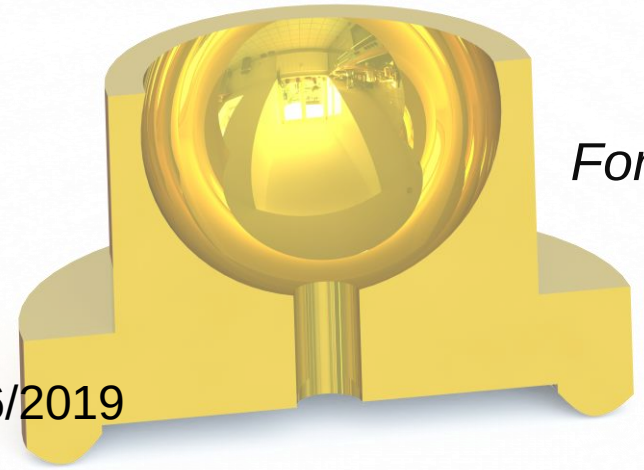
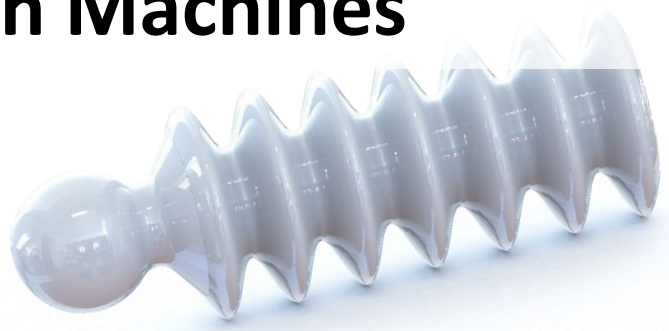
Pushing the Performance Limits of the Lubricating Interfaces in Axial Piston Machines



Meike Ernst
Advisor:
Formerly Dr. Ivantysynova
Currently Dr. Vacca

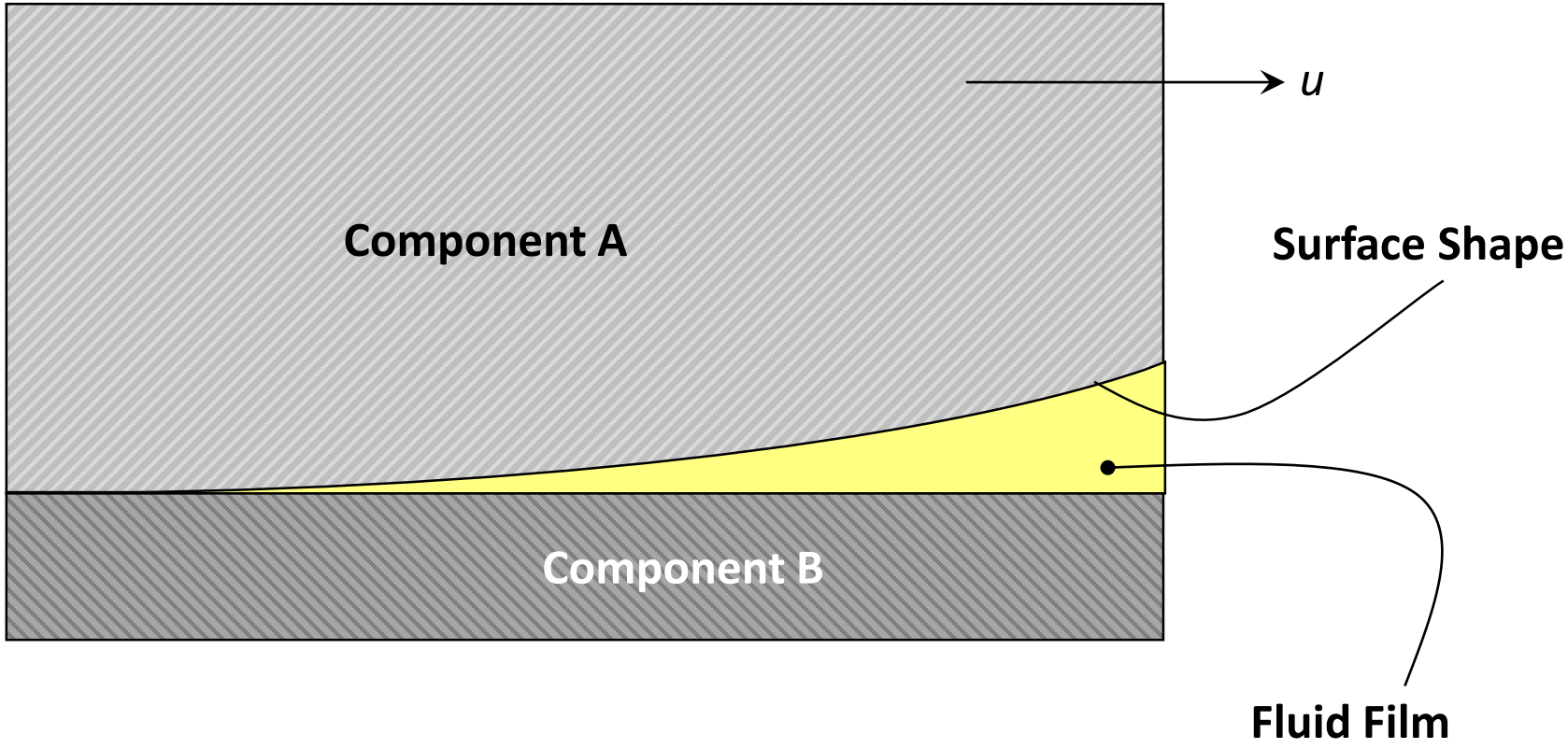


6/6/2019

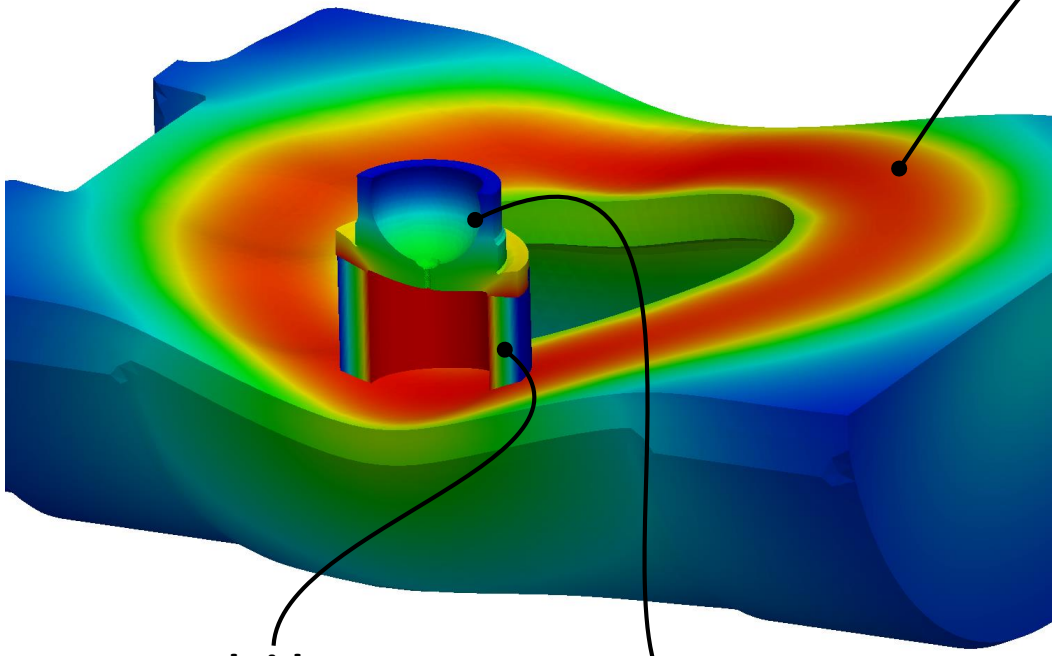
Maha Fluid Power Research Center
1500 Kepner Dr.
Lafayette, IN 47905

Shaping the component surfaces that form the lubricating interfaces

Shape is on the order of microns in height



Load Support and Power Loss at the Interfaces



Swashplate Solid Body

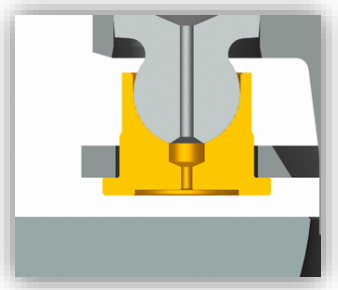
Fluid

Slipper Solid Body

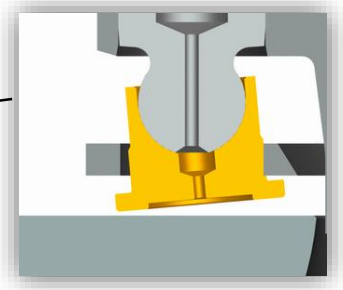
Relative motion of components builds hydrodynamic pressure.

