

A Technical Note on Mechanical Architecture and Kinematic Constraints in a Roto-Dynamic Variable Compression Ratio (RVCR) Engine Concept.

Working technical note – not for citation or distribution

Abstract

Rotary internal combustion architectures have historically promised mechanical simplicity but have struggled with sealing, combustion phasing, and durability under high compression ratios. This note examines the mechanical architecture and kinematic structure of a **roto-dynamic variable compression ratio (RVCR)** engine concept, in which compression, combustion, and expansion are governed through controlled kinematic sequencing and **valving for gas exchange**, rather than continuous chamber deformation. The intent is not to present performance claims, but to articulate the mechanical logic, kinematic constraints, and governing load paths of the system. Assumptions are stated explicitly, and conditions under which the architecture would face limitations are identified.

1. Framing and scope

This note addresses **mechanical architecture and kinematics only**.

It does **not** address:

- Combustion chemistry
- Efficiency or power density claims
- Materials selection
- Manufacturing readiness
- Commercial viability

The objective is narrower:

to examine whether the RVCR mechanical and kinematic structure enables distinct, controllable compression–combustion–expansion sequencing under conservative assumptions.

2. Problem context: why rotary engines fail mechanically

From a mechanical standpoint, most rotary engine concepts encounter one or more of the following failure modes:

1. **Continuous chamber deformation during combustion**, leading to:
 - Variable volume during flame development
 - Sealing elements exposed to peak pressure while in motion
2. **Rigid coupling of compression and rotation**, forcing:
 - High side loads on seals
 - Unfavourable bearing load paths
3. **Poorly defined dwell near peak compression**, limiting:
 - Residence time for controlled combustion
 - Pressure rise management
4. **Thermal distortion of sealing interfaces**, leading to:
 - Escalating leakage
 - Wear-driven loss of compression

The RVCR architecture applies kinematic decoupling to separate compression, combustion, and expansion.

3. RVCR architectural premise (mechanical view)

At a high level, the RVCR concept is defined by:

- **Roto-dynamic motion** as the governing geometric driver
- **Variable compression ratio achieved kinematically**, not through elastic or hydraulic means
- **Controlled valving for gas exchange**, independent of the combustion chamber's primary load-bearing geometry
- **Distinct sequencing** of compression, combustion, and expansion events

Critically, **the combustion chamber geometry is mechanically stabilized during peak pressure rise**, rather than undergoing continuous deformation.

Mechanically, this enables:

- Well-defined dwell for long residence time during combustion
 - Reduced relative motion of sealing interfaces at peak pressure
 - Predictable load paths into bearings and supporting structures
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4. Kinematic structure

4.1 Degrees of freedom

The RVCR mechanism comprises:

- A primary rotational degree of freedom associated with power output
- Secondary controlled motion elements that govern compression ratio and phase sequencing
- A **switching clutching mechanism** that alternates rotor link sequences to achieve the desired cycle progression

Compression ratio is therefore:

- **Not fixed by geometry alone**
- **Not continuously varying during combustion**
- **Set and held kinematically during the dwell window**

This switching and sequencing capability is central to RVCR's differentiation.

4.2 Motion sequencing (conceptual)

A representative cycle may be idealized as:

1. **Intake phase**
 - Chamber opened via controlled valving for gas exchange
 - Minimal sealing load
2. **Compression phase**
 - Compression ratio established kinematically
 - Controlled motion with moderate seal velocity
3. **Dwell / combustion phase**
 - Complete constant volume
 - Well-defined dwell allowing long residence time
 - Minimal relative seal motion
4. **Expansion phase**
 - Kinematic re-coupling transfers torque to the output
5. **Exhaust phase**
 - Valving clears the chamber for the next cycle

The mechanical novelty is not the presence of dwell per se, but that **dwell duration is a controllable kinematic outcome**, not a marginal geometric artifact.

5. Load paths and bearing implications

5.1 Pressure-induced forces

Peak combustion pressure generates:

- Radial forces on chamber boundaries
- Tangential forces contributing to torque

- Reaction forces resolved through the kinematic structure

The RVCR architecture routes:

- Primary load paths being reacted through **rolling bearings**, not sliding seals
- Seals acting primarily as **pressure boundaries**, not load-bearing members

Seal loading is further minimized by:

- **Minimizing the projected area exposed to gas pressure**
- Avoiding seal involvement in torque transmission

If seals were required to carry significant structural load, the architecture would lose its mechanical advantage.

5.2 Bearing loading (revised)

Because combustion pressure acts on a minimized projected area, bearing loads during combustion remain limited in magnitude and duration. Peak pressures may be high; resultant reaction loads are reduced by geometry and load orientation. Load management is achieved through large-diameter, low-speed rolling bearings and conservative surface stress design.

Bearing load concentration is **not inherently problematic** in RVCR; rather, the design challenge lies in maintaining synchronization and load sharing through the switching sequence.

6. Sealing interfaces (mechanical perspective)

From a purely mechanical standpoint:

- Seals are short, discrete, and pressure-biased
- Relative sliding velocity during peak pressure is minimized
- Contact loads are governed primarily by preload and pressure balance, not torque transmission

The architecture is compromised only if:

- Projected seal area increases beyond controllable limits
 - Thermal distortion disrupts kinematic alignment
 - Seals are forced into load-bearing roles
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7. Comparison to known architectures (mechanical focus)

Architecture	Primary mechanical challenge
Wankel	Continuous seal motion under peak pressure
Quasi-turbine	Poorly defined dwell and sealing geometry
Opposed piston	Synchronization complexity and packaging
RVCR	Switching clutching mechanism and sequential operation integrity

RVCR does not eliminate mechanical complexity; it **repositions complexity into controlled kinematic sequencing**, which is a fundamentally different problem domain.

8. Speed and scaling considerations

Mechanically, RVCR is:

- **More tolerant at slow and moderate speeds**
- Less naturally suited to very high RPM operation

High-speed operation is not fundamentally prohibited but would require:

- Complex timing and control algorithms
- Precise synchronization of the switching clutching mechanism
- Careful management of dynamic loads during rapid sequence transitions

Diameter-based scaling is mechanically more favourable than speed-based scaling.

9. Open technical questions (reframed)

The key unresolved mechanical questions are:

- **What maximum dwell duration can be sustained kinematically without destabilizing the sequence?**
- How robust is sequential operation over long duty cycles?
- How sensitive is synchronization to wear and tolerance stack-up?
- How does switching behaviour evolve at higher rotational speeds?

These questions are central to assessing the operational envelope of RVCR.

10. Closing remark (revised)

The critical assessment criterion is whether sequential operation integrity can be preserved as rotational speed increases, without destabilizing kinematic control or load paths.

Compression, combustion, and expansion are kinematically distinct and mechanically controlled in RVCR; the critical question is not whether separation exists, but how robustly it can be sustained under dynamic conditions.

Footnote (context only)

The RVCR architecture is protected by granted patents in multiple jurisdictions and has undergone technical review within academic and industrial forums in the EU and India. This note is intended solely as a mechanical and kinematic examination and does not constitute a performance claim.