Rotary Platen Dynamics in Hydraulic Molding Presses

Fred Fisher

President, Validus Group

U.S. Precision Manufacturing

Automation & Integration Solutions

September 2025

Executive Summary

Rotary platen molding presses couple a high-inertia rotating mass to a hydraulic drive. Velocity (set primarily by flow) and torque/force capability (set primarily by pressure) are distinct control dimensions, yet they interact through rotational mechanics. A proximity sensor (prox) provides angular position feedback to initiate a controlled deceleration (*soft stop*)—reducing shock loads, protecting tooling, and improving alignment accuracy.

This paper summarizes the underlying physics, links them to hydraulic drive behavior, and provides practical guidance for tuning prox-gated soft stops in rotary platen applications.

1 Fundamentals

1.1 Rotational inertia and torque

For a platen carrying molds at radius r, the composite polar moment of inertia is

$$I = \sum_i m_i \, r_i^2.$$

Net torque τ and angular acceleration α are related by

$$\tau = I \, \alpha.$$

Deceleration distance (in angle) for a constant angular deceleration $\alpha < 0$ from ω_1 to ω_2 is

$$\Delta\theta_{\text{decel}} = \frac{\omega_1^2 - \omega_2^2}{2\,|\alpha|}.$$

1.2 Hydraulic drive relations (idealized)

Let V_d be the motor displacement, Q the flow, ΔP the pressure drop, and η_m, η_v the mechanical and volumetric efficiencies. A useful set of approximations is:

$$\tau \approx \frac{\Delta P\, V_d}{2\pi}\,\eta_m, \qquad \omega \approx \frac{2\pi\, Q}{V_d}\,\eta_v, \qquad P_{\text{mech}} \approx \Delta P\, Q\, \eta.$$

Thus, *flow predominantly sets speed* while *pressure predominantly sets available torque*. In practice, servo valves, line compliance, and controller bandwidth couple these dimensions.

What is Q (flow), and why does $2\pi Q_{\text{max}}$ appear?

Definition. Q is the *volumetric flow rate* of hydraulic fluid (e.g., L/min or m^3/s). It is produced by the pump and metered by the valve. Q_{max} is the maximum flow available without violating limits (pump curve, valve capacity, cavitation).

Units & conversion. If motor displacement is V_d (m^3/rev), then Q/V_d has units of rev/s. Multiplying by 2π converts rev/s to rad/s:

$$\omega \approx \frac{2\pi\, Q}{V_d}\,\eta_v \quad \Rightarrow \quad \omega_{\text{max}} \approx \frac{2\pi\, Q_{\text{max}}}{V_d}\,\eta_v.$$

So $2\pi Q_{\text{max}}$ is simply the pump/valve's maximum volumetric flow expressed as an *angular rate* before accounting for V_d and η_v.

Engineering note. During a soft stop, the controller reduces Q (speed) while maintaining sufficient ΔP (torque) so $\tau_{\text{avail}} \geq \tau_{\text{load}}$ and the index is reached without overshoot.

1.3 Control concept: prox-gated soft stop

A prox at angle θ_{prox} triggers a multi-stage deceleration profile (e.g., S-curve or piecewise-constant α) to a final index angle θ_{idx}. The controller reduces commanded flow (velocity) while preserving sufficient pressure (torque) to overcome load torque (gravity bias, seal drag, external friction) and to hold position without overshoot.

2 Interplay of Velocity and Pressure

Distinct yet coupled. Flow-limited operation caps speed regardless of pressure headroom; pressure-limited operation caps torque regardless of flow. Transitions between these regimes occur during starts, acceleration transients, and final braking. Poor coordination can induce pressure spikes, cavitation risk, or overshoot/oscillation.

Engineering guidance.

- Use prox-based deceleration to enter a *controlled* pressure-limited braking zone at a reduced speed.
- Verify $\tau_{\text{avail}}(\Delta P)$ exceeds $\tau_{\text{load}}(\omega, \theta)$ throughout deceleration.
- **Decel window:** choose

  $$\Delta\theta \;\geq\; \frac{\omega_{\text{pre}}^2 - \omega_{\text{final}}^2}{2|\alpha_{\text{cmd}}|}$$

  with margin for compliance and delay.
- Use S-curve or piecewise-α shaping to reduce jerk; verify pressure ripple and line resonance.

3 Hydraulic Drive Torque–Speed Map (Figure 1)

Figure 1 illustrates the conceptual relationship between torque and speed for a hydraulic motor driving a rotary platen.

