Design Modification and Analysis of Bevel Gear of Ring Spinning Machine

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Abstract: The bevel gear is use in the ring spinning machine to lift the spindle mechanism. The bevel gears are attached with the cam for spinning the yarn about spindle. During the working tangential force is acting on bevel gear. Which may cause to break the teeth? The tangential load which is applied on the gear is from pinion. The bevel gear are working similar to the bevel gear and transmitting the power. The intersection axis of both the gear and pinion at right angle to each other. The failures of the gear are due to low strength of the gear material. The beam strength of the bevel gear is low as compare to the tangential load that's why the bevel gear fails. By changing the various material of gear we can prevent the gear from failure. The design modification involves changing the material. But in that case by changing the dimension likes to change the module and thickness which may affect the working of machines. Similarly to change in the setup of machine in that case it is desirable to chance the material of bevel gear with high strength material than the existing one. The main cause of bevel gear failure is due to bending stress is more than the allowable stress of that gear material. So in this paper we increase the beam strength of gear by using various gear material.

Keywords: Bevel gear, Bending Stress, Spinning Machine, Gear Material,

I. INTRODUCTION

Gear is one of the most critical components in mechanical power, for transmission system. The surface strength bending and of the gear tooth are considered to be one of the main parameters for the failure of the gears. For optimal design of gear and to reduce their failure the stresses are becoming increasingly important. All the analytical investigations would be carried out on the basis of Lewis stress formula and contact stresses are calculated by using Hertz formula of contact stress.

Bevel gears typically have a straight or skewed tooth line and varying tooth profile in normal cross section at different radius from major to minor diameter. These Bevel gears are engaged with spur or helical involutes pinions at intersecting or crossed axes.

About Hi- Spin Ring Spinning Frame Machine: - Texaco Mo –Hi-Spin Ring Spinning Frame is design and manufacture to run at the highest obtainable spinning speed in the industry with ring and traveler combinations.

However, to fully utilize the design and manufacturing of this machine careful handling by the operator is essential.

Redesign: - Much more frequently, engineering design is employed to improve an existing design .the task may be to redesign a component in a product that is failing in service or to redesign a component so as to reduce its cost of manufacture. Often redesign is accomplished without any change in the working principal or concept of original design. For example, the shape may be change to reduce a stress concentration or a new material substitute is reduce weight or cost. When redesign is achieved by changing some of the design parameter, it is often called variant design.

What is a Bevel gear:-

This is a pseudo bevel gear that is limited to 90^0 intersection axis. The Bevel gear is a circular disc with a ring of teeth cut in its side face, hence the name Bevel gear. Tooth elements are tapered toward it's center. The made is spur or helical pinion.

Characteristic of Bevel gear:-

1. The pinion of Bevel gear is either a spur or a helical gear.
2. Bevel gears are mounted on intersecting shaft that is at right angle to each other.
3. The teeth of Bevel gear can be straight or curved.

Bevel gears have some of the following advantages:-

1. They can be cut with gear shapers and spur gear cutter.
2. The axial position of the pinion is not critical as in case of bevel gear.
3. Reduce level of noise due to the very low level of transmission error.

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Fig.No.1 – Bevel gear

II. REVIEW OF LITERATURE

The previous research works on gear teeth failure analysis published by some author is as follows,

Dr. V. B. Sondur have discussed about theoretical and finite element analysis of load carrying capacity of asymmetric involute spur gears. In this paper they had presented a method for investigating the bending stress at the critical section of "Asymmetric Involute spur Gear". The gears with different pressure angle have been model by using CATIA software and analysis was carried out. The results obtained from theoretical method have been verified by using ANSYS. From their work they have proved that bending stress can be minimized up to 20% by increasing pressure angle from 20° to 35°. Thus from their work it is clear that FEA can be the best technique for analyzing and designing analyzing mechanical component. [1]

