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Analysis and Tuning of Discrete MPFM Concept

Piston Capture Meter (PCM)

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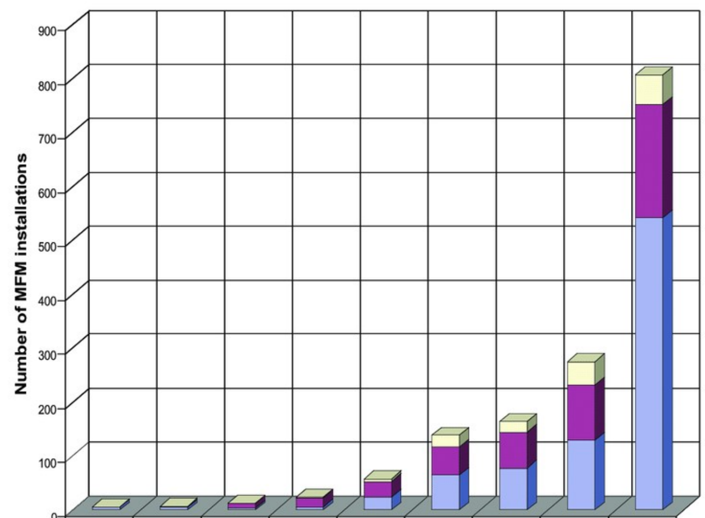
Where energy is opportunity™

Brief History

- Coriolis meter brought to market in 1977.
- O&G industry investing in MPFM tech in early 80's
- No meters in use until early 90's
- Development by Schlumberger, Roxar/Emerson,

  MPM, Framo, Pietro Fiorentini, and others
- Introduction of radioactive measurement methods
- Over 8000 MPFM's in use worldwide today



	1992	1993	1994	1995	1996	1997	1998	1999	2000
Offshore subsea	0	0	0	1	5	22	20	43	55
Offshore topside	1	2	10	17	29	52	66	103	210
Onshore	5	5	3	6	24	65	78	129	542

Falcone, Gioia & Hewitt, G.F. & Alimonti, Claudio & Harrison, B.. (2013). Multiphase Flow Metering: Current Trends and Future Developments. Journal of Petroleum Technology. 54. 10.2118/71474-MS.

Multi-Phase Flow Metering Challenge

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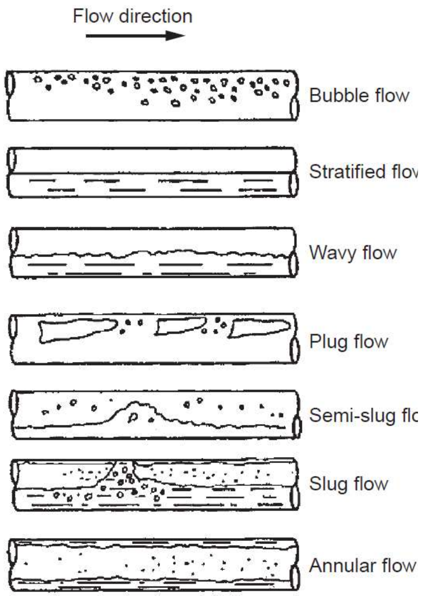
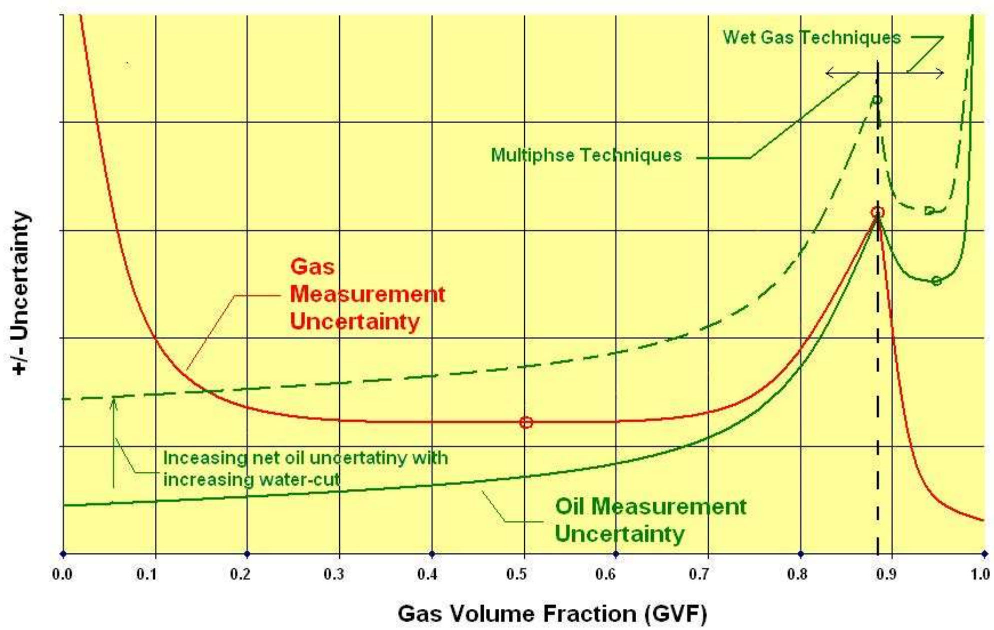
- Phase slip
- Flow regime
- Fluid properties
- 0-100% GVF
- 0-100% WC
- Non-radioactive
- Non-intrusive



