THE GROWTH OF CONTACT AREA OF THE TOOTH IN DEPENDING OF INCREASING THE LOADING

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Abstract
The article deals with measuring contact area of the tooth of helical gearing depending on increasing load. Overall contact area of the tooth has big influence on vibration and noise of gearing. The result is finding correlation between contact area of the tooth and the loading.

Key words: *helical gearing; footprints; involute gearing; gear wheels; vibration; noise.*

INTRODUCTION

The transmission of the torque in the gearbox is realized by meshing of helical gears. The teeth of the gear wheels fit together and thanks to attend they transfer the torque. However, in real operation it is very difficult to achieve that the contact of the tooth flanks is accurately through all surface. As the transmitted torque causes deformation on the individual components of the entire gearbox (shafts, tooth, gear case, etc.). All of these factors then causes that the contact of tooth flanks is not provide all his surface but only specific part of the tooth flanks. Therefore, the geometry of the tooth is modified in such a way that it will deliberately change its shape against the direction of all acting deformations so that the subsequent loading of the gearbox causes the deformations to be eliminated and the contact of the tooth flanks is higher than contact of the tooth flanks without modification *(Moravec, 2001; Mark, 2013)*.These modifications go hand in hand with the level of radiated energy in the form of noise. Acoustic emission of gearbox is a very important factor, especially when designing gearboxes for the automotive industry *(Tůma, 2014)*. Gearbox noise reduction is antagonistic with weight reduction. This results in a number of negative factors. The main thing is that the gear case does not absorb radiant acoustic energy and so the noise more penetrates the surroundings. Therefore, a number of modifications are made to the tooth flanks to keep the contact area of tooth as large as possible while as little radiated acoustic energy as possible.

MATERIALS AND METHODS

The basic idea is that maximum tooth contact area radiates the least acoustic energy *(Tůma, 2014)*. For these studies, four pairs of toothed wheel sets were produced. On each of them were manufactured different modifications on tooth flanks. These modifications are intended to provide better growth of the tooth flanks contact area in the context of increasing the loading. Realization was performed on the test gearbox. In the gearbox was created hole for application identification layer on the tooth flanks and for photography of the results. Creation of identification layer was performed by special color. On the tooth flanks was applied by using a brush. Special color called: "Gear marking compound" is able created very thin layer of the color which don't change properties during the time. Layer of color is also very sensitive because is easy wipe it. The place on the tooth flank where is layer of color removed indicates real contact of teeth *(Pavlík, 2016)*. The gearbox with modified gears was placed in testing device. Testing device is able created different loading condition of torque. So on the tooth flanks was applied thin layer of color, on the testing device was set a torque and after that was turn on the testing device. Tested modified gear wheels created several of rotation and where tooth flanks in contact so identification layer was removed. After that was footprints on the tooth flanks photographed. This process was carried out on several load torque levels (0, 30, 50, 70, 100 Nm) and also for all four modified toothed wheel sets. At the same time this method verifies the correctness of created geometrical modifications on the toothed wheel sets. All created photography were in special software modified. The real places with contact of tooth flanks depending on different loading of torque are illustrated on figure (Fig. 1). For easier reading of footprints were photos redrawn.

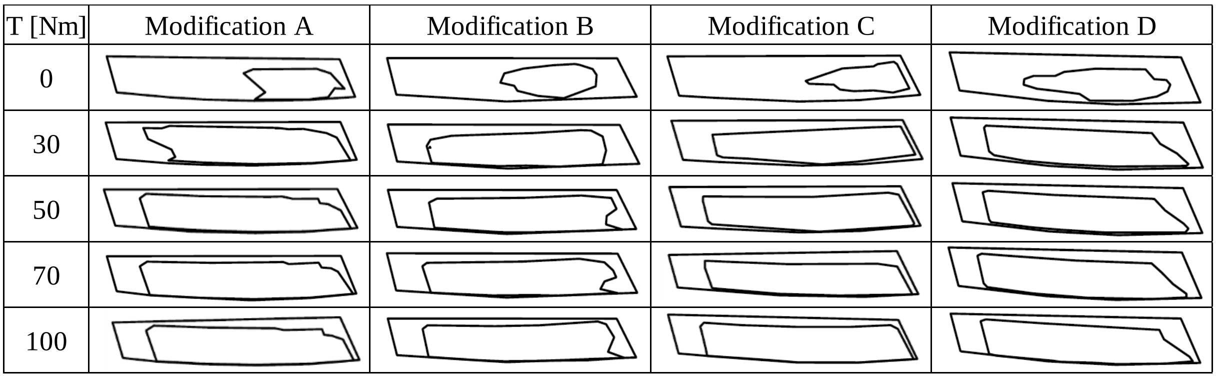

Fig. 1 Comparison of footprints created on gear wheels with different geometry modification

The redraw photographs give a clear view of the tooth modification and their dependence on the increasing loading of torque. Selected modifications which were used on four different toothed wheel sets are governed by generally known rules. Basically the modifications takes into account the initial position of footprints in the center of the tooth up to its edge. For these four different modifications were also measured average sound pressure. Results are shown in the next table (Tab. 1).

Tab. 1 Average sound pressure of different tooth modification

	Modification A	Modification B	Modification C	Modification D
Avg. sound pressure [dBA (20μPa)]	33,84	34,90	31,83	38,42

Measurement of acoustic pressure was for this case of study taken as supplementary information. The main point of these study is finding a correlation between the tooth contact area and increasing loading.

