Breathing Capacity & Energy Buffering — RME vs Conventional (NA & Turbo)

Scope: Compare natural breathing capacity and compression-event power for an RME (2-stroke, every stroke a power stroke) against a conventional 4-stroke (80x80 mm), both naturally aspirated and a turbo case sized to match the RME per-cycle breathing. Then design a flywheel and an electrical capacitor to buffer the RME per-event compression energy at 1000/2000/3000 RPM.

Units & Conversions

Length: mm -> m (1 mm = 1e-3 m); Area: mm^2 -> m^2 (1 mm^2 = 1e-6 m^2); Volume: 1 L = 1e-3 m^3; Pressure: 1 bar = 100 kPa; Energy: joule (J); Power: watt (W), kilowatt (kW).

Given Geometry & Thermo Assumptions

* Bore area (main): 5,024 mm^2; Main stroke: 80 mm.

* Floating piston area: 12,638 mm^2; Floating stroke: 55 mm.

* Compression ratio: CR = 17.0:1, adiabatic index gamma = 1.4. Intake pressure P1 = 1.0 bar (100 kPa).

* Conventional engine geometry is 80 mm bore x 80 mm stroke (same as main piston).

Step 1 — Displacements per Thermodynamic Cycle

Conventional (4-stroke) single cylinder: Vs = A_main x S_main = 401,920 mm^3 ~= 0.402 L.

RME (2-stroke style) total: main 0.402 L + floating 0.695 L = 1.097 L.

Per-cycle displacement ratio (RME/Conv) = 2.729.

Step 2 — Breathing Capacity (Volumetric Flow)

Cycles per second: RME does one thermodynamic cycle per revolution => nu_RME = RPM/60. A 4-stroke completes a cycle every two revolutions => nu_conv = RPM/120.

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Ideal volumetric flow (before VE): Q_RME = Vs_RME * RPM/60; Q_conv_NA = Vs_conv * RPM/120.
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RPM	Q_RME (L/s)	Q_Conv NA (L/s)	Flow ratio (RME / Conv)
1000	18.284	3.349	5.459
2000	36.567	6.699	5.459
3000	54.851	10.048	5.459

With equal volumetric efficiency (VE), the RME moves about 5.46x the volume per second as the NA conventional at the same RPM. If VE differs, multiply Q by the respective VE.

Step 3 — Turbo Sizing for Matching Per-Cycle Mass

Assume good intercooling so density scales with compressor pressure ratio (PR). To match RME per-cycle mass with a 4-stroke of the same geometry:

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PR_match ~= (Vs_RME * VE_RME) / (Vs_conv * VE_Conv). For equal VE, PR_match ~= Vs_RME / Vs_conv.
```

Numerically, PR_match ~= 2.729. The conventional turbo at this PR has the same per-event compression work (see next step).

Step 4 — Compression Work per Event (Adiabatic Air)

Use the standard adiabatic work expression:

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W_comp = P1 * V1 * (CR^(gamma-1) - 1)/(gamma - 1), with V1 = Vs * CR/(CR - 1).
```

Because V1 is proportional to Vs, for fixed CR and gamma the work scales with P1*Vs.

Results at P1 = 1 bar: RME W_comp ~= 614 J; Conv NA W_comp ~= 225 J.

Conventional Turbo at PR ~= 2.729: W_comp,turbo ~= PR * W_comp,NA ~= 614 J (about equal to RME).

Step 5 — Compression Event Power (Not Cycle-Averaged)

Compression stroke duration is 180 degrees of crank, so T_comp = 30/RPM seconds for both engines. Event-average power is W_comp / T_comp.

RPM	T_comp (s)	RME P_event (kW)	Conv NA P_event (kW)	Conv Turbo P_event (kW)
1000	0.030	20.45	7.49	20.45
2000	0.015	40.91	14.99	40.91
3000	0.010	61.36	22.48	61.36

These are the actual shaft power levels required during the compression window at each RPM.

Step 6 — Speed-Dependent Friction & Inertial KE (for context)

Friction model (your rule): F = c*v => instantaneous p = F*v = c*v^2. Over a friction distance s within the compression stroke, the average friction power is:

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P_f,avg = (c * v * s) / T_comp. (This is small vs the kW-level compression power for
reasonable c.)
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Inertia: average over the event is zero, but the kinetic-energy swing sizes the torque ripple. Use KE_max = 0.5*m*v_max^2 per piston.

Example KE swings (m = 0.4 kg each): RME main ~= 40.5 J; RME floating ~= 19.2 J; Conventional main ~= 96.8 J.

You can plug your preferred v_max values directly; the formulas above in the Excel planner will still hold.

Step 7 — Flywheel Sizing to Buffer deltaE ~= 614 J

Energy available from a flywheel with inertia J and speed droop delta (omega1 = (1-delta)*omega0):

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deltaE_FW = 0.5 * J * (omega0^2 - omega1^2) = 0.5 * J * omega0^2 * [1 - (1-delta)^2]
==> J_min = 2*deltaE / (omega0^2 * [1 - (1-delta)^2]).
```

RPM	omega (rad/s)	J_min (kg*m^2)	r=0.20 m: rim/disk mass (kg)	r=0.25 m: rim/disk mass (kg)
1000	104.72	1.148	28.70 / 57.39	18.37 / 36.73
2000	209.44	0.287	7.17 / 14.35	4.59 / 9.18
3000	314.16	0.128	3.19 / 6.38	2.04 / 4.08

Step 8 — Capacitor Sizing (Electrical Buffer)

To supply the same deltaE during the compression window with DC bus sag V0 -> V1 = (1-eps)*V0:

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C = 2*deltaE / (V0^2 * [1 - (1-eps)^2]).
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For deltaE ~= 614 J and eps = 10%: C ~= 2.81 F @ 48 V or 0.70 F @ 96 V. Power stage must handle the event power from Step 5.

Key Takeaways

- Per-cycle displacement: RME 1.097 L vs Conv 0.402 L => ratio 2.729.

- At the same RPM, ideal breathing rate of the RME is about 5.46x the NA conventional (before VE).

- To match RME per-cycle mass, the 4-stroke needs turbo PR ~= 2.73 (assuming equal VE and good intercooling).

- Per-event compression work (CR=17): RME ~= 614 J; Conv NA ~= 225 J; Conv Turbo@PR ~= 614 J.

- Event power (not cycle-average) scales as W_comp / (30/RPM).

- Flywheel and/or a small supercap can buffer the ~614 J pulse so a single-cylinder RME runs smoothly.