Static load and dynamic forced performance of rigid rotor supported on short length journal bearings (includes thermal effects)

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$ORIGIN := 1$

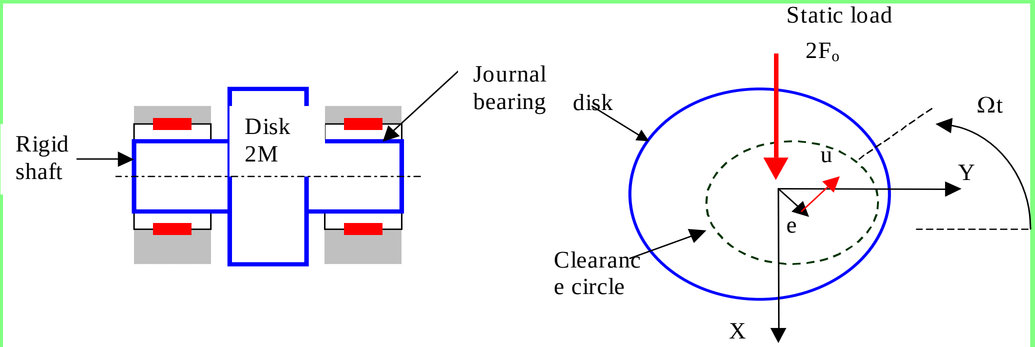


Figure 5.1. Rigid rotor supported on journal bearings. (u) imbalance, (e) journal eccentricity

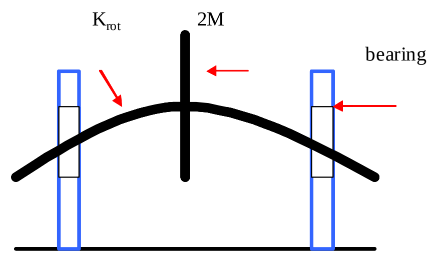
rotor properties

DATA for rotor

$W_T := 500 \cdot lbf$ **Rotor weight**

$W := \frac{W_T}{2}$ **Load per bearing**

$W = 1.112 \times 10^3 newton$



$M := \frac{W}{g}$ $M = 250\,lb$ **1/2 rotor mass**

$k_{shaft} := 40 \cdot 10^6 \cdot \frac{N}{m}$ **Rotor stiffness on each side of disk (at midspan)**

$k_{shaft} = 2.284 \times 10^5 \frac{lbf}{in}$

$Rotor\_sag := \frac{W}{k_{shaft}}$ **Rotor sag at midspan:**

$Rotor\_sag = 1.095 \times 10^{-3} in$

rotor properties

bearing geometry

BEARING GEOMETRY

$D := 6 \cdot in$ **journal diameter**

$R := \frac{D}{2}$ **journal radius**

$L := 2 \cdot in$ **bearing length**

Static shaft deflection due to rotor weight = % of clearance

$c := 0.003 \cdot in$ **radial clearance**

$\frac{L}{D} = 0.333$

$\frac{Rotor\_sag}{c} = 0.365$

bearing geometry

$RPM\_max := 10000$

MAXIMUM & design speeds

# of cases for analysis $Nmax := 50$

$RPM_{design} := 7200$

$a := 0.2 \cdot c$ Amplitude of imbalance on rotor disk

Thermal model conditions

$\kappa := 0.8$ **Mechanical energy convected by lubricant.**

$\lambda := 0.70$ **Heat carry over - thermal mixing coefficient.**

$T_{supply} := 50K$ Supply Oil Temperature Take deg-K as deg-C

Lubricant properties

PROPERTIES OF LUBRICANT **MOBIL velocite No 10 (ISO VG 22)**

$\mu_{supply} := 0.0143 \cdot \frac{N \cdot s}{m^2}$ Lubricant viscosity at Tsupply in Pa-sec.

$\alpha := 0.028 \cdot \frac{1}{K}$ Alpha coefficient for viscosity equation.

$\rho := 862 \cdot \frac{kg}{m^3}$ Density in kg/m^3.

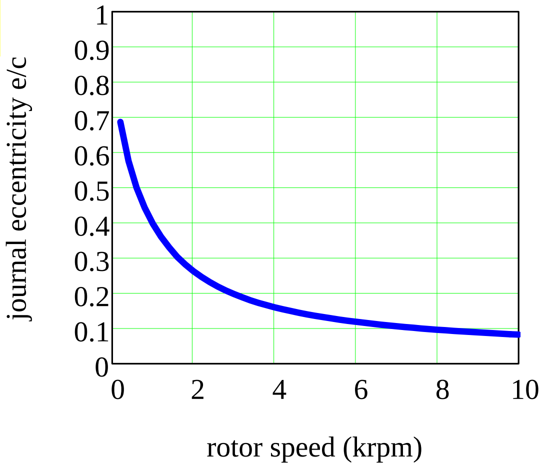
$Cp := 1880 \cdot \frac{J}{kg \cdot K}$ Specific Heat in kJ/(kg C).