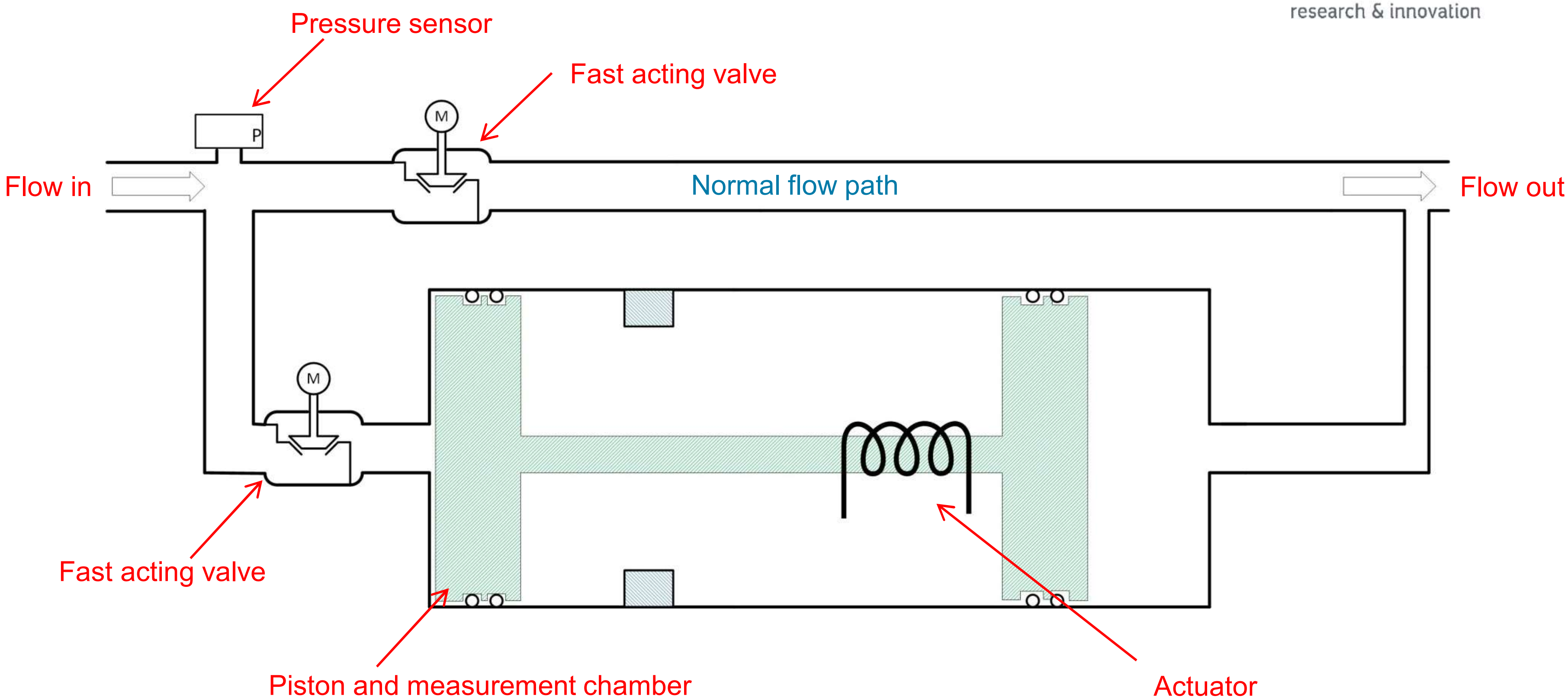
Falcone, G., Hewitt, G. F., & Alimonti, C. (2008). *Multiphase flow metering: Principles and applications*. Oxford: Elsevier.