James W. Dalley has explained various experimental techniques which can be used for analysis including fracture mechanics. Strain measurements with electrical strain gauges, strain gauge circuits, Moiré method, theory of photo elasticity and brittle coating methods in the book Experimental of Stress Analysis. [2]

Gitin M. Maitra, V.B. Bhandari, **PSG College of Technology, Norton, P. C. Gope, M. F**. Spotts have explained all the details of every type of gear including geometry, gear related parameters, force calculations, deflections, effect of heat generation, stress concentration, design criterion, load rating and efficiency of gears, friction in worm gears, material selection and strength rating of worm gears in their respective books.[4]

Prashant Patil have discussed about 3D Photo elastic and Finite Element Analysis of helical gear. They have discussed an industrial problem which uses spreading machine to spread bag. This spreading machine has Positive Infinite Variable gearbox which contains helical gears. In working condition, helical pinion fails due to load coming on the teeth. It seemed that the failure was due to stress concentration as well as bending stresses at tooth root of gear. The calculation of maximum tensile stress at tooth root was a three dimensional problem. Thus they have analyzed the stress pattern by using 3D Photo elasticity techniques. Also they have verified obtained results with FEA. They have found out that the failure of helical gear of PIV gear box may be due to improper alignment and due to improper heat treatment process during teeth hardening.[4]

Bensely In this paper failure investigation of crown wheel and pinion has been done. A fractured gear was subjected to detailed analysis using standard metallurgical techniques to identify the cause for failure. The study concludes that the failure is due to the compromise made in raw material composition by the manufacturer which is evident by the presence of high manganese content and non-existence of nickel and molybdenum. This resulted in high core hardness (458 HV) leading to premature failure of the pinion. [5]

From the above literatures survey it has been conclude that the failures of gears are due to tooth load coming on the gears is more than the beam strength of the tooth and the failure of the teeth of gears are due to bending failure.

III. DESIGN OF SPIRAL BEVEL GEAR

Problem Formulation

The Bevel gear and pinion is used in spinning machine gearbox. During operation it was observed that the Bevel gear fail due to load coming on the teeth. The failure starts at the central thickness of tooth and continue up to the root of the tooth. The failure occurs once within operational period of about certain days. So the industry has replace Bevel gear which is not cost effective. The material of Bevel gear is cast iron and pinion is forged carbon steel SAE 1045.

In order to study failure analysis of gears in industries, the present work is prepared. Gears generally fail when the working stress exceeds the maximum permissible stress. The gears generally fail when tooth Stress exceeds the safe limit. Therefore it is essential to determine the strength of that gear tooth is subjected to under a tangential load. Analysis of the gears strength is carried out so we can be prevented teeth from failure.

The design of the Bevel gear for power transmission in spinning machine plays an important role. This gear is used for moving the bobbins in upward and downward direction. This gives the data of spinning machine for requiredparameter and fulfill the design requirement.

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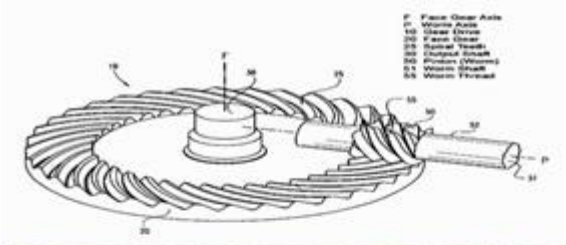

Fig.No.2.The image of Failure of Bevel gear

Fig.No.3.The image of Failure of Bevel gear

Design of Gear Teeth

The process modification of designing in gear teeth is somewhat arbitrary in that the specific application in which the gear will be used determines many of the key design parameters. This is the analytical method for finding the beam strength of bevel gear.

The following are the input parameter to design the Bevel gear.

