Development and validation of integrated design framework for compressor system model

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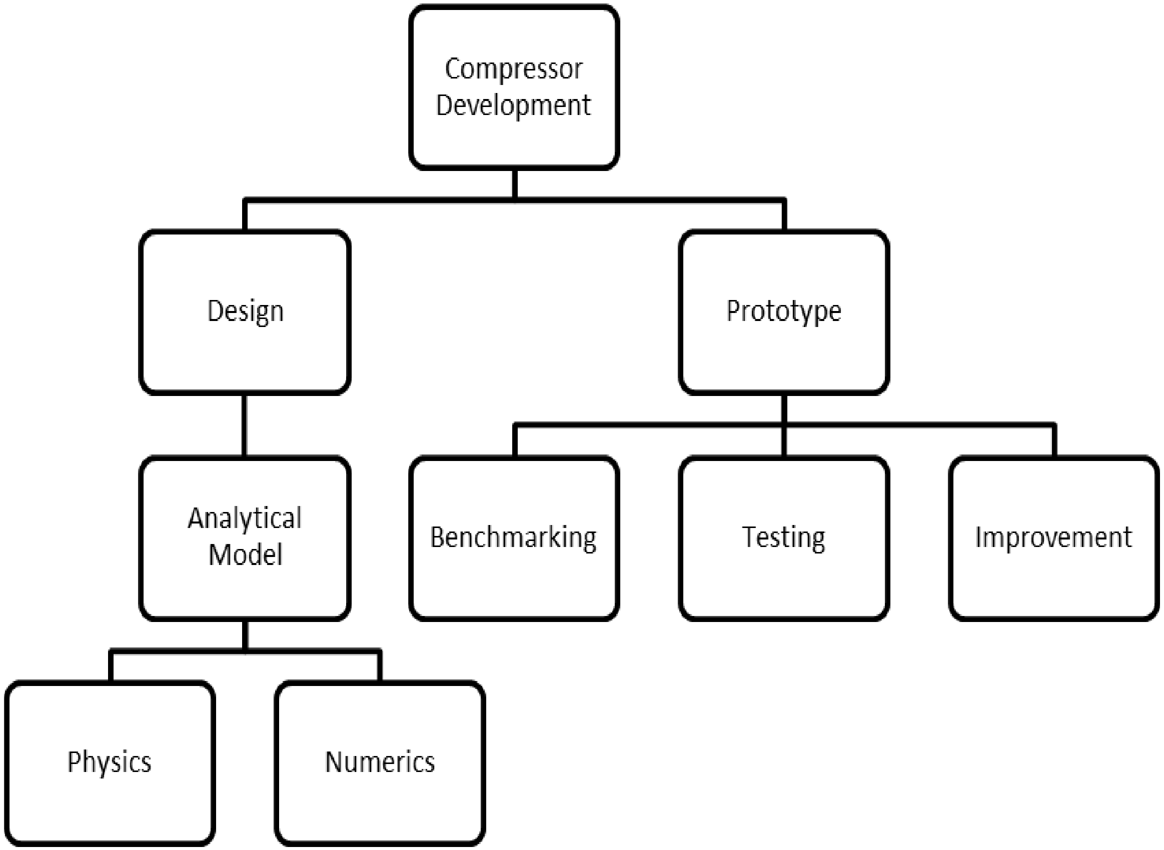
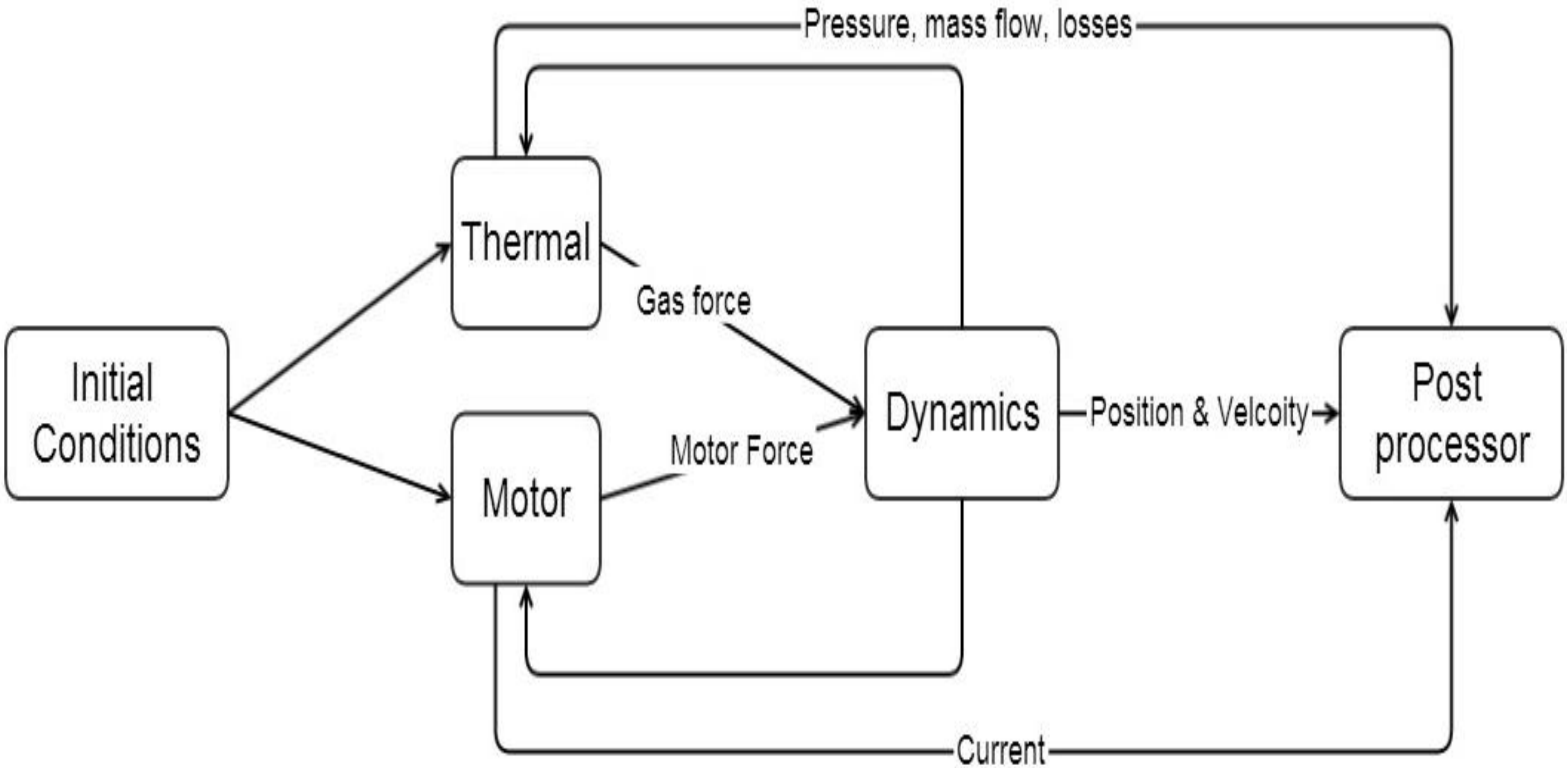
Introduction (Compressor Development)