Typical Multiphase Metering Uncertainty



SPE Multiphase Metering Workshop, Galveston TX 2020, With permission to share from Robert (Bobb) Webb

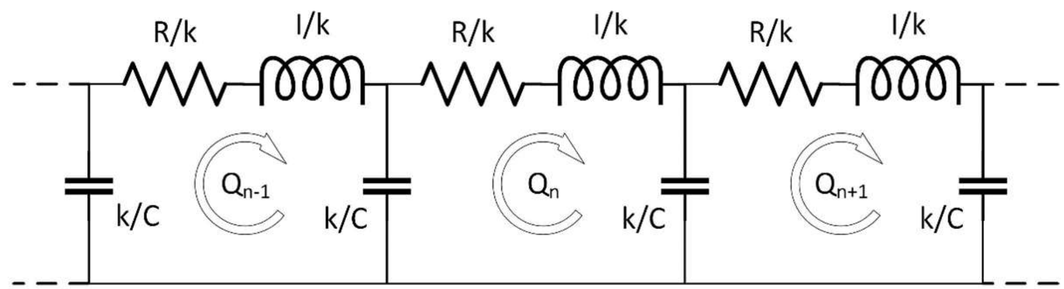
Piston Meter Concept



Mathematical Model

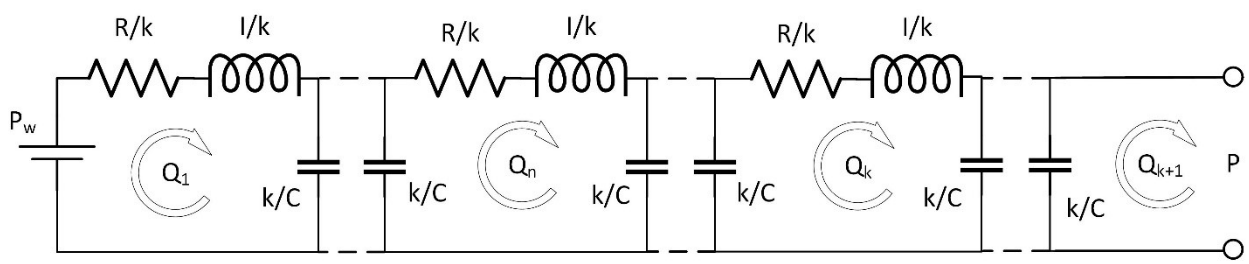
- Similar to transmission line model
- Lumped parameters in k loops

- P – Pressure
- Q – Flow rate
- R – Pipeline resistance
- C – Fluid compliance
- I – Fluid inertance



Loop model

$$\frac{k}{C}\left(\int Q_{n-1}dt - \int Q_n dt\right) - \frac{R}{k}Q_n - \frac{I}{k}\dot{Q}_n - \frac{k}{C}\left(\int Q_n dt - \int Q_{n+1}dt\right) = 0$$

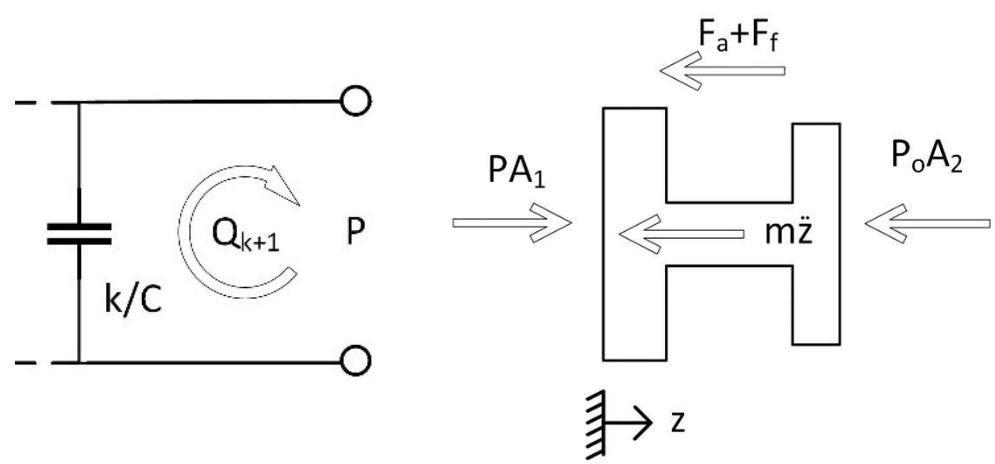


Full model

Mathematical Model Cont.

