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Heat Generation Analysis and its Reduction in Meshing Gears

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ABSTRACT

It is required to have smooth power transmission between meshing gears of gear train. Generally heat is produced in meshing gears due to friction. This friction further increases the heat, which affects the working condition & life of gears. Hence it is required to remove this heat and maintain the gear temperature of gear train for smooth working & higher efficiency. It is necessary to analyze the rate of heat generation from particular types of gears, then decide the amount and type of lubricating oil be supplied to remove the generating heat to maintain the temperature of gears at safe working level.

The printing machines used for printing was run at very high speed. Hence machine requires high accuracy and good quality for efficient work. These machines includes gear box for transmission of motion to printing rollers. Rotating motion to printing rollers is transmitted through gear box in single step. The problem of heat generation in meshing gears is predominant and hence it is necessary to study & analyze to 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, Heat Generation, Analysis, Reduction.*

1. INTRODUCTION

Printing machine is used for printing at very high speed through roller support. This machine includes the gear box for transmission of motion. In this gear box heat is generated due to meshing gears. The machine is having 10 no. of gears in the gear train which run at speed of 583.33 rpm. Total power transmitted is 16 kW. Gear train includes two types of gears one is spiral bevel gear which made up of En-353 material and another one is helical gear which made up of En-8 Fe620 material. In this gear train splash lubrication system is used with mobalics-Ep2 lubricant to reduce the heat generation in meshing gears. This work is related with the analysis of heat generation in the meshing gears of gear and provides a suitable solution to reduce heat generation.

2. INDENTATIONS AND EQUATIONS

3.1 Fundamental Law of Gearing

The angular velocity ratio between the gears must remain constant throughout the mesh. The angular velocity ratio Mv is equal to the ratio of the pitch radius of the input gear to that of output gear.
P.C.D. of helical gear: 174.047
P.C.D. of spiral bevel gear: 87.02

$$mv = \frac{Wout}{Win} = \pm \frac{rin}{rout} \quad (1)$$

3.2 Temperature Factor Kt

The lubricant temperature is a reasonable measure of gear temperature for steel materials in oil temperature up to above 250 degree F; Kt can be set to 1.
For higher temperature Kt can be estimated from

$$Kt = \frac{460 + Tf}{620} \quad (2)$$

Where Tf is the oil temperature in ^{0}F.
Lubricant oil temperature in gear train 70^{0}C.
Celsius to Fahrenheit Formula

$$f^0 = (C^0) \times \frac{9}{5} + 32$$

Then Tf of the oil temperature in degree F is 158^0F.

3.3 Heat Dissipation

The amount of heat generation in gears. J/s

$$Q = 1000(Kw)(1-\eta) \quad (3)$$

Where η=efficiency

Kw= power transmitted.

3. GEOMETRY AND FE MODELLING

3.1 Geometry

The geometry of the gears has been done using modeling software called Solidedge. Individual models are created and then these models are assembled to form the final assembly as shown in the fig 1 & fig 2.

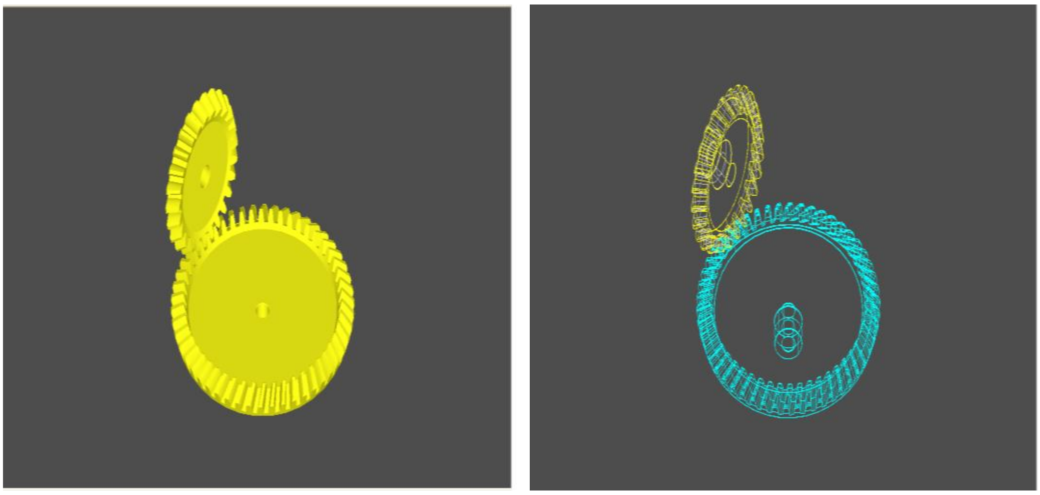

Fig 1: Gear Assembly (Solid Model and Wireframe Model).

