Investigating the Influence of a Coupled Formulation on Journal Bearing Models

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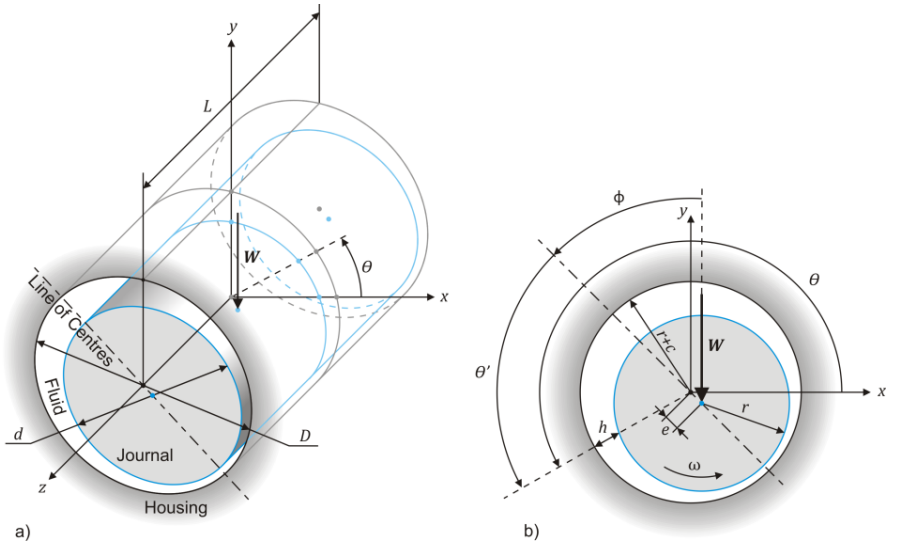

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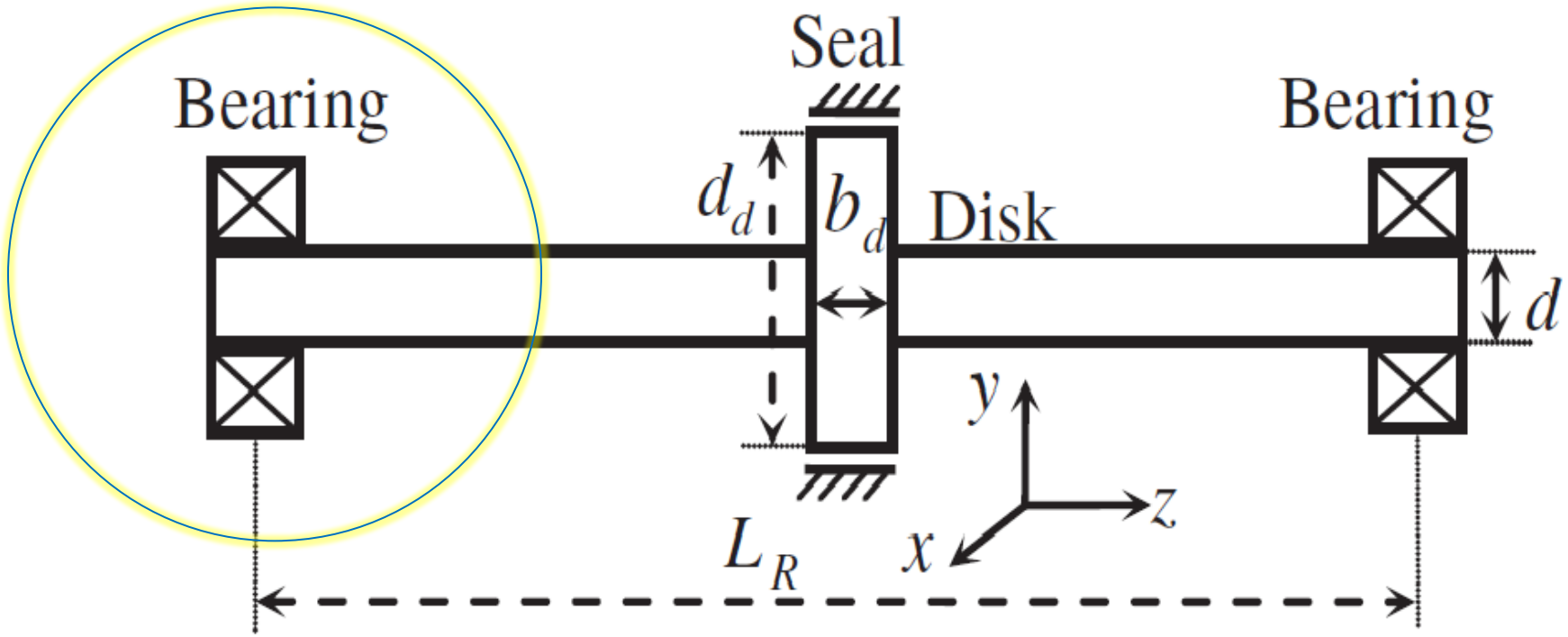
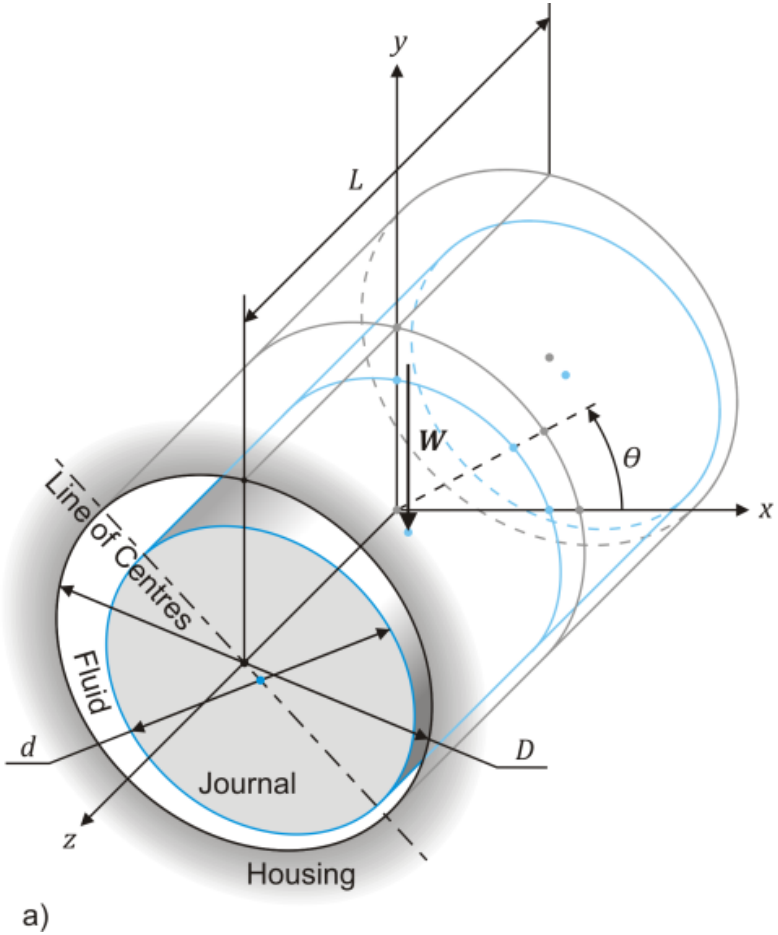
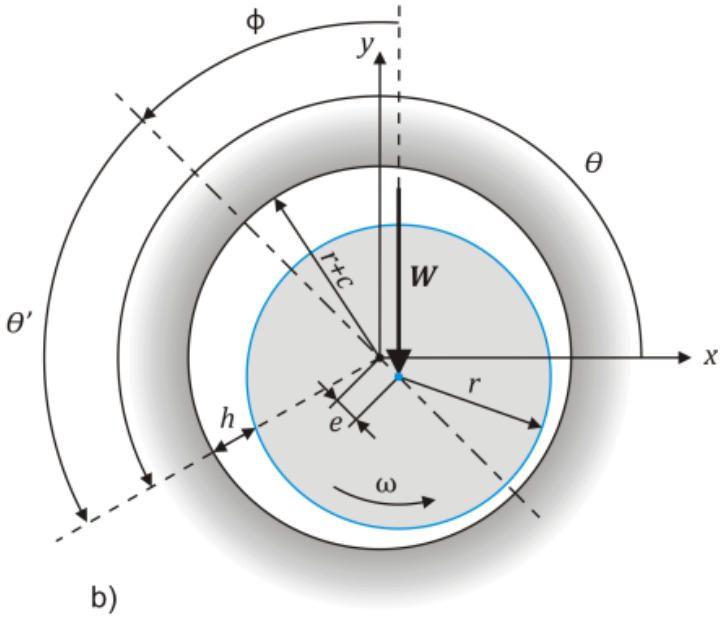
Context of Study – Rotor-Bearing-Seal System:



