DESIGN AND ANALYSIS OF SHAFT AND BEARING FOR VIBRATING SCREEN

TejaVunadavalli[1], G.Bheemanna[2] and Dr P. SampathRao[3]
[1]*PG Student Department of Mechanical Engineering, Vijay Rural Engineering College,*
[2]*Asst Professor Department of Mechanical Engineering, Vijay Rural Engineering College,*
[3]*Professor Department of Mechanical Engineering, Vijay Rural Engineering College,*
Nizamabad, Telangana, India-503003

***Abstract*—The project deals with the design and analysis of bearing for the vibrating screen of capacity 100 tones per hour transmitting 20 B.H.P at a speed of 850 rpm. The design is based on the standard design procedure. In the present work by using the standard design procedure diameter of vibrating screen shaft has been designed. Select the bearing based on shaft diameter from the standard design data and calculate the bearing life. For the safe design, the values obtained from the present design were compared with the values and results of the analysis obtained from the ANSYS package. When the shaft rotates under no-load conditions, deflections and bending will occur due to critical speed of the shaft and the transverse loads applied on the shaft. To compensate this bending and deflections, shaft is designed such that the frequency and speed of the shaft is within critical limits. In this project the shaft and bearing assembly is modeled using PRO-ENGINEER modeling package. And using ANSYS package fem model of the shaft is developed, meshing of the shaft model is done and response of the model for the load applied is checked. The stresses and the bending moments obtained in the shaft are analyzed to get the design as a safer one.**

I. INTRODUCTION

Vibrating screens are used to screen the material to different sizes with the help of the screen the material that are crushed are categorized into various as per the requirement, and then sent to further processes. These are used in cement industries and thermal plants to screen the various sizes of the coal that comes to the screen from the crusher. The required size of the coal are filtered to the bottom of the screen and sent to the next processing section and the remaining material is sent again to the crusher.

II. DESIGN OF SHAFT

A shaft is a rotating machine element which is used to transmit power from one place to another.The power is delivered to the shaft by some tangential force and the resultant torque (or twisting moment) set up with in the shaft permits the power to be transferred to various machine linked up to the shaft.

3.1CLASSIFICATION OF SHAFTS

Shafts involved in power transmission may be classified as

1) Transmission shafts are used to transmit power between source and the machines using the power. They include line shafts, jack shafts and counter shafts.

- **i) Line shaft** is a long continuous shaft which receives power from the source and distribute to different machines.
- **ii) Jack shaft** is directly connected to the source of power and from which other shafts are driven.

iii) **Counter shafts** receive power from line shaft and transmit to a machine.

2) Machine shafts are incorporated within the machine, such as crank shaft.

3.2. MATERIAL USED FOR SHAFTS

The material used for shafts should have the following properties:

1. It should have high strength.
2. It should have good machinability.
3. It should have low notch sensitivity.
4. It should have good heat treatment property.
5. It should have high wear resistant property.

Depending on the requirement, the shafts can be made of plain carbon steel or alloy steel.

3.3. DESIGN OF SHAFT

The shafts may be designed on the basis of

1) Strength and 2) rigidity and stiffness

In designing shafts on the basis of strength, the following cases may be considered:

1) Shafts subjected to twisting moment or torque only.
2) Shafts subjected to bending moment only.
3) Shafts subjected to combined twisting and bending moment
4) Shafts subjected to axial loads in addition to combined torsion & bending loads

Shafts subjected to twisting moment or torque only

When the shaft is subjected to twisting moment (or torque) only, then the diameter of the shaft may be obtained by using the torsion equation. We know that

$$\frac{T}{J} = \frac{f_s}{r}$$

Where,

T=Twisting moment acting on the shaft,

J=Polar moment of inertia of the shaft about the axis of rotation,

F_s =Torsional shear stress, and

r=Distance from neutral axis to the outer most fiber

=d/2

We know for round solid shaft, polar moment of inertia,

$$J = \frac{\pi}{32} d^4$$

The equation may be written as

$$\frac{T}{\frac{\pi}{32} d^4} = \frac{f_s}{\frac{d}{2}}$$

$$\boxed{T = \frac{\pi}{16} f_s d^3}$$

$$\boxed{M = \frac{\pi}{32} f_b d^3}$$

Twisting moment (T) may be obtain by the following relation:

