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Design of a Sintered Spur Gear by Using Pro-E Modelling and Ansys Analysis

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ABSTRACT:

In this paper a PRO-E is developed for the modeling of a sintered spur gear for both standard and profile corrected tooth. This model is then imported to an analysis software ANSYS for carrying out the static analysis. Finally the comparisons for stress is carried out for both the standard sintered spur gear and profile corrected sintered spur gear. Finally the results are tabulated and graphically shown.

INTRODUCTION:

Gears are a means of changing the rate of rotation of a machinery shaft. They can also change the direction of the axis of rotation and can change rotary motion to linear motion.

SINTERED SPUR GEAR:

Gears are commonly machined from forged billets or bar stock. This manufacturing method generates a significant amount of waste material, and machining operations like turning, mobbing, and shaving are time consuming, and thus costly. By using PM the amount of waste material is radically decreased, and the net shape manufacturing method that includes compaction of metal powder and sintering ensures that machining operations, in most cases, are avoided. The manufacturing costs can therefore be significantly lowered.

MANUFACTURING OF SINTERED GEAR:

Sintered gears are generally manufactured as follows: a metal powder is filled in a mold, which is compressed by the use of punch in the vertical direction to form a compact; and the compact obtained in the shape of a gear is sintered., since such a sintered gear can be manufactured in large quantities at low costs, sintered gears of various applications are commercially available as varied products.In this paper we comparing with standard sintered material and steel material. Whereas combination of sintering material is (Fe-C-Cu). A new alloy, Fe-C-Cu, was developed using a powder metallurgy processing route for gear and bearing running under un-lubricated operating conditions. Spur gears were compacted from the pre-alloyed powders and sintered. The gear performance was evaluated using a power absorption type gear test rig. The temperature rise measured during testing depends on the material composition, porosity, and coefficient of friction. The analytical model predicts the temperature rise with a reasonable accuracy.In this paper for standard sintered spur gear chemical combination were taken as follows, according to Design Data Book LINGAIAH Volume - I.

Fe	Cu	C
98.5	3.9	0.3

Composition of Sintered Material :

COMPARISION BETWEEN STEEL AND SINTERED MATERIAL:

Copper based sintered material was slide against steel in paraffinic mineral oil, with the careful measurements with surface temperature, ambient oil temperature, normal load, and friction force. The sintered properties obtained with a specific iron powder grade depend on several factors including density, sintering time, temperature; atmosphere of this type is present in this technical catalogue for most of the available powder grades. Powder metal 400 series stainless steel exhaust components are being increasingly used in US made automobiles.

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These components are shown to have superior leak-tightness and resistance corrosion and wrought stainless steel exhaust components.

PROFILE CORRECTION:

Profile corrections in gears are generally used method to reduce the interference and transmission error of a gear pair. Profile corrections are different types i.e.; short or long linear corrections, short or long corrections in arc form, fully crowned profile and others. The calculation of the meshing of a gear pair under load is very complicated and therefore time consuming. A larger pinion blank is to be machined, the diameter of which can be calculated by formulae. When a standard, uncorrected pinion is cut by the rack, the pitch line is tangent to the pitch circle of the pinion at the normal pitch point P. when, however the rack is withdrawn, this situation alters. Instead, it is away by an amount equal to xm millimetres.

This amount of xm is the profile correction of the gear and the coefficient x is known as the "correction factor". Nate that x is dimensionless, but xm is expressed in mm. positively corrected gear is known as S-plus gearing and negatively corrected gear is known as S-minus gearing. To find the correction factor for pinion whose number of teeth lies within the minimum number specified to avoid undercutting. The rack is withdrawn just enough so that the addendum line of the rack passes through the interference point T of the pinion. This point T is the position from which the involute profile of the pinion tooth starts.

In this paper, So gearing is considered, the correction factor is 0.5 then the
$x1+x2=0$ or $x2=-x1$
$x1=0.5$ and $x2=-0.5$.
In this project using So gearing, in this gearing centre distance, pitch circle and base circle dimensions are remain same. The addendum circle and root circle dimensions will change.

