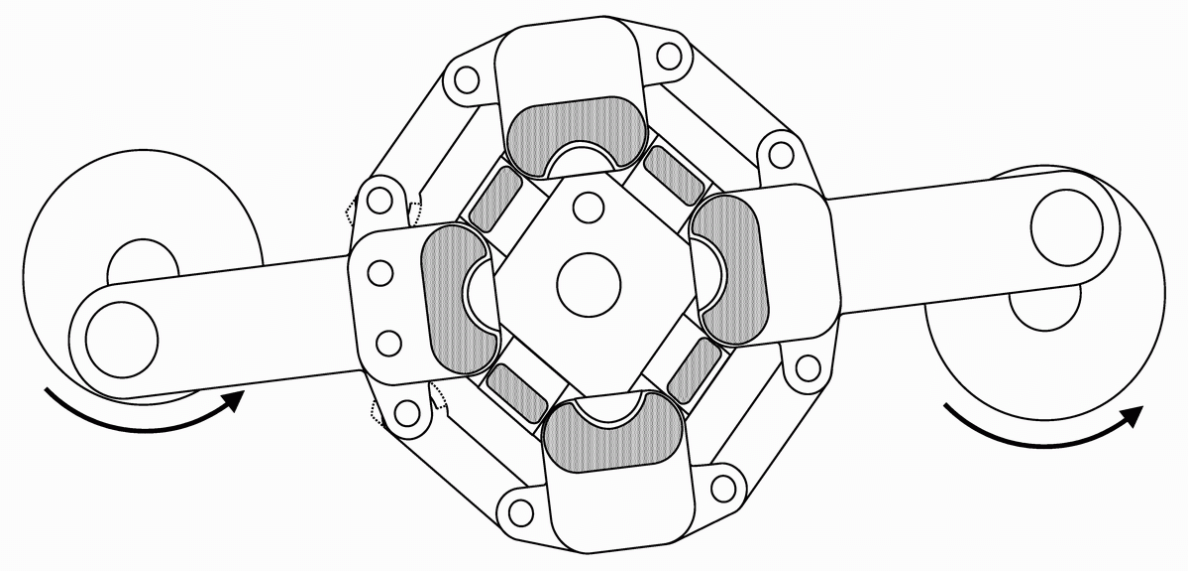
ARTICULATED RHOMBIC PRISM PISTON ENGINES



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ARTICULATED RHOMBIC PRISM PISTON

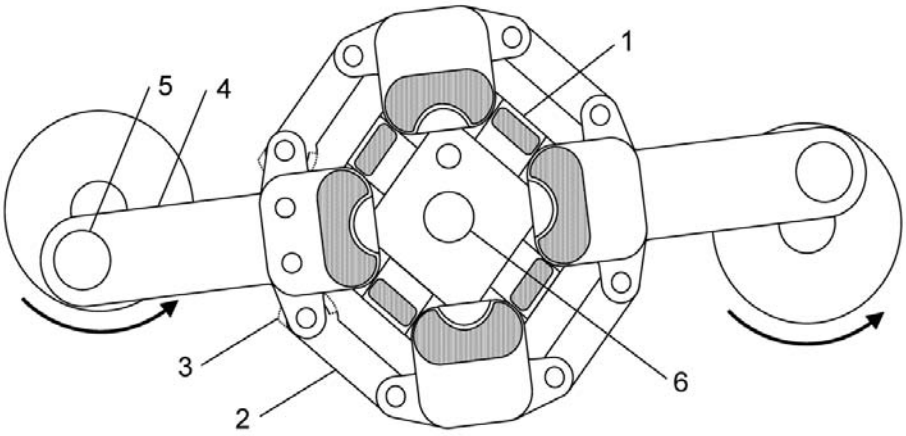
ABSTRACT

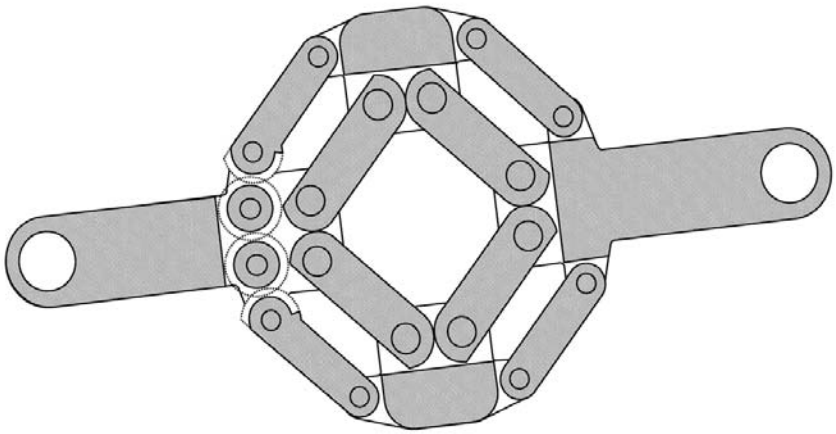
Articulated rhombic prism piston for thermal machines, provided with four movable sides (1), hinged to four links (2), so as to cooperate with two parallel planes inside a machine body, to form a variable geometry closed chamber, substantially shaped as a right rhombic prism, whose volume varies as the relative orientation of said four sides varies.