In S.I units, power transmitted (in watts) by the shaft,

P=2ΠNT/60or **T=P*60/2ΠN**

Where,

T=Twisting moment in N-m

N=Speed of the shaft in RPM

In M.K.S units, horse power transmitted by the shaft,

P=2ΠNT/4500 or **T=P*4500/2ΠN**

Where,

T=Twisting moment in Kgf-cm and

N=Speed of the shaft in RPM

Shafts subjected to bending moment only:

When the shaft is subjected to a bending moment only, then the maximum stress (tensile or compressive) is given by the bending equation. We know that

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

Where,

M=Bending moment, N-mm

I=Moment of inertia of cross-sectional area of the shaft about the axis of rotation, mm^4

Fb =Bending stress, N/mm² and

Y=Distance from neutral axis to the outer-most fiber, mm

We know that for a round solid shaft, moment of inertia,

and $I = \frac{\pi}{64} d^4$ y=d/2

Substituting these values in the equation

$$\frac{M}{\frac{\pi}{64} d^4} = \frac{f_b}{\frac{d}{2}}$$

Shaft calculations:

Given data:

- Power transmitted by the shaft= 20hp
- Speed of the shaft =850 rpm
- Weight of the screen=4500kg
- Beam length =230cm
- Arm length =15cm
- Shear stress =650 kg/cm²
- Bending stress =1000 kg/cm²

Case 1: Arm length= 15cm

Twisting moment:

Power p=2ΠNT/4500

20=2Π*850*T/4500

T=16.85 Kg-m (OR) 1685 Kg-cm

We know

$T=\pi/16*\tau*d^3$

$1685= \pi/16* 650*d^3$

d= 23.6 mm

Bending moment:

M=weight of screen*arm length

= 4500*15

=67500 kg-cm

We know

$M=\pi/32*\sigma b*d^3$

$67500= \pi/32*500*d^3$

d=11.12cm (or) 111.2mm

Combined bending and twisting moment:

We know

$\pi/32*\sigma b*d^3=1/2[M+\sqrt{M^2+T^2}]$

$\pi/32*500*d^3=1/2[67500 +\sqrt{67500^2+1685^2}$

d=111.2 mm

Fluctuating loads:

We know

$\pi/16*\tau*d^3 =\sqrt{(Km*M)^2+(Kt+T)^2}$

$\pi/16*650*d^3 =\sqrt{(2*67500)^2+(2*1685)}$

d=101.9mm

Deflection of shaft

Actual deflection $\delta=w/24*E*I(3L^2-4A^2)$ $=4500/24*2.1*10^6*211.3 (3*230^2-4*15^2)$

=0.0189mm

Allowable deflection =L/1500

=230/1500

=0.1533mm

F.S=allowable deflection / Actual deflection

=0.1533/0.0189

=8

Selected dia of shaft=100mm

Arm length=6 cm

Twisting moment:

Power p=2ΠNT/4500

20=2Π*850*T/4500

T= 1685 Kg-cm

We know

$T=\pi/16*\tau*d^3$

$1685= \pi/16* 650*d^3$

d= 23.6 mm

Bending moment:

M=weight of screen*arm length

= 4500*6

=27000 kg-cm

We know

$M=\pi/32*\sigma b*d^3$

$27000= \pi/32*500*d^3$

d=81mm

Combined bending and twisting moment:

We know

$\pi/32*\sigma b*d^3=1/2[M+\sqrt{M^2+T^2}]$

$\pi/32*500*d^3=1/2[27000 +\sqrt{27000^2+1685^2}]$

d= 81 mm

Deflection of shaft

Actual deflection $\delta=w/24*E*I(3L^2-4A^2)$

$=4500/24*2.1*10^{\wedge}6*211\ (3*230^2-4*6^2)$

=0.0669mm

Allowable deflection =L/1500

=230/1500

=0.1533mm

F.S=allowable deflection / Actual deflection

=0.1533/0.0669

=2

SAFE STRESS:

