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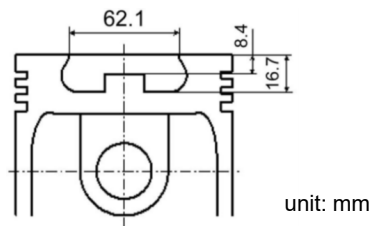


Figure 1 Cross section of the piston

