Opposed-Piston 2-Stroke Engines and H2 Combustion: The Perfect Match?

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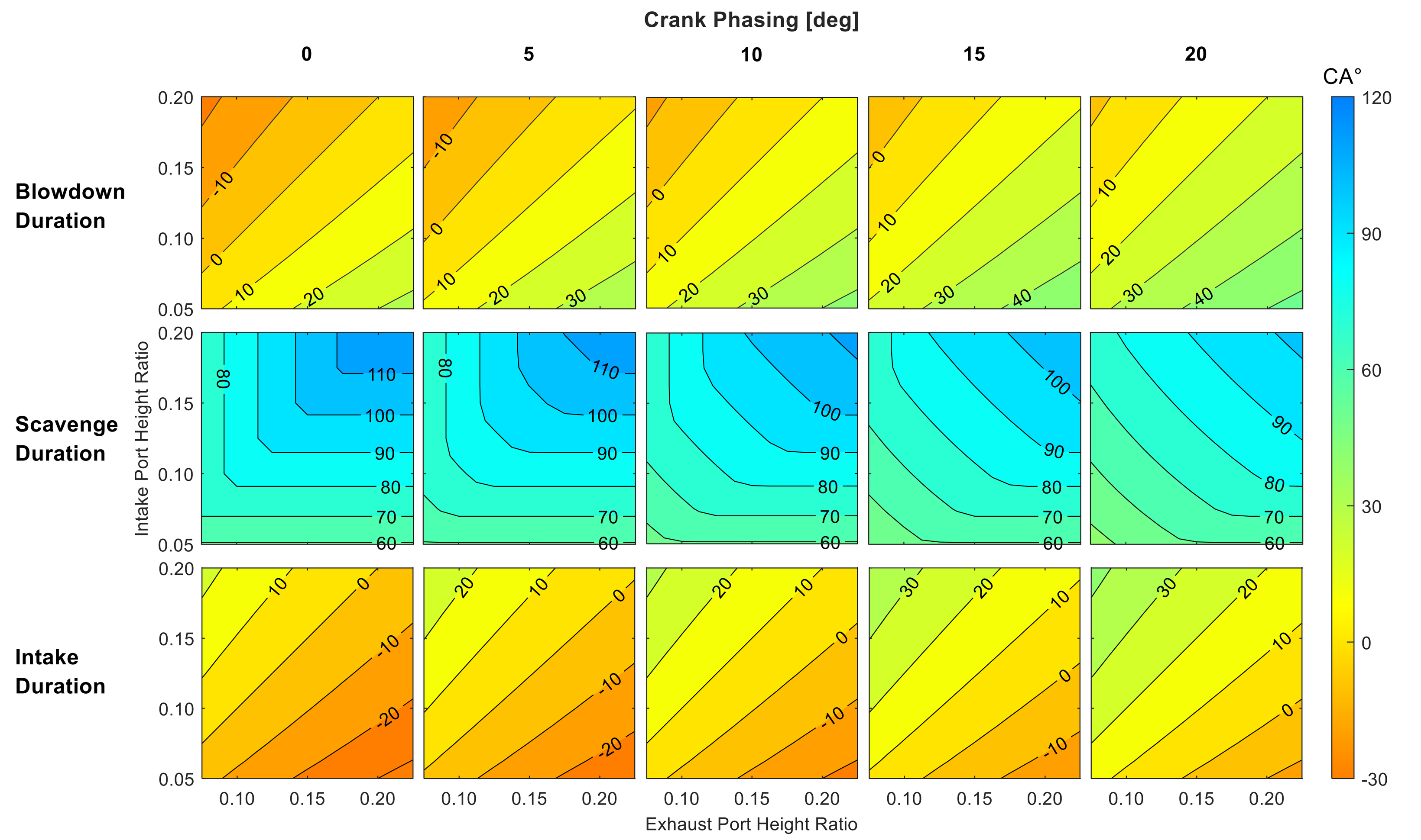
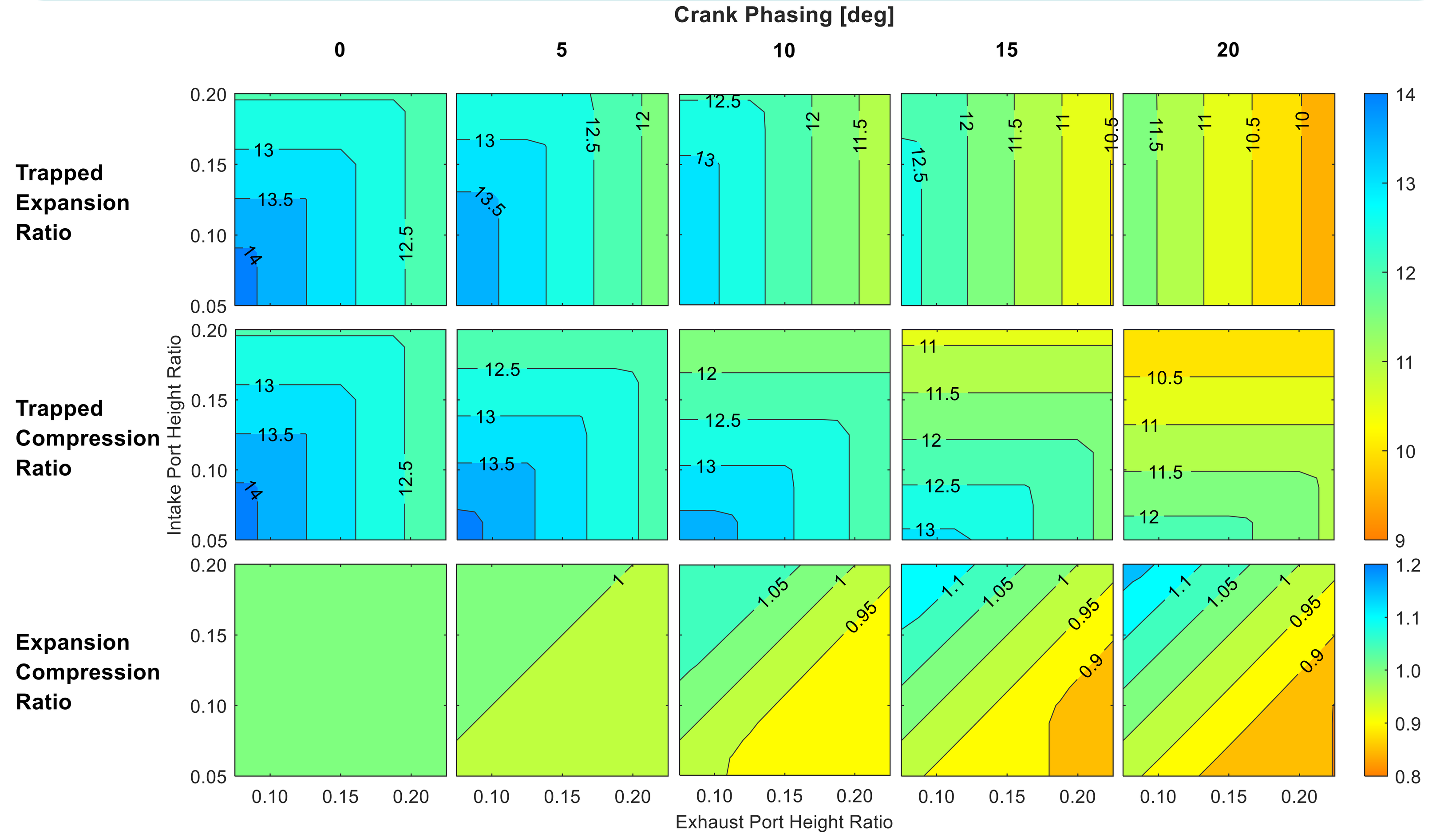
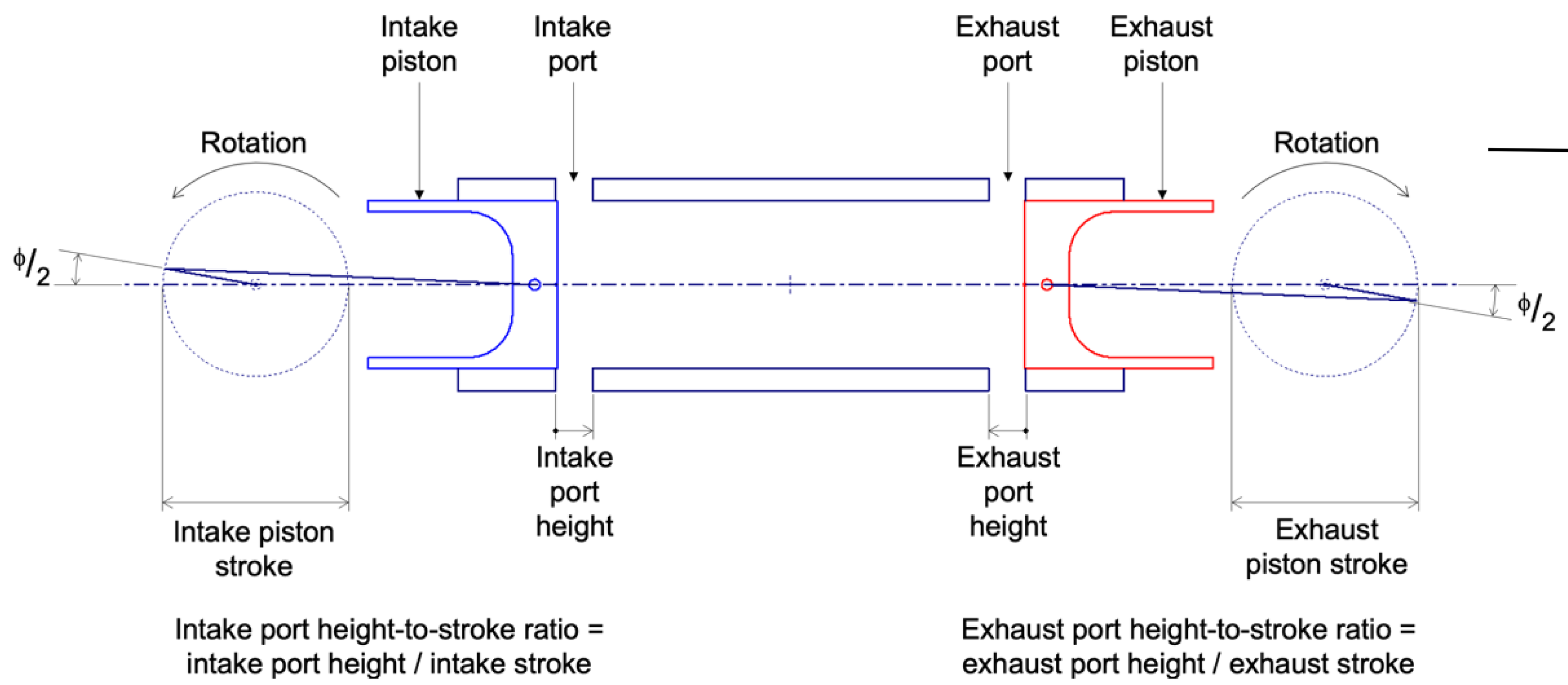
Opposed-piston, two-stroke (OP2S) engines reveal degrees of freedom that make them excellent candidates for hydrogen internal combustion engines. Firstly, variable compression ratio can be achieved in OP2S engines by varying the crankshaft phasing, allow for more efficient and better controlled H2 combustion. Furthermore, hydrogen can burn more efficiently in OP2S engines due to lower heat losses from the low surface-area-to-volume ratio combustion chamber at minimum volume, when compared to a standard combustion chamber of similar displacement. This poster contains simulation results from a 0.75 L, single-cylinder opposed-piston two-stroke engine that explore the influence of key control and geometrical parameters, specifically crankshaft phasing and intake and exhaust port height-to-stroke ratios, in obtaining best thermal efficiency for gasoline compression ignition. However, going forwards, these learnings can also be applied to hydrogen combustion.

