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Stress Analysis of V-Stirrer Blade Made For Conical Agitation for MDF

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***Abstract*— This work gives approach for performing stress analysis of an agitator of a large mixing vessel used in pulping process plant. The analysis is carried out to estimate stress and deflection in agitator body. The agitator is subjected to vibration due to multi-axial forces resulting from bending and torsional loading imposed by the mixing operation. The approach followed in this work involves Stress analysis of agitator blade for unit displacement using FE method. The work also discusses an alternative approach for estimating stress amplitude variation through dynamic stress analysis. Research work gives solution for developing the agitator with V shaped weldment which is made by using weldment techniques. Agitator looks V shaped from Front view and circular hub is designed to hold the structure of agitator. Project gives result and validation on the basis of software tool as well as mathematical tool. This proves the strength in designed agitator. Along with agitation process of pulping stirrer is also considered which is mounted on top of the agitator hub.**

***Index Terms*— Agitator, Ansys, Deformation, Hub, Pulp, Stresses, Stirrer, weldment.**

I. INTRODUCTION

Agitation is the process to induce motion of material in a specified way. In the chemical and other processing industries, many operations are dependent to a great extent on effective agitation and mixing of fluids. Mixing is one of the most widely used unit operations in the chemical and allied industries. Generally, agitation refers to forcing a fluid by agitator means to flow in a circulatory or other pattern inside a vessel. In spite that agitator is very effective in industry today but still has many problems which affect the agitation process.

II. NECESSITY OF CONICAL AGITATOR

In fiberboards manufacturing plant glue binders are added with sawdust in a cylindrical vessel and mixed together by the use of an agitator. When process is stopped for some time may be one or two days so residual mixture remains at the bottom of the vessel even after empting. This gets hardened over a period of time and needs to be cleaned every time which is tedious and laborious process. To overcome this difficulty bottom of the vessel can be made of conical shape instead of cylindrical. In conical vessel material gets sloping surface to flow down. This results in redesigning of agitator blades to suit the shape of the vessel. So in this project agitator blade can be designed.

III. OBJECTIVES

Main objectives in this Paper are as follows:
1. To design compact and vertical mount conical cabinet agitating device.
2. To perform the analytical design and software validation for blade mechanism which is withstand with the boundary conditions of the working system.

IV. ANALYTICAL CALCULATION

A) Downward force of pulp acting on blade

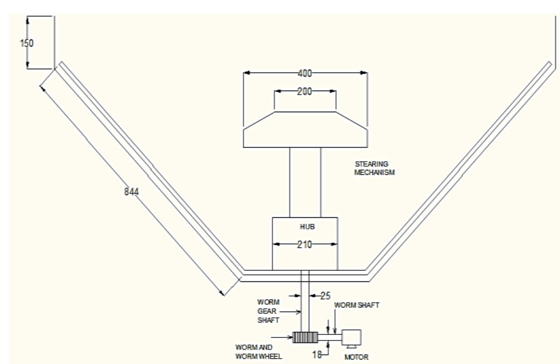

Fig 4.1: Layout of an agitation setup

Weight of total stirring assembly $= 546.06$ N
Weight of blade assembly, $W = 423.31$ N
Weight of pulp $= 9195.13$ N
Downward force of pulp $= V \times \rho \times g = 745.32$ N

Analysis of blade for downward force

As one end of blade fixed to the hub and other end of blade is free therefore agitator blades behaves like a cantilever beam.

W = 745.32 N, b = 248 mm, h = 12 mm,
L = 848.53 mm

$$\text{Maximum moment, } M = \frac{W \times L}{3} = 210808.79 \text{ Nmm}$$

E = Elastic modulus = 193000 M pa;

$$\text{Moment of Inertia, } I = \frac{b \times h^3}{12} = 18712 \text{ mm}^4$$

Hence,

$$\text{Maximum deflection, } \Delta_{max} = \frac{W \times L^3}{8 \times E \times I} = 15.76 \text{ mm}$$

Stress developed in the agitator blade due to action of pulp
By using flexural formula

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

Where
M = 210808.79 Nmm, I=18712 mm4 , Y= 6 mm.

$$\frac{210808.79}{18712} = \frac{\sigma}{6}$$

$$\sigma = 67.59 \text{ MPa}$$

Therefore, yield strength of AiSi316 is Syt =870 MPa and fs = 4
Then,

$$\sigma_{per} = \frac{S_{yt}}{fs} = 217.5 \text{ MPa}$$

$$\sigma_{per} = 217.5 \text{ MPa} > \sigma = 67.59 \text{ MPa}$$

Here the stress developed in the agitator blade due to action of pulp is σ=67.59MPa. This is less than permissible stress σPer =217.5 MPa. Therefore design is safe.

