Sliding Bearing Oil Film Analyis of Reciprocating Compessors

H. Németh, Á. Veress, Cs. Kiss

Knorr-Bremse Research & Development Center, Budapest

ERCOFTAC Spring Festival 2009

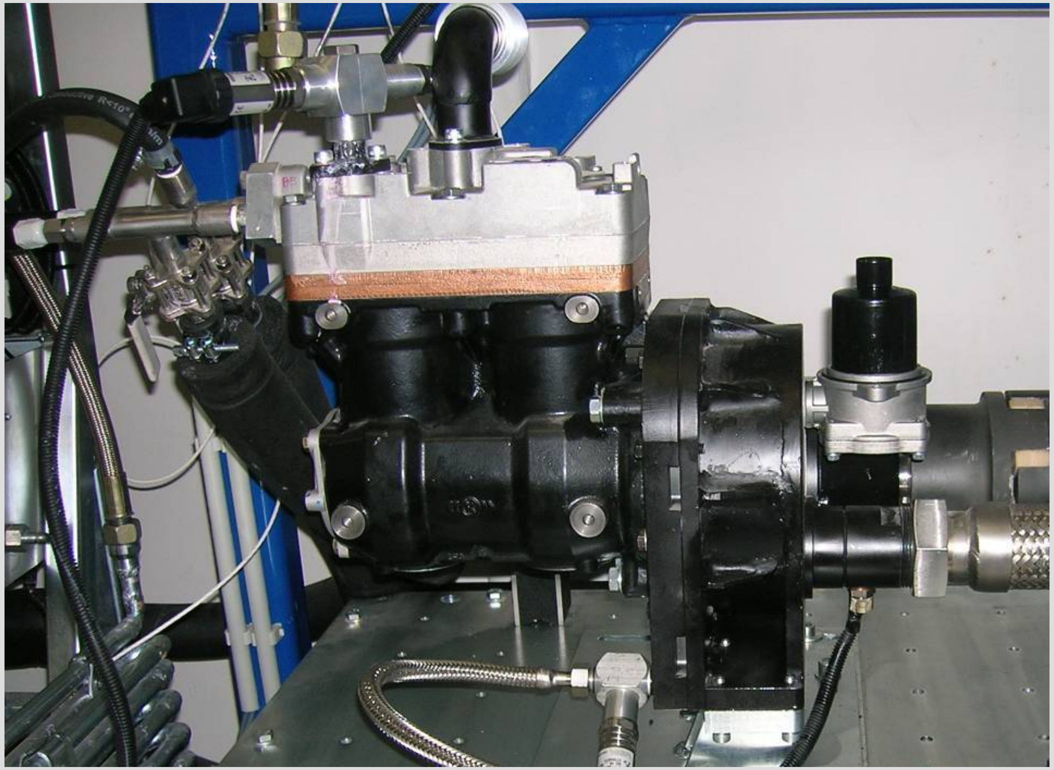
Contents

- Motivation
- Compressors and their bearings
- Excitation thermodynamics
- Sliding bearing oil film model
- Results
- Conclusions

Reciprocating compressors and motivation

Reciprocating compressors

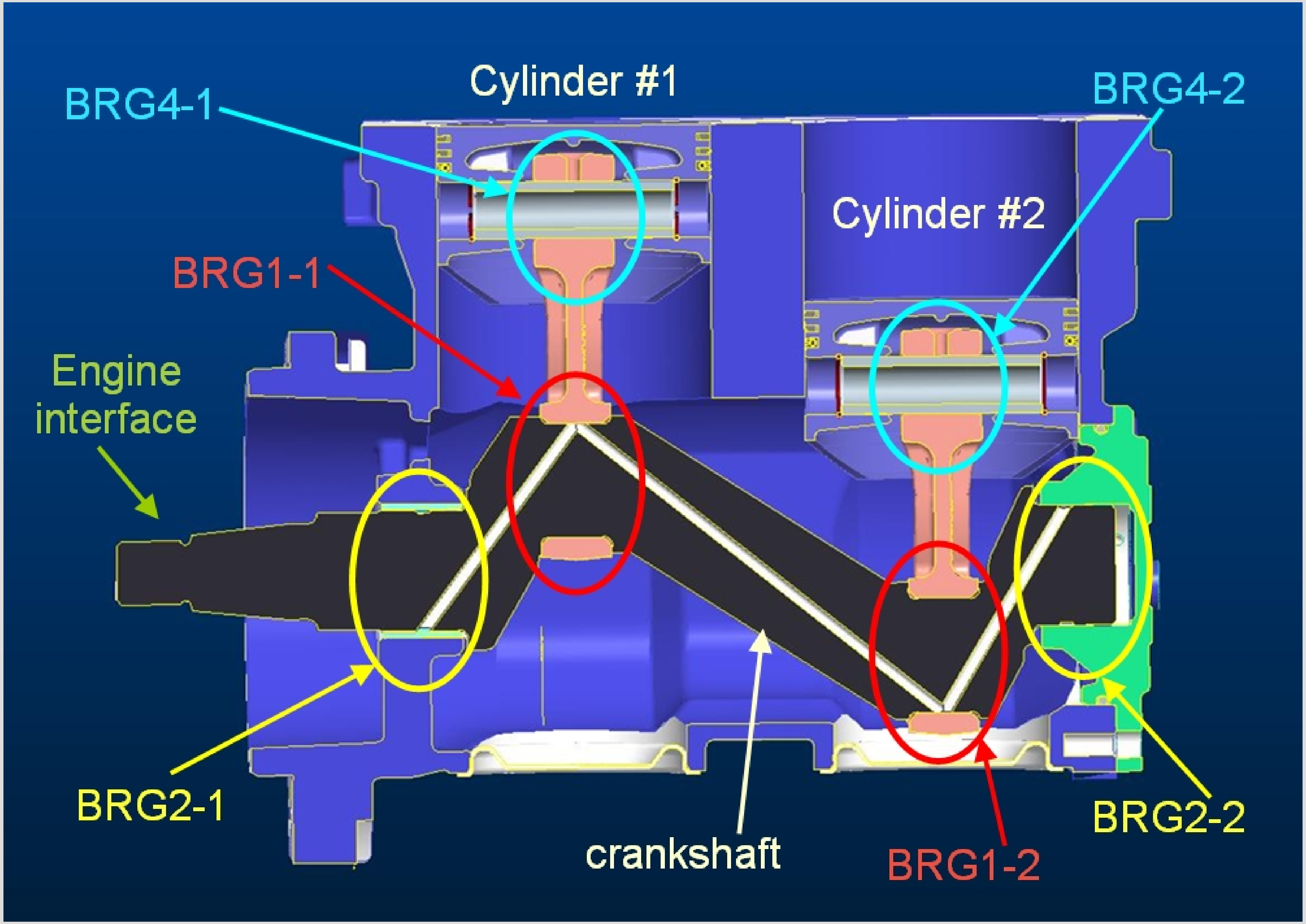
- Widely used in industry and commercial vehicle air system
- Usually single or twin cylinder
- Mostly using sliding bearing at each pins or journals
- Sliding bearing design highly determines the lifetime of the compressors