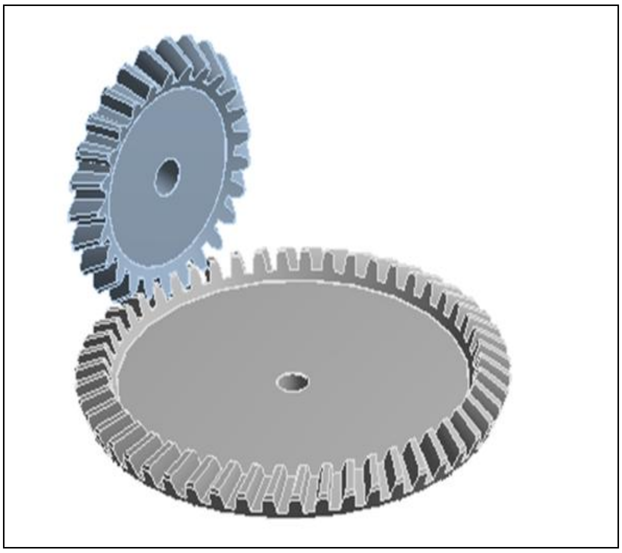

Fig 2: 3D Model of Gear Assembly

3.2 FE Model

Second order tetrahedral elements (10 noded tetrahedral) is used for the analysis using Ansys workbench module with good quality. The complete assembly consist of 120235 no of nodes and 55231 no of elements and FE model is shown in the below plot.

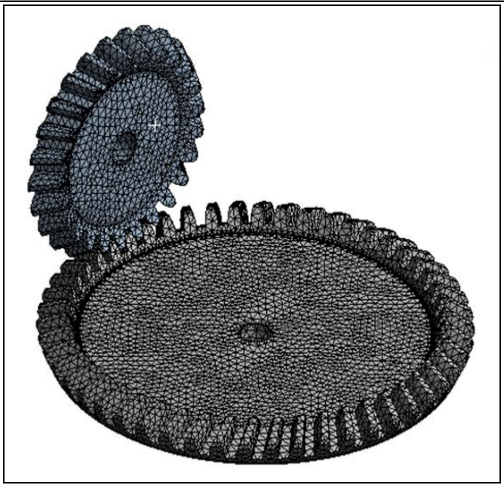

Fig 3: Mesh Model of Gear Train.

3.3 Boundary Conditions

The heat flux of 320 J/sec is applied at gear teeth interface as shown below

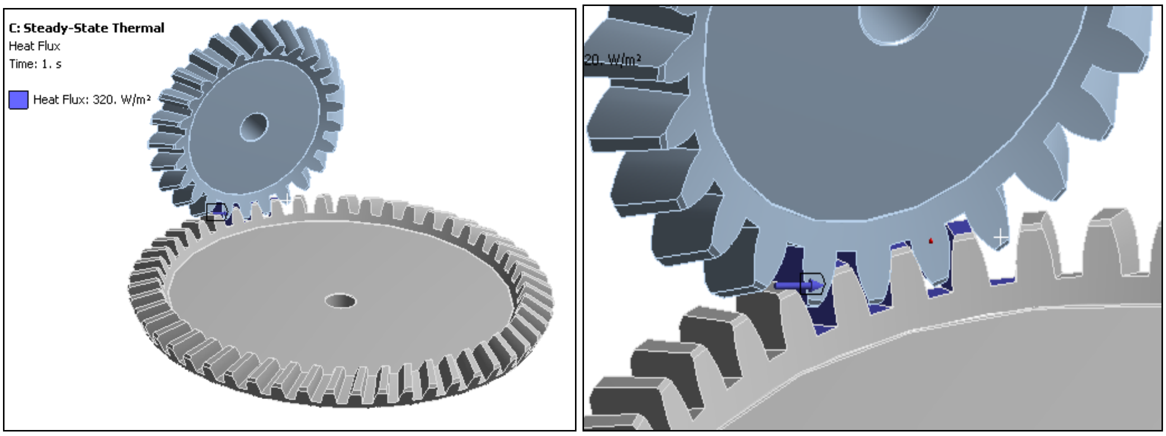

Fig 4: Plot Showing Heat Flux at the Contact Region.

The heat generated values are calculated from the gear and lubricant properties using empirical formulae mentioned in the above section.

The convective heat transfer coefficient of 50 W/m^2K with temperature of 25^0C is defined for the full model as shown below. The HTC values are defined to simulate the cooling effect.

