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# Duncan Dowson's impact on industrial tribology

**Robert I. Taylor**[1]

## Abstract

Professor Duncan Dowson had close connections with industry throughout his academic career, and viewed industrial tribological challenges as problems to be solved and as a source of new ideas. Professor Dowson's famous work on a numerical solution for the lubrication of an elastohydrodynamic line contact, with professor Higginson, was motivated by the need to better understand gear lubrication. These first calculations took 18 months to complete(!), and simpler correlation functions fitted to numerical simulations were developed to enable tribologists in academia and industry to apply elastohydrodynamic lubrication theory without the need for full scale models. Industrial partners such as Shell supplied high-pressure fluid properties required for the elastohydrodynamic calculations (such as the pressure coefficient of viscosity and the way in which lubricant density varies with pressure). Professor Dowson also famously served on the Jost Committee, which quantified, for the first time, the financial impact of tribology, and highlighted that investments in good tribological practices would pay for themselves many times over. It should be remembered that in setting up the Jost Committee, the UK Government specifically asked the committee '*to investigate the state of lubrication education and research and to establish the requirements of industry in this regard*'. Personal memories of the significant collaborations that I was involved with, as an industrial research scientist, with Leeds University from the mid-1990s to around 2013, which predominantly focused on piston ring tribology are also included as is a brief discussion of the Leeds-Lyon Symposia on Tribology.

## Keywords

Elastohydrodynamic lubrication, piston ring, biotribology, gears, lubricants, lubrication

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## Introduction

Professor Duncan Dowson collaborated with many industrial partners during his academic career, and I believe he viewed industrial tribological challenges as problems that could usefully be solved by academia, and as a source of ideas for new projects. In addition, of course, industrial partners provided much-needed funding for PhD students or post-doctoral fellows to work on specific tribological problems. Professor Dowson himself worked in the industry for two years (for the Sir WG Armstrong Whitworth Aircraft Company[1]) after his PhD[2] before he returned to Leeds University as a lecturer in 1954.

The study of elastohydrodynamic lubrication in the United Kingdom was initiated in 1956 by a letter from Dr F.T. Barwell at the Department of Scientific and Industrial Research offering research contracts to study the lubrication of concentrated contacts such as that in gears and rolling bearings.[3] Professors Dowson and Gordon Higginson took on the task and published the first well-known numerical solution for the lubrication of an elastohydrodynamic line contact[4] in 1959. (Later, it was discovered that an earlier numerical solution had in fact been published by Russian researchers[5]). Although there was great academic interest in research on elastohydrodynamic lubrication, there was also practical industrial interest too. The interest in elastohydrodynamic lubrication arose from understanding how gears were successfully lubricated. A simple application of the Reynolds' equation to gears, assuming a fixed lubricant viscosity, and rigid, unyielding surfaces, gave oil film thickness estimates in gears that were very low,[6] much lower than the surface roughness of the gears themselves. Yet, in practice, gears could last for many years and seemed to be successfully lubricated. Professors Dowson and Higginson investigated whether the assumptions of (a) a lubricant viscosity that increased exponentially with pressure and (b) metal surfaces that deformed elastically under significant pressures would lead to

[1]University of Central Lancashire, UK

**Corresponding author:**
Robert Ian Taylor, University of Central Lancashire, Preston PR1 2HE, UK.
Email: RITaylor@uclan.ac.uk

substantially thicker oil films, and their numerical investigations found that this was indeed so.[4]

These early numerical simulations were extremely time-consuming, with the first solutions taking almost 18 months to complete! Professors Dowson and Higginson realised that to be of use to practicing engineers, simpler methods for predicting the oil film thickness in elastohydrodynamic contacts would be needed, and they developed 'correlation' equations[7] that were based on a number of detailed numerical simulations.

