COMSOL CONFERENCE
2016 MUNICH

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Innovation Engineering

Implementation of a Thermo- Hydrodynamic Model to Predict "Morton Effect"

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Contents

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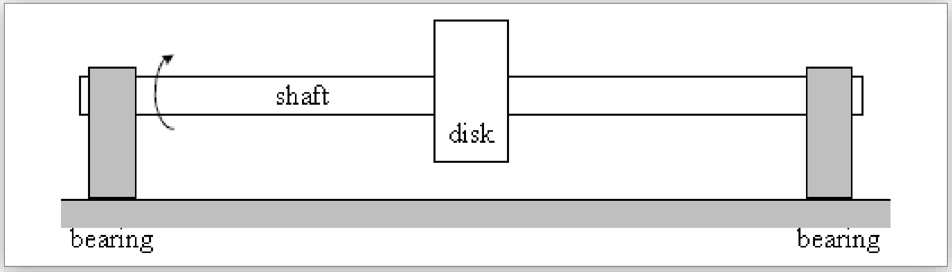
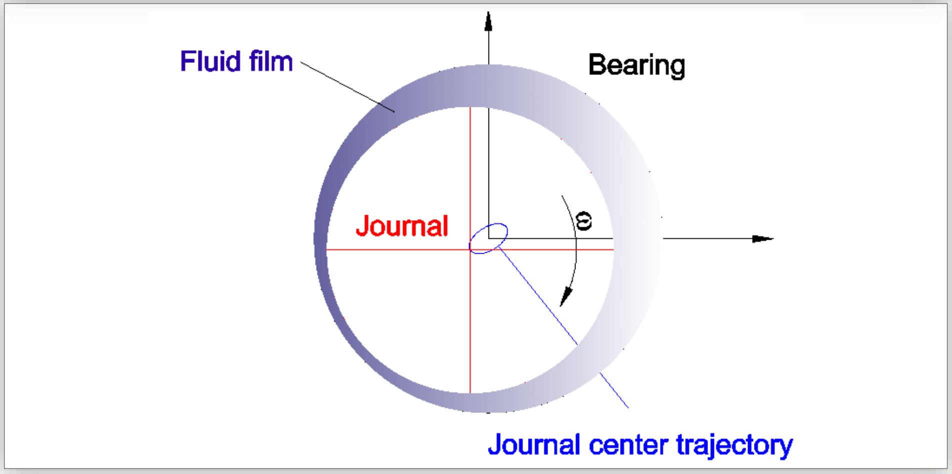
1.A - Morton effect and its explenations

- Shaft sustained with fluid film bearings



- Every journal has a residual unbalance
- The journal exhibits a synchronous orbit



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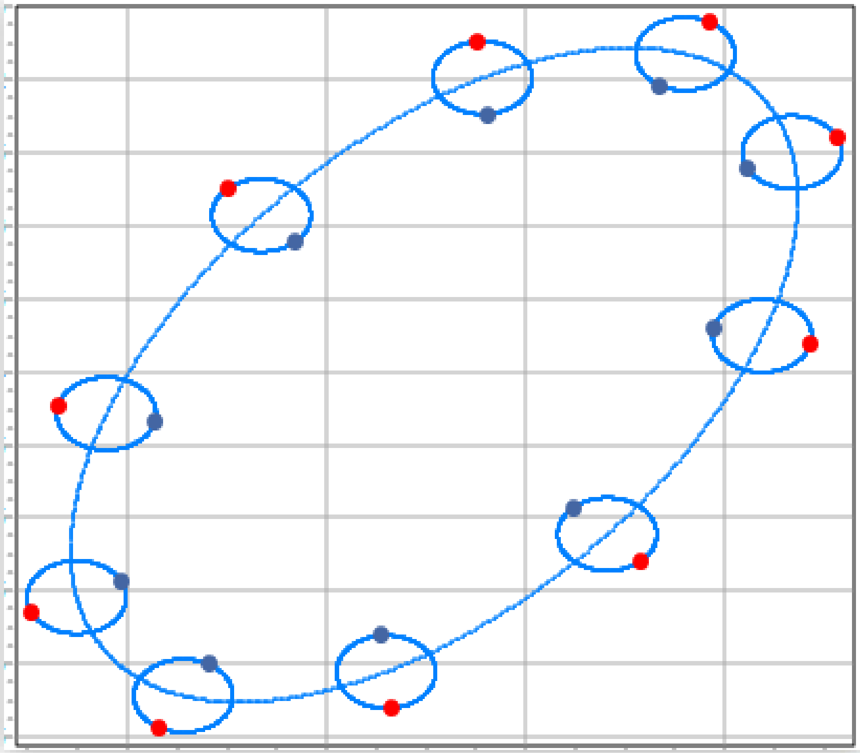
1.B - Morton effect and its explenations

- Inside fluid film bearing a small part of the journal is HOT, while the opposite side is COLD
- Non uniform temperature distribution inside oil
- Thermal bending



