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Impact of selected errors in production and installation of bevel gear elements on total transmission error

Łukasz Jedliński, Józef Jonak

Lublin University of Technology, Department of Machine Design
20-618 Lublin, ul. Nadbystrzycka 36, e-mail: l.jedlinski@pollub.pl, j.jonak@pollub.pl

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Abstract

The article tackles the problem of evaluating the errors in production and installation of bevel gear which have impact on the transmission error. The production defect has been determined as an incorrect construction of bearing openings causing the change of angle between the axes toothed gears and installation error – as failure to meet the mounting distance of crown wheels. The tests were conducted as simulative tests mainly due to the time and cost of tests. Toothed gears were modeled as solid models and then a virtual installation and a single flank testing were conducted. As a result, data about the positions of angular toothed gears were received on the basis of which the transmission error was calculated. This error reflects the constancy of the driven shaft's rotational speed and thus it is associated with the gear's vibration and acoustic activity.

Introduction

Toothed gears continue to be the object of scientific interest due to the commonness of their application and the possibility to improve certain structural and technological aspects. A great number of theses applies to the scope of improvement in the outline of the toothing, especially of conical gears. The second important group of theses refers to the possibility to diagnose toothed gears using vibroacoustic methods.

The article presents results concerning the impact of installation error [1] and production error on the transmission error. Simultaneous testing of various production and installation errors is possible due to single flank testing or double flank testing.

Testing bilateral co-operation requires instruments of simpler construction. In the course of tests, the inspected wheel is pushed to the control wheel in such a way, so that the play between teeth is zero. Production errors in wheels cause the change in the distance of toothed gear axes during revolutions, which is reflected on the chart using a special mechanism. The disadvantage of this method is the fact that the non-working side of the tooth [2] has impact on the results. In the case of a gear with large plays between teeth, the vertex play may be cancelled. The results from this method are also difficult to analyze [3, 4].

In the case of single flank testing, the tested wheel co-operates with the control wheel as in actual conditions and thus the distance between the toothed gear axes is constant. Plays are also maintained. The angular position of toothed gears are measured by means of encoders. Production errors in wheels cause the driven wheel speed to be variable at constant rotational speed of the driving wheel. This method does not have the defects of the previous method.

The article uses the single flank testing method to test the impact of incorrect construction of the casing's bearing openings, causing the change of angle between the toothed gear axes (Fig. 1) and to test the impact of incorrect installation in the form of incorrect mounting distance (Fig. 2) on the transmission error. The transmission error is defined as the difference between the actual and theoretical location of the driven wheel [7]. Since on-the-job tests are expensive and time-consuming, simulation tests were used here [8]. The whole simulation took place in the NX program by

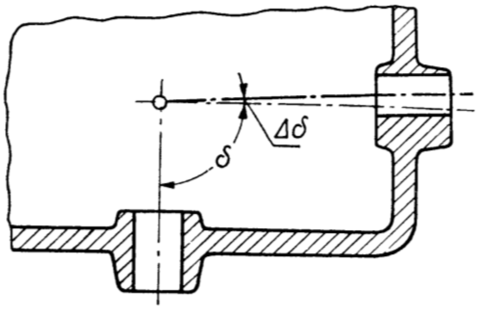

Fig. 1. Angle error between axes of bearing openings [5]

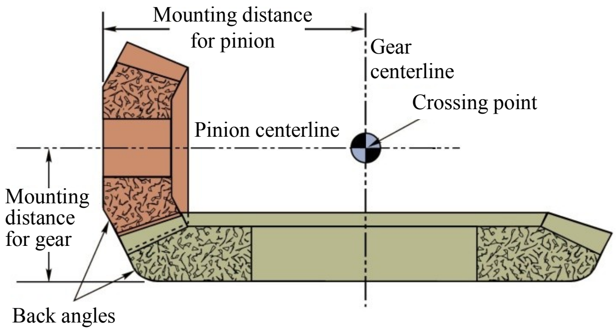

Fig. 2. Mounting distances of toothed gears [6]

Siemens PLM Software. In the first step, solid models of conical toothed gears with circular-arc teeth were built. Then, the wheels were placed in relevant positions with respect to each other and simulations of toothed gear single flank testing method were conducted.

