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Calculations of Bending and Contact Rigidity of Gear Teeth and Wheel

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Abstract: This article examines the influence of wear loss values in the unit and parts of the wheel-motor unit of the UZTE16M mainline diesel locomotive on the dependence of the contact and bending stiffness of the gear and wheel.

Keywords: gear, locomotive, degree of gear overlap, radius, gear width, tooth angle.

Introduction

Uzbekistan Temir Yollari JSC carries out tasks not only for regular and uninterrupted transportation of general purpose cargo, but also for increasing the economy of use of both locomotives and diesel locomotives. The central unit of any rolling stock is the wheel-motor unit, which after the first repair sharply reduces the traction force of the locomotive and reduces the coefficient of adhesion of the wheel to the rails. The repair process requires fundamental improvement, which is impossible without the creation of a mathematical model and dynamic models [1].

In addition, there is a change in the reliability values of the working unit of the main locomotives.

The bending rigidity of the gear teeth and wheel significantly depends on the coefficient of the degree of gear overlap, which is determined by the formula according to [2-3].

$$Ea = \frac{\sqrt{R_{c1}^2 - R_{01}^2} + \sqrt{R_{c2}^2 - R_{02}^2} - (A + \Delta A)\sin\alpha_{3i} + b \cdot tg\beta}{\Pi \cdot m_S} \quad (1)$$

Where: R_{C1}, R_{C2}, are the radii of the circles of the gear and wheel protrusions;

R_{O1}, R_{O2}, – radii of the main circles

b – gear width;

m – end gear module;

The table 1 below shows the geometric parameters of the traction gearbox of the mainline diesel locomotive type UZTE16M.

Table 1. Geometric parameters of the traction transmission of the gearbox of a mainline diesel locomotive type UZTE16M

№	Параметры	Шестерня	Зубчатое колесо
1	Number of teeth	17	75
2	Clutch module, mm	10	
3	Adhesion angle	20^0	
4	Correction factor	0,505	0,437
5	Distance between axles, mm	468,8	
6	Number of gears	4,412	

B = 24º 37' 12" – angle of inclination of teeth along the dividing cylinder;

α_{3i} – the gear engagement angle in the end section corresponding to a determined increase by ΔA = 1,2,3 mm in the intercenter distance of the gear due to wear of the liners of the motor-axial bearings.

To calculate the angle α_{3i} we use formula (1)

$$\cos\alpha_{3i} = \frac{m_s(z_1+z_2)\cos\alpha}{2(A+\Delta A)} \quad (2)$$

From formula (2) it is clear that the value of the gear engagement angle in the end section changes with wear of the motor-axial bearing liners (Fig. 1)