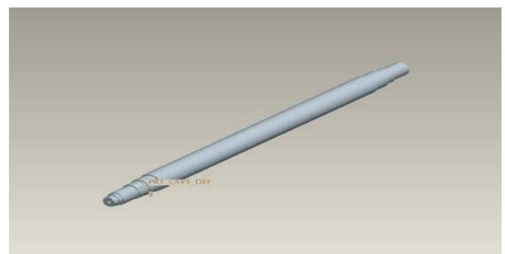
Safe stress= yield stress/ factor of safety

Yield stress in EN8 steel = 280 N/mm²

Safe stress in shaft-1= 280/8 =35 N/mm²

Safe stress in shaft-2= 280/3 =93 N/mm²

Safe stress in shaft-3= 280/2 =140 N/mm²



Shaft

III. DESIGN OF BEARING

A bearing is a machine element which supports another moving machine element knows as journal. It permits a relative motion between the contact surfaces of the member, while carrying the load. The efficiency of the mechanical system depends to a great extent on the efficiency of its bearings.

A necessity for the efficient working of the bearings is that the running surface should be adequately supplied with lubricant. For this purpose the oil is supplied through a lubricating ring firmly clamped on the shaft at the after end and a wiper device fitted in the upper part. This device, together with correctly formed oil grooves in the bearing shells ensure that in bearings the oil supply is maintained in all circumstances even at low revolutions.

Classification of bearings:

Bearings may be classified as given below

1. Depending upon the direction of load to be supported. The bearing under this group are classified as

a) **Radial bearings:** The load acts perpendicular to the direction of motion of the moving element.

b) **Thrust bearings: T**he load acts along the axis of rotation.

2. Depending upon the nature of contact. The bearing under this group are classified as:

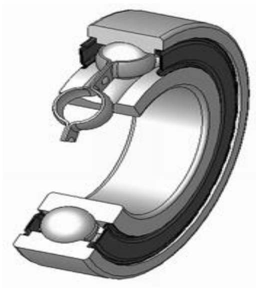
a) **Sliding contact bearings:** The sliding takes place along the surface of contact between the moving element and the fixed element. The sliding contact bearing are also knows as **plain bearings**. To minimize the friction these surfaces are usually separated by film of lubrication.

b) **Rolling contact bearings:** The steel balls or rollers are interposed between the moving and fixed element. The object of rolling contact bearing is to minims the friction by substituting pure rolling motion for sliding motion. Since the rolling friction is much less than the sliding friction, rolling contact bearings are called **anti-friction bearings.**

Bearings used in vibrating screen:

Mainly rolling contact bearings are applicable in vibrating screens because they have the following advantages.

- Can be adopted for combined radial and axial loads without any complications.
- More compact design.
- Maintenance cost is low.
- Low starting friction.
- Easier to provide lubrication and requires small consumption of lubrication.
- Accuracy alignment of parts can be maintained.
- Reliable in service.
- The dimensions are internationally standardized.



Bearing

Bearing Failure

Excessive Loads

Excessive loads usually cause premature fatigue. Tight fits, brinelling and improper preloading can also bring about early fatigue failure.

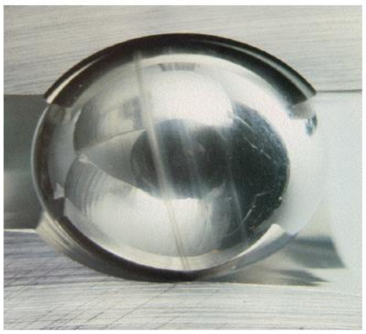
The solution is to reduce the load or redesign using a bearing with greater capacity.

Overheating:

Symptoms are discoloration of the rings, balls, and cages from gold to blue. Temperature in excess of 400F can anneal the ring and ball materials. The resulting loss in hardness reduces the bearing capacity causing early failure. In extreme cases, balls and rings will deform. The temperature rise can also degrade or destroy lubricant.

Reverse Loading:

Angular contact bearings are designed to accept an axial load in one direction only. When loaded in the opposite direction, the elliptical contact area on the outer ring is truncated by the low shoulder on that side of the outer ring. The result is excessive stress and an increase in temperature, followed by increased vibration and early failure. Corrective action is to simply install the bearing .



