

Analysis of Temperature Field of High Speed Gear Box Based on ANSYS Workbench

WEI Ling hui^a, XU Hong hai

North China University of Technology, Beijing 100144 , China

Weilinghui@126.com

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Abstract: Using the computational fluid dynamics, heat transfer theory and mechanics theory to analyze the internal heat source types and heat transfer path of high speed gear box, and establishing the steady-state heat transfer model. Based on the finite element theory, the finite element model of fluid solid coupling is analyzed, the distribution of temperature field for the gear box is obtained, and the key part of the distribution of temperature field is determined. Through simulation results of the finite element, the basis for the prediction and reliable operation for the gear box of high speed can be provided by the analysis model of fluid solid coupling.

1. Introduction

High speed drive gear box is an important device for power transfer and movement, and responsible for delivering the power of device to the execution part, and has an important influence on the equipment safety, dynamic performance and power transmission. Because of the higher speed and increasing heat loss of the transmission system of the high speed gear box, there are many problems faced on every part of the lubricating surface. Taking a certain type of high speed gear box as the research object, conducting simulation analysis for heat transfer model of heat flow coupling, the change law of the relevant physical quantities is analyzed by means of the working process of the gear box. The reference basis for the balance temperature, temperature distribution of key parts and temperature forecast and research structure of the new operating conditions can be provided with the help of finding out the heat balance of the gear box.

2. Analysis of heat balance process and heat source for gear box

Heat source calculation is the basis of the research on temperature field of the gear box. The heat generated during the transmission of high speed gear box is mainly derived from the power loss of various kinds of friction pairs which mainly include the power loss of bearing friction, oil film viscous friction between lubricating oil layer and sliding, and rolling friction between two meshing tooth .

The transmission of heat in the gear box is: heat source generated can be transmitted to the parts of gear surface, internal gear and transmission shaft, and the temperature field was built. Eventually the heat is transferred to the gear box, and is sent out through the form of forced convection. The heat of the oil and gas mixture formed by the lubricating oil and air is circulated through the box body to the outside air in the form of heat convection. To ignore the radiation heat transfer between the various parts of the body, the heat is continuously passed to the outside air, and ultimately achieve dynamic balance. The heat transfer route can be expressed in Figure 1.

3. Heat source of gear box calculation

Heat power of each heat source is calculated according to heat source analysis of the gear box. The distribution of heat source is shown in figure 2.

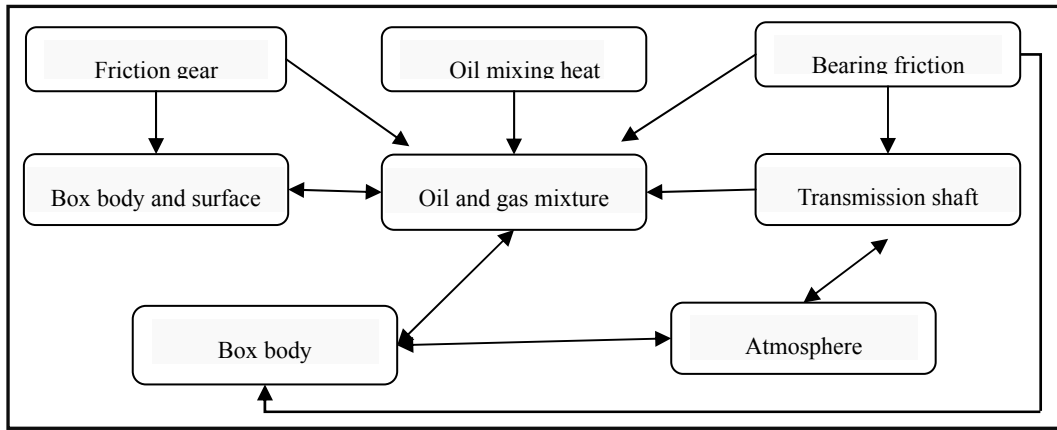


Fig.1 Route of heat transmission

Working condition is set as follow: clockwise, the running speed is 300km/h, the quantity of oil injection is 6L, the wind speed is 5m/s, the ambient temperature is 27°.

