DTU

FVM bulk flow equation solution

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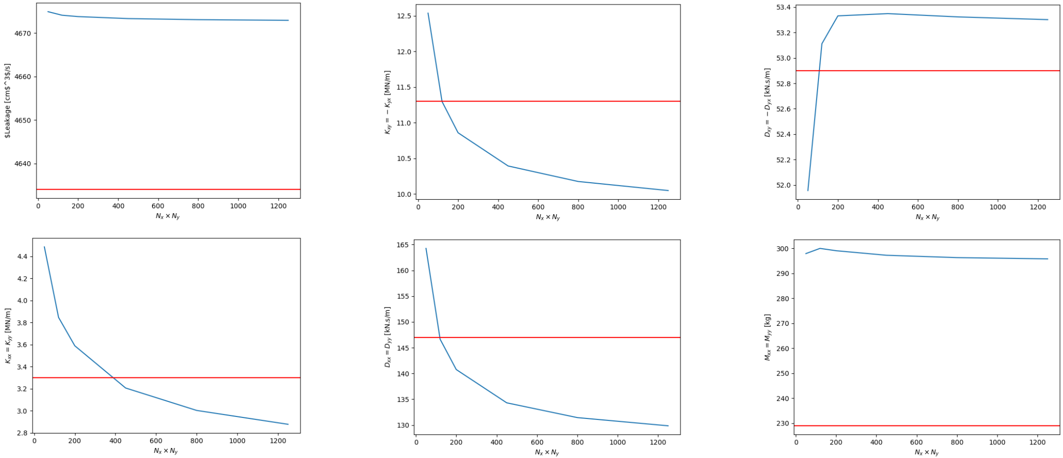
Setup: [Kanki and Kawakami, 1984] "seal 1" (long)

- $C/R = 0.005$
- $\Omega = 2000$ [rpm]
- **"Long", L/R = 2.0**
- Turbulent flow, $Re_a = 16,707$, $Re_\Omega = 11,890$
- Water (incompressible flow)
- Isothermal
- Blasius friction factor using $n = 0.079$ and $m = -0.25$
- $\omega/\Omega = [0.0, 0.12, 0.23, 0.36, 0.48, 0.60]$ (nominal)
- $\xi_i = 0.2$ inlet loss, $\beta = 0.2$ inlet swirl ratio

Effect of grid density on dynamic coefficients



Model-predicted results compare well with experiment

```
----q [cm^3/s]-------
--predicted--
4673.096044318607
--Exp.--
4634.0
----K [MN/m]-------
--predicted--
[[  3.0039233   10.17509099]
 [-10.17509099   3.0039233 ]]
--Exp.--
[[  3.3   11.3 ]
 [-10.3    3.89]]
```

```
----D [kN.s/m]-------
--predicted--
[[131.44393675  53.32320909]
 [-53.32320909 131.44393675]]
--Exp.--
[[147.   52.9]
 [-57.7 147. ]]
----M [kg]-------
--predicted--
[[ 2.96334041e+02 -1.85514291e-01]
 [ 1.85514291e-01  2.96334041e+02]]
--Exp.--
[[229.  16.]
 [ 32. 214.]]
```

Comments: [Kanki and Kawakami, 1984] "seal 1" (long)

- Model predictions compare well w/ experiments, except added-mass
- Added mass notably difficult to estimate accurately (see literature)
- Grid convergence
  - Stiffness and and direct damping most sensitive to grid density
  - Fully grid converged solutions not obtained
  - Acceleration of some parts of code in order to run more refined grids

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Setup: [Kanki and Kawakami, 1984] "seal 2" (short)

- $C/R = 0.005$
- $\Omega = 2000$ [rpm]
- **"Short", $\mathbf{L/R = 0.4}$**
- Turbulent flow, $Re_a = 36,253$, $Re_\Omega = 13,216$
- Water (incompressible flow)
- Isothermal
- Blasius friction factor using $n = 0.079$ and $m = -0.25$
- $\omega/\Omega = [0.0, 0.12, 0.23, 0.36, 0.48, 0.60]$ (nominal)
- $\xi_i = 0.25$ inlet loss, $\beta = 0.5$ inlet swirl ratio

Model-predicted results DO NOT compare well with experiment

```
----q [cm^3/s]-------
--predicted--
9013.111342534996
--Exp.--
9047.0
----K [MN/m]-------
--predicted--
[[ 0.59767211  0.35023527]
 [-0.35023527  0.59767211]]
--Exp.--
[[ 3.96   0.664]
 [-0.337  4.01 ]]
```

```
----D [kN.s/m]-------
--predicted--
[[ 3.36521127  0.72851788]
 [-0.72851788  3.36521127]]
--Exp.--
[[ 24.82  12.3 ]
 [-10.88  24.46]]
----M [kg]-------
--predicted--
[[ 3.48121243  0.10085464]
 [-0.10085464  3.48121243]]
--Exp.--
[[0. 0.]
 [0. 0.]]
```

Comments: [Kanki and Kawakami, 1984] "seal 2" (short)

- Model predictions not as accurate compared with long seal
- Alternative friction factor formulation and/or friction factor parameters to improve results
- Convergence rate of 1st-order problem is very slow –> need to investigate cause and remedy

TODO

- Add additional validation cases for incompressible flow seals
- Finish adding compressible flow method to seal class
- Add compressible flow validation cases
- Code documentation (Sphinx)
- Acceleration of code –> port some functionality to FORTRAN and/or use numba jit compiler flags (both require some mods to data types)

References I

Kanki, H. and Kawakami, T. (1984).
Experimental study on the dynamic characteristics of pump annular seals.
IMechE, paper, pages 159–166.