The point to emphasise in this section is that the correlation functions were specifically developed so that working tribologists (in both academia and industry) could quickly apply elastohydrodynamic line contact theory to gears and other important contacts, without the need to numerically solve the elastohydrodynamic equations themselves (which at the time, in the 1960s, would not have been possible). It was later found that earlier work by Russian scientists[8] had also found relatively simple equations for the minimum oil film thickness in elastohydrodynamic contacts which broadly agreed with the correlation equations found by Dowson and Higginson. The work on elastohydrodynamic lubrication was later extended to point contacts[9] by Bernard Hamrock (of NASA's Lewis Research Centre) and correlation equations were developed for such contacts, and this work clearly had practical implications for rolling element bearings.

In the 1960s, there was no internet, and academic papers were only readily available in libraries, so an important aspect of the communication of elastohydrodynamic lubrication theory, and its application, was the classic textbook produced by Dowson and Higginson in 1966,[7] which gave a concise account of the theory behind elastohydrodynamic lubrication, the experimental data that supported the theory, and how elastohydrodynamic lubrication theory could be applied to rolling bearings and gears. It is worth pointing out that in the preface to this textbook, specific acknowledgement was given to the Thornton (Shell) Research Centre for providing crucial lubricant data (on the pressure viscosity coefficient of lubricants and on how lubricant density varied with pressure). Further information on the industrial impact of elastohydrodynamic lubrication is given in the relevant section following the introduction.

Following on from his success in developing elastohydrodynamic lubrication theory, professor Dowson was asked to serve on what is now known as the Jost Committee, which was set up by the UK Government '*to investigate the state of lubrication education and research and to establish the requirements of industry in this regard'*. The outcome of the Jost Committee was the famous 'Jost Report',[10] published in 1966, which for the first time quantified the significant economic benefits for the improved control of lubrication friction and wear, and coined the word 'tribology' for the interdisciplinary subject. Further details of professor Dowson's contribution to the Jost Committee are given in the relevant section below.

Professor Dowson continued to work with industrial partners on the tribology of various engine components, such as valve trains, journal bearings and piston rings (a good summary of this work can be found in Taylor[11]). My personal involvement with professor Dowson and the Leeds University tribology group began in 1994 when I attended my first Leeds-Lyon Symposium on Tribology and also was in contact with Martin Priest (now a professor at Bradford University) who was then working with Shell on a PhD to investigate the 'running-in' wear of piston rings that used a single cylinder Caterpillar diesel engine located at Shell's Thornton Research Laboratory. The work led to a widely cited paper by Martin Priest, Duncan Dowson and Chris Taylor[12] with more details in the full PhD thesis.[13] At the time I was developing mathematical models (and computer codes) for piston ring lubrication, and so a close cooperation developed between Shell and Leeds University that lasted until around 2013. A large number of joint projects were initiated that focused on (a) engine and piston friction, and the use of lower viscosity lubricant to reduce friction, (b) fuel–lubricant interaction in the top piston ring zone and (c) a collaboration that also involved York University and the additive company Infineum, to investigate lubricant oxidation at the high temperatures in the top piston ring zone. Further details of this work are outlined in the section below.

Finally, professor Dowson's initiative, with Maurice Godet of INSA Lyon, to set up the Leeds-Lyon Symposium on Tribology, should not be overlooked. Although a relatively small conference (usually with delegate numbers of 150–250) it attracts tribologists from around the world, from both academia and industry, and some of the early conferences that focused on specific topics are still useful references for those topics (such as the first Leeds-Lyon Symposium in 1974 on the topic of 'Cavitation and Related Phenomena in Lubrication', the third Leed-Lyon Symposium on 'Wear of Non-Metallic Materials', the eighth Leeds-Lyon conference, 'The Running-In Process in Tribology'). Further details are provided in the separate section on the Leeds-Lyon Symposium.

One of professor Dowson's legacies is the large number of PhD students that studied at Leeds University and then moved on to tribology positions in academia or within tribology groups in the industry. Those tribologists are now starting to make their own significant impact within the tribology community.