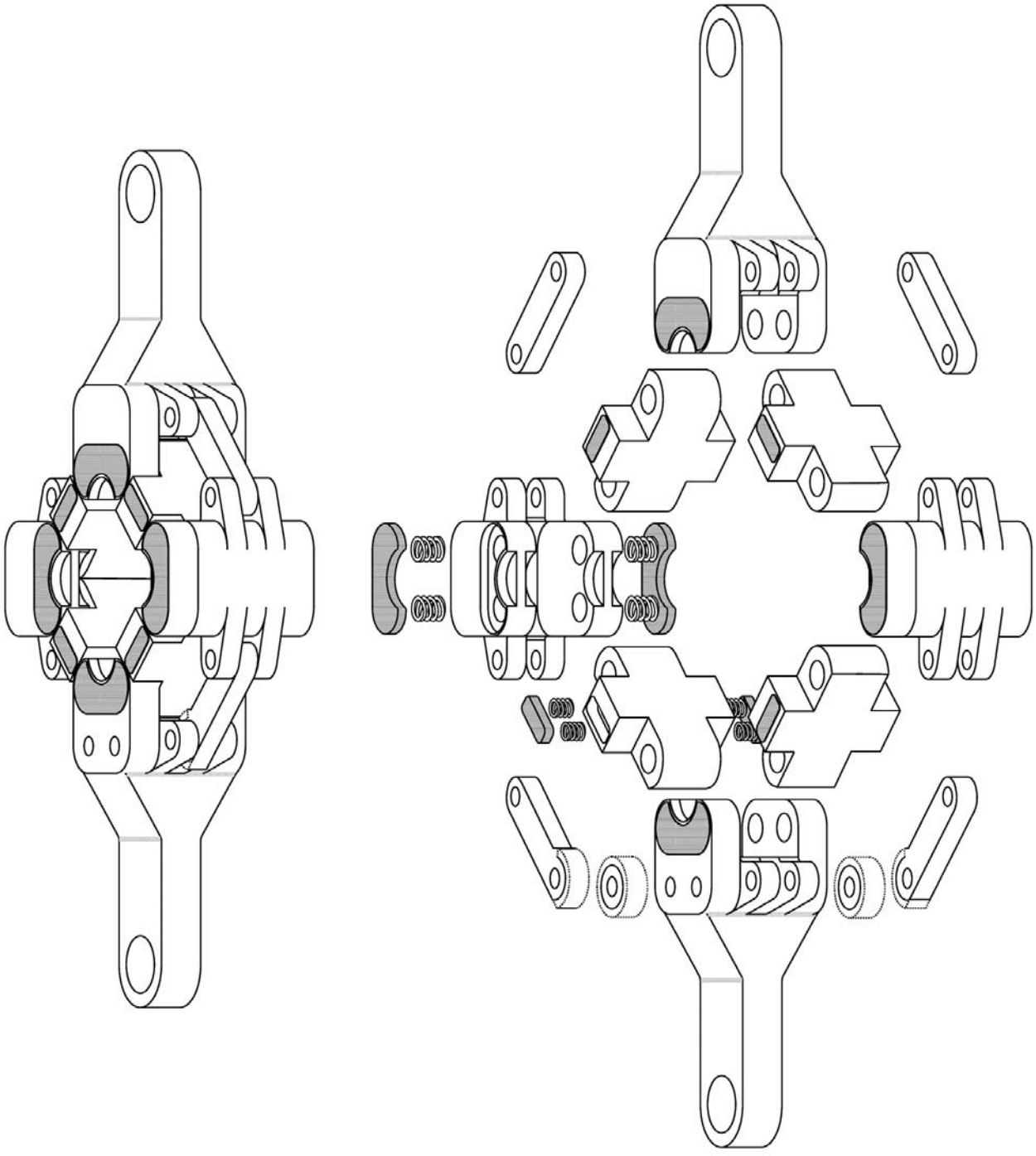
Two opposed articulated edges of said piston are provided with piston rods (5), linked to two cranks (6), which, by effect of a transmission system, rotate in the same direction, at the same speed and with a 180° phase-shift with each other, so that said articulated rhombic prism keeps itself always centred with intake and exhaust valves (7), placed in front of each other in said two parallel planes of said machine body. Parallelism and alignment among said components of said piston are assured by means of auxiliary connecting rods (3) and gears (4).

Applications of articulated rhombic pistons include:

- **direct injection gasoline engines,**
- **indirect injection gasoline engines,**
- **Diesel engines**;
- **closed cycle Stirling engines;**
- **inverted cycle Stirling heat pumps.**

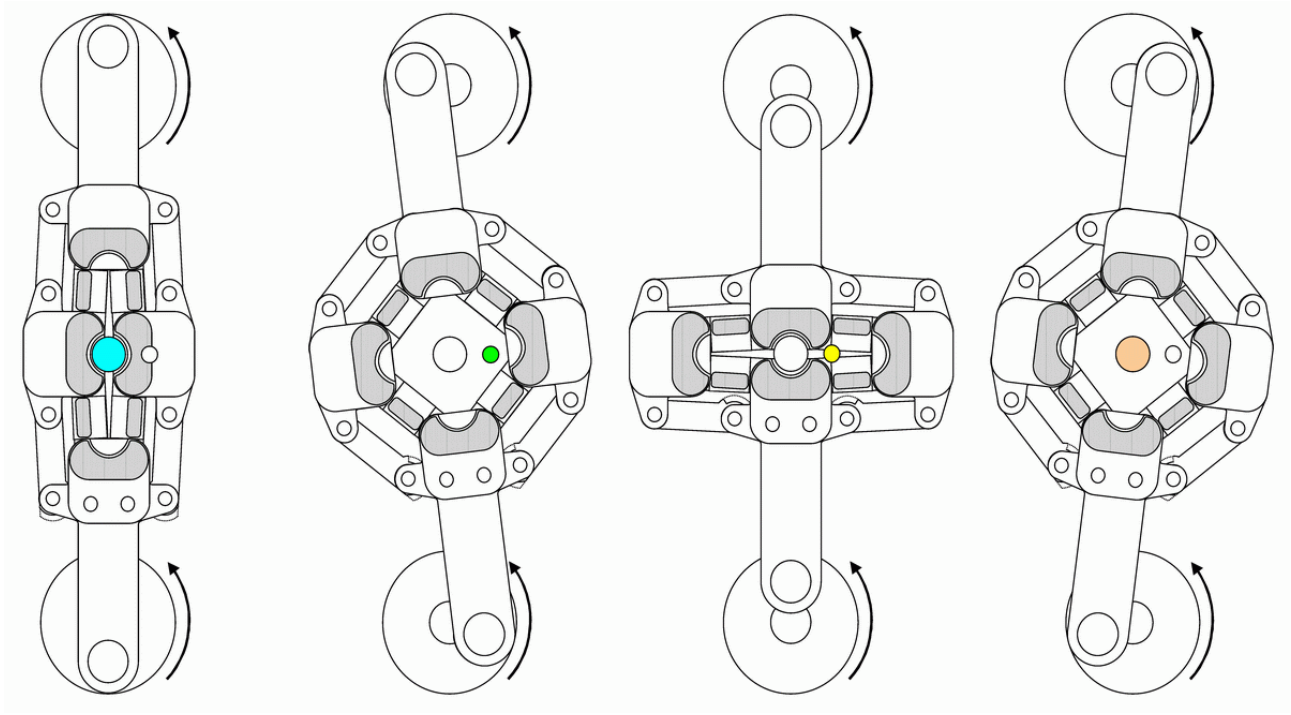






ARTICULATED RHOMBIC PISTON ENGINES
- CHARACTERISTICS AND ADVANTAGES -

1	**DOUBLE SPECIFIC POWER** An articulated rhombic piston completes a **four strokes cycle within a single drive shaft revolution**, rather than two revolutions needed by a cylindrical piston.

