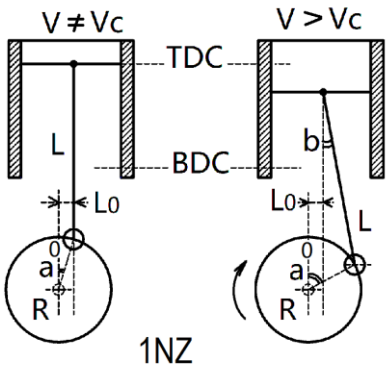
Comparisons between Toyota model 1NZ and the new engine

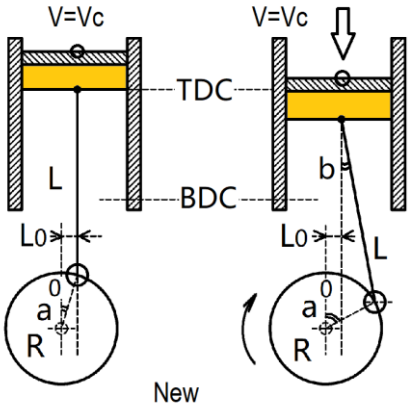


Toyota 1NZ.

R=42.18mm, L=140.85mm, Vc=84.7, L0=12mm.

Cylinder head is fixed, combustion chamber is determined by (main) piston.

Clearance volume V=Vc at 3.759°

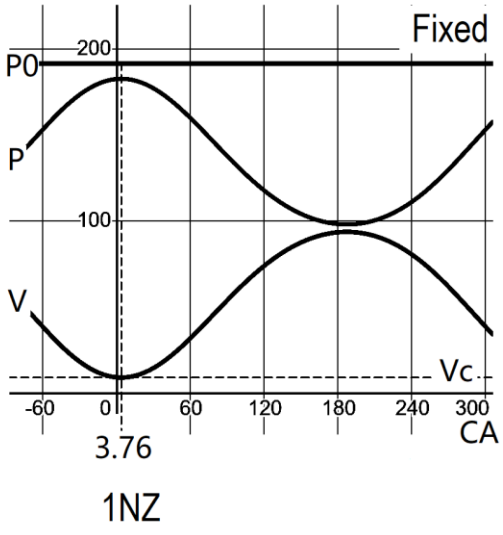


New engine, with an auxiliary piston.

R=42.18mm, L=140.85mm, Vc=84.7, L0=12mm.

Cylinder head is moving, combustion chamber is determined by both (main) piston and auxiliary piston.

Clearance volume V≈Vc extends from 3.759° to 40°.



Toyota 1NZ, piston position and volume.

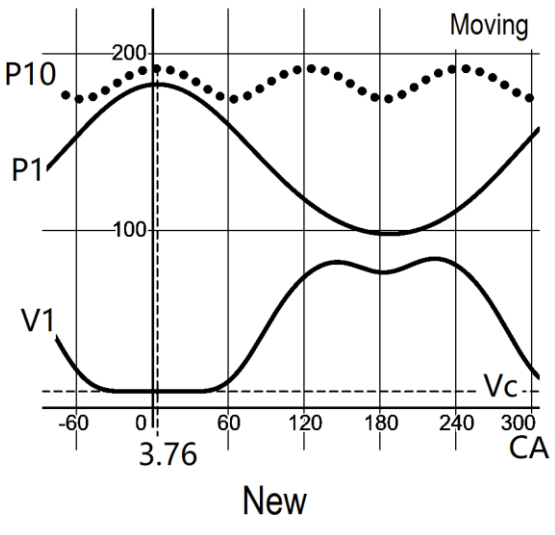
R=42.18mm, L=140.85mm, Vc=84.7, L0=12mm.

V=Vc at 3.759°.

P0: cylinder head, P: position of piston.

V: combustion chamber volume.

Trajectories of two (main) pistons are the same.



New engine: piston positions and volume.

R=42.18mm, L=140.85mm, Vc=84.7, L0=12mm.

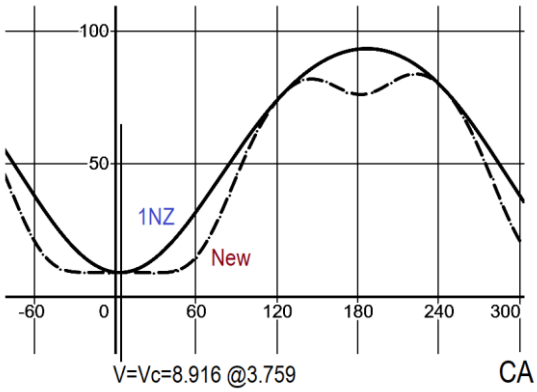
V≈Vc from 3.759° to 40°.

P10: cylinder head, P1: position of piston.