Load support

Translation



Tilt



Translation and tilt can increase **leakage**

From the work of Andrew Schenk (2014)

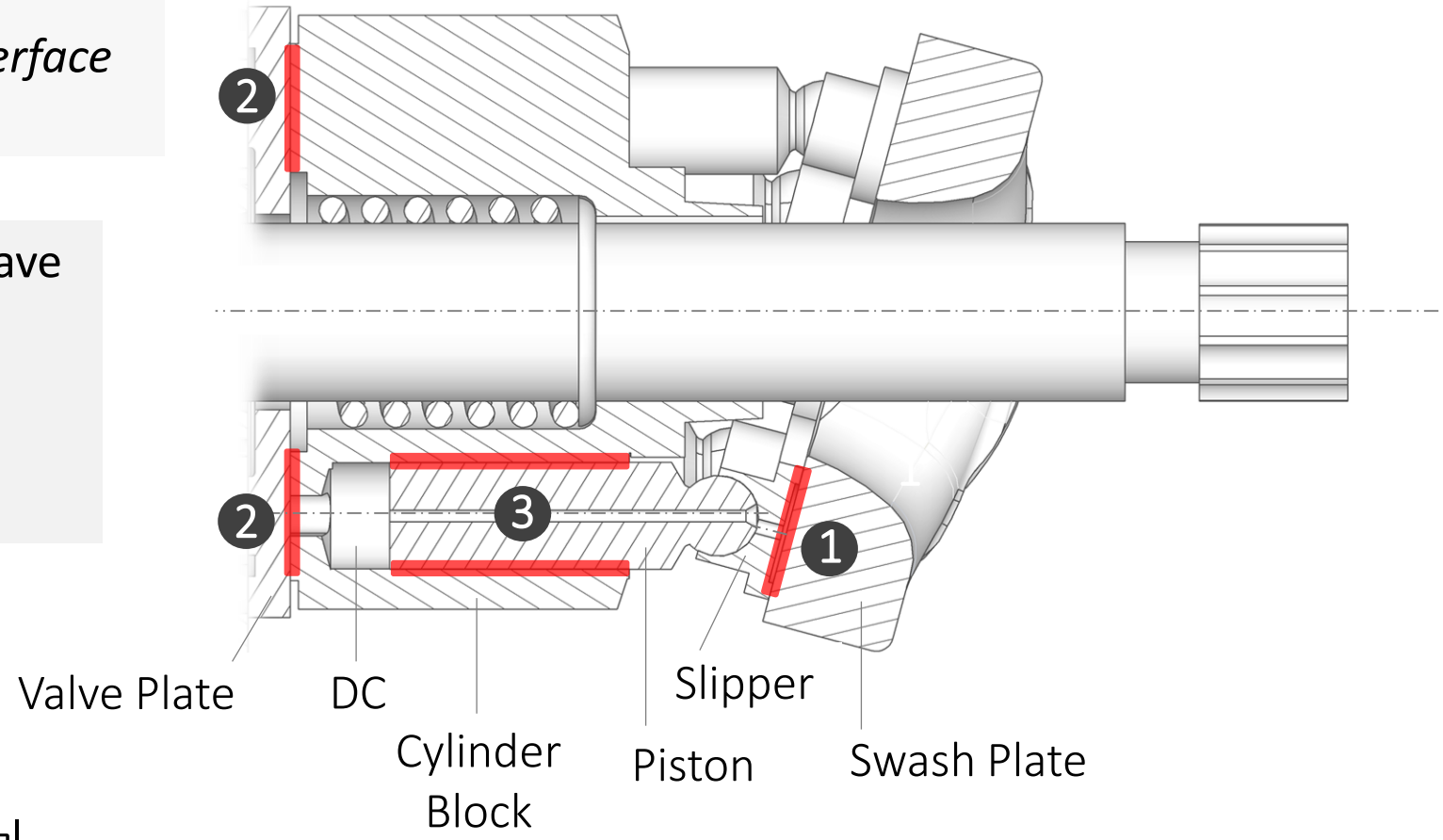
Table of Contents

The Lubricating Interfaces of Axial Piston Machines

1. *Slipper-swash plate interface*
2. *Cylinder block-valve plate interface*
3. *Piston-cylinder interface*

These lubricating interfaces have two important functions:

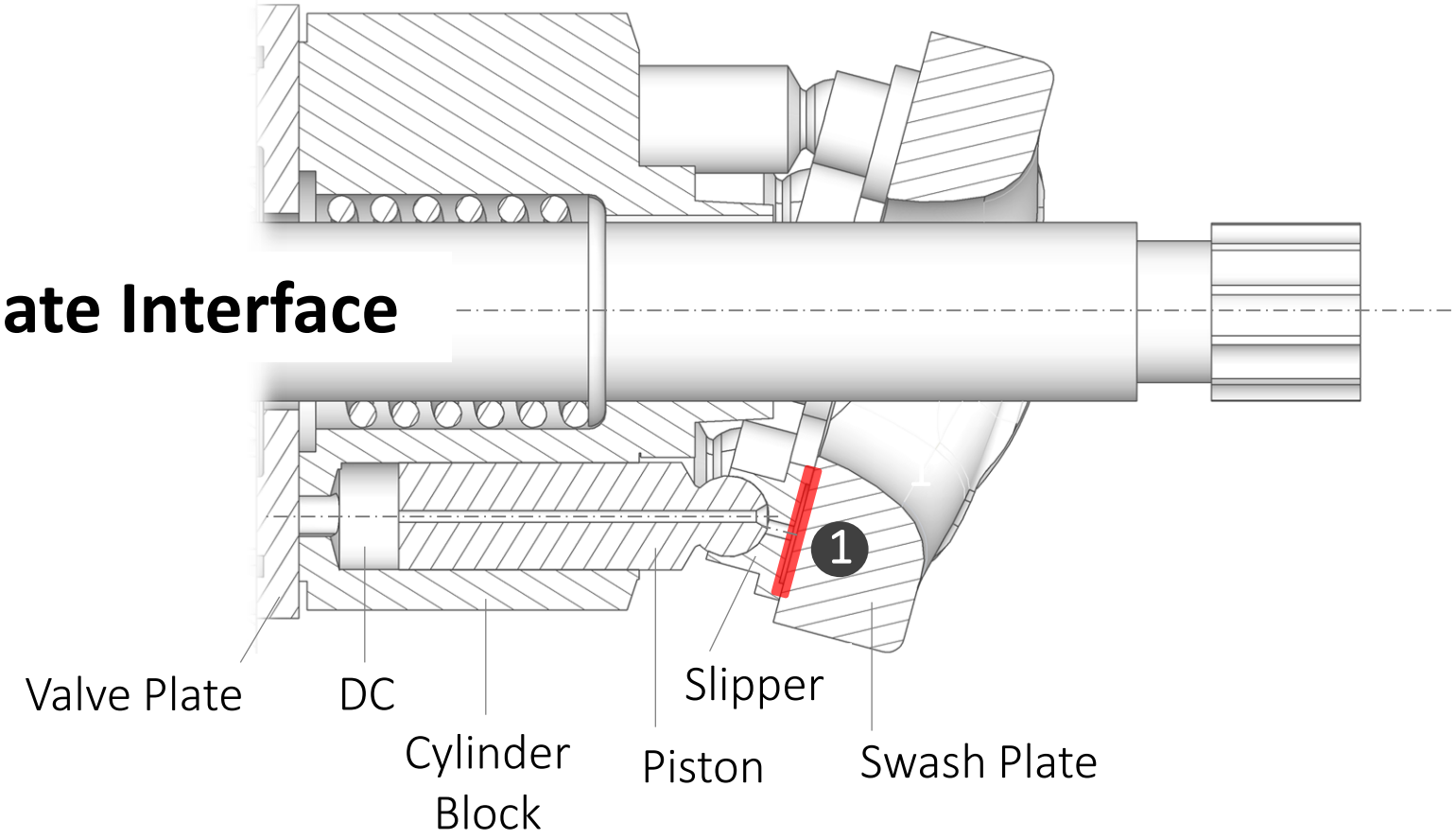
- Bearing function
- Sealing function



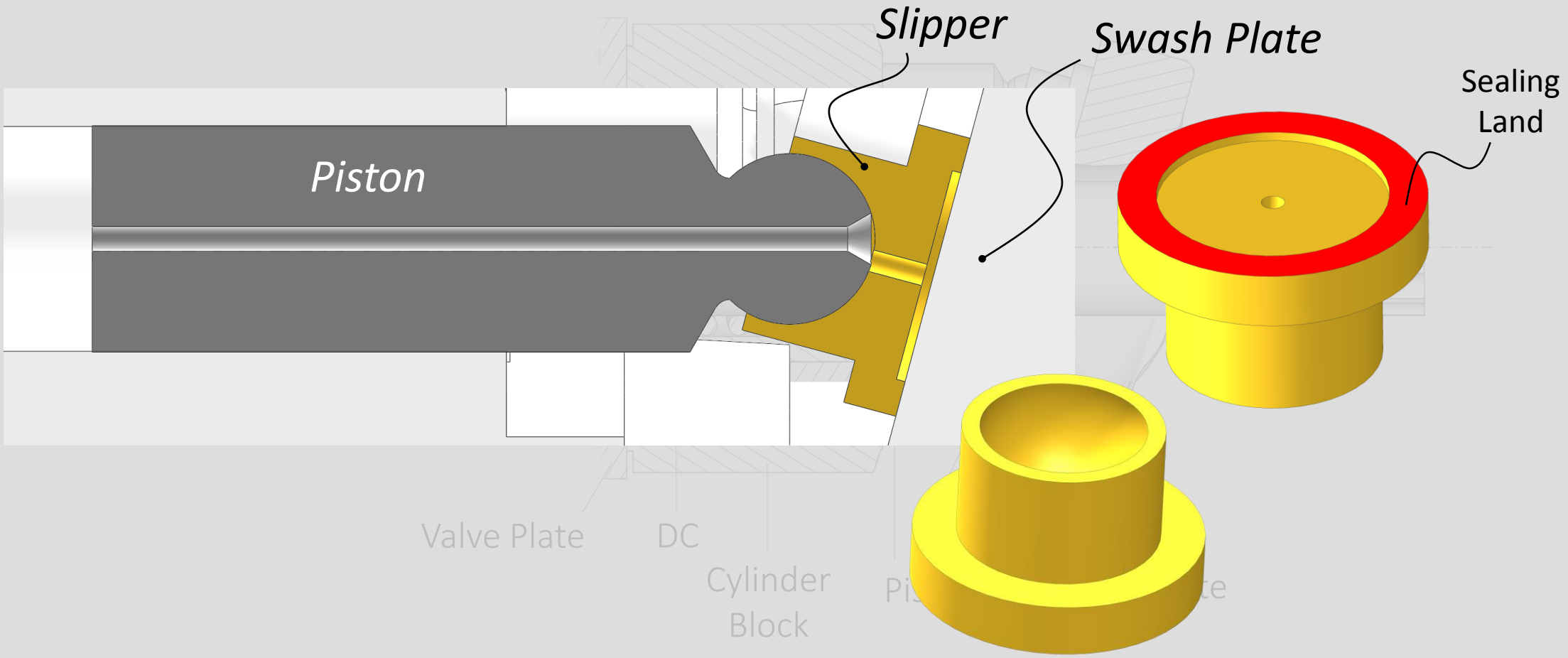
FSTI

a piston pump CAE tool

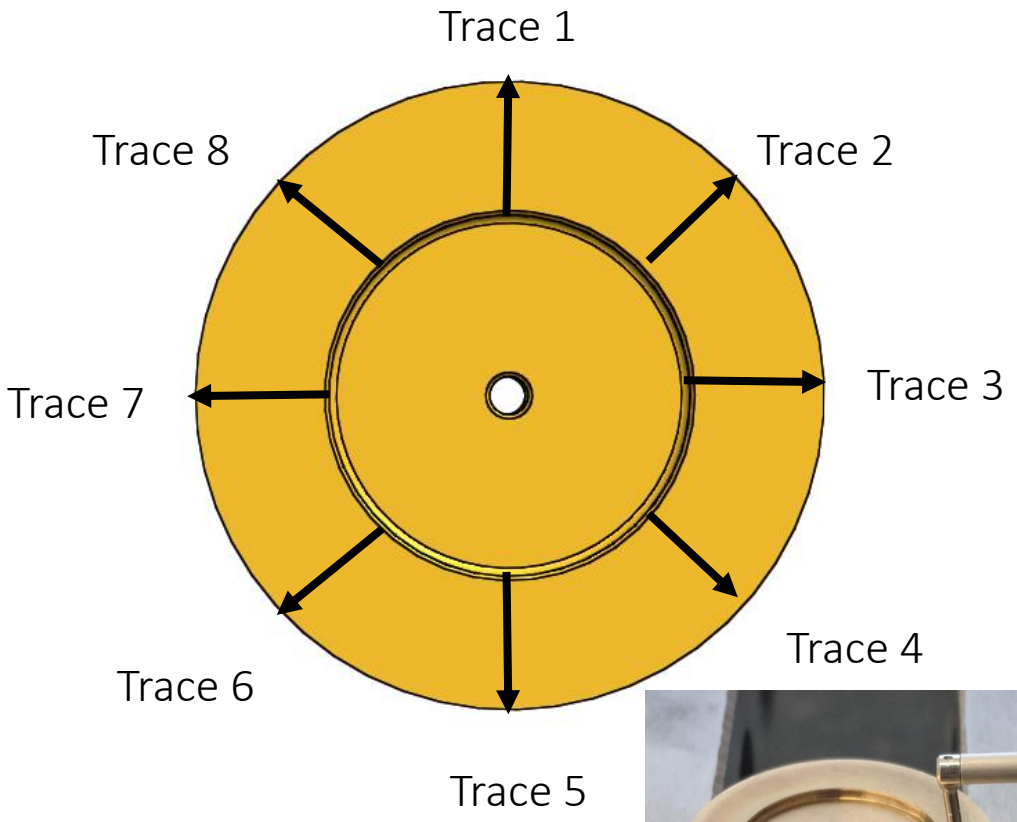
Slipper-Swash Plate Interface

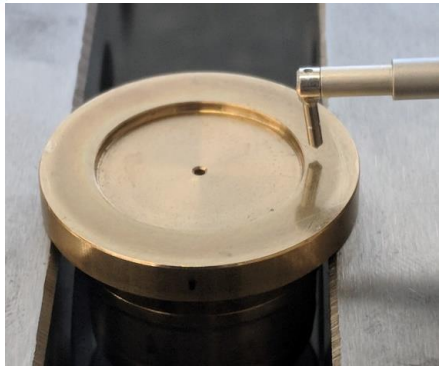


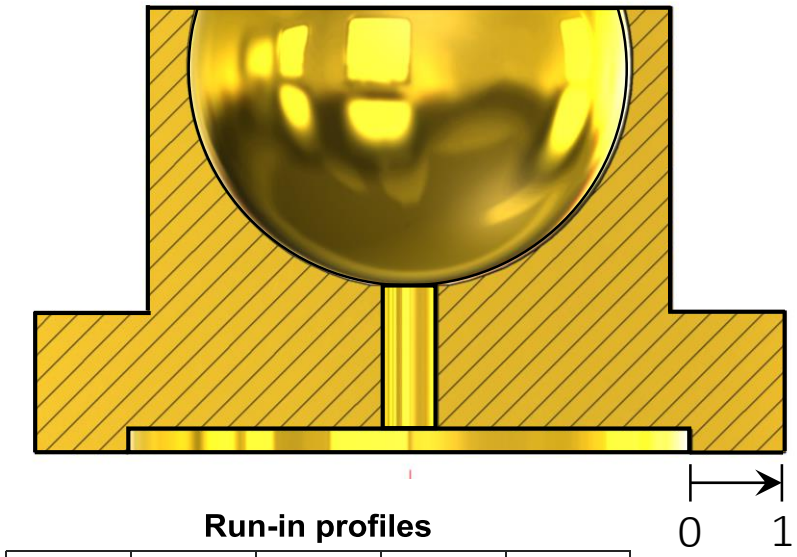
The Slipper

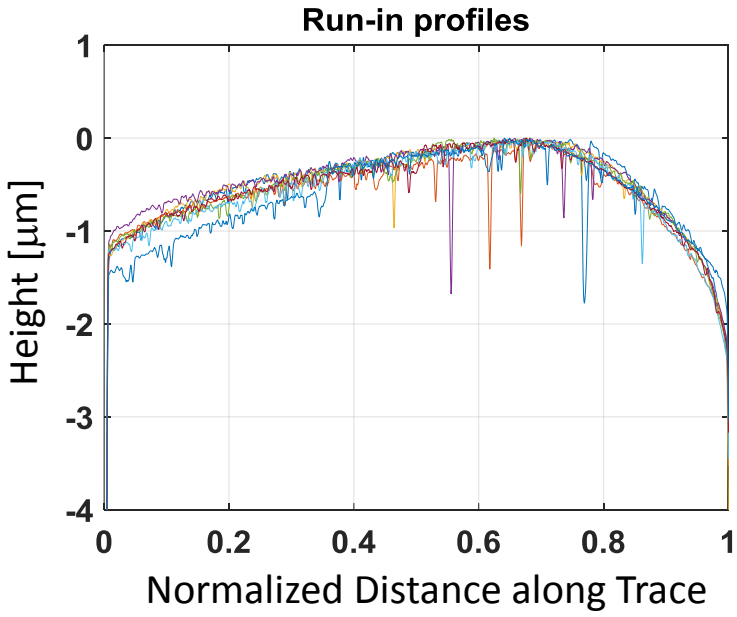