Finally, it must also be mentioned that the tribology community clearly held professor Dowson in the highest esteem as he was elected as a winner of the Tribology Gold Medal (the highest honour in tribology) in 1979 and served as President of the UK's Institution of Mechanical Engineers in 1992.

## Elastohydrodynamic lubrication

### *Elastohydrodynamic line contact correlation equations*

As discussed in the Introduction, although the numerical solution of the line elastohydrodynamic contact problem was a significant step forward, professors Dowson and Higginson realised that simpler equations would be needed by practicing tribologists that needed to apply elastohydrodynamic theory to gears, or other line contacts (such as the cam/follower or cam/tappet contact in the valve train of an automotive engine). Thus, they developed 'correlation equations' based on data from a number of detailed simulations, which are still widely used today.

Within their elastohydrodynamic theory of line contacts, a number of useful dimensionless parameters were found to be of use, in particular, $U$ (a speed parameter), $W$ (a load parameter) and $G$ (a materials parameter), which are defined below:

$$U = \frac{\eta_o u}{E' R} \tag{1}$$

$$W = \frac{w}{E' R} \tag{2}$$

$$G = \alpha E' \tag{3}$$

where $\eta_o$ is the lubricant dynamic viscosity at the inlet to the contact (Pa·s), $u$ is the speed (m/s), $w$ is the load per unit length (N/m), $E'$ is the effective elastic modulus of the contact surfaces (Pa), $R$ is the effective radius curvature of the contact (m) and $\alpha$ is the viscosity pressure coefficient ($Pa^{-1}$) of the lubricant (typical values for this parameter are 10 to 20 inverse GPa, although the pressure viscosity coefficient varies with both temperature and pressure, and type of base oil used in the lubricant).

In terms of these dimensionless parameters, the correlation function for the minimum oil film thickness of an elastohydrodynamic line contact was found to be[7]:

$$H_m = \frac{h_{\min}}{R} = 1.6 G^{0.6} U^{0.7} W^{-0.13} \tag{4}$$

As mentioned in the introduction, it was later discovered that earlier work in Russia had led to a simple, analytical expression for the minimum oil film thickness in an elastohydrodynamically lubricated line contact. This expression is generally referenced as being due to Grubin,[8] although it is thought the original work was done by Ertel. Their result was found to be:

$$\begin{aligned} H_m &= 1.95 (GU)^{8/11} W^{-1/11} \\ &\simeq 1.95 (GU)^{0.73} W^{-0.091} \end{aligned} \tag{5}$$

It should be noted that the above equation is the one quoted in Dowson and Higginson's book on elastohydrodynamic lubrication (equation (4.9) on page 54 of Dowson and Higginson[7]). However, in a recent review of Ertel–Grubin methods[14] a slightly different equation was quoted:

$$\begin{aligned} H_m &= 2.2081 (GU)^{3/4} W^{-1/8} \\ &= 2.2081 (GU)^{0.75} W^{-0.125} \end{aligned} \tag{6}$$

The author does not know why there is a discrepancy between these two different results.

Later researchers[15,16] developed elastohydrodynamic correlation functions that could be applied across the whole lubrication regime, using two dimensionless constants rather than three (the correlation functions in equations (4) and (5) only apply in the elastohydrodynamic lubrication regime).

## *Application of elastohydrodynamic lubrication theory*

In their classic textbook, Dowson and Higginson showed how to apply their elastohydrodynamic line contact theory to roller bearings and gears. Clearly the application to gears is straightforward as these are indeed line contacts. However, for roller bearings, strictly speaking, the theory should only apply to needle roller bearings. For rolling element ball bearings, elastohydrodynamic lubrication theory needed to be extended to point contacts before it could be applied fully.