B) Centripetal force acting on blade

Knowing the values for the cross-sectional area, density, angular velocity and radii, calculate the force on one blade. Once this force has been calculated, estimate the nominal stress σ on the blade root using the following relation

$$\sigma = \frac{F}{A_{root}}$$

Where A_{root} is the cross sectional areas of blade root
By using following data
Velocity of blade, N = 20 rpm
Hence Angular velocity,

$$\omega = \frac{rpm \times 2\pi}{60} = 2.09 \text{ rad/sec}$$

Material density, ρ = 7860 kg/m3
Blade tip radius, r2= 800 mm
Radius of base, r1 = 200 mm
Blade root cross-sectional area, Aroot =0.002976 mm2

$$F = \rho \times A \times \omega^2 \times \left(\frac{r_2^2 - r_1^2}{2}\right) = 300.7 \text{ N}$$

This is the force acting on blade due to rotations. Centripetal force directly proportional to the speed of blade as speed increases centripetal force increases.

Analysis of blade for centripetal force

Consider, W = 300.7 N,b = 248 mm, h = 12 mm,
L = 848.53 mm

$$\text{Max. moment, } M = \frac{W \times L}{3}$$

$$M = 85050.99 \text{ N mm}$$

Maximum deflection

$$\Delta_{max} = \frac{W \times L^3}{8 \times E \times I} = 6.3586 \text{ mm}$$

Stress developed in the agitator blade due to action of pulp
By using flexural formula,

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

$$\frac{85050.99}{18712} = \frac{\sigma}{6}$$

σ= 27.27 N/mm²

Here the stress developed in the agitator blade due to action of centripetal force is 27.27N/mm2. This is less than permissible stress. Therefore design is safe.

C) Analysis of blade for combined resultant force

This is the combined force acting on blade. By considering the blades of agitator as cantilever beam, the combined resultant force will be exerted on the blade by the pulp.
Combined resultant force (R) = W = 803.693 N, b=248 mm, h = 12 mm, L = 848.53 mm

$$\text{Max. Moment, } M = \frac{W \times L}{3} = 227319.2071 \text{ Nmm}$$

$$\text{Max Defletion, } \Delta_{max} = \frac{W \times L^3}{8 \times E \times I} = 22.9951 \text{ mm}$$

Stress developed in the agitator blade due to action of pulp
By using flexural formula,

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

$$\frac{227319.2071}{18712} = \frac{\sigma}{6}$$

$$\sigma = 72.88 \text{ N/mm}^2$$

Here the stress developed in the agitator blade due to action of combined force of pulp is 72.88N/mm2. This is less than permissible stress. Therefore design is safe.

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V. CAE MODELING

1) Analysis of downward force 745.32 N

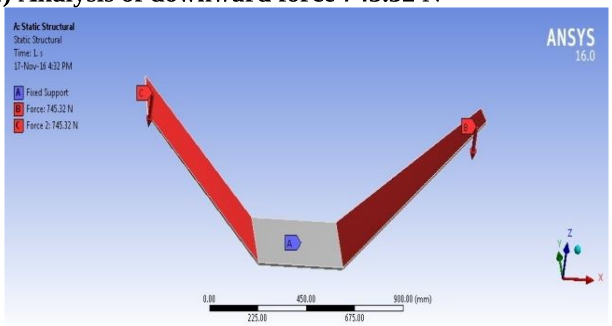

Fig 5.1: Boundary condition for downward force

Following are the boundary conditions applied on blade assembly

A – Fixed support at the center of assembly

B – Downward force F1 = 745.32 N on first blade

C – Downward force F2 = 745.32 N on another blade

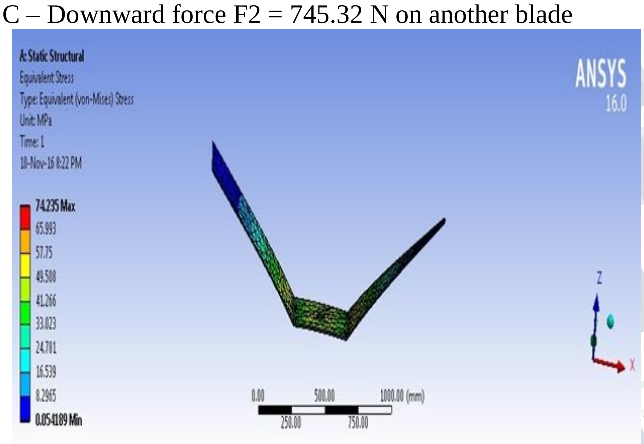

Fig 5.2: Equivalent stress for downward force

By using ANSYS16 software downward force 745.32 N is act on the blade surface. The maximum stress is developed at tip of the blade and minimum stress is developed on the horizontal plane. The maximum equivalent stress developed in blade assembly at tip of the blade is 74.235MPa.

