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Tooth wear modeling and prognostication parameters of engagement of spur gear power transmissions

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Abstract

In this paper, the wear model of tooth surface contact has been developed. This model takes into consideration the conditions of machine operation, corresponding tribological theories, the eccentricity of pitch circle and the instant temperature in the contact. The prognostication model of gear teeth characteristics takes into account the continuous influence of profile form on the contact parameters and the influence of parameters of contact on the profile form. The full model is done in the form of a package of computer programs. This model includes the kinematic model of tooth engagement with any form of profiles, the elastic dynamic model with four degrees of freedom, the tooth wear model for the boundary lubrication regime of friction and the model of synthesis of tooth wear profile.

Keywords: Gear transmissions; Specific friction power; Specific wear intensity; Wear model; Synthesis of tooth wear profile; Prognostication parameters of engagement

1. Introduction

In the modern world machines are obviously the major means of mechanization used for manufacturing and transportation of huge quantities of all sorts of production. Efficiency of these highly mechanized processes appreciably depends on the reliability of work of tooth gearings of machine drives. Operating conditions for machines used in mining, mining-concentrating, metallurgy, transport, etc. are extremely difficult because of high loadings, high speeds, rough environments which are significantly polluted by abrasive dust. The basic work performance criteria for tooth gearings are based on the computations of bending durability as well as contact endurance, scoring and wear of working surfaces. The wear calculation is the least reliable of all kinds of calculations in spite of a huge number of investigations devoted to this problem. There are two possible reasons for such a phenomenon.

The first reason of insufficient reliability of wear computation has to do with a wide range of lubrication regime being the major factor determining process of wear. Many researchers divide the whole range of lubri-

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Nomenclature

m module (mm)
z_p and z_w number of teeth pinion and wheel;
$u = \frac{z_w}{z_p}$ gear ratio for unworn teeth or average gear ratio for worn teeth
x_p and x_w shift profile coefficients of pinion and wheel
d_{ap} and d_{aw} diameters of addendum circle of pinion and wheel (mm)
ρ_p radius of curvature in the contact point of pinion (m)
ρ_w radius of curvature in the contact point of wheel (m)
$\rho_{\text{red}} = \frac{\rho_p \rho_w}{\rho_p + \rho_w}$ reduced radius of curvature in the contact point of pinion and wheel (m)
a center distance (mm)
b_{min} minimal face width from two contacting toothed wheels (mm)
T_p input torque (N m)
T_w output torque (N m)
W_{n} load per unit width (N/m)
ω_p angular velocity of pinion (rad/s)
BHN_p and BHN_w Brinell hardness numbers of working surfaces of the teeth of pinion and wheel (N/m^2)
RHN_p and RHN_w Rockwell hardness numbers of working surfaces of the teeth of pinion and wheel
σ_{ssp} and σ_{ssw} limits of stretching strain of materials of toothed wheels (N/mm^2)
s_{c} contact stress (of Hertz) (N/mm^2)
E_p and E_w modulus of elasticity for pinion and wheel (N/mm^2)
$E_{\text{red}} = \frac{2E_p E_w}{E_p + E_w}$ reduced module of elasticity of pinion and wheel materials (N/mm^2)
v_p and v_w Poisson's ratio for materials of pinion and gear
R_{ap} and R_{aw} average arithmetic deviation of roughness of tooth shapes of contacting materials (mm)
f_{pb1} and f_{pb2} errors of the basic tooth step (mm)
j_{n} normal lateral backlash (mm)
J_p and J_w polar mass of inertia of pinion and wheel of the researched tooth gearing (kg m^2)
$J_{d,p-1}$ reduced polar mass of inertia from motor to tooth wheel previous to pinion (kg m^2)
$J_{r,w+1} J_{r,w+1}$ reduced polar mass of inertia from working mechanism to the tooth wheel nearest to the researched one (kg m^2)
$C_{d,p}$ reduced torsion rigidity factor of shafts of drive from motor to pinion of the researched transmission (N m/rad)
$C_{r,w}$ reduced torsion rigidity factor of shafts of drive from working mechanism of machine to wheel of the researched transmission (N m/rad)
υ_{typ} and υ_{tyw} rolling velocities of moving of the zone of contact on tooth shapes of pinion and wheel (m/s)
$\upsilon_{sz} = \upsilon_{typ} - \upsilon_{tyw}$ sliding velocity between teeth (m/s)
b_{H} half Hertzian width (mm)
P_z specific power of friction forces in teeth contact with relative rolling and sliding (W/mm^2)
f_z coefficient of friction between the teeth
K_{d} dynamic factor
K_β load distribution factor on the length of face width
v_{t° and η_{t° kinematic and dynamic viscosity of oil at a working temperature of teeth t° (m^2/s)

cation regime into three subdivisions in which processes determining the intensity of wear process of contacting surfaces are qualitatively different. They are:

- the boundary lubrication regime;
- the elastohydrodynamic lubrication (EHL) regime;
- the partial- or mixed-elastohydrodynamic lubrication regime.