Slipper
Swash Plate
Sealing Land
Piston
Valve Plate
DC
Cylinder Block

Measuring Slipper Wear



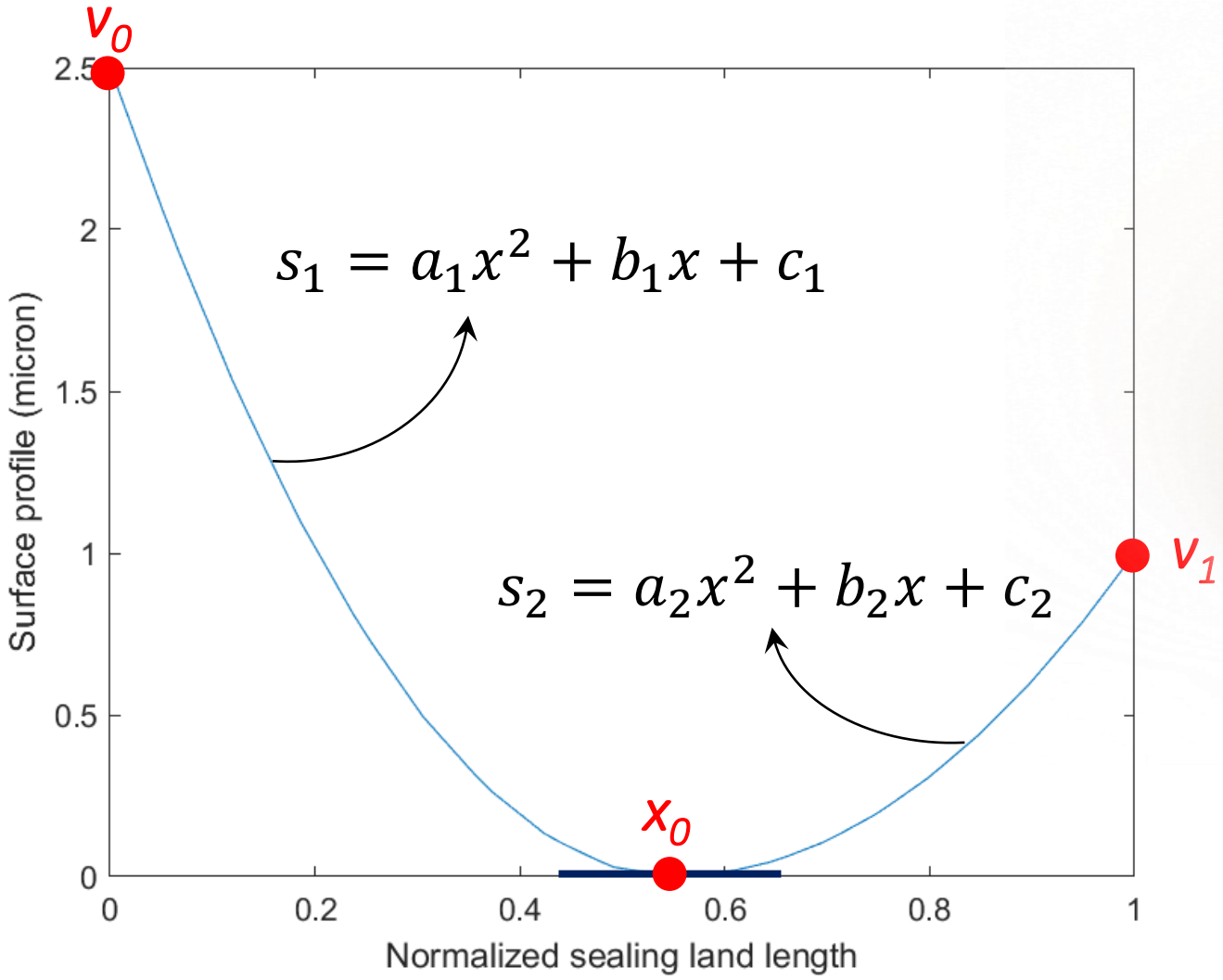


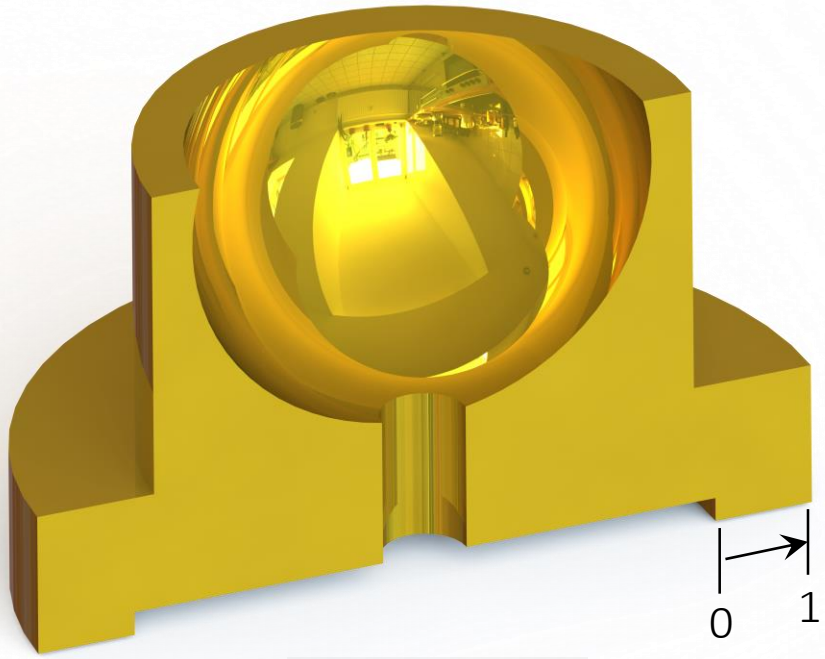




From the work of Ashkan Darbani (2019)

Slipper Surface Shaping



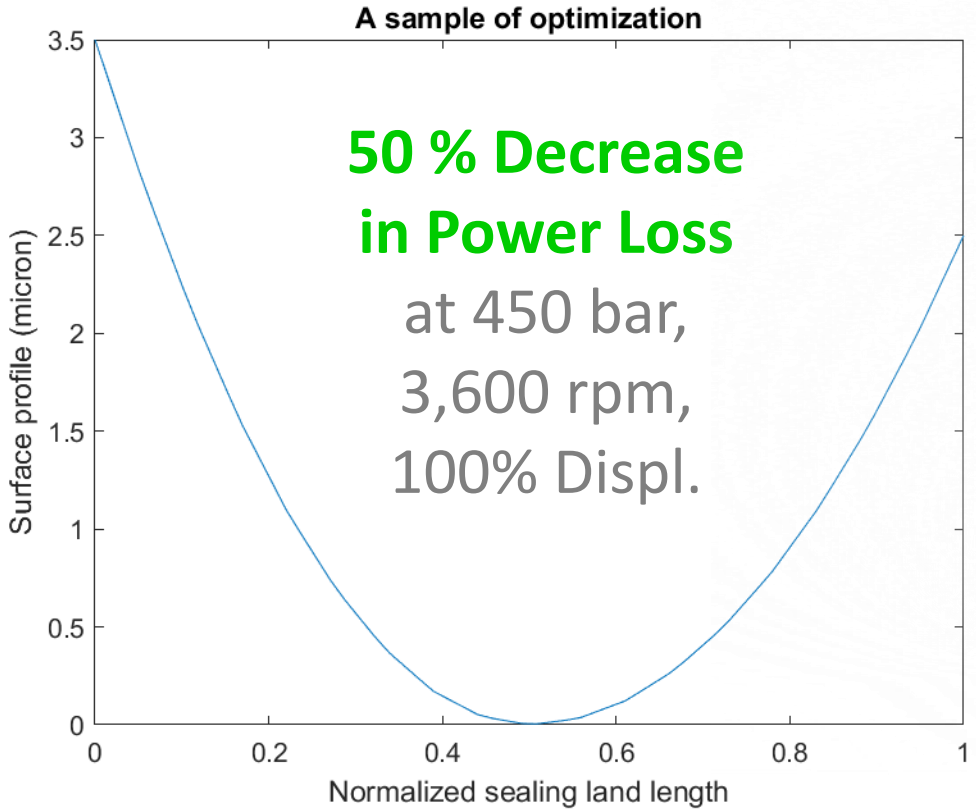


Variables:
v_0, v_1, x_0

From the work of Ashkan Darbani (2019)