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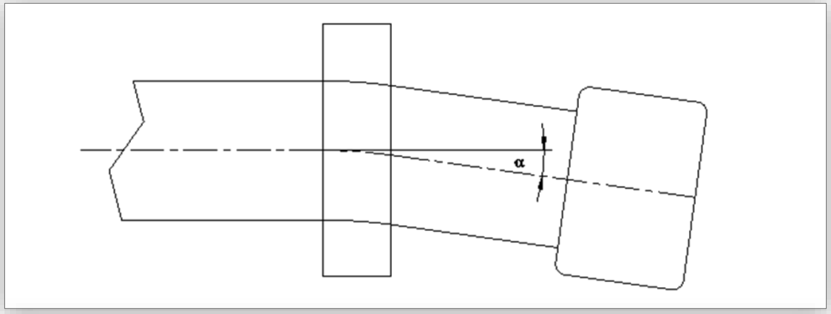
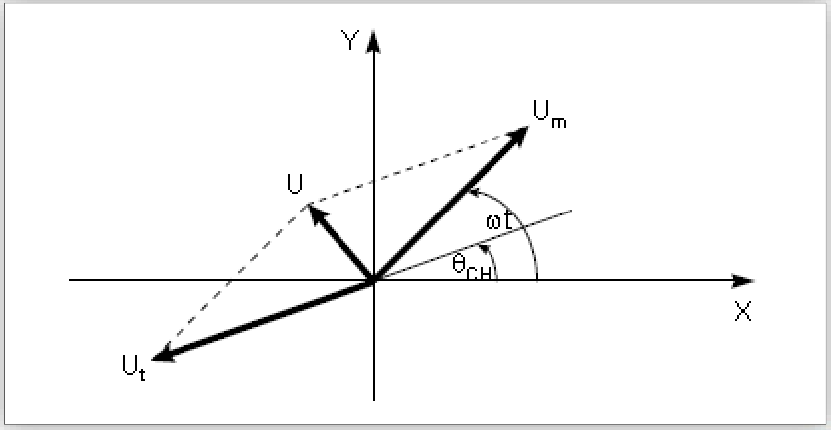
1.C - Morton effect and its explenations

Now consider an overhung mass…



- Thermal bending causes a certain unbalance
- Thermal unbalance can:
  - reinforce the effect reducing again minimum film thickness (UNSTABLE)
  - reduce the effect counter-balancing the mechanical unbalance (STABLE)



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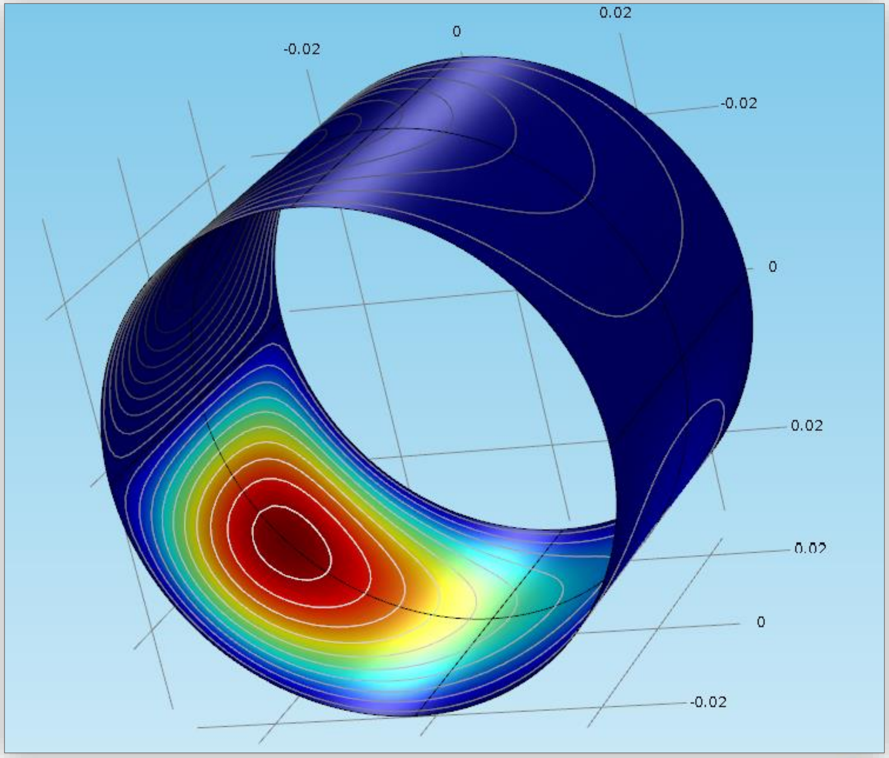
2.A - Physics behind the effect

CFD physics: Reynolds equation

$$\begin{cases} \nabla_T \cdot \left(\dfrac{-\rho h^3}{12\mu} \nabla_T p + \dfrac{\rho h}{2} (v_a + v_b) \right) = \dfrac{\partial(\rho h)}{\partial t} & (x,y) \in \Omega_1 \\ p(x,y) = 0 & (x,y) \in \Omega_2 \end{cases}$$



