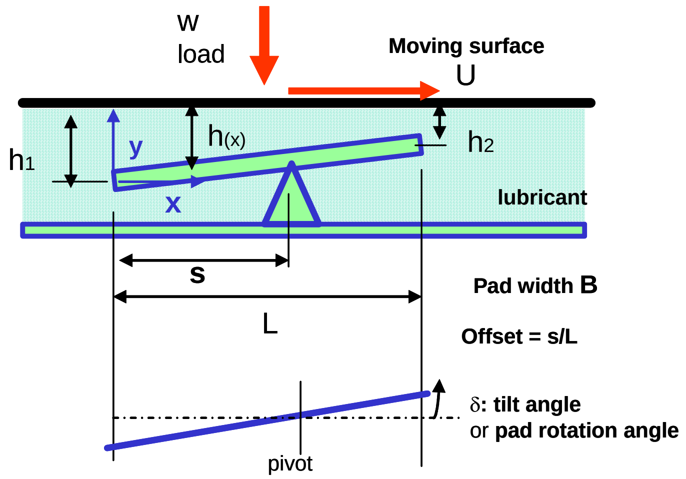
Performance of 1D-Tilting Pad Bearing

Luis San Andres (c) 2006, 2009



film thickess expression

$$h(x) := h_2 \cdot \left[\alpha + (1-\alpha) \cdot \frac{x}{L} \right] \qquad \alpha := \frac{h_1}{h_2}$$

$$\delta = \frac{(h_1 - h_2)}{L}$$

U: surface speed - varies

Bearing geometry:

$L := 0.06$ m length and width of bearing

$B := 0.180$

$offset := 0.59$ pad pivot location s/L

Fluid properties $\mu_{in} := 0.0597$ Pa-sec $\rho := 878$ kg/m3 $c_p := 1880$ J/kg-degC

$\alpha_v := 0.0414$ 1/degC viscosity temperature coefficient

Operating conditions:

$T_{inlet} := 40$ degC - inlet temperature

$W := 40000$ N external load

$\kappa_T := 0.80$ thermal convection parameter

=0 isothermal

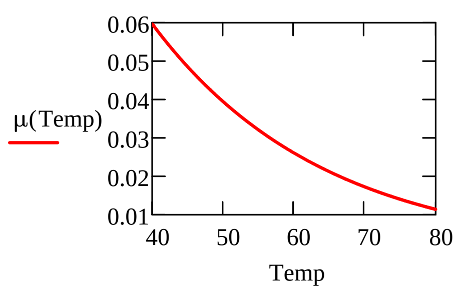
visc-Temperature relationship

$$\mu(T) := \mu_{in} \cdot e^{-\alpha_v \cdot (T - T_{inlet})}$$

Convergence params in load (N), moment (Nm) & temp (degC):

$W_{eps} := 0.001$ (ratio) $M_{eps} := W \cdot \frac{offset \cdot L}{100000}$

$T_{eps} := 0.01$ $M_{eps} = 0.01$



visc-Temperature relationship

Calculated performance (Vary runner surface speed)

$U_{min} := 2$ $U_{max} := 15$ [m/s]

