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Design and Analysis of Polymer PEK Spur Gear under Static Loading Condition using FEA

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Abstract— this work presents the design and Analysis of polymer PEK spur gear and Comparison of results of PEK with Metallic Cast Iron under limited loading conditions. Application of Plastic gear reduces the weight and noise vibration. Analytical Method is used to calculate Tooth load with help of Lewis equation & dynamic tooth load with help of Buckingham equation. Gear profile modeling is done by using SOLIDWORKS 2015. Finite Element Method is used for Static analysis of the gear to find the Von-misses stress on the tooth of the gear using ANSYS and these values are compared with Analytical values.

Index Terms—SOLIDWORKS, ANSYS, Lewis and Buckingham Equation, PEK.

I. INTRODUCTION

Due to High strength to weight ratio and Low noise vibration, High Corrosion resistant and Low maintenance, Plastic gears finding their application in every industries. Polymer Ether Ketone is a family of plastic material available. PEK material will be considered as most superior polymer material even over existing PEEK material. It could well lead to more than 70% weight reduction, more than 3 db of noise reduction and more than 80% reduction in moment of inertia when used as gear material over standard metal materials commonly used in gear industry. PEK has more resistance to high pressure water and steam, higher melting point temperature and glass transition temperatures as against PEEK. Besides, Strength, wear and thermal properties of PEK makes it perfect replacement of PEEK material. Existing applications of PEEK material, mainly in aerospace, surgical implants, oil and gas filters and gears are all set for usage of PEK as substitute for better results. PEK applications can even be 3-d printed using SLS.

II. MATERIAL SELECTION

In this papers following two materials are considered and analyzed for loading conditions.

1. PEK
2. Cast iron

PEK: Ultra-high Performance Thermoplastic (Poly Ether Ketone) material, virgin, semi crystalline granules suitable for injection molding, easy flow, Beige in color. Application Areas: Suitable for high temperature application, high wear & abrasion resistance, high chemical resistance & for metal to plastics conversion etc.

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Cast Iron: Cast iron is a group of iron-carbon alloys with carbon content greater than 2%. Cast iron has good compressive strength but relatively poor tensile strength. Because of the impurities in cast iron and its crystalline structure, although it is a strong material in compression, it is weak in tension and is very brittle. The alloy constituents affect its color when fractured: white cast iron has carbide impurities which allow cracks to pass straight through.

Properties	PEK	Cast Iron
Density	1300 $\frac{kg}{m^3}$	7200$\frac{kg}{m^3}$
Young's Modulus	4300Mpa	165000MPa
Yield Stress	110Mpa	140MPa

III. GEAR DESIGN

A. INTRODUCTION:

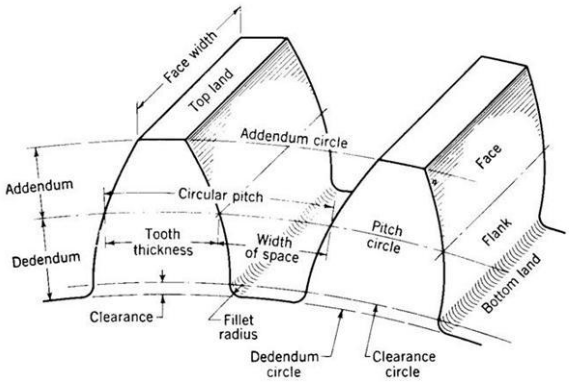
Gears are defined as toothed wheel used for transmitting both motion and power from one shaft to another shaft by successive engagement of teeth.

Gears are mainly classified

A. According to the position of axes of shaft
   1. Parallel
   2. Intersecting
   3. Non-intersecting and non-parallel
B. According to peripheral velocity of gears
   1. Low
   2. Medium
   3. High
C. According to type of gearing
   1. External
   2. Internal
   3. Rack and pinion

B. BASIC PARAMETERS OF SPUR GEAR

GEAR NOMENCLATURE



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- Module: It is the ratio of the pitch circle diameter in millimeter to the number of teeth.
- Addendum: It is the radial distance of a tooth from the pitch circle to the top of the tooth.
- Dedendum: It is the radial distance of a tooth from the pitch circle to the bottom of the tooth.
- Tooth Thickness: The thickness of the tooth along the pitch circle is called the tooth thickness.
- Face width: It is the width of gear tooth measured parallel to its axis.
- Pressure Angle: The angle between the line joining the centers of the two gears and the common tangent to the base circles.

