Pièce de résistance

Professor Roland Larsson, coordinator of the PROACT project, demonstrates the significance of the burgeoning field of tribological research, which could have applications across many sectors, including the automotive and energy industries

What are the principal goals of the Predicting and Optimizing Efficiency and Service Life of Complex Systems (PROACT) project?

The PROACT project aims primarily at developing multi-scale simulation models and tools to predict wear rate, friction, scuffing and seizure risk of lubricated components. It aspires to establish computational technology, in the Swedish industry, as a competitive tool for the development of mechanical systems which will last longer and consume less energy. In addition, it investigates how computational tribology can be used online to predict maintenance needs and maximise efficiency.

Can you provide insight into the emergence of tribology as a distinct field of study? In what sense are low friction and long-life properties seen to be highly important factors for the sustainable growth of industry and society?

Tribology has many advantages: it ensures better quality, has a lower environmental impact, incurs smaller costs, and saves energy. The word 'tribology' was first defined as "the science and technology of interacting surfaces in relative motion and the practices related thereto" by Peter Jost in a 1966 report given to the UK Department of Education and Science. The Jost report showed that "tribological losses" may annually give rise to costs as high as 5-7 per cent of a country's GNP! Although reduced, tribological losses are still significant today, especially with the introduction of new technology. Downsizing, for example, can maximise tribological impact since the same forces must be carried by smaller components.

Why is the prediction and optimisation of friction recognised as being very important for the development of sustainable mechanical components and systems? Can you outline some real-life applications to which your studies bear significance?

Our models and simulation tools have been applied in the making of large heavy-duty hydraulic motors which are used for rotating large machines in mines, paper mills, offshore oil platforms, etc. The hydraulic drive is a good alternative to electric motors with gearboxes, especially at low rotational speeds. We are also trying to reduce the friction between the piston ring and cylinder liner in combustion engines.

What advancements have computer simulation models facilitated in the field of tribology?

The models of lubricated interfaces such as those in bearings, seals, clutches and other components have been improved. Lubrication mechanisms are based on the hydrodynamic effect whose force can, at times, separate the contact surfaces. When surfaces come into contact, part of the load is carried by the 'asperities' (the peaks in surface roughness). This causes wear and higher friction. Our models can be employed for predicting optimum types of surface roughness and lubricants.

Despite such developments, to what extent could it be argued that such computer simulations remain at a somewhat embryonic stage? In what ways is your research engaging with this issue, and what has stifled the assimilation of such technologies into industrial fields?

Most engineers are using finite element rather than tribological analyses to study the strength of components, the flow around them, or the vibrations they may cause. Tribological simulations had not emerged until now because they are complex processes and could not be supported by computer hardware or software. Another problem has been the education syllabuses of young engineers, which do not traditionally include practice in tribological simulations. We hope to change this by sending new PhDs (and some MScs), confident in the use of tribo-simulations, to work in the industry.

Aside from Luleå University of Technology (LTU), the project comprises seven other partners. In what ways is each partner contributing to the fulfilment of the project's aims? Can you give an insight into the specific skillsets or resources they offer?

We have been working with Hägglunds and the automotive industry on clutches and gears. They provide us with knowledge, data and experimental material.

Can you highlight some of the project's key achievements to date?

One of PROACT's major achievements is the reduction of power loss in Hägglunds's motors. Furthermore, we have developed a mechanics model and simulation tool which can be used for wear studies and studies of running-in processes. In addition, we have significantly increased our understanding and knowledge on friction, lubrication, and the influence of surface roughness and texture on friction.

To what extent does the dissemination of results form an important part of the project's remit, and in what ways is this facilitated in practice?

We conduct regular meetings and an annual conference or workshop where we present our findings to all industry partners. We have numerous publications in doctoral theses and scientific journals, and we also participate in international conferences. Another important and efficient way to collaborate with industry is via PhD-students employed at our partnering companies. In the PROACT project two of our students are employed in industry while conducting their PhD studies.

Smooth running

Advanced computational simulations of tribological phenomena such as wear, friction and lubrication of mechanical systems will lead to a better, more efficient and environmentally friendly industry. Research conducted at **Luleå University of Technology** is challenging older modelling techniques, paving the way to a more promising future

THERE IS A direct correlation between the prediction of friction and wear, and energy saving, fuel consumption and service life of mechanical components. Losses and failures due to friction have been proven to be more frequent, costly and damaging to industry and the environment than those from broken parts. Therefore, investigations focused on tribological phenomena – that is, the study of the effects of friction, wear and lubrication of interacting surfaces – can significantly improve the production and maintenance of machines. Predicting the effects and impact of friction will not only save energy, but also reduce emissions of toxic substances and waste.

While the growing use of computer simulations has enabled evaluations to become more rapid and cost-effective, wear and friction simulations are still in a nascent stage and in limited use. All but a few reliable models can predict levels of wear, frictional loss, service life, scuffing and seizure risk. The Predicting and Optimizing Efficiency and Service Life of Complex Systems (PROACT) project fills this gap in industry, and aims primarily at developing multi-scale simulation models and tools for the accurate and reliable prediction of the above phenomena. The project is funded by Proviking (the Swedish Foundation for Strategic Research), the Swedish Research Council, Marie Curie Action 'Wemesurf' and the Swedish industry. PROACT is run by the Machine Elements group, one of the largest tribology research groups in Europe, based at Luleå University of Technology (LTU), Sweden, and consists of professors, PhD and postdoctorate researchers, teachers, administrators and technicians. The Machine Elements group is a multidisciplinary team which includes specialists from various fields such as mathematics, physics, material science, chemistry and mechanics. The research is divided into the following categories: lubrication and lubricants, modelling of tribological processes, friction and wear of materials, and the tribology of components. Most of the research is experimental and is supported by a large part of the international automotive industry. Professor Roland Larsson is the project leader.