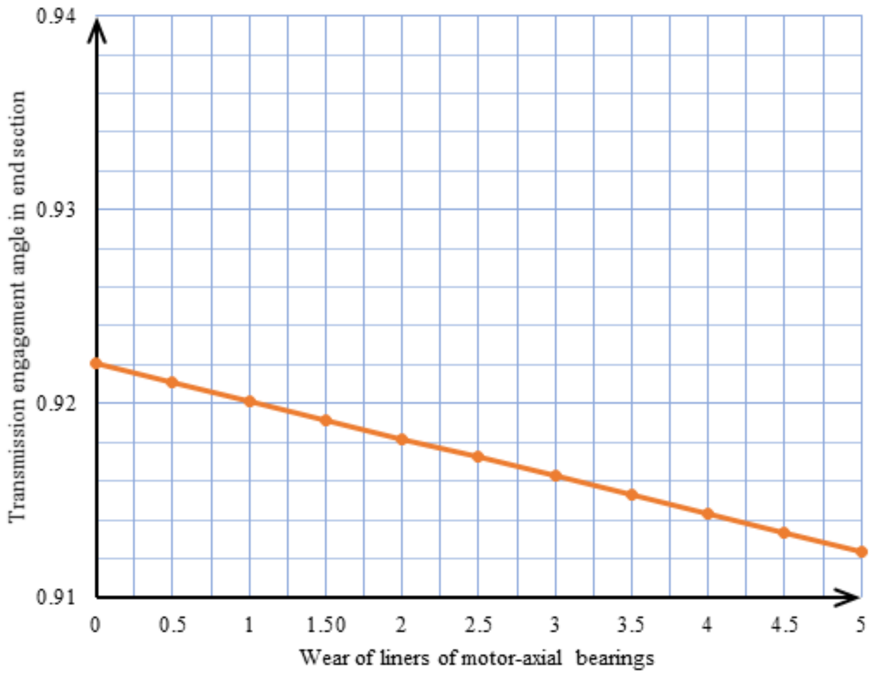

Fig. 1. Gear engagement angle

Due to the wear of the liners of motor-axial bearings, the height of the gear teeth and gears changes, as well as the bending rigidity of the gear teeth and wheels (Fig. 2, 3).