One area in which there was significant collaboration with industry was in the application of elastohydrodynamic lubrication theory to valve train contacts. In 1986, professor Dowson published a paper entitled 'The lubrication of automotive cams and followers' in the proceedings of the 12th Leeds-Lyon Symposium[17] 'Mechanisms & Surface Distress' (which was held in Lyon in 1985) and the work was sponsored by the Ford Motor Company (from their UK Dunton location). This specific work focused on direct acting bucket tappet type valve trains. The application of elastohydrodynamic theory to the valve train was of considerable interest to industrialists, since this is an automotive component that could be subject to considerable amounts of wear (due to the thin oil films between the moving surfaces). Other research at the time was being pursued separately by both Shell[18] (for finger follower valve train designs) and Ford.[19] Later, useful papers by Bovington[20] (Infineum), Coy[21] (Shell) and Moore[22] (BP) explained how elastohydrodynamic lubrication theory was being used by industry to solve practical problems. Shell also sponsored a PhD student (Marco Workel) at Leeds University between 1996 and 1999 to investigate the use of a 'bouncing ball' apparatus for measuring high pressure properties of lubricants.[23,24]

Elastohydrodynamic lubrication theory was also applied by the Leeds group to human joints, in particular the hip joint. Early work in this area was reported by Dowson[25] in 1966 and a comprehensive review of biotribology was recently published by Dowson[26] in 2012. This was an area where there was significant interaction between academia and industry (in this case, medical professionals). As detailed in Morris et al.,[27] it was not initially clear what mode of lubrication the hip joints operated in. Some medical practitioners believed the hip joint was boundary lubricated,[28] others believed it was hydrodynamic,[29] while others believed it was there was a 'weeping' lubrication mechanism.[30] In 1967, a symposium was held that involved both the Institution of Mechanical Engineers and the British Orthopaedic Association, where Dowson demonstrated that the primary modes of lubrication were elastohydrodynamic with squeeze effects.[31] Professor Dowson worked closely with Verna Wright, an eminent rheumatologist based in Leeds and both had significant interest in joint lubrication and bioengineering. Another significant, long-lasting collaboration then developed between professor Dowson and John Charnley, one of the pioneers of hip joint surgery. Charnley's original interest was in the use of an ultra-high molecular weight polyethylene (UHMWPE) socket against a metal femoral head. Professor Dowson, had, at the time, been investigating UHMWPE as a novel bearing material that could be used in the presence of water and high humidity environments (work that was sponsored by the UK's Ministry of Defence). The reason for Charnley's interest in UHMWPE was that in previous hip joint replacements polytetrafluoroethylene (PTFE) had been initially used since Charnley believed that a low friction coefficient between the moving parts of the hip joint was desirable; however, when PTFE was used in actual hip replacements, significant wear occurred, and in addition, there were undesirable reactions with surrounding soft tissues which meant the hip joints needed removing. The use of UHMWPE solved the issues found with PTFE. During the many meetings between the two men, either at Leeds University or at Wrightington Hospital, there eventually emerged the Charnley low friction arthroplasty,[32] which is generally referred to as the 'Charnley joint' which was the first artificial hip joint replacement in widespread worldwide use. The Charnley joint was first implanted in a patient by Charnley in 1962.[33] Later analysis found that the dimensions of the Charnley joint were close to optimum for low wear.[34] Later industrial collaborations between Dowson and DePuy International focused on the use of laboratory based hip joint simulators to investigate metal–metal hip joints.[35,36] A comprehensive review of the history of hip joints was published by Dowson[37] in 2001.

## Jost report

It is well known that professor Dowson served on the Jost Committee. This committee was set up by the UK Government to *investigate the state of lubrication education and research and to establish the requirements of industry in this regard*.

For the first time, the potential savings from good tribological practices (regular servicing and oil changes, running machines correctly, using recommended lubricants in machines, etc.) were quantified, and it was found that savings of about £515 million[10,38] could be achieved (these were 1965 figures, when the UK's gross domestic product (GDP) was about £36 billion, so the potential savings were ~1.4% of GDP).