DESIGN OF STANDARD SPUR GEAR:

Formulae and Dimensions for Standard Spur Gear [2]
Input Parameters for Gear Ratio 'i' = 1:1.5
Module (m)= 10
Pressure angle (α)= 200
No. Of teeth on pinion (z1)= 14
No. Of teeth on gear (z2) = 21
Speed (N1)= 1000 (assume)
Speed ratio (i) = i = N1 /N2 = 1000 /N2
Speed of the Gear= 666.66 rpm
Center distance =(140+210)/2=175 mm
Circular pitch 'p'= π*10 = 31.415 mm
Face width 'b' = 3*π*10 = 94.274 mm

	Pinion	Gear
No. of teeth	14	21
Pitch circle diameter	140	210
Tip circle diameter	160	230
Root circle diameter	116.86	186.86
Base circle diameter	131.55	197.33
Tooth thickness on pitch circle	15.70	15.70

Table 5.1.1: Dimensions for Standard gear and pinion

DESIGN OF CORRECTED SPUR GEAR:

Formulae and Dimensions of So Gearing:

For, $x1 + x2 \neq 0$ or $x1 = -x2$
Where x1 is correction factor for pinion, x2 is correction factor for gear.
Pitch circle diameter for pinion, $d1 = m*z1$
Pitch circle diameter for Gear, $d2 = m*z2$
Base circle diameter for Pinion, $db1 = d1*\cos\alpha$
Base circle diameter for Gear, $db2 = d2*\cos\alpha$
Tip circle diameter for pinion,
$da1 = d1 + 2m + 2x1m$
Tip circle diameter for gear,
$da2 = d2 + 2m - 2x1m$
Root circle diameter for pinion,
$df1=d1-2(1.25 - x1)m$
Root circle diameter for gear,
$df2=d2-2(1.25 + x1)m$
Tooth thickness on pitch circle for pinion,
$S1 = \pi m/2 + 2x1m\tan\alpha$
Tooth thickness on pitch circle for gear,
$S1 = \pi m/2 - 2x1m\tan\alpha$
Centre distance, $a = (d1 + d2)/2$
Total Depth, $h = 2.25*m$

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Circular pitch,p = πm
Face width,b = 3*π*m
Input Parameters for Gear Ratio 'i' = 1:1.5
When x1 = 0.5, x2 = - 0.5 and x1+x2=0
Module (m)= 10
Pressure angle (α)= 200
No. Of teeth on pinion (z1)= 14
No. Of teeth on gear (z2) = 21
Speed (N1)= 1000 (assume)
Speed ratio i = N1 /N2 = 1000 /N2
Speed of the Gear=666.66 rpm

	Pinion	Gear
No. of teeth	14	21
Pitch circle diameter	140	210
Tip circle diameter	170	220
Root circle diameter	125	175
Base circle diameter	131.55	197.33
Tooth thickness on pitch circle	19.34	12.06

Face width 'b' = 3*π*10 = 94.247 mm

Dimensions for So gearing when correction factor is 0.5. (All dimensions are in mm)
STRESS & LOAD CALCULATIONS FOR SINTERED (FC-0200).
Modulus of Elasticity (E)= 1.3x105 N/mm2
Poisson's ratio μ=0.30
Yield stress= σy= 160 N/mm2
BHN=<350
Tensile strength = σu = 255 N/mm2
Design bending stress σb = -1
Kσ = 1.5
σ-1 = 0.35σu+120 = 365 N/mm2
n = 2.5
σb = 136.266 N/mm2
Induced bending stress σb = [Mt]
Form factor (y) = 0.330
Torque [Mt] = Mt*k0*kkd
Power =
Mt = 95.492 Nm
Shock factor (K0) = 1.5
K = 1.06
Kd = 1.4
Torque [Mt] = 212.567 N.m
σb = 9.763 N/mm2
Design contact stress σc = CR*HRC*Kcl N/mm2
CR = 26.5
HRC = 30
Kcl = 1
σc = 795 N/mm2
Induced contact stress σc = 0.74
σc = 224.545 N/mm2
Tangential Load (Ft) = σb*b*pc*y
Induced (σb) = 9.763 N/mm2
Circular pitch (pc) = πm
Ft = 9539.258 N
Normal Load (Fn) = = 10151.466 N
Radial Load (Fr) = Fn sinα = 3477.002 N