Motivation

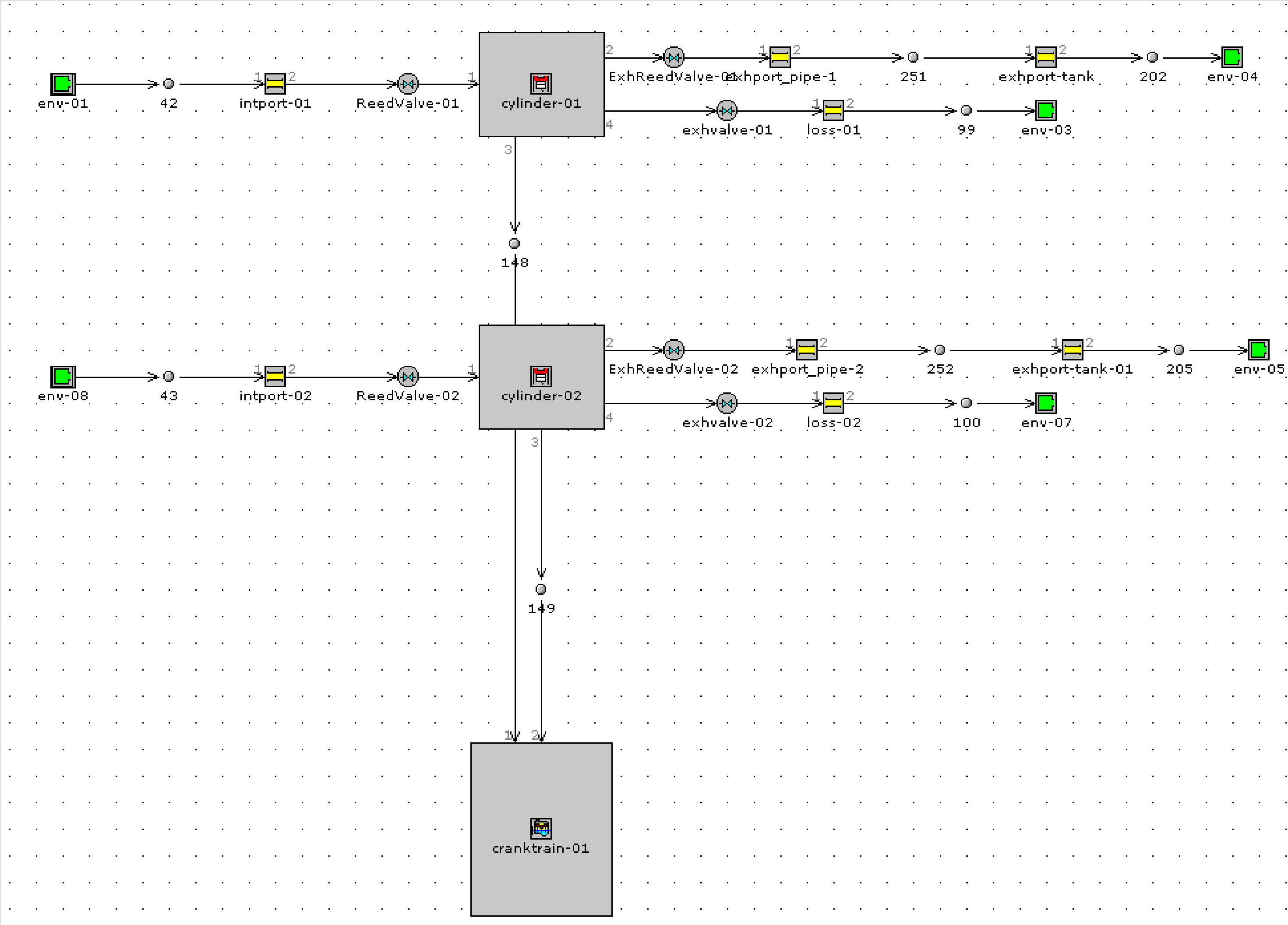
- Give a reasonable description of sliding bearings of reciprocating compressors
- Better insight into sliding bearing operation and design criteria
- Establish an optimization frameworks