- Simple equation of motion

- Friction forces
- Pressure
- Acceleration
- Applied force from actuator (forcing function)



$$m\ddot{z} = PA_1 - F_a - F_f - P_oA_2$$

State Space Model

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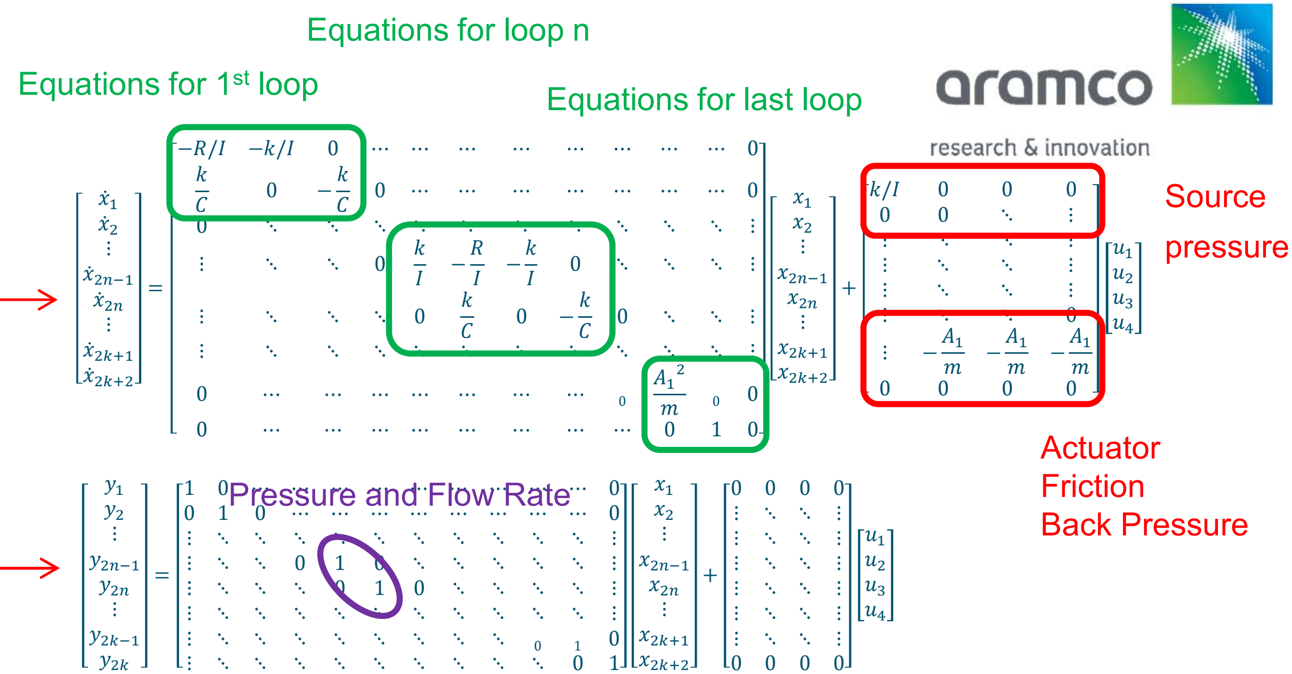
$$\dot{X} = aX + bU \rightarrow$$