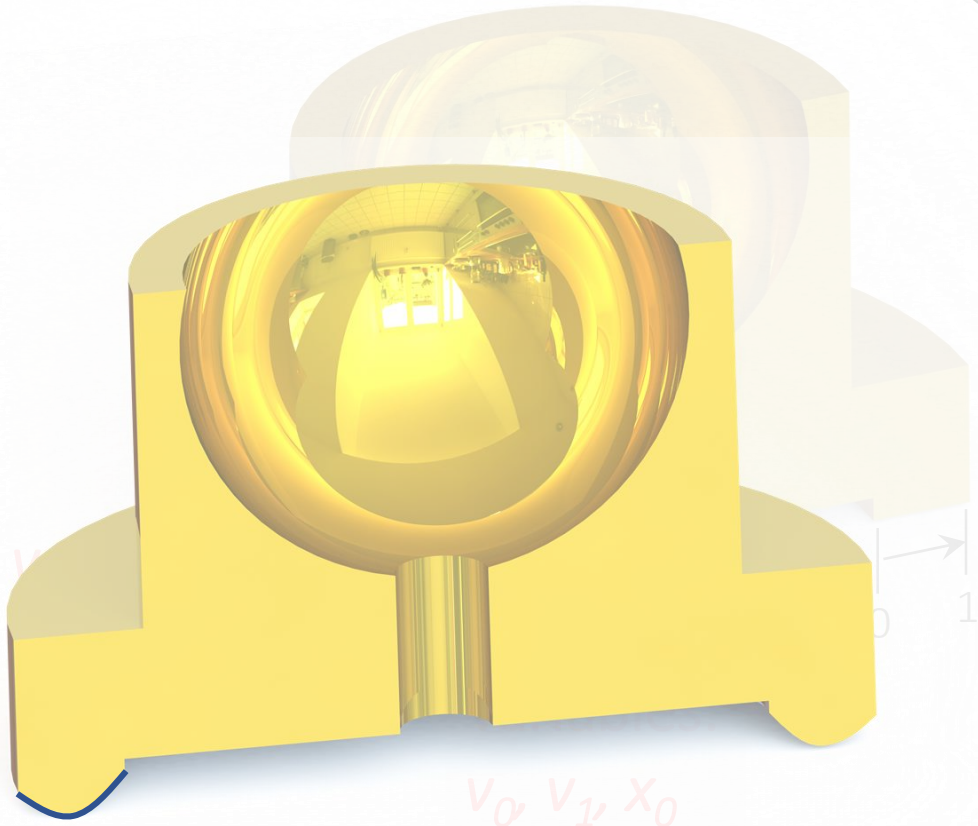
Slipper Surface Shaping

Optimized Profile



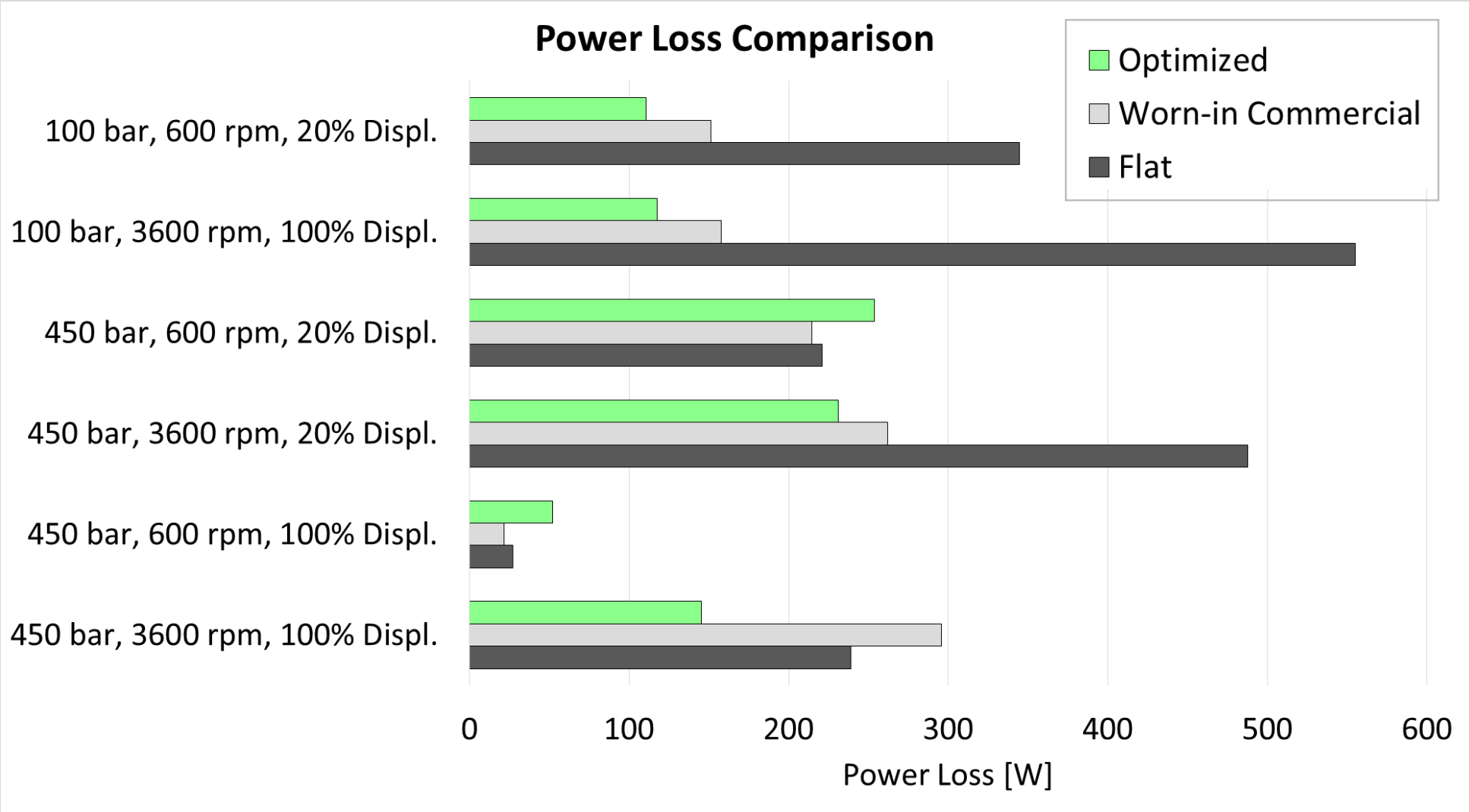
50 % Decrease in Power Loss

at 450 bar,
3,600 rpm,
100% Displ.



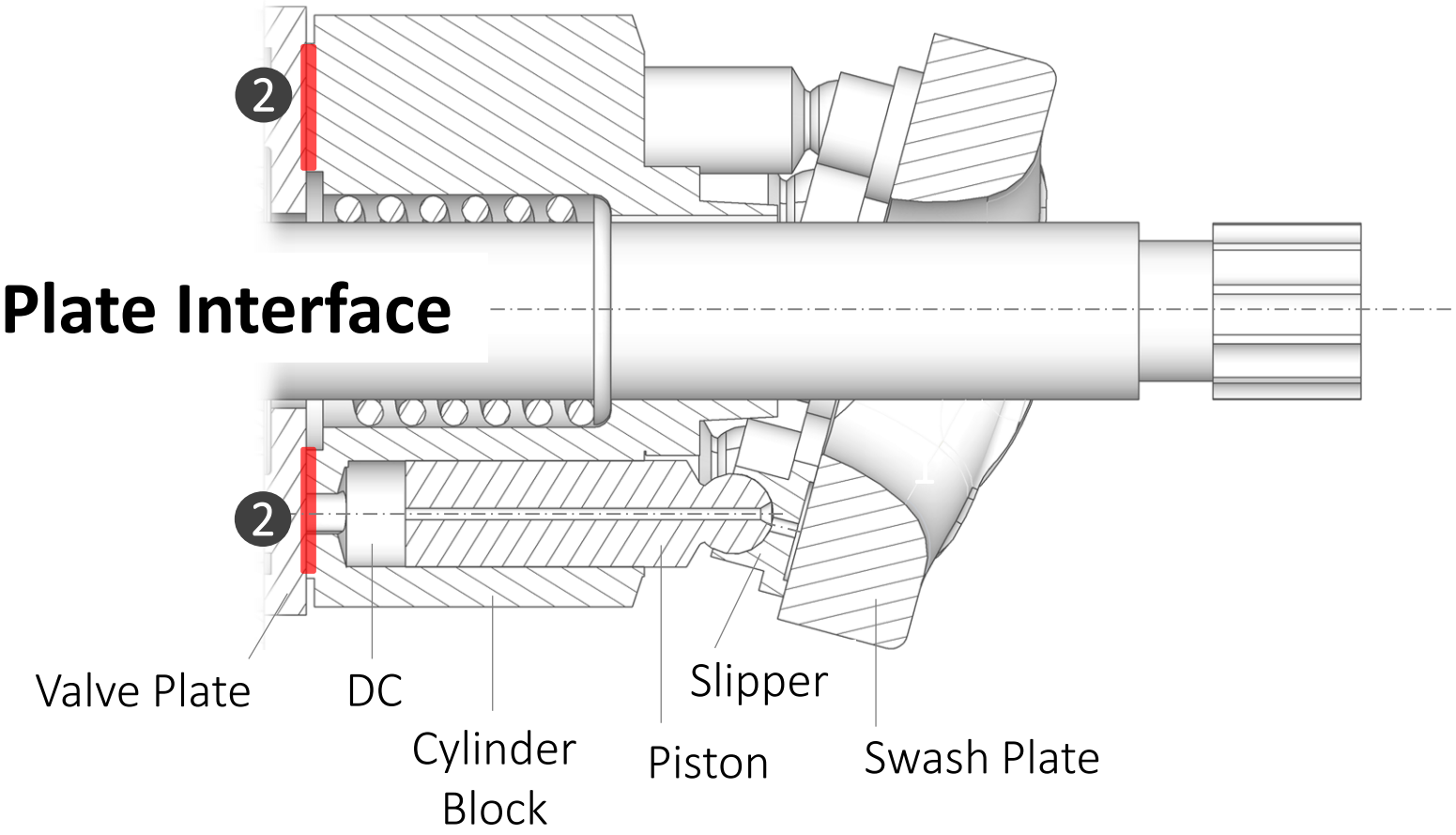
From the work of Ashkan Darbani (2019)

Optimization Results (Cont.)



From the work of Ashkan Darbani (2019)