Sliding bearings in the compressor

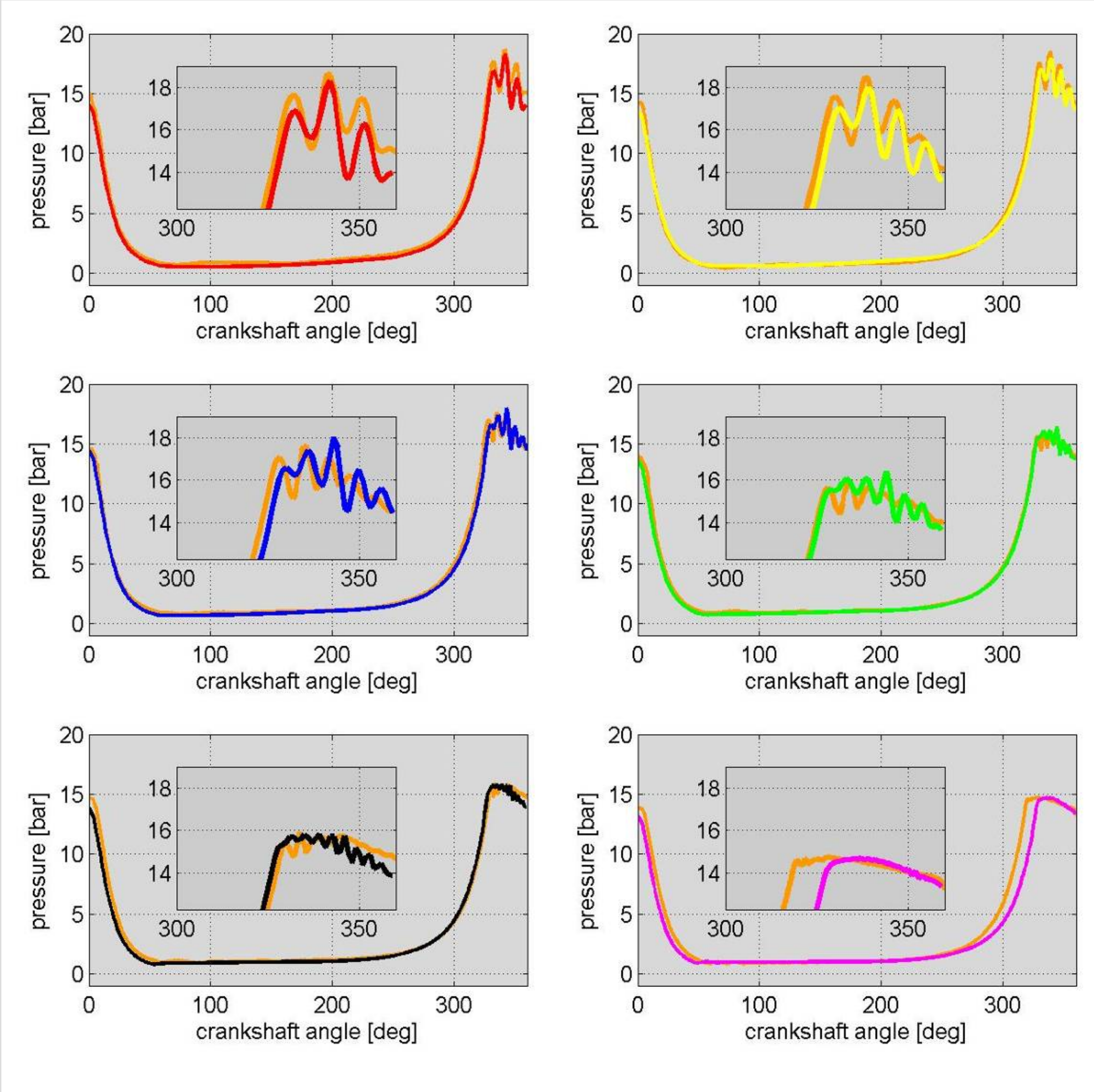


Excitation thermodynamics – Wave action engine model

- **Main goal**: Generate the loading pressure curves
- 1D-CFD in intake and discharge lines, 0D thermodynamics in cylinder
- Reed valve dynamics imposed
- Cylinder blow-by considered
- Operation point with **12.5 bar** service pressure
- Implemented in GT-Power



Excitation thermodynamics – Results

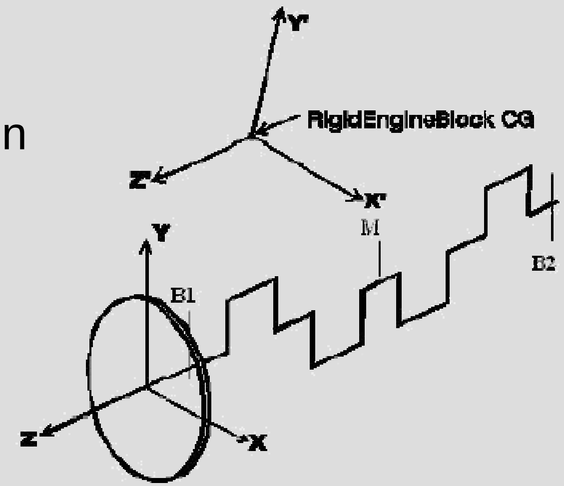


Bearing oil film modelling

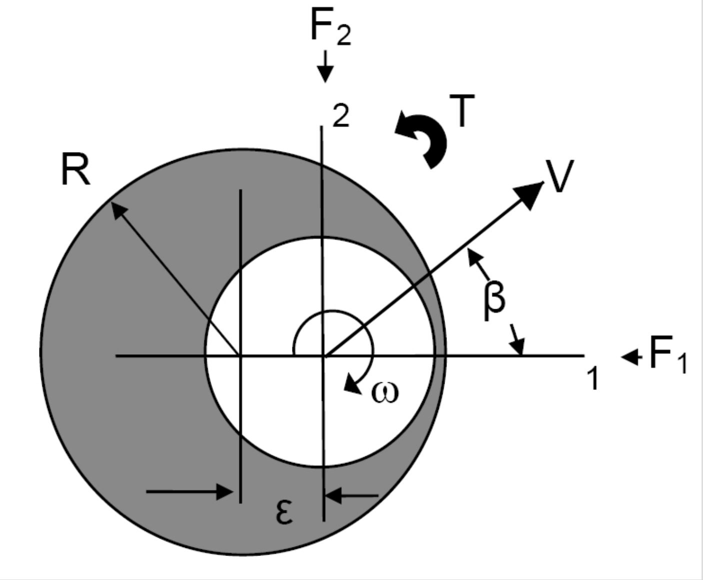
- **The oil film distribution in the sliding bearing is governed by the Reynolds-equation**

$$\frac{P_a d^2}{12\eta_{eff}} \nabla^2 \left(\frac{p(x,y,t)}{P_a} \right) - \frac{\partial}{\partial t} \left(\frac{p(x,y,t)}{P_a} \right) = \frac{\partial}{\partial t} \left(\frac{z}{d} \right)$$

- **To avoid the need to solve the journal dynamics and film distribution the problem is separated (impedance technique)**
- The bearing hydrodynamic forces are as dimensionless maps (depending on bearing geometry only)
- Asperity force maps are additionally generated
- The journal dynamics is solved separately
- The obtained trajectory is used to calculate the film pressure distribution (Booker and Goenka)



Bearing oil film modelling



- The resultant journal velocity is

$$V = \sqrt{V_1^2 + (V_2 + V_{eq})^2} \qquad V_{eq} = -\frac{|\omega|}{2}\varepsilon$$

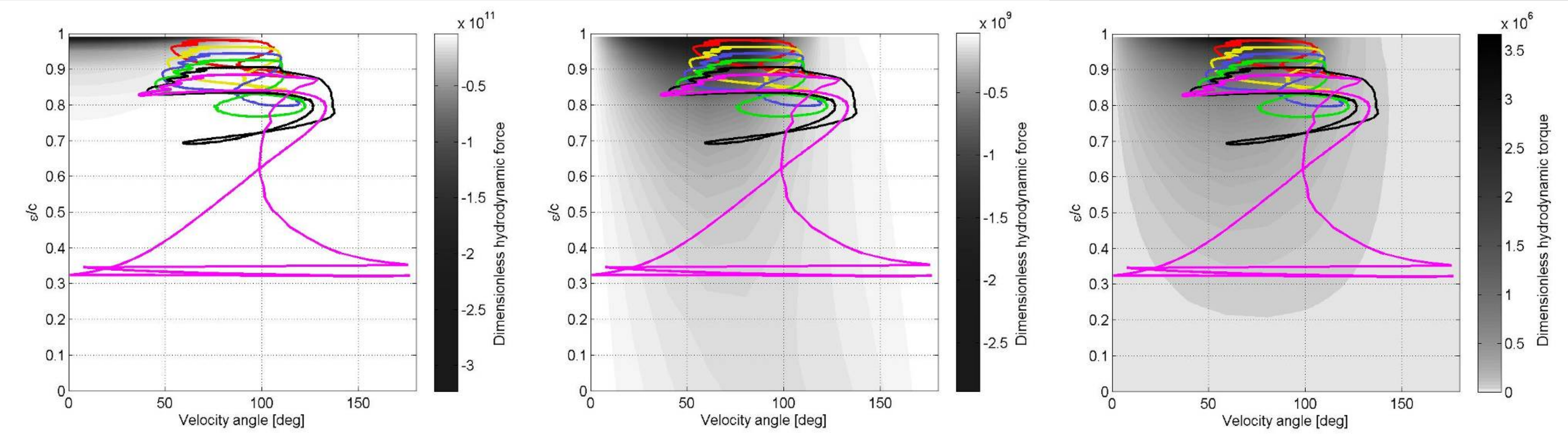
- The solution of dimensionless the Reynolds-equation can be given by the dimensionless forces and torques as