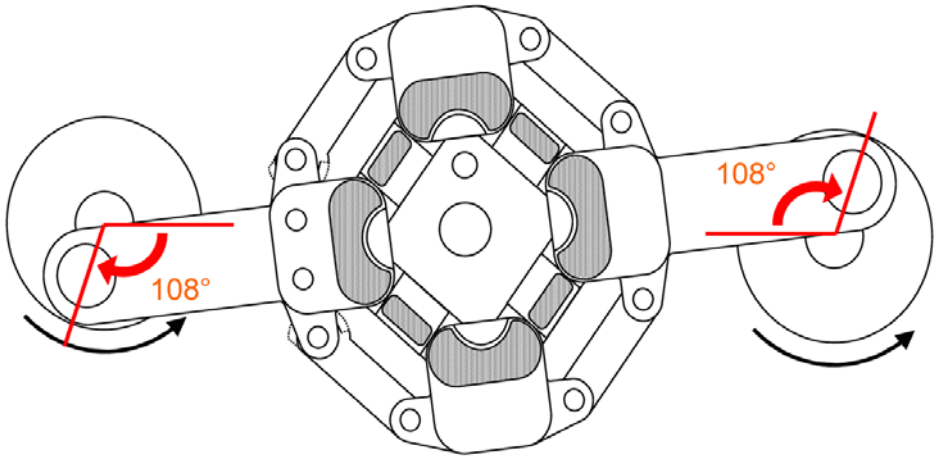


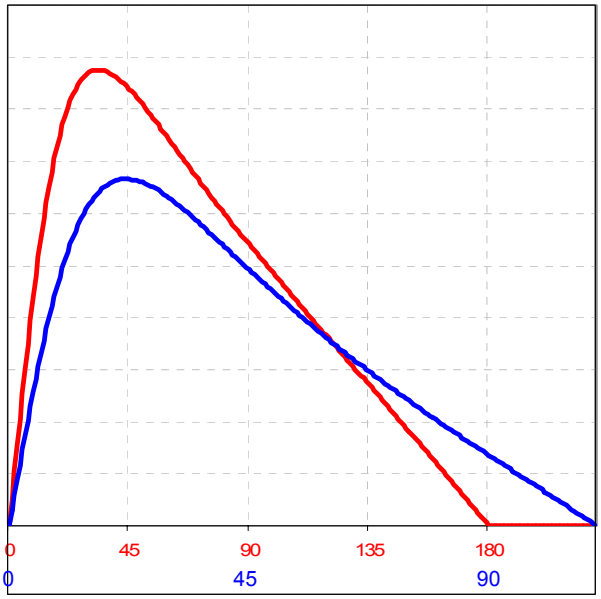
Start of intake	Start of compression	Ignition and start of expansion	Start of exhaust

VANTAGGI

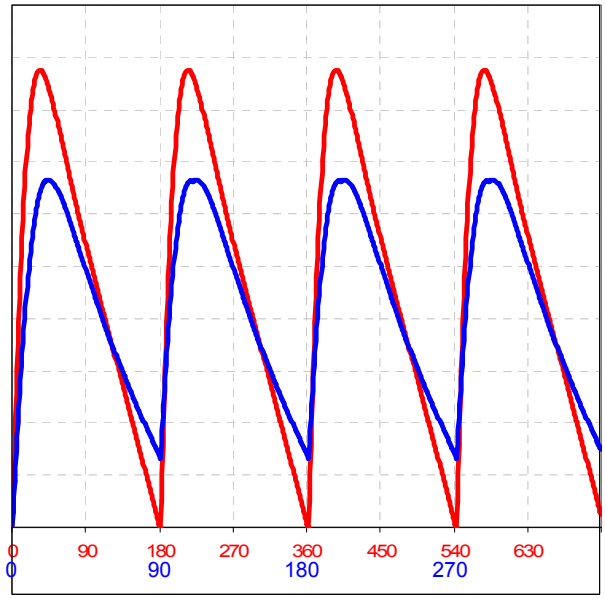
Improved performance	Improved efficiency	Cost reduction	Lower vibration/ noise	Longer durability	Higher reliability	Notes
*** Double specific power (at the same RPM)						At the same rotational speed, it doubles the ignition rate and the output power.
	*** Half RPM (at the same power output)		***	**		It outputs the same power at halved rotational speed, and reduces: • by 75% vibration and related power loss • by over 50% friction power loss and friction wear

2	**MORE LEVELLED OUTPUT TORQUE** An articulated rhombic piston **outputs torque for 108° out of 360°, that is 30% of a revolution.** **In a four-piston engine, power strokes will overlap by 20%, and the torque output will be more levelled, similar to that of a 5 cylinders engine.**