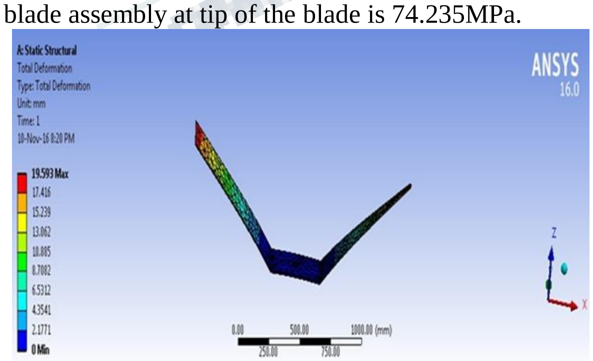

Fig 5.3: Total deformation due to downward force

Blade works like a cantilever beam fixed at bottom and free at the top end. The maximum deformation developed at free end of the cantilever beam. The maximum deformation developed in blade assembly is 19.59 mm at tip of the blade.

2). Analysis of centripetal force 300.7 N

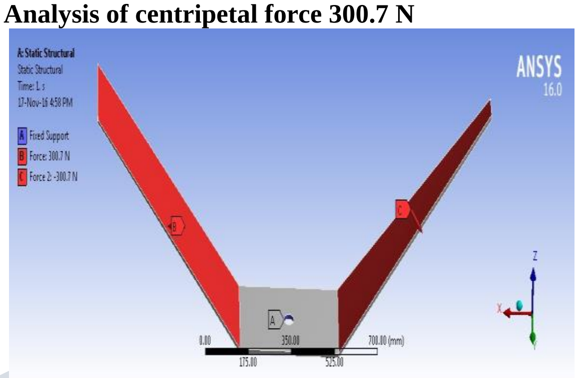

Fig 5.4: Boundary conditions for centripetal force

Following are the boundary conditions applied on blade assembly

A – Fixed support at the center of assembly

B – Centripetal force F3 = 300.7 N on first blade

C – Centripetal force F4 = 300.7 N on another blade

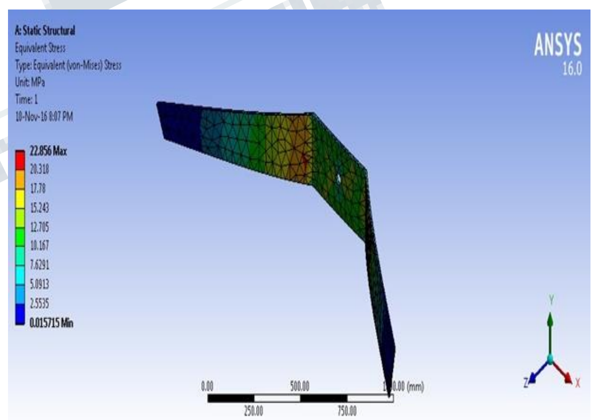

Fig 5.5: Equivalent stress on blade due to centripetal force

Centripetal force 300.7 N is acts on blade surface. The maximum equivalent stress developed in blade assembly at tip of the blade is 22.856 MPa.

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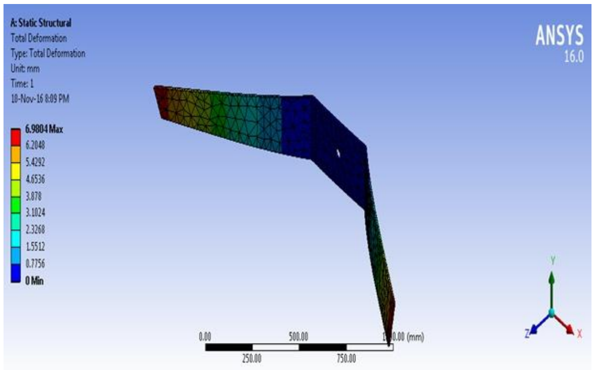

Fig 5.6: Total deformation of blade due to centripetal force

The maximum deformation developed in blade assembly is 6.9806 mm at tip of the blade.

