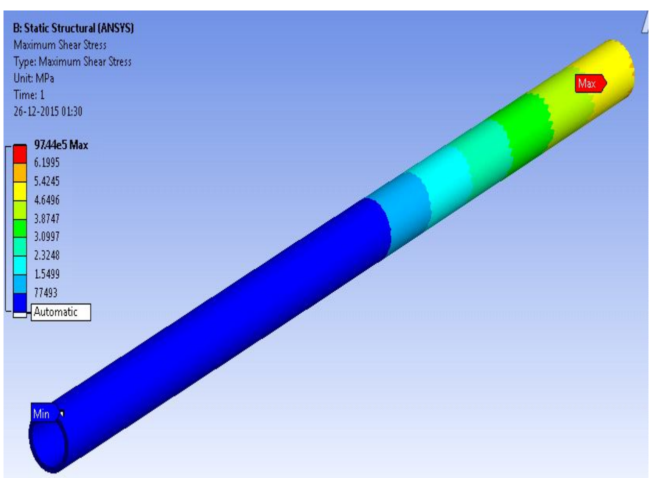

Fig. 15 Maximum shear stress induced in component shaft

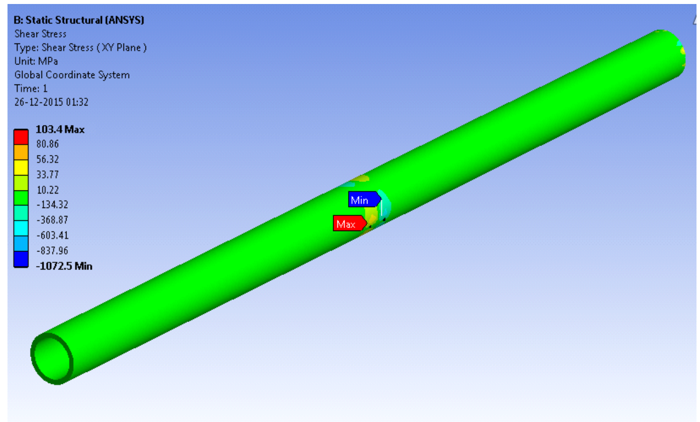

Fig. 16 Maximum shear stress in component shaft by Global Co-ordinate system

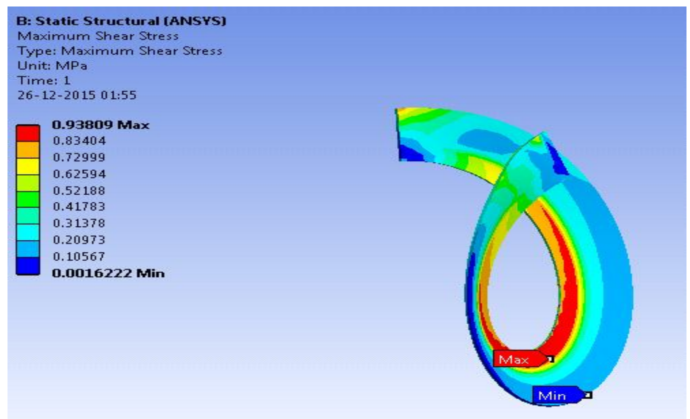

Fig. 17 Maximum shear stresses in weldment flight

VI. CONCLUSION & FUTURE SCOPE

It is found that aerator mixing body assembly is feasible solution for optimizing the processes which were incorporated in old design. Manufacturing cost saving can be expected as material processes and volume is optimized.

Spiral shape screw design concept works here for bending flights design also axle mounting is feasible hence it can be used in multiple applications like pulping, food, beverages processing industries.

In future this design can work for higher density material medium for processing. According to designed parameters in axle, flights, sheet metal process, weld preparation may change.

Again shaft less flights can be used. Shaftless spirals are normally used to convey sticky materials in centerless screw conveyors. The spiral lies on liners and is given at one end by a gear box. The shaftless spiral will allow the movement of more materials than a shafted spiral of the same size.

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