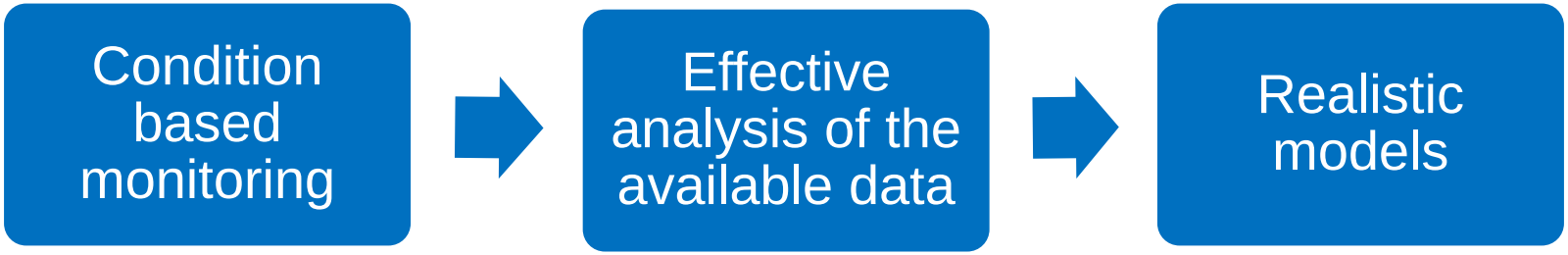
This study was concerned with the bearing models.

Context of Study – Bearing:





Context of Study:

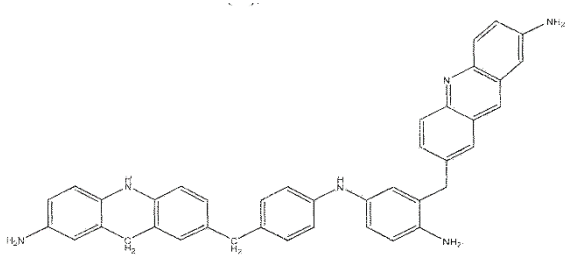


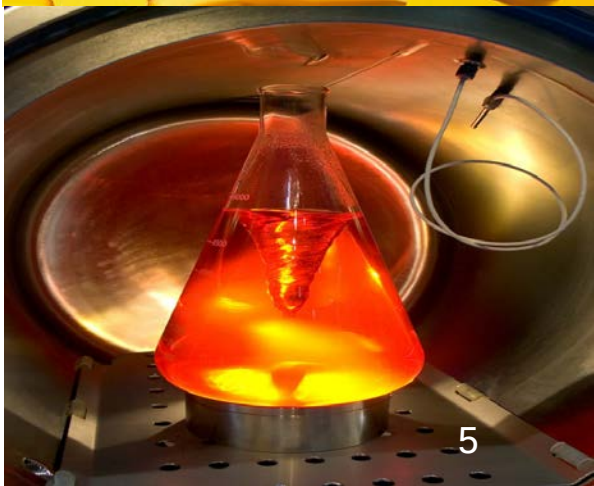
- In order to monitor the condition of steam turbines in real time we need to use the available information more effectively.
- This requires the development of a complete, realistic model of the rotor-bearing system.
- Armand Kruger is working on the rotor model and my study was concerned with the bearing models.

The Issue:

Multi-Grade Oil

- Polymer additives
- Solvent: Mineral Oil





Fluid Models:

Viscoelastic Formulation	Viscous Formulation
▪ Fluid motion is modelled by the Cauchy equation of motion (neglecting body forces): $$\rho\left[\frac{\partial \bar{v}}{\partial t} + (\bar{v}\cdot\nabla)\bar{v}\right] = -\nabla p + \nabla\cdot\bar{\bar{\tau}}$$ ρ - Density of the fluid. $\bar{v}$ - Velocity field. p - Pressure field. $\bar{\bar{\tau}}$ - Extra-stress tensor.	▪ Fluid behaviour modelled by a generalized Navier-Stokes Formulation: $$\rho\left[\frac{\partial \bar{v}}{\partial t} + (\bar{v}\cdot\nabla)\bar{v}\right]$$ $$= -\nabla p + \nabla\cdot[\eta(\nabla\bar{v}^T + \nabla^T\bar{v})]$$ ρ - Density of the fluid. $\bar{v}$ - Velocity field. p - Pressure field.

