Design and Analysis of Stepped Shaft in Inclined Position
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Abstract— Shaft is an important machine element and is required to design with extreme accuracy of well-functioning of a machine. The shaft is generally acted upon by bending moment, torsion and axial force. A spindle is a short rotating shaft. Spindles are used in all machine tools such as the small drive shaft of a lathe or the spindle of a drilling machine. There is a requirement of some specific machines to have a spindle in inclined position. Determination of loads acting on shaft and angle of inclination of shaft is an important task during design. We have taken maximum shear stress theory into consideration. It also generates the diagrams for horizontal, vertical and resultant bending moments over the lengths of the shaft. In this paper we used “CREO PARAMETRIC” software for modeling and “ANSYS” for checking failure of a design. ANSYS is used extensively for checking the stresses in a component and deflection of shaft gives complete idea of displacement of component. It is accurate and also has a number of built in functions which makes it versatile. As different computer software are used shaft design becomes easy, fast and error free.

Key words: Shaft, inclined, ANSYS, stress, diameter

I. INTRODUCTION
A. Shafts:
A term ‘Transmission Shaft’ is usually refers to a rotating machine element, circular in cross section , which supports transmission elements like gears, pulleys etc. along with transmitting power. A shaft is always stepped with the maximum diameter in the middle portion and minimum at the ends. In this paper shaft is provided with a step, for its positioning in inclined position. Shafts must have adequate torsion strength to transmit torque and not to be over stressed. In this paper a shaft is assumed to be loaded at its one end with a dead weights and a shaft is designed with the steps to support it in inclined position.

B. Material for Shafts:
Various different materials are used for shaft such as ferrous, non-ferrous and non-metals depending on the application. Ordinarily shafts are made if medium carbon content from 0.15 to 0.40 percent such as 30C8 or 40C8. These are commonly called as ‘machining steels’. Where greater strength is required, high carbon steels such as 45C8 or 50C8 or alloy steels are employed. Alloy steels are costly compared with plain carbon steels. However alloy steels have higher strength, hardness and toughness. They possess greater resistance to corrosion compared with plain carbon steels.

Shafts are produced by hot rolling and finished to size either by cold drawing or by turning and grinding.

En9 is special type of alloy steel that has a good machinability and used mainly to manufacture pulleys, cam, sprockets, shafts etc. These materials are used for relatively severe service conditions. When the situation demands great strength then alloy steels are used. They have fewer tendencies to crack, warp or distort in heat treatment. Residual stresses are also less compared to CS (Carbon Steel).

II. DESIGN OF SHAFT
There are basically two theories considered while design of a shaft that are listed below
- Maximum shear stress theory.
- Maximum normal stress theory.

Since the shafts are made up of ductile material it in more logical to design using maximum shear stress theory.

And also it is applicable because as in inclined position shear force acting on shaft will have more pronounced effect than the normal stress.

A. Maximum Shear Stress Theory:
According to this theory, principal shear stress is given by

\[ \tau_{max} = \frac{16}{\pi d^2} \sqrt{(M_b)^2 + (M_t)^2} \]

One important approach of designing a shaft is to use ASME code. According to it bending and torsional moments are to be multiplied by factors Kb and Kt respectively.

Hence maximum shear stress theory of failure is modified as,

\[ \tau_{max} = \frac{16}{\pi d^2} \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \] ............... (1)

values of shock and fatigue factor Kb and Kt

<table>
<thead>
<tr>
<th>Sr no</th>
<th>Application</th>
<th>Kb</th>
<th>Kt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Load gradually applied</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>Load suddenly applied (minor shock)</td>
<td>1.5-2.0</td>
<td>1.0-1.5</td>
</tr>
<tr>
<td>3</td>
<td>Load suddenly applied (heavy shock)</td>
<td>2.0-3.0</td>
<td>1.5-3.0</td>
</tr>
</tbody>
</table>

Table 1:

III. DESIGN OF A SHAFT
A. Design Specification:
Primary load carried by shaft is of dead weight at two positions and force acting on gear attached to transmit the power. Speed of rotation is considered to be around 40 rpm so centrifugal force acting on shaft is very less. A shaft is considered to be inclined at an angle 30° with horizontal , distance between two bearings is 300mm and length of shaft
is 500 mm, distance between force A and B is 140 mm, distance between B2 and G is 50 mm.
Force A = 250 N, Force B = 300 N, P_t = 5823.807 N, P_r = 2119.7 N, \( \phi = 30^\circ \)
G = Gear, B1 and B2 = Bearings
Considering En9 as a material for shaft

2) Horizontal Plane Analysis:

IV. DIAMETER OF SHAFT
Referring table 1 with minor shocks Kb and Kt values are 2.0 and 1.5 respectively
Mb = 202714.26 Nmm, Mt = 31428.42 Nmm, from the material properties and with ASME code, \( \tau_{\text{max}} \) = 93.375 N/mm^2
Substituting above values in equation (1)
Diameter of shaft (di) = 28.1313

Selecting from the standard diameter for shaft, with consideration of material non homogeneity as 35 mm.

V. ANALYSIS OF SHAFT IN ANSYS
“CREO PARAMETRIC 1.0” is a software used to model the shaft in computer and further it is exported to ANSYS for further analysis. ANSYS is used widely for various analysis of a design component. As it is considered, the
speed of rotation of shaft is low hence using static structural analysis of the component.

A. Meshing Of a Shaft:

![Meshing Of a Shaft](image1)

**Fig. 6: Meshing Of a Shaft**

B. Maximum Principal Stress Induced In Shaft:

![Maximum Principal Stress Induced In Shaft](image2)

**Fig. 7: Maximum Principal Stress Induced In Shaft**

C. Total Deformation in a Shaft:

![Total Deformation in a Shaft](image3)

**Fig. 8: Total Deformation in a Shaft**

VI. RESULTS

1) From ANSYS maximum principal stress induced in shaft is 3.2 N/mm², which is well below allowed stress limit, hence the shaft will not fail in working condition.
2) Deflection of shaft is another parameter to be considered, here value from analysis is very low. Hence shaft will remain stable in static position.
3) Material used for shaft have sufficient strength and rigidity to sustain load

VII. CONCLUSION

A stepped shaft made from En9 is designed theoretically and analysed in ANSYS. As shaft is revolving with low speed the centrifugal component of force acting on shaft is negligible. For the numerical study shaft is modelled in CREO and it is exported to ANSYS. Stepped shaft used will be stable in inclined position from above results. Results obtained from the analysis, when compared with the theoretical values are having very small deviation.

REFERENCES