Number of cases: $N_{cases} := 6$

EXPAND regions below to display code

pad bearing parameters

$$\mathrm{Find\_pars}\left(h_2,\alpha,U,T_{out}\right) := \left|\begin{array}{l} T_{eff} \leftarrow 0.5\cdot\left(T_{inlet}+T_{out}\right) \\ \mu_{eff} \leftarrow \mu\left(T_{eff}\right) \\ q \leftarrow \dfrac{\alpha}{1+\alpha} \\ p_{max} \leftarrow \dfrac{1}{4}\cdot\dfrac{(\alpha-1)}{\alpha\cdot(1+\alpha)} \\ w \leftarrow \dfrac{1}{(1-\alpha)^2}\cdot\left[\ln(\alpha)+2\cdot\dfrac{(1-\alpha)}{(1+\alpha)}\right] \\ f \leftarrow -1\cdot\left(\dfrac{6}{1+\alpha}+4\cdot\dfrac{\ln(\alpha)}{1-\alpha}\right) \\ t \leftarrow \dfrac{f}{q} \\ M_{pad} \leftarrow -6\cdot\dfrac{[(1-\alpha)\cdot(1+5\cdot\alpha)+2\cdot\alpha\cdot(2+\alpha)\cdot\ln(\alpha)]}{2\cdot(1-\alpha)^2\cdot\left(1-\alpha^2\right)} - \mathrm{offset}\cdot 6\cdot w \\ \mathrm{Cpre} \leftarrow \mu_{eff}\cdot U\cdot\dfrac{L}{h_2^{\,2}} \\ \mathrm{Force} \leftarrow 6\cdot\mathrm{Cpre}\cdot B\cdot L\cdot w \\ Q \leftarrow q\cdot U\cdot h_2\cdot B \\ \mathrm{ShearF} \leftarrow f\cdot\mathrm{Cpre}\cdot B\cdot h_2 \\ \Delta T \leftarrow t\cdot\kappa_T\cdot\dfrac{\mathrm{Cpre}}{\left(\rho\cdot c_p\right)} \\ T_{out} \leftarrow T_{inlet}+\Delta T \\ P_{max} \leftarrow p_{max}\cdot\mathrm{Cpre}\cdot 6 \\ M_{pad} \leftarrow M_{pad}\cdot\mathrm{Cpre}\cdot B\cdot L^2 \\ \left(h_2\ \ T_{eff}\ \ \mathrm{Force}\ \ \mathrm{ShearF}\ \ Q\cdot 60000\ \ T_{out}\ \ \mu_{eff}\ \ P_{max}\ \ M_{pad}\right) \end{array}\right.$$

From:

$$w(\alpha) := \frac{1}{(1-\alpha)^2}\cdot\left[\ln(\alpha)+2\cdot\frac{(1-\alpha)}{(1+\alpha)}\right]$$

or

$$\mathrm{Mpad}(\alpha) := -6\cdot\frac{[(1-\alpha)\cdot(1+5\cdot\alpha)+2\cdot\alpha\cdot(2+\alpha)\cdot\ln(\alpha)]}{2\cdot(1-\alpha)^2\cdot\left(1-\alpha^2\right)} - \mathrm{offset}\cdot 6\cdot w$$

For Pad moment to be null

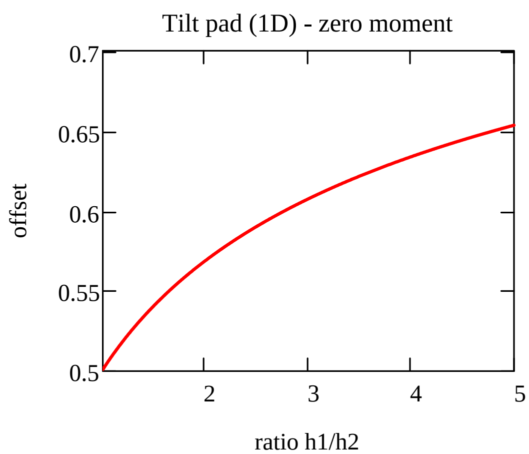
$$6\cdot\frac{[(1-\alpha)\cdot(1+5\cdot\alpha)+2\cdot\alpha\cdot(2+\alpha)\cdot\ln(\alpha)]}{2\cdot(1-\alpha)^2\cdot\left(1-\alpha^2\right)} := -(\mathrm{offset}\cdot 6\cdot w)$$

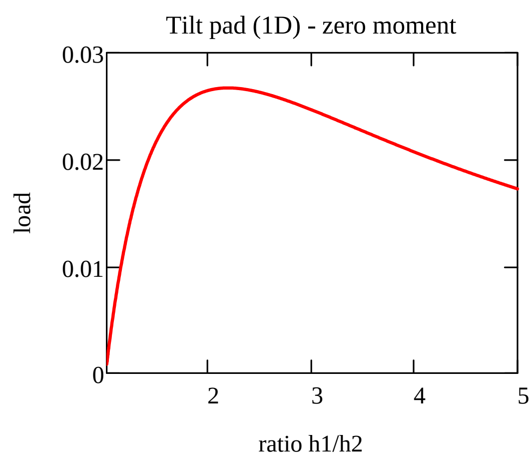
$$\text{Offset}(\alpha) := \frac{\dfrac{-[(1-\alpha)\cdot(1+5\cdot\alpha)+2\cdot\alpha\cdot(2+\alpha)\cdot\ln(\alpha)]}{2\cdot(1-\alpha)^2\cdot\left(1-\alpha^2\right)}}{\left[\dfrac{1}{(1-\alpha)^2}\cdot\left[\ln(\alpha)+2\cdot\dfrac{(1-\alpha)}{(1+\alpha)}\right]\right]}$$