Heat Transfer:

- The first law of thermodynamics in differential form, for incompressible fluids, is used to model the heat transfer:

$$\rho C_p \left[\frac{\partial T}{\partial t} + (\bar{v} \cdot \nabla)T\right] = \bar{\bar{\sigma}} : \nabla \bar{v} + \nabla \cdot (k \nabla T)$$

C_p- heat capacity of fluid.

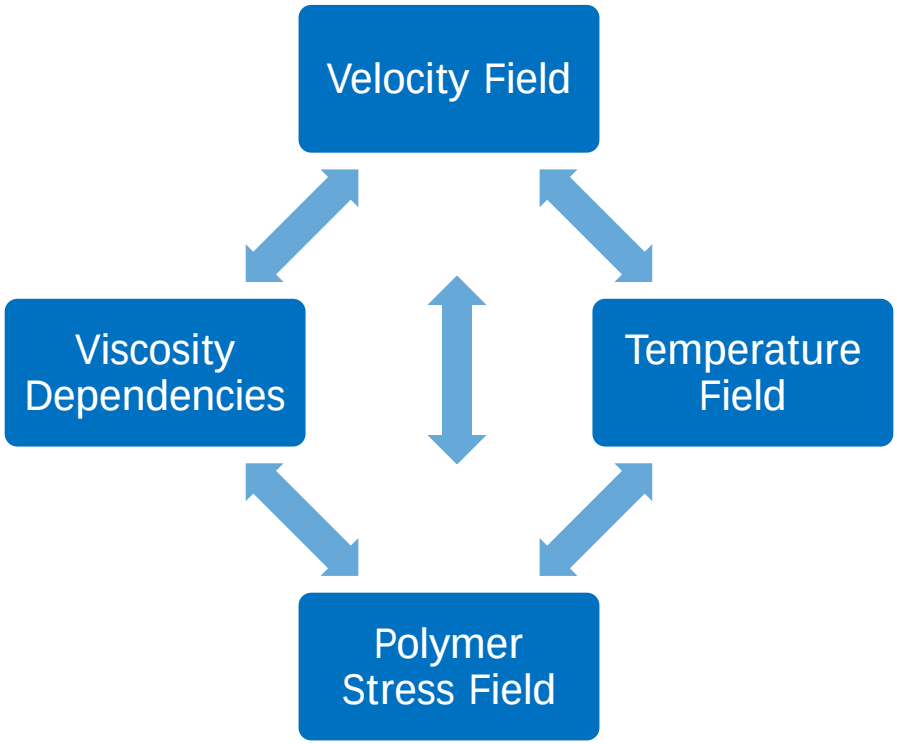
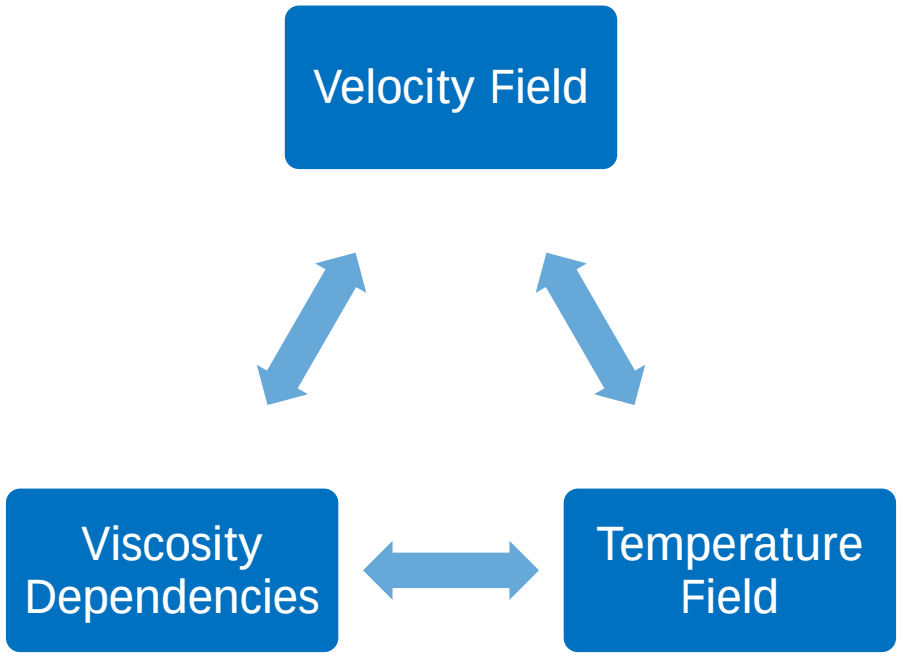
k - Thermal conductivity of the fluid.