Bearing life calculations:

Case 1: Bore diameter is 80mm

1. Deep groove ball bearing:

We know

L10 = (C / P) ^10/3 × (B / n) × a

= (163000/44145) ^10/3*(16666.6/850)*1

=**1519 hr**

Where C= radial rating of the bearing in N (from data book)

=163000 N

L=60NLh

=60*850* 1519

=77.46*10^6 revolution

2. Cylindrical roller bearing:

We know

L10 = (C / P) ^10/3 × (B / n) × a

= (415000/44145) ^10/3*(16666.6/850)*1

=**34125 hr**

Where C= radial rating of the bearing in N (from data book)

=415000 N

L=60NLh

=60*850* 34125

=1740.37*10^6 revolution

3. Tapered roller bearing:

We know

L10 = (C / P) ^10/3 × (B / n) × a

= (251000/44145) ^10/3*(16666.6/850)*1

=**6396 hr**

Where C= radial rating of the bearing in N (from data book)

= 251000 N

L=60NLh

=60*850* 6396

=326.19*10^6 revolution

4.Spherical roller bearing:

We know

L10 = (C / P) ^10/3 × (B / n) × a

= (490000/44145) ^10/3*(16666.6/850)*1

=**59334 hr**

Where C= radial rating of the bearing in N (from data book)

=490000 N

L=60NLh

=60*850* 59334

=3026.03*10^6 revolution

Case 2: Bore diameter is 100mm

1. Deep groove ball bearing:

We know

L10 = (C / P) ^10/3 × (B / n) × a

= (190000/44145) ^10/3*(16666.6/850)*1=**2529hr**

S.NO	Types of bearings	Bore dia80mm Life in Hrs	Bore dia 100mm Life in Hrs
1	Deep Groove Ball Bearing	1519	2529
2	Cylindrical roller Bearing	34125	25437
3	**Spherical Roller Bearing**	**59334**	**53479**
4	Tapered Roller Bearing	6396	24124

Where C= radial rating of the bearing in N (from data book)

=190000 N

L=60NLh

=60*850* 1519

=12.6*10^7 revolution

2. Cylindrical roller bearing:

We know

L10 = (C / P) ^10/3 × (B / n) × a

= (380000/44145) ^10/3*(16666.6/850)*1

=**25437 hr**

Where C= radial rating of the bearing in N (from data book)

=380000 N

L=60NLh

=60*850* 34125

=12.97*10^8 revolution

3. Tapered roller bearing:

We know

L10 = (C / P) ^10/3 × (B / n) × a

=(374000/44145) ^10/3*(16666.6/850)*1

=**24124 hr**

Where C= radial rating of the bearing in N (from data book)

=374000 N

L=60NLh

=60*850* 6396

=12.30*10^8 revolution

Conclusions on bearing life calculations:

From the above table we can conclude that the Spherical roller bearings are best suitable for vibrating application because of its high dynamic load rating and also life of Spherical roller bearings is more compare to other bearing .

IV. PRO-ENGINEER

Computer aided design (CAD) is defined as any activity that involves the effective use of the computer to create, modify, analyze, or document an engineering design. CAD is most commonly associated with the use of an interactive computer graphics system, referred to as cad system. The term CAD/CAM system is also used if it supports manufacturing as well as design applications.

The design software used to design the shaft and bearing assembly of the vibrating screen is pro/engineering.

CAPABILITIES AND BENEFITS

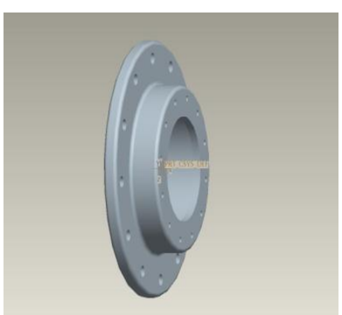
1. Complete 3D modeling capabilities enable you to exceed quality arid time to arid time to market goals.
2. Maximum production efficiency through automated generation of associative C

tooling design, assembly instructions, and machine code.

