Modeling of the edge effects for Main Bearings of a Multi-supporting Crankshaft of an Internal Combustion Engine: the Theory

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The mathematical model for improving of the calculation of the main bearings system of a multi-supporting crankshaft of an internal combustion engine is offered. It's based on applying the continuous scheme of the multi-supporting crankshaft with the liquid friction supports which are fixed into the elastic crankcase. The crankshaft is loaded with forces which change both in magnitudes and directions. The elastic behavior of a crankcase is simulated by the finite elements method. The nonlinear properties of the lubricant layers are considered in the continuous model of a crankshaft. To define these properties the set of equations of the movement of a journal (a shaft neck) on a lubricant layer and Reynolds's modified equation for the non-Newtonian liquid has been constructed for each bearing. While creating the set of the motion equations, it was supposed that each journal has 5 degrees of freedom: two linear coordinates of the mass center and three Euler's angles. The rheological model of the non-Newtonian liquid

$$\mu^*(V_{x,z},T,p)=\mu\cdot(I)^{\frac{n-1}{2}}\cdot e^{\alpha(T)p}\cdot C_1 e^{C_2/(T+C_3)}$$

presented in [1] is used in the Reynolds modified equation.

Where μ is viscosity of the lubrication at a low share rate (to 10^2 sec^{-1}); $I_2=\left(\frac{\partial V_x}{\partial y}\right)^2+\left(\frac{\partial V_z}{\partial y}\right)^2$ is the second invariant of share rates; n is the parameter which characterizes the degree of the non-Newtonian behavior of the lubricant; T is the lubricant temperature; p is the hydrodynamic pressure; $\alpha(T), C_1, C_2, C_3$ are the lubricant fluid constants.

It is known that the major problem in the solution of the similar tasks is extremely low values of the film thickness (up to contact) in the areas close to the edges of the bearing (edge effect). Lubricants application with the load-carrying additives significantly reduces the edge effect. To simulate the edge effects including the multiple-viscosity oils properties, the model of the structured lubricant layer presented in [2] is used. It is based on idea of the irregular structure across the layer thickness. This irregularity is caused by interaction of the additives molecules with the journal and bushing materials. Viscosity is presented by the following function

$$\mu^*(y)=\mu_0+\mu_s\left(\exp\left(-\frac{y_1}{l_{h1}}\right)+\exp\left(-\frac{y-y_2}{l_{h2}}\right)\right) .$$

Where μ_0 is the initial viscosity of the liquid at the infinite distance from a surface; μ_s is viscosity of the boundary layer (viscosity of the layer adsorbed on a surface); y is the coordinate in the direction along a normal to a friction surface; y_1, y_2 are the thicknesses of the boundary layers determined by minimization of the hydrodynamic friction forces; l_{h1}, l_{h2} are the reference parameters various for each combination of the lubricant and the material of surfaces. The parameters of the model are defined by means of the original combined computational and experimental technique. More details are explained in [2, 3]. This model has allowed to appropriate quantity of the minimum film thickness value for the big-end connecting rod bearings which have a small film thickness.

The implementation of the presented mathematical statement of the problem, taking into consideration the adequate experimental choice of the models parameters, will allow to increase the quality of the main bearings design of the multi-supporting crankshaft for an internal combustion engine. This will happen due to the simultaneous considering of misalignments of the journals and bearings axes, flexibility of a crankshaft and a crankcase and rheological behavior of the multiple-viscosity oils.

References

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