$\bar{\bar{\sigma}}$ - Cauchy stress tensor

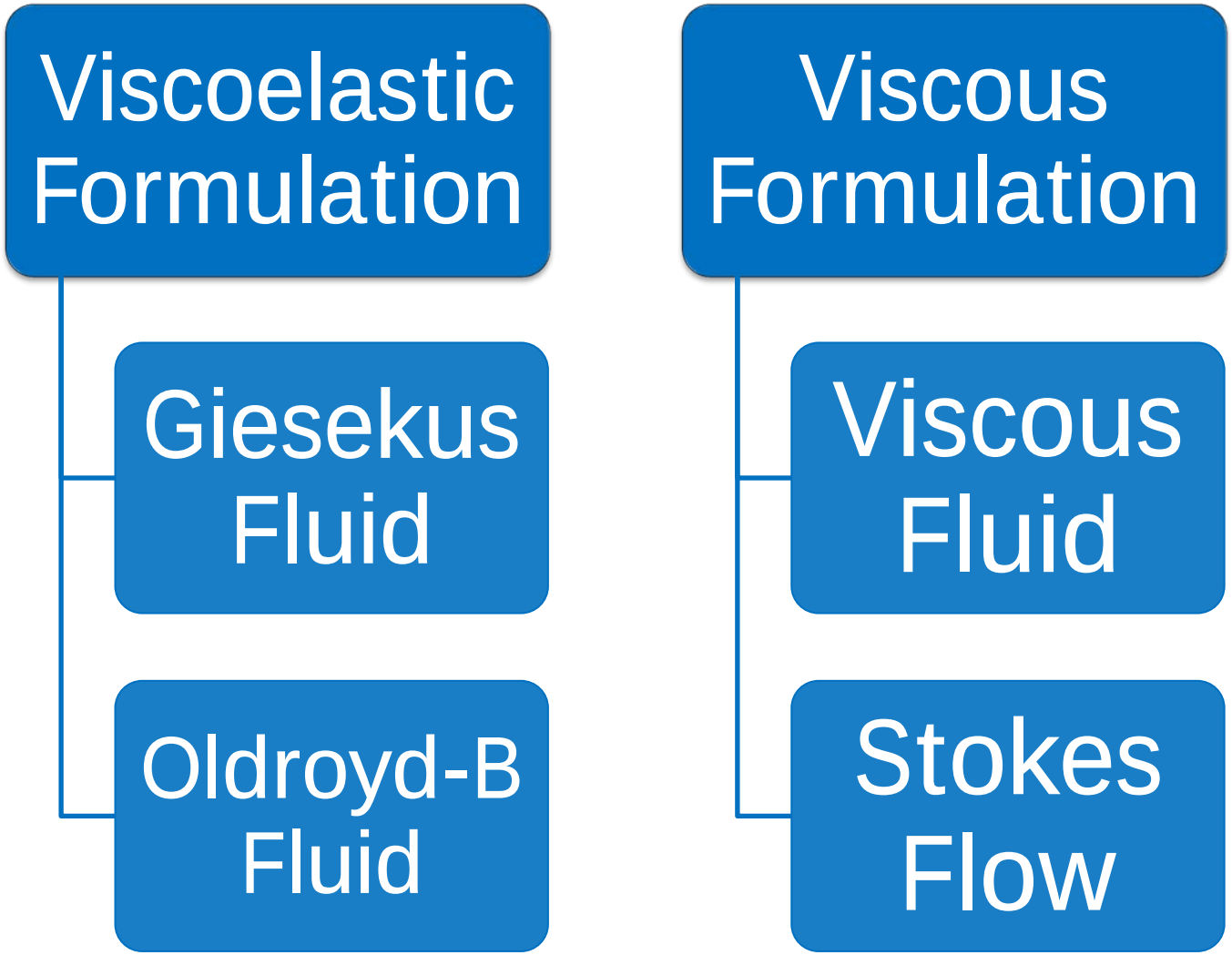
Numerical Solvers:

- OpenFOAM was used to develop the numerical solvers.
- OpenFOAM is a C++ library that provides various interpolation schemes as well as algebraic solvers.
- OpenFOAM solves PDEs and can give tensor, vector and scalar fields as outputs.

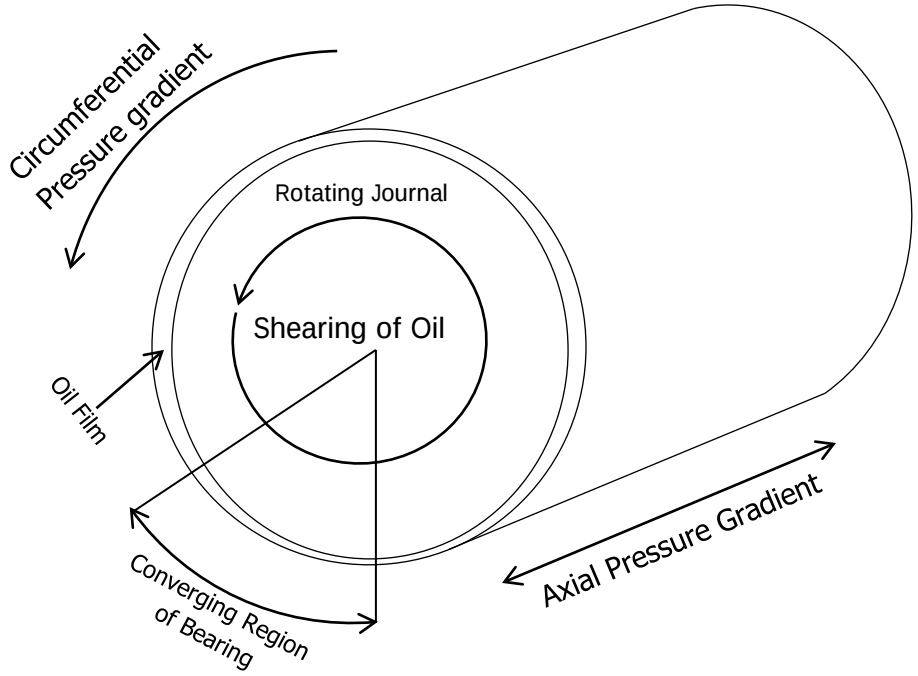
Coupling of Fluid Formulations:

Viscoelastic Formulation	Viscous Formulation
	

Solvers Developed:



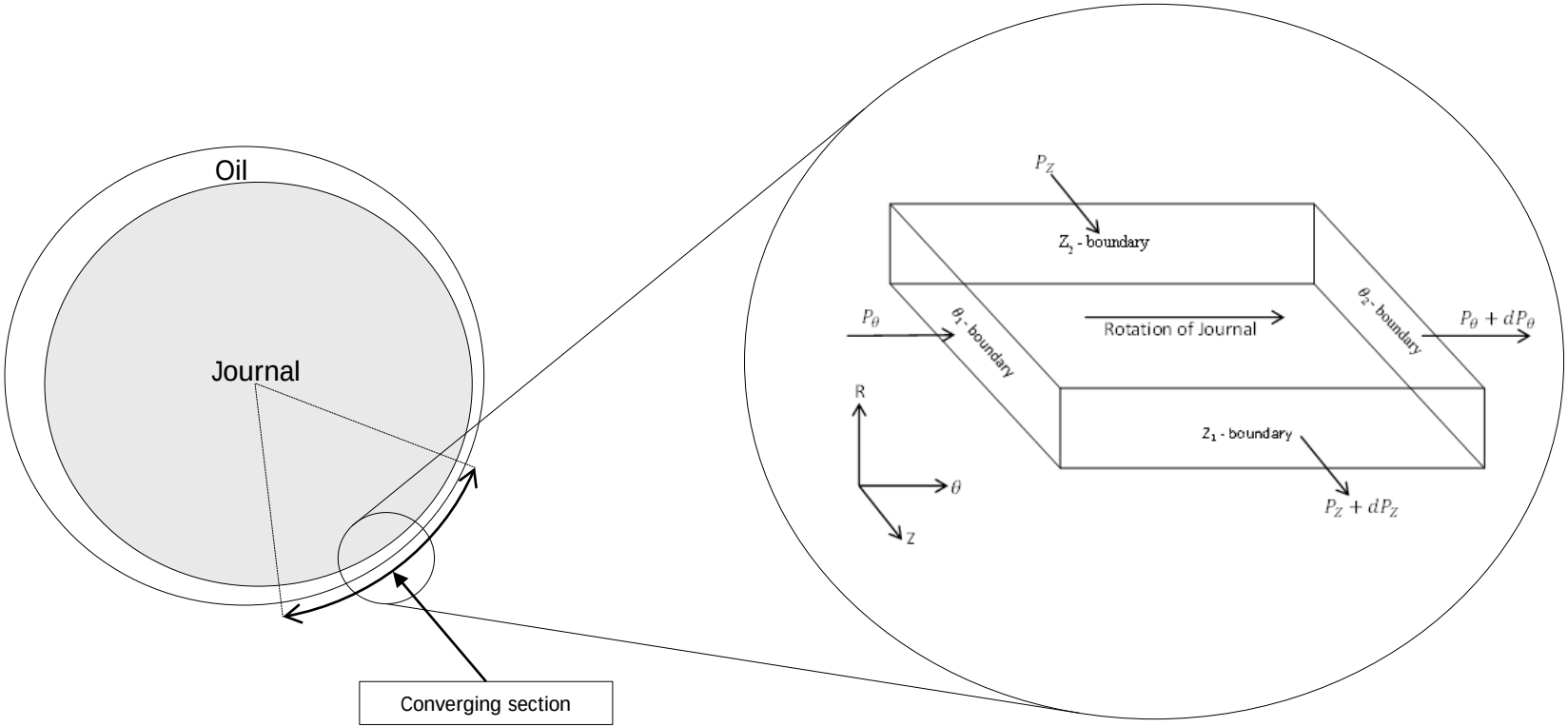
Driving Forces for the Flow:



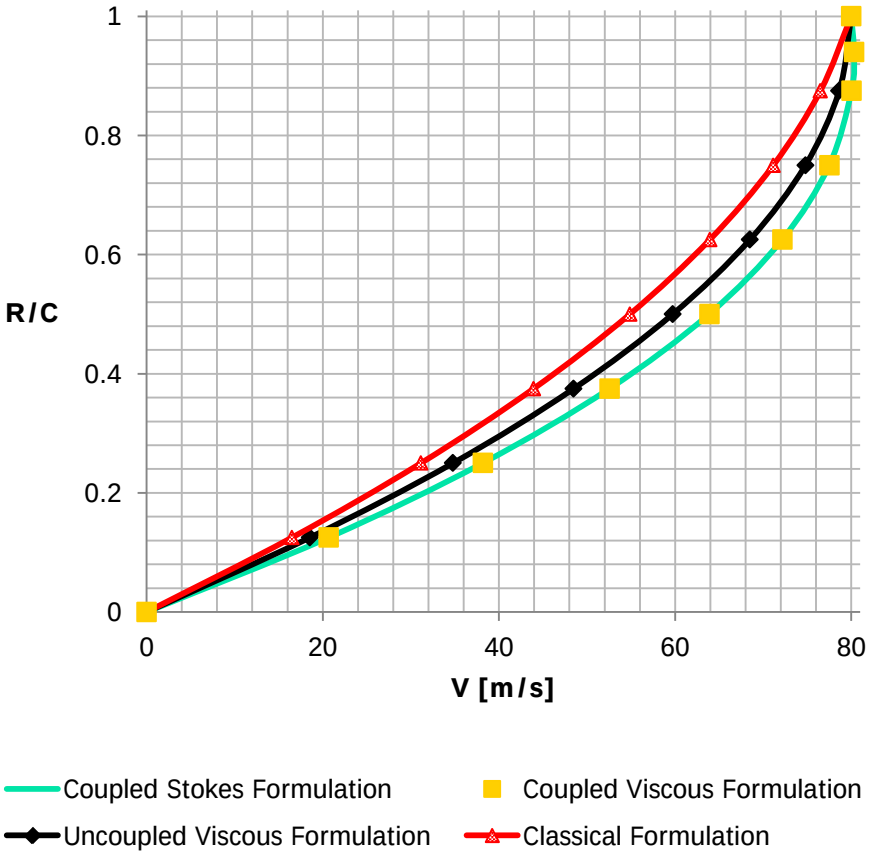
Simulation of a full scale journal bearing would require 5×10^9 control volumes!