Motor power = P=15kW =20 HP.No. of teeth on pinion = t_p = 10 No. of teeth on gear = tg =43 RPM of pinion = N_p = 20

RPM of gear= N_g = 15

V.R.= N_p/N_g = 20/15 = 1.333

Module = m =5.5

Step No.1 - Pitch diameter of gear & pinion

$D_g = m \times t_g$

$= 5.5 \times 43$

$= 236.5$ mm

$D_p = m \times t_p$

$=5.5 \times 10$

$= 55$ mm

Step No.2 - Pitch angle ϒ of gear and pinion

1. $\tan \Theta_p = [1/ VR]$ VR= DG/DP = 236.5/55 = 4.3

Θ_p = Pitch angle of pinion $=\tan^{-1} (1/4.3)= 13.10^0$

2. $\tan \Theta_g = [1/ VR]$ VR= DP/DG = 55/236.5 = 0.2325

Θ_g = Pitch angle of gear$=\tan^{-1} (1/0.2325)= 76.9^0$

Step No.3 - Pitch line velocity

$V_p = \frac{\pi .Dp .Np}{60\times1000} = \frac{\pi\times55\times 20}{60\times1000}$ 0.05759 m/s

Step No.4 – The power of motor is = 15 kW and RPM is 1440.This power is transmitted by whole gear train at various RPM.So we are taking the ratio of power input to the power output at pinion. The pinion RPM is 20

The power required to drive the pinion is given by = $\frac{15\times20}{1440}$= 0.2083 kW

P_d = design power

$P_d = P_p\times K_l$ Where K_l = load factor, for steady load and continuous duty.

Pd = 0.2083×1.25=0.26041 kW

Tooth load = $F_t = P_d / V_p$ = 260.41/0.05759

= 4521.90 N

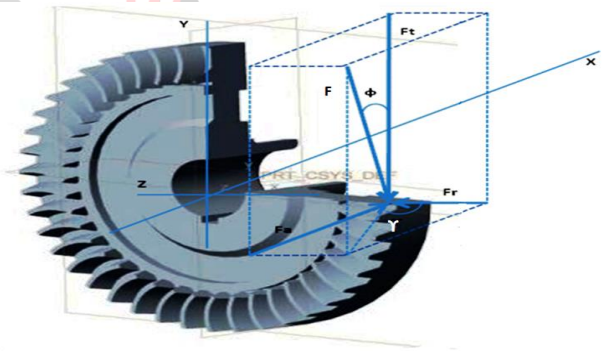

Fig. No. 4 Bevel gear tooth forces

Axial load = $F_a = \frac{Ft}{Cos\Psi}\times (\tan \phi\times \sin\Upsilon_p + \sin \Psi \times \cos\Upsilon_p)$

Where Ψ is spiral angle = 35^0

Where ϕ = pressure angle = 20^0

$= \frac{4521.9}{Cos\ 35} \times (\tan 20\times \sin 76.9 + \sin 35 \times \cos 76.9)$

= 2674.53 N

Radial load $=F_r = \frac{Ft}{Cos\Psi}\times (\tan \phi\times \cos\Upsilon_p - \sin \Psi \times \sin \Upsilon_p)$

$= \frac{4521.9}{Cos\ 35}(\tan 20\times \cos 76.9 - \sin 35 \times \sin 76.9)$

= - 2628.48 N

Step No.5 –Beam strength, $F_{B,\ N}$

$F_B = S_0 \times C_V \times b\times Y \times m\times (1-b/L)$

Where,

F_B = Beam Strength (N)

S_0 = Basic stress of material = $S_0 = S_{yt}$ /1.5 (N/mm^2)