$$F_1^* = \frac{F_1}{\eta VR}; \quad F_2^* = \frac{F_2}{\eta VR}; \quad T^* = \frac{T}{\eta VR^2}$$

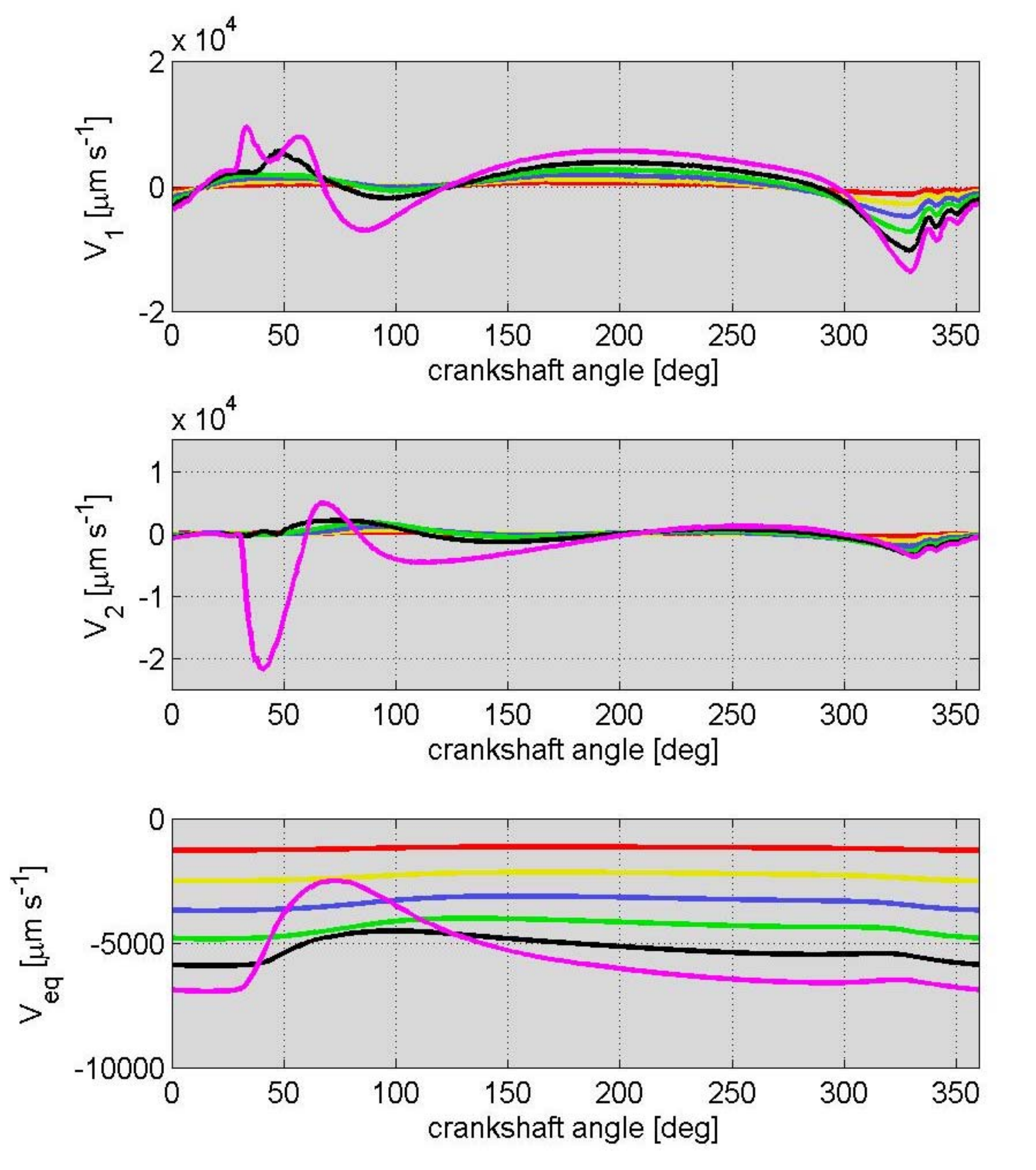
- I can be proved that these quantities depend only on eccentricity to clearance (ε/c) and velocity angle (β) hence a bearing specific map can be generated for each sliding bearing
- The dimensionless asperity contact force is calculated from the Greenwood-Williamson asperity contact model as function of (c-ε)/σ_s