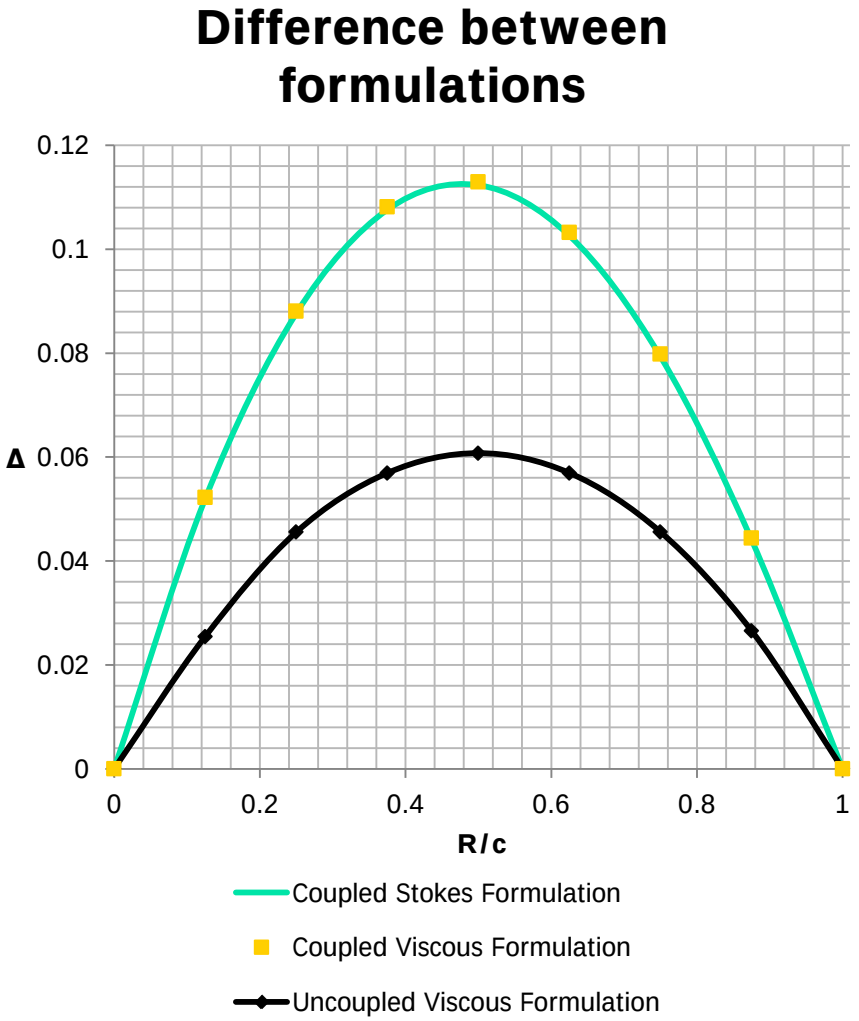
Alternative Approach

- A section of the bearing is extracted form the converging section of the bearing.
- The extracted section has the same driving forces in the same measure as the corresponding point in the bearing.

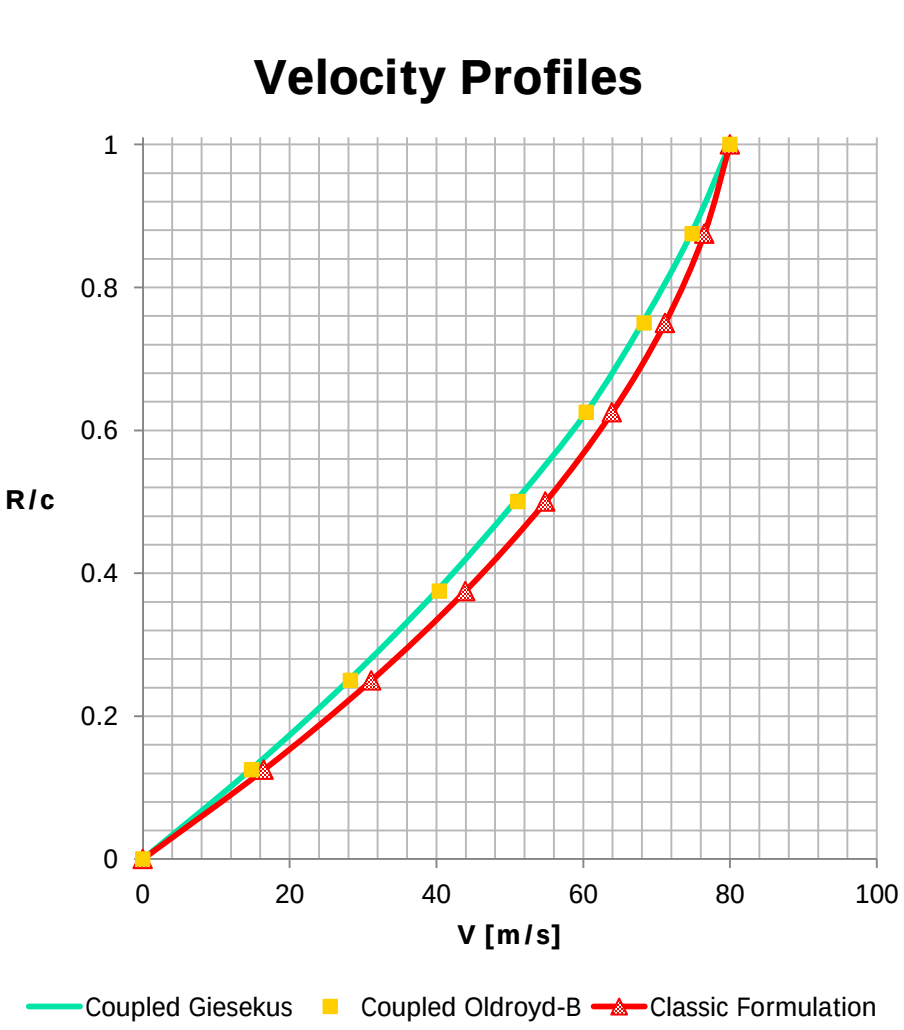


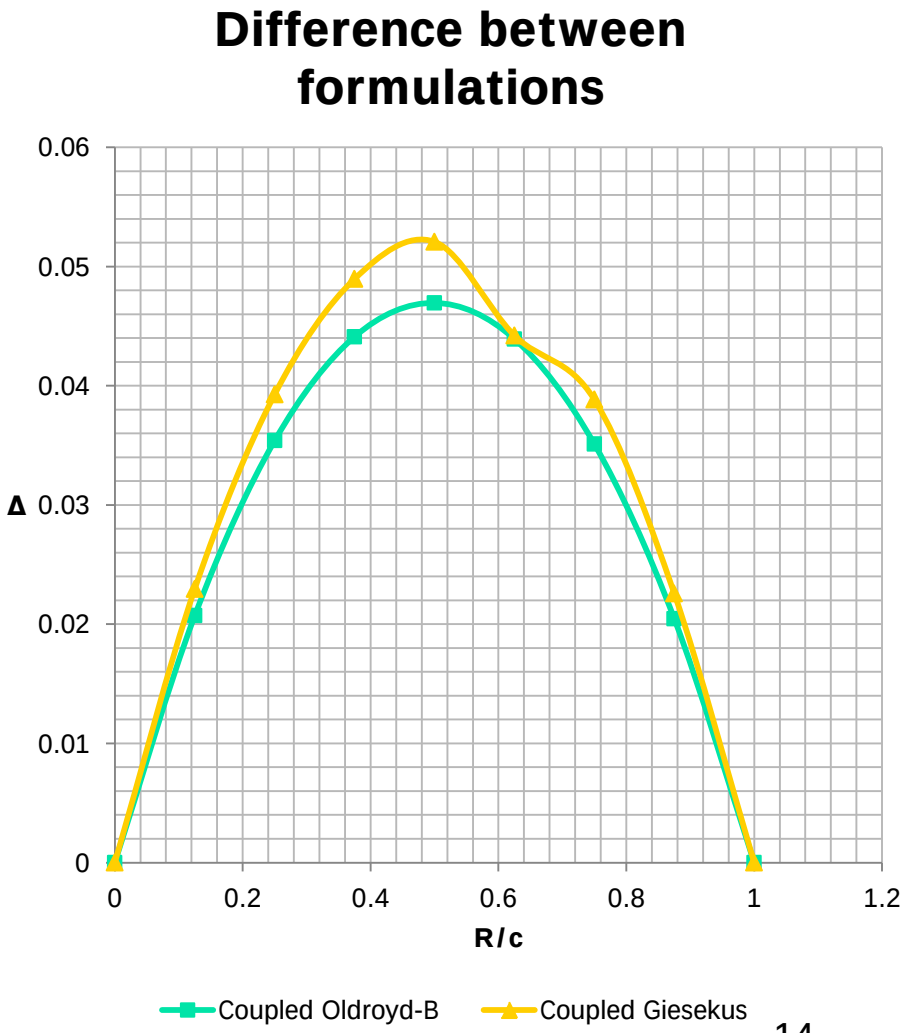
Weak Coupling - Viscous Formulation:



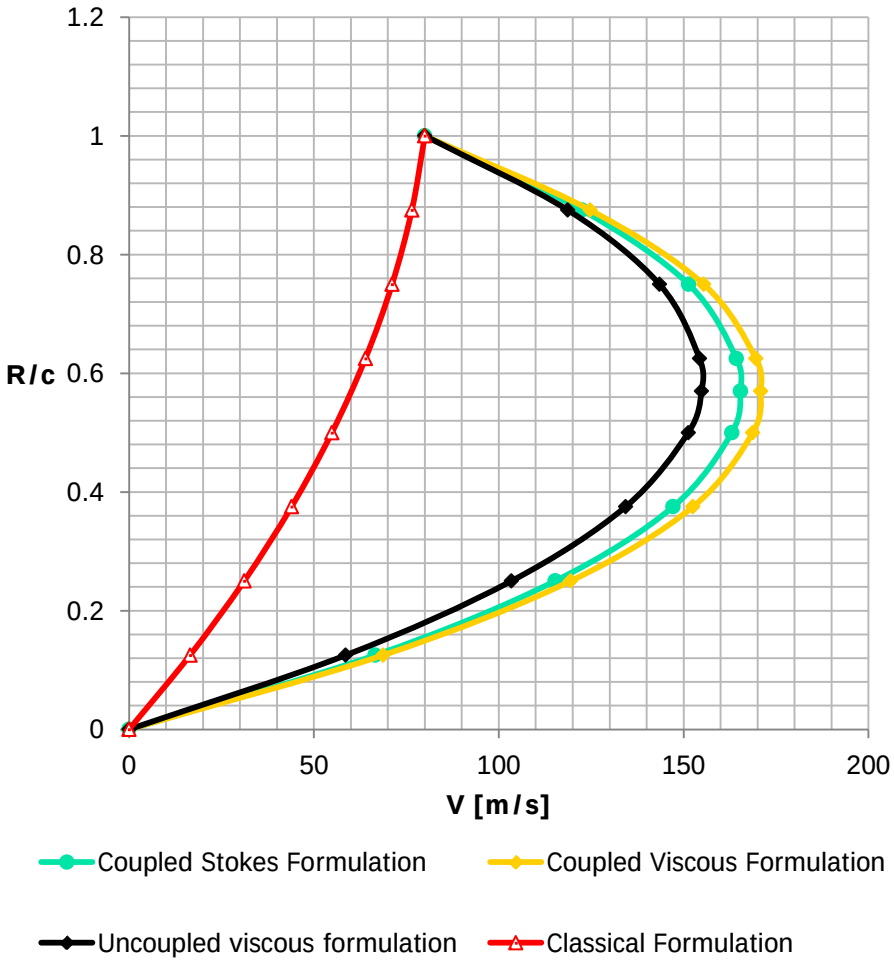


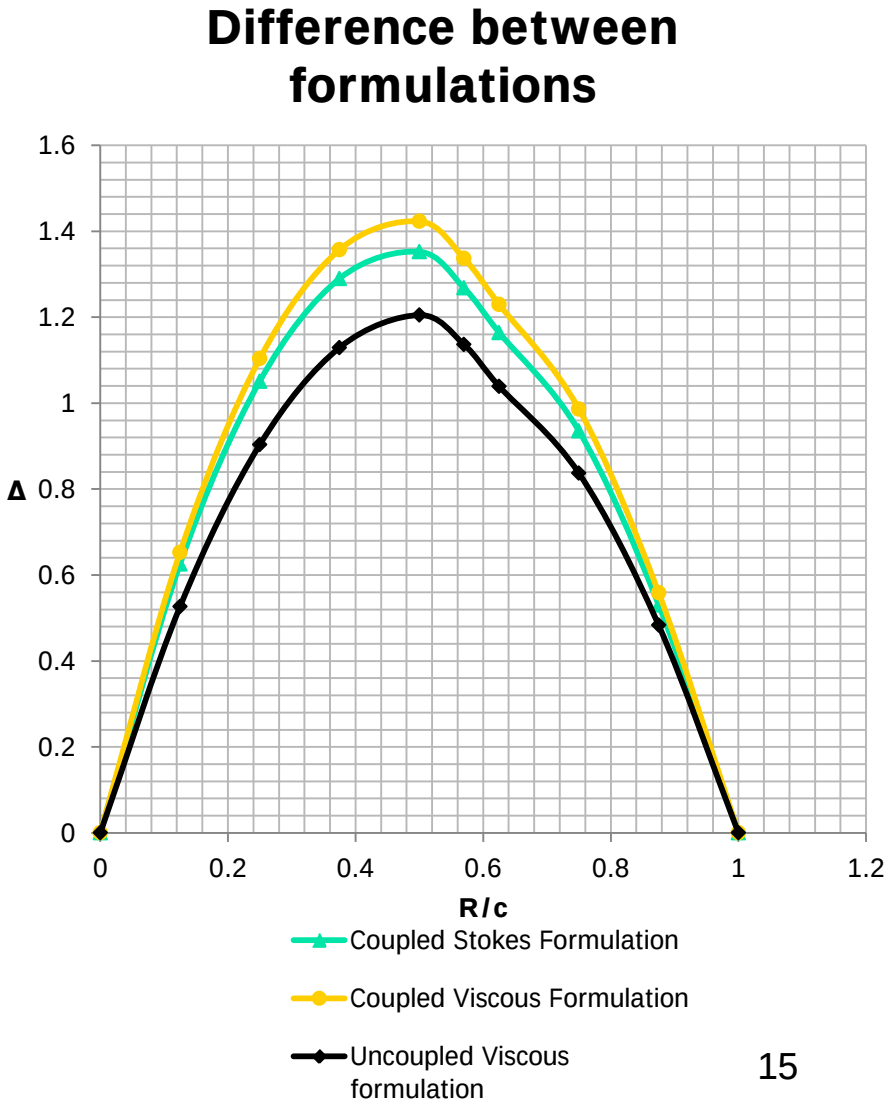
Weak Coupling – Viscoelastic Formulation:



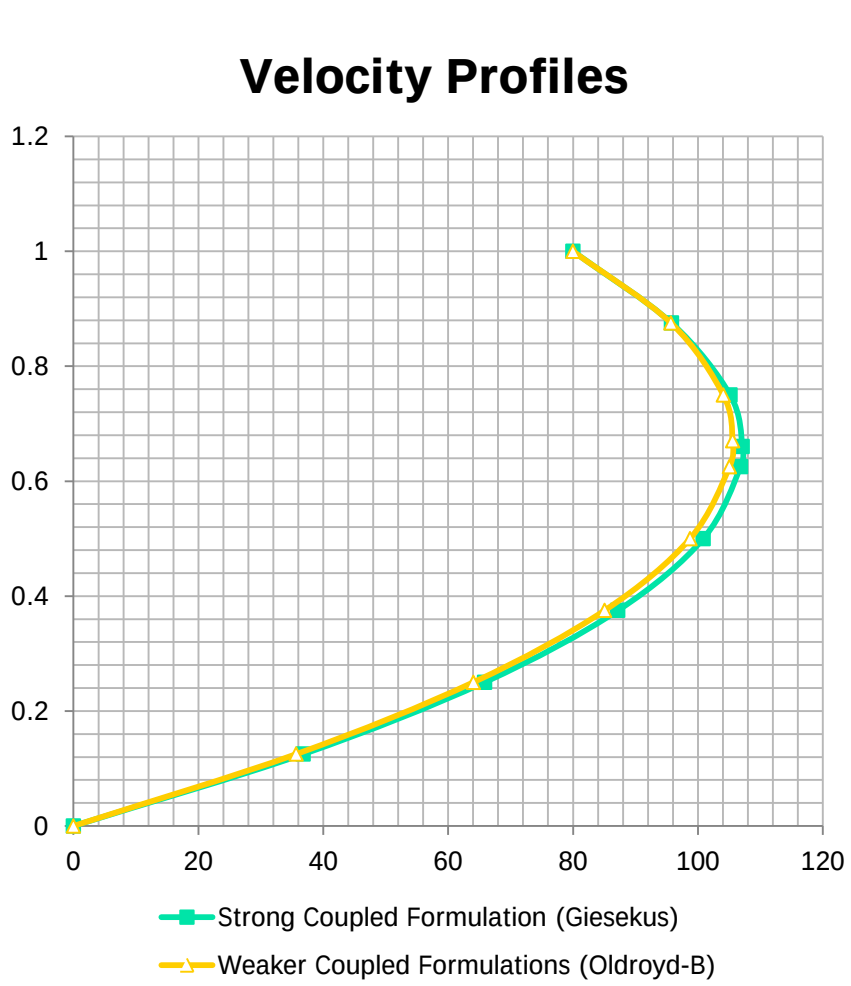


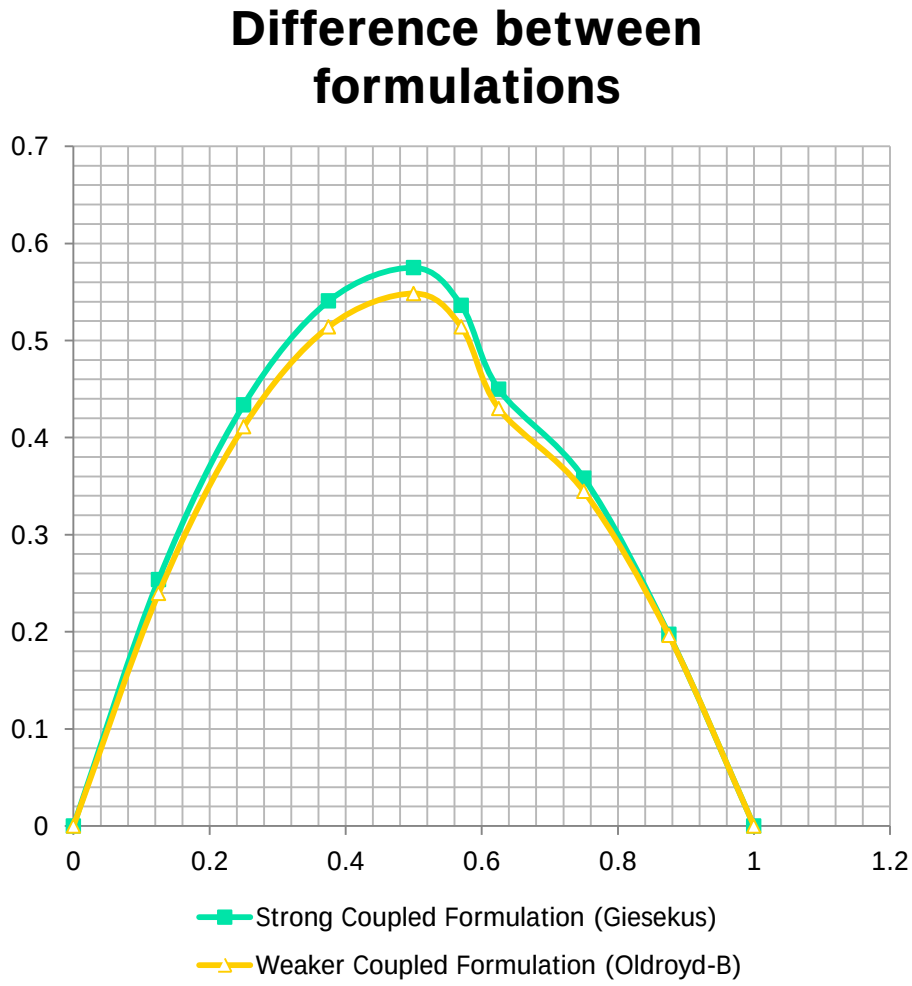
Strong Coupling – Viscous Formulation:





Strong Coupling – Viscoelastic Formulation:





Conclusion:

- The coupling, whether weak or strong, was seen to significantly affect the fluid behaviour.
- The Strong coupling was seen, in particular, to change the nature of the flow behaviour by departing form the classical formulation in a non-homogeneous way.
- A coupled formulation is vitally important to accurately model large scale journal bearings!

Questions?