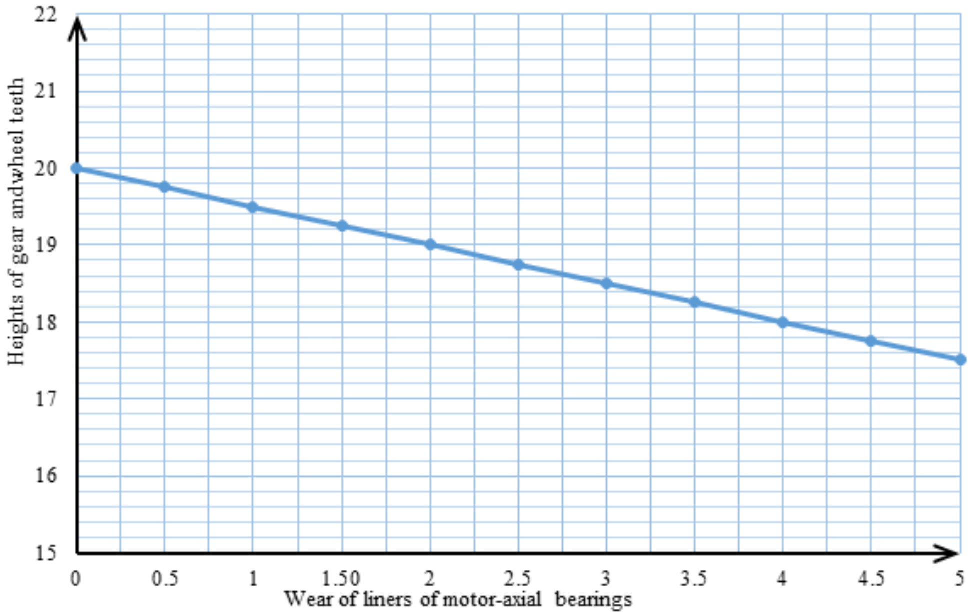

Fig.2. Height of gear teeth and gears

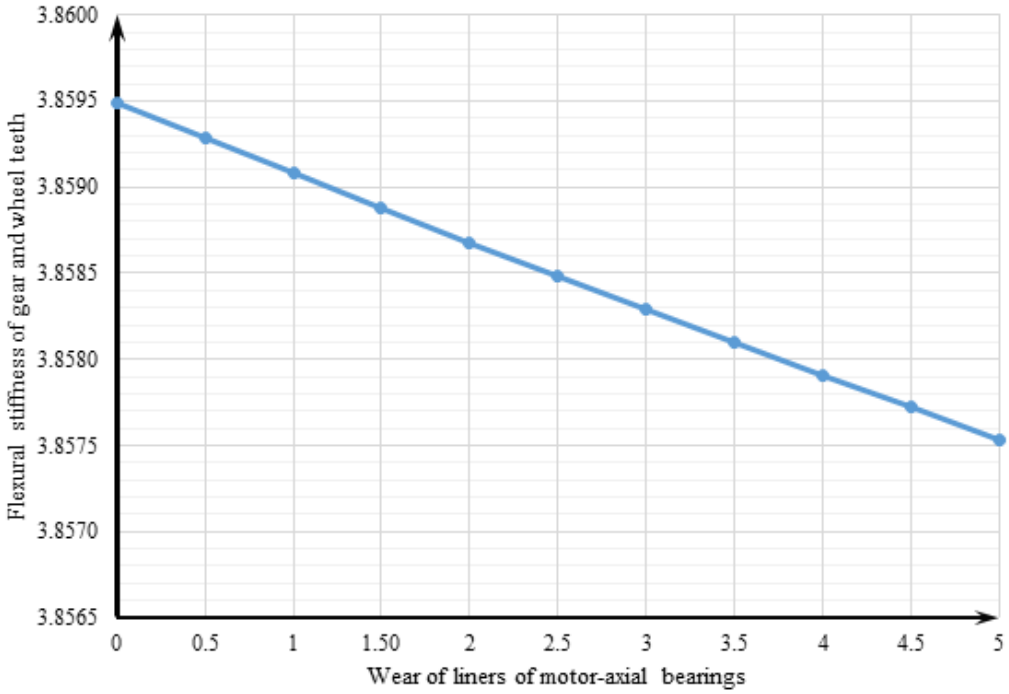

Fig.2. Flexural stiffness of gear and wheel teeth

The choice of the maximum design value ΔA=3 is due to the rejection size of the gap between the axle of the wheelset and the liners for the motor axle bearings of the UZTE16M diesel locomotive up to 2.5 mm for the operating conditions.

The bending stiffness of one tooth of the gear and wheel is calculated using the formulas:

$$C_{3i} = \frac{E \cdot b \cdot S_{ui}^{3}}{4 \cdot h_{3}^{3} \cdot \cos\beta} \qquad (3)$$

Where:: S_{III1}, S_{III2} – average integral thicknesses;

$$S_{ui} = \frac{1}{2}(S_{oi} + S_i) + tg\alpha(2m_n - h_i) - 2\delta \tag{4}$$

Where:: S_{01}, S_{02} – thickness of gear and wheel teeth on the arc of the lugs circle: $S_{01}= S_{02}=6$ мм

S_1, S_2 – the thickness of the gear and wheel teeth along a constant chord at a distance h_1 and h_2, respectively, from the circumferences of the protrusions.

The results of the calculation of C_{31}, C_{32}, and $S_{Ш1}$, $S_{Ш2}$, depending on the wear of the teeth by thickness, are summarized in Table 2.

Table 2 summarizes the results of calculating the torsional compliance of the entire gear train.

$$e_{3k} = \frac{2\cos\beta}{E_{AO} + E_{A3}}\left[\frac{1}{C_{31}\cdot r_1^2}\left(\frac{Z_1}{Z_2}\right)^2 + \frac{1}{C_{32}\cdot r_2^2} + \frac{1}{C_k\cdot r_2^2}\right] \tag{5}$$

Table 2. Calculation results of the torsional compliance of the entire gear train

2δ, [mm]	**0**	**0,5**	**1**	**1,5**	**2**	**3**
$S_{Ш1}$,[mm]	15,25	13,95	13,45	12,95	12,45	11,45
$S_{Ш2}$,[m]	15,37	14,06	13,56	13,06	12,56	11,56
C_{31}[kN/mm]	2,2	2,04	1,9	1,76	1,68	1,39
C_{32}[kN/m]	2,25	2,09	1,97	1,81	1,68	1,45
$e_{3к}$[rad/kN]	1,73	1,92	1,96	2,19	2,22	2,59

Conclusion

Data analysis [4-6] and table. 1, table. 2, the gap between the wheel pair and the motor-axle bearing of the UZTE16M diesel locomotive is up to 3 mm, then the torsional compliance limit changes to 1.73-2.59 rad/kN.

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