Analysis of combined forces acting on blade assembly

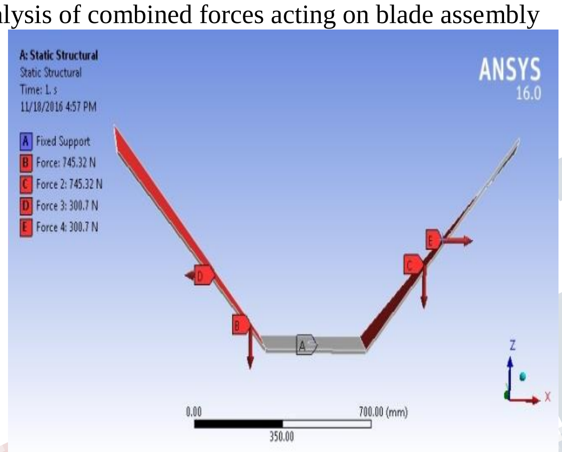

Fig 5.7: Boundary conditions for combined resultant force

Following are the boundary conditions applied on blade assembly

A – Fixed support at the center of assembly
B – Downward force F1 = 745.32 N on first blade
C – Downward force F2 = 745.32 N on another blade
D – Centripetal force F3 = 300.7 N on first blade
E – Centripetal force F4 = 300.7 N on another blade

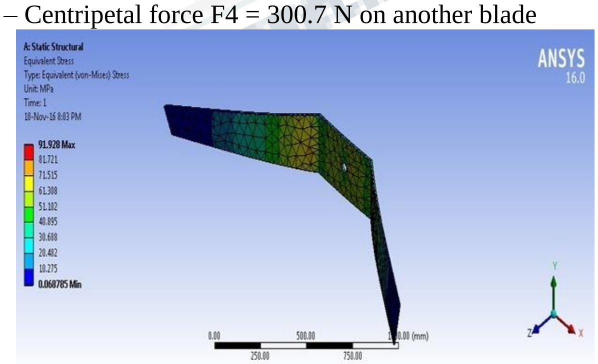

Fig 5.8: Equivalent stress on blade due to combined resultant force

Combined resultant force 803.693 N is act on blade surface. The maximum equivalent stress developed in blade assembly at tip of the blade is 91.928MPa.

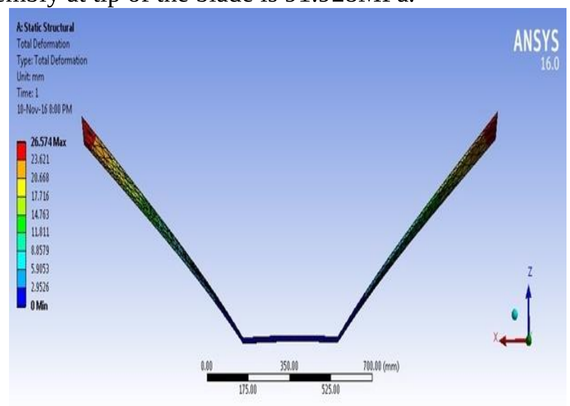

Fig 5.9: Total deformation of blade due to combined resultant force

The maximum deformation developed in blade assembly is 19.59 mm at tip of the blade.

VI. OBSERVATIONS

Table 6.1: Readings for equivalent stress

Sr. No.	Parameters	Analytical (N/mm2)	CAE (N/mm2)
1	Equivalent stress for downward force	67.59	74.235
2	Equivalent stress for centripetal force	27.27	22.856
3	Equivalent stress for combined resultant force	72.88	91.928

Table 6.2: Readings for total deformation

Sr. No.	Parameters	Analytical (mm)	CAE (mm)
1	Total Deformation for downward force	15.76	19.59
2	Total Deformation for centripetal force	6.3586	6.9804
3	Total Deformation for combined resultant force	22.9951	26.574

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VIII.CONCLUSION

From present study on structural behavioral analysis of V-stirrer blade made for conical agitation following conclusions have been drawn:
Analytical calculation and ANSYS software results have been compared. The maximum equivalent stress and deformation by analytical calculation are 72.88 MPa and 22.99 mm respectively. The maximum equivalent stress and deformation by FEA are 91.92 MPa and 26.57 mm respectively. These values are within permissible value therefore V-stirrer blade agitator is feasible.
Due to sloping surface of conical agitator material collection can be avoided and agitation process has been maintenance free.

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