Bearing position optimization for machine shaft

Mr. Patil Amit V., Prof. Meghna Pathak, Prof. P.K. Sharma

***Abstract*— the present work is carried on the shaft of special purpose machine. The shaft is supported by the two bearings. The special purpose machine is used for boring operation. The arrangement of bearings is optimized using the simulation software. Optimum design is verified with a simulation of a conceptual design of a balance shaft of a special purpose machine. Total 4 models have been tested on ANSYS software. At the end of paper results has been discussed from the software analysis.**

***Index Terms*— Optimization,deflection.,bearing position.**

I. Introduction

Special purpose machines are designed and manufactured for specific jobs. Here special purpose machine is used for boring operation. It is the horizontal boring machine. Boring is a process of producing circular internal profiles on a hole made by drilling or another process. Bearings are important component of any rotating machinery. The bearing withstands two types of loads - radial load and thrust load. Radial loads are forces that occur at right angles to the shaft. These forces tend to make the shaft move side to side or up and down. Thrust loads are forces that are directed axially along the length of the shaft. These forces tend to make the shaft move back and forth along its axis. The shaft is supported by the two bearings. Initial distance between the bearings is 168mm.The value of L= distance between bearing, is taken as follows:

Table I:

position	Bearing span L (mm)	Boundary condition
first	X1=158	minimum
second	X2=168	minimum
third	X3=178	maximum
fourth	X4=198	maximum

A. *Specifications:*

Power of motor (p) = 7457 watts.
Speed of motor (N_1) = 25 rps.
Speed of shaft (N_2) = 20 rps.
Diameter of motor pulley (D_1) = 118 mm.
Diameter of spindle pulley (D_2) = 141 mm.
δ = deflection at the point of application of load mm
δ_1 = deflection due to radial yielding of the bearings mm
δ_2 = deflection due to elastic bending of the shaft mm

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a = length of the overhanging portion of the shaft from the effective support of bearings.
S_A = Radial stiffness of the bearing near the load point kgf/mm
S_B =Radial stiffness of the bearing away from the load point, kgf/mm
Ia= Moment of inertia of overhang portion of shaft mm^4
I_L = Moment of inertia of spindle section between bearings mm^4
L= distance between two bearings, mm
S= p/δ= overall stiffness of the shaft, kgf/mm

II. LITERATURE REVIEW

H. Eskicioglu et al. used PRO-LOG to develop rule-based algorithm for the selection of bearing arrangement. PRO-LOG is programming language for expert systems. Type of cutting operation, the required cutting force and life of bearings used to determine bearing arrangement. Yang used static stiffness to optimize a bearing position and his methods are used to solve the multi-bearing span optimization. Lee and Choi minimized the weight of the rotor-bearing system by optimization design Lagrange multiplier method. Nataraj and Ashrafiuon demonstrated the optimization results to minimize the forces transmitted by the bearings to the supports.

III. THEROTICAL FORMULATIONS

Maximum center distance = C = 2 (D_1+D_2) ------------ (1)
Pitch length of belt (Lp) = 2C+1.57 (D_1+D_2) + (D_2- D_1)^2/4C ------------ (2)
The deflection of the shaft is due to:

A. Tensioning of belt
B. Axial & radial forces

A. Load calculation due to tensioning of belt

P=F/K-1*HK^2+1+2 K cos (180-_) ------ (3)
a= 94mm
L= X1= 158mm (Distance between the effective support points of front & rear bearings)
Ia = 4.611* 10^6 mm^4
I_L = 8.475425*10^5 mm^4

B .Load calculation due to axial and radial forces:

Power = 9.67*10^{-6} (d1-d2) * f * Kc * v --- (4)

C. Total power for roughing station:

Boring:
1.Ø 27.4 P = 412.9 W
2. Ø 41.4 P = 638 W
Total Power P = 6100.9 W

D. Deflection Calculation:

S_A= 58715.6 kgf/mm
S_B= 41284.4 kgf/mm
$\delta_1=P\,[1/S_A\,(a+L/L)^2 + 1/S_B\,(a/L)^2]$ ---- (5)
$\delta_2=P\,[a^2/3E\,(a/Ia + L/I_L)]$ ------ (6)
$\delta = \delta 1+\delta 2$ ----- (7)

D. Stiffness calculation for the shaft:

$S= p/\delta$

IV. FINITE ELEMENT FORMULATIONS

Finite element analysis has been carried out by ANSYS software.
In general, a finite-element solution may be broken into the following three stages.

A. *Pre-processing: defining the problem*

The major steps in pre-processing are
(i) Define key points/lines/areas/volumes,
(ii) Define element type and material properties and (iii) mesh lines/areas/ volumes as required.