Investigated object and simulation parameters

The tested conical toothed gear with circular-arc teeth was described, e.g. in paper [9]. For the purpose of simulation tests, solid models of toothed gears were created in CAD-type software. The basic parameters of toothed gears include: the number of teeth of pinion 19, crown wheel 42, frontal module 2.9 mm and angle between axes 90°.

The production errors of gear casing and the installation error were taken into consideration. The faulty production of bearing sockets may result in the fact that the angle between toothed gear axes will not be maintained. Figure 3 presents the error of failure to observe the angle between axes $\Delta\delta$. The simulation took place for 9 positions, pinion rotation took place every 0.1°, one position is for proper position of the wheels. The symbol "+" means that the rotation was in the direction for which the angle between axes decreased, and "–" – increased.

The installation error in the form of failure to observe the mounting distance of the crown wheel is demonstrated in figure 4. There were also 9

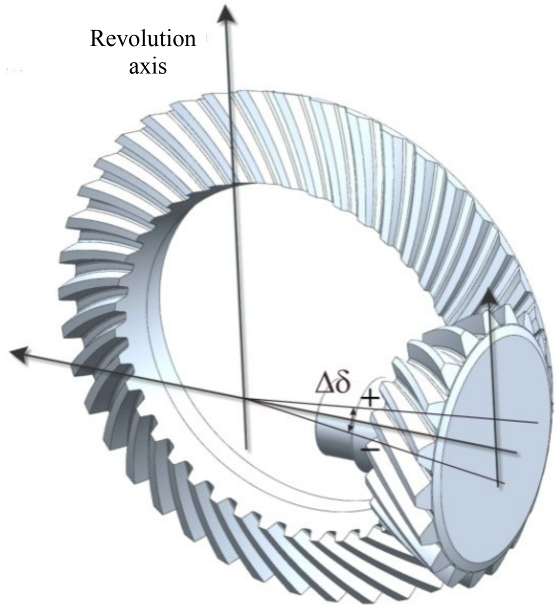

Fig. 3. Error of failure to observe angle between axes of toothed gears

positions for which the simulation of single flank testing was conducted. The shift took place every 0.1 mm in the scope of ±0.4 mm. The mounting distance was greater than that required for the direction "+" and smaller for the direction "–" .

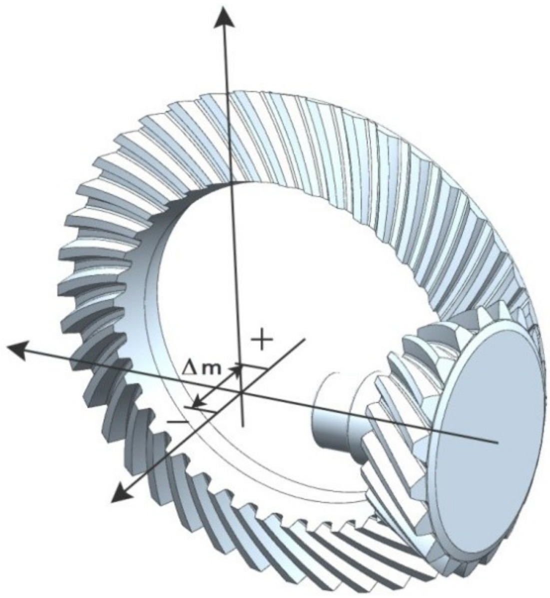

Fig. 4. Error of failure to observe mounting distance of crown wheel

The simulation of single flank testing took place using solid models of toothed gears. These models, apart from reflecting the geometry of teeth and other dimensions, also reflect material properties. Steel with the following properties was adopted for the material in wheels: density $\rho = 7829$ kg/m^3, Young's modulus $E = 20694 \cdot 10^7$ Pa, Poisson's ratio $\nu = 0.288$. The simulation took place for small rotational speed 0.01745 rad/s (1/6 rpm). A low breaking torque was applied which provided continuous contact of teeth of value 0.01 Nm. Simulation time was one rotation of the pinion. The low rotational speed and low breaking torque allow to state that the models of toothed gears should be regarded as rigid solids.