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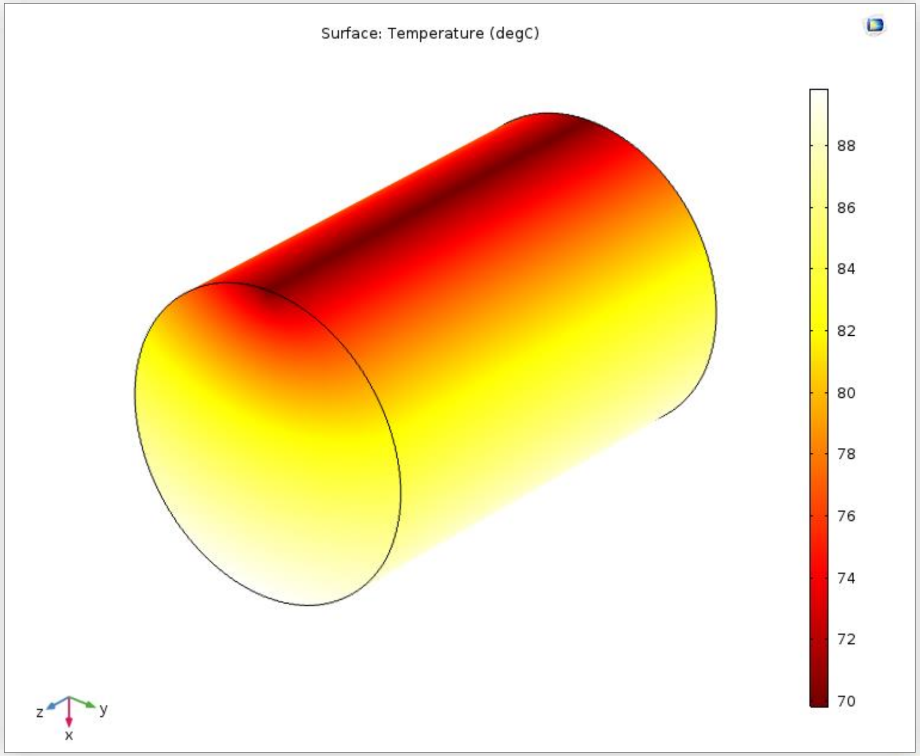
2.B - Physics behind the effect

Thermal physics

Energy generation rate + Influx energy rate = energy accumulation rate

$$\dot{q} + \nabla \cdot (k \nabla u) = u_t$$



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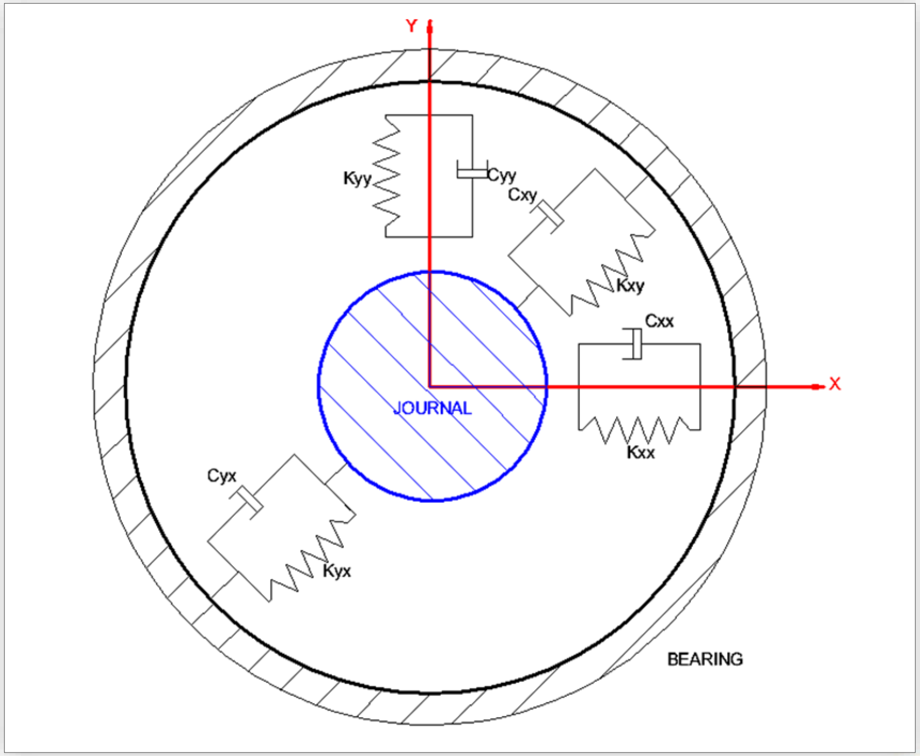
2.C - Physics behind the effect

Mechanical physics and multibody dynamics

$$\boldsymbol{M}\ddot{\boldsymbol{X}} + \boldsymbol{C}\dot{\boldsymbol{X}} + \boldsymbol{K}\boldsymbol{X} = \boldsymbol{M}\boldsymbol{u}\omega^2 \begin{pmatrix} sin\ \omega t \\ cos\ \omega t \end{pmatrix}$$