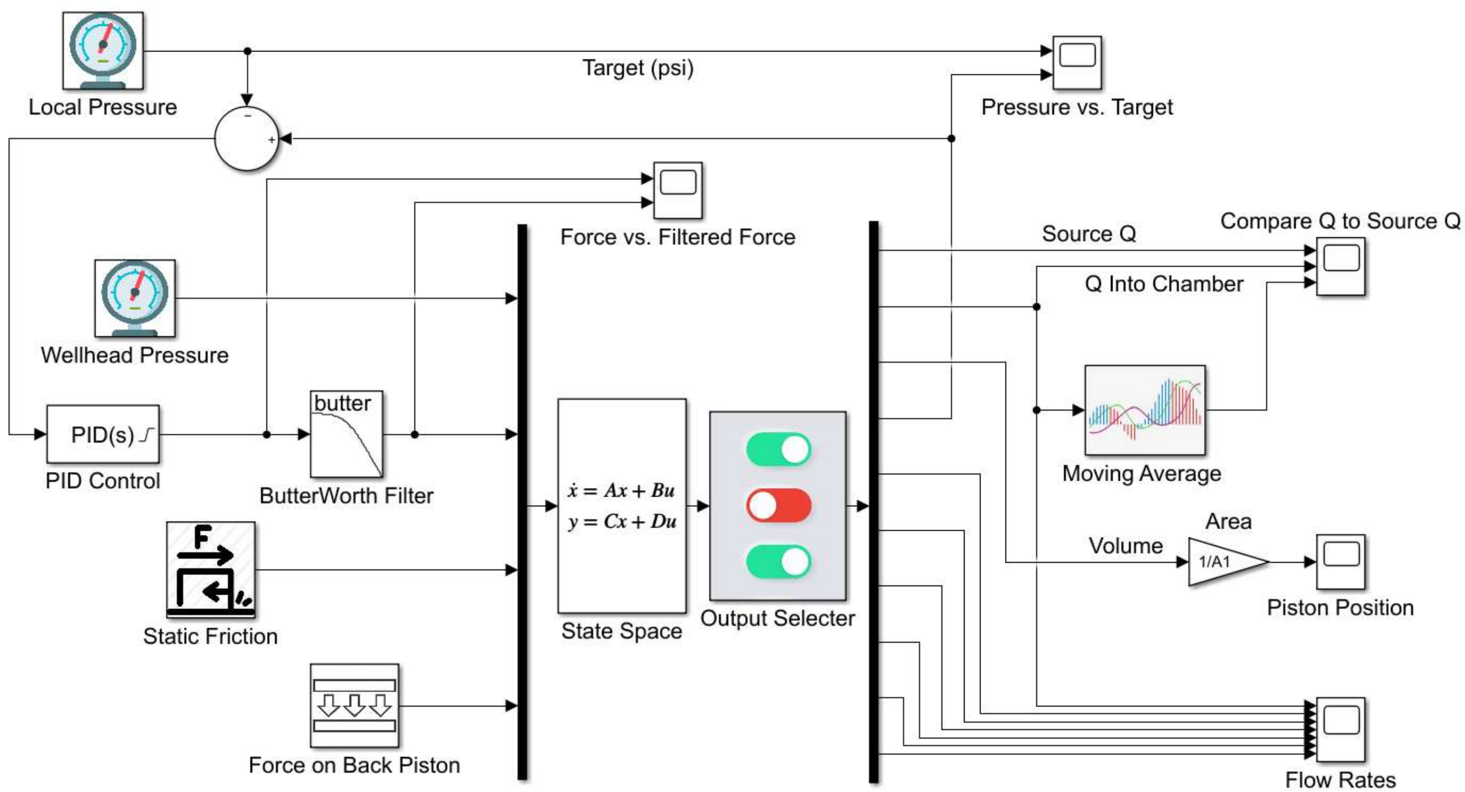
$$Y = cX + dU \rightarrow$$



Parameters

```
diameterPistonMin = 3 ; diameterPistonMax = 12 ; diameterPistonStep = 10 ;          %[Inches]
diameterPistonMin = diameterPistonMin * 0.0254; diameterPistonMax = diameterPistonMax * 0.0254; diameterPistonStep = (diameterPistonMax-diameterPistonMin)/(diameterPistonStep-1);
gasVolumeFractionMin    = 0.05 ;   gasVolumeFractionMax   = 0.95 ;   gasVolumeFractionStep   = 10 ;   %[Fraction 0-1]
gasVolumeFractionStep = (gasVolumeFractionMax-gasVolumeFractionMin)/(gasVolumeFractionStep-1);
velocityFluidMin        = 1 ;      velocityFluidMax       = 4 ;      velocityFluidStep       = 4 ;    %[m/s]
velocityFluidStep = (velocityFluidMax-velocityFluidMin)/(velocityFluidStep-1);
pressureWellMin         = 200 ;    pressureWellMax        = 600 ;    pressureWellStep        = 5 ;    %[PSI]
pressureWellMin = pressureWellMin * 6894.757; pressureWellMax = pressureWellMax * 6894.757; pressureWellStep = (pressureWellMax-pressureWellMin)/(pressureWellStep-1);
pressureTargetStep      = 5 ;
massPistonMin = 20 ; massPistonMax = 100 ; massPistonStep = 4 ;          %[kg]
massPistonStep = (massPistonMax-massPistonMin)/(massPistonStep-1);
```

