A robust piston ring lubrication solver: influence of liner groove shape, depth and density.

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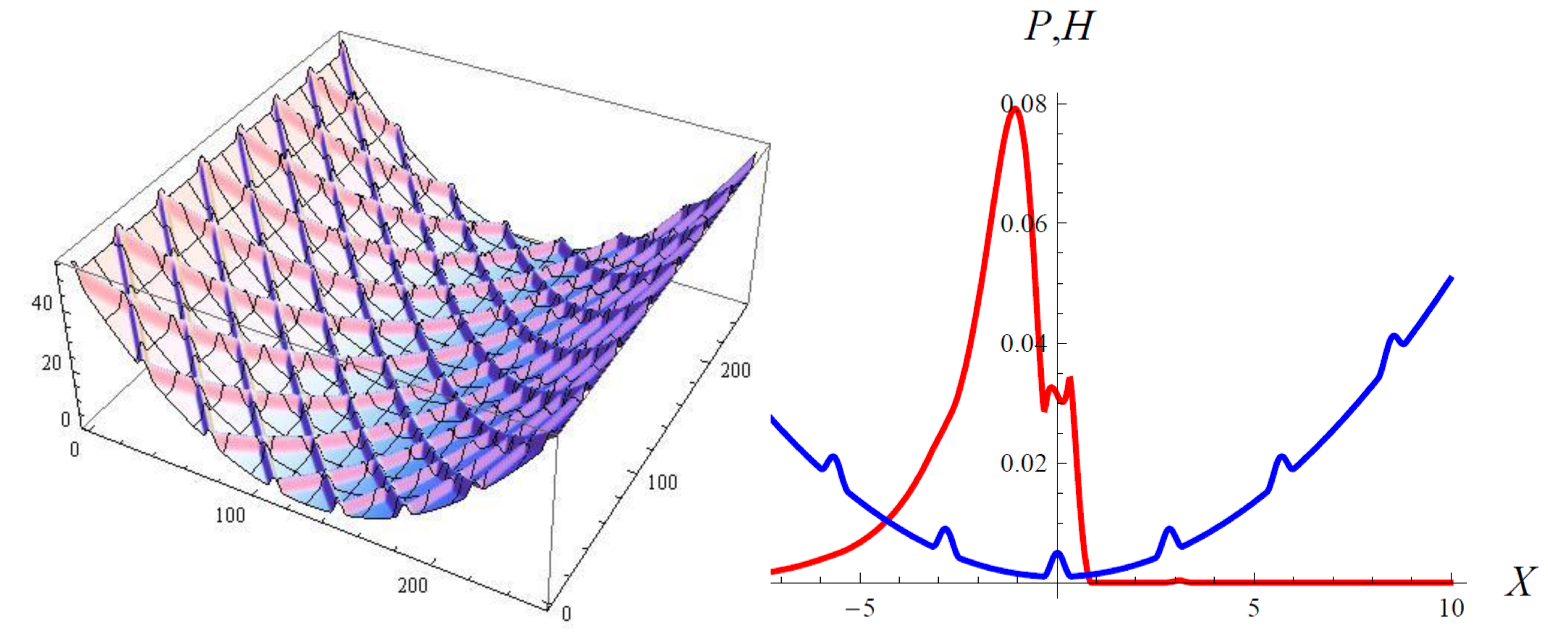
Introduction