Lubricant properties

Calculations

STATIC LOAD PERFORMANCE: journal cccentricity and attitude angle

ε



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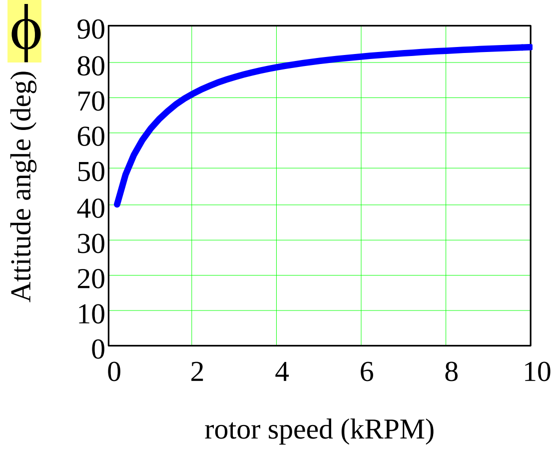
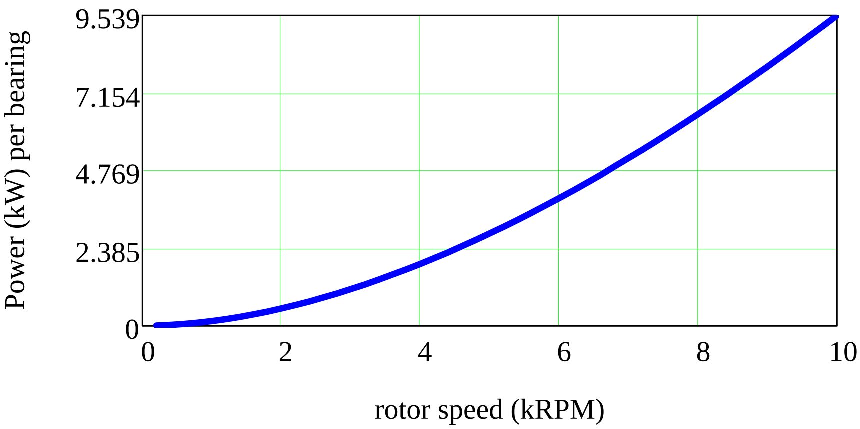