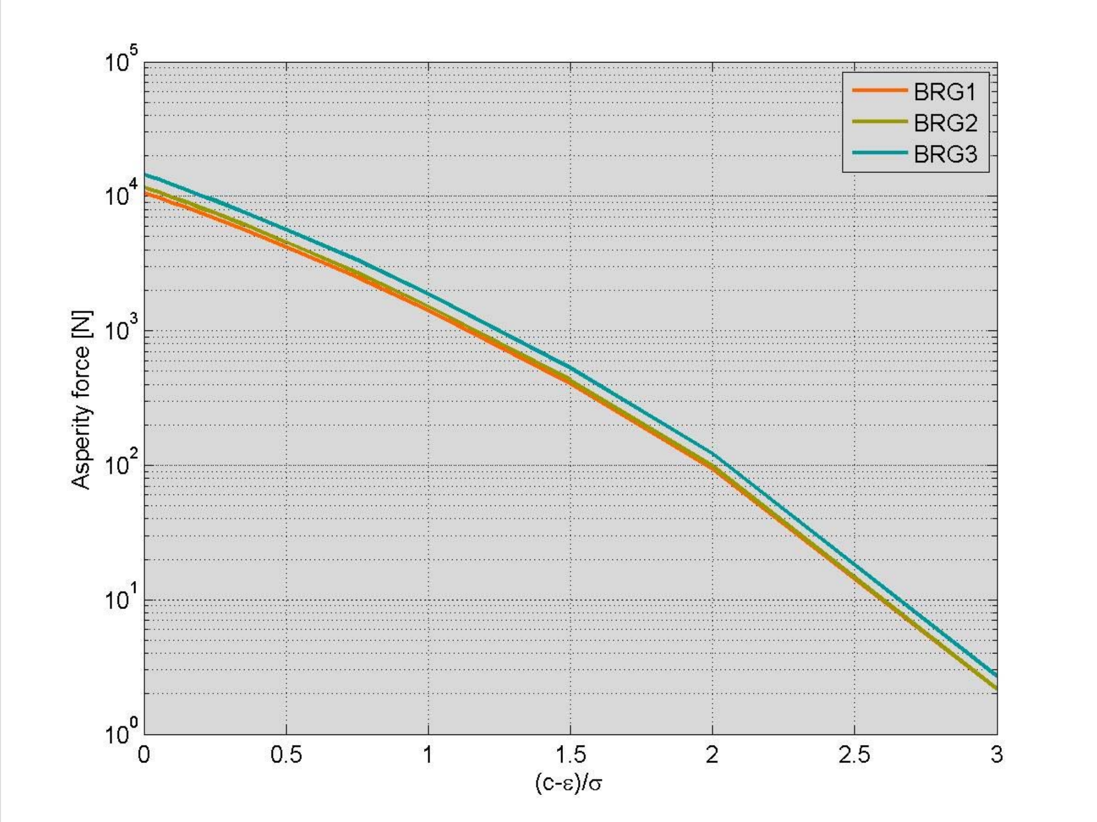
$$F_c^* = \frac{F_c}{ER^2}$$

Solution – Conrod bearing forces and torques

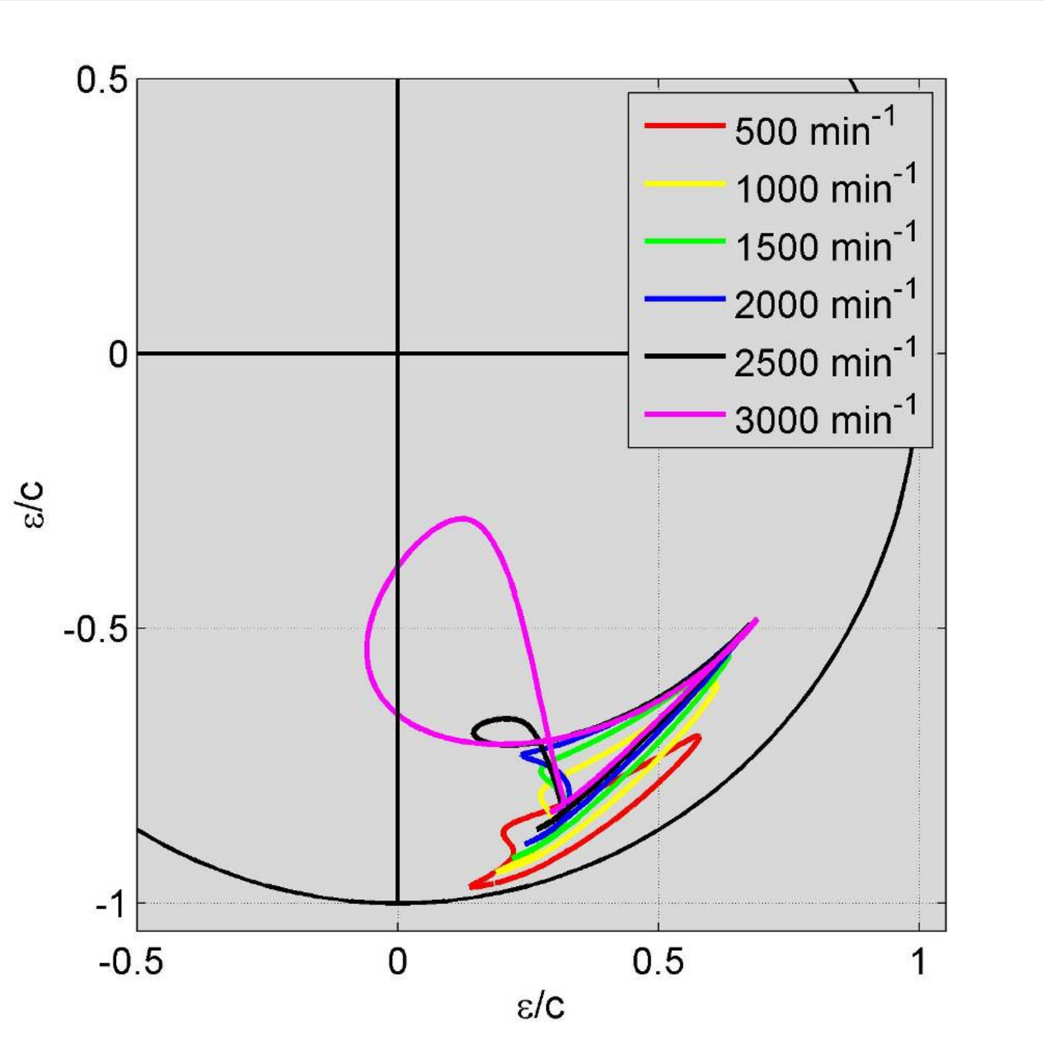


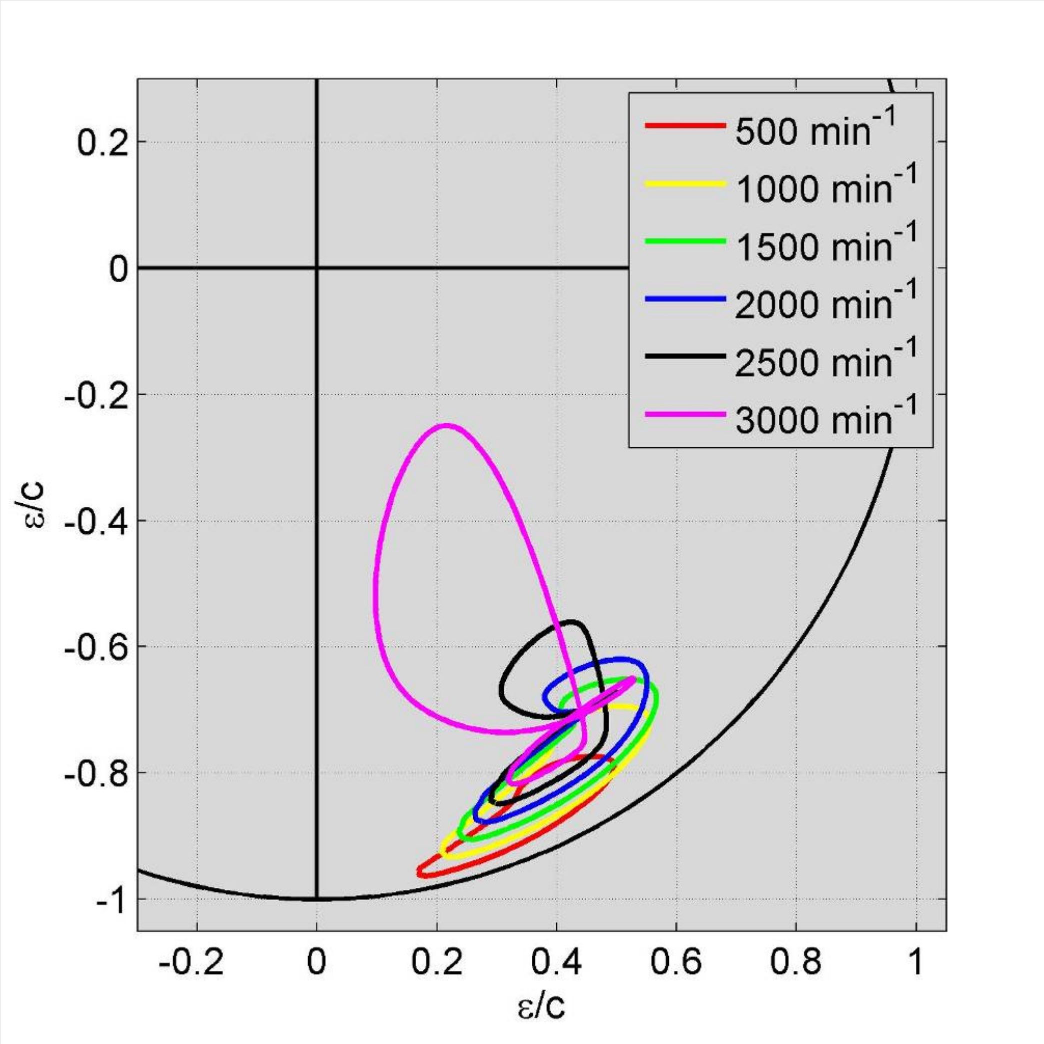
Solution – Conrod journal velocity and asperity contact force





