Discussion on Paper by A.A. Lierecht et al.: "Solving Reynolds Equation for the EHL line contacts by application of a multigrid method"

must have overlooked the paper, "Die Theorie der hydrodynamischen Schmierung unter besonderer Beruecksichtigung physikalischer Erweiterungen", published by W. Peppler several years earlier (V.D.I. Berichte, Vol. 20, V.D.I. - Verlag, Dusseldorf, West Germany, 1957).

In discussing the figure on page 13 of his paper W. Peppler points out that it was reproduced from an unpublished memorandum of the present discusser. Now, in so far as the results depicted in the figure concerned were not attributed to others, they date back to work the discusser did at the then Royal Dutch/Shell-Laboratory "Delft" in 1944. The three major results then obtained, but never published by the author himself, are the following ones of which the first two are reflected in that figure.

First, by suitably combining dimensional analysis with the complete analytical formulation of the isothermal E.H.L. problem it was proved that, without loss of generality, results in terms of minimum film thickness can be expressed through a set of only three dimensional groups. In fact, once only one such "triple" set has been derived, quite a variety of interdependent such sets can readily be established for the different evaluational and correlational purposes that one may have in mind. The set used in the figure concerned, and also that in the "Moes" E.H.L. Chart (see, e.g., the authors' figures 1, 2 and 5), belongs to that variety of "triple" sets.

Second, a comparatively simple method was developed for arriving at a first approximation to the limiting curve for E.H.L. conditions where the flow in the film may be considered not only isothermal but even isoviscous, i.e. in that the effects of pressure on viscosity may be ignored. The curve thus obtained was indeed depicted in Peppler's, or say the discusser's, figure.

Third, a rigorous method for evaluating the same limiting curve boiled down to an integral equation. In 1968 it was K. Herrebrugh who published his skilful numerical evaluation of the same equation. Remarkably enough it then turned out that, at least up to about M=5 (see the authors' nomenclature), the discusser's approximate curve came fairly close to Herrebrugh's rigorous one. In any case, the discusser agrees fully with naming the present limiting curve after the latter investigator.

Mr H J van Leeuwen (Eindhoven University of Technology, The Netherlands).

The multigrid method seems to be very powerful in ehd line contacts and elliptical contacts. It is appreciated that calculation times can be reduced by several orders of magnitude. In this discussion I would like to pay attention to the Moes curve fit of all obtained numerical data. This curve fit shows an inherent smooth merging of three asymptotes, viz the Ertel/Grubin solution for heavily loaded deforming contacts, the Moes/Herrebrugh solution for elastic/isoviscous contacts, and the Martin/Gümbel solution for inelastic/isoviscous contacts. This is possible by using the dimensionless groups H', L and M, a representation which lends itself to curve fitting very well.

By using this formula, which can be easily programmed on a pocket calculator, designers can now calculate a minimum film thickness estimate, without having to worry about the operating conditions. One formula fits the whole map, which seems very elegant.

Can the authors give some idea of the accuracy in the so-called VR-regime (rigid surfaces, piezoviscous fluid), which is important for e.g. cone roller bearings, and in the very high load part of the regime investigated by Dowson and Higginson, where Hooke (1978) finds an initially positive slope in the Johnson (1970) map? In the VR regime, film thickness is higher than predicted by the Grubin formula, I believe. And in the very highly loaded VE regime, film thickness is a bit lower than predicted by the Dowson and Higginson formula, or the Grubin/Ertel approximation. The formula proposed by the authors is most welcome and will be a very useful design tool.

Reply by Mr A.A. Lubrecht, Dr G.A.C. Breukink, Dr H. Moes, Dr W.E. ten Napel and Professor R. Bosma (Twente University of Technology, The Netherlands).

The authors thank Professor H. Blok for his comments and they agree that perhaps another name should be given to the film thickness plot and the dimensionless parameters used, honouring also the early contributors in this field.

The authors thank ir H. van Leeuwen for his comments and they would like to answer that the accuracy of the numerically calculated minimum film thickness values was better than 5%, except for the L=25 calculations. The fit of formula (15) is believed to be better than 10% and it is exact for the asymptotes.

For those who want to use this equation as a design tool, the simplifications used should be pointed out i.e. isothermal flow and, very important, fully flooded conditions have been assumed.

SESSION IX - ELASTOHYDRODYNAMIC LUBRICATION (4)

'Transient Oil Film Thickness in Gear Contacts Under Dynamic Load'.

A.K. TIEU and J. WORDEN.

Mr H.J. van Leeuwen (Eindhoven University of Technology, The Netherlands).

It seems that Vichard's 1971 paper is becoming a classic in the transient EHD lubrication camp. This discussion is rather a short commentary than a question.

The crucial point in Vichard's paper is the (redundant) boundary condition, that the reduced fluid film pressure be equal to the inverse value of the pressure-viscosity coefficient not at the entrance of the Hertzian contact zone, but in the centre. Under stationary conditions his equations merge into the Ertel/Grubin equations. By putting the boundary condition in the centre rather than at the inlet, the additional load due to the