$W = 250\,\text{lbf}$

$c = 3 \times 10^{-3}\,\text{in}$

POWER LOSS (kW) on each bearing

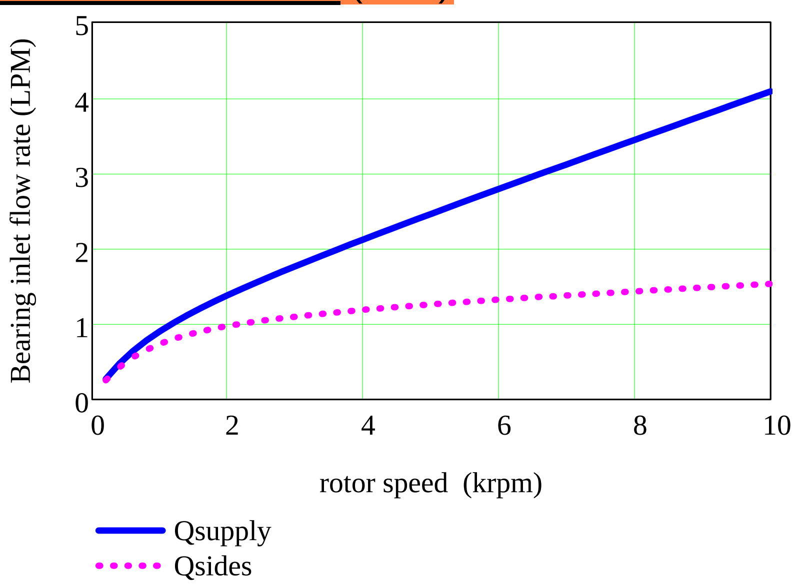


$$\frac{W}{L \cdot D} = 20.833\,\text{psi}$$

$L = 2\,\text{in}$

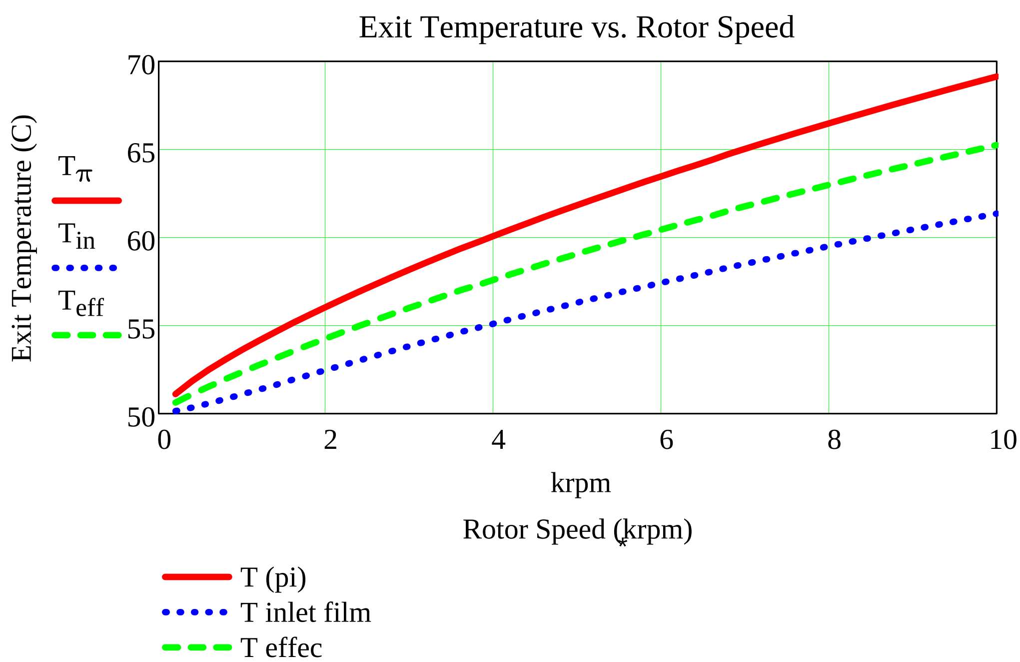
$D = 6\,\text{in}$

LUBRICANT FLOW RATE (LPM)



FILM temperatures: effective, inlet to film, exit at 180deg

$T_{supply} = 50\,K$



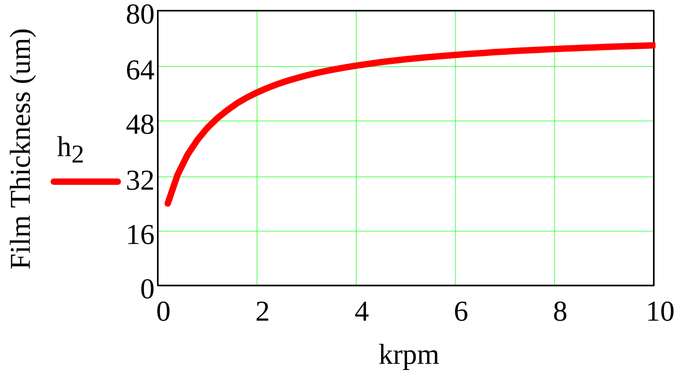
OTHER BEARING OPERATING PARAMETERS

Minimum Film Thickness

$h_{2_n} := \left[c \cdot \left(1 - \varepsilon_n\right)\right] \cdot 10^6$

Minimum Film Thickness vs. Speed

$c = 0.076\,\text{mm}$

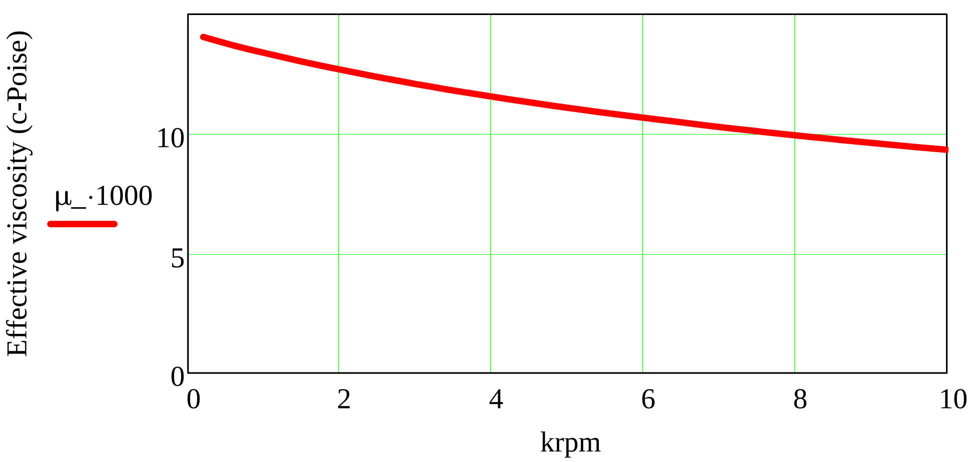


Rotor Speed (krpm)

Effective viscosity (C-Poise)