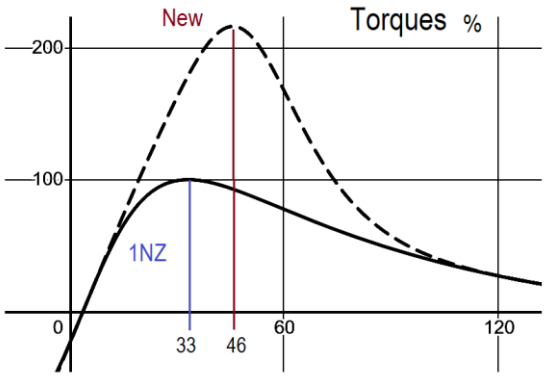
V1: combustion chamber volume.

Trajectories of two (main) pistons are the same.

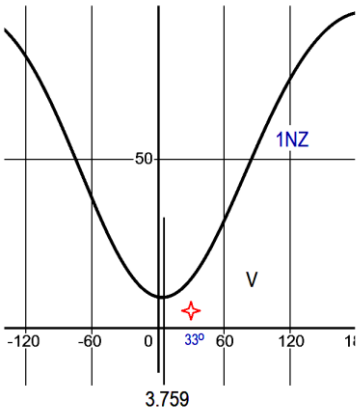
Torque VS peak combustion position @ 1unit fuel



Combustion chamber volumes: 1NZ vs New engine.
In the new engine, Vc extends from 3.759° to near 40°
The valley (near 180°) in the new engine can be eliminated by configuring cam profile.

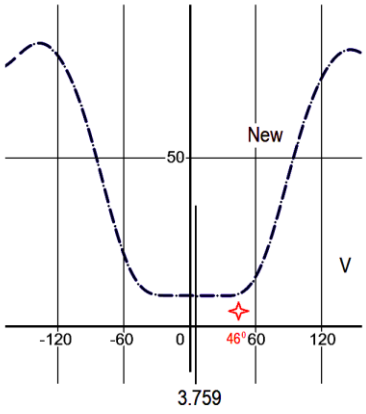


Torque on main pistons. (@ 1 unit of fuel combusted)
1NZ vs New engine. (normalised as 1NZ=1.00).
1NZ: 100% at peak. Peak locates at 33°
The new engine: 216% at peak. Peak locates at 46°.
***Torque increment is related to clearance Vc.*



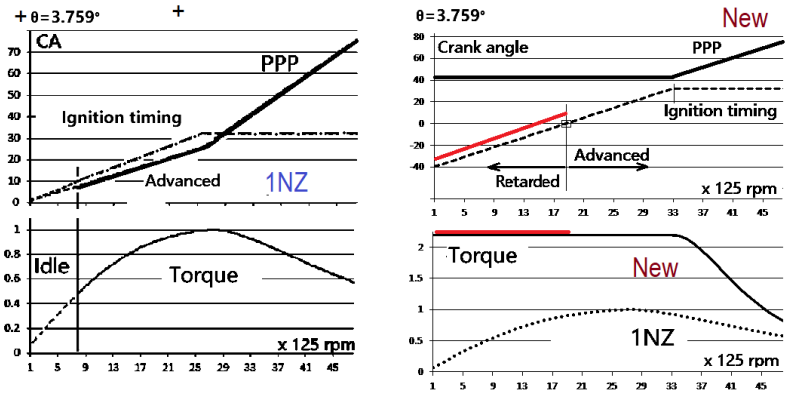
1NZ , ignition and peak combustion pressure.

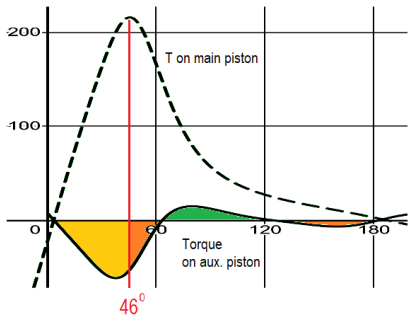
Advanced ignition only from low to high rpm.
Peak combustion pressure is locates apart from 33°.
(far before 33°).



New engine: ignition and peak combustion pressure.

Retarded ignition at low rpm (100-2000rpm).
Peak combustion pressure locates at 46° exactly.
Retarded ignition is preferred in the new engine.
Time interval is increased by 13° in crank angle from ignition to peak combustion pressure.





1NZ ve new engine: A big difference.

PPP: peak combustion pressure positions.

1NZ: Only advanced ignition at low rpm, low torque at low speed.

Peak combustion pressure locates far apart from 33°.

New: Retarded ignition at low rpm, high torque at low speed.

Peak combustion pressure locates at 46° exactly.