Output torque of a single piston



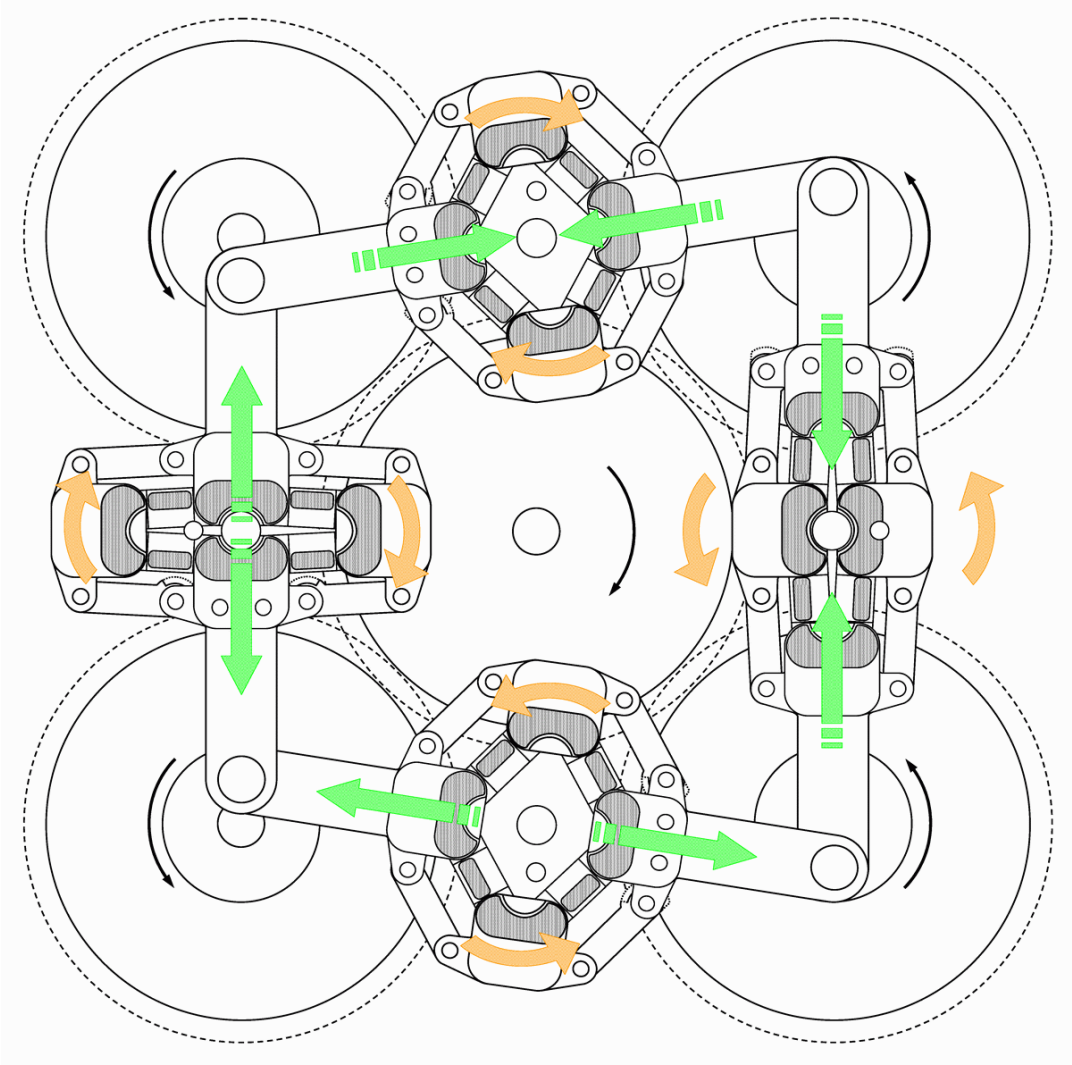
Output torque of a four pistons engine

● = Cylindrical piston ● = Articulated rhombic piston

ADVANTAGES

Improved performance	Improved efficiency	Cost reduction	Lower vibration/ noise	Longer durability	Higher reliability	Notes
*** More levelled output torque		**	**			Output torque is more levelled, similar to that of a 5 cylinders engine, however no balance shaft is needed.
		**				The flywheel may be reduced, or eventually eliminated.

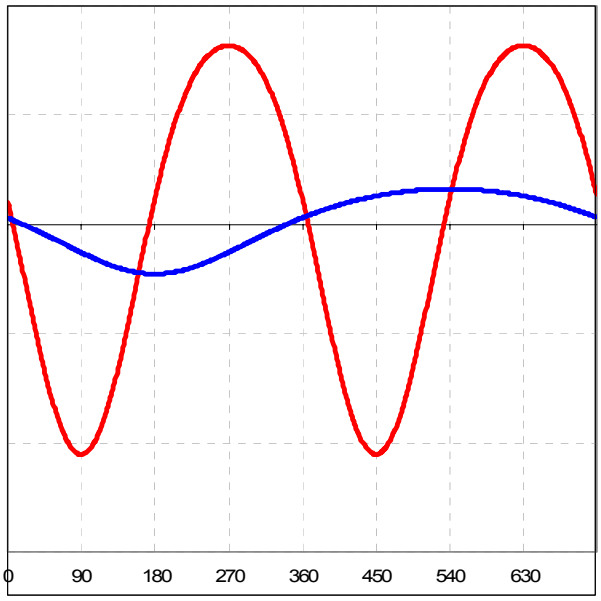
3	**DRASTIC REDUCTION OF VIBRATION** An articulated rhombic piston **does not cause linear vibration**, since its main moving masses are balanced by equivalent masses in opposite motion (●). **A four-piston engine does not cause significant torque vibration**, since vibration produced by each piston are substantially annulled by opposite vibration produced by the opposite piston (●).



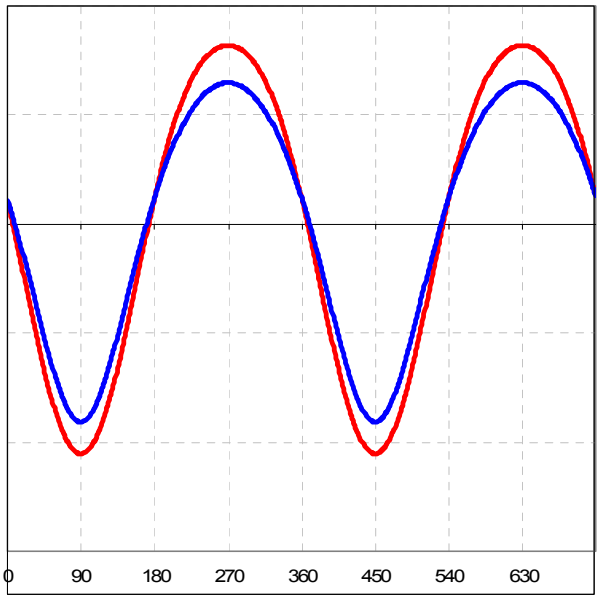
ADVANTAGES

Improved performance	Improved efficiency	Cost reduction	Lower vibration/ noise	Longer durability	Higher reliability	Notes
	**		***	**	**	Drastic reduction of vibration and related power loss and effects on durability and reliability
		*** Reduction of dampers and noise insulations				Substantial simplification of vibration damping and noise insulation
		**				No rotating counterweights are needed

4	**REDUCED ACCELERATIONS** The stroke length of an articulated rhombic piston is 160% that of a cylindrical piston of equal displacement; however, since it is equally shared by two opposite cranks, the effective stroke length of each crank is about 80% that of the crank of a cylindrical piston of equal displacement: • **at the same power output** (i.e. at half rotational speed) **acceleration of moving masses are reduced by 80%**; • **at the same rotational speed** (i.e. double power output) **accelerations are anyway reduced by 20%**



Accelerations at the same power output



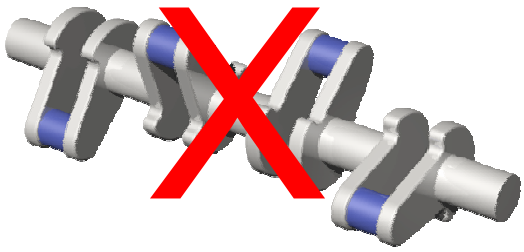
Accelerations at the same rotational speed