C_V = Velocity factor

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b = Bevel width of gear

Y = Lewis form factor based on virtual no. of teeth

m = Module

L = Cone distance

(1-b/L) = Bevel factor

t_f = Formative teeth

$t_{f(p)} = t_p / \cos\Upsilon_p$

$= 10/ \cos 13.1$

$=10.26$

$t_{f(g)} = t_g / \cos\Upsilon_g$

$= 43/\cos 76.9$

$= 189.71$

Y = Lewis form factor for involutes gear, for 20^0 full depth type of profile

$Y_p = 0.485 – (2.87/ t_{f(p)})$

$= 0.485 – (2.87/10.26)$

$= 0.2052$

$Y_g = 0.485 – (2.87/ t_{f(g)})$

$= 0.485 – (2.87/189.71)$

$= 0.4698$

Cone distance = $L = \sqrt{(\frac{Dp}{2})^2 + (\frac{Dg}{2})^2}$

$= \sqrt{(\frac{55}{2})^2 + (\frac{236.5}{2})^2}$

$= 121.40$ mm

The material of gear is gray cast iron, having basic stress = S_0=56 MPa

The material of pinion is forged carbon steel having basic stress = S_0 = 245 MPa

$(S_0Y)_g = 56 \times 0.4698$

$= 26.30$ MPa

$(S_0Y)_p = 245 \times 0.2052$

$= 50.27$ MPa

$(S_0Y)_g < (S_0Y)_p$ Hence pinion is strong and gear is weak.

C_V = Velocity factor =3/(3+V_P)---commercial cut and velocity 2.5 - 5m/s…..DDB page no. 166

$C_V = 3/(3+V_P)$

$= 3/ (3+0.05759)$

$= 0.9811$

b = 46 mm

The beam strength of gear is given by,

$=56 \times 0.9811 \times 46 \times 0.4698 \times 5.5 \times (1-(46/121.4))$

$= 4055.9$ N

$F_B = S_0 \times C_V \times b \times Y_g \times m \times (1- (b /L))$

$F_B < Ft$, i.e. $4055.9 < 4521.9$ N.

Hence, gear is fail.

The beam strength of pinion is given by

$F_{BP} = S_0 \times C_V \times b \times Y_p \times m \times (1- b /L)$

$= 245 \times 0.9811 \times 46 \times 0.2052 \times 5.5 \times (1-(46/121.4))$

$F_{BP} = 7750.5$ N

The following table show that the material and their basic stress for gear

Table No.1 - Material and their basic stress

Sr. No.	Material	S_0, MPa
1	Cast iron / FG 200	70
2	Cast iron / FG 350	105
3	Cast steel ,0.20% carbon	140

In order to increase the beam strength, the suitable material is select, which is having basic stress more than that of existing material of gear.

[1] The material is selected cast iron ,FG 200

S_0 = 70MPa

For that material, calculate the beam strength

$F_B = S_0 \times C_V \times b \times Y \times m \times (1- b/ L)$

$= 70 \times 0.9811 \times 46 \times 0.4698 \times 5.5 \times (1-(46/121.4))$

$= 5069.8$ N.

Here $F_B > F_t$ i.e. the material selected is suitable for the given application.

[2] The second choice of material is Cast iron ,FG 350

S_0 = 105 MPa

For that material, calculate the beam strength

$F_B = S_0 \times C_V \times b \times Y \times m \times (1- b/ L)$

$= 105 \times 0.9811 \times 46 \times 0.4698 \times 5.5 \times (1-(46/121.4))$

$= 7604.8$ N.

Here $F_B > F_t$ i.e. the material selected is suitable for the given application

[3] The third choice of material is Cast steel,0.20% carbon ,

S_0 = 140MPa

For that material, calculate the beam strength

$F_B = S_0 \times C_V \times b \times Y \times m \times (1- b/ L)$

$=140 \times 0.9811 \times 46 \times 0.4698 \times 5.5 \times (1-(46/121.4))$

$= 10139.7$ N.

Here $F_B > F_t$ i.e. the material selected is suitable for the given application.

We have three choices, but the beam strength for Cast steel, 0.20 % carbon, is more than that of pinion. So it may fail the pinion. The following table show that beam strength of varies gear material and tooth load.

