THE INFLUENCE OF TOOTH SURFACE MATCHING OF BEVEL GEARS IN AUTOMOTIVE TRANSMISSIONS ON THE MESHING PROCESS

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In bevel gear transmissions, the quality of the meshing process is determined by the spatial geometry of the tooth surfaces and the degree of their mutual geometric conformity. The matching of the tooth surfaces directly affects the position, size, and shape of the contact pattern within the meshing zone, thereby defining the load distribution characteristics. If the tooth surfaces are not theoretically well matched, the contact zone shifts, the load is distributed unevenly, and, as a result, additional dynamic loads, increased noise, and intensified wear processes occur in the gear pair.

Under practical manufacturing conditions, technological factors lead to certain geometric deviations on the tooth surfaces of gears, which disrupt the conformity between mating surfaces and cause the meshing process to deviate from its optimal state. Therefore, the analysis of tooth surface topography, the quantitative evaluation of deviations, and their purposeful modification are of significant scientific and technical importance for improving the operational reliability of gear pairs.

If it is necessary to improve this conformity condition (i.e., the meshing quality), it can be achieved by modifying the relationship of deviations between the tooth surfaces [1, 2].

If the deviation value at each grid point of the current tooth surface is denoted by $\Delta\delta_i$, and the deviation at the corresponding point of the corrected (modified) tooth surface is denoted by $\Delta\delta_i'$, the magnitude of the change can be determined by the following expression:

$$\Delta\varepsilon_i = \Delta\delta_i' - \Delta\delta_i$$

The current tooth surface of the driving gear can be represented using a vector equation, where ψ_q $(q = 1 \div k)$ denotes the adjustment parameters, and $r_1^{(C)}(u_1, \theta_1, \varphi_1, \psi_q)$ are the parametric coordinates of the tooth surface.

Table 1. Geometric Parameters of the Bevel Gear Pair

Geometric parameter	Driving gear	Driven gear
Number of teeth	10	43
Spiral direction	Left-hand	Right-hand
Shaft angle (°)	90	90
Offset distance (mm)	35	–
Module (mm)	6.283	6.283
Mean spiral angle (°)	50.24	31.37
Pressure angle (°)	22.5	22.5
Face width (mm)	44.4	38
Whole depth (mm)	12.15	11.89
Addendum height (mm)	8.99	1.59
Pitch cone angle (°)	13.1	76.2
Working surface angle (°)	18.3	77.13
Base angle (°)	12.2	70.75

Table 1 presents the main geometric parameters of the bevel gear pair. The numbers of teeth of the driving and driven gears, equal to 10 and 43 respectively (using the GAZ A65K3360 vehicle as an example), determine the transmission ratio, while the selection of opposite spiral directions ensures smooth meshing. A shaft angle of 90° and the presence of a 35 mm offset for the driving gear indicate the hypoid nature of the transmission. The choice of the module and pressure angle, equal to 6.283 mm and 22.5° respectively, is intended to ensure proper conformity of the tooth profiles. Differences in spiral angles, face width, and whole depth between the driving and driven gears indicate the non-uniformity of tooth surface topography, thereby justifying the need to analyze the conformity characteristics.

The target tooth surface is described by the corresponding vector function. Accordingly, the deviation vector between the current and target tooth surfaces can be expressed by the following equation [3, 4].

$$r = r_1^{(T)} - r_1^{(C)}(u_1, \theta_1, \varphi_1, \psi_q) \quad (1)$$

By multiplying both sides of Equation (1) by the unit normal vector and performing differentiation, the following expression is obtained.

$$\delta r \cdot n_1^{(C)} = -\left(\frac{\delta r_1^{(C)}}{\delta \psi_1} \times \delta \psi_1 + \frac{\delta r_1^{(C)} \cdot n_1^{(C)}}{\delta \psi_2} \times \delta \psi_2 + \ldots \frac{\delta r_1^{(C)} \cdot n_1^{(C)}}{\delta \psi_k} \times \delta \psi_k \right) \quad (2)$$

Here, Δε denotes the deviation value of the tooth surface.

In this study, the mutual conformity of tooth surfaces in a bevel gear pair used in automotive transmissions was quantitatively evaluated using the deviation values $\Delta\delta_i$ and $\Delta\delta_i'$, and their difference $\Delta\varepsilon$ was defined as the main indicator characterizing meshing quality. Based on the spatial vector model of the driving gear tooth surface, the distribution of deviations was determined, and the geometric parameters presented in the table confirmed the non-uniform nature of tooth surface topography. The obtained results demonstrate that modifying tooth surface deviations makes it possible to stabilize the meshing process and improve the operational performance of the gear pair.

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