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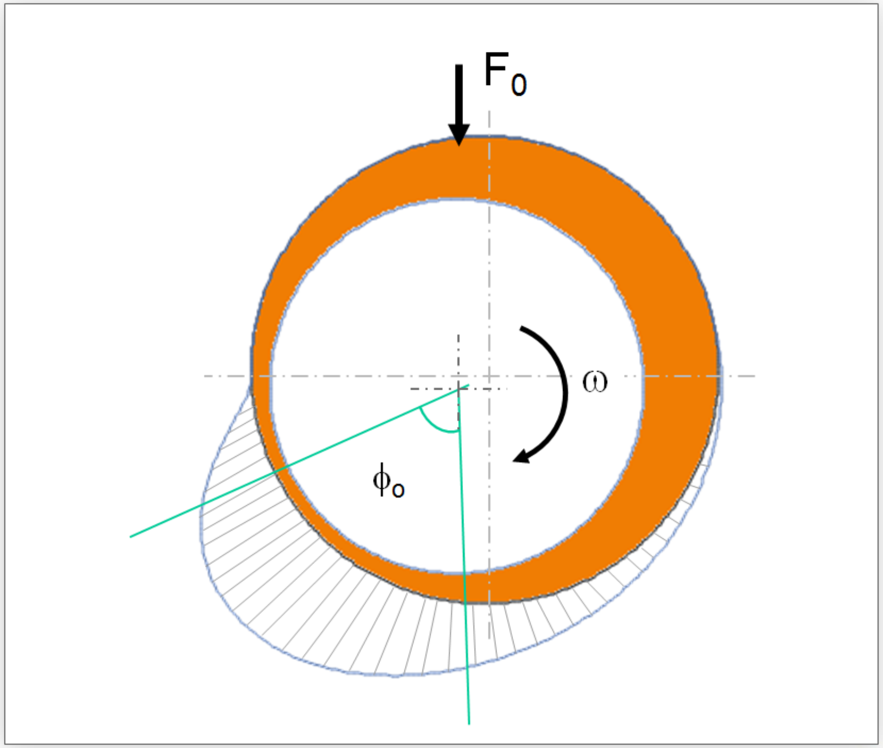
3.A - Approximation and methodology

Static equilibrium position
(short bearing approximation)

$$F_0 = \mu\omega RL\left(\frac{L}{C}\right)^2 \frac{\varepsilon}{4}\frac{\sqrt{16\varepsilon^2+\pi^2(1-\varepsilon^2)}}{(1-\varepsilon^2)^2}$$

$$\tan(\phi_0) = \frac{\pi\sqrt{1-\varepsilon^2}}{4\varepsilon}$$



A. C. Balbahadur, R. G. Kirk, Part I—Theoretical Model for a Synchronous Thermal Instability Operating in Overhung Rotors, *International Journal of Rotating Machinery*, 10(6): 469–475, 2004

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3.B - Approximation and methodology

Orbit and motion (short bearing approximation)

$$k_{xx} = K_{xx}\frac{C}{F_0} = \frac{f_{r0}}{\varepsilon(1-\varepsilon^2)}\left(f_{r0}^2 + 1 + 2\varepsilon^2\right)$$

$$k_{yy} = K_{yy}\frac{C}{F_0} = \frac{f_{r0}}{\varepsilon(1-\varepsilon^2)}\left(f_{t0}^2 + 1 - \varepsilon^2\right)$$

$$k_{yx} = K_{yx}\frac{C}{F_0} = \frac{f_{t0}}{\varepsilon(1-\varepsilon^2)}\left(f_{r0}^2 - 1 + \varepsilon^2\right)$$

$$k_{xy} = K_{xy}\frac{C}{F_0} = \frac{f_{t0}}{\varepsilon(1-\varepsilon^2)}\left(f_{r0}^2 + 1 + 2\varepsilon^2\right)$$

$$c_{xx} = C_{xx}\frac{C\omega}{F_0}\frac{2f_{t0}}{\varepsilon(1-\varepsilon^2)}\left((2+\varepsilon^2)f_{r0}^2 + 1 - \varepsilon^2\right)$$

$$c_{yy} = C_{yy}\frac{C\omega}{F_0} = \frac{2f_{t0}}{\varepsilon(1-\varepsilon^2)}\left((2+\varepsilon^2)f_{t0}^2 - 1 + \varepsilon^2\right)$$

$$c_{xy} = c_{yx} = C_{xy}\frac{C\omega}{F_0} =$$

$$= \frac{2f_{r0}}{\varepsilon(1-\varepsilon^2)}\left((2+\varepsilon^2)f_{t0}^2 - 1 + \varepsilon^2\right)$$