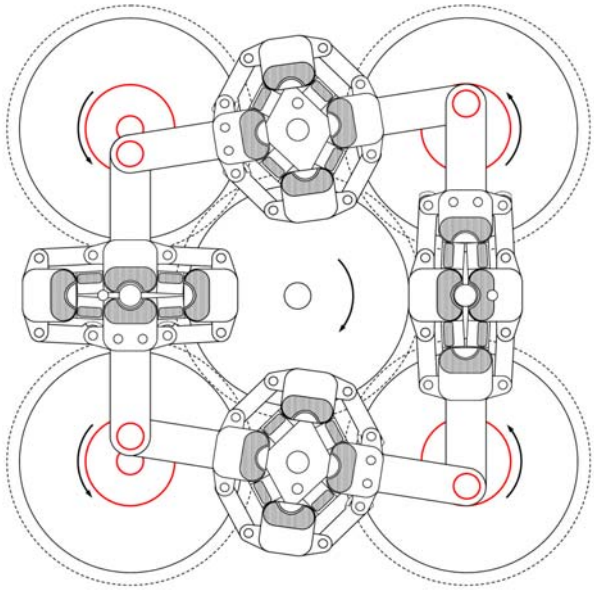
● = Cylindrical piston ● = Articulated rhombic piston

ADVANTAGES

Improved performance	Improved efficiency	Cost reduction	Lower vibration/ noise	Longer durability	Higher reliability	Notes
	**			**	**	Reduced mechanical stress and power loss for vibration

5	**ELIMINATION OF CRANKSHAFT** **A four-piston engine does not need a crankshaft**, since its four pistons are linked to four single cranks.

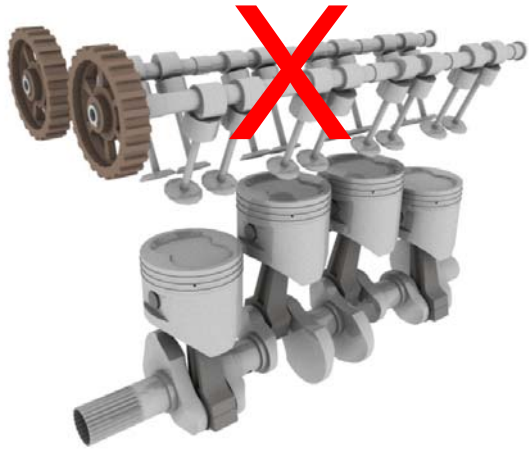


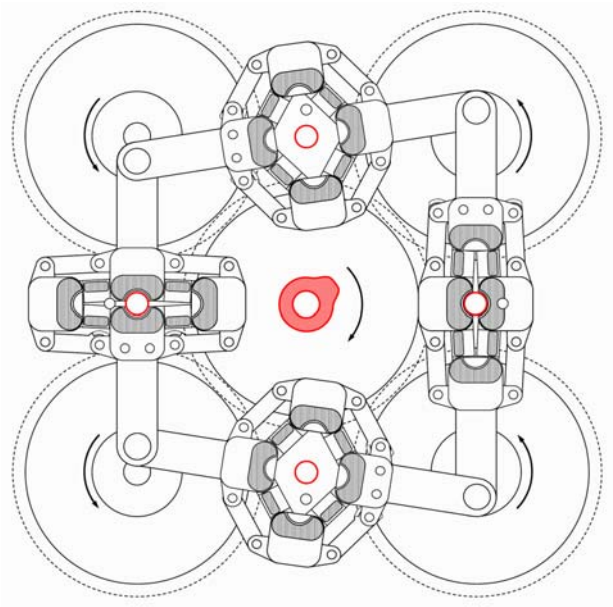


ADVANTAGES

Improved performance	Improved efficiency	Cost reduction	Lower vibration/ noise	Longer durability	Higher reliability	Notes
	**	*** Elimination of the crankshaft				Elimination of the crankshaft and reduction of cost, size, weight.

6	**ELIMINATION OF CAMSHAFTS** In a **four-piston engine**, intake and exhaust valves can be operated by **only two cams,** on both sides of the main drive shaft, since the direction of rotation of said shaft corresponds to the sequence of operation of the valves of said four pistons.

