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Comprehensive summary

Since the early seventies the IRG Transition Diagram has been well established as a means of characterizing lubricants, lubricant additives, surfaces and surface treatments for use under conditions of lubricated concentrated contact, as occurs in, for instance, sliding cams and tappets.

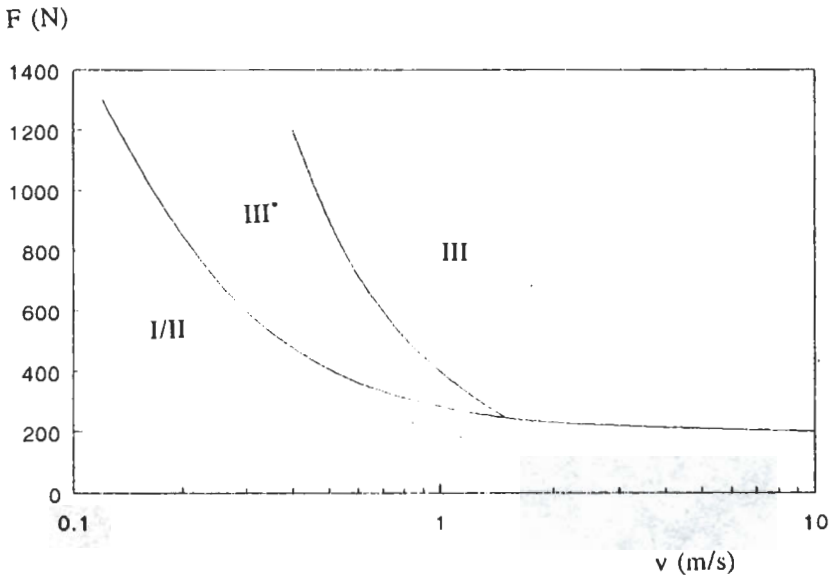


Fig. 1 IRG Transition Diagram (schematic)

Briefly, the diagram, shown in Fig. 1, shows three lubrication regimes, i.e. regime I/II (formerly called I), with coefficients of friction f of the order of 0.1, later changing to approx. 0.02 and specific wear rates k of the order of 10^{-8} mm³/Nm, regime III* (formerly called II), with f of the order of 0.35, later changing to approx. 0.12 and sometimes to approx. 0.02 and k of the order of 10^{-5} , later changing to 10^{-6} and sometimes to 10^{-8} and regime III with f of the order of 0.5 and $k > 10^{-4}$ mm³/Nm.

Analysis has shown that in regime I/II the concentrated contact is protected by a lubricant film which, in a large range of speed values, can be characterized as "partial EHL" because initially some of the highest roughness peaks touch so that the system shows some very mild running-in wear. In regime III* the contacting surfaces are at first unprotected and mild adhesive wear occurs. However, after oxidation of the surfaces boundary lubrication takes over. Finally in regime III the surfaces remain essentially unprotected during the whole contact period and severe adhesive wear occurs ("scuffing regime").

The transitions between regime I/II to regime III* and from regime I/II to regime III are usually associated with failure of the (partial) EHL film, which protects the surfaces in regime I/II. In the present work it was tried to establish whether or not such failure occurs at a well-defined "critical λ -value (λ_c), λ being the ratio of the minimum lubricant film thickness h_{\min} and the combined surface roughness ΣR_a (" λ_c hypothesis"). If so, quantitative transfer of data on load carrying capacity from the laboratory to practice would become possible. To that purpose a new series of experiments was performed, using the (fixed) ball against cylinder geometry and applying three straight paraffin oils with increasing viscosity as lubricants, two oil bath temperatures ($T = 30^\circ\text{C}$ and $T = 60^\circ\text{C}$) and three sliding speeds ($v = 1, 2$ and 4 m/s).

As usual, transition loads F_t were determined by performing 5 min tests at increasing values of force F for each combination of oil, oilbath temperature and sliding speed. Each 5 min test was performed with fresh surfaces and in each test the test load was applied in less than 1s. Criteria for transition were a stepwise increase in the coefficient of friction (I/II-III* transition) and a stepwise increase in wear rate (I/II-III transition).

Applying a newly-developed numerical calculation programme for dry-running contacts, values of the entrance temperature T_e , i.e. the temperature at the entrance of the Herizian deformation zone, could be calculated on the basis of chosen values of T and v and measured values of f_t (coefficient of friction at a load, just below F_t)¹ and F_t .

Using these T_e values, corresponding values of λ (λ_{T_e}) could be calculated (Chittenden equation for elliptic contacts), taking into account the local temperature rise of the lubricant. Unfortunately, these λ_{T_e} values were found to vary from 0.09 to 1.43, depending on the combination of lubricant (viscosity level), oilbath temperature T and sliding speed v . Thus experimental results and calculations did not yield a constant λ_c value.

Still this does not prove the " λ_c hypothesis" to be invalid.

Possible reasons for λ_{T_e} not being constant might be:

- * The Chittenden equation does not (fully) apply.
- * The lubricants do not behave Newtonian over the whole range of test conditions.
- * As a result of elastic compression, roughness in the Herizian contact zone is lower than that outside the Herizian contact zone, elastic compression increasing and λ_c decreasing with increasing F .
- * The value of λ_c increases with increasing v because the time, available for the formation of protective surface layers in between subsequent contacts decreases.
- * Viscous friction in the lubricant, outside the Herizian contact zone ("inlet shear heating") contributes substantially to T_e ².

A detailed analysis of the results (not given in this summary) shows that the latter factor probably predominates. Also it can be shown that λ_c probably has a value of about 0.2³.

¹Note that by using these measured f_t values, the presence of a lubricant was acknowledged to some extent.

²Remember that the temperature calculations were performed for a dry running contact!

³Note that this λ_c value is calculated for an undeformed combined roughness of $0.12 \mu\text{m}$.