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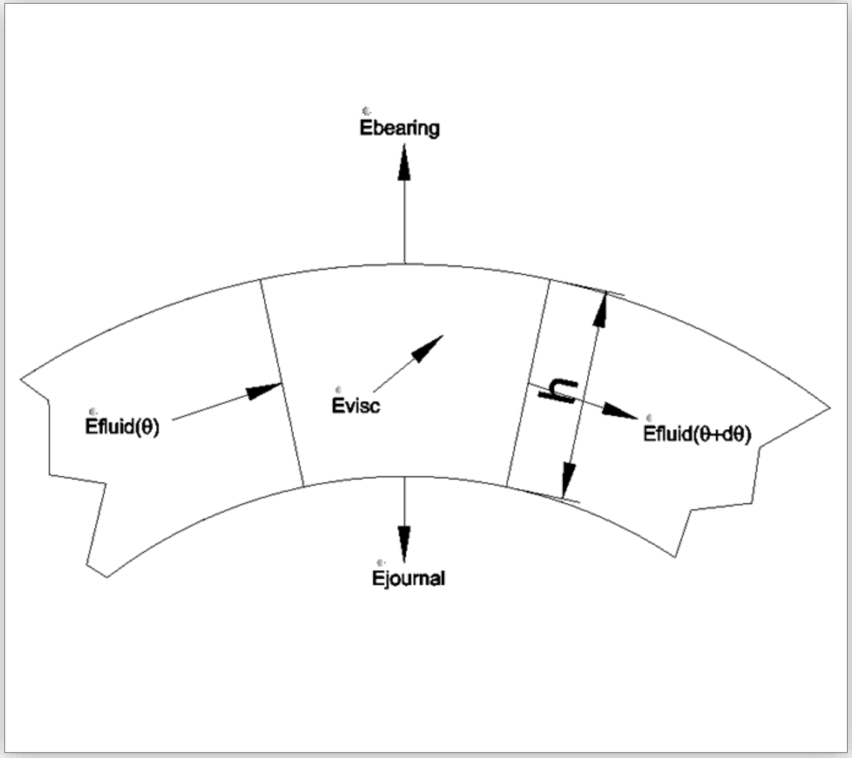
3.C - Approximation and methodology

Temperature distribution
(short bearing approximation)

$$\dot{E}_{visc} = \dot{E}_{fluid}(\vartheta + d\vartheta) - \dot{E}_{fluid}(\vartheta) + \dot{E}_{journal} + \dot{E}_{bearing}$$

$$\frac{dT}{d\xi} + \frac{2H}{\rho c \omega h} - \left(\frac{2HT_{amb}}{\rho c \omega h} + \frac{2\mu\omega R_j^2}{\rho c h^2} \right) = 0$$



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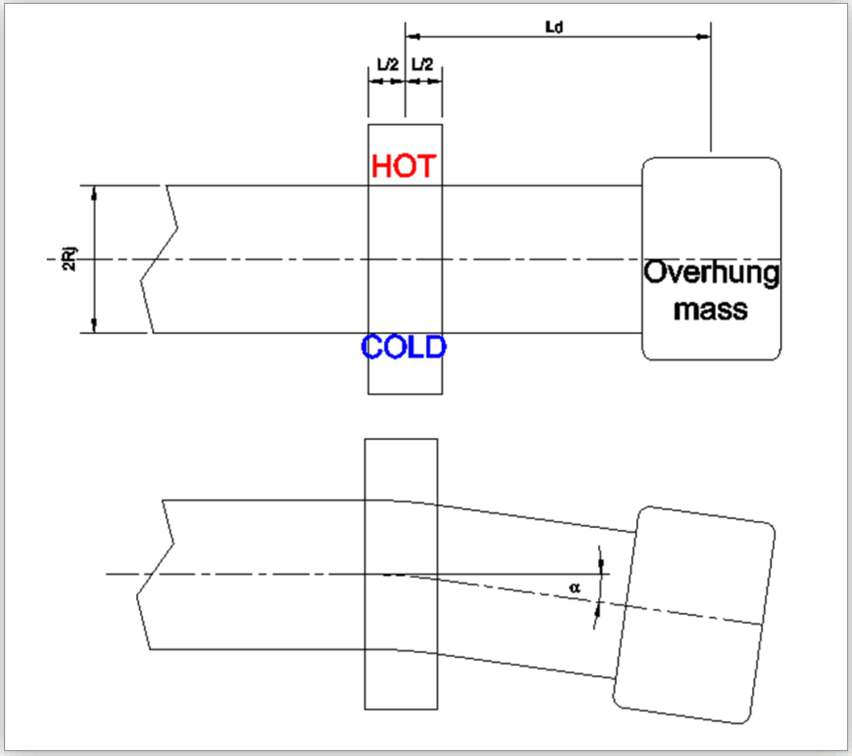
3.D - Approximation and methodology