3. Ability to simulate and analysis virtual prototype to improve production performance and optimized product design.
4. Ability to share digital product data seamlessly among all appropriate team members.
5. Compatibility with myriad CAD tools-including associative data exchange and industry standard data formats.

V. MODELING PICTURES

The spherical roller bearing consists of an inner race which is mounted on shaft or journal and the outer race are which is carried by housing or casing. In between the inner race and outer race there are rollers. A number rollers are used these are held in proper distance by retainer so that do not tough each other. Race and rollers are made of high carbon chromium steel while the cages are usually made of brass. Inner diameter is 80mm, outer diameter is 170mm and the width of bearing is 58mm.



Bearing housing

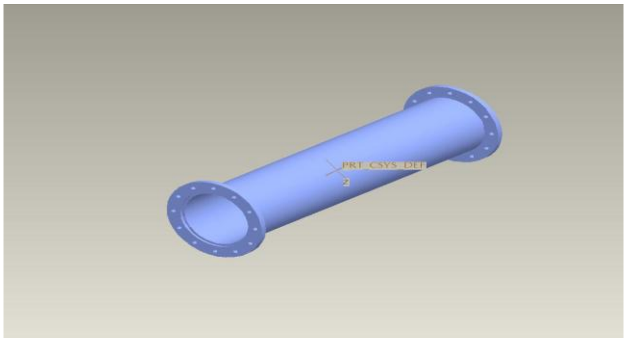
Bearing housing is used for housing the bearing in a proper way and it is made of cast steel. Quantity is two in number one is placed in drive side another one is in non-drive side. The outside diameter of housing is 375mm, inside diameter is 104mm and the width is 114mm. Weight of the housing is 67 kg. It consists of 120holes circumferentially on the pitch circle diameter is 325mm.

Bearing labyrinth cover

Outer diameter and inside diameter of labyrinth cover is 172 and s95 respectively. It consists of circular groove which is fitted in the bearing locking cover. Weight of the component is 1.45 Kg. Quantity is two in number one is placed in drive side another one is in non-drive side.

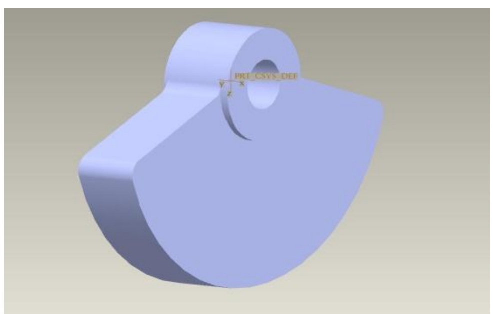
Bearing locking cover

Outer diameter and inside diameter of labyrinth cover is 270 and 111 respectively. Weight of the component is 17.22Kg. Quantity is two in number one is placed in drive side another one is in non-drive side. Bearing locking cover made of cast iron and it is used for prevent to allow dust particles.



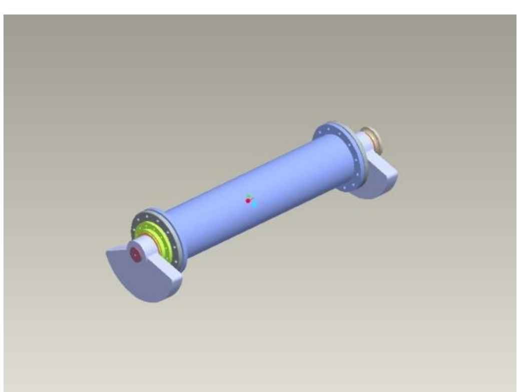
Center pipe

Center pipe is also called as shaft protection pipe and it is used to protect the shaft externally. Outer diameter and inside diameters are 375 and 259 respectively. Weight of the component is 90.83Kg. The pipe having 12 hole with diameter 21on pitch circle diameter 325 and the length of pipe is 1492mm.



Counter weight

Counter weights are made of cast iron and these are used to create vibrating motion to the screen. The weight of counter weight is 30.29 Kg. Quantity is two in number. Outer diameter and inside diameters are 140 and 70 respectively.