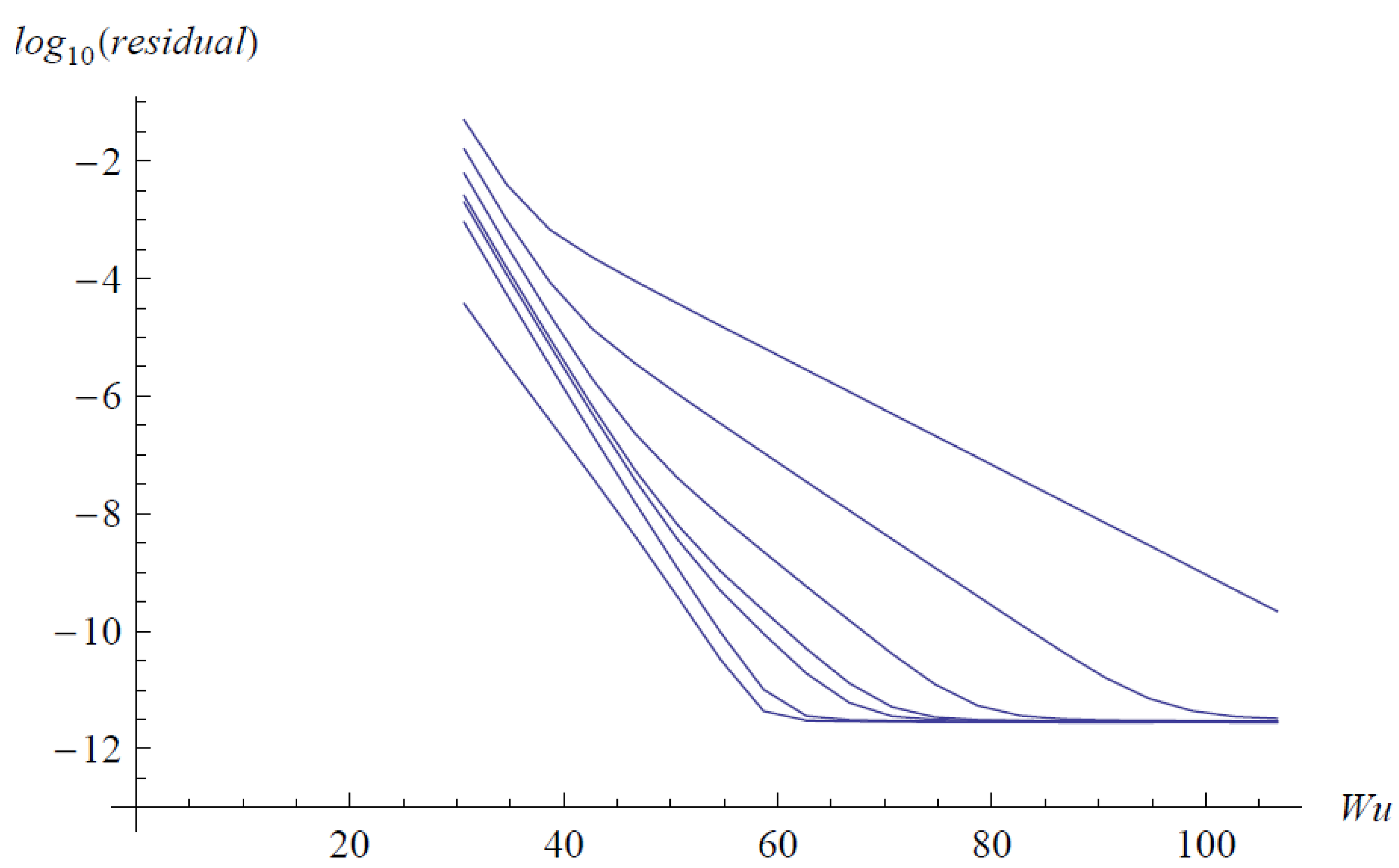
- In internal combustion engines the piston-ring cylinder liner (PRCL) is an important source of friction, while oil consumption is a big source of pollution.
- Alcouffe's[1] ideas were adapted to obtain a robust and efficient multigrid solver for the hydrodynamic PRCL contact.
- The code has been tested for a cross hatched texture and shows good convergence for deep grooves.
- Results were compared with a recent 1D analytic model proposed by N. Biboulet and A.A. Lubrecht[2]

Results 1: convergence

- Analytic cross hatched geometry and central pressure (red) and central geometry (blue) for grooves of depth 4