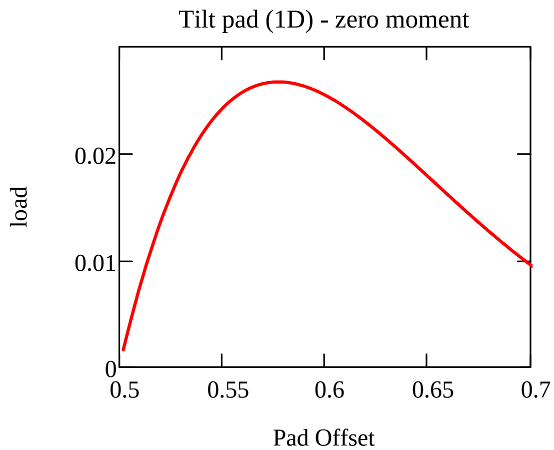
pad bearing parameters

The following graphs show dimensionless parameters: load and offset needed for null moment versus film inlet/outlet ratio

Each pad offset determines a fixed α ratio satisfying the pad moment =0.
Note that there is a certain offset given the optimum load, i.e. (offset = 0.59)approximately







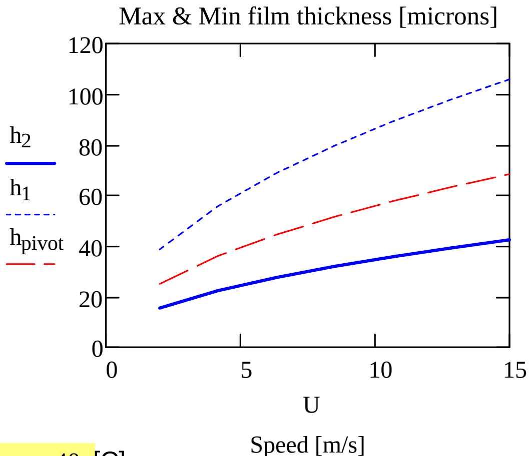
iterative loop

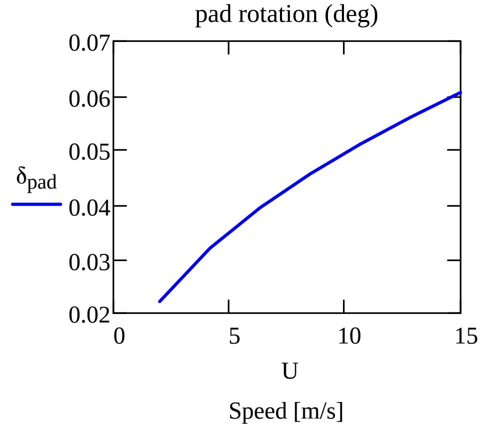
Guess values $imax := 199$ Max number of steps for convergence

$h_2 := 20\cdot10^{-6}$ $h_1 := 3\cdot h_2$ $T_{out} := 50$ based on experience

GRAPHS of Tilting Pad Bearing Performance versus runner speed. $W = 4 \times 10^4$ [N] $offset = 0.59$