Viscosity vs. Rotor Speed

$\mu\left(T_{supply}\right) = 0.014\,\text{N} \cdot \frac{s}{m^2}$

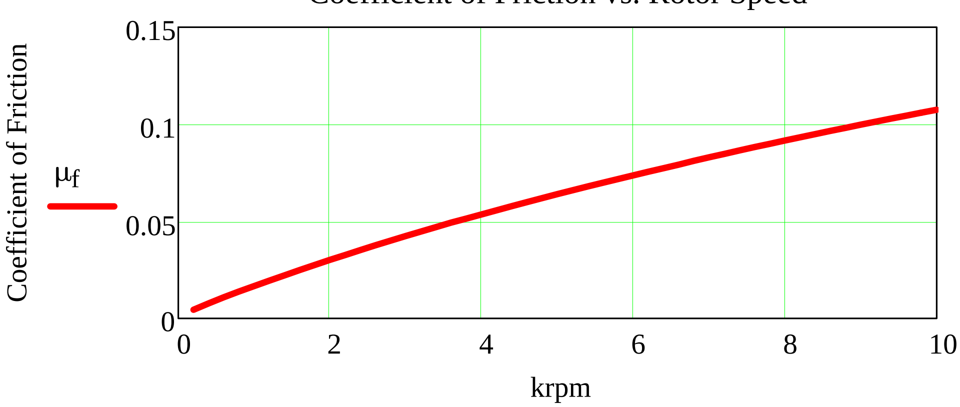


Rotor Speed (krpm)

Friction Coefficient

$\mu_{f_n} := \frac{Power_n}{\Omega_n \cdot R \cdot W}$

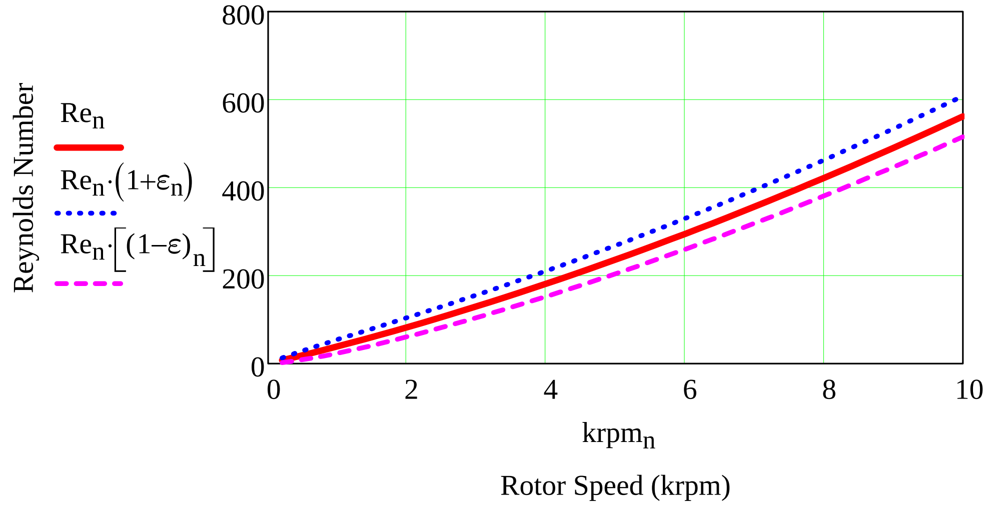
Coefficient of Friction vs. Rotor Speed



Rotor Speed (krpm)