C. SPUR GEAR TOOTH PROFILE DESIGN

Consider a Gear made of
Module (m) = 4,
Number of Teeth (Z) = 18
Pressure Angle (α) = 20^0
Other Tooth parameters are calculated by Involute teeth standards.
Pitch Circle Diameter (D) = module ×Number of Teeth
D = 4×18
D = 72mm
Circular pitch (C.p) = $P_c = \frac{\pi D}{T} = \frac{\pi * 72}{18}$ = 12.568
Diameteral pitch (D.P) = $\frac{T}{D} = \frac{18}{72}$ = 0.25
Addendum = m = 4 mm
Dedendum= 1.25m = 5 mm
Tooth Thickness = 1.5708m = 6.2832 mm
Fillet radius = 0.4m = 1.6mm
Working Depth = 2 m = 8 mm
Whole Depth = 2.25m = 9 mm
Addendum Circle diameter = 2×Addendum+ Pitch Circle Diameter
= 2×4+72
= 80 mm
Dedendum Circle Diameter
= Pitch Circle Diameter-2×Dedendum
= 72-2×5
= 62 mm
Clearance Depth = 0.25×m = 1m

IV. DESIGNING OF SPUR GEAR

A. ASSUMPTION:

- Effect of radial load (P_r) which induces compressive stress is neglected.
- Tangential load (P_t) is uniformly distributed over the entire face width.
- The effect of stress concentration is neglected.
- At any time, only one pair of teeth is in contact i.e. contact ratio is 1.
- The tooth is assumed to be cantilever.
- Selecting 20° full Depth involutes' tooth system.

B. TANGENTIAL TOOTH LOAD CALCULATION:

Considering gear to transmit power of 10 KW rotating with a speed of 500 rpm. The following parameters are calculated.
Considering factor of safety: FOS=4
Mean velocity is

$$v_m = \frac{\pi DN}{60} = \frac{\pi m z_1 N}{60} = \frac{\pi * 0.004 * 18 * 500}{60} = 1.88\, {}^{m}/_{s}$$

Velocity factor is

$$c_v = \frac{3 + v_m}{3} = \frac{3 + 1.88}{3} = 1.627$$

Apply the Lewis equation

$$y_p = \pi\left(0.154 - \frac{0.912}{z_1}\right) = \pi\left(0.154 - \frac{0.912}{18}\right)$$

$$y_p = 0.3246$$

Tangential load is calculated as follows

$$f_s = m * b * y_p * \sigma_b = m * b * y_p * \sigma_y * c_v$$
$$= 84.50 * \sigma_y \quad (N)$$

Bending strength is

$$\sigma_b = \sigma_y * c_v = 27.5 * 1.627 = 44.74\ MP_a$$

Sr. No	Parameters	Yield Strength $\sigma_y(MPa)$	Bending Strength $\sigma_b(MPa)$	Tangential Tooth Load $f_s(N)$
1.	PEK	110	44.74	2323.75
2.	Cast Iron	140	56.95	2957.5

V. MODELLING OF SPUR GEAR

Spur gear is modeled in SOLIDWORKS 2015 using Parametric Design, so that it can be easily editable as per customer requirement means Customization becomes very easy. Parameters required for Designing of spur gear is calculated analytically.

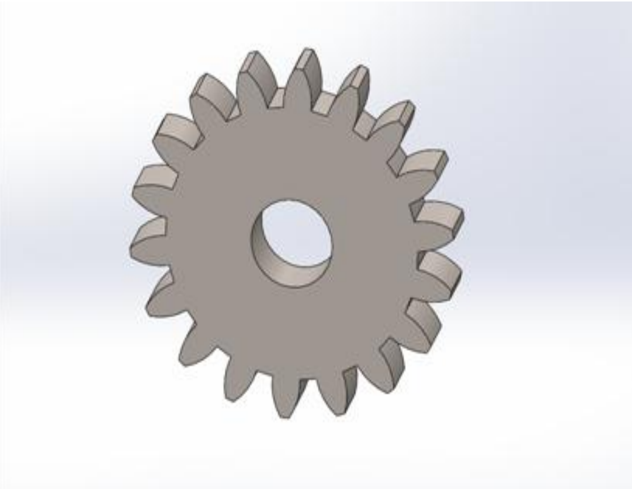

Fig. 5.1 Modeling of Spur Gear in SOLIDWORKS 2015

VI. ANALYSIS

Finite element analysis of Spur gear is analyzed using ANSYS 14.0. By FEM we calculated the Bending stress produced in the spur gear when it is considered as a cantilever beam subjected to transverse tangential load. Simulation results of spur gear are shown below.