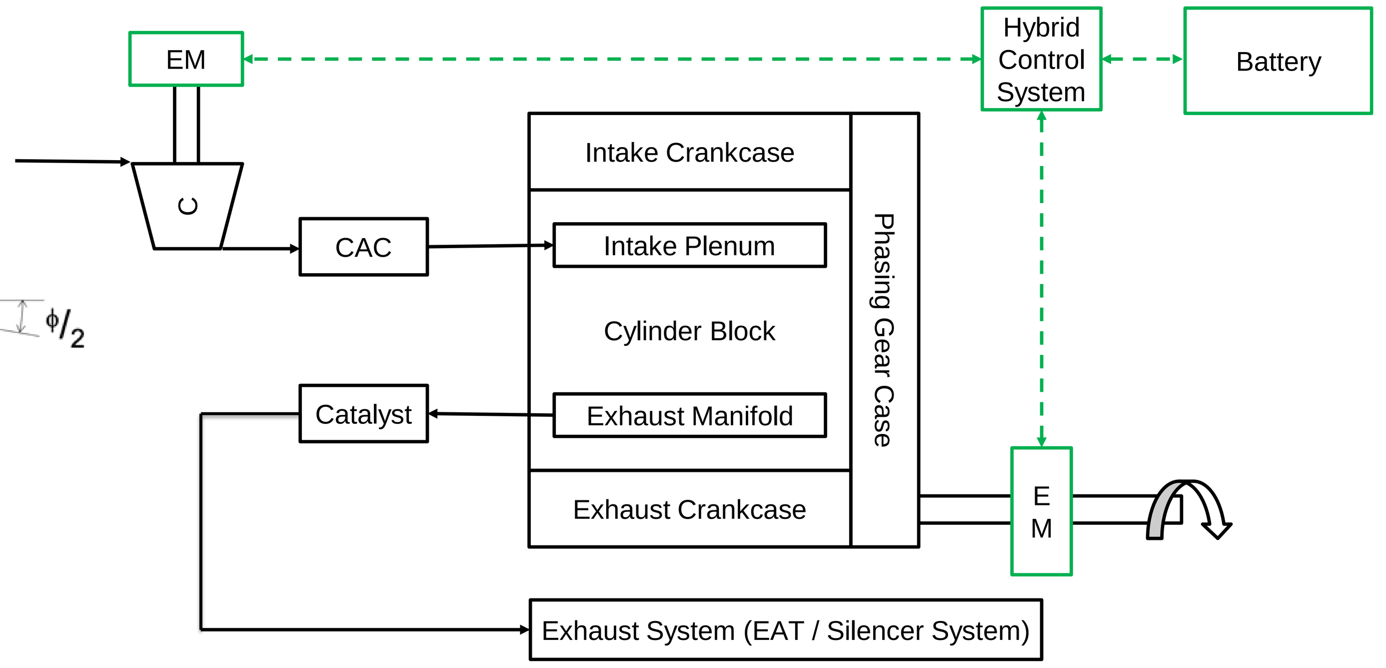


Above: Figure 8. Impact of crankshaft phasing and intake and exhaust port height-to-stroke ratio on blowdown, scavenge and intake durations (in CA°).
Below: Impact of crankshaft phasing and intake and exhaust port height-to-stroke ratio on trapped expansion ratio, trapped compression ratio, and ratio of expansion to compression ratios.

