THE OPERATIONAL TEETH AND OIL TEMPERATURE DIFFERENCES

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Abstract
This short article describes the differences between teeth and oil temperature during the gearbox operation. The temperature is an operation parameter which can limit a lifetime of gearbox. The oil temperature impacts the friction parameters. The heat is naturally generated by the friction between tooth flanks during the gear operation. The temperatures of all gearbox parts by the generated heat are affected. The optimal temperature of oil and teeth for the failure-free gearbox operation is necessary. The goal of this article is temperature of teeth and oil temperature measurement research, temperature differences as an important parameters are emphasized.

Key words: *temperature; spur gear; pinion; teeth; final drive; automobile; gearbox; oil.*

INTRODUCTION

During the gearbox operation the heat is generated. For the trouble-free and economical operation of gearbox an optimal temperature is necessary. The optimal temperature about 90°C (194°F) is supposed. Temperature influence the condition of all gearbox parts, the mechanical wills can be changed too. Too high or low temperature can change viscosity and tribological parameters of oil, lubrication film can not be able to adequate lubricate a tooth flanks - damage is possible (f.e.(Davis, 2005)). The automobile gearbox is usually fixed to combustion engine and a heat is transferred to gearbox by the case (usually made from aluminium alloys with high thermal conductivity), the optimal oil temperature is easier to ensure.

Gears generate a heat during their operation, heat is transmitted by oil and other parts of gearbox to the surroundings. The oil parameters are depend on temperature. Tribological parameters during the gear operation on the current oil condition are depend too. The quantity of produced hest is on tribological parameters depend too (Elshourbagy, 2012).

The mathematical simulation for the behaviour and mechanical parameters (f.e (Skrivanek, 2012)) of mechanical system is possible to use. The simulation of all gearbox operation parameters is still almost impossible and ever passed simulation is useful to verify.

MATERIALS AND METHODS

This short paper describes a measurement of oil and teeth temperature inside a common automobile gearbox. The gearbox operation conditions are mostly similar as during the operation in car. For the measurements the gearbox MQ100 was used. MQ100 is a manual shifted gearbox used in small passenger car Skoda Citigo (or VW Up). The helical gears in MQ100 are used.

For the temperature measurements the special testing stand were used (Mazac, 2014). The stand is powered by the common Skoda 1,2HTP/44kW combustion engine. The loading by the electric dynamometer was realized. Maximal output torque of gearbox is about 1350Nm. The MQ100 gearbox similar as in car is fixed. The tested gearbox is isolated from the combustion engine by the shaft, the heat transfer is not possible. The electric fan for the cooling of tested gearbox was used. The air temperature around the tested gearbox was regulated by air conditioning and it was 20°C(68°F).

The temperatures of teeth were measured on a final drive pinion. The teeth temperatures by the thermistors were realized. The temperature data from the rotating shaft by the contactless equipment were transmitted (Mazac, 2015). The oil temperature were measured by the resistive thermometer Pt100 installed in the oil drain plug. The place of oil temperature measurement is near of final drive gear. The testing stand is on Fig.1., the measurement places are described here too.

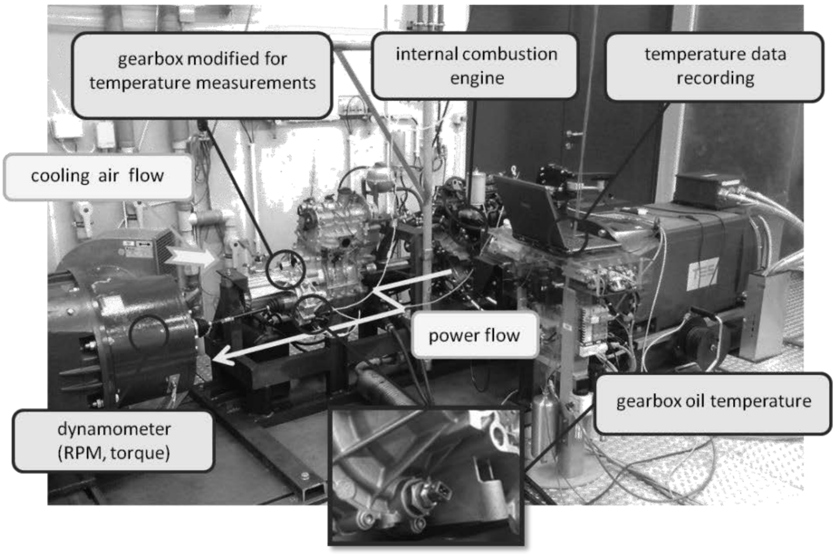

Fig. 1 The stand for gearbox loading and temperature measurement

The temperature measurements during a defined operation regimes were realized (Mazac, 2016). The temperature measurement during all five shifted speed operation were realized, our research were focused on 1st and 5th gear only. Engine velocity (input of gearbox) were 3000, 3650 and 4300RPM. Load of gearbox output was 25, 50, 75% of maximal torque, maximal input torque is 100Nm (73,8 lbf·ft). The loading parameters (output torque and RPM) for the 1st gear are in the Tab.1. The operation parameters during the 5th gear performance are in Tab.2.