Simulation results

The conducted simulation of single flank testing provided information about the angular position of the pinion and the crown wheel. Further analysis was conducted in Excel software. Chart 5 presents the dependence between the angular location of the pinion and the transmission error (nine lines of the chart corresponding to the analyzed positions). By analogy, chart 6 presents the transmission error depending on the crown wheel's installation error.

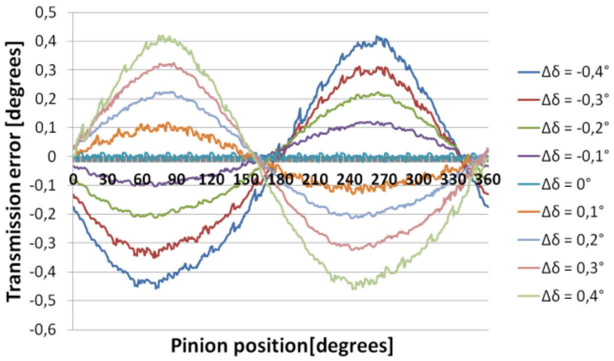

Fig. 5. Transmission error for $\Delta\delta$

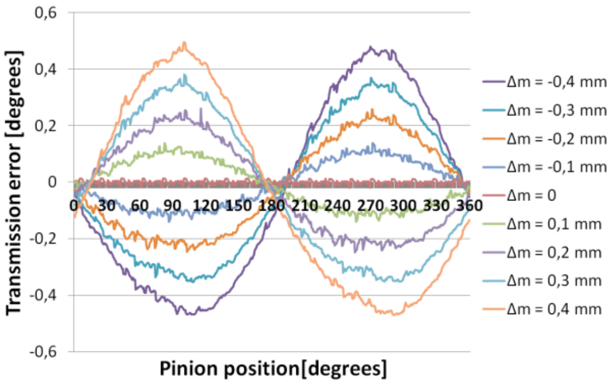

Fig. 6. Transmission error for Δm

Analyzing both charts, it may be stated that the smallest transmission error is for correct position and it increases along with the position error of toothed gears. This is clearly visible in figure 7 where the total transmission error is presented. The teeth of toothed gears were constructed as ideal and thus the transmission error is caused only by improper position of wheels with respect to each other.

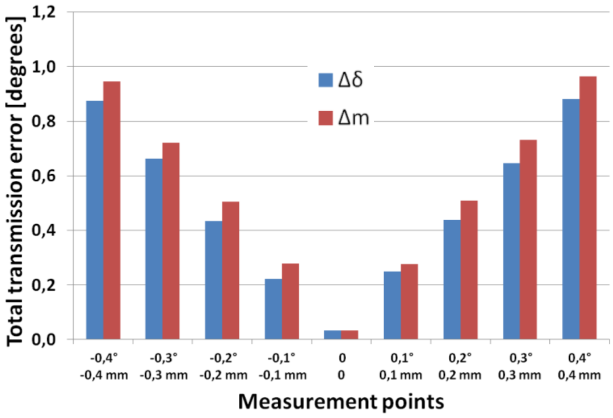

Fig. 7. Total transmission error

Conclusions

The thesis analyzes the impact of installation error and executive error on the transmission error. The simulation of single flank testing turned out to be a fast and useful tool.

The analysis of error of failure to observe angle between axes of toothed gears shows a clear correlation between the value of error and the total transmission error. The greater the error of this angle, the greater the total transmission error. The same dependence occurred for the failure to observe the mounting distance of the crown wheel.

Errors caused in the course of production of elements and in the course of installation have impact on the transmission error. This causes an uneven rotational speed of the output shaft and thus the formation of additional vibrations and noise.

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