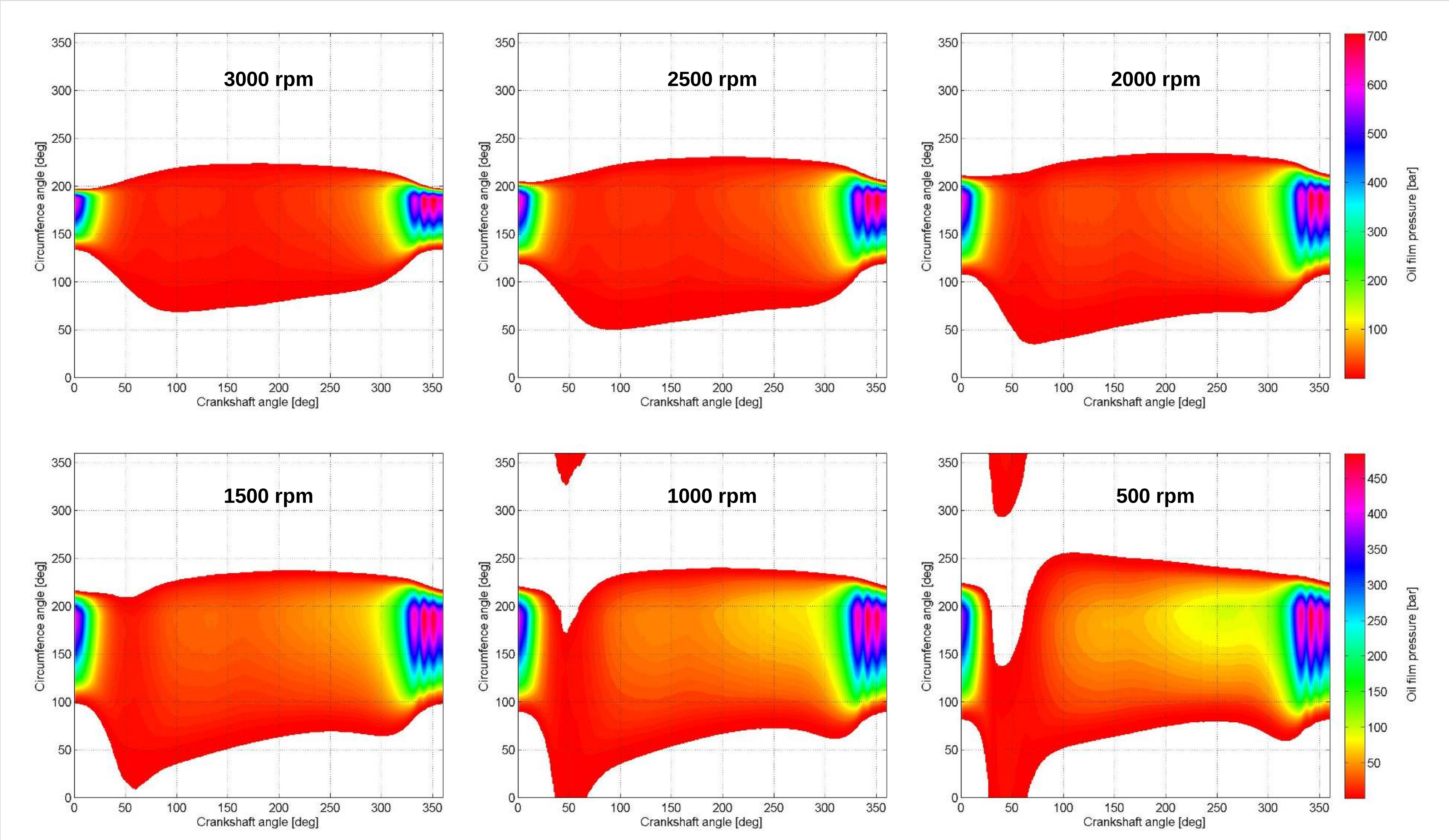
Solution – Conrod bearing journal orbit



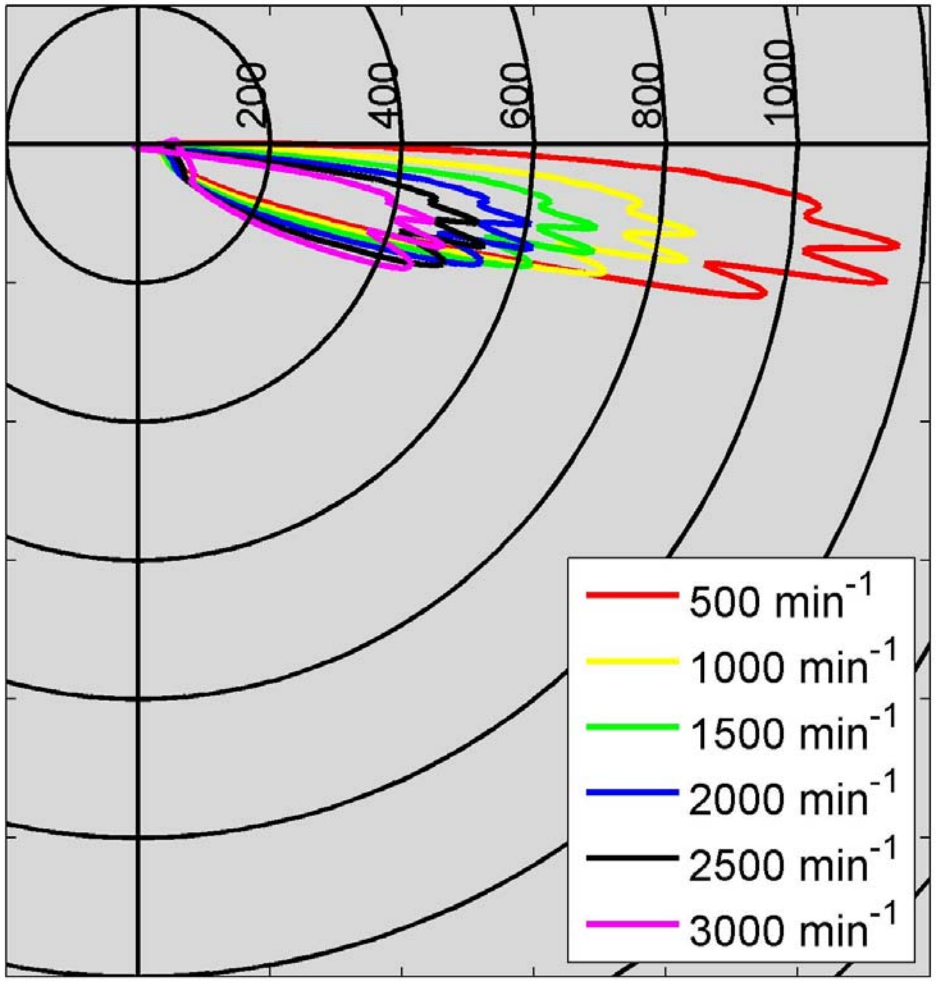


Global coordinate system **Bearing coordinate system**

Solution – Conrod bearing pressure distribution – bearing coord.