Cylinder Block-Valve Plate Interface



Circumferential Sine Wave Surface Shape

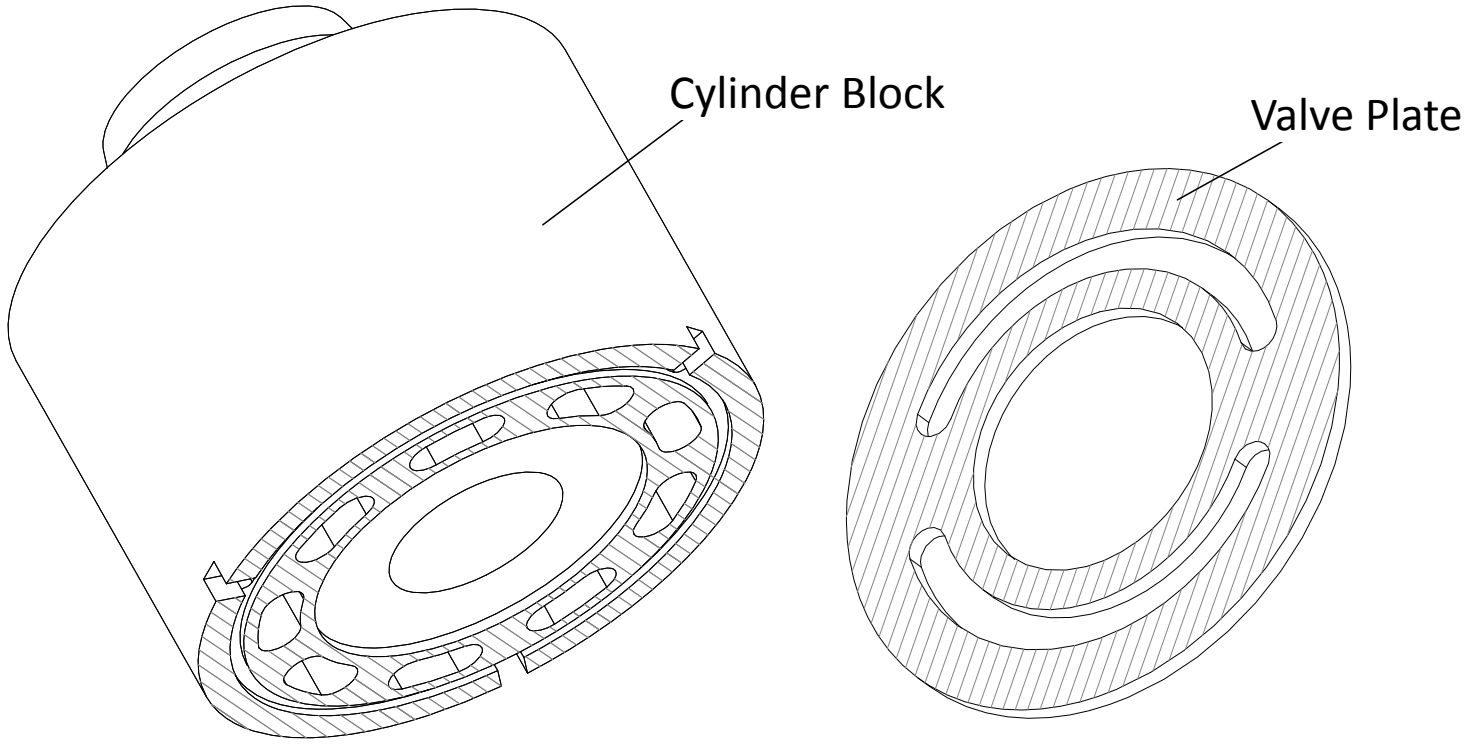


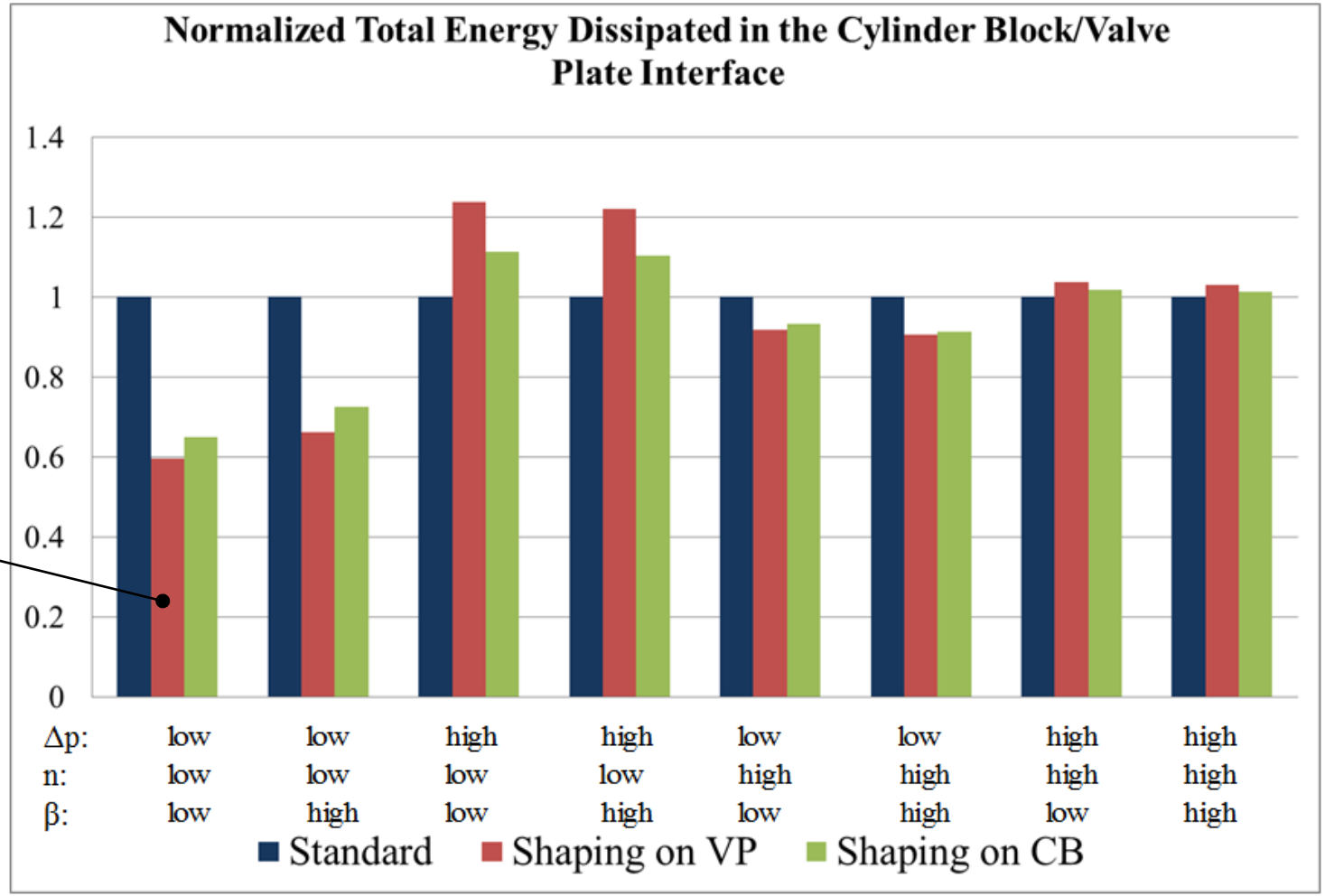
Figure from Baker (2008)

Circumferential Sine Wave Surface Shape:

From the work of Rene Chacon (2014)

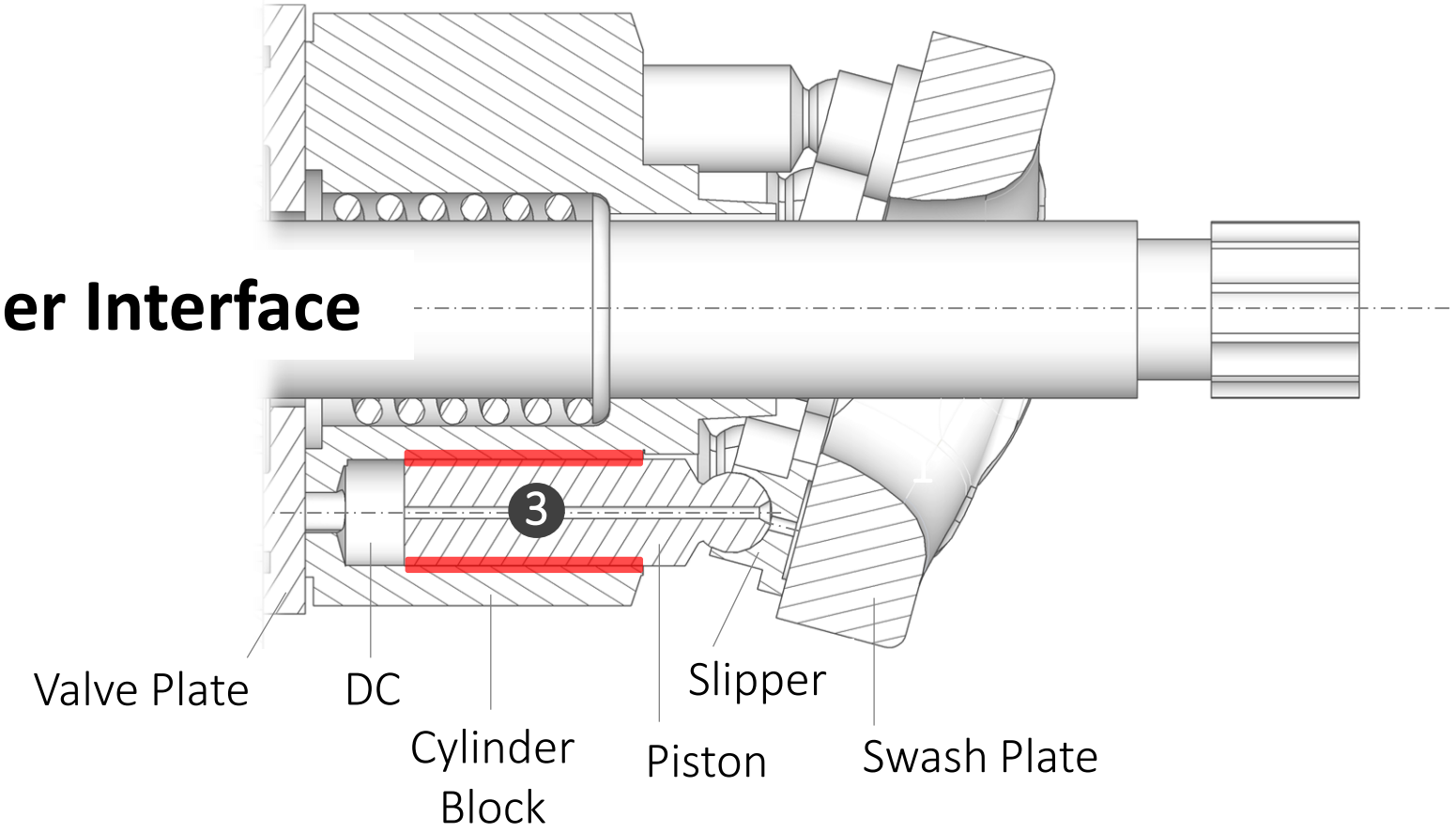
Results

~40% reduction
in power loss

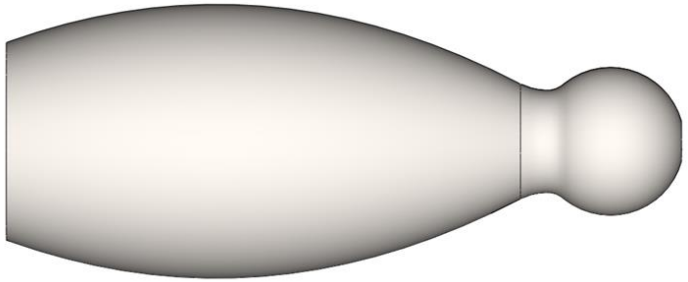


From the work of Rene Chacon (2014)

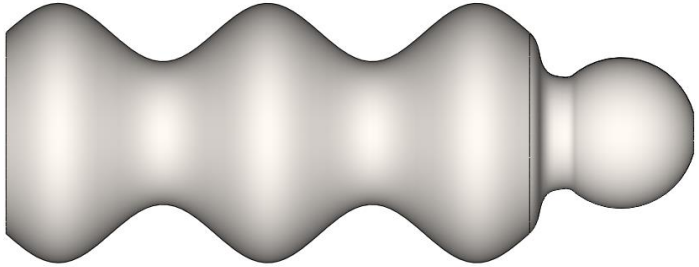
Piston-Cylinder Interface



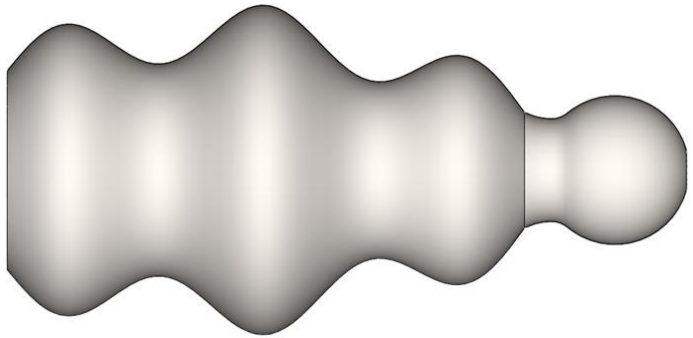
Piston Surface Shaping to Increase Efficiency