Bill of Materials

Sl.no	Description	Qty	Material
1	Bearing Housing	02	C.I-GR30(Is210)
2	Bearing locking Cover	02	C.I-GR30(Is210)
3	Labyrinth Cover	02	C.I-GR30(Is210)
4	Shaft	01	EN8
5	Shaft Cover pipe	01	Seamless PIPE & IS2062
6	Plan drum with counter weights	02	CI-GR30(IS210)
7	End Cover	02	IS 2062 GrB
8	Spacer between counter and pulley	01	IS 2062 GrB
9	Spacer for locking bearing drive end	01	C.I-GR 30 (IS210)
10	Spacer for locking bearing non-end drive	01	----------
11	Spherical roller bearing (22324CC)	02	C4 CLEARANCE

12	Locking plate (drive & driven side)	02	----------
13	Oil seal (dia 140×170×15)	02	----------
14	Oil seal (dia 130×160×12)	02	----------
15	Hexagon socket head cap screws M 12×30 LG	08	GR-10.9
16	V-pulley	01	--------
17	High tensile bolt with hex nut M24×125LG	32	GR-10.9
18	High tensile bolt+ washer M12×30 LG	16	GR-10.9
19	Hex HD screw + washer M20×45 LG	02	GR-10.9
20	Hex HD screw + washer M16×110 LG	24	GR-10.9
21	Grease	750gms/each	INDIAN OIL-MAKE
22	Keybars-32×18×165 LG	02	--------
23	Keybars-28×16×75 LG	01	--------
24	C-bend for pad plate back up	02	M.S(IS 2062)
25	Counter weights segments	2 sets	C.I-GR 15 (IS 210)

VI. FINITE ELEMENT METHOD

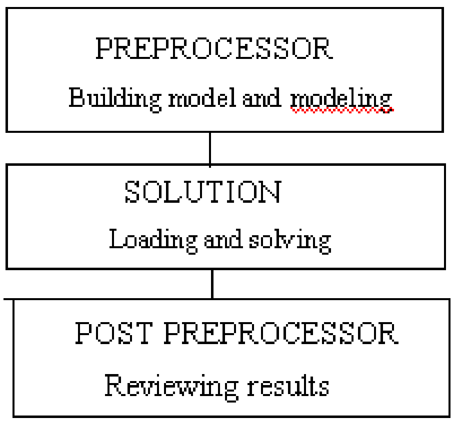
The basic idea in the FEM is to find the solution of complicated problems by replacing it by a simpler one. Since the actual problem is replaced by a simpler one in finding solution , be will be able to find only an approximate solution rather than the exact solution. The existing mathematical tools will not be sufficient to find the exact solutions (and some times, even an approximate solutions) of most of the practical problems. Thus in the absence of any other covenant method to find even the approximate solution of given problem, we have to prefer the FEM. the FEM basically consists of thus following procedure. First, a given physical or mathematical problems is modeled by dividing it into small inter connecting fundamental parts called **“Finite element”**. Next, an analysis of the physical or mathematics of the problem is made on these elements: Finally, the elements are re-assembled into the whole with the solution to the original problem obtain through this assembly procedure.

The finite element method has developed simultaneously with the increasing use of high speed electronic digital computers and with the growing emphasis on numerical method for engineering analysis. Although the method was original developed for structural analysis the general nature of the theory on which it is based has also made possible us successful application for so of problem in other fields of engineering.

VII. STRUCTURAL ANALYSIS

Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

BASIC STEPS IN ANSYS (Finite Element software)



ELEMENTS USED FOR ANALYSIS

BEAM3 is a uniaxial element with tension, compression, and bending capabilities. The element has three degrees of freedom at each node: translations in the nodal x and y directions and rotation about the nodal z-axis. Other 2-D beam elements are the plastic beam.

