On boundary layers and pressure spikes

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One of the most enigmatic features in EHL has been the outlet pressure spike as first shown by Petrusevitch. In the outlet zone the pressure distribution exhibits a logarithmic singularity. This pressure singularity is accompanied by a local film thickness reduction. Numerical calculations by Dowson and Higginson show the spike shape evolution as a function of the operating conditions. Safa and Gohar were the first to successfully measure the spike using a sensor deposited on the discs.

Even though its existence has been recorded for many decades, the precise behaviour has remained elusive because of numerical and experimental difficulties. The current paper studies the spike shape and location as a function of the operating conditions, using fine grid calculations and a boundary layer analysis. As both its changing position and its singular character make a head-on study complicated, the inlet boundary layer was studied as a first step. A quick comparison shows that the pressure difference behaviour in inlet and outlet zone are very similar. Using this difference with the dry contact Hertzian pressure distribution, the inlet boundary layer is examined. It is shown that the pressure difference is first positive, then it reaches a sharp peak, before a smooth negative zone occurs. For increasing loads (M) the width of the inlet pressure difference sweep reduces as well as its peak height. True to a boundary layer, its width tends to zero. Scaling the height and the width on the dimensionless load parameter (M) makes all the pressure difference curves collapse onto one another.

It is tempting to try the same scaling parameters in the outlet region. However, the inlet pressure difference peak is located at X=-1, whereas the outlet spike moves from X=0 to X=1, for increasing load. Therefore, the pressure spike location has to be fitted first. This done, it can indeed be shown that the same scaling parameters used in the inlet make the pressure spike difference to collapse onto a single curve.

Finally, the issue of obtaining experimental proof of the spike characteristics is addressed. Once again, a direct approach was considered too complicated, and it was decided to try to infer the pressure spike shape from precise film thickness measurements of the film restriction. These measured film thicknesses were compared with detailed numerical calculations. The film thickness difference was computed using the same operating conditions for measurement and calculation. This film thickness difference was deconvoluted into a pressure difference. This deconvolution increases the measurement noise to the same level as the pressure spike. Taking advantage of the angular symmetry of the pressure spike, an arc averaging filter was applied to reduce the noise to 10% of the spike height. For the lubricant and operating conditions studied, the "measured" spike and the computed spike have a very similar height.

At a 10% slide to roll ratio, the spike height shows a significant reduction.