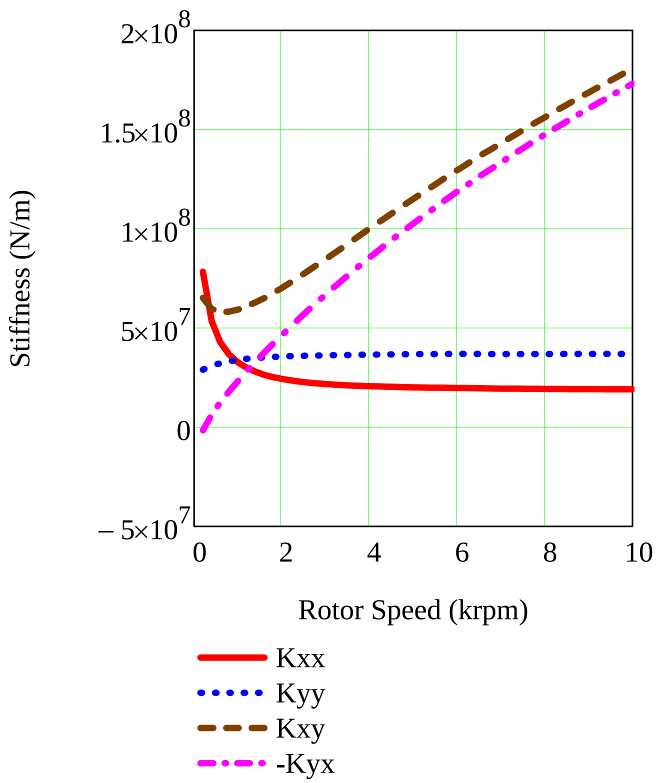
Reynolds Number

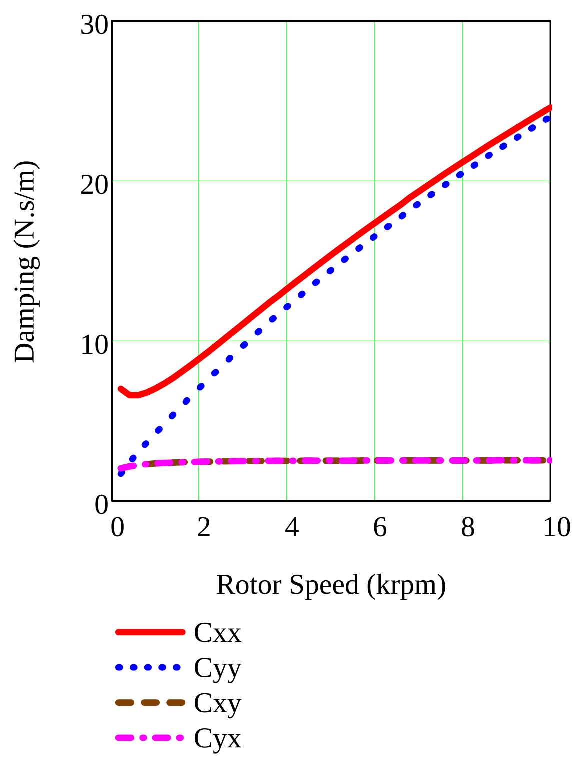
$$Re_n := \rho \cdot \Omega_n \cdot R \cdot \frac{c}{\mu\_n}$$



Force coefficients evaluation

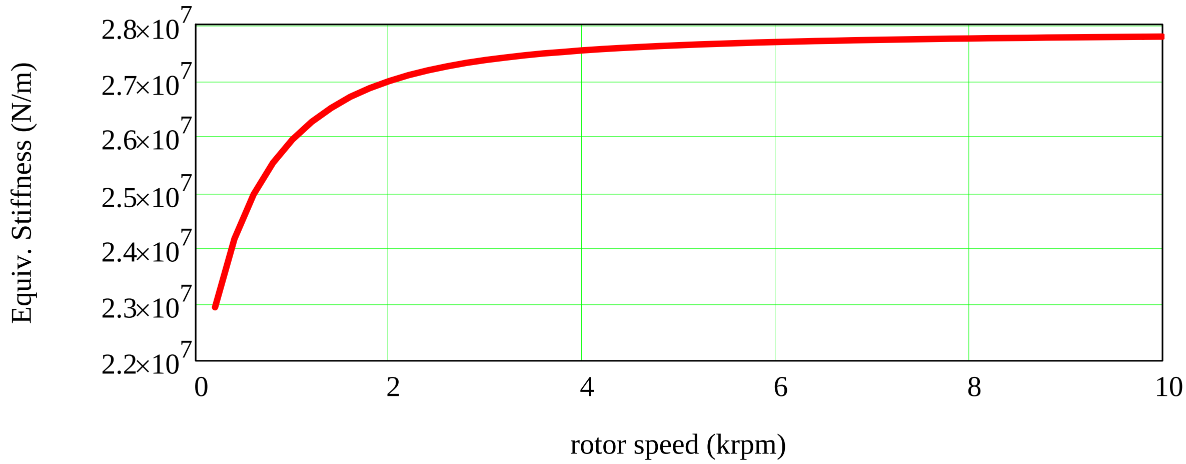
STIFFNESS AND DAMPING COEFFICIENTS





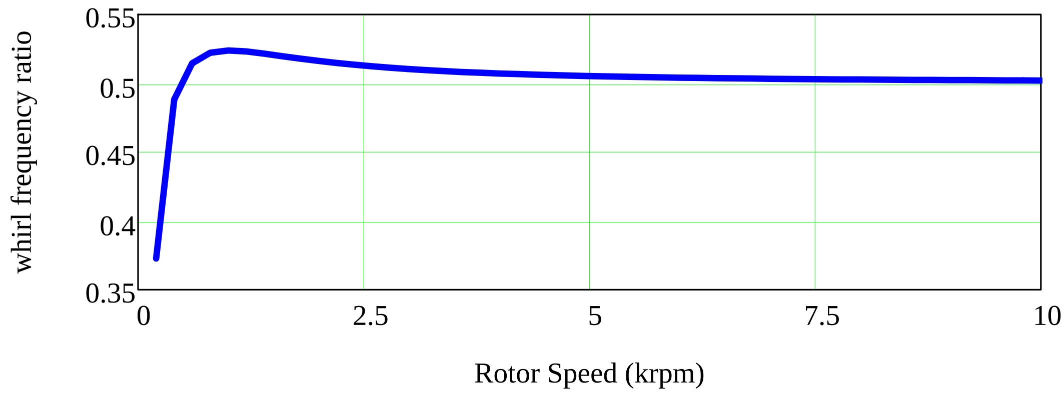
Equivalent bearing stiffness for rigid rotor

$$k_{eq_n} := \frac{k_{xx_n} \cdot c_{yy_n} + k_{yy_n} \cdot c_{xx_n} - c_{yx_n} \cdot k_{xy_n} - c_{xy_n} \cdot k_{yx_n}}{c_{xx_n} + c_{yy_n}}$$