STRESS & LOAD CALCULATIONS FOR ALLOY STEEL (40 CR 1)

Modulus of Elasticity (E)= 2.1x105 N/mm2
Poisson's ratio μ=0.30
Yield stress= σy=540 N/mm2
BHN= <350
Tensile strength = σu =700 N/mm2
Design bending stress σb = -1
Kbl = 1
Kσ = 1.5
σ-1 = 0.35σu+120 = 365 N/mm2
n = 2.5
σb = 136.266 N/mm2
Induced bending stress σb = [Mt]
Form factor (y) = 0.330
Torque [Mt] = Mt*k0*kkd
Power =
N = Speed = 1000 rpm
Mt = 95.492 Nm
Shock factor (K0) = 1.5
K = 1.06
Kd = 1.4
Torque [Mt] = 212.567 N.m
σb = 9.763 N/mm2
Design contact stress σc = CR*HRC*Kcl N/mm2
CR = 26.5
HRC = 40
Kcl = 1
σc = 1060 N/mm2
Induced contact stress σc = 0.74 $\frac{i+1}{a}\sqrt{\frac{i\pm1}{ib}E[Mt]}$

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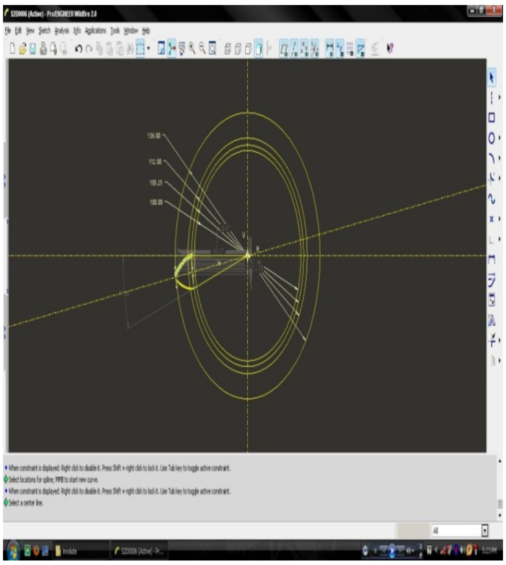
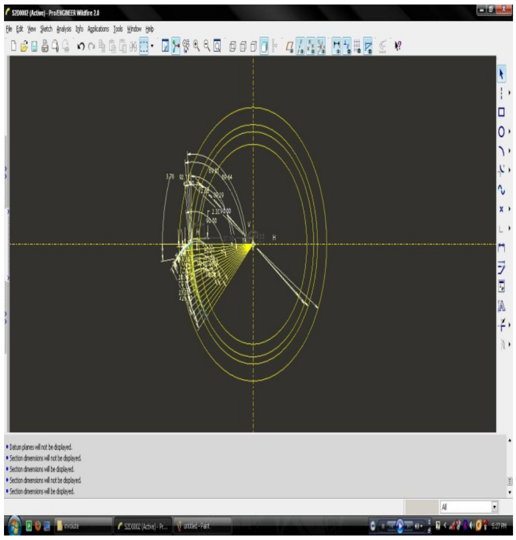
σc = 285.391 N/mm2
Tangential Load (Ft) = σb*b*pc*y
Induced (σb) = 9.763 N/mm2
Circular pitch (pc) = πm
Ft = 9539.258 N
Normal Load (Fn) = = 10151.466 N
Radial Load (Fr) = Fn sinα = 3477.002 N
With the help of above calculated readings we design a pair of meshing of pinion and gear