A number of potential research and development projects were proposed for funding to help realise the savings reported. A number of these projects were on tribological subjects directly linked to subjects that professor Dowson had experience in (rolling element bearings, gears, journal bearings, etc.) and also included topics that Leeds University had not, until then, worked on (such as the lubrication of piston rings and the use of lower viscosity lubricants). To some extent, then, the Jost Report laid out a research roadmap in tribology that professor Dowson, and Leeds University, followed, after their success in elastohydrodynamic lubrication. It can hardly be a coincidence that work on piston ring lubrication began at Leeds University in the late 1960s/early 1970s after this topic was specifically mentioned as one worthy of study in the 1966 Jost Report.[10]

A further finding from the Jost Report that would have found favour with professor Dowson would have been the recommendation to set up improved education/training in the subject of tribology. Training courses were set up in the United Kingdom, both as part of the Undergraduate engineering curriculum, and as separate Masters' courses. In addition, short, one-week courses were set up in the United Kingdom, mainly aimed at industry (such as the well-known Cambridge course on Tribology that was run until recently by professors John Williams and Ian Hutchins).

Another recommendation from the Jost Report was the establishment of three UK centres of industrial tribology, one in Risley (near Warrington), one in Swansea and one in Leeds. The Leeds centre was known as the Industrial Unit of Tribology, which opened in 1968, and eventually became integrated with the Mechanical Engineering Department at Leeds University.[39] The Industrial Unit of Tribology was intended to operate on a commercial basis linking to industry and providing consultancy and undertaking sponsored projects. The initial intention was that the Leeds centre would specialise on bearing design and application, although it later also provided advice on elastohydrodynamic lubrication and other tribological topics. In the sense of linking academia with industry, the Leeds Industrial Unit of Tribology was well ahead of its time. It closed in 1997, most likely because University departments were then being tasked to become more commercial, and so in some sense the Mechanical Engineering Department academics were likely competing with the Industrial Unit of Tribology staff for industrial funding.

## Shell/Leeds collaborations on piston lubrication

My own first interactions with professor Dowson, and the Leeds University Tribology group, occurred in 1994. That year, I attended the Leeds-Lyon Symposium on Tribology for the first time, and I also became involved with a Shell sponsored Leeds University PhD project focusing on the wear and lubrication of piston rings. The student involved in the study, Martin Priest, later went on to become a professor at the Leeds University Mechanical Engineering

Department and is now a professor of Tribology at Bradford University. At the time, Martin spent a considerable amount of time at Shell's Thornton Research Laboratory where he used a single cylinder Caterpillar 1Y73 diesel engine for his studies. He installed new piston rings in the engine, and operated the engine for ~100 h, and removed the top piston ring every 10 h or so of engine operation, and measured the amount of wear, and the change in ring profile that had occurred. The objective of the research was to better understand piston ring wear during 'running-in', and how 'running-in' affected the shape of the piston ring and its lubrication. During his PhD project there were of course many meetings between the Shell and Leeds University scientists, and professor Dowson was regularly at these meetings. A widely cited paper[12] on the work was published in 1999. The lubrication of piston rings had been a topic of research at Leeds University from the early 1970s[40–44] onwards. During the early to mid-1990s Shell had been developing mathematical models and computer codes for modelling piston ring lubrication, with a view to including realistic lubricant properties[45] (including the effects of lubricant shear thinning). The motivation for this work was the need to reduce friction in automotive engines by moving to lower viscosity, friction modified lubricants, and so there was a need to better model the oil film thickness in critical engine components for these new oils, to assess the friction reduction potential, and to assess the impact of the lower viscosity lubricants on wear. I had the good fortune to co-author a paper with professor Dowson around this time on the topic of the different cavitation boundary conditions that can be used for piston ring lubrication.[46] Soon after, a useful collaboration started between Shell and Leeds University on the general topic of piston lubrication and engine friction, in the late 1990s and went on until around 2013, and there was regular contact with the Leeds University tribology team (including professor Dowson) and the Shell scientists. At the time of this work, professor Dowson had retired, and was an Emeritus Professor and so no longer had a day-to-day role in the projects but was still very encouraging behind the scenes and was interested to hear and read about the research results.