Tab. 1 Operation and loading parameters - 1st gear (transmission ratio = 14,18)

Load [%]	3000[RPM] in		3650[RPM] in		4300[RPM] in	
	torque out [Nm]	RPM out [min^{-1}]	torque out [Nm]	RPM out [min^{-1}]	torque out [Nm]	RPM out [min^{-1}]
0%	0,00	211,45	0,00	257,26	0,00	303,07
25%	33,96	211,45	336,96	257,26	336,96	303,07
50%	673,93	211,45	673,93	257,26	673,93	303,07
75%	1010,89	211,45	1010,89	257,26	1010,89	303,07

Tab. 2 Operation and loading parameters - 5st gear (transmission ratio = 3,10)

Load [%]	3000[RPM] in		3650[RPM] in		4300[RPM] in	
	torque out [Nm]	RPM out [min^{-1}]	torque out [Nm]	RPM out [min^{-1}]	torque out [Nm]	RPM out [min^{-1}]
0%	0,00	967,32	0,00	1176,90	0,00	1386,49
25%	73,66	967,32	73,66	1176,90	73,66	1386,49
50%	147,31	967,32	147,31	1176,90	147,31	1386,49
75%	220,97	967,32	220,97	1176,90	220,97	1386,49

The gearbox ran for 15 minutes with a described mechanical parameters (Tab.1 and Tab.2). The final average tooth temperatures arise from last 60 temperature values mesured during the measurement interval (average of the last minute temperature values, temperature were measured every second).

RESULTS AND DISCUSSION

To verify the assumption that the temperature of the wheels is higher than the surroundings was the main aim of the study. When the wheel and teeth temperature is higher, the heat can be share to oil and other parts of gearbox. Can be that the dissipated energy during the tooth flank friction (natural process during the gear operation) is so low and the gears absorbing the heat from oil.

The graphs of teeth and oil temperature were create - Fig.2, Fig.3. The graphs contains the average teeth temperature and average oil temperature depends on input RPM and percent loading. The graph for the 1st gear is on Fig.2. The graph for the 5st gear is on Fig.3.