	Sintered Gear	Steel Gear
Modulus of Elasticity (E), N/mm^2	$1.3x10^5$	$2.1x10^5$
Poisson's ratio μ	0.3	0.3
Yield stress(σ_y), N/mm^2	160	540
Tensile strength (σ_u), N/mm^2	255	700
Design bending stress (σ_b), N/mm^2	136.266	136.266
Induced bending stress (σ_b), N/mm^2	9.763	9.763
Design contact stress (σ_c), N/mm^2	795	1060
Induced contact stress (σ_c), N/mm^2	224.545	285.391

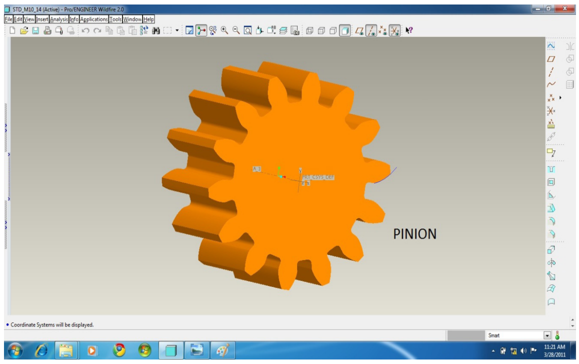
Table:Design & Induced Stresses for Sintered & Steel Gears:

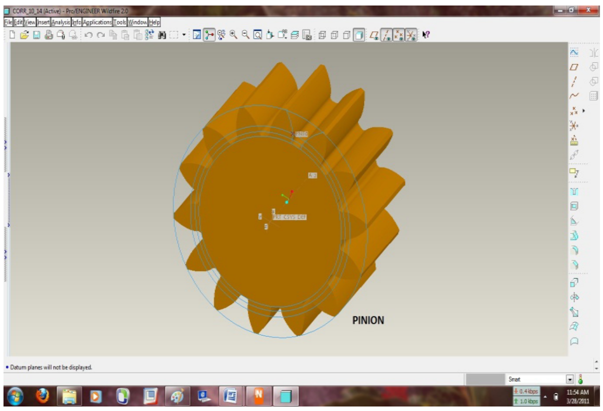
INVOLUTE CURVE PROFILE BY TANGENT METHOD THROUGH PRO-E/ENGINEER APPLICATION:





GEAR MODELS
Module=10 Numberofteeth=14 Pressure angle=200





Standard Pinion Model in Pro/E.
Corrected Pinion Model in Pro/E.
Gear Ratio = 1:1.5 Module = 10 Pinion = 14 Gear = 21