Unbalance (mechanical, total, limit)

$$U_t = m_o y_o = m_o \frac{\alpha \Delta T}{R_j} L L_o$$

$$U_{thr} = \frac{0.15\, W}{\omega^2}$$



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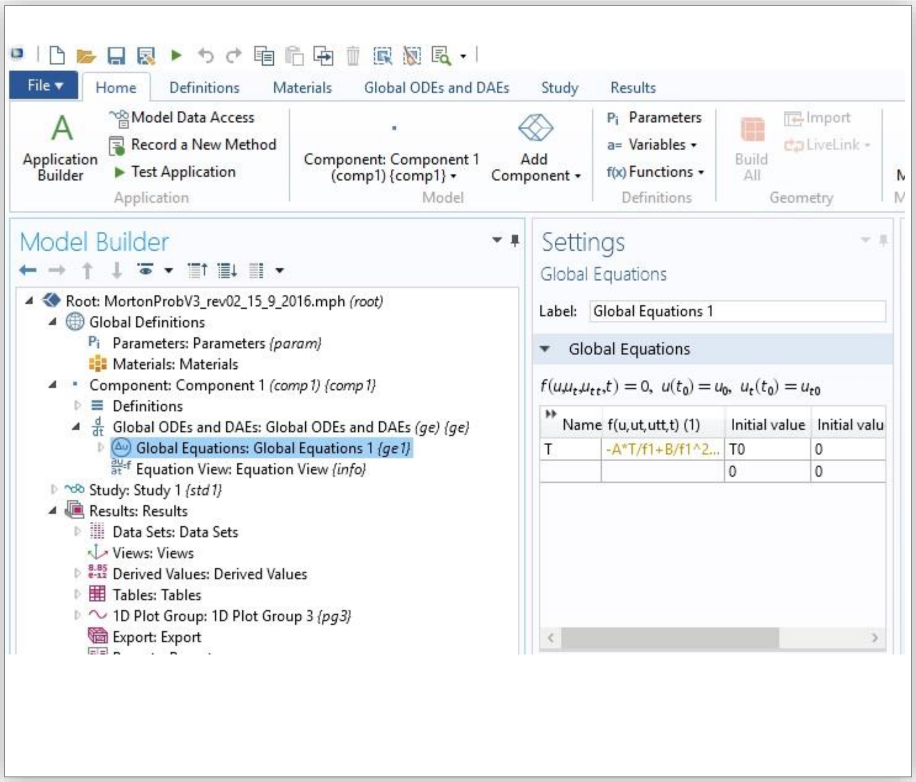
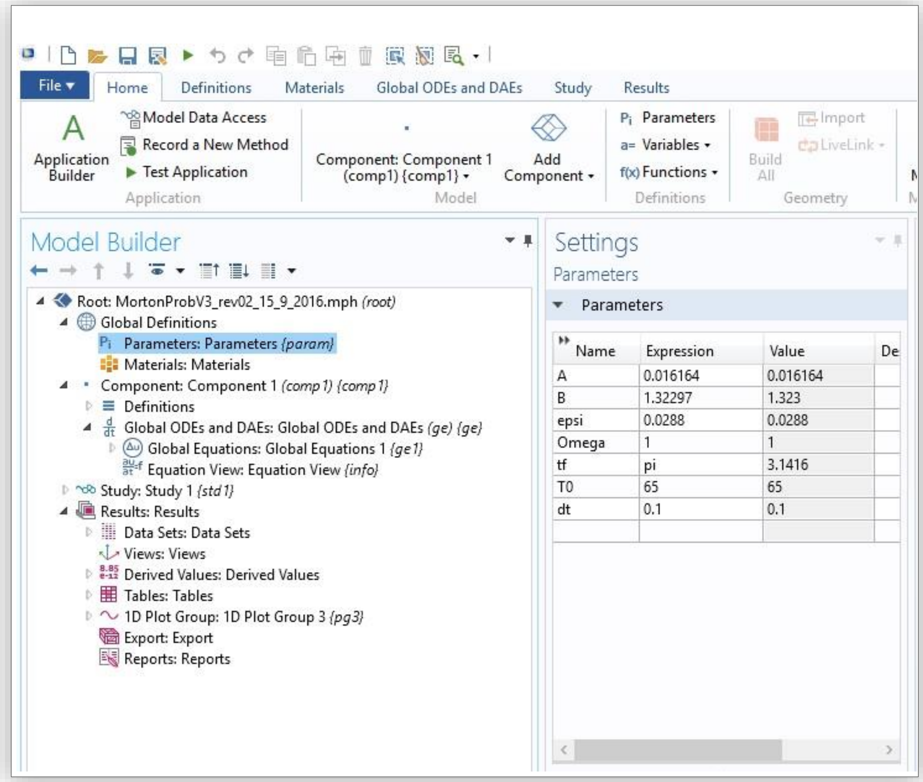
4 – Comsol implementation





