Brief statement and opponency review on the thesis by Ing. Ildiko Ficza

presented to the Faculty of Mechanical Engineering of Brno University of Technology: "Effects of Non-Newtonian Lubricants on Surface Roughness in Point Contacts"

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Brief statement

The thesis of Ildiko Ficza deals with special phenomena related to EHL lubrication of rolling contacts with rough surfaces. When rough surfaces pass through a rolling contact, the pressure distribution in the EHL fluid film will be altered and, at the same time, the shape of the surface micro geometry will change through elastic deformation. In turn, hydrodynamics will be affected.

This complex interaction has already been treated in the past by special numerical techniques assuming Newtonian fluid behavior. However, in concentrated contacts, another complication arises through Non-Newtonian fluid rheology in the high pressure regime.

The thesis presented by Ildiko Ficza addresses this problem and aims at modelling the principal mechanisms involved. A partial aim is to develop a fast and stable numerical solver. For that purpose, a single transverse ridge is studied in an exemplary manner.

At first, the problem is mathematically described. The equations are subsequently solved by applying a multigrid technique. Experimentally, the same configuration is applied to a model ball on disc type rolling contact test set-up which allows to measure film thicknesses and to observe the deformation of the model roughness feature. By varying the fluid properties and operating conditions, the numerical model is validated.

In detail, at first the literature published on numerical simulation of idealized roughness models is reviewed. The influence of fluid rheology and different rheological fluid models are discussed.
Subsequently, the objectives of the research work described in the thesis are lined out.
The following chapter describes the mathematical model and the improved numerical methods applied to solve it.
Finally, simulation results for a wide variation of parameters and a comparison with experiments and other publications are presented and discussed.

As one main result, a faster and more stable simulation technique based on the multigrid method is now available.
Furthermore, it could be demonstrated that non-Newtonian fluid behavior influences pressure and film thickness distributions in a contact featuring roughness mainly at rolling with sliding conditions. Under pure rolling, the alterations are marginal.
Rolling-sliding conditions intensify the elastic deformation of the investigated roughness feature. Non-Newtonian fluid behavior reduces the pressure variations in the vicinity.

Opponency Review

The topic of the dissertation presented by Ildiko Ficza reflects a major issue in the current debate on EHL-lubrication: the role of non-Newtonian fluid rheology and its proper reflection by numerical simulations especially in connection with real surface micro geometries featuring imperfections.

The dissertation meets the stated objectives by enhancing the speed and stability of the numerical solution and demonstrating its effectiveness in an exemplary manner by studying the effects of non-Newtonian lubricant rheology and roughness on local film thicknesses and pressures in lubricated rolling-sliding contacts featuring a transverse ridge. Not surprisingly, there remain areas of improvement concerning convergence and matching experimental data. These are clearly and openly stated.

The procedures applied by the candidate are scientifically sound and appropriate. The results of simulation are repeatedly at each step challenged by a comparison with experiments, alternative methods and results published in literature. Nevertheless, some parameters in the study arguably could have been chosen differently and thus delivered even better results. Especially, the high slide to roll ratios applied both in simulations and experiments are debatable in my view. On one hand, they accentuate the effects of non-Newtonian fluid behavior on simulation results. This is certainly helpful. On the other hand, though, these high slide to roll ratios will entrain significant thermal effects in reality and therefore make it difficult to compare isothermal simulations and experimental data. This issue should have been addressed more clearly.

The specific contribution of the candidate is obvious both regarding the improved numerical methods and the combination of non-Newtonian rheology with geometrical surface imperfections in EHL.

The work presented in the dissertation is an important step in closing the gap between EHL-theory and real applications. It improves the calculation of film thickness and pressures in rolling-sliding contacts which is crucial for the prediction and control of surface induced rolling contact fatigue and wear in bearings, cams and gears.

The structure, formal arrangement and linguistic level of the dissertation is excellent and requires only some minor corrections before publication.

I therefore regard the research as described in his thesis as largely sufficient to recommend awarding the Doctor degree to Ildiko Ficza.

Hannover, July 10, 2015

Prof. Dr.-Ing. Gerhard Poll