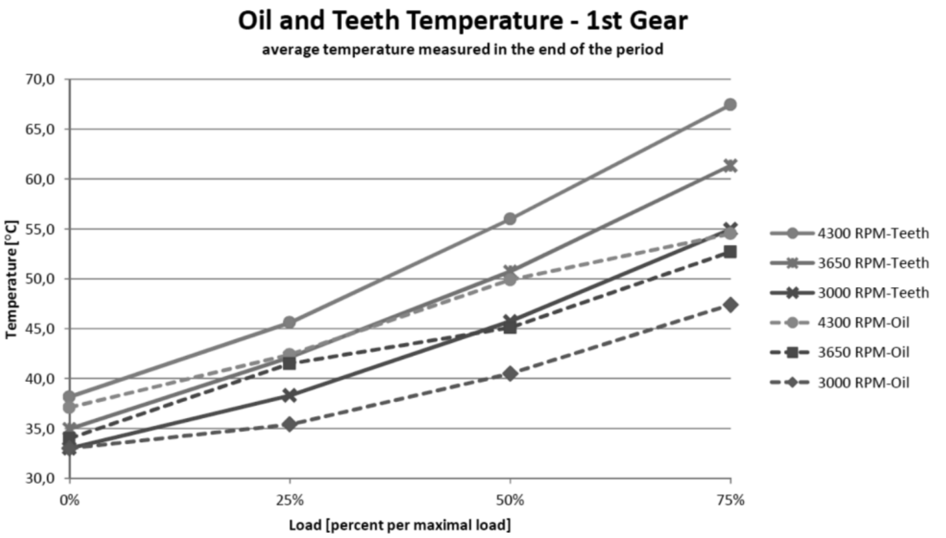

Fig. 2 Oil and teeth temperature graph - 1st gear

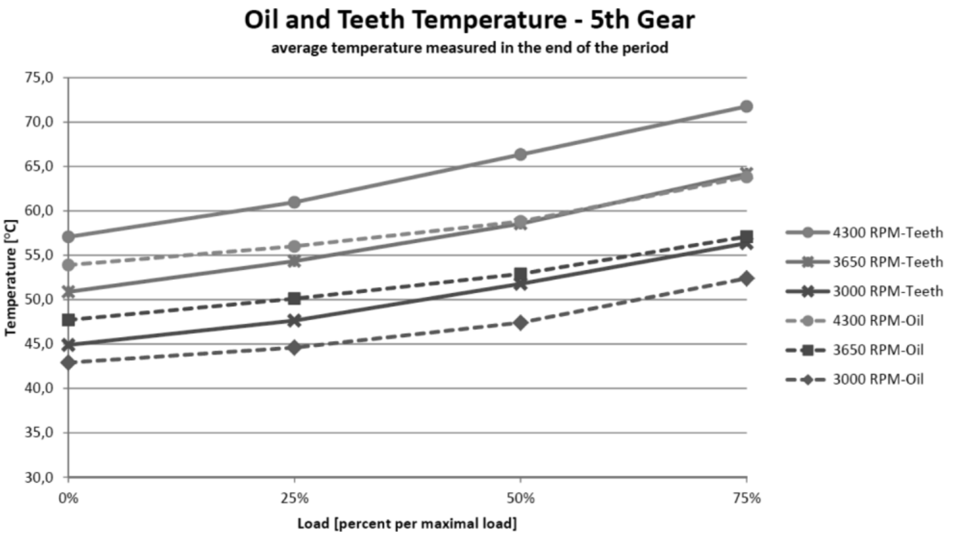

Fig. 3 Oil and teeth temperature graph - 5th gear

The average teeth temperature was higher than oil temperature in almost tested operation conditions. The assumption was confirmed and is possible to say that during the operation of MQ100 gearbox with chosen operation condition the teeth flank friction is the heat source.

The differences between temperatures of teeth and oil are contents in graphs Fig.4 and Fig.5.