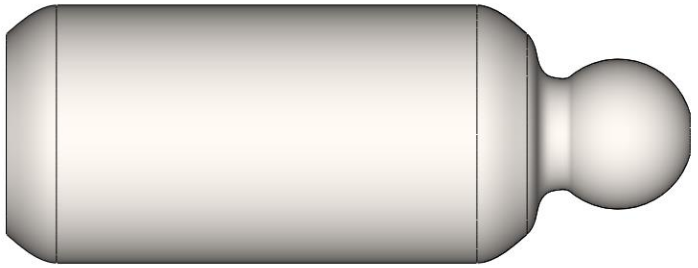
Half-Barrel



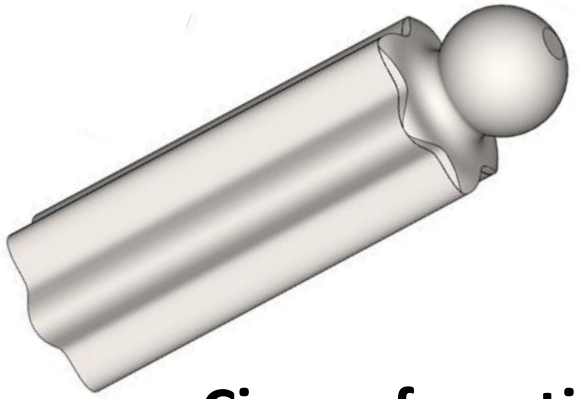
Axial Sine Wave



Waved Barrel



"Flat"



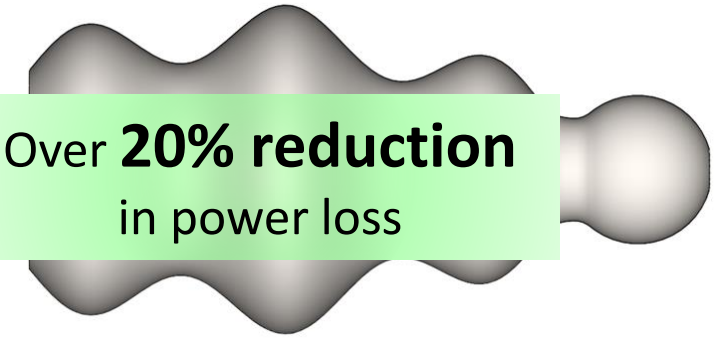
Circumferential Sine Wave

From the work of Ashley Wondergem (now Dr. Busquets) (2018)

Piston Surface Shaping to Increase Efficiency

Over **50% reduction** in power loss

Half-Barrel



Over **20% reduction** in power loss

Waved Barrel

75 cc Unit
Nominal clearance reduced to ~60% of original unit

Operating Condition:
350 bar, 1,500 rpm,
20% Displacement

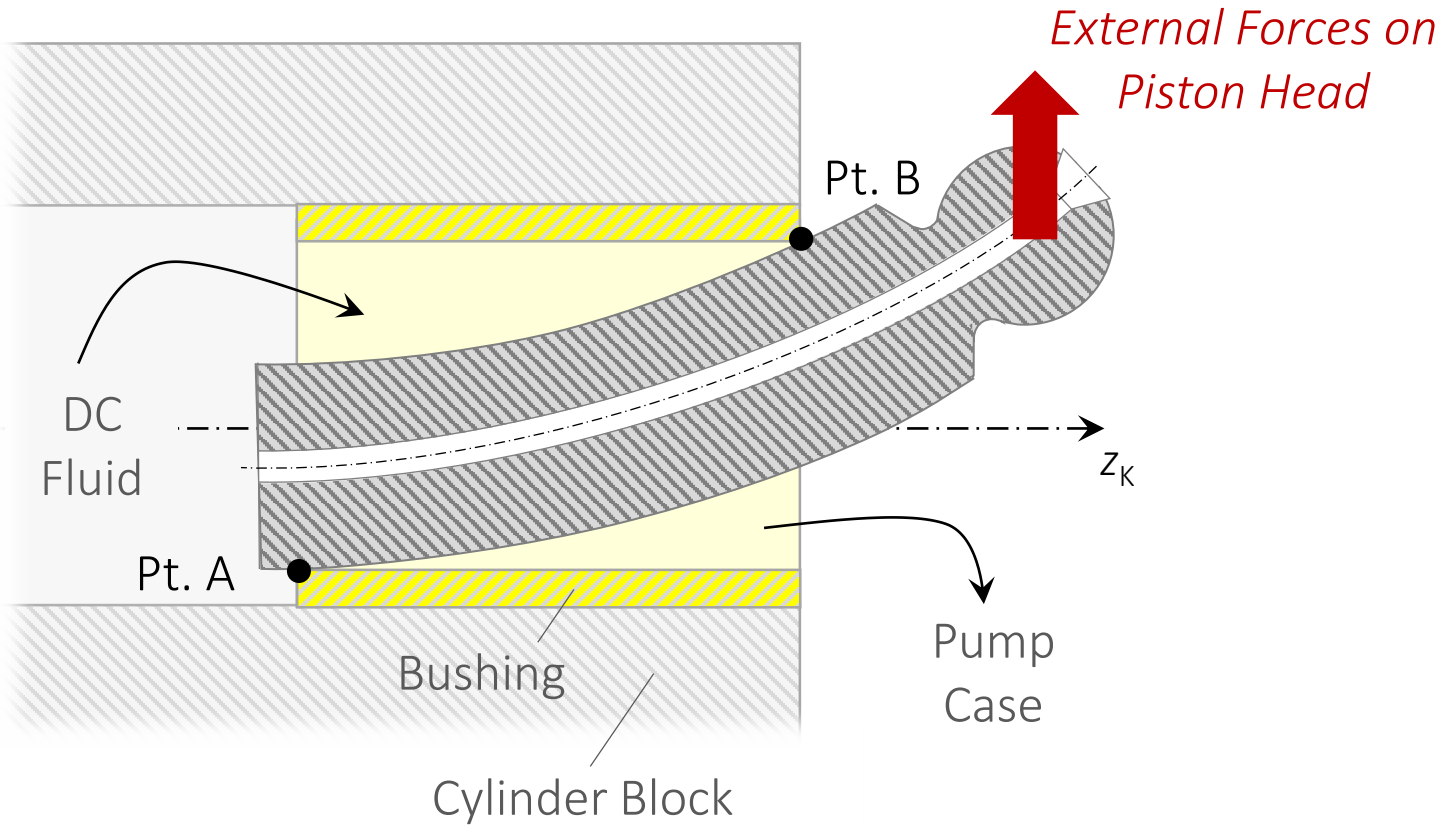
From the work of Ashley Wondergem (now Dr. Busquets) (2018)

Why Water???

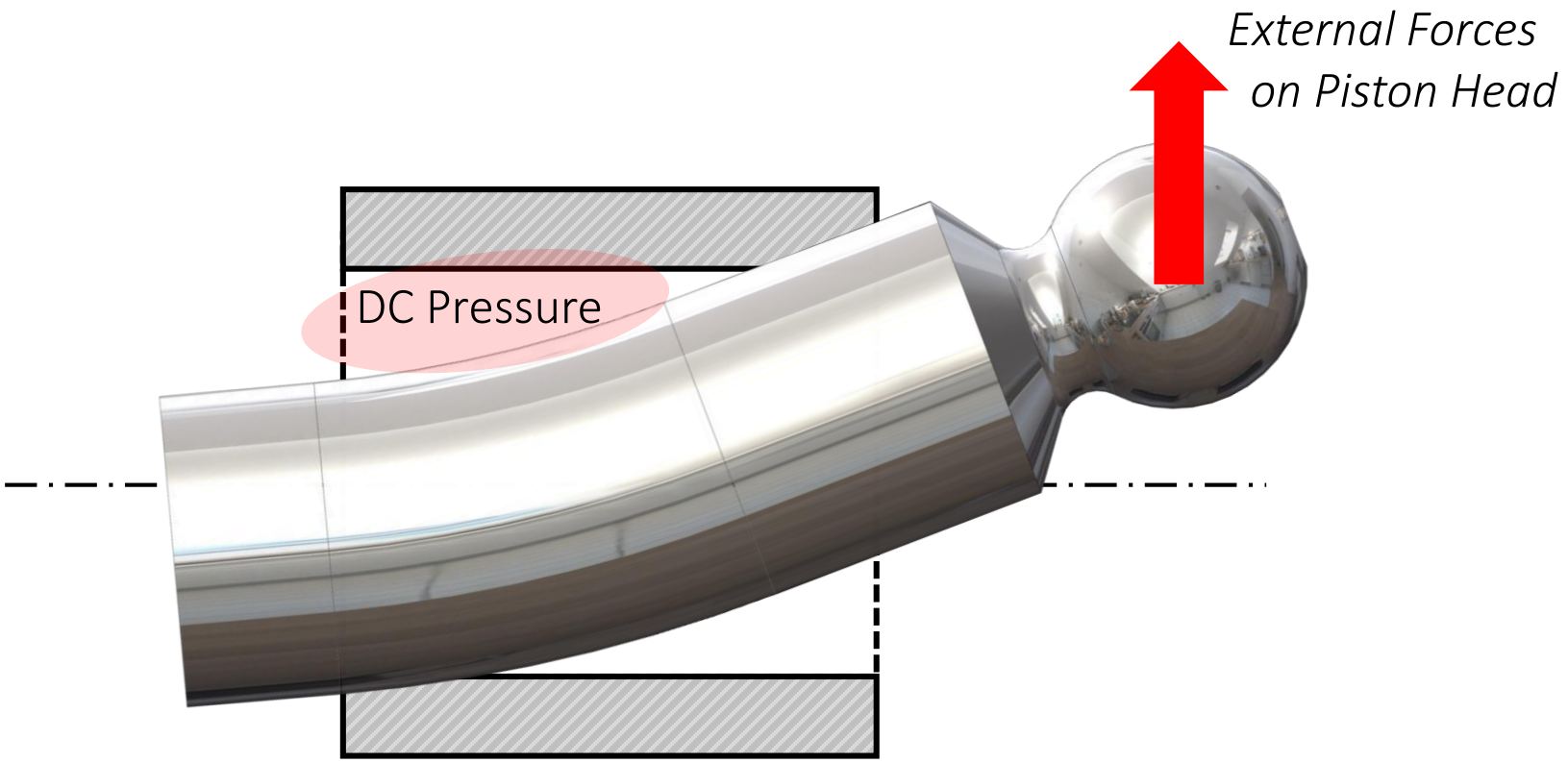
- Green (sustainable resource)
- Cheap
- Widely available