Highlights from this work were:

- An extended collaboration that involved Leeds, York Universities, Shell and Infineum started in 1999. The objective of the collaboration was to better understand both the tribology and the chemistry of the lubricants within the piston assembly. The detailed work included taking top ring zone lubricant samples to estimate the degree of lubricant oxidation, and the impact that different lubricant additives had on engine operation. Separately, at York University, the chemical pathways leading to hydrocarbon oxidation were investigated, with the aim of better understanding how polymerisation could occur in the later stages of oxidation. Chemical reaction pathways were found that led to molecules with half and double the molecular weight of the original hydrocarbon (in the simplest chemical models of hydrocarbon oxidation, the products had a similar molecular weight as the starting hydrocarbons, so in these simple models it was difficult to understand how polymerisation could occur, although it was well known in practice that oxidation ultimately led to higher molecular weight components). Infineum left the collaboration around 2004–2005, and the focus shifted to fuel–lubricant interaction in the piston zone, and the impact of biofuels on piston ring tribology. Work from this ambitious project was reported in numerous papers from 2003 through to 2011.[47–55]
- A project to measure engine friction on the single cylinder Hydra engine at Leeds University started in 2000 and was initially sponsored by the UK Engineering and Physical Sciences Research Council, Shell, Jaguar (later Ford) and Federal-Mogul. Torque transducers were attached to the camshaft and crankshaft of a single cylinder Hydra engine (based on a 2.0 litre GM gasoline engine with a bore diameter of 85.99 mm and a stroke of 86 mm). These torque transducers enabled the direct measurement of crank angle resolved valve train and total engine friction. In addition, a strain gauge placed mid-way on the con-rod could be used to measure piston assembly friction. (A grasshopper linkage was attached at the bottom of the con-rod to enable data transmission out of the engine. The use of a linkage limited the maximum speeds that could be used to about 2000 r/min.) Crankshaft bearing friction could then be estimated by subtracting the measured piston assembly and valve train friction from the measured total engine friction. As part of the project, Shell supplied Leeds University with a range of lubricants (of different viscosity grade) some of which also contained friction modifier additives. Successful measurement of engine and component friction was achieved, and a number of papers were published on the work.[56–60]

With the closure of Shell's Thornton Research Laboratory in 2013, the formal Shell collaboration with Leeds University unfortunately finished, although support for the Leeds-Lyon Symposium continued (through attendance, presentation of papers and financial support for Student Best Paper award).

One lasting legacy of this particular period of industry/University collaboration was that a large number of PhD students have since become successful researchers in tribology, and a number have gone on to successful tribology careers in industry and academia (e.g. Dr Peter Lee is Head of Tribology at the Southwest Research Institute, Dr Oliver Smith was at Lubrizol Research for a number of years and is now chief executive officer and co-founder of a start-up company and Dr Riaz Mufti is a professor at the National University of Sciences and Technology (NUST) in Pakistan, as well as the Technical Director of a NUST spin-off company).

## Leeds-Lyon symposia

Professor Dowson established the concept of the Leeds-Lyon Symposium on Tribology with professor Maurice Godet, and the first symposia took place in Leeds in 1974, on the topic of 'Cavitation and Related Phenomena in Lubrication' (and cavitation was the topic of professor Dowson's PhD studies). The symposia then alternated, with the second conference taking place in Lyon. Virtually all the Leeds-Lyon conference have taken place in Leeds or Lyon, the only exceptions being in 1997 (when it was held in London, as part of the World Tribology Congress taking place there) and in 2001 (when it was held in Vienna, again as part of the 2001 World Tribology Congress).