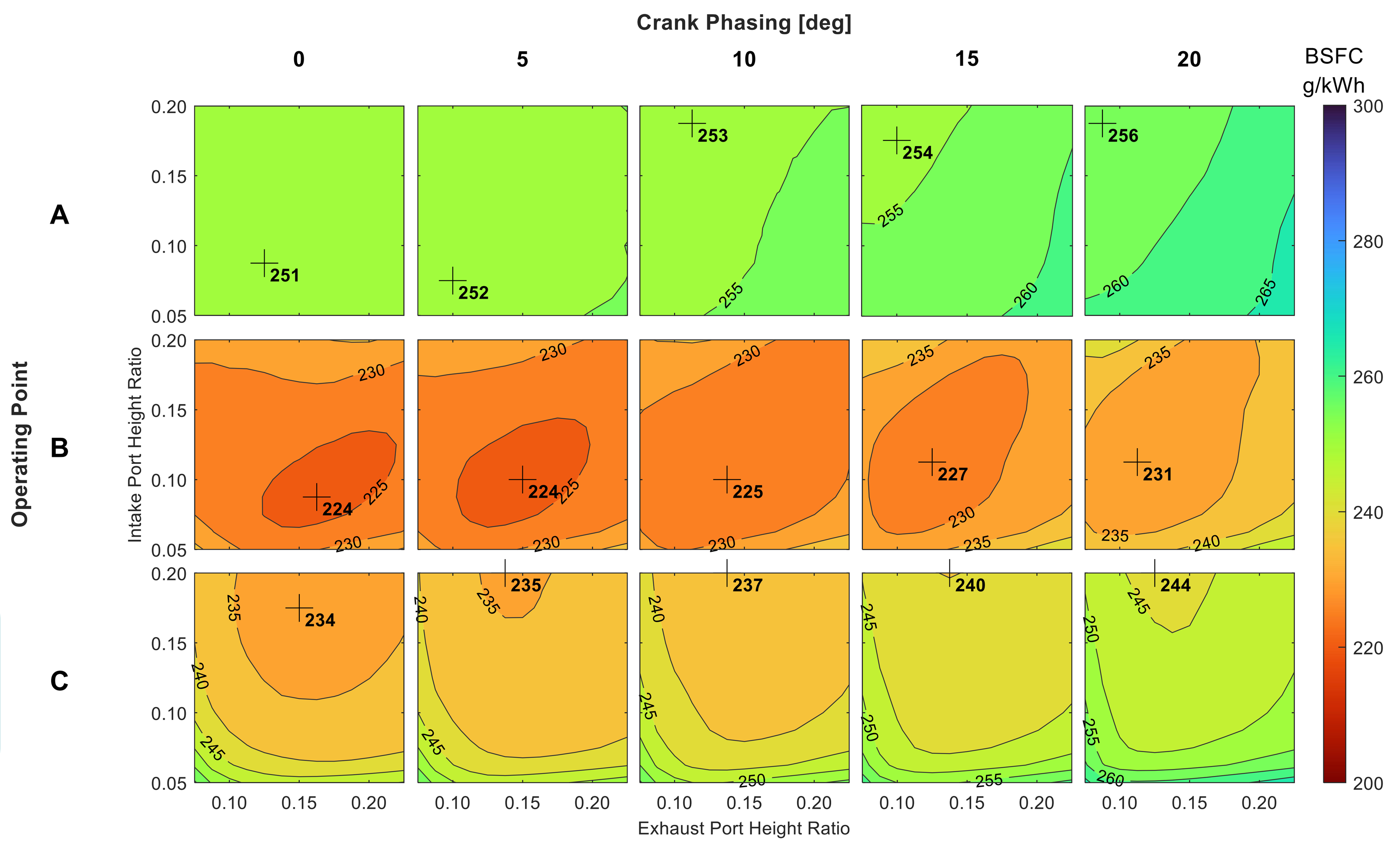




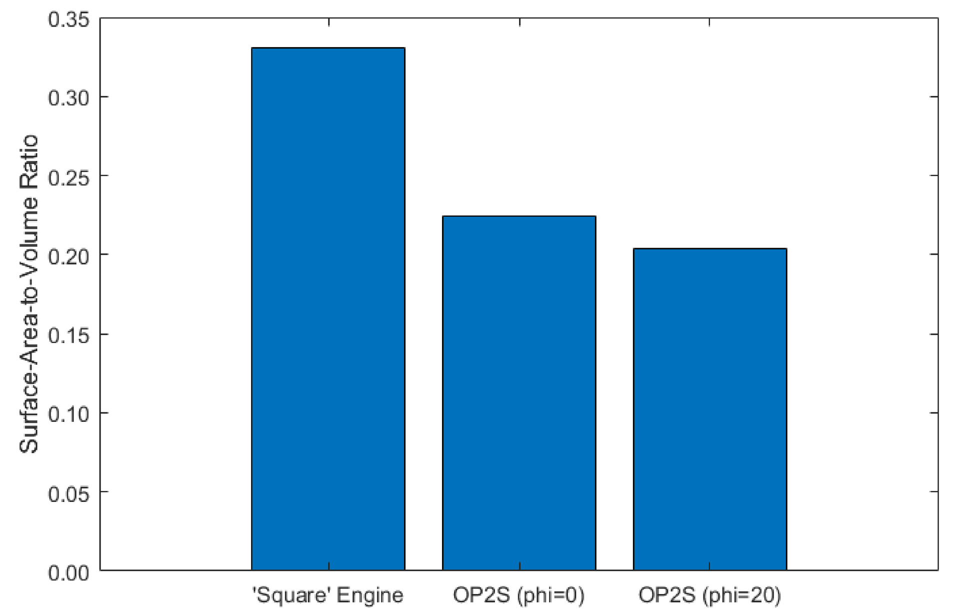
Above: Scale diagram of the OP2S cylinder model drawn for a crankshaft phase angle phi of 20° at an instant when the intake and exhaust pistons lie 10° before and after bottom dead centre, respectively.