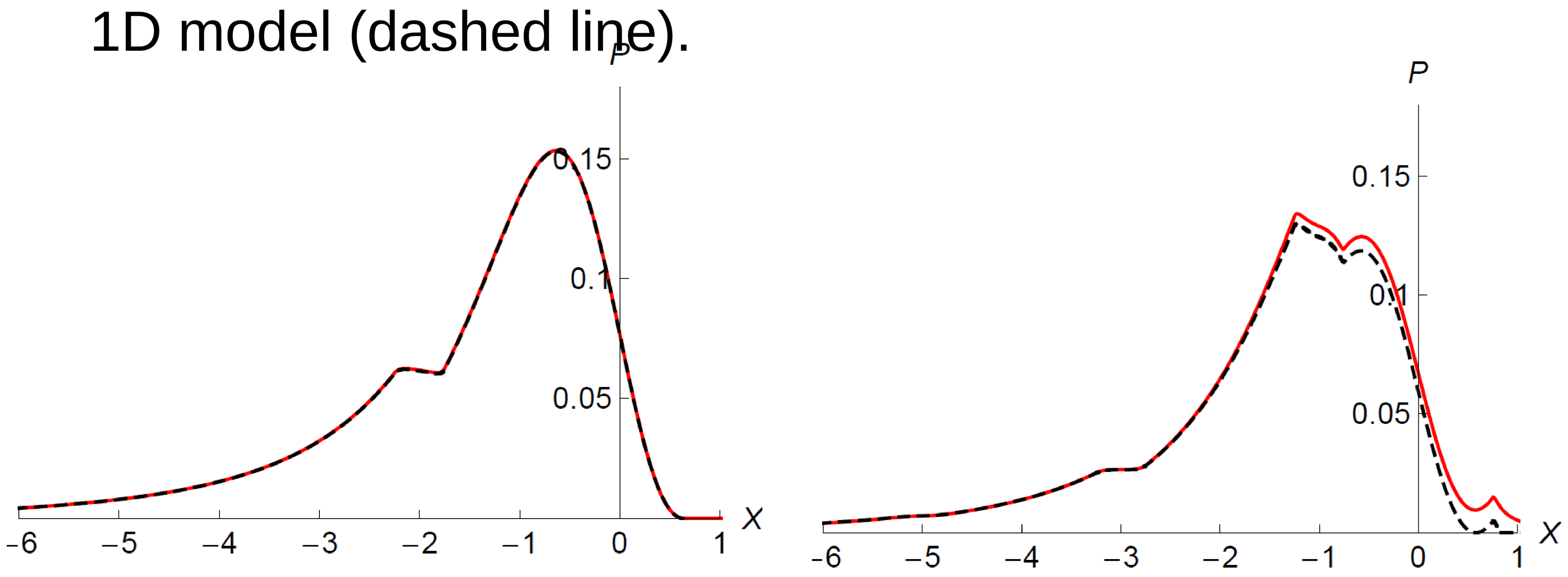


- Convergence: evolution of the residual as a function of the number of work units – grooves of depth 0, 0.4, 0.8, 1, 2, 4 and 10 from bottom to top.