B. *Solution:*

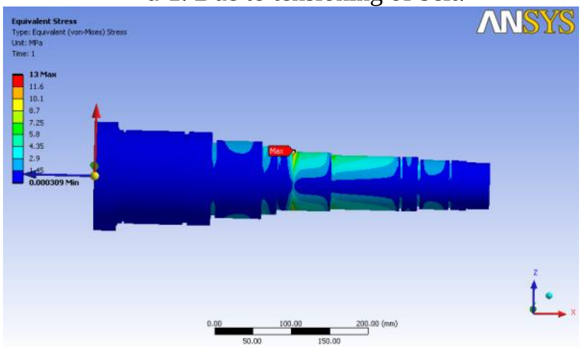
Assigning loads, constraints and solving. Here, it is necessary to specify the loads, constraints and finally solve the resulting set of equation.

C. *Post processing:*

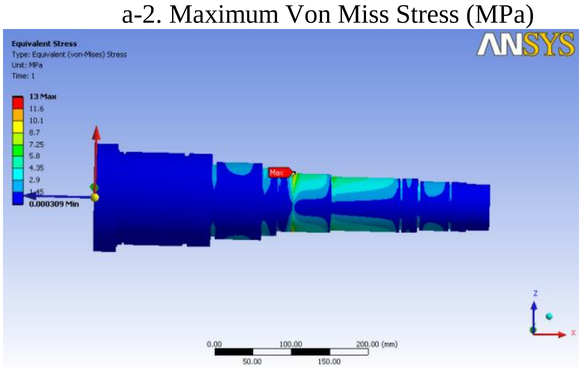
In this stage we can see (i) lists of nodal displacements, (ii) element forces and moments, (iii) deflection plots and (iv) frequencies and temperature maps.
Following steps show the guidelines for carrying out Modal analysis.

Define Materials
1. Set preferences. (Structural)
2. Define constant material properties.
Model the Geometry
3. Follow bottom up modeling and create/import the geometry
Generate Mesh
4. Define element type.
5. Mesh the area.
Apply Boundary Conditions
6. Apply constraints to the model.
Obtain Solution
7. Specify analysis types and options.
8. Solve.
5. Mesh the area.
Apply Boundary Conditions
6. Apply constraints to the model.
Obtain Solution
7. Specify analysis types and options.
8. Solve.
The ANSYS software was used for this purpose. Total four bearing's spans were tested for deformation of the shaft.
For the model creation different dimensions taken as follows:
Spindle diameter = 70mm
The result of ANSYS analysis for the first bearing span is as follows:

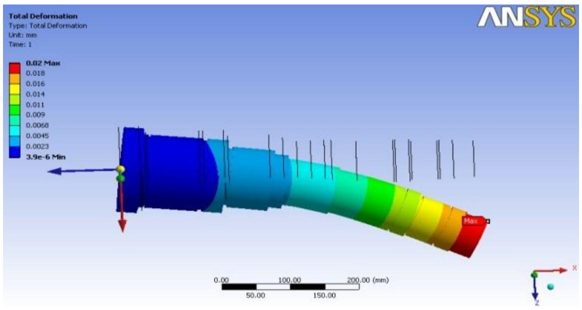
a-1. Due to tensioning of belt:



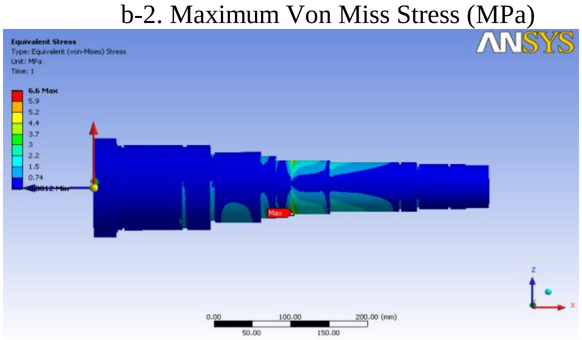
a-2. Maximum Von Miss Stress (MPa)



b-1. Due to axial and radial forces:



b-2. Maximum Von Miss Stress (MPa)



V. RESULTS

The results are tabulated in the table form:
Where
Def. = deflection of the shaft.

A. *Table 1:*

	X1		X2	
operation	Def.	stress	Def.	stress
Tensioning of belt	0.039	13	0.036	12.9
Axial & Radial forces	0.02	6.5	0.019	6.2
Boring operation	0.025	6.6	0.024	6.4

B. Table 2:

	X3		X4	
operation	Def.	stress	Def.	stress
Tensioning of belt	0.033	12.7	0.032	10.7
Axial& Radial forces	0.018	5.8	0.015	5
Boring operation	0.023	6.1	0.022	5.1

VI. CONCLUSION

From Table 1 & Table 2 :
Bearing span with 158mm shows stress and deformation higher than other position.
Initial bearing span is 168mm but bearing span with 198mm distance shows better results than other variants.

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