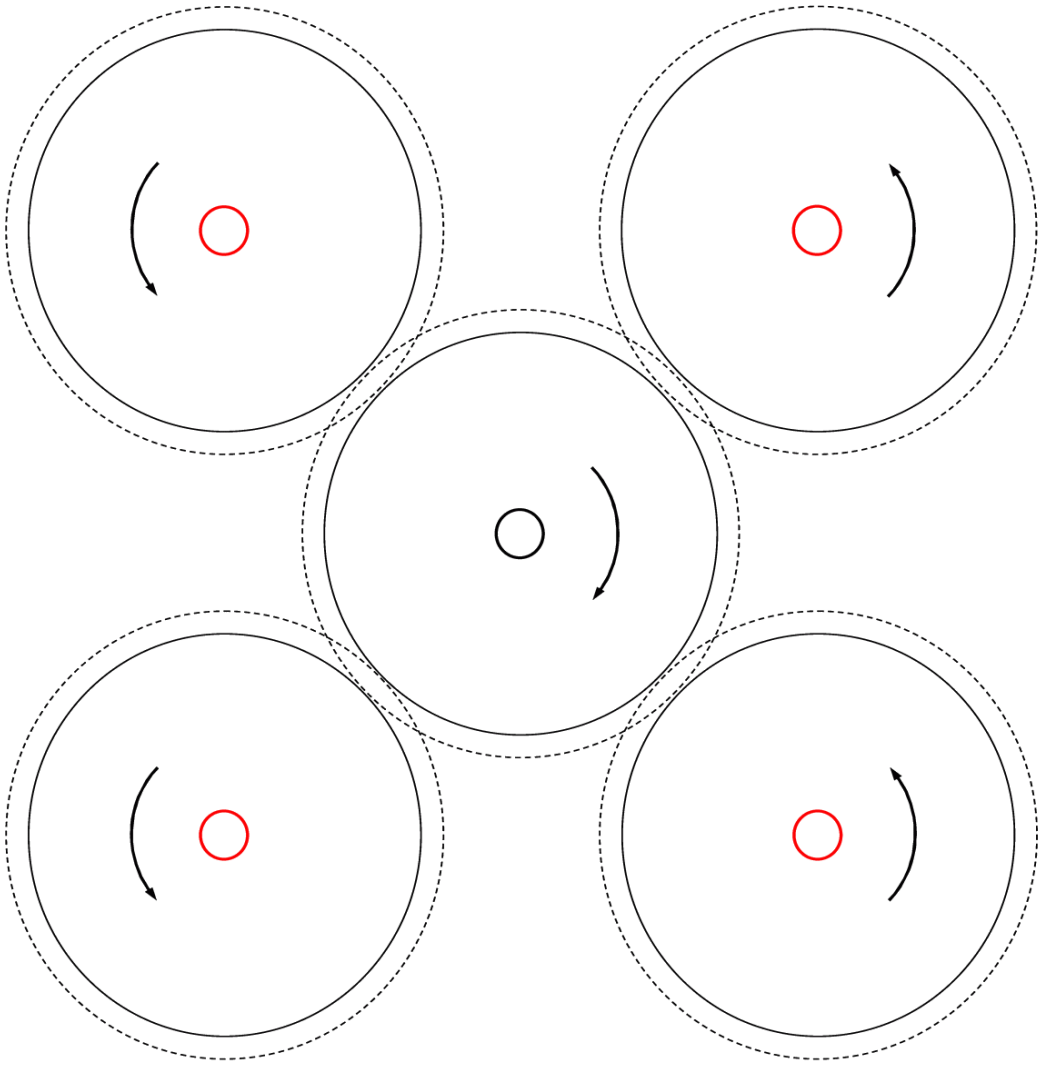




ADVANTAGES

Improved performance	Improved efficiency	Cost reduction	Lower vibration/ noise	Longer durability	Higher reliability	Notes
	**	*** Elimination of the camshafts	**			Elimination of the camshafts and related transmission components (toothed wheels, chains, belts, pulleys,...), and related power power loss, noise, insulations, failures.

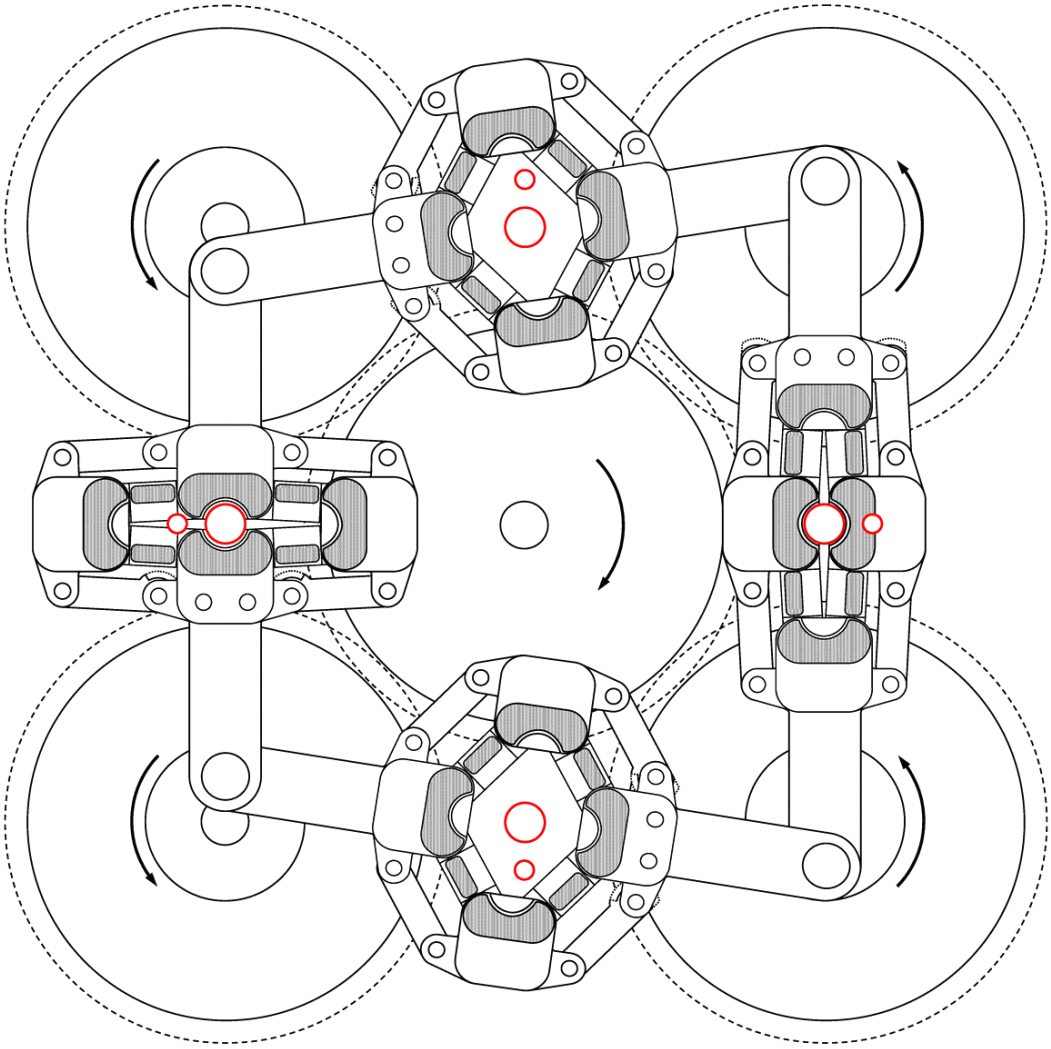
7	**ELIMINATION OF AUXILIARY TRANSMISSION COMPONENTS** **A four-piston engine** is provided with **four additional rotating shafts**, besides the main drive shaft, which can be used for the direct operation of alternator, pumps, compressors, or other devices, without additional transmission components, as toothed wheels, belts, pulleys, etc.



ADVANTAGES

Improved performance	Improved efficiency	Cost reduction	Lower vibration/ noise	Longer durability	Higher reliability	Notes
	**	*** Elimination of auxiliary transmission components	**		***	Direct operation of alternator, pumps, compressors, or other devices, without additional transmission components, as toothed wheels, belts, pulleys, etc.