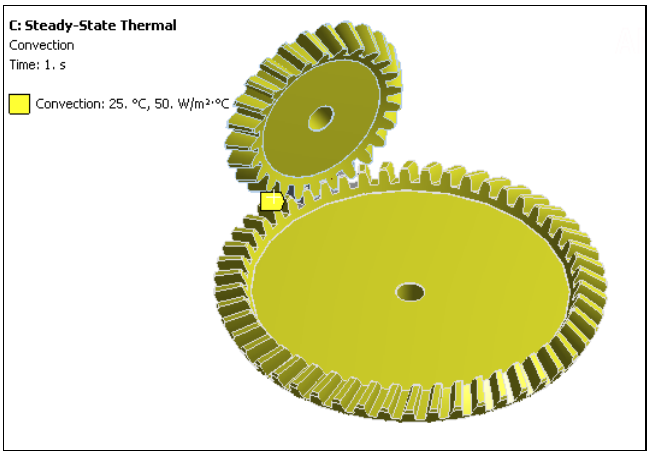

Fig 5: Plot Showing Free Convection Applied on the Gear Assembly.

HTC values are calculated from the lubricant properties using empirical formula as mentioned in the above section.

4. RESULTS AND DISCUSSIONS

The steady state thermal analysis is carried out for two different parameters such as varying input torque and varying speed as shown below. Heat generation is calculated for each speed and torque parameter and is applied at the gear teeth interfaces. The Mobilux-Ep2 and Mobilux-Ep23 is used as Lubricants in this analysis. The heat transfer coefficient value of 50 W/m^2K and 100 W/m^2K with bulk temperature of 25^0C is used.

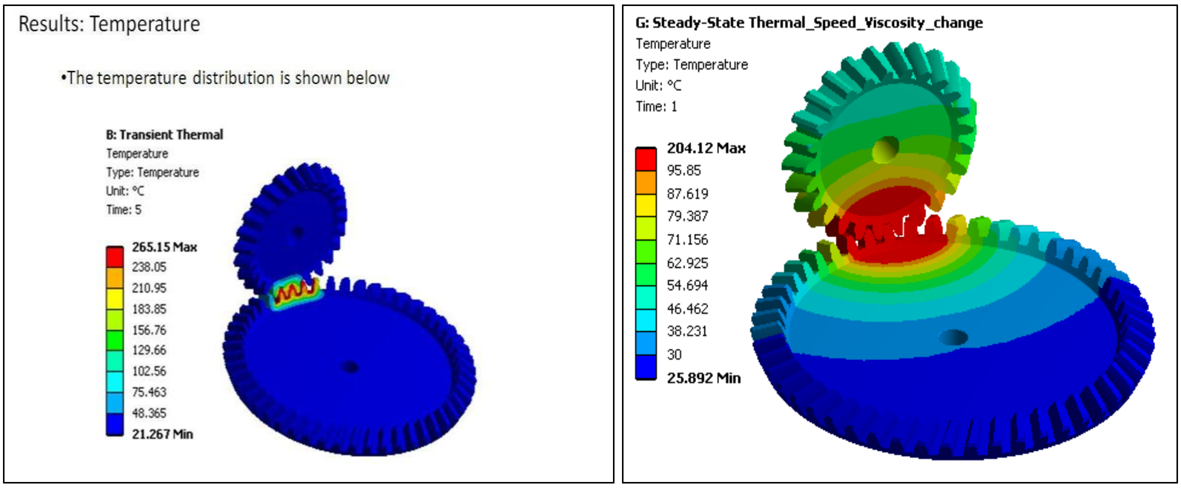

Fig 6: Thermal Analysis of Gear and Pinion.

The variation of temperature with respect to torque is shown in below graph. Form the below graph it is clear that the temperature in gear assembly increases with increase in speed of the gear assembly.

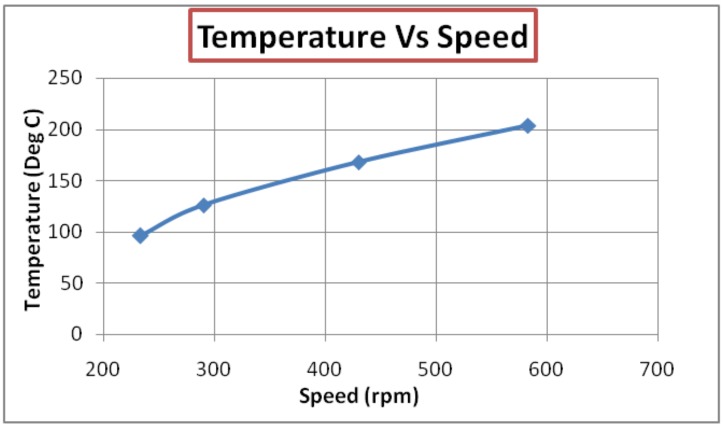

Fig 7: Temperature Versus Speed Plot Obtained from Ansys.

Bulk Temp (Deg C)	HTC (W/m^2K)	Speed (RPM)	Temperature (Deg C)
25	100	583	96
		430	126
		290	168
		233	204

Table 1: Speed versus Temperature.

The variation of temperature with respect to torque for two lubricants is shown in below graph.