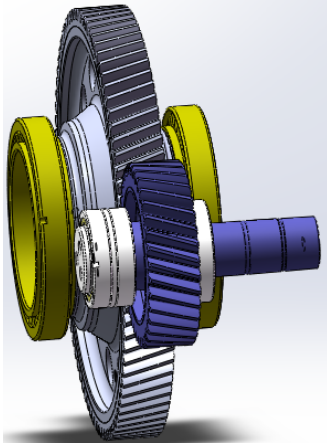


Fig. 2 The distribution of heat source

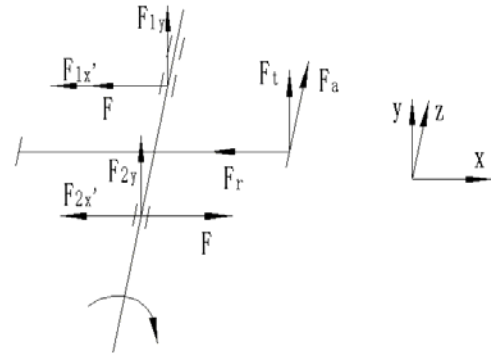


Fig. 3 diagram of the bearing force

(1) Bearing heating power calculation

The maximum output power of the motor is 615kw, and the basic parameters of gear is shown in Table 1.

Table 1 the basic parameters of gear

Gear parameters	Symbol	Active gear (small)	Driven gear (large)
Normal modulus	m_n	6	
Teeth number	Z	35	85
Transmission ratio	i	$85/35=2.429$	
Pressure angle	α_n	20°	
Helix angle	β	18°	
teeth width	b	69	65
Gear center distance	a^*	380	
Tooth top circle diameter	d_a	236.277	546.753
Gear design service life		$2 \cdot 4 \times 10^5 \text{ km}$	
Indexing circle diameter	d	220.807	536.246
root circle diameter	d_f	207.307	520.332

1) input shaft bearing capacity calculation

$$T = 9550 \times \frac{P}{n}, n_1 = \frac{v}{2\pi r}, n_2 = i \times n_1.$$

Obtained motor torque transmission T , and circumferential force. Gear is $F_t = 2000 * T/d$.

Radial force $F_r = F_t * \tan \alpha_n / \cos(\beta)$.

Axial force $F_a = F_t * \tan(\beta)$.

According to the distribution of heat source on the shaft, the torque of the gear is generated by the axial force, and F is generated by the torque acting on the bearing.

$$F = F_a \cdot r / a = 3588.0N, \quad F_{1x}' = F_r a_2 / a = 1787.6N, \quad F_{2x}' = F_r a_1 / a = 2580.0N$$

$$F_{1y} = F_t a_2 / a = 4671.1N, \quad F_{2y} = F_t a_1 / a = 6741.6N, \quad F_{1x} = F_{1x}' + F = 5375.6N$$

$$F_{2x} = F_{2x}' - F = -1008.0N, \quad F_1 = \sqrt{F_{1x}^2 + F_{1y}^2} = 7121.5N$$

$$F_2 = \sqrt{F_{2x}^2 + F_{2y}^2} = 6816.5N, \quad F_5 = F_a = 3708.2N$$

Similarly the output shaft bearing force can be calculated, Bearing 3, 4 of the force is

$$\begin{cases} F_3 = 7633.5N \\ F_{3z} = 0 \end{cases} \quad \begin{cases} F_4 = 11028.8N \\ F_{4z} = 3708.2N \end{cases}$$

2) Heating power of each bearing

P is equivalent dynamic load of bearing. M is Friction torque of bearing and Q is calorific value of bearing.

$$P_1 = 1.2F_1 = 8545.8N, \quad M_1 = 0.5\mu P_1 d_1 = 961.4Nmm, \quad Q_1 = 1.05 \times 10^{-4} M_1 n_1 = 470.4W.$$

The calorific value of the bearing is shown in Table 2.

Table 2 Calorific value of bearing

Position	Bear1	Bear2	Bear3	Bear4	Bear5
Calorific value	470.4W	450.2 W	369 W	491.2 W	81.7 W

3) Heating power of oil mixing calculation

Heating power calculation of the loss of oil mixing $Q_6 = 347.5bhv^{1.5}$

b-Large gear width (0.0645m) .

v-Large gear pitch circle line speed (53.8m/s) .

h-Gear oil height (0.053m) .