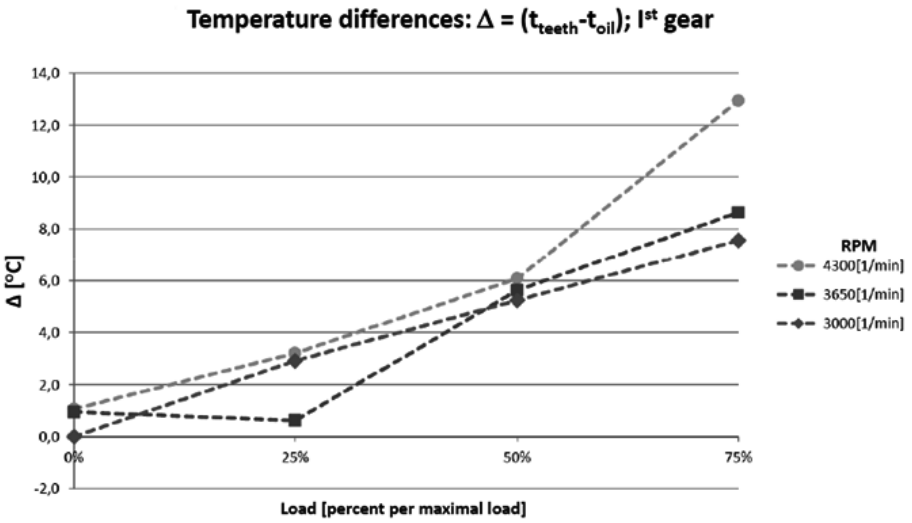

Fig. 4 Temperature differences graph - 1st gear

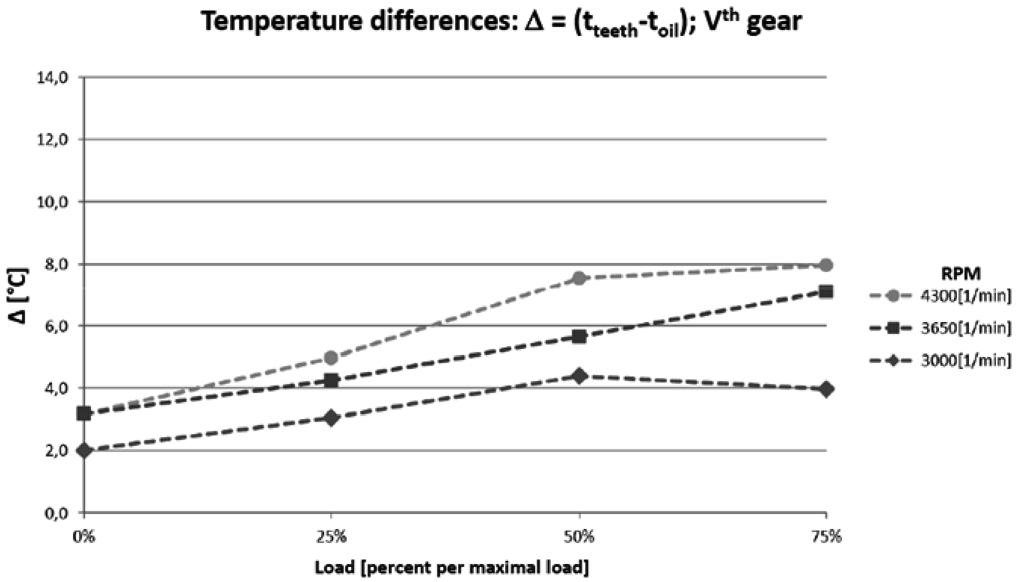

Fig. 5 Temperature differences graph - 5th gear

The graphs on Fig.4 and Fig.5 show that the highest differences of the teeth and oil temperature were measured during the 4300RPM, 75% load and 1st gear operation. The temperature difference was 13°C (23,4°F).

On the Fig.6 are plot the both temperature differences measured during the operation on a 1st and 5th gear. Is apparent that the temperature differences are lower during the low load operation and the temperature differences increasing trend depend on higher loading.

The gradients of the temperature connecting lines shows that the increasing rotation velocity of the gears cause the lower influence of the load on the temperature teeth and oil differences.

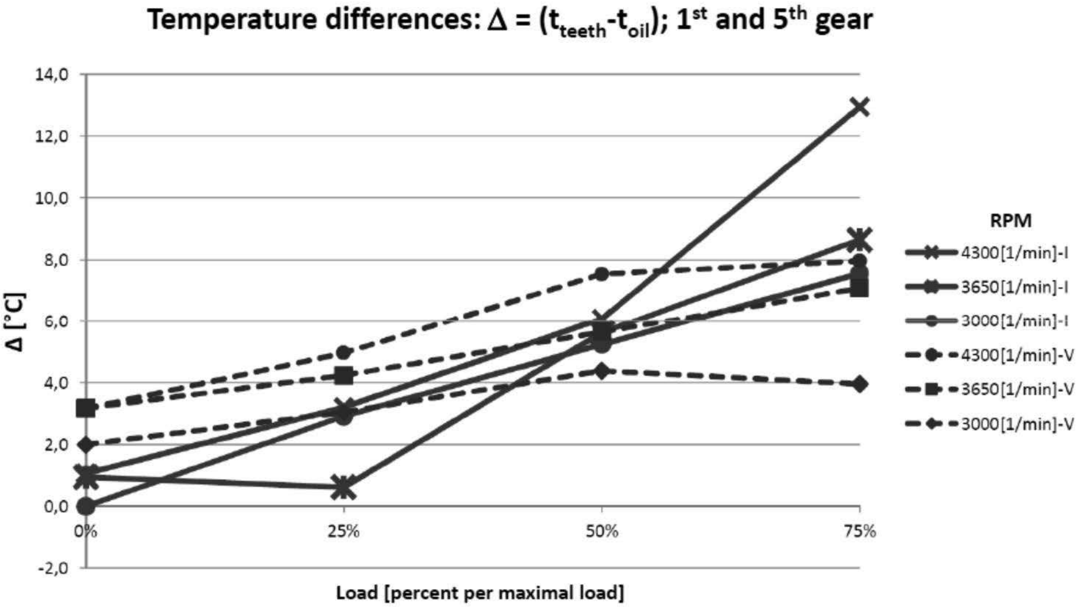

Fig. 6 Summary temperature differences graph - 1st and 5th gear

CONCLUSIONS

This short paper describes a measurement and evaluation the temperatures of average teeth and oil temperature during the mostly (without partial heating by the combustion engine) real operation of Škoda Auto a.s. MQ100 automobile gearbox. The research were focused on a 1st and 5th gear operation. The results show the teeth and oil temperature depended on the load. The temperature differences are higher during the higher load operation regimes. The differences are closer to constant during the operation with a higher RPM regimes. The differences of temperatures are compare in a summary graph.

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