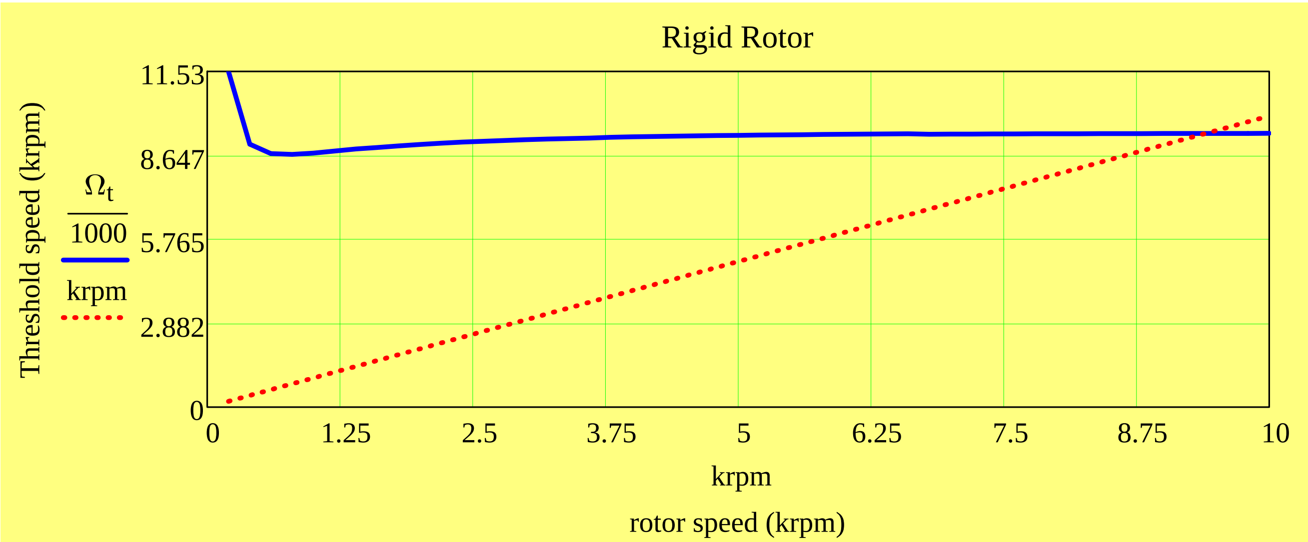
Whirl frequency ratio

$$WFR_n := \sqrt{\frac{\left(k_{eq_n} - k_{xx_n}\right) \cdot \left(k_{eq_n} - k_{yy_n}\right) - k_{xy_n} \cdot k_{yx_n}}{c_{xx_n} \cdot c_{yy_n} - c_{xy_n} \cdot c_{yx_n}}}$$



Threshold speed of instability(krpm)

$$\Omega_{t_n} := \sqrt{\frac{k_{eq_n} \cdot F_{o_n}}{M \cdot c}} \cdot \frac{\left(\frac{30}{\pi}\right)}{WFR_n}$$

