Special Issue: Hommage to Prof. Duncan Dowson

Institution of MECHANICAL ENGINEERS

Journal of ENGINEERING TRIBOLOGY

Proc IMechE Part J:
J Engineering Tribology
2021, Vol. 235(12) 2614–2615

DOI: 10.1177/13506501211047736
journals.sagepub.com/home/pij
SAGE

# The importance of the work of Duncan Dowson for modeling grease lubrication in rolling bearings

**Piet M Lugt**[1,2]

Most rolling bearings are lubricated with grease which has many advantages over oil lubrication. The main disadvantage is that grease has a finite life, which is almost always shorter than bearing fatigue life [1]. The end of grease life is defined as the point in time where the grease is no longer able to lubricate the bearing, leading to bearing seizure. This is caused by a reduction of the thickness of the lubricating film that separates the rolling element from the rings in time and/or by the loss of the "lubricity" of this film. This elasto-hydrodynamic lubrication (EHL) film is mainly formed by oil that is slowly bleeding from the lubricating grease into the running tracks. During the first revolutions of the bearing, after filling the bearing with grease, grease will be pushed sideways making a so-called "channel." Here the drag forces will be high, leading to higher friction and higher temperatures. After this channeling phase, it may take a few hours before the tracks are completely cleared from excess of oil and/ or grease and the resulting higher friction and temperatures give the impression that the channeling phase just continues. This combined "channeling" and "clearing" phase is denoted by the "churning phase." During this phase there will be much grease in-between the rolling elements leading to a situation where the contacts will be flooded with oil leading to "fully flooded" conditions. Side flow is induced by the motion of the rolllers/balls in the inlet of the contacts, but also inside the EHL contacts due to the high pressures, leading to starvation. This is counteracted by effects such as contact replenishment by local capillary flow and globally by oil separation from the grease reservoirs, that were formed during the churning phase, located under the cage and on the bearing shoulders.

The calculation of the thickness of the EHL film forms the starting point of any physical model that is used to predict grease life or other aspects of grease performance in rolling bearings. It goes beyond the scope of this letter to give an historical overview. For this, the reader is referred to Duncan Dowson's History of Tribology [2] or review papers on EHL [3–6]. The review papers show the impressive contribution of Duncan Dowson to the development of the EHL theory, numerical models, and engineering models. I will focus here on the practical implementation of his work on grease lubrication modeling.

In order to predict the evolution of the lubricating films over long times, numerical EHL models are not very practical and Duncan Dowson was the first one, together with Higginson, to develop relatively simple equations for line contact [7,8] and later for point contact and elliptical contacts, together with Hamrock [9–11]. Others have continued with this work and further developed/refined this after him [12] by increasing the accuracy of the predicted film thickness. Dowson extended his EHL film thickness equations towards starvation [13], making it possible to use these for grease lubricated bearings. Due to the above mentioned complex feed and loss mechanisms in rolling bearings one may argue that these may not be directly applicable. However, Poon [14] and Dowson, together with Aihara [15], suggested in experimental work using a two-disc machine, that the film thickness can be estimated as 70% of its value assuming fully flooded conditions. Developed in the 1970s, this is today still the standard "engineering approach" to calculate the film thickness in grease lubricated bearings.

The other main result of Duncan Dowson's work in predicting the films in grease lubricated bearings was his development of dimensionless groups to characterize the lubrication problem. He defined four groups for the ellipticity, speed, material, and load[16]. In 1965, Moes wrote a discussion on this work[17], where he showed that there are only two dimensionless groups needed (later described in more detail in[18]). Both types of dimensionless numbers are still widely used today. The ones from Duncan Dowson because they are easier to interpret.