The result of Calculation $Q_6 = 468.8W$

4) Mesh calculation of heating power

$$Q_7 = Q - Q_1 - Q_2 - Q_3 - Q_4 - Q_5 - Q_6$$

Q_7 - Gear meshing heating power.

Q - Total heating power of gear box, efficiency of gear box is 0.99, input power is 615KW.

The calculation result is 468.8W

5) Calculation of Convective heat transfer coefficient for box wall.

(a) Calculation of convective heat transfer coefficient for box inner wall.

$$Nu = 0.664 Re^{\frac{1}{2}} Pr^{\frac{1}{3}}$$

Nu-Plate average heat transfer coefficient.

Re-Reynolds coefficient.

Pr-Prandtl constant

and, $Re = uL / \nu$

u-Lubricating oil flow rate

L-Wall characteristic length

ν -Kinematic viscosity

In summary, the convection coefficient of heat transfer between fluid and inner wall of the gear box is $h_1 = \lambda Nu / L$

(b) Calculation of total heat transfer coefficient of gear box.

According to the empirical formula: $K = 24.6 + 3.3\sqrt{V}$

Vehicle driving speed.

(c)The coefficient calculation of convection heat transfer in external box wall

$$K = \frac{1}{\frac{1}{h_1} + \frac{\delta}{\lambda} + \frac{1}{h_2}}$$

δ -thickness of gear box wall

λ -heat conduction coefficient of box

h_2 -Heat transfer coefficient of box external wall

The calculated result from above $h_2=52\text{W}/(\text{m}^2\cdot\text{k})$

4. Establishment of simplified calculation model

The model was simplified in SolidWorks. The fillet, chamfer, bolts and other important structures and parts was removed in order to ensure the accuracy of results, the model was maintained as far as possible as required, The simplified 3D model was filled with the DM workbench module, and grid division was completed in workbench of meshing module. The totality grid model was gotten as shown in Figure 4.

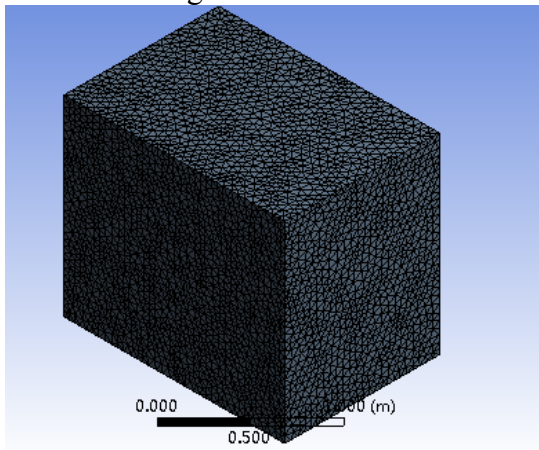


Fig. 4 Totality grid model

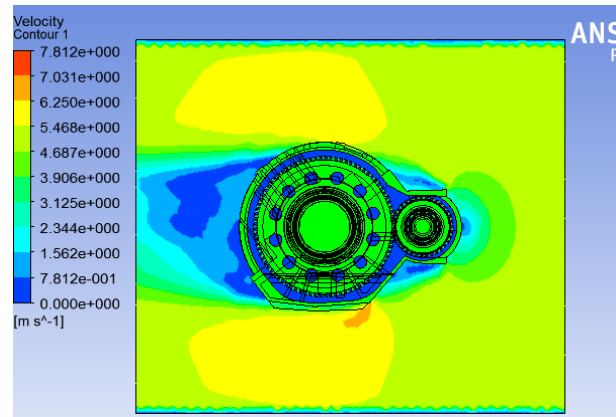


Fig. 5 nephogram of velocity

5. Results of simulation analysis

The nephogram of velocity field is as shown in figure 5. In this nephogram, inlet velocity is 5m/s, top speed is 7.812 m/s, and the case is happened in sharp change area of the shape of the box.

The situation of steady-state temperature field of box wall is as shown in Figure 6 to 9.