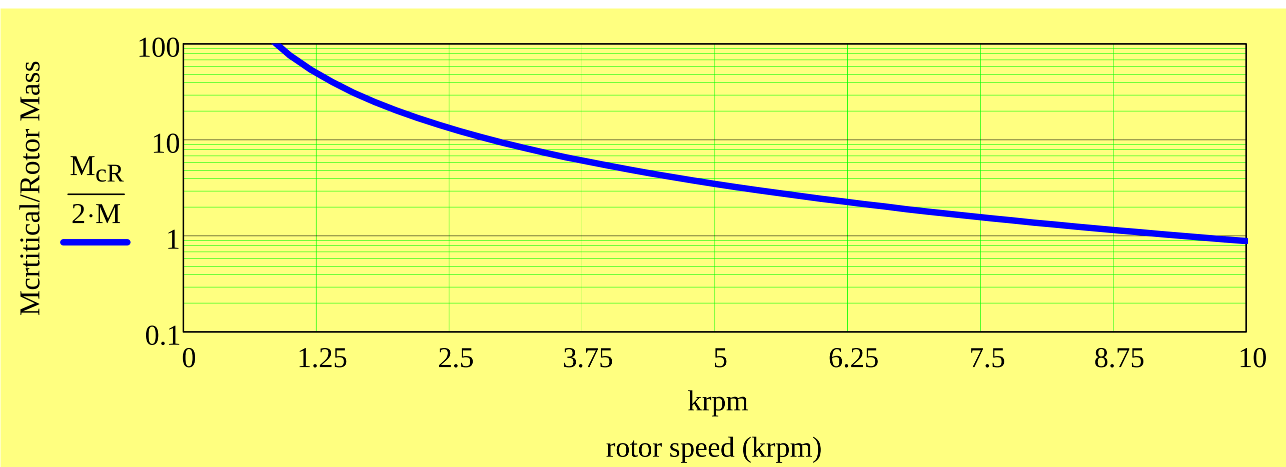


Critical Rotor Mass for rigid rotor

$$M_{c_n} := \frac{k_{eq_n} \cdot F_{o_n}}{c \cdot (\Omega_n)^2 \cdot (WFR_n)^2}$$

Recall the rotor mass: $2 \cdot M = 226.796\,kg$

$$M_{cR_n} := 2 \cdot M_{c_n}$$



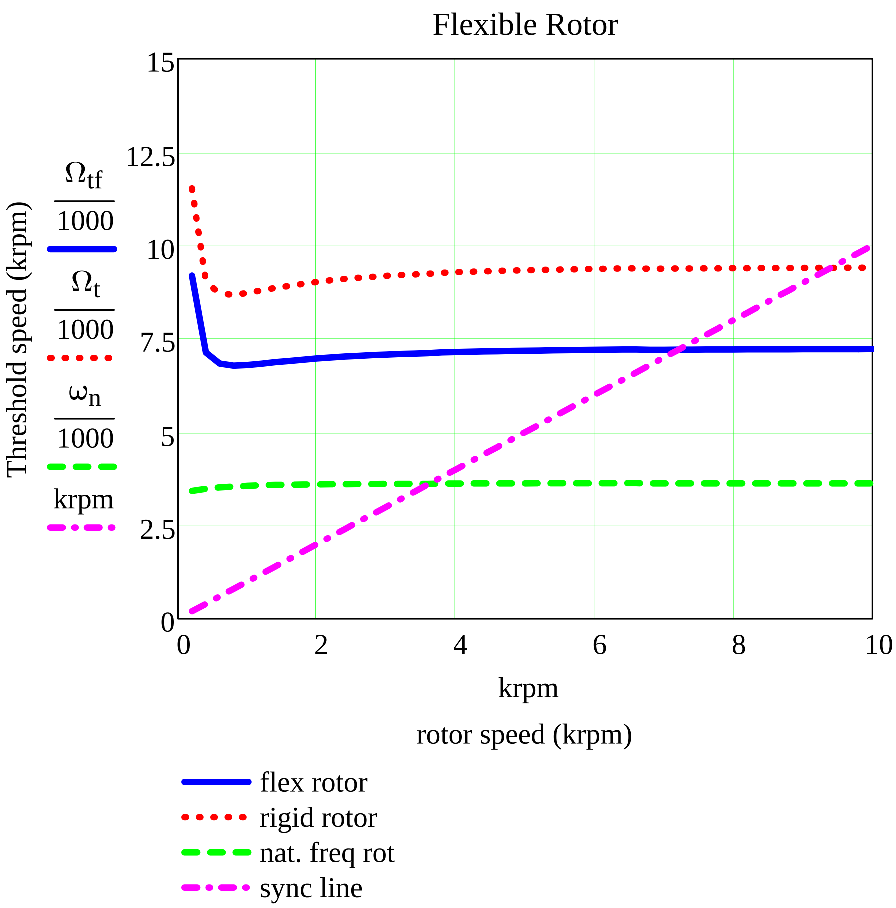
Effect of shaft flexibility on threshold speed of instability:

Threshold speed of instability calculated including rotor sag at midspan.

$$\Omega tf_n := \frac{\Omega t_n}{\left(1 + k_{eq_n} \cdot \frac{Rotor\_sag}{c}\right)^{\frac{1}{2}}}$$