Beam input summer

Nodes

I, J

Degrees of freedom

UX, UY, ROTZ

Real constants

AREA- Cross-sectional area

IZZ- Area moment of inertia

HEIGHT- Total beam height

SHEARZ- Shear deflection constant

ISTRN- Initial strain

ADDMAS- added mass per unit length

Material properties

EX, ALPX (or CTEX or THSX), DENS, GXY, DAMP

Surface loads

Pressure- -

Face 1 (I-J) (-Y normal direction)

Face 2(I-J) (+ X tangential detection)

Face 3(I) (+X axial direction)

Face 4(j) (-X axial direction) (use a negative value for loading in the opposite direction)

Body loads

Temperature

T1, T2, T3, T4

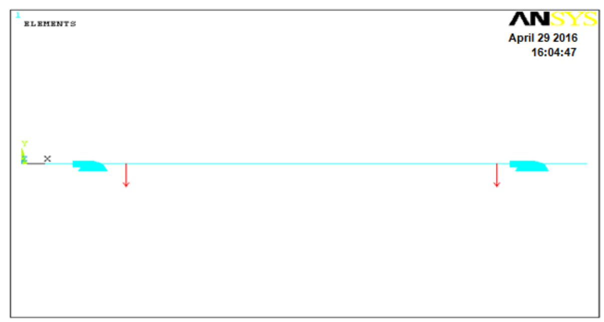
Special feature

Special stiffening

Large deflection

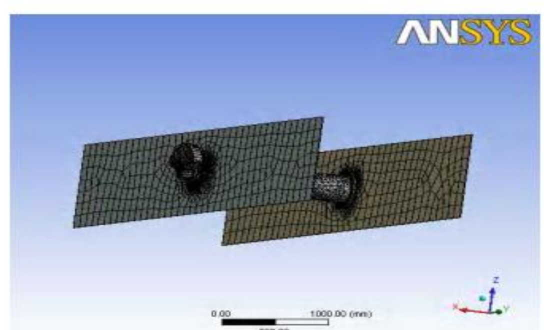
Birth and death

Ansys results for 100mm diameter shaft

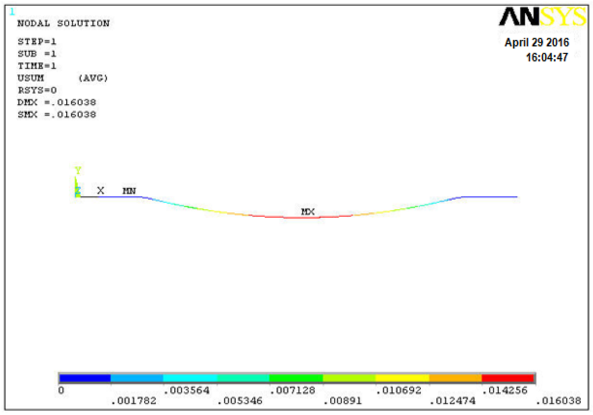


Applying boundary conditions and loads on shaft

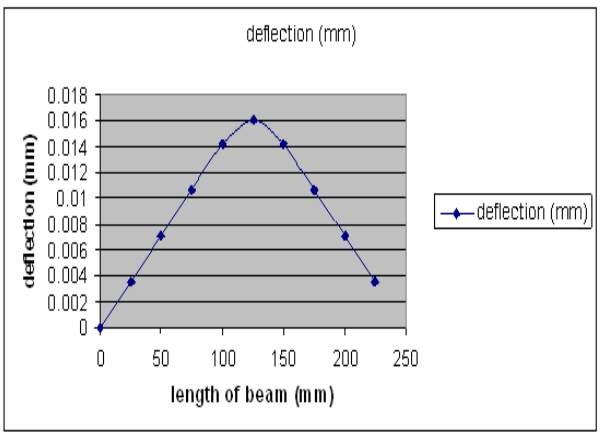
Maximum deflection of beam

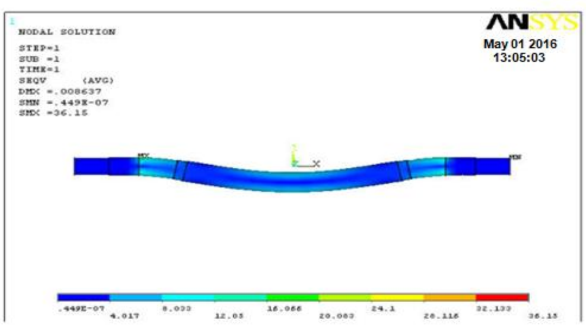


The above figure shows the displacement i.e. maximum deflection occurs at centre of the beam due to applied load. .Maximum deflection of beam=0.016038mm



Maximum deflection of beam= 0.016038mmMinimum deflection of beam=-0.016038 mm





3D ANALYSIS OF SHAFT

First solid shaft is modeled in the PRO-E and then imported from PRO-E to ANSYS. Let us see the results for 80mm diameter 3D solid shaft. We have taken solid as an element type and the static analysis is performed on it. The below figure shows the simple 3D solid shaft. Translatery moments are restricted at bearing surface and apply the loads i.e.22072N at the points with the arm length 6 Cm from the bearing centre axis shown in figure.