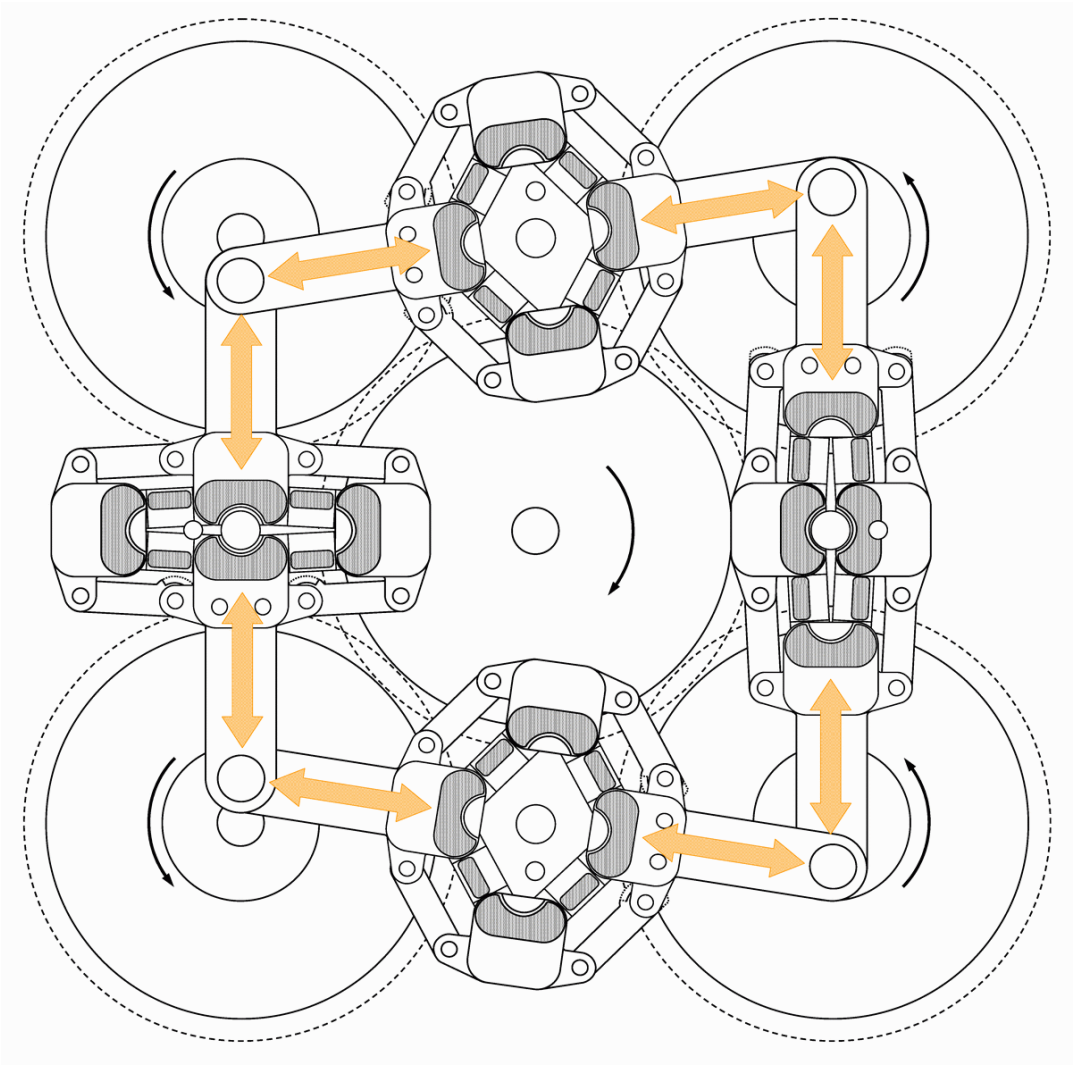
8	**REDUCTION OF DIMENSIONS AND WEIGTH** **A four-piston engine features optimal space occupation and limited size**. The positions of intake and exhaust valves and of injectors and spark plugs, correspond to spaces not occupied by transmission toothed wheels, so that the overall thickness of the engine is limited too.



ADVANTAGES

Improved performance	Improved efficiency	Cost reduction	Lower vibration/ noise	Longer durability	Higher reliability	Notes
	**	***				Reduced size and weight.

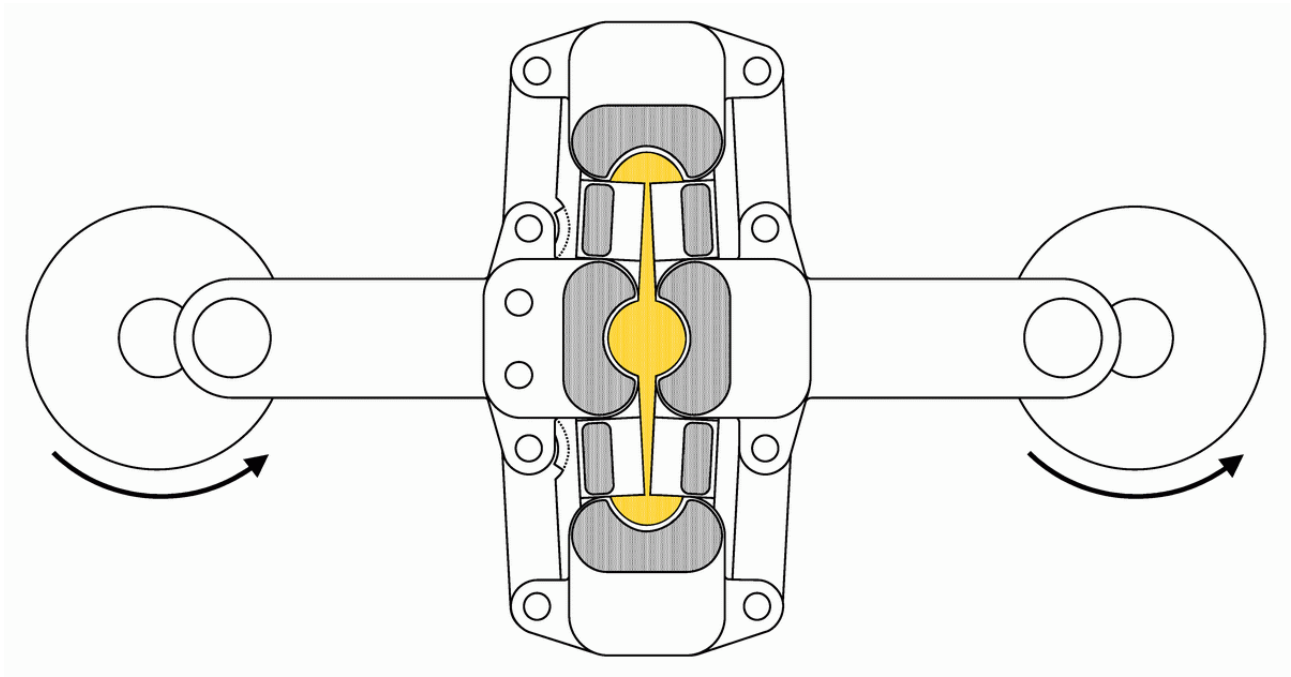
9	**REDUCTION OF WEAR** In an articulated rhombic piston, **connecting rods are always loaded axially.**



ADVANTAGES

Improved performance	Improved efficiency	Cost reduction	Lower vibration/ noise	Longer durability	Higher reliability	Notes
				***		Minimum wear of pistons and of the parallel planes of the engine body
		**				Connecting rods can be lighter

10	**REDUCTION OF MECHANICAL STRESS** An articulated rhombic piston, on ignition, produces a **reduced force on the parallel planes of the engine body**, since the exposed surface is reduced. As the exposed surface increase,s during the power stroke, pressure decreases and the total force on the parallel planes of the engine body is kept substantially constant.