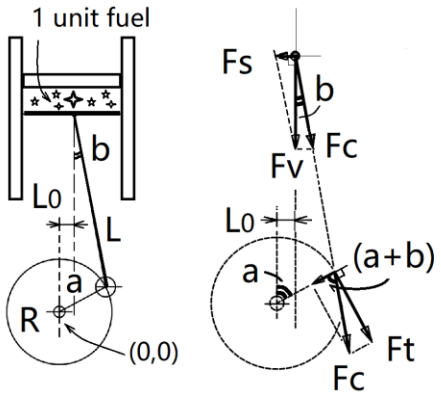
New engine: @ 1 unit of fuel

Torque losses on the auxiliary piston

21% at peak losses. (orange)

Losses are recovered partially

after 60°(green)



Main Piston

1) $b_1 = \sin^{-1}\left(\frac{R}{L}\cdot\sin a - \frac{L_0}{L}\right)$

2) $P_1 = R\cos a + L\cos b_1$

3) $V_1 = -P_1 + P_{10}$

4) $T_1 \propto \frac{\sin(a+b_1)}{\cos(b_1)}\cdot\left(\frac{1}{V_1}\right)$

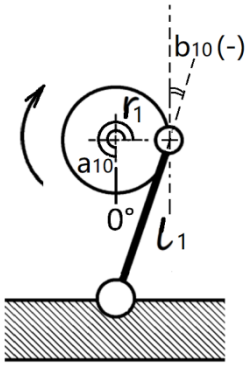
6) $\theta = \sin^{-1}\left(\frac{L_0}{L+R}\right)$

Auxiliary Piston

7) $a_{10} = k\cdot(a-\theta)+180^{\circ}$

8) $b_{10} = \sin^{-1}\left(\frac{r_1}{l_1}\cdot\sin a_{10}\right)$

9) $P_{10} = D-(r_1\cos a_{10} + l_1\cos b_{10})$



3X rpm

Mathematic expressions used in simulations

Conditions:

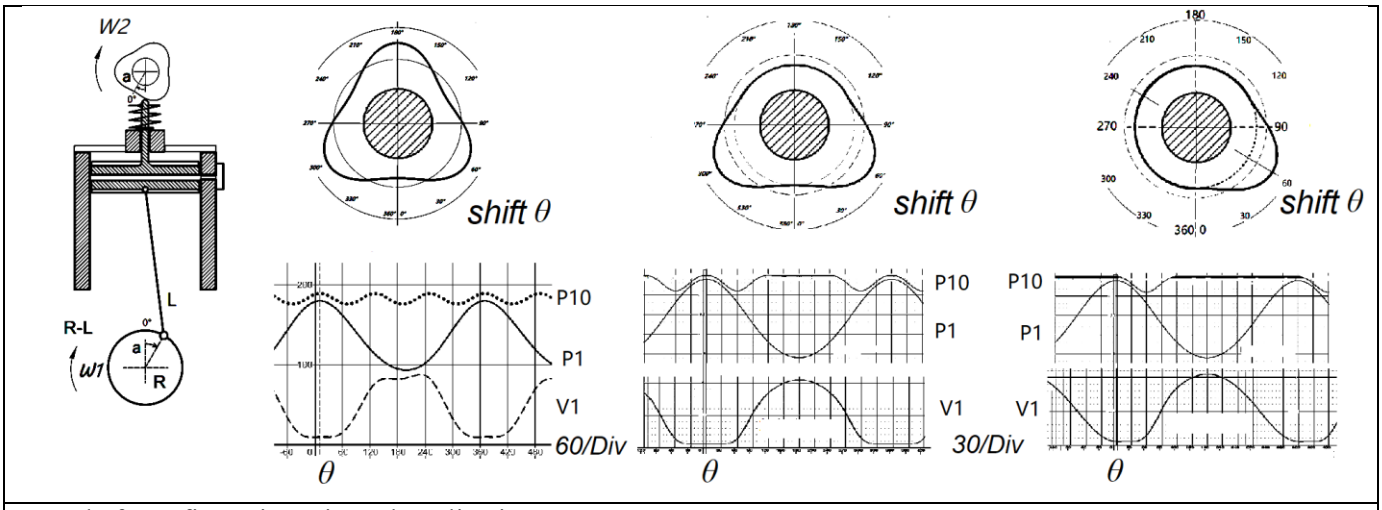
Cylinder bore area=1.00, 1 unit of fuel combusted completely.

Torques are normalised.

The auxiliary piston used in simulations:

r1=R/4.88. l1=L/5.20.

rotation speed=3X rpm



Camshaft configurations: in real applications.

Different cam profiles used in controlling the auxiliary piston.

From θ=3.759° to 120°, the profiles follow the *mathematic expressions above*.

Summary of key results:

1, the main piston is the same as in 1NZ (and most Toyota models), peak combustion pressure is shifted to 46°.

2, torque is increased to **216%** in peak at same fuel combusted.

3, knocking is eliminated by injecting fuel *after TDC*, or by igniting *after TDC*, or both.

4, much higher compression ratio is practicable, without worrying about engine knocking.

5, multi fuel can be used in a same engine.

6, losses in advanced combustion pressure (leading combustion before TDC in 1NZ) is eliminated.

7, low speed limit can be extended to 100rpm, idle speed can be as low as 100rpm.

8, the multi-valves can be simplified as one auxiliary piston with intake/exhaust controls.

9, smoother transition from fossil fuel to bio-fuel, nature gas or H2; without huge infrastructure investment.

10, this technology may beat electrification of transportation both in cost and emission.

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Simulation links at youtube: https://www.youtube.com/watch?v=mTjatf3PuKM