From graph it is reveals that, lubricant 2 gives the better performance in terms of temperature reduction compare to lubricant 1. The temperature in gear is less for lubricant 2 because of its high viscosity, due to which cooling effect has been increased, results in less temperature in the gear and pinion.

The variation of temperature with respect to speed for two lubricants is shown in below graph. From graph it is clear that, lubricant 2 gives is having less temperature compare to lubricant 1. The temperature distribution is less in lubricant 2 because of its cooling properties.

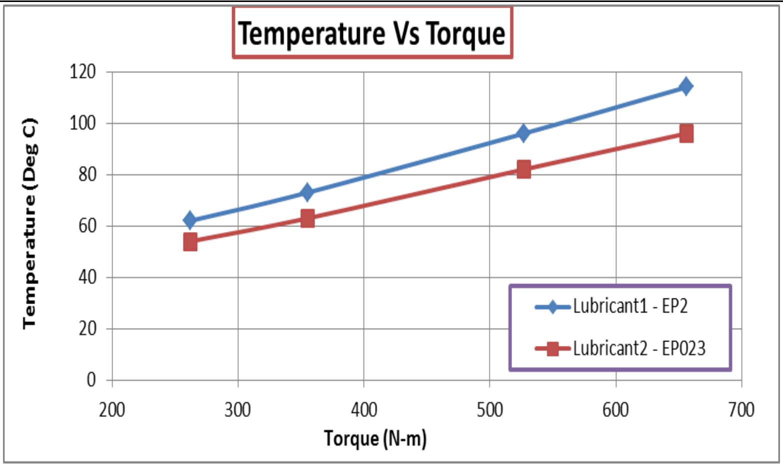

Fig 8: Temperature versus Torque Plot for both the Lubricants.

Torque (N-m)	Temperature (Deg C)	
	Lubricant1 - Mobilux-EP2	Lubricant2 - Mobilux-EP023
262	62	54
355	73	63
527	96	82
656	114	96

Table 2: Temperature Comparison for Lubrications with Respect to Torque.

The variation of temperature with respect to speed for two lubricants is shown in below graph. From graph it is clear that, lubricant 2 gives is having less temperature compare to lubricant 1. The temperature distribution is less in lubricant 2 because of its cooling properties.

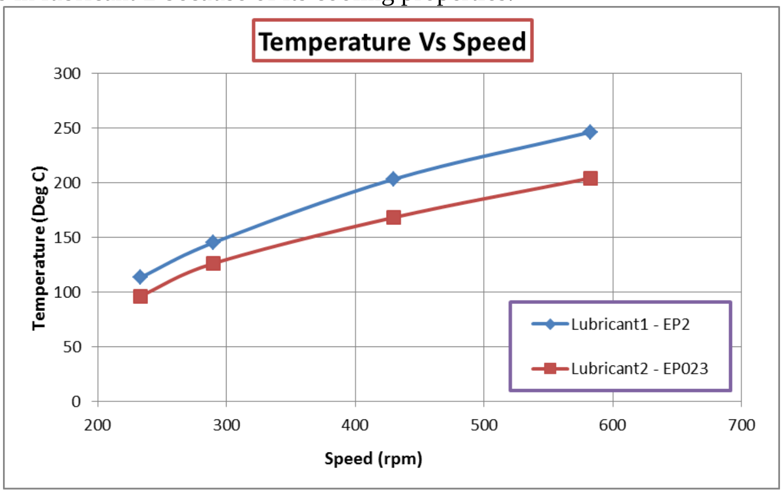

Fig 9: Temperature versus Speed Plot for both the Lubricants.

Speed (RPM)	Temperature (Deg C)	
	Lubricant1 - Mobilux-EP2	Lubricant2 - Mobilux-EP023
233	113	96
290	145	126
430	203	168
583	246	204

Table 3: Temperature Comparison for Lubrications with Respect to Speed.

5. CONCLUSION

In the study of designing the gear box by using ANSYS method with input power of 16 kW, input speed 583 rpm, it is concluded that with the analysis using ANSYS at both condition temperature are within the safe limits than earlier.

- The temperature induced in the gear assembly is increases with increase in speed.
- The temperature induced in the gear assembly is increases with increase in input torque.
- The temperature induced in the gear assembly for lubricant 2 is less compare to lubricant 1.
- The viscosity is playing important role in cooling of gear assembly, due to heat transfer co efficient.
- From FEA results, it is clear that lubricant 2 gives the better performance compare to lubricant 1.
- Hence lubricant 1 can be replaced with lubricant 2 for better and long running life of gear and pinion.

So the design of gearbox is safe. The heat generated while functioning of the gearbox is found to be 204.12^0 C, which is not within permissible limit, therefore, further computational fluid dynamics analysis can be done and find necessary solution using these methods to reduce the temperature.

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