ADVANTAGES

Improved performance	Improved efficiency	Cost reduction	Lower vibration/ noise	Longer durability	Higher reliability	Notes
		*** Lighter construction of the engine body				Reduced force on the parallel planes of the engine body.

NEW FRONTIERS OPENED BY ARTICULATED RHOMBIC PISTONS

11	**FAIL-SAFE UTILIZATION OF ELECTRONICALLY OPERATED VALVES** An articulated rhombic piston is **interference-free, even if valves should stay open**, so that it is particularly suitable to be used in conjunction with **electronically operated valves**, which allow **variable valve timing and optimization of performance/ efficiency**, without any risk of catastrophic failures..

ADVANTAGES

Improved performance	Improved efficiency	Cost reduction	Lower vibration/ noise	Longer durability	Higher reliability	Notes
*** Optimization of performance/ efficiency	*** Optimization of performance/ efficiency					Utilization of electronically operated valves + variable valve timing

12	**POSSIBLE HIGHLY ENERGY-EFFICIENT 8 STROKES CYCLE**
	By virtue of the double specific power of an articulated rhombic piston and of its overlapping power strokes, **a four-piston engine** can be hypothesized, whose pistons can be switched into **an 8 stroke mode:**
	• **Four regular strokes**,
	• **Four additional strokes, without fuel injection**, wherein:
	  • **residual heath of the combustion chamber is recovered**,
	  • eventually, **further heath is recovered from exhaust**,
	  • with the additional advantage that **the cooling system becomes superfluous**.

ADVANTAGES

Improved performance	Improved efficiency	Cost reduction	Lower vibration/ noise	Longer durability	Higher reliability	Notes
	*** Utilization of residual heath					Energy extraction from residual heath
		*** Elimination of the cooling system			***	Cooling the engine by extracting mechanical work and elimination of the cooling system

13	**POTENTIAL ELIMINATION OF GEARBOX** By virtue of the double specific power of an articulated rhombic piston and of overlapping power strokes, **a four-piston engine** can be hypothesized, which, at regimens ranging from 300 RPM (equivalent to 600 RPM) to 6000 RPM (equivalent to 12.000 RPM), would run a vehicle at a speed range from 10 to 200 km/h, with a **1:1 fixed gear ratio** and a 1:2,8 differential gear ratio and 50 cm diameter wheels.

ADVANTAGES

Improved performance	Improved efficiency	Cost reduction	Lower vibration/ noise	Longer durability	Higher reliability	Notes
	**	*** Eventual elimination of the gearbox				Elimination of the gearbox and reduction of size, weight, power loss and cost.

ARTICULATED RHOMBIC PISTON ENGINES
- CHARACTERISTICS IN SYNTHESIS -

A. PERFORMANCE

*** **Double specific power**	(at the same rotational speed)
*** **More leveled output torque**	(similar to that of a 5-cylinder engine)
EVENTUAL (NEW FRONTIERS)	
*** **Optimization of performance/ efficiency**	(by using electronically operated valves)

B. FUEL ECONOMY

*** **More than halved friction power loss**	(halved regimen, at the same power output)
*** **Nearly total elimination of power loss for vibration**	(intrinsically balanced moving masses) (halved regimen, at the same power output) (shorter crank stroke and reduced accelerations of moving masses)
*** **Reduction of engine's size and weight**	(optimal space occupation) (reduced forces on the engine at ignition)
** Weight reduction by elimination of the crankshaft	(single cranks are used)
** Reduction of friction by elimination of the camshaft	(only two cams on the main drive shaft)
** Reduction of friction in the operation of auxiliary devices	(direct operation of alternator, pumps, compressors, etc.)
EVENTUAL (NEW FRONTIERS)	
*** **Optimization of performance/ efficiency**	(with electronically operated valves)
*** **Utilization of residual heath**	(eventual 8 stroke cycle)
*** **Eventual elimination of weight and power loss of gearbox**	(eventual fixed 1:1 ratio)

C. VIBRATION AND NOISE

*** **Nearly total elimination of vibration**	(intrinsically balanced moving masses) (halved regimen, at the same power output) (shorter crank stroke and reduced accelerations ov moving masses)
*** **Elimination of auxiliary transmission components**	(direct operation of cams, alternator, pumps, compressors, etc.)

D. COSTS

*** **Elimination of the crankshaft**	(four single cranks)
*** **Elimination of the camshaft**	(only two cams on the main drive shaft)
*** **Elimination of auxiliary transmission components**	(direct operation of cams, alternator, pumps, compressors, etc.)
*** **Reduction of dampers, and noise insulations**	(nearly total elimination of vibration) (elimination of auxiliary transmission components for cams, alternator, pumps, compressors, etc.)
*** **Reduction of engine's size and weight**	(optimal space utilization)
*** **Lighter engine body construction**	(reduced forces on the engine at ignition)
*** **No counterweights or balancing shafts required**	(moving masses are intrinsically balanced)
** Reduction or eventual elimination of the flywheel	(more leveled torque, similar to a 5 cylinder engine)
** Lighter connecting rods	(connecting rods are always loaded axially)

EVENTUAL (NEW FRONTIERS)

*** **Eventual elimination of the cooling system**	(eventual 8 stroke cycle)
*** **Eventual elimination of the gearbox**	(eventual fixed 1:1 ratio)

E. DURABILITY

*** **Minimum wear**	(motion of pistons always parallel to the same plane) (halved regimen - at the same output power)
** Drastic reduction of vibration	(moving masses intrinsically balanced)
** Nearly total elimination of vibration	(intrinsically balanced moving masses) (halved regimen, at the same power output) (shorter crank stroke and reduced accelerations of moving masses)

F. RELIABILITY

*** **Elimination of auxiliary transmission components**	(direct operation of alternator, pumps, compressors, etc.)
** Nearly total elimination of vibration	(intrinsically balanced moving masses) (halved regimen, at the same power output) (shorter crank stroke and reduced accelerations of moving masses)
** Reduced mechanical stress	(shorter crank stroke and reduced accelerations of moving masses)

EVENTUAL (NEW FRONTIERS)

*** **Eventual elimination of the cooling system**	(eventual 8 stroke cycle)