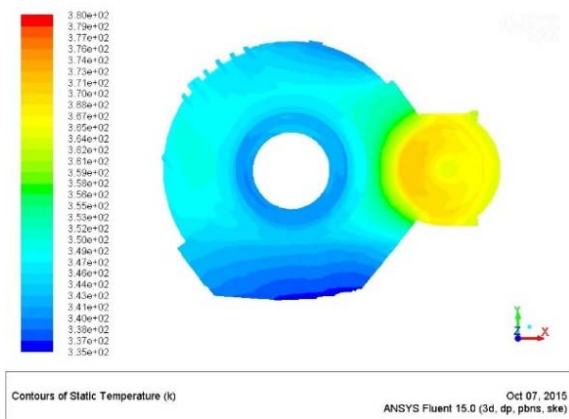


Fig. 6 nephogram of A surface temperature field

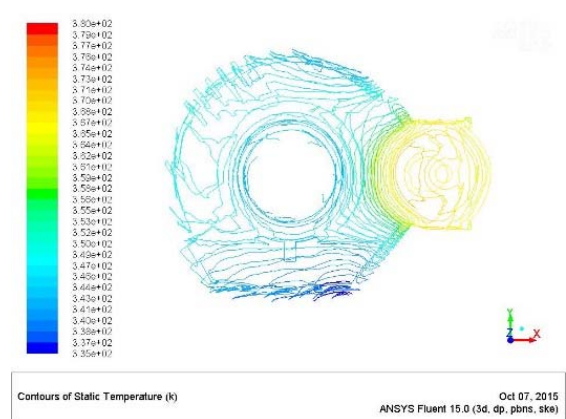


Fig. 7 contour map of A Surface

The highest temperature pinion of A surface happened on the external surface of box which focused on the pinion bearing and the gear wheel side bias. The highest temperature is 372k, i.e. 99

C.

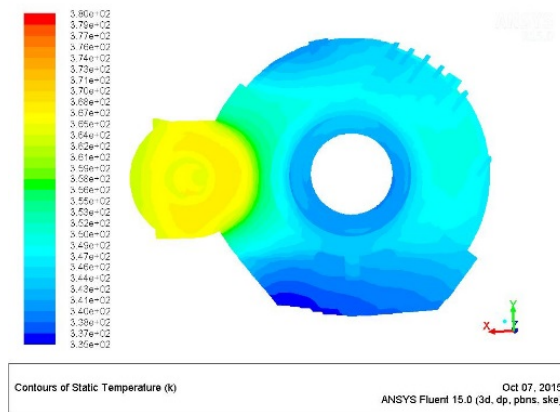


Fig. 8 nephogram of B surface temperature field

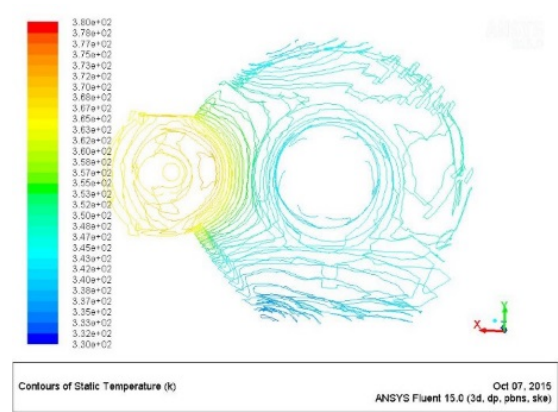


Fig. 9 contour map of B Surface

Table 3 Condition 1 temperature situation table

Site name	$T_{MAX} (^{\circ}C)$	Temperature maximum part
Box A surface	99 $^{\circ}C$	the external surface of box which focused on the pinion bearing and the gear wheel side bias
Box B surface	95 $^{\circ}C$	the external surface of box which focused on the pinion bearing and the gear wheel side bias

6. Conclusion

In this paper, the heat source and heat transfer process was analyzed, the heat transfer model of the transmission gear box was built, and losses of various thermal power of gear box were analyzed and calculated according to the actual use of the high speed transmission gear box. The temperature field of the gear box is analyzed to find out the different position of the highest balance temperature of the gear box. The analysis process can provide reference basis for the forecast of temperature distribution of the high speed gear box and the temperature distribution of the key parts and so on.

Acknowledgements

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