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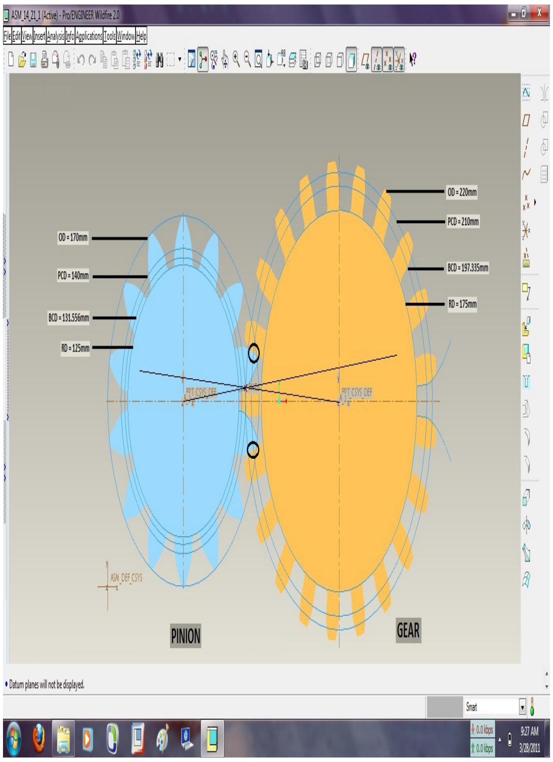
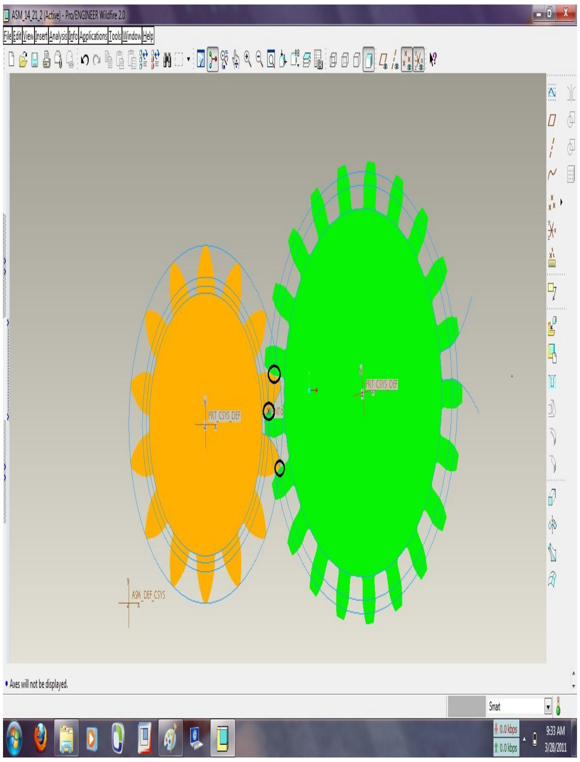
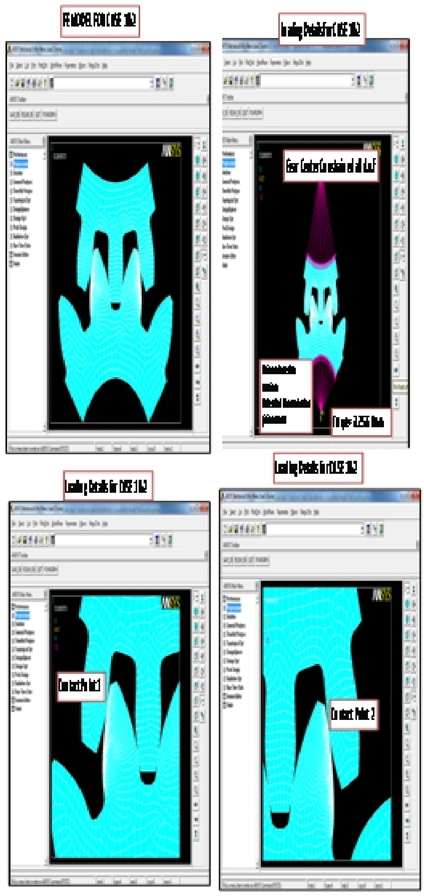


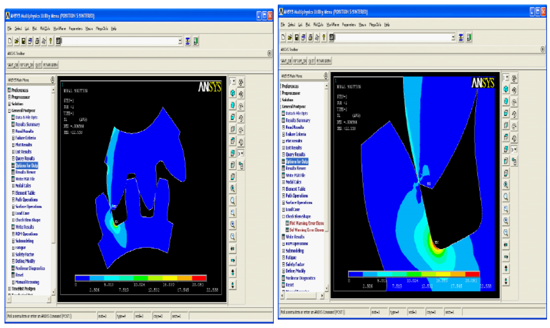


Gear Mesh Model and Point of Contact for Corrected Pair

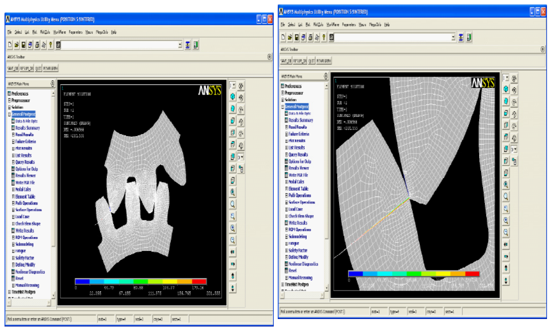
MESHING & ANALYSIS OF A SPUR GEAR ANALYSIS MODELS FOR STANDARD GEAR PAIR FE MODEL FOR STANDARD GEAR WITH POC



