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Thermal Analysis of Helical and Spiral Gear Train

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ABSTRACT

The work presented here is the study of thermal analysis of helical and spiral gears transmission gearbox. Firstly the design of the gearbox is done by empirical formulas. The 2D drawing is then drafted to a 3D model by 3D modeling software. The thermal analysis is done for the temperature generated at the tip of the mating gears. The temperature relation is studied for no load and full load condition.

The problem of heat generation in meshing gears is predominant and hence it is necessary to study & analyze this problem & reduce the amount of heat generation. This will improve the performance of the printing machine which in turn will improve the production rate and quality.

Keywords - *Printing Machine, Gear Box, Design, Thermal Analysis, Helical Gear.*

1. INTRODUCTION

Gears are the most common means of transmitting motion and power in the modern mechanical engineering world. They form vital elements of mechanisms in many machines just as automobiles, metal cutting printing machine and transmitting machinery. Toothed gears are used to change the speed and power ratio as well as direction between an input and output shaft. In helical gears and spiral gears the leading edges of the teeth are not parallel to the axis of rotation, but are set at an angle. Since the gear is curved, this angling causes the tooth shape to be a segment of helix.

The spiral bevel gear is a bevel gear with helical teeth that is having certain helix angle. The main application of this is in a vehicle differential, where the direction of drive from the drive shaft must be turned 90 degrees to drive the wheels. The helical design produces less vibration and noise than conventional straight-cut or spur-cut gear with straight teeth.

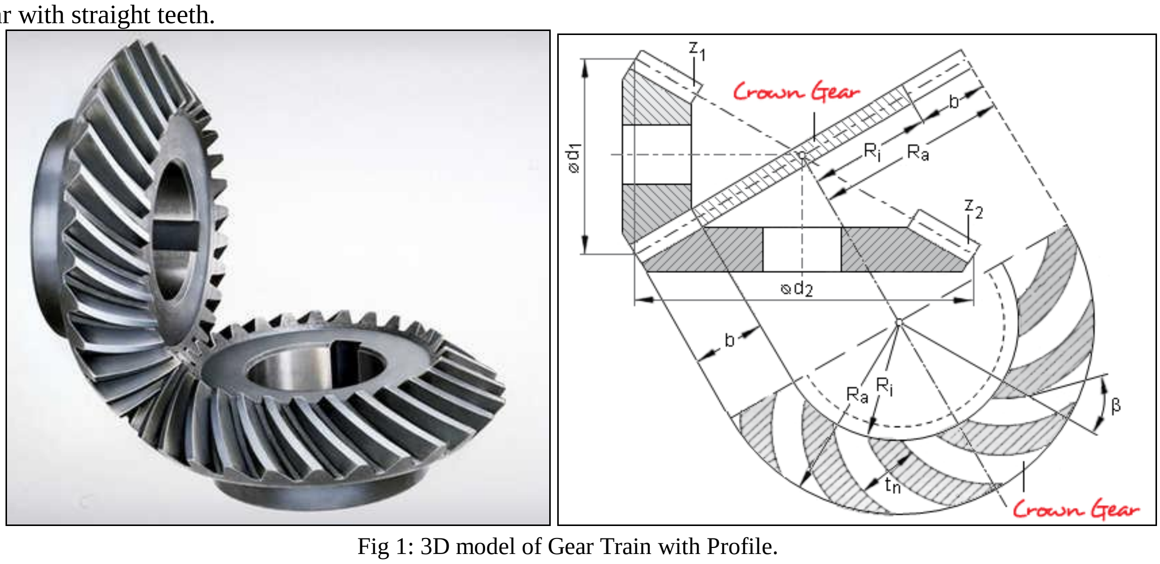

Fig 1: 3D model of Gear Train with Profile.

Spiral bevel gear set should always be replaced in pairs i.e. both the left hand and right hand gears should be replaced together since the gears are manufactured and lapped in pairs.

The right hand spiral bevel gear is one in which the outer half of a tooth is inclined in the clockwise direction from the axial plane through the midpoint of the tooth as viewed by an observer looking at the face of the gear.

Left hand spiral bevel gear is one in which the outer half of a tooth is inclined in the counterclockwise direction from the axial plane through the midpoint of the tooth as viewed by an observer looking at the face of the gear.

2. THEORETICAL BACKGROUND

Designing of gears need special consideration when it comes to calculation part, as point of contact plays a very important role in energy consumption and to avoid over heating of the gears. Some of the points considered for calculation is tabulated in the below table.