The Leeds-Lyon Symposium on Tribology has become established as one of the main regular European tribology meetings, although it is a relatively small conference (with delegate numbers typically between 150 and 250). The meetings attract a mix of academics and industrialists (mainly from lubricant or lubricant additive companies or from car, truck and engine manufacturers). The conference has always attracted a strong contingent from the far east (Japan, and more latterly China). The good reputation that the conference has in Japan may stem from the fact that one of professor Dowson's former research students was Shuhei Toyoda, who is now President of the Toyota Boshoku Corporation in Japan.

One of the unique aspects of the Leeds-Lyon Symposia is that each year a separate specific topic is chosen as the main theme of the conference. In the early years, some of the themes were very specific (such as 'The Running-in Process in Tribology' (eighth symposium), 'Cavitation and Related Phenomena in Lubrication' (first symposium), 'The Tribology of Reciprocating Engines' (ninth symposium), 'Elastohydrodynamics and Related Topics' (fifth symposium), 'The Wear of Non-Metallic Materials' (third symposium), etc.) For researchers in industry these self-contained conference proceedings were extremely useful references (since in the early days of the conferences, internet access to research was not available, and finding academic references usually meant a trip to the library).

Another attractive feature of the Leeds-Lyon Symposia was that although there was an overarching theme to the conference, one could always find other, more diverse talks on tribology that were not usually encountered at other tribology conferences. An example that comes to mind is professor Dowson's paper 'A Tribological Day'.[61] This paper discussed everyday tribology (mainly soft tribology) such as the operation of human joints (such as knees and hips), washing, bathing and showering, the combing, brushing and washing of hair, skin tribology, shaving, and the tribology considerations associated with shoes, clothing and textiles, oral tribology (eating, chewing, teeth and tongues), the tribology associated with eyes, and animal tribology. Industrial colleagues interested in shampoo, or shaving foam, or food tribology would clearly find such a paper of great interest and look for collaboration opportunities. Other talks at Leeds-Lyon over the years have also included, for example, papers on the tribology of snail motion.[62] These diverse and unusual talks at the symposium open the eyes of participants to the wider world of tribology applications and can be a source of new ideas and new innovations.

Industrial partners at the conference are also present at the exhibition (usually manned by journal publishers or companies that make tribometers) and have also contributed to the finances of the conference (e.g. funding prizes for best papers at the conference).

## Conclusions

In summary, professor Dowson worked with many industrial collaborators, including lubricant and lubricant additive companies, engine and component designers and manufacturers, rolling element bearing and gear manufacturers, medical practitioners and medical companies that manufactured hip joints and organisations such as the UK's Ministry of Defence. These companies provided useful funding for research students, and over the years professor Dowson advised over 100 research students. Professor Dowson was committed to education, and was a prime mover, along with professor Maurice Godet, in establishing the annual Leeds-Lyon Symposium on Tribology. His work on elastohydrodynamic lubrication enabled a much better understanding of the tribology and lubrication of highly loaded components such as gears, automotive valve trains and rolling element bearings which was clearly of great interest to manufacturers of such components. In addition, the lubricant was a key component in elastohydrodynamic lubrication whose properties could be controlled by lubricant companies (through choice of base oils and additives) and so lubricant and lubricant additive companies were enthusiastic sponsors of tribology research at Leeds University (and continue to be today). Professor Dowson also investigated the tribology of piston rings at Leeds University, and a significant collaboration began between Shell, Leeds University and others (including York University, Infineum, Jaguar, Ford and Federal-Mogul) that ran from 1999 to about 2013 which looked at fuel–lubricant interactions, lubricant oxidation and degradation in the piston ring zone, the impact of biofuels on piston ring lubrication, and the impact of lubricant formulation (viscosity grade and friction modifier content) on piston assembly and engine friction.

In addition, professor Dowson was keen to quantify the financial benefits of tribology, and was considered a valuable member of the Jost Committee (by Peter Jost himself[63]).

In conclusion, in addition to his already recognised academic contributions, professor Dowson has also had a huge impact on the many industrial partners he collaborated with over the years.

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## ORCID iD

Robert I. Taylor https://orcid.org/0000-0002-3132-8469

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