LIMITATIONS OF EXISTING MODELS

Friction is normally studied by using the 18th Century Coloumb friction model, whereas the only technique available for testing the efficiency and optimum life of new mechanical systems is the Edisonian 'trial and error' technique. The former model leaves out important parameters such as surface topography, sliding speed, temperature, local contact pressure and lubrication. Friction, in this case, becomes a constant value and is measured empirically or by simple tests. Naturally, a model such as the above cannot give reliable results to improve and optimise systems. Wear modelling is just as problematic: most modern models are based on the linear Archard wear equation. Not unlike the aforementioned Coulomb friction model, the Archard equation neglects important surface features, material properties and operating conditions.

GROUNDBREAKING TECHNIQUES

The PROACT project focuses on friction under boundary, mixed and full-film lubrication to account for most tribological interfaces which are lubricated. Boundary lubrication (BL) is becoming very common as downsizing and higher power rating increase density. Even so, boundary lubrication models remain greatly simplified due to the complexity of the phenomenon that is defined by multiple parameters. K C Ludema, a leading researcher in boundary lubrication, states that up to 80 parameters are required in modelling boundary lubrication. The difficulty lies in measuring and estimating those parameters. The most important input parameters for a boundary lubricated model are the operating conditions, ie. sliding speed, contact pressure, contact temperature, lubricant, and the material features (that is, additive chemistry, additive-surface reactivity, surface material hardness and strength). The output parameters are friction, wear (rate), scuffing risk, seizure risk and distributions of contact temperature, contact pressure and elasto-plastic contact deformation. A description of the hydrodynamic lift and the contact mechanics of rough surfaces is also required for constructing models of lubrication processes. At present, lubrication models are categorised into the mechanic model and the physico-chemistry model. The first type is the most common, though very few attempts have been made to simulate their interaction.

Researchers within PROACT have developed a two-scale technique to model hydrodynamic load-carrying capacity of lubricant films. This technique utilises both deterministic and statistical models. The first scale is the micro- or asperity scale, while the other is the global or macro scale. Advanced mathematics, or so-called homogenisation, is used for discovering the average effect that the micro-scale has on the global scale. Those are combined with a deterministic approach of contact mechanics, particularly at the micro-level. This new technique has been named the Luleå model. Aside from a few exceptions, such as SKF's Beast software and AVL's Excite software, modelling and simulation of friction and wear – ie. computational tribology – is sparsely used in industry. However, the new models and methods developed within the PROACT project can be applied to the above software, as it is used by the project's industry partners, SKF and Scania.

FROM RESEARCH TO WIDER PRACTICE

PROACT's goal is to bring science and fundamental research into industrial application, moving the industry to a higher scientific level. The research team is interacting with other research groups from the fields of mathematics, physics and chemistry. A number of its activities aim at improving experimental observations of friction and wear phenomena. These observations will stand as the foundation for the construction of models used in simulation tools. PROACT's aspiration is to make available accurate and reliable simulation tools that can be put into practice by industry partners, who will, in turn, be able to optimise the developed systems. Owing to their ability to actively or adaptively control or make adjustments to a mechanical system, simulations have various applications. Yet in all cases the goal is to maximise efficiency and predict maintenance needs and durability.

MARKET ADVANCES

Working on the manufacturing of sustainable and energy-efficient products offers obvious market opportunities which can be extended further to include the actual computational models and simulation tools. PROACT's new modelling and simulation techniques can reduce losses by more than 50 per cent reaching up to 80 per cent. Those technological advances achieved within the project can provide effective and versatile tools that could be used not only in the automotive industry, but in a variety of settings, including wind farms or wave power plants. In addition, the introduction of new technology creates further challenges in terms of maintenance and longevity. Extensive testing is required which can be facilitated by those new simulation tools. One of PROACT's partners is a software company called Comsol, whose multi-physics software has gained much international attention because of its flexibility. When used in combination with tribology models, the software can be applied to almost any case. Clearly, the PROACT project has opened up new market potentials for its partners as well as wider industry.

> Technological advances achieved within the project can provide effective and versatile tools that could be used in the automotive industry, as well as wind farms or wave power plants

INTELLIGENCE

PROACT

PREDICTING AND OPTIMIZING EFFICIENCY AND SERVICE LIFE OF COMPLEX SYSTEMS

OBJECTIVES

PROACT aims to develop computational simulations of tribological phenomena such as lubrication, friction and wear. In doing so, the project seeks to address the fact that industries seldom use computer models to estimate friction and wear behaviour. New tools and software will help to optimise machines' energy consumption (fuel, electricity), and will enable the optimisation of surfaces, lubricants, and the shape of contact surfaces.

PARTNERS

Scania
SKF
Volvo Construction Equipment
Hägglunds Drives
Haldex Traction
Statoil Lubricants
SAAB

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PROFESSOR ROLAND LARSSON was awarded his MSc in Mechanical Engineering in 1988 and was employed at Asea Brown Boveri, Finspong, Sweden, from 1988-91. He defended his PhD in 1996 at Luleå University of Technology, Sweden, and became Professor in Machine Elements in 2005. Presently, he is the Head of the Machine Elements group at Luleå.

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