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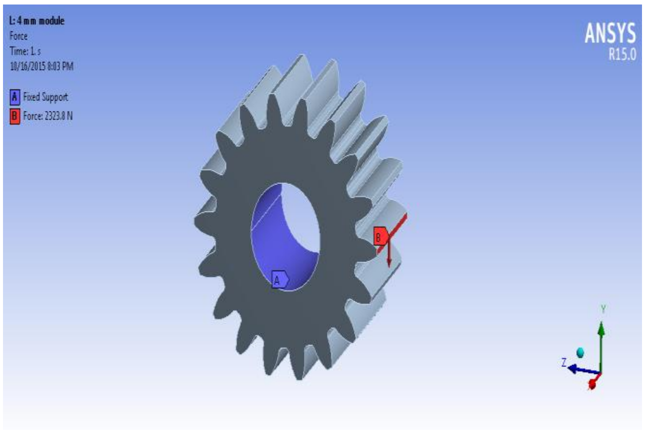

Fig. 6.1 Loading of PEK

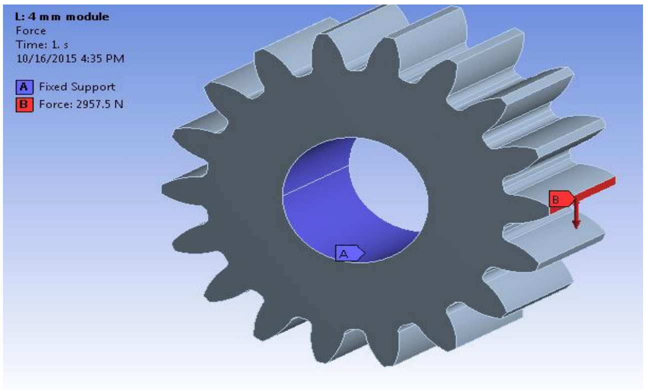

Fig. 6.2 Loading of Cast iron

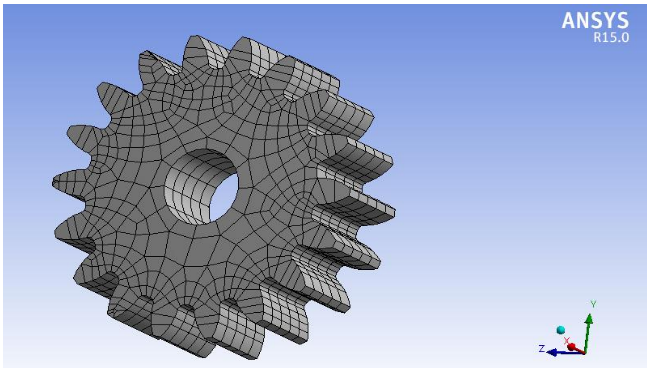

Fig. 6.3 Meshing of PEK Spur Gear

MESHING

Meshing Details:

Type: Tetrahedral

Number of nodes: 14478

Number of elements: 2646

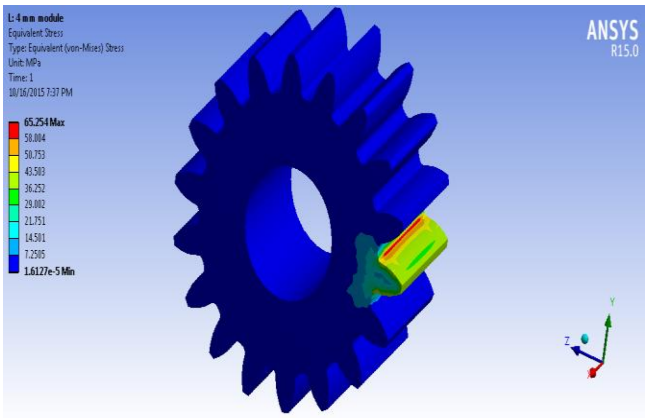

Fig. 6.4 Von Mises Stress distribution in PEK spur Gear

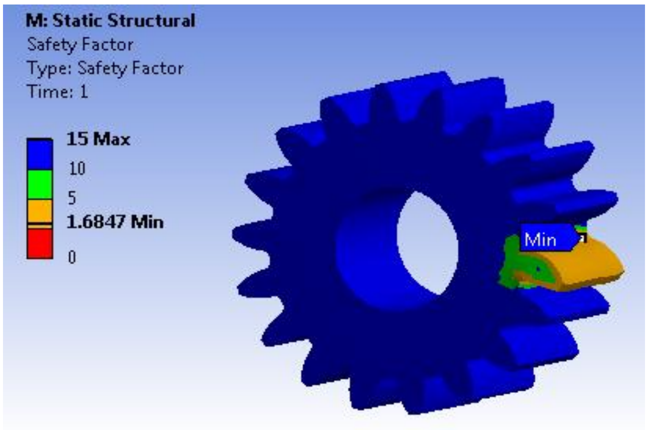

Fig. 6.5 Factor of Safety of PEK Spur Gear

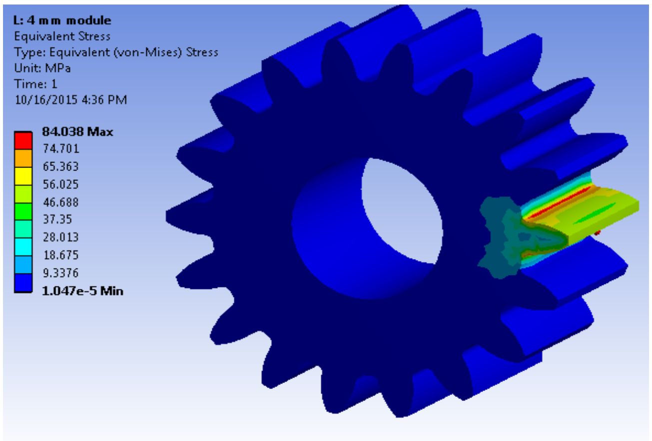

Fig. 6.6 Von Mises Stress distribution in Cast Iron spur Gear

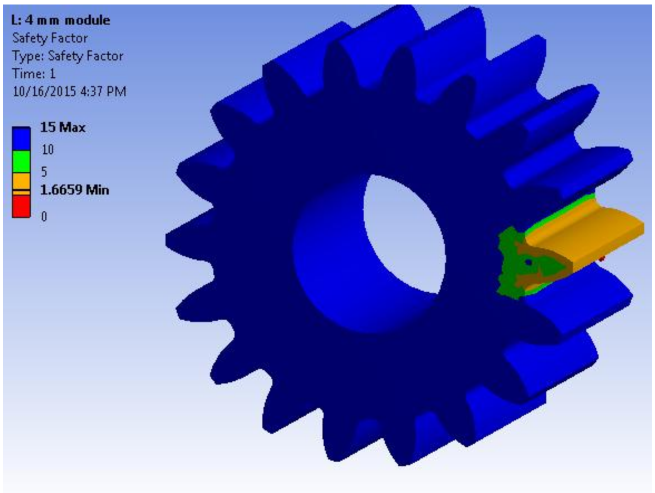

Fig. 6.7 Factor of Safety of Cast Iron Spur Gear

VII. RESULTS

Finite Element Method results shows that bending stress produced in PEK gear is less as compared to Cast iron Gears. These values are calibrated by analytical method to find the bending stress.

Materials	Von misses Stress, MPa	
	Analytical Stress	FEA Stress
PEK	44.77	65.254
Cast Iron	56.45	84.038

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VIII. CONCLUSION

Analytical and Finite Element Methods are applied to check the Bending stress produced in the spur gear. The results show that spur gear made from PEK has more bending strength than Cast Iron Spur gear. Also the Density of PEK is also less than the cast iron. So by replacing cast iron Gear by PEK gear we can achieve high strength, Low Weight and Noise free Motion of Gears.

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