Bending Stress–22.55N/mm² Sintered- case5 Bending Stress–22.55N/mm² Sintered- case5



Contact Pressure – 201.55 N/mm² Sintered- case5 Contact Pressure – 201.55 N/mm² Sintered- case5



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BENDING & CONTACT STRESSES AT CASE-5 FOR SINTERED MATERIALS

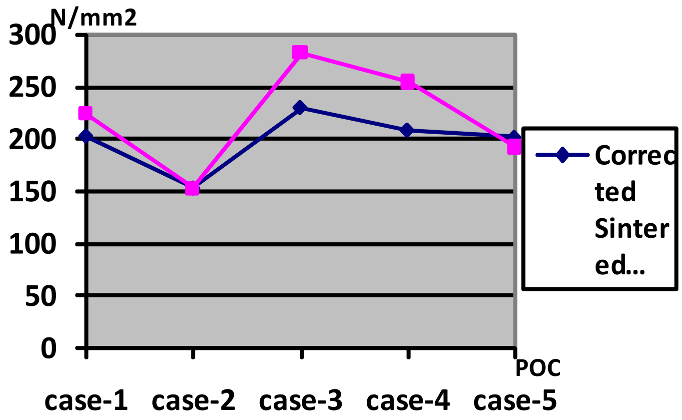
RESULTS & CONCLUSION

Theoretical Values for Sintered Material

Contact Stress: 224.545 N/mm2 Bending Stress :9.763 N/mm2

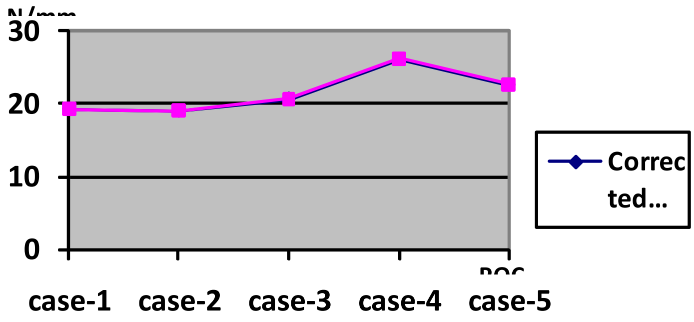
POINT OF CONTACT	SINTERED MATERIAL	CONTACT STRESS N/mm^2	BENDING STRESS N/mm^2
Case 1	Standard	212.00	12.96
	Corrected	**202.92**	**19.25**
Case 2	Standard	207.30	14.83
	Corrected	**153.72**	**18.97**
Case 3	Standard	198.34	18.60
	Corrected	**229.8**	**20.64**
Case 4	Standard	215.00	23.45
	Corrected	**208.4**	**26.12**
Case 5	Standard	212.56	23.43
	Corrected	**201.55**	**22.55**

Table 8.1.2: Bending & Contact Stresses for Sintered Material



Vertical Axis = Contact Stress in N/Mm2
Horizontal Axis = Point of Contact Case Wise

GRAPH.NO- 8.5 Graph between Corrected steel & Corrected Sintered for Contact Stresses



Here Vertical Axis = Bending Stress in N/Mm2
Horizontal Axis = Point of Contact Case Wise

Graph between Corrected steel & Corrected Sintered for Bending Stresses

Conclusion:

In this project, the stress analysis of the standard and profile corrected Steel & Sintered gear pair was done. The geometry of the gear was done by modelled by modelling software Pro-E. The meshing was done by Hypermesh, and analysis was done by ANSYS software. This project concludes that influence of profile correction on stresses on spur gears for different materials, the stresses at the root section of the tooth are lesser in profile corrected gears.

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The maximum bending occurs at the case 3(pitch point contact), also there is no much difference in the bending for steel and sintered materials, only the contact stresses are varying. The graphs are plotted for Standard & Corrected for Contact & Bending Stresses and plotted for corrected steel & corrected sintered.

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