Duncan Dowson's equations are still used by my colleagues and me almost every day because of their "ease of use." In grease lubrication there is generally no need for having extremely accurate solutions for the EHL film thickness because of the uncertainties in the continuously changing replenishment effects and rheological

[1]SKF Research and Technology Development, the Netherlands
[2]University of Twente, the Netherlands

**Corresponding author:**
Piet M Lugt, SKF Research and Technology Development, Houten, the Netherlands.
Email: piet.lugt@skf.com

properties that are mentioned above. The grease bleed, evaporation, oxidation, leakage, and other models have not yet reached the "maturity" of the EHL film thickness models. This does not mean that there is no need to further develop these EHL models/equations. There are still many challenges such as the incorporation of non-Newtonian effects. However, understanding the degradation of the grease, leading to an evolution/continuous change of the physical and chemical properties is still the main challenge that needs to be modeled. As mentioned above, in the absence of "engineering models" for this, Duncan Dowson's equations form today still the standard.

To conclude, Duncan Dowson has laid the foundation for EHL numerical models, fundamental understanding of EHL and "engineering models" for EHL, which are directly applicable to grease lubrication in rolling bearings, for which I am very grateful.

## ORCID iD

Piet M Lugt https://orcid.org/0000-0001-9356-7599

## References

1. Lugt PM. *Grease lubrication in rolling bearings*. United Kingdom: John Wiley & Sons, Ltd., The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, 1st edn, 2013.
2. Dowson D. *History of tribology*. New York: John Wiley & Sons Inc, 1999.
3. Dowson D and Ehret P. Past, present and future studies in elastohydrodynamics 1999; 213: 317–333.
4. Lugt PM and Morales-Espejel GE. A review of elasto-hydrodynamic lubrication theory 2011; 54: 470–496.
5. Spikes HA. Sixty years of EHL. *Lubrication Science* 2006; 18: 265–291.
6. Zhu D and Wang QJ. Elastohydrodynamic lubrication: a gateway to interfacial mechanics–review and prospect 2011; 133: 041001.
7. Dowson D and Higginson GR. A numerical solution to the elasto-hydrodynamic problem. *J Mech Eng Sci* 1959; 1: 6–15.
8. Dowson D and Higginson GR. *Elastohydrodynamic lubrication: The fundamentals of roller and gear lubrication*. Oxford: Pergamon, 1966.
9. Hamrock BJ and Dowson D. Isothermal elastohdrodynamic lubrication of point contacts, part I, theoretical formulation 1976; 98: 223–229.
10. Hamrock BJ and Dowson D. Isothermal elastohdrodynamic lubrication of point contacts, part II-ellipticity parameter results 1976; 98: 375–383.
11. Hamrock BJ and Dowson D. Isothermal elastohdrodynamic lubrication of point contacts, part III-fully flooded results 1977; 99: 264–276.
12. Nijenbanning G, Venner CH and Moes H. Film thickness in elastohydrodynamically lubricated elliptic contacts. *Wear* 1994; 49: 217–229.
13. Hamrock BJ and Dowson D. Isothermal elastohdrodynamic lubrication of point contacts, part IV, starvation results 1977; 99: 15–23.
14. Poon SY. Experimental study of grease in elastohydrodynamic lubrication. *Journal of Lubrication Technology, Transactions of the ASME* 1972; 94: 27–34.
15. Aihara S and Dowson D. A study of film thickness in grease lubricated elasto-hydrodynamic contacts. *Proc. 5th. Leeds-Lyon Symp. on Tribol., Mech. Eng. Publishers, London*, 1978, pp. 105–115.
16. Hamrock BJ and Dowson D. Elastohydrodynamic lubrication of elliptical contacts for materials of low elastic modulus 1 – fully flooded conjunction 1978; 100: 236–245.
17. Moes H. Discussion on a paper by D. Dowson. In Proceedings of the Institution of Mechanical Engineers, part 3B; Elastohydrodynamic Lubrication: A symposium arranged by the Lubrication and Wear Group 21st-23rd September 1965; vol. 180. Leeds, UK: Institution of Mechanical Engineers.
18. Moes H. Optimum similarity analysis with applications to elastohydrodynamic lubrication. *Wear* 1992; 159: 57–66.