Integrated Model



EQUATIONS OF MOTION

Dynamics

- $M\ddot{x} + C\dot{x} + Kx = F_{gas} + F_{motor}$

Thermal

- $P_t = P_{t-1}\left\{\frac{m_{t-1}}{\rho_0 V}\right\}^n$
- $m_t = m_{t-1} \pm \int C_d A_0 \sqrt{2\rho\Delta P}$

Motor

- $\alpha\, {}^{dx}/_{dt} = [V - iR - L\, {}^{di}/_{dt}]$

A	*Orifice area*
C	*Damping constant*
C_d	*Discharge coefficent*
F_{gas}	*Gas force*
F_{motor}	*Motor force*
M	*Piston Mass*
K	*Spring Constant*
L_e	*Inductance*
R_e	*Resistance*
V	*Voltage*
m	*Mass flow*
n	*Polytropic constant*
α	*Motor constant*

EQUATIONS OF MOTION (CONTD.)

Valves

- $m_d\ddot{x}_d + c_d\dot{x}_d + k_d x_d = (P_{cyl} - P_d)A_{dv} + F_{prestress}$
- $m_{svLeak} = Cd_{svLeak}A_{svLeak}\left(\sqrt{2\rho_{cyl}(p_{cyl} - p_s)}\right)$

Oil Stiction

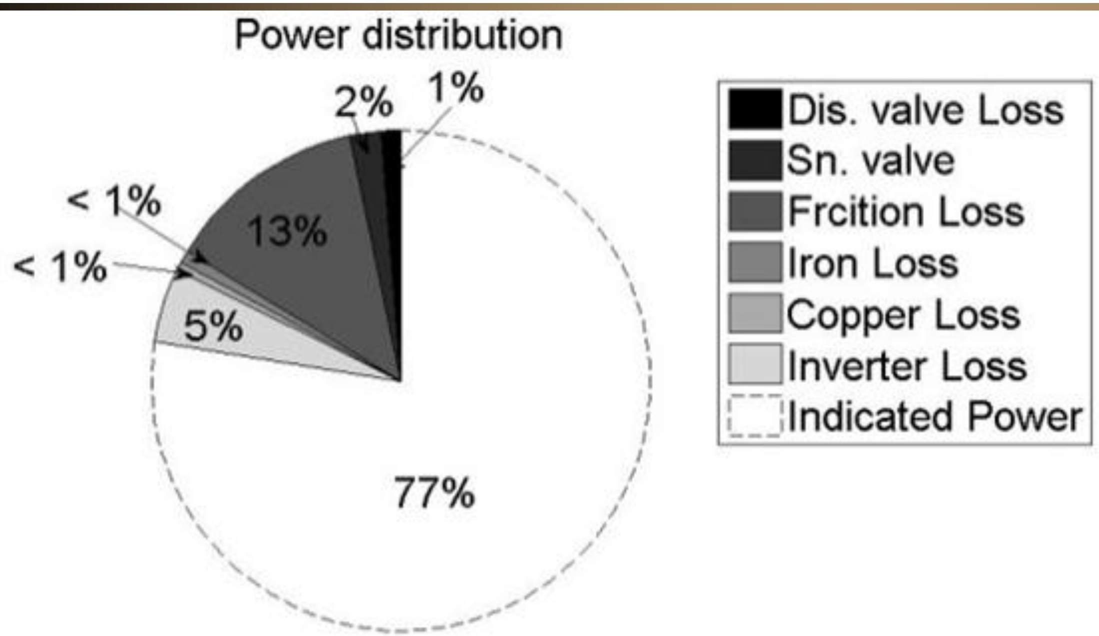
- $C_{stiction}(t) = \frac{3\pi\mu r_{sv}^4}{2h^3}.\left(1 - X_0(t)^4 + \frac{1-2X_0(t)^2 + X_0(t)^4}{log(X_0(t))}\right)$

Blow By

- $m_{bb} = \Delta t\ \rho_{cyl}\ (\pi\ D_{piston}c)\ \left(\frac{v}{2} - \frac{c^2}{12\mu}\frac{\Delta P_{bb}}{L_{bb}}\right)$

C_d	*Discharge coefficent*
$C_{stiction}$	*Stiction Coefficient*
r_{sv}	*Suction port radius*
μ	*Oil viscocity*
p_{cyl}	*Cylinder pressure*
P_d	*Discharge Pressure*
L_{bb}	*Blowby engagement length*
D_{piston}	*Piston Diameter*
$svLeak$	*Suction valve leak*
X_0	*Radial extent of the oil wetting normalized by the port radius*
X_d	*Discharge valve displacement*