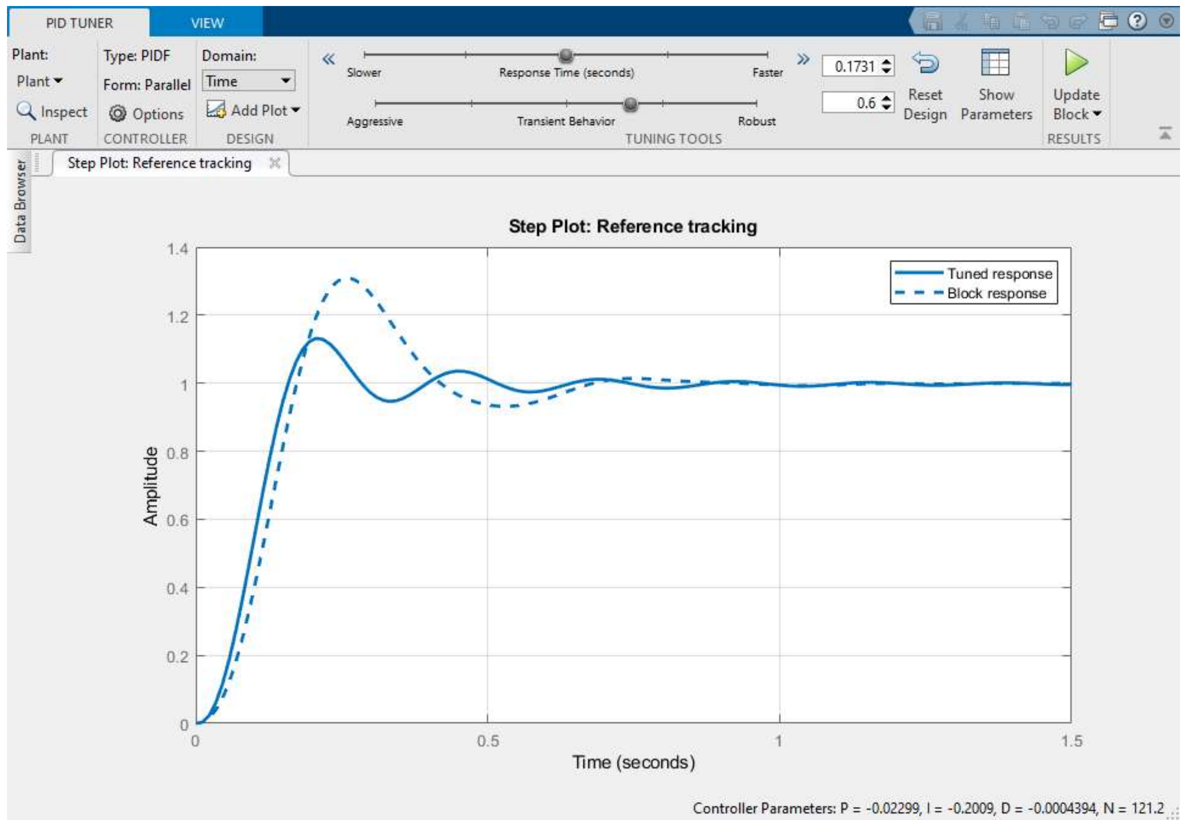
Simulink Model



PID Tuning

- PID Control tuning with Simulink Control Design

- Tuned gain values were well fit for real system



Example Results – Pressure and Flow

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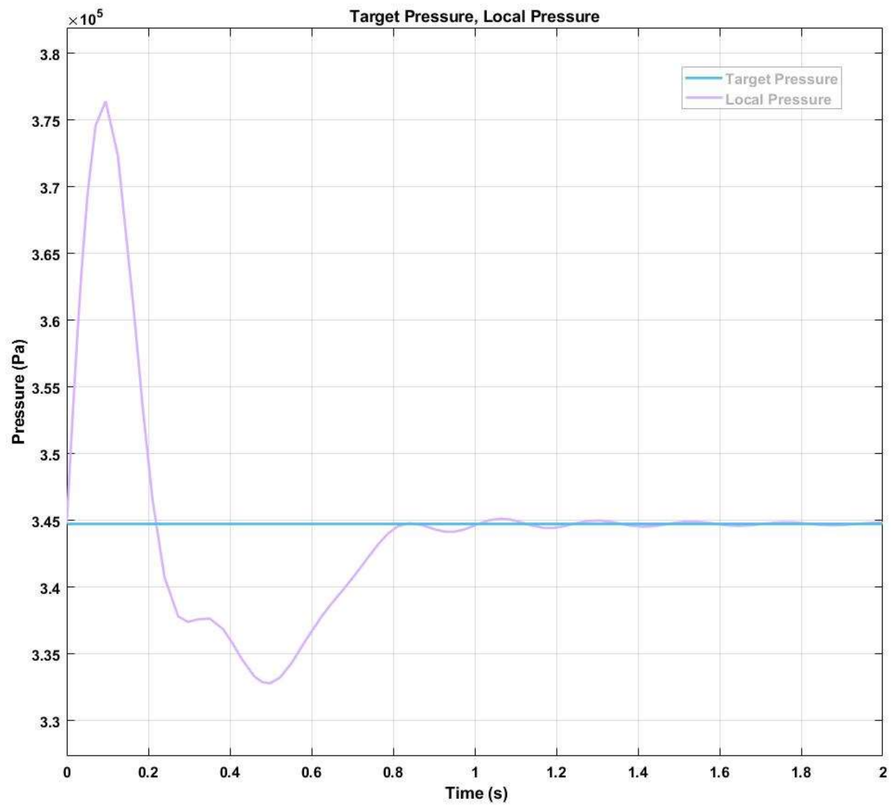