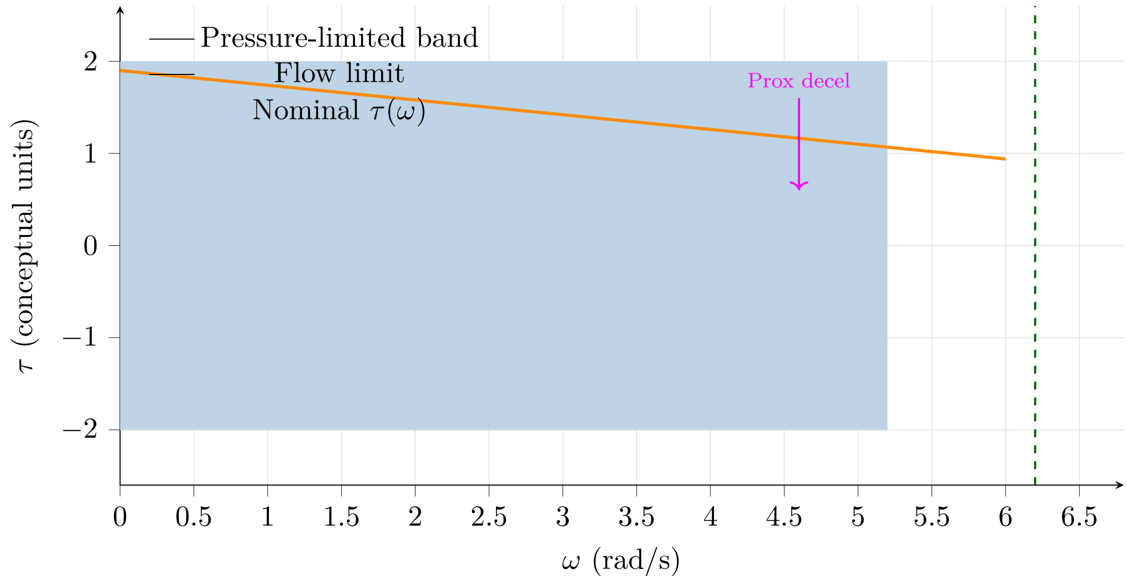

Figure 1: Hydraulic motor torque–speed concept with pressure-limited torque at low speed and a flow-limited speed ceiling.

Figure 1 — How to read this map

Axes. Horizontal: angular speed ω (rad/s), governed mainly by flow Q. Vertical: torque τ, governed mainly by pressure drop ΔP.

Blue band (pressure-limited). At low speed the motor hits a torque ceiling set by $\Delta P_{\max}$; reducing speed cannot increase torque beyond this band.

Green dashed line (flow limit). At high speed the motor hits a speed ceiling set by $Q_{\max}$; extra pressure will not raise ω past this limit.

Orange curve (nominal $\tau(\omega)$). Available torque typically *droops* as speed rises due to leakage and efficiency losses.

Magenta arrow (prox-gated decel). When the prox trips, the controller reduces Q (thus ω) while maintaining enough ΔP (thus τ) to arrest inertia and index without overshoot.

Why it matters. The map shows why hydraulic drives are torque-bounded at low speed and flow-bounded at high speed, and why a prox-triggered soft stop is essential for heavy, high-inertia platens.

4 Rotary Platen Schematic with Prox Soft Stop (Figure 2)

Figure 2 shows a simplified rotary platen, a heavy mold at the rim, the hydraulic motor, and the prox-based soft-stop window.

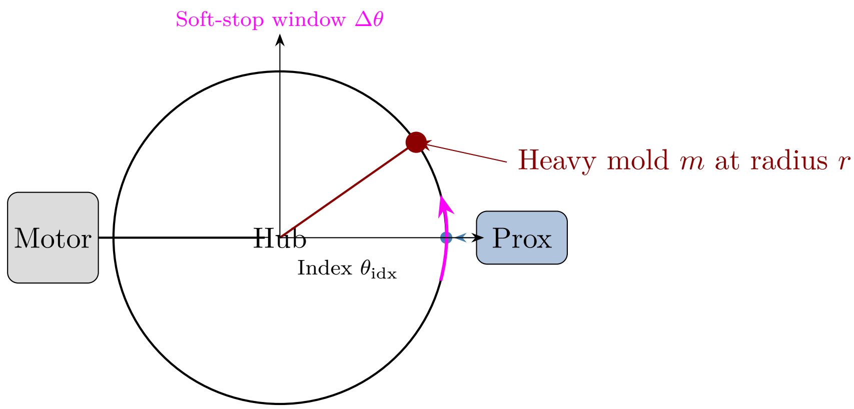

Figure 2: Rotary platen with prox-gated soft stop; labels are positioned to avoid overlap.

Figure 2 — What the schematic shows

Platen + inertia. A heavy mold at radius r dominates the moment of inertia $I = \sum m_i r_i^2$, raising torque demand for any change in speed.

Hydraulic motor. Provides shaft torque proportional to ΔP and speed proportional to Q (with efficiencies).

Prox at index. When the feature passes the prox, the controller gates a reduced-flow profile (lower ω) while holding sufficient ΔP to resist inertia, creating a soft stop at θ_{idx}.

Why it matters. Keeping deceleration within the soft-stop window $\Delta\theta$ minimizes shock loads, wear, and misalignment, especially with large I from heavy molds at the rim.

5 Units & Conversions (Quick Reference)

Power from pressure and flow

SI: $P_{\mathrm{kW}} = \dfrac{p_{\mathrm{bar}} \cdot Q_{\mathrm{L/min}}}{600}$ (equivalent to $P = \Delta P\, Q$ in coherent units).

Imperial: $\mathrm{HP} = \dfrac{\mathrm{PSI} \cdot \mathrm{GPM}}{1714}$.

Motor speed from flow

RPM (Imperial): $\mathrm{RPM} \approx \dfrac{231\ \mathrm{GPM}}{D\ (\mathrm{in}^3/\mathrm{rev})}\, \eta_v$.

Rad/s (SI): $\omega \approx \dfrac{2\pi\, Q}{V_d}\, \eta_v$ with Q in m^3/s, V_d in $\mathrm{m}^3/\mathrm{rev}$.

Motor torque from pressure

Ideal: $\tau_{\mathrm{ideal}} = \dfrac{\Delta P\, V_d}{2\pi}$; Real: $\tau \approx \tau_{\mathrm{ideal}} \eta_m$.

Kinematics (constant decel)

$$\omega_f^2 = \omega_i^2 + 2\alpha\, \Delta\theta \quad \Rightarrow \quad \Delta\theta_{\mathrm{decel}} = \frac{\omega_i^2 - \omega_f^2}{2|\alpha|}.$$

6 Conclusion

Coordinating flow (velocity), pressure (torque), and prox-gated deceleration is essential for accurate indexing and long component life in rotary platen systems. The included formulas, units, and figures provide a practical framework for sizing, tuning, and communicating the design rationale to stakeholders responsible for mold safety, uptime, and repeatability.