$\alpha_1 = 2.49$

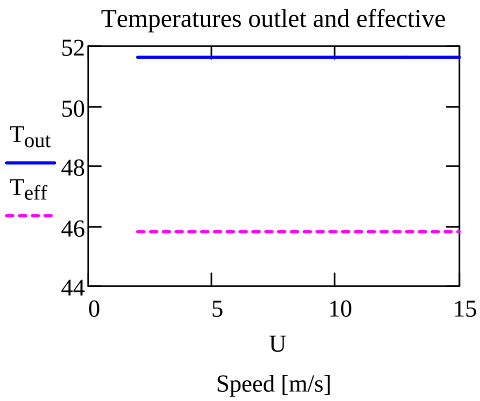


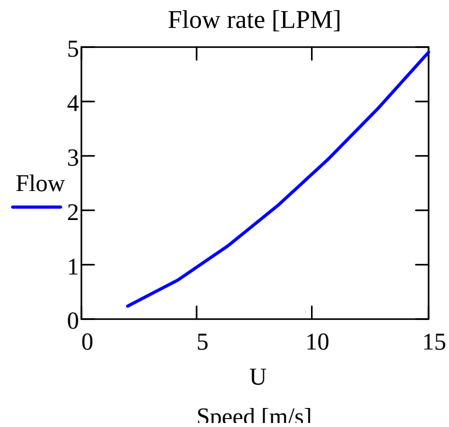


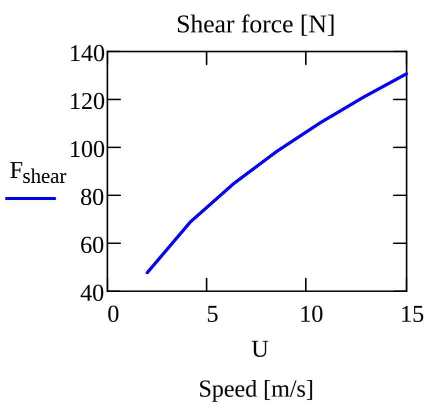
$\max(h_2) = 42.42$

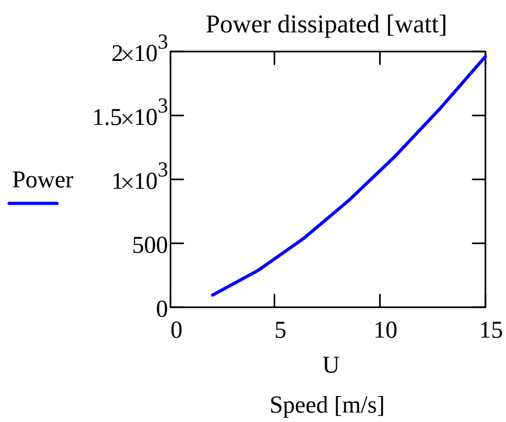
$\min(h_2) = 15.49$

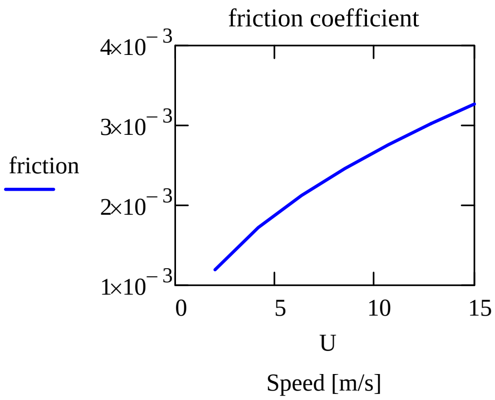
$T_{inlet} = 40$ [C]

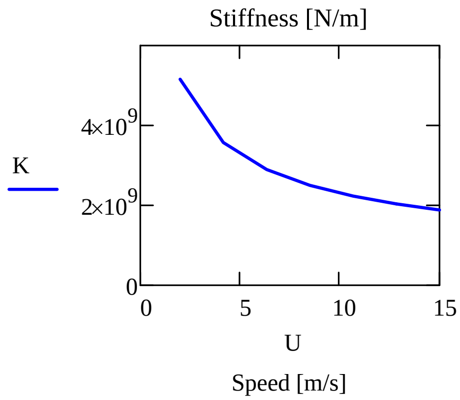




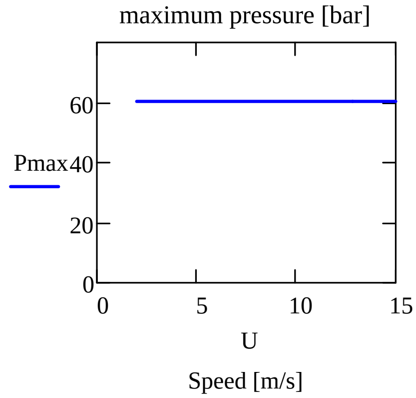








$P_{spec} = 37.04$ [bar] specific pressure = load/area



imax = 199