RESULTS AND DISCUSSION

In the special software were measured surfaces of created footprints from all four different toothed wheel set modifications. Results are shown in next table (Tab.2).

Tab. 2 Measured tooth flanks contact area

Torque [Nm]	Modification A [kpx]	Modification B [kpx]	Modification C [kpx]	Modification D [kpx]
0	780,39	772,96	631,24	1063,54
30	2030,54	1768,33	1929,63	1965,27
50	2170,13	1951,36	1955,43	2047,94
70	2214,99	1968,82	2070,19	2122,05
100	2323,28	2143,59	2339,72	2226,38

Showed values are in kilo-pixels because surfaces were evaluated from photos. So it was assessed how many pixels are located on the surface of the tooth flanks which are touching each other. This measurement method relatively simple and accurate. For clear view was created graph tooth contact area dependence on torque (Fig.2).

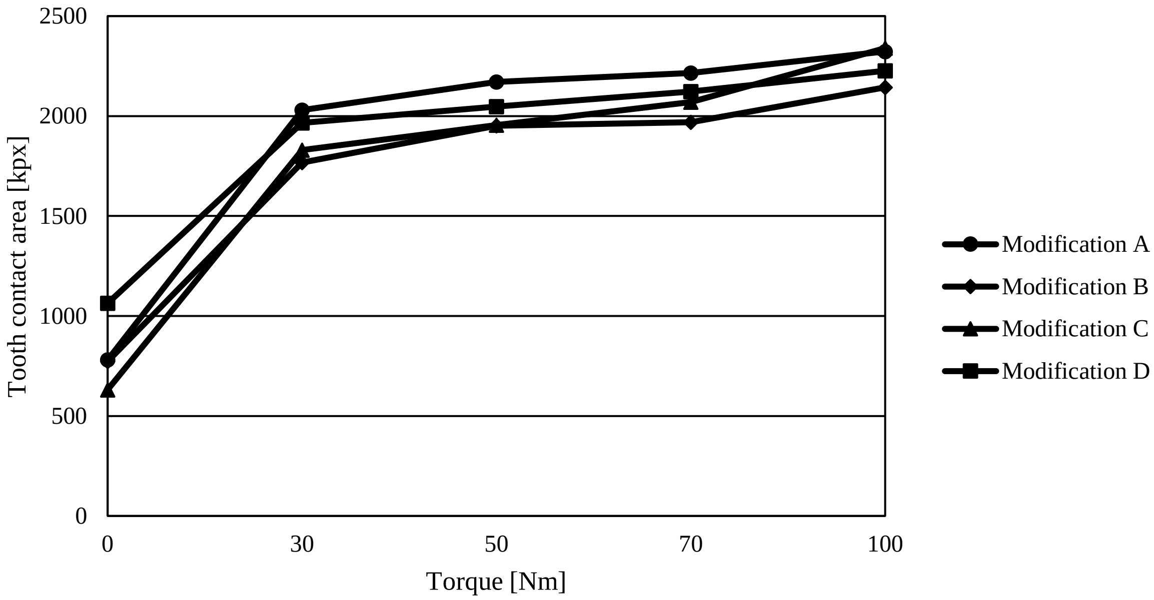

Fig. 2 Measured data of increasing tooth contact area depending on torque

The basic idea of this study was whether the growth contact surface of the tooth flanks is linear but graph (Fig. 2) clearly say that not. Is clear from the graph that course of surface growth is practically the same for all four modifications and also that the quietest toothed wheel set started from smallest surface area to largest surface area. More information is practically impossible to read. But when we compare the initial position of footprints and his appearance with average sound pressure, we see that in this test gearbox probably occurs a significant deflection of the shafts. Because the best result have Modification C with the initial position of footprints on the edge (only 31,83 dBA). This finding totally destroy all general recommendations regarding the appearance and position of contact surfaces on the tooth flanks. The general rule says that the footprint should extend evenly to all sides and that the edge touch is wrong *(Moravec, Deil, Němček, Folta, & Havlík, 2009)*. In this case is visible that edges contact can occur but only in low loading of torque. Of course that nevertheless immediately with increasing loading of torque must also increase contact area of teeth toward the opposite side. This assumption should be the subject for further investigation that would confirm the correlation between the growth of contact area and the deflection of the shafts.

CONCLUSIONS

The aim of this study was to find the growth of the contact area of the tooth in the depending of increasing the load. This study is basically experiment because is very difficult to find information in the literature and scientific articles that would serve as a good background. In the commonly available literature, problems are described very well, but only in general. For measuring contact surfaces was manufactured four toothed wheel sets. On their tooth flanks were made different geometrical modifications. This modification changes the initial position of the contact area and his overall size. On the testing device were created real contact area of tooth flanks at various values of loading torque. Created footprints were photographed and measured. Also for this four different toothed wheel sets were measured average sound pressure. All of these data were analysed and correlated. A simple general finding of the correlation between the tooth contact area and the loading has failed completely because from the graph (Fig. 2) is practically impossible anything to read. But comparison the initial position of footprints and his appearance with average sound pressure shown that the test gearbox probably have a significant deflection of the shafts. This idea shows fact that Modification C has initial position of contact on the edge with lowest overall average sound pressure. For future study of factors generating noises and vibration of the gearing, should be taken into account fact with the shafts deflection.

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