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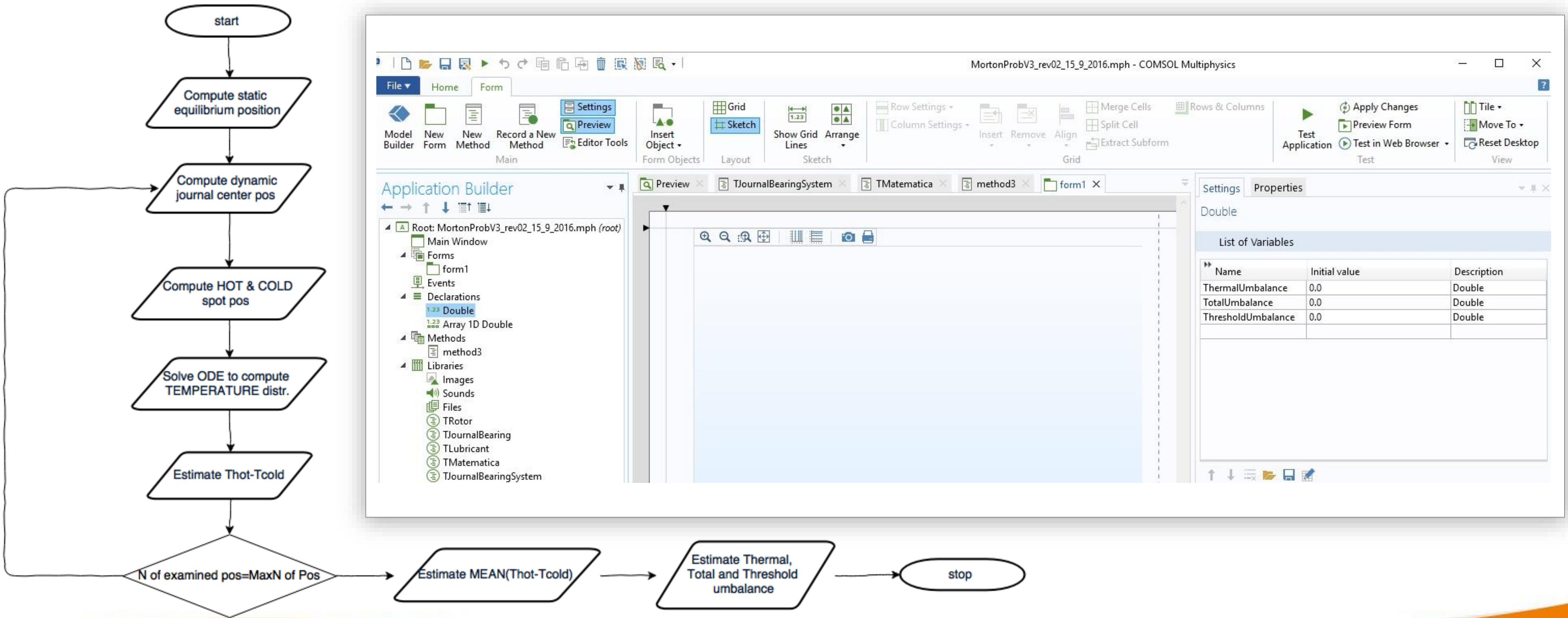
4 – Comsol implementation



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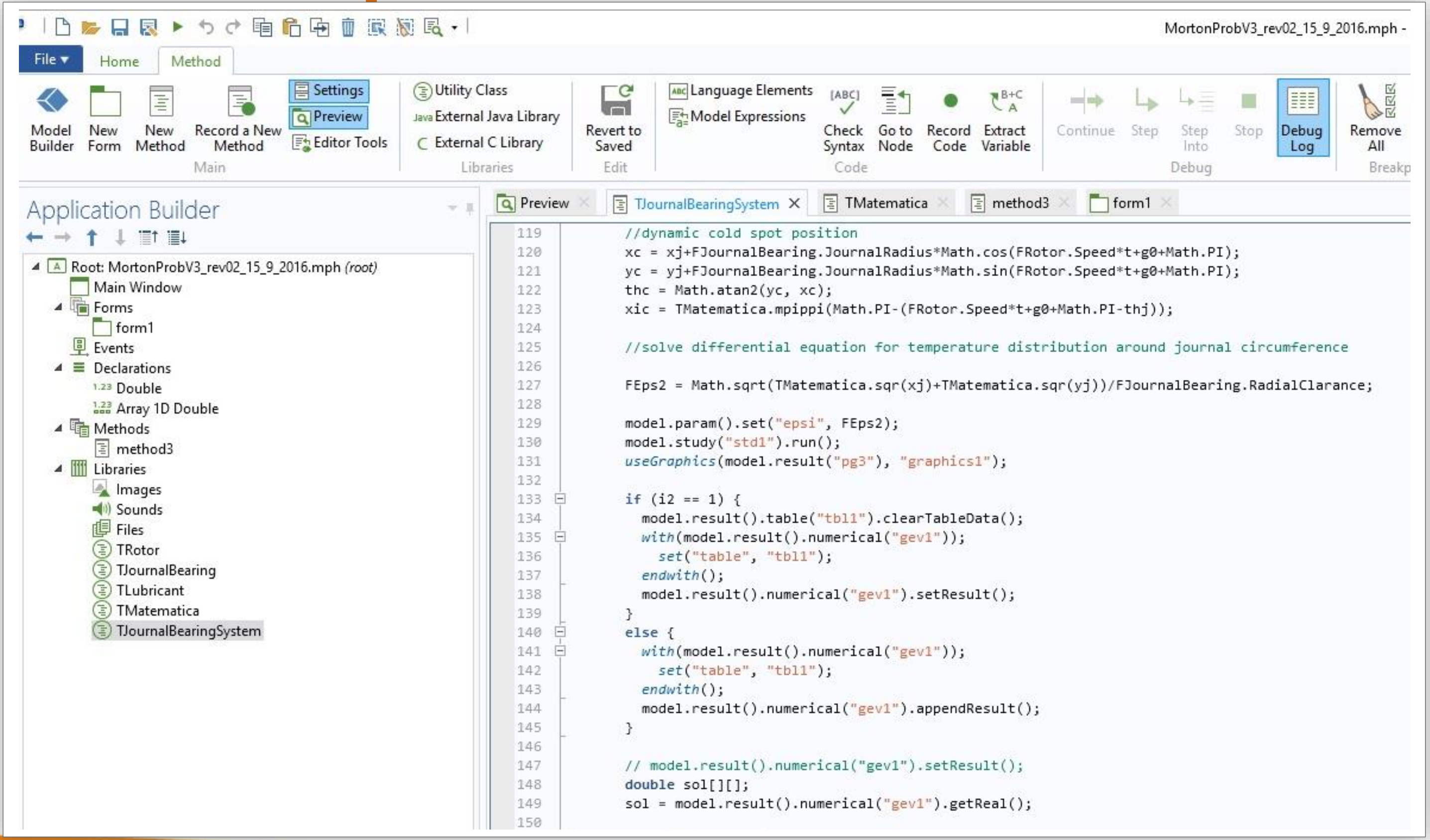