Natural Frequency (rpm) of ***Flexible*** Shaft

$$\omega_{n_n} := WFR_n \cdot \Omega tf_n$$



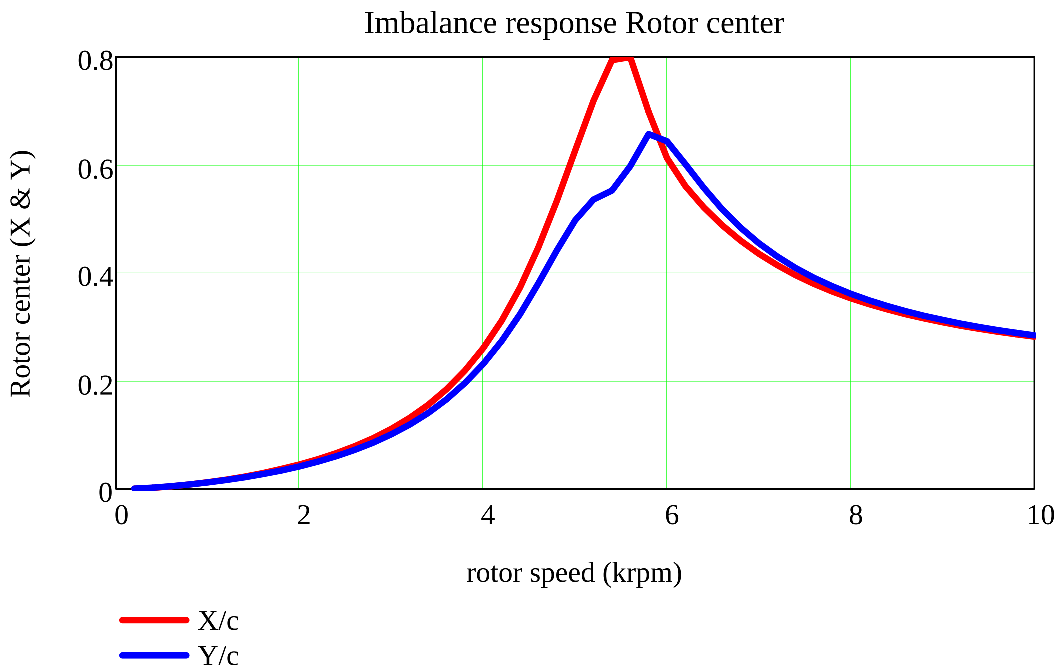
$$k_{shaft} = 4 \times 10^{7} \frac{N}{m}$$

$$\frac{Rotor\_sag}{c} = 0.365$$

The threshold speed of instability is lower for the flexible rotor than for the rigid rotor model.

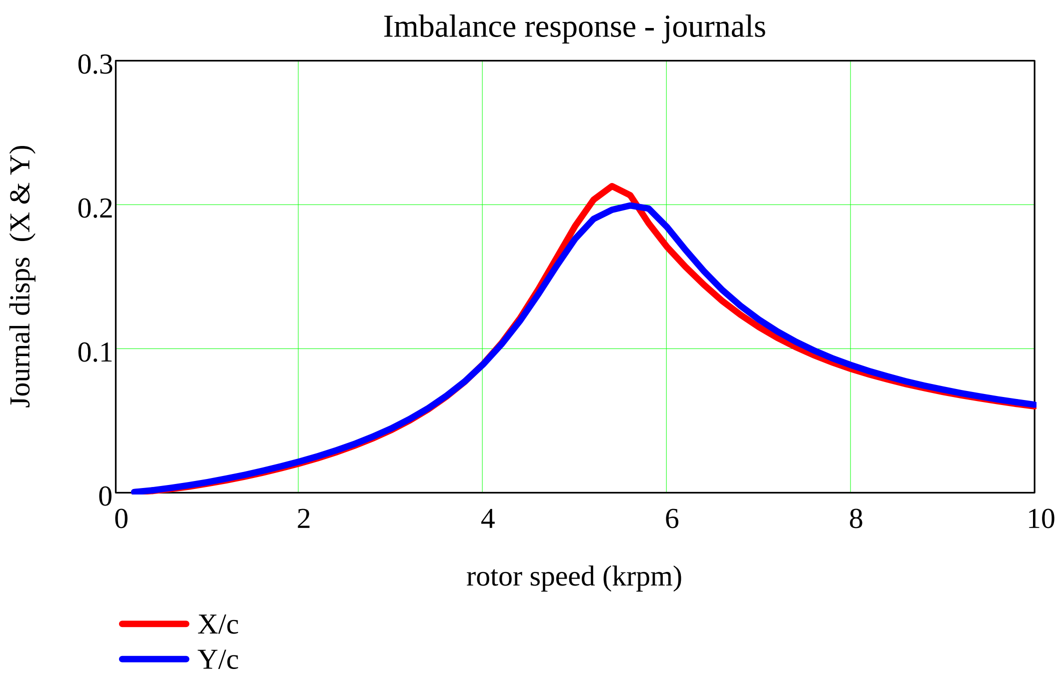
Synchronous response of flexible rotor due to imbalance

show responses in dimensionless form (amplitude/clearance)



ROTOR CENTER

$\frac{a}{c} = 0.2$



JOURNALS CENTER

Exercise: Calculate the major and minor axes of the ellipses describing the (X,Y) motions. See Appendix A of Childs' Rotordynamics Book:.