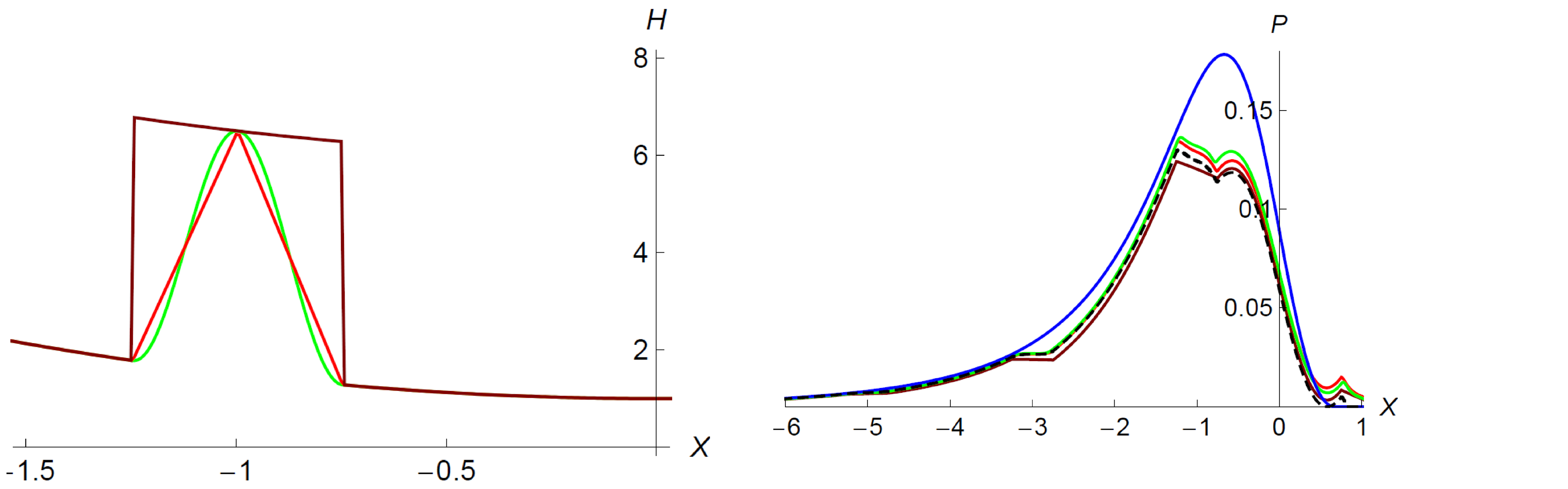
Results 2: code validation

- Numerical pressure distribution on the central line - Triangular groove of depth 5 perpendicular to the sliding direction: single groove (left), multiple grooves (right) and 1D model (dashed line).



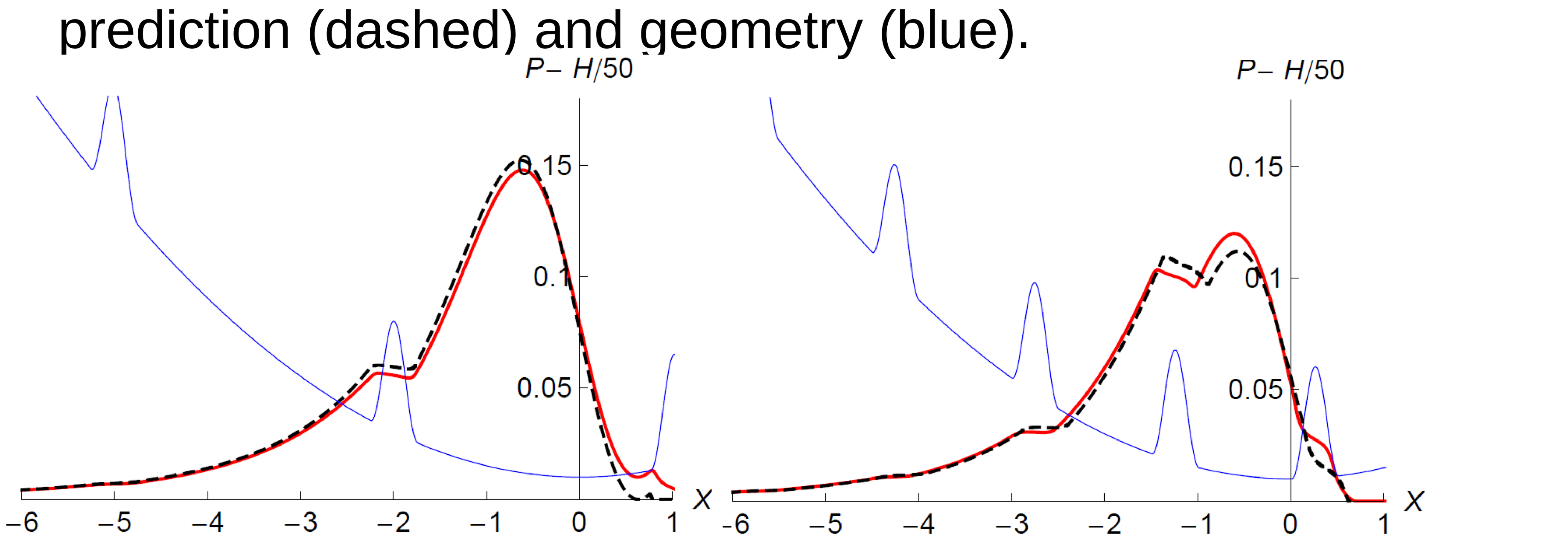
Results 3: influence of groove shape

- Different groove shapes (left) and the corresponding numerical pressure distributions (right) for grooves of depth 5, perpendicular to the sliding direction spaced by 2 and 1D model (dashed line) and smooth pressure (blue).