Sr. No.	Material	Basic Stress S_0 MPa	Beam Strength of gear F_B in N	F_t in N
1	Cast Iron/ FG 150	56	4055.9	4521.90
2	Cast iron / FG 200	70	5069. 8	4521.90
3	Cast iron/ FG 350	105	7604.8	4521.90
4	Cast iron ,0.20% carbon	140	10139.7	4521.90

Table No. 2 – Beam strength and Tooth load

We have two choices from above material i.e., Cast iron FG 200 and Cast iron FG 350.

1. If we select FG 200, which have basic stress 70 MPa. In that case gear is fail because the bending stress is

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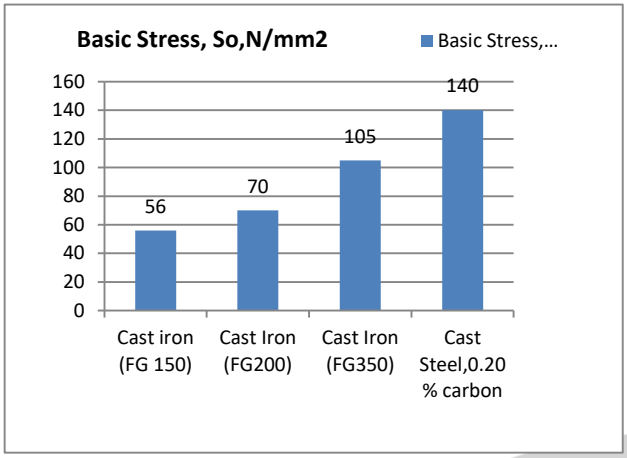
87.72 MPa. So gear the material is not suitable for this purpose.

2. The basic stress of cast iron FG 350 material is more than cast iron FG 200, so material selected is cast iron FG 350

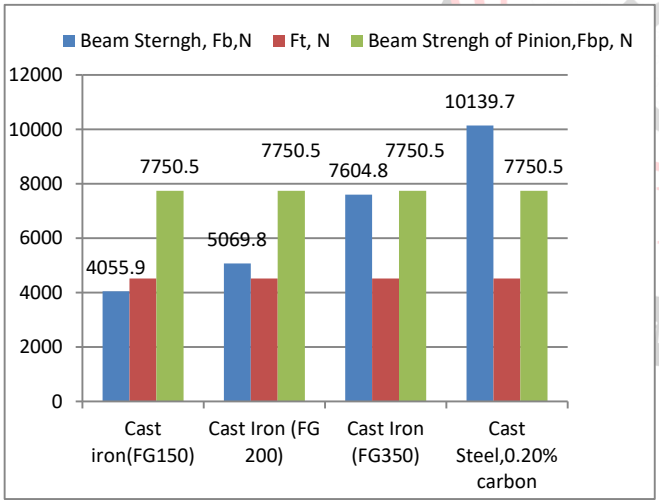
IV. RESULT

4.1 Graph of Basic stress of gear material



From above graph it show that the basic stress of cast iron (FG 150), cast iron (FG 200), cast iron (FG 350) and cast steel, 0.20 % carbon, it indicate that the basic stress is different for different material.

4.2 Graph of Beam strength, Fb , F_t , Fbp



From above it indicate that, cast iron FG 350 is suitable for Bevel gear material because the beam strength is more than tooth load Ft, and the beam strength of pinion is also more.

V. CONCLUSION

In this project work, the failure of Bevel gear is due to the tooth load. The another load i.e. axial load and radial load is less as compare to tooth load. Due to this tooth load, the stress develop in tooth is more than the basic stress of gear, that why the gear fail. Due to gear fail, the machine is in break down stage, so the production is hampering. To avoid breakdown it is very important to chance the material of gear. Here in this project, an analytical calculation of Bevel gear is done, using different cast iron.

From the result of analytical calculation it is stressed that FG 350 material is suitable to avoid failure. Therefore modification in the material is done without changing its design parameter.

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