

Wear Equation for Paper-Based Friction Materials for Oil-Immersed Clutches

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Paper-based friction materials are widely used in oil-immersed clutches for automatic transmissions for automobiles. They are composed mainly of cellulose fibers and hard particulates bonded by a thermoset resin to give a porous structure. Observation of contact points on a contact microscope has revealed that real contact of the paper-based materials with a flat takes place at the fibers and the particulates on their surface. In its consequence, wear predominantly occurs on them, and the observed contact area under a certain pressure increases with the number of engagement cycles. By closer observation of the contacts by laser microscopy, the contact area determined on the contact microscope was found to be 'contour contact area', not 'real contact area.'

Then, in the present work, analysis is made to describe the progress of wear of paper-based friction materials and the increase in the contour contact area under a certain pressure. A wearing surface of the materials is modeled with a number of spheres and columns, each representing the particulate and fibrous constituents, having the peak heights following exponential distributions. Each of those spheres and columns is assumed to be supported by a spring representing elasticity of the matrix. When a friction material is made slid against a flat steel plate during an engagement, some of the spheres and the columns make contact under different loads depending on their individual heights which means different deformation of the springs, and accordingly wear occurs differently on each of them depending on the particular load distribution. In the successive engagements, different wear of those spheres and columns rearranges their deformation and therefore the load on themselves, resulting in their different wear depth increments which further modify the load distribution.

Mathematical expressions are derived for relating the distribution of the load on the spheres and the columns, the distribution of the deformation of the springs supporting them, and the distribution of wear on them by assuming the linear wear law, as a function of the number of engagement cycles in recurrent formulae. Numerical calculation is conducted and the result shows qualitative agreement with the experimental results obtained from SAE No.2 friction tests.