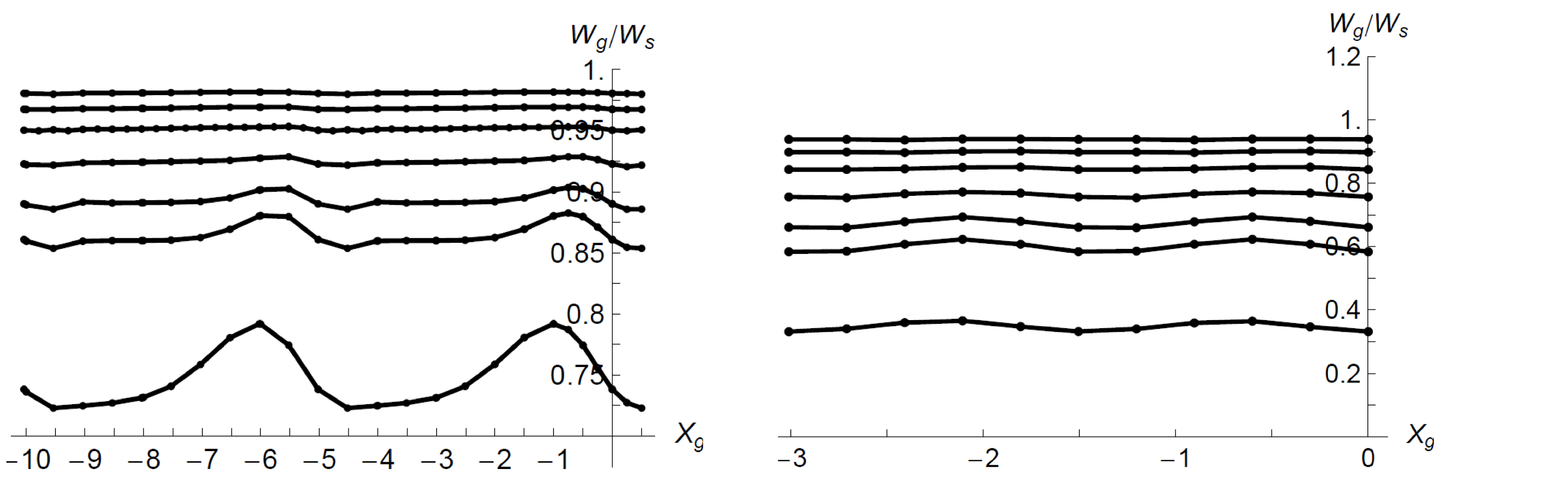
Results 4: angle influence

- Cross-hatched pattern with grooves of depth 5 spaced by D=3 and groove angle α=5°. Pressure distribution on the central line (left) and on the line $Y=-0.25D/\sin(\alpha)$ (right) with 1D prediction (dashed) and geometry (blue).



Results 5: load carrying capacity (LCC)

- Textured LCC as a function of groove position–cross hatched surface, groove angle α=5°, groove depth 0.5, 1, 2, 5, 10, 15 and 50 from top to bottom, grooves spaced by D=10 (left) and D=3 (right).



Conclusion

- Developed a multigrid code based on Alcouffe[1] for the hydro-dynamic lubrication of PRCL contacts with a textured surface.
- Good convergence and robustness, even for deep grooves.
- Results were compared with a 1D analytic model for grooves perpendicular to the sliding direction.
- The groove shape is not an important factor.
- For small angles the pressure distributions are close to the 1D analytical predictions.
- Generally, the 1D analytical predictions of Biboulet et al.[2] are confirmed and only small differences observed.

[1]**Alcouffe E., Brandt A., Dendy J. E. and Painter J. W.**, 1981, "The multi-grid method for the diffusion equation with strongly discontinuous coefficients", *SIAM J. Sci. Stat. Comput, Volume 2, p. 430-454.*

[2]**Biboulet N., Lubrecht A. A.**, 2015, "Analytical solution for textured piston ring-cylinder liner contacts (1D analysis)", *Tribology International, under review.*

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