Post Processing

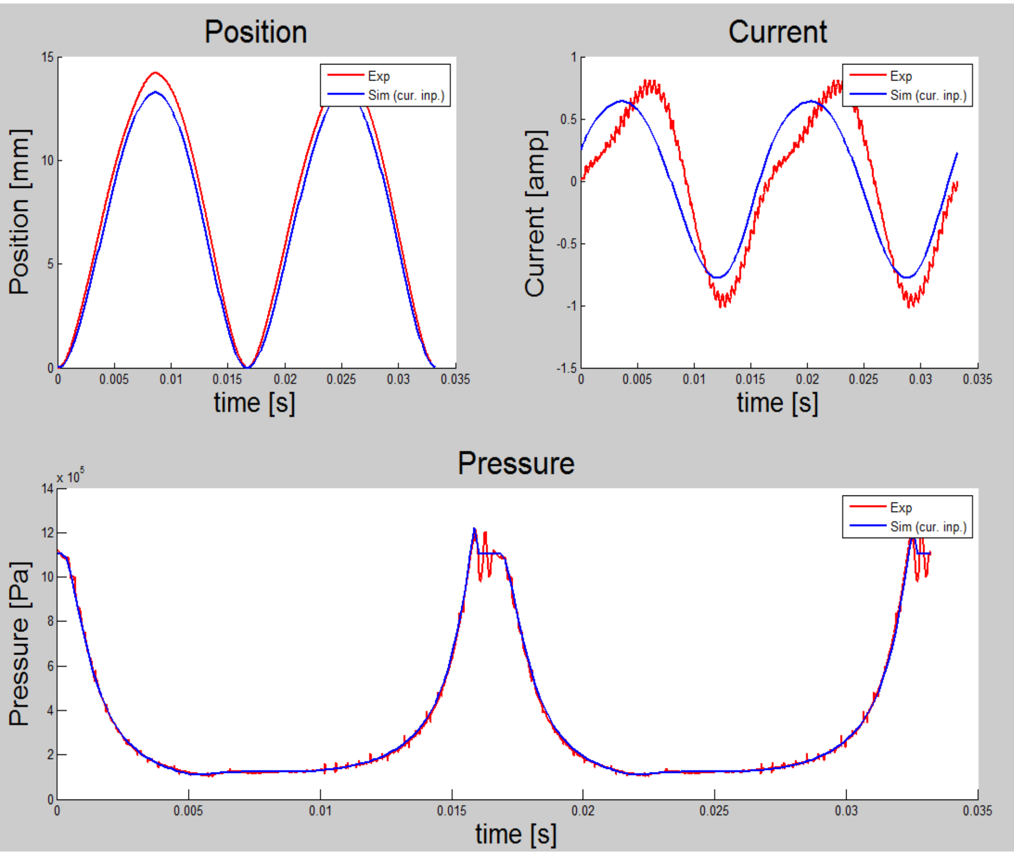


$$Cooling\ capacity = \left[\int (\mathrm{m_t} - (m_{svLeak} + m_{dvLeak} + m_{bb}))\ dt \right] f \Delta h$$

$$P_{in} = \int F_{motor} v\ dt + iron\ loss + cu.loss + inv.loss$$

$$EER = \frac{cooling\ capacity}{P_{in}}$$

Validation



Parameter	0.57	0.54	-5 %
Power [W]	76.9	75.6	%1
Cooling Capacity (BTU/Hr)	460	460	Modulated to match
EER	5.97	6.05	1 %

CONCLUSION

- A novel and innovative technique for modeling the system level dynamics of compressor is developed in MATLAB/SIMULINK environment.
- Each module is rigorously designed with physics based equations and validated with experimental data.
- The system level validated model is used successfully for optimization and performance prediction