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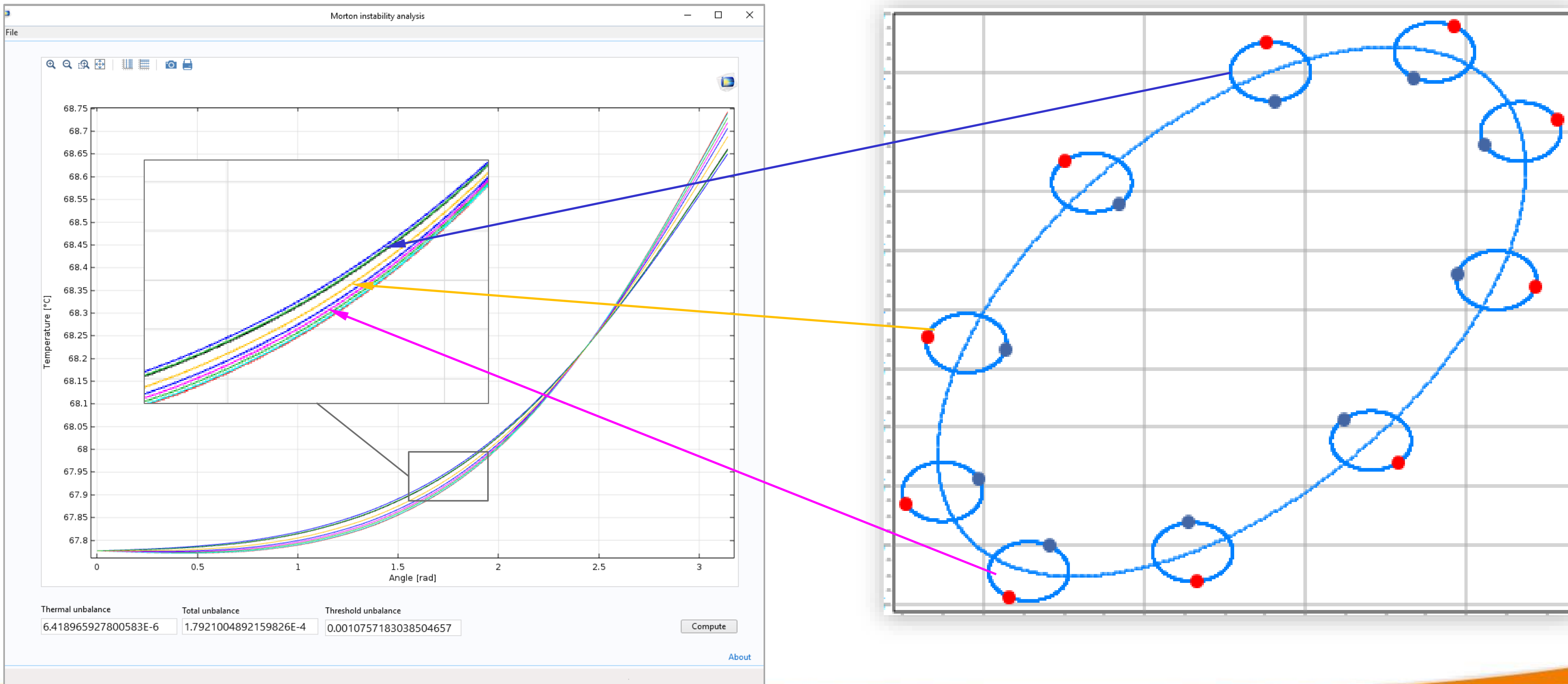

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Conclusion & future works

Implementation of a model to predict Morton effect (suggested by the literature)

- Hard numerical computation made by COMSOL
- A dedicated algorithm uses result computed with COMSOL

FUTURE WORKS

Eliminate approximation introduced to compute

- temperature distribution
- static equilibrium position

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Thank you for your kind attention

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