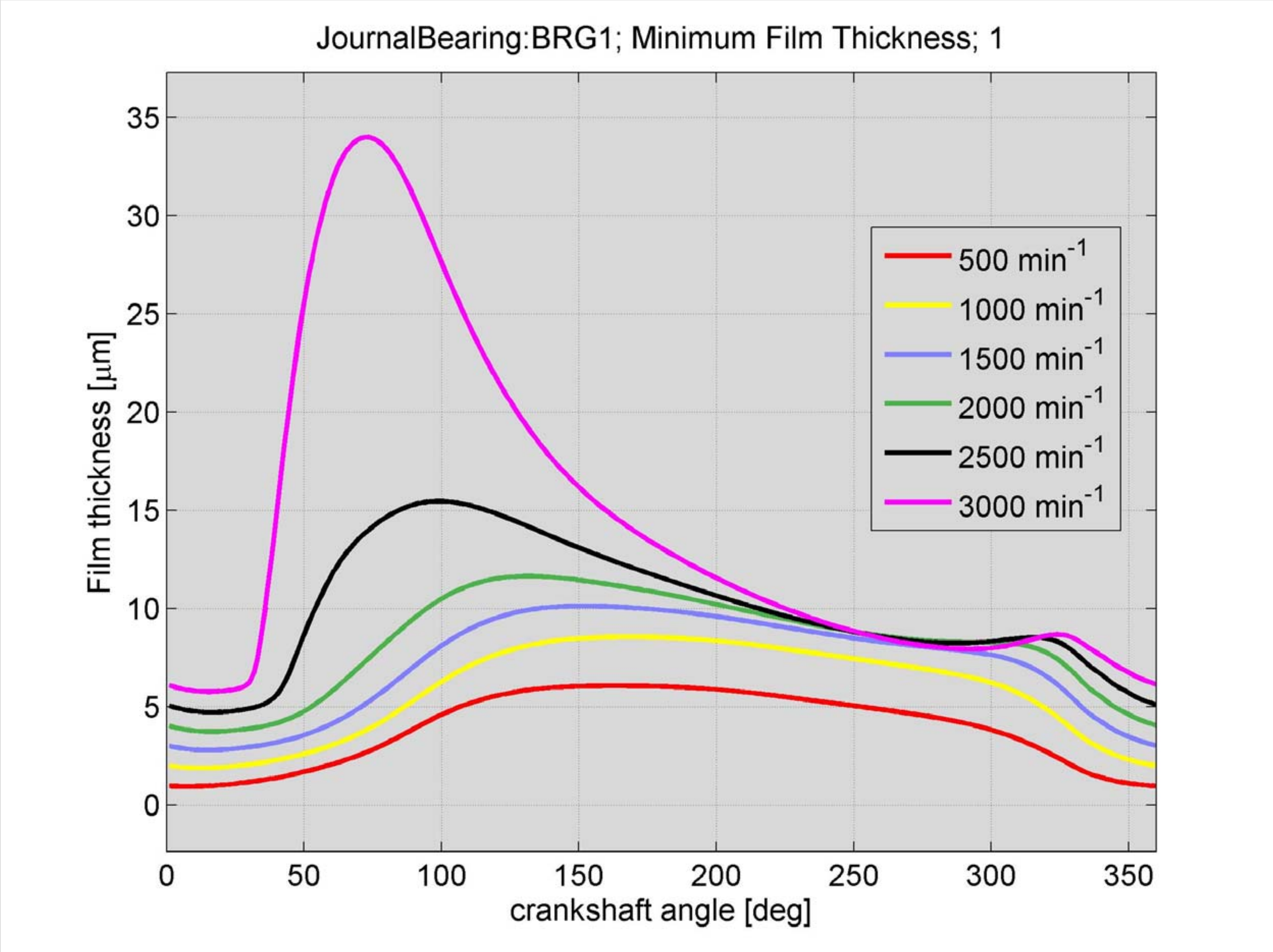


Solution – Conrod bearing oil pressure

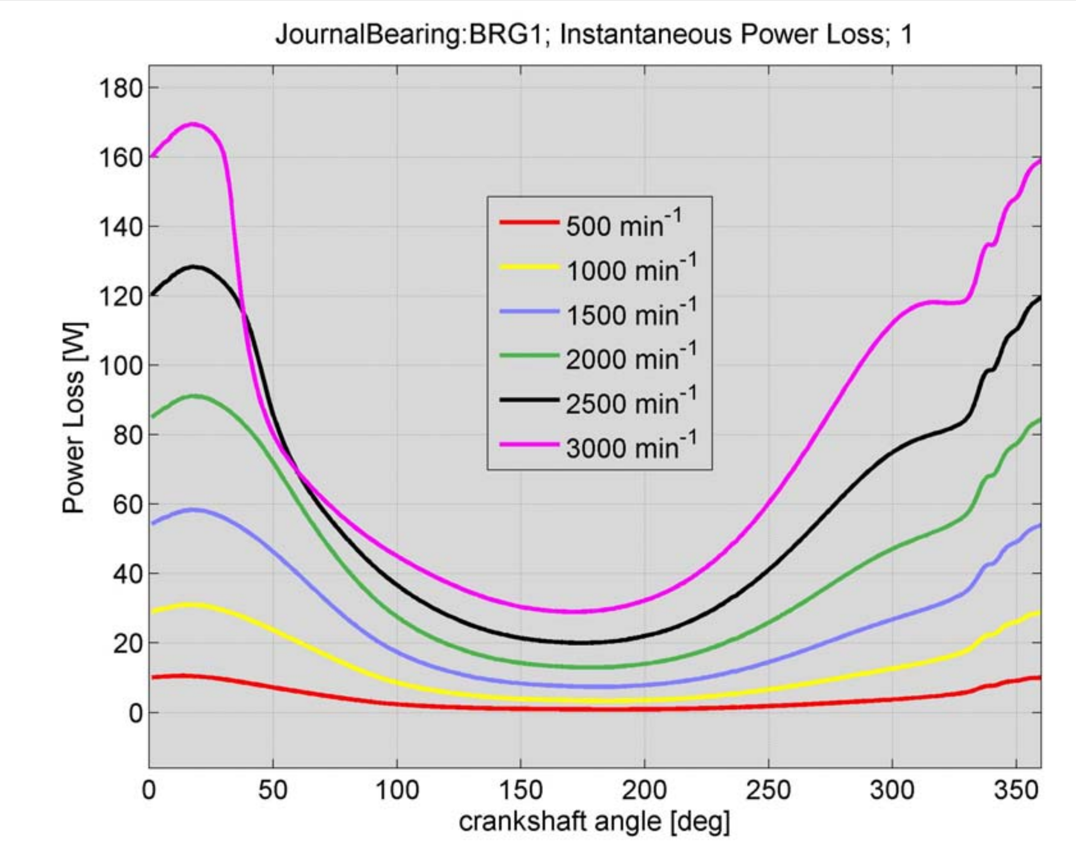


Maximum oil film pressure [bar]

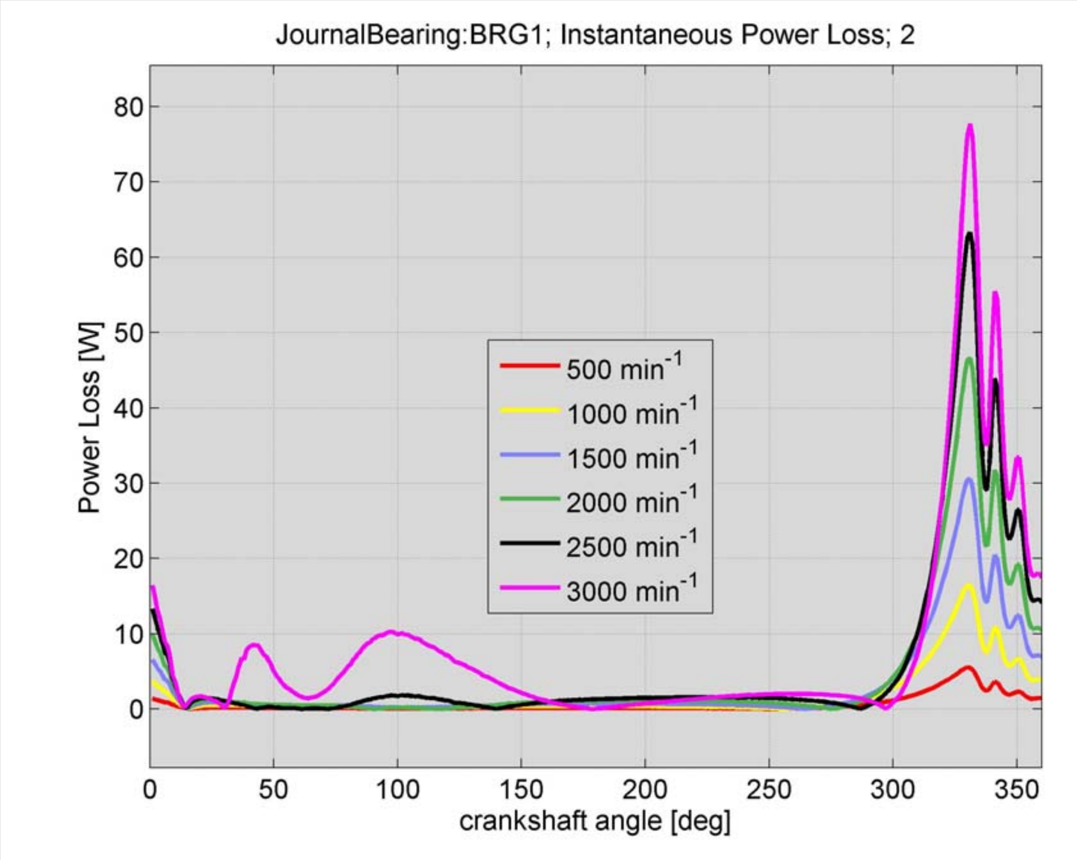
Solution – Conrod bearing oil film thickness



Solution – Conrod bearing power loss



Viscous loss



Squeeze loss

Conclusions

- Sliding bearing calculation procedure has been implemented for reciprocating compressors
- By using the impedance technique the solution is computationally cheap
- There is no numeric convergence issue
- Significantly more straightforward optimization with this tool compared to experimental way

Thank you for your attention

Dr. Huba NÉMETH
KNORR-BREMSE R&D Center Budapest
Department T/BZA
Major u. 69
H-1119, Budapest
Phone: +36 1 3829-828
Fax: +36 1 3829 810
mailto: huba.nemeth@knorr-bremse.com
http://www.knorr-bremse.com