Metal-Metal Contact

Piston During the High-Pressure Stroke

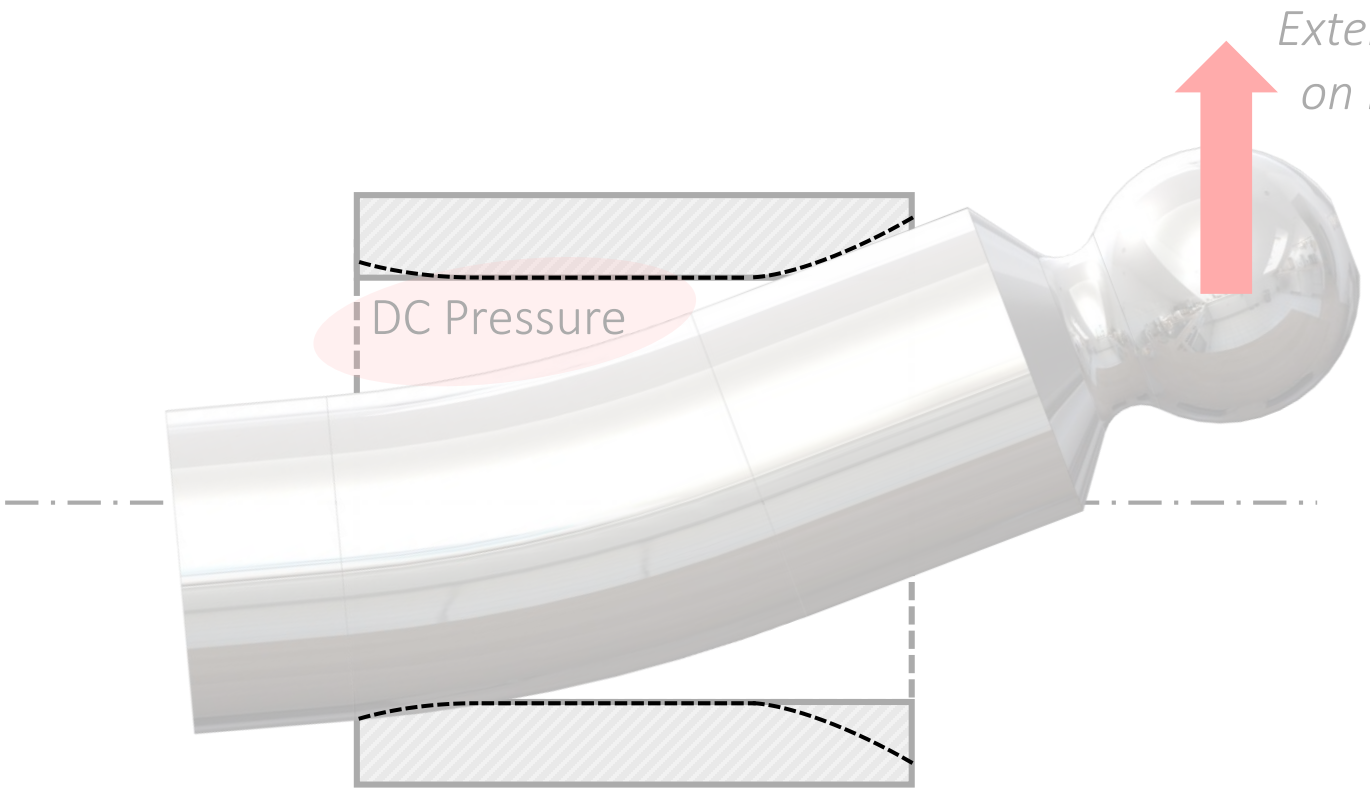


Current Work



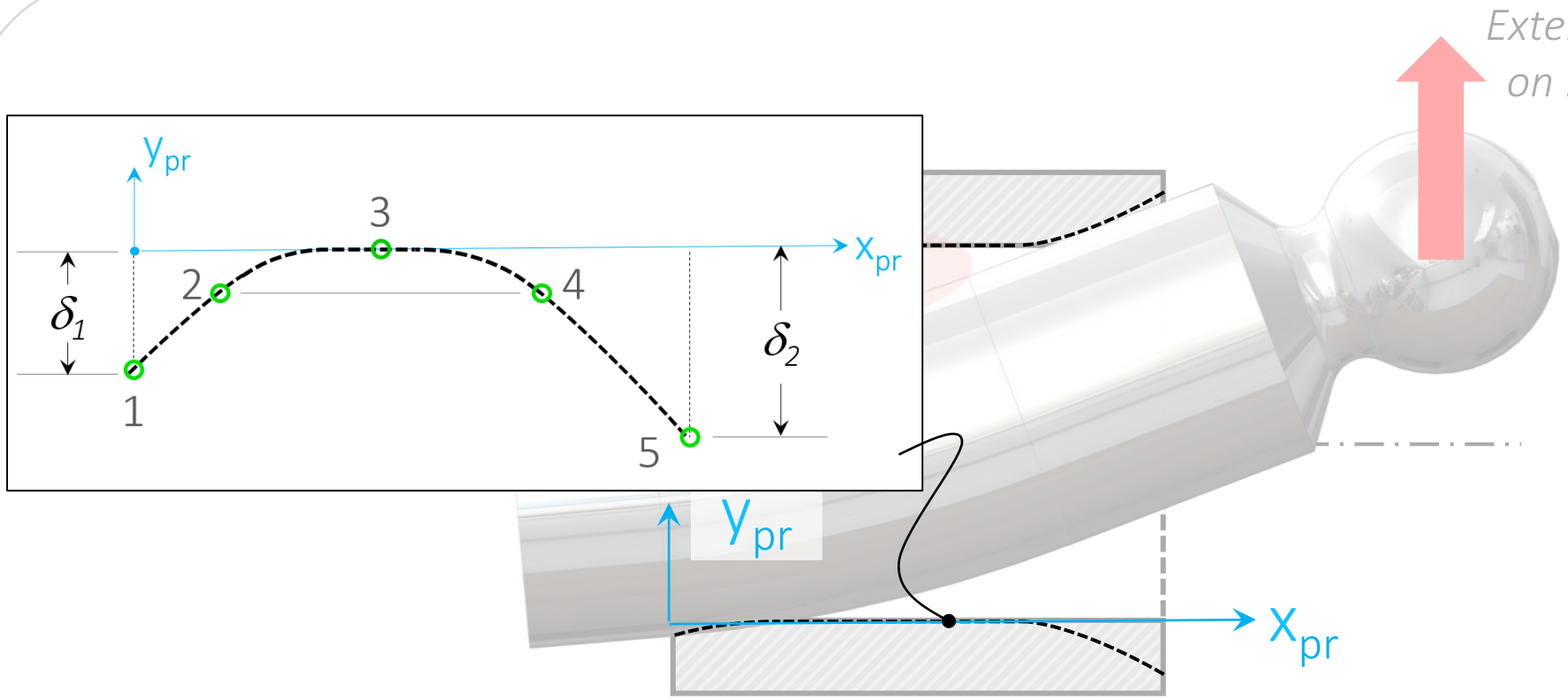
Piston Deformation during the High-Pressure Stroke

Current Work



Piston Deformation during the High-Pressure Stroke

Current Work



Piston Deformation during the High-Pressure Stroke

Conclusions

- The Maha Fluid Power Research Center in-house model:
  - State of the art multi-physics simulation tool
  - Today's presentation focused on its virtual prototyping capabilities

- Well-designed surface shaping can:
  - Drastically reduce power loss
  - Increase achievable load support for low-viscosity fluids

- Surface shaping is the FUTURE:
  Advances in manufacturing allow for more complex shaping

Questions?

References

Busquets, A. **(**2018). An Investigation of Micro-Surface Shaping on the Piston/Cylinder Interface of Axial Piston Machines, PhD thesis, Purdue University.

Chacon Portillo, R. (2014). Cylinder Block/Valve Plate Interface Performance Investigation through the Introduction of Micro-Surface Shaping, Masters thesis, Purdue University.

Darbani, A. A. (2019). An Investigation in Slipper-Swashplate Interface of Axial Piston Machines, Masters thesis, Purdue University.

Ernst, M. and Ivantysynova, M. (2018), 'Axial Piston Machine Cylinder Block Bore Surface Profile for High-Pressure Operating Conditions with Water as Working Fluid'. *2018 Global Fluid Power Society PhD Symposium (GFPS)*. Samara, 18-20 July.

Ivantysyn, J., and Ivantysynova, M., 2003, *Hydrostatic Pumps and Motors,* Tech Books International, New Delhi, pp. 134-141, Chap. 4.

Ivantysynova, M., Garrett, R. A. & Frederickson, A. A. (2012), 'Positive Displacement Machine Piston with Wavy Surface Form'. Lasaar, R. (2003), *Eine Untersuchung zur mikro- und makrogeometrischen Gestaltung der Kolben-/Zylinderbaugruppe von Schraegscheibenmaschinen*, VDI Verlag GmbH, Duesseldorf.
URL: *http://www.sciencedirect.com/science/article/pii/S0257897205008807*

Lasaar, R. (2003), *Eine Untersuchung zur mikro- und makrogeometrischen Gestaltung der Kolben-/Zylinderbaugruppe von Schraegscheibenmaschinen*, VDI Verlag GmbH, Duesseldorf.

Pelosi, M. (2012), An Investigation on the Fluid-Structure Interaction of Piston/Cylinder Interface, PhD thesis, Purdue University.

Schenk, A. (2014). Predicting Lubrication Performance between the Slipper and Swashplate in Axial Piston Machines, PhD thesis, Purdue University.