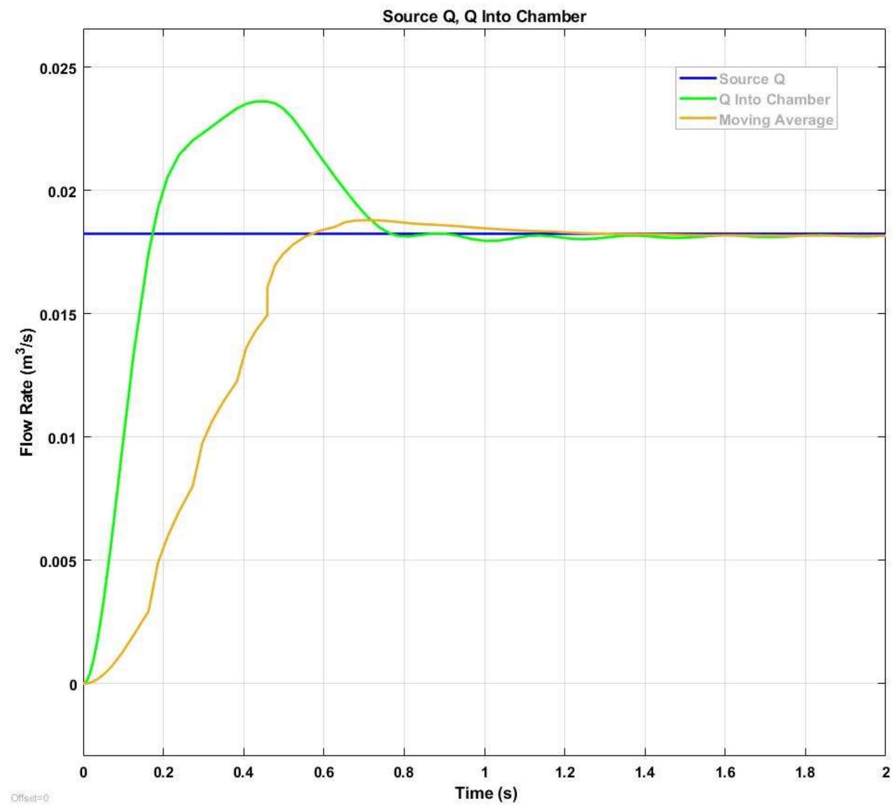

Example Results – Forces and Upstream Analysis

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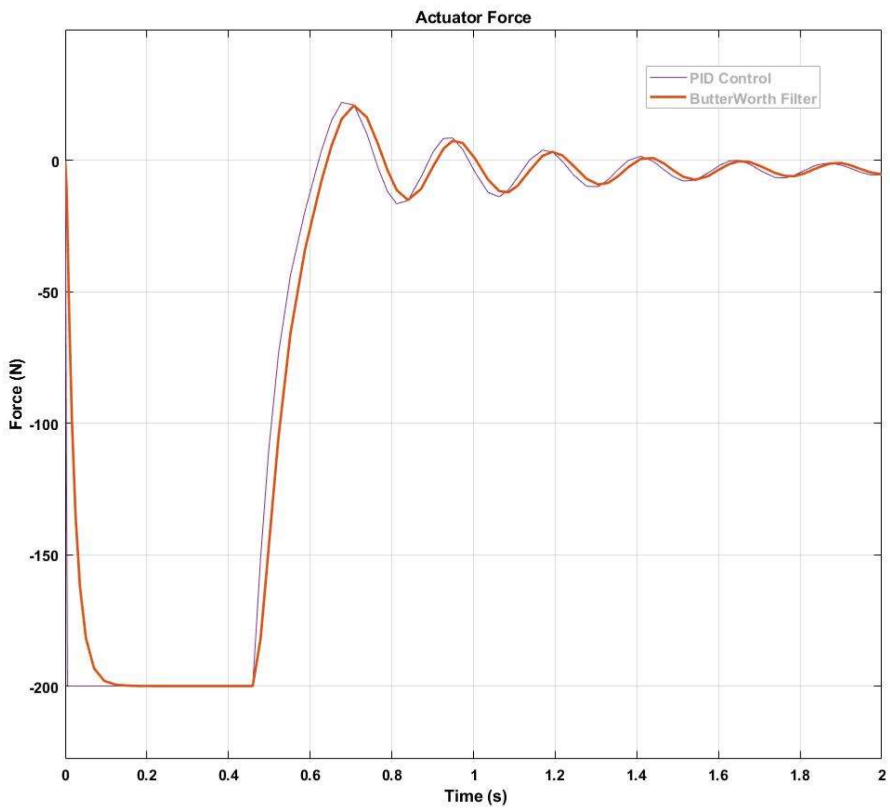

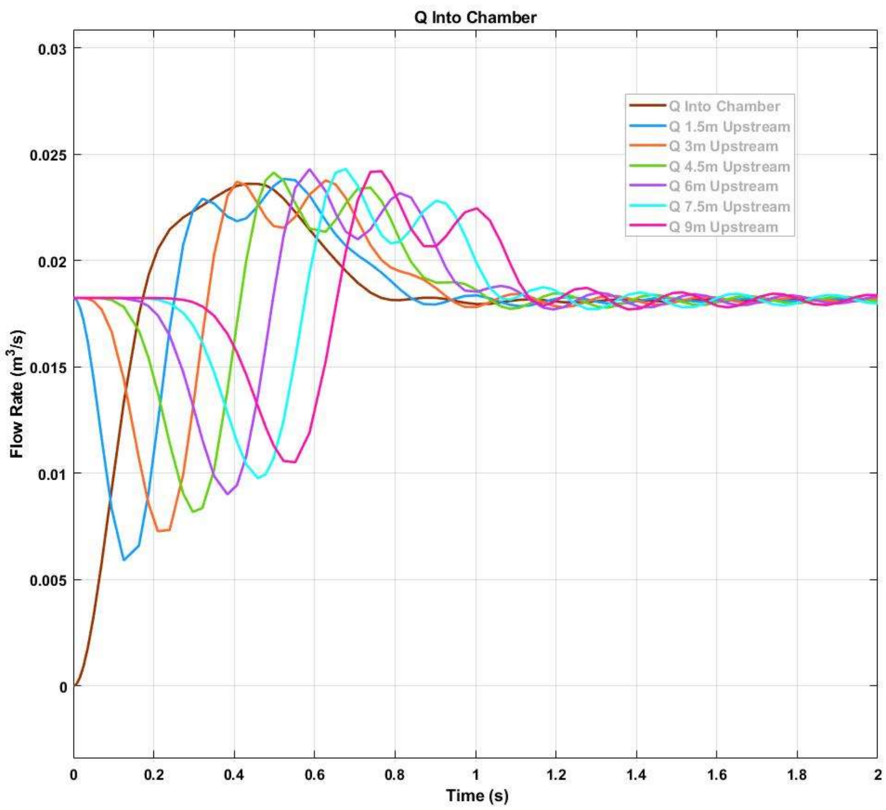

Conclusions

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- Fluid flow analysis without CFD
- Power of iteration with state space modelling in MATLAB
- Ability to tune PID system with Simulink Control Design
- Simulated results match expectations, validates concept

MathWorks products and toolboxes used:

- MATLAB R2019b
- Simulink V10.0
- Simulink Control Design V5.4
- Signal Processing Toolbox V8.3
- DSP System Toolbox V9.9
- Control System Toolbox V10.7

Questions and Comments

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