Above: Schematic representation of OP2S engine configuration with electric compressor (C, top left), using electrical power transmission as the method of variable-speed drive. CAC: charge air cooler; EM: electric machine; EAT: exhaust aftertreatment.

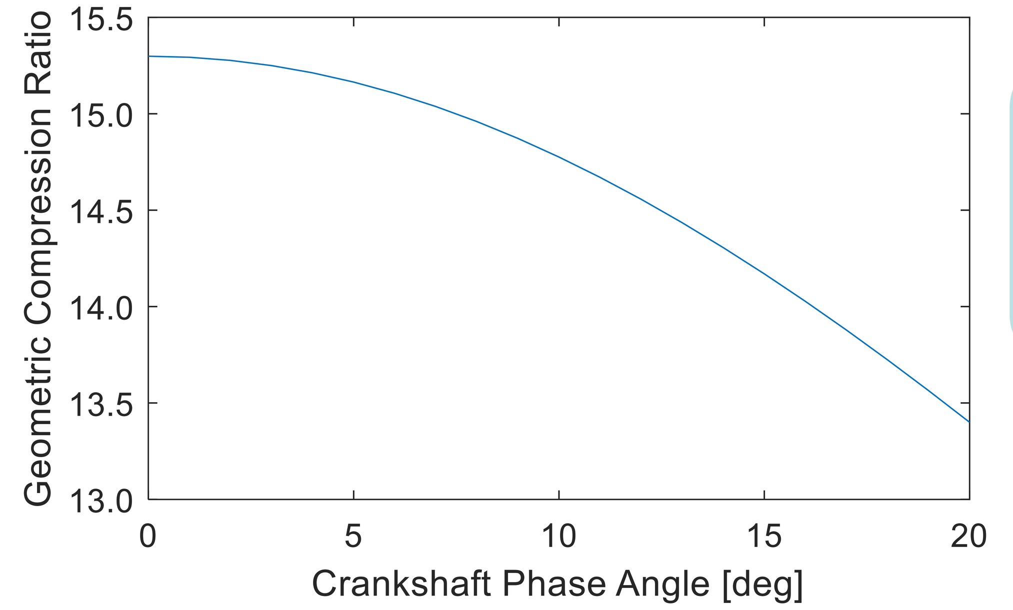


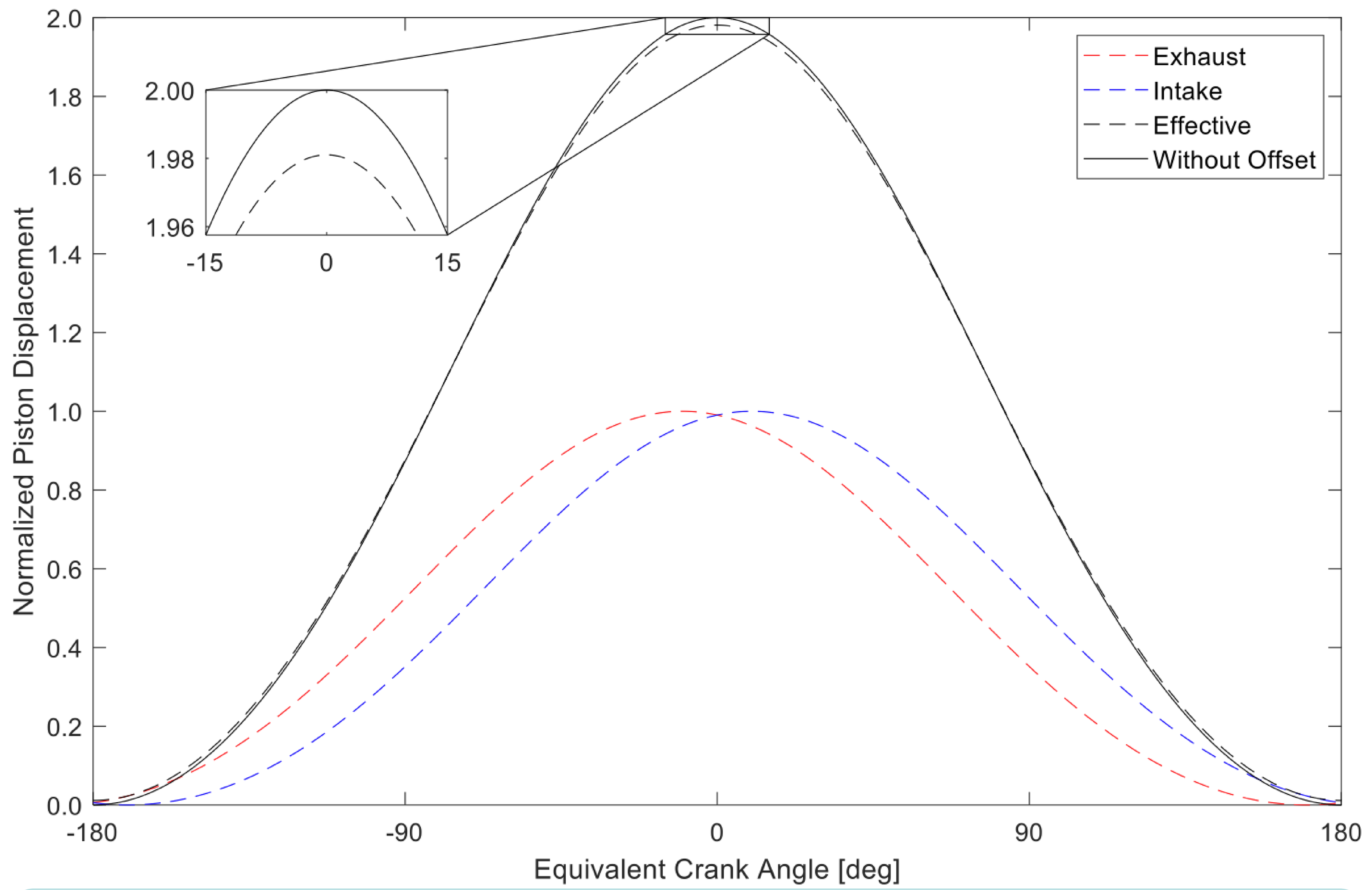
Above: Variation of BSFC with crankshaft phasing and intake and exhaust port height-to-stroke ratio, at operating points A, B, and C (1500 min-1, 3 bar BMEP; 1500 min-1, 12 bar BMEP; and 3000 min-1, 10 bar BMEP, respectively); Lambda = 1.
Below: Effect of crankshaft phasing and intake and exhaust port height-to-stroke ratio on delivery ratio, trapping ratio, charging efficiency, scavenging efficiency, and delta pressure, at operating point B (1500 min-1, 12 bar BMEP); Lambda = 1.



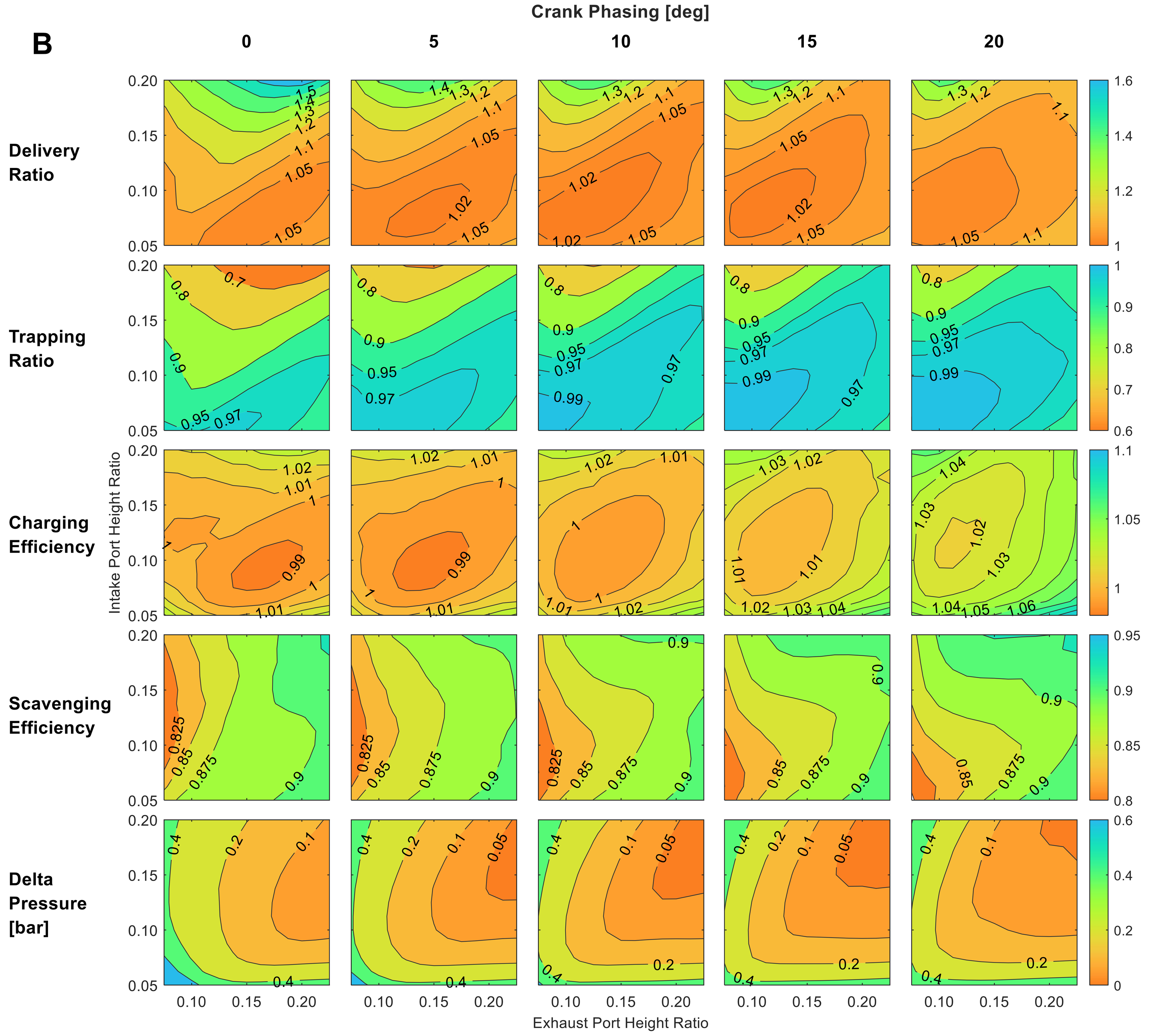
Left: Comparison of Surface-Area-to-Volume Ratios between conventional square (Stroke:Bore Ratio = 1) engine and OP2S engine at two different crankshaft phase angles (phi = 0° & 20°).

Right: Effect of crankshaft phasing on geometric compression ratio.





Above: Instantaneous displacements of the (leading) exhaust (red) piston and the intake (blue) piston for the maximum crankshaft phase angle phi of 20°, and the resultant effective (inter-piston) stroke-normalized displacement (black), over an engine cycle.



Simulations of engine operation corresponding to a medium-duty truck application (points A, B, and C) show that under stoichiometric operation, the optimal phasing can be found between 0–5° of crankshaft phase angle, lower than the 10–15° range quoted in literature. When using intake pressure to target BMEP with a fixed phi, an inverse relationship between charging efficiency and thermal efficiency is seen. This is apparent during higher crankshaft phasing where the charging efficiency required to meet the desired BMEP is higher due to the reduced efficiency by virtue of lower compression ratios. The increasing trend in trapping ratio with increased crankshaft phasing is one of the main factors for the improved scavenging caused by asymmetric timing. It is these two opposing phenomena that cause the optimum crankshaft phasing to vary depending on operating conditions. If operating points are equally weighted, the optimal intake and exhaust port height-to-stroke ratios would be 0.1250 and 0.1625. But once these have been selected, there appears little to be gained from implementing variable crankshaft phasing, particularly under stoichiometric operation where the optimal crankshaft phase angle lies at or close to 0°.

Young, A.G.; Costall, A.W.; Coren, D.; Turner, J.W.G. The Effect of Crankshaft Phasing and Port Timing Asymmetry on Opposed-Piston Engine Thermal Efficiency. *Energies* **2021**, *14*, 6696. https://doi.org/10.3390/en14206696