Stress behavior in the solid shaft

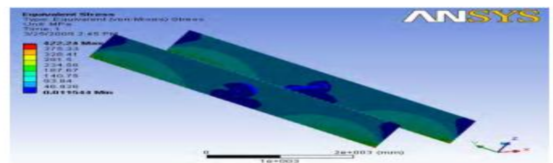
Maximum stress induced in the shaft=36.15 N/mm²

Imported Model of shaft and bearing assembly in Ansys

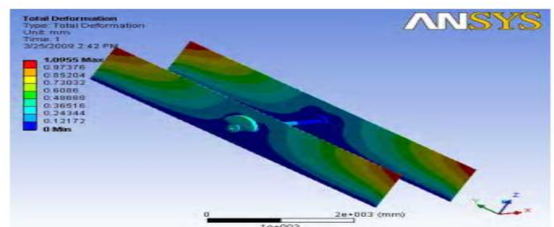
Mesh in Ansys

Total Deformation in assembly

Total deformation in the assembly body=1.0955mm



Equivalent stress in the assembly



Maximum stress in the assembly =422.24 Mpa

Minimum stress in the assembly =0.011544 Mpa

VIII. RESULTS

- Diameter of the shaft given by Bevcon was 100mm of EN8material and calculations and analysis has proven that 80mm of EN8 material is best suitable.
- By reducing the arm length diameter of shaft also can be reduced.
- Shaft diameter 80mm is concluded as selected dia because of its factor of safety is 2.
- We can conclude that the shaft diameter 80mm is the best choice for manufacturing, more efficient working of vibrating screen.
- In place of cylindrical roller bearings which Bevcon uses they are replaceable by spherical

roller bearings because of high dynamic load rating (490000 N).

- Based on the life also spherical roller bearings are higher than the cylindrical roller bearings (59334 Hrs).

FUTURE SCOPE OF THE WORK

- The shaft has to be manufactured according to the design calculations done in the thesis.
- Vibrating tests have to be performed considering the factor for effective, efficient and validation.
- The present work is to be carried with different screen testing methods.
- The present work is to be carried out on portable vibrating screens, which are the future vibrating screens.

REFERENCES

[1] Dennis Hunt, SPTF, "Screen tensioning method", SGIA journal, vol 1, 2001, page 34-36.
[2] Datong& Taiyuan, "Application of experimental model analysis technique to structural design of linear vibrating screens", Taiyuan University of technology, 2004, vol 10, issue 1, pages 243-245
[3] "Design data ", PSG college of technology, 1983, page 1.10-1.12, 7.19-7.24, and 7.42.
[4] Hall, Holowenko Laughlin, "Theory and problem of machine design", Scheme's series, page 101-130.
[5] JackieKeul, Telsmith, "Vibrating test goal: efficient, effective and valid", COTS journal, 2006, page 208-213.
[6] J.N.Reddy, "An introduction to finite element method", 3rd edition, TMH, page 233-248
[7] RichardG.BudynasJata. "Advanced strength and applied stress analysis", 2nd edition, McGrawhill, page 132-152
[8] R.K.Allan, "Roller bearing", 3rd edition, page 233.
[9] RobertL.Norton, "Machine design", 2nd edition.
[10] R.S.Khurmi&J.K.Gupta "Machine design", page 997-1007.
[11] SchamTickoo, "Pro-engineer-2001", 2nd edition, pages 5-15,175-193.
[12] SKF.com journal "rolling contact bearing"
[13] V.B.Bhandari, "Introduction to Machine design," TMH, page 216-253,581-590