2.1 Gear Analytical Details

Name	Symbol		Degree	Pinion (1)	Gear (2)
Shaft angle	**Σ**		90		
Module	**m**		3		
Normal Pressure Angle	**αn**		20		
Mean Spiral Angle	**βm**		35		
Number of Teeth and Spiral Hand	**z**			20	40
Transverse Pressure Angle	**αt**	$\tan^{-1}\left(\frac{\tan\alpha_n}{\cos\beta_m}\right)$		23.96	
Reference Diameter	**d**	**z*m**		60	120
Reference Cone Angle	**δ_1**	$\tan^{-1}\left(\frac{\sin\Sigma}{\frac{z_2}{z_1}+\cos\Sigma}\right)$		26.57	63.43
	δ_2	$\Sigma-\delta_1$			
Cone Distance	**R**	$\frac{d_2}{2\sin\delta_2}$		67.08	
Facewidth	**b**	it should be less than 0.3R or 10m		20	20
Addendum	**h_{a1}**	$1.700m-h_{a2}$		3.43	1.67
	h_{a2}	$0.460m+\frac{0.390m}{\left(\frac{z_2\cos\delta_1}{z_1\cos\delta_2}\right)}$			
Dedendum	**h_f**	$1.888m-h_a$		2.24	3.99
Dedendum Angle	**θ_f**	$\tan^{-1}(h_f/R)$		1.91	3.41
Addendum Angle	**θa1**	**θ_{f2}**		3.41	1.91
	θa2	**θ_{f1}**			
Tip angle	**δ_a**	$\delta+\theta_a$		29.97	65.34
Root angle	**δ_f**	$\delta-\theta_f$		24.66	60.03
Tip diameter	**d_a**	$d+2h_a\cos\delta$		66.13	121.49
Pitch Apex To Crown	**X**	$R\cos\delta-h_a\sin\delta$		58.48	28.50
Axial Facewidth	**X_b**	$\frac{b\cos\delta_a}{\cos\theta_a}$		17.36	8.35
Inner Tip Diameter	**d_i**	$d_a-\frac{2b\sin\delta_a}{\cos\theta_a}$		46.11	85.12

Table 1: Important Gear Parameter and Calculated Values.

3. GEOMETRY AND FE MODELLING

3.1 Geometry Modeling

The design of the gearbox is done by using the empirical formulas, from which the basic dimensions and geometry of the gearbox are achieved. Working parameters are as follows:

Power: 16 kW
Input rpm: 583
Output rpm: 15

The model is generated in Catia V5 and model is exported in .stp format with ISO standard. The model is generated by extrude and revolve command of the software. In part modeling, the dimensioning system is designed for ease in modeling, after that the each part is made separately and are assembled later to get the full gearbox model.

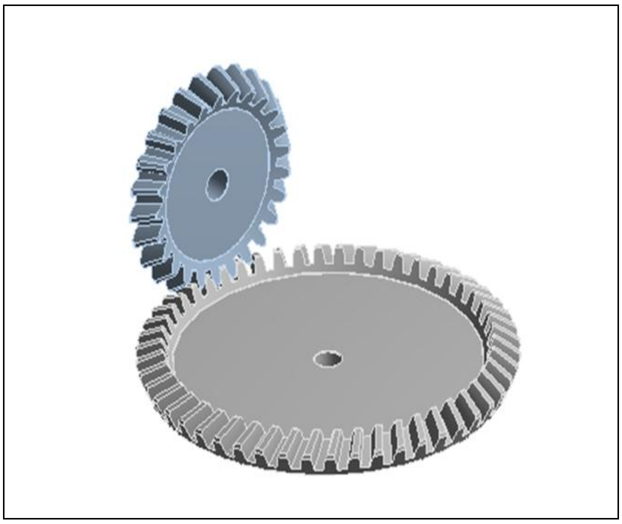

Fig 2: 3D model of Gear Train.

3.2 Finite Element Analysis (FEA)

It is widely accepted method of accessing product performance without the need for physical building and testing. It also shortens prototype development cycle times & facilitates quicker product launch. FEA consists of a computer model of a material or design that is loaded and analyzed for specific results. It is used in new product design, and existing product refinement. Meshing is very important task in any FE analysis especially when two part mate at a particular point which demand for contact analysis example gear and pinion, iron ball rolling thin aluminum plate, etc. , bad meshing (coarse mesh) at the contact point will rise to erroneous results or un-converged solution.

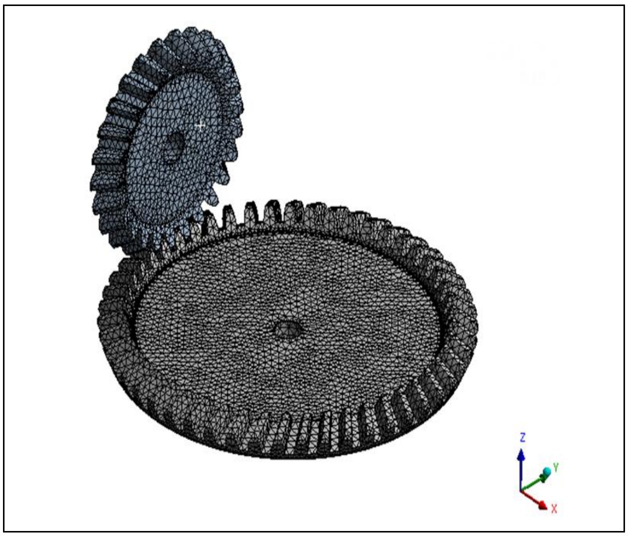

Fig 3: Meshing Model of Gear Train.

Steps required for development of finite element model are as under:

- Assigning material and its properties to various parts.
- Discretize and choose element types.
- Choose a displacement function.
- Derive the element stiffness matrix and equations.
- Generate global or total equations from the element equations, impose loads and boundary conditions.
- Solving for elemental strains and stresses and interpretation of the model.

4. RESULTS AND DISCUSSIONS

Main aim is to check the structural behavior of the gear in the working condition, in order to succeed this initially model is analyzed for the structural working i.e. angular velocity with room temperature. Contact pairs are created at the gear and pinion interface with friction of 0.15 and the heat generated is calculated along with the stress and displacements.

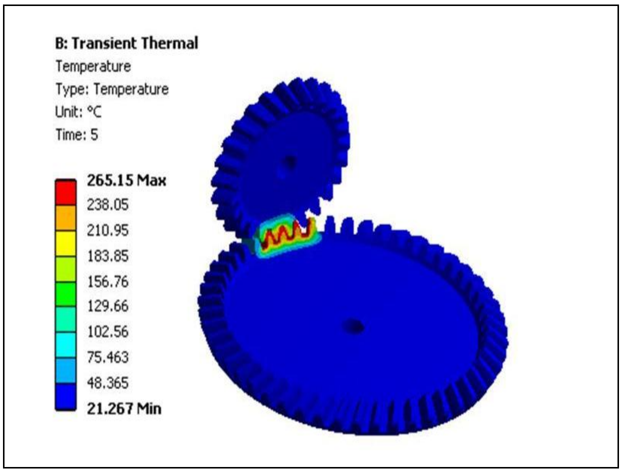

Fig 4: Thermal Analysis of Initial Loading Conditions.

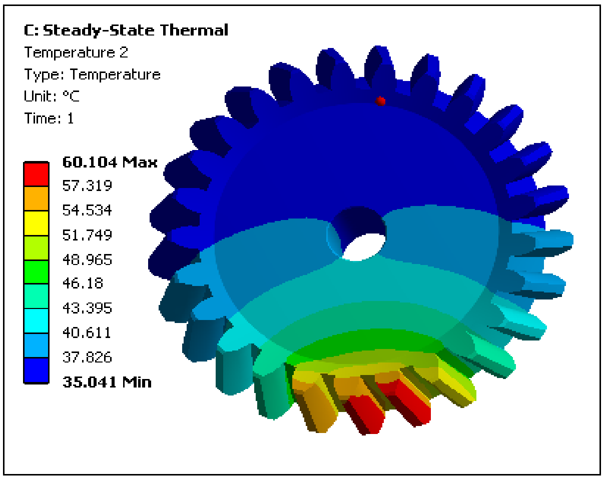

Fig 5: Temperature Distribution in Pinion.

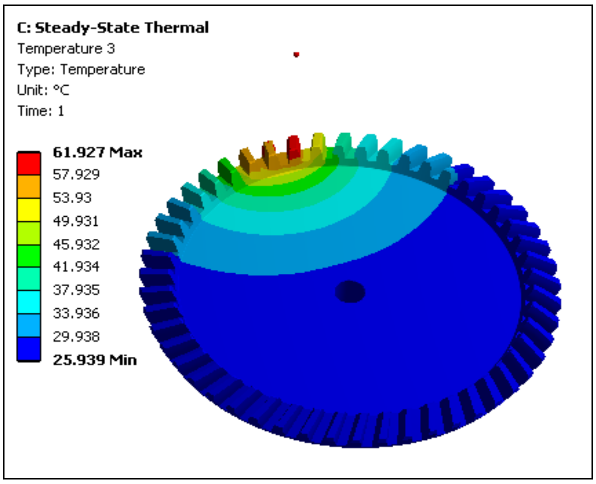

Fig 6: Temperature Distribution Plot for Gear.

From the above plot it is noticed that the induced temperature at the gear tooth is 265.150C which is higher than the limited temperature value for the gears. From this analysis, it is clear that the cooling effect is to taken in notice in order to capture the exact temperature values.

5. CONCLUSION

In the study of designing the gear box by analytical method with input power of 16KW, input speed 583 rpm, it can be concluded that.

For 5 and 8 mm module, the induced stresses are well within the safe limit for the given material type which intern shows the design of the gearbox is safe, but, the heat generated due to friction between the gearboxes is found to be 265.15^{0}C which is exceeding the permissible limit of the standards. Therefore, further analysis need to be carried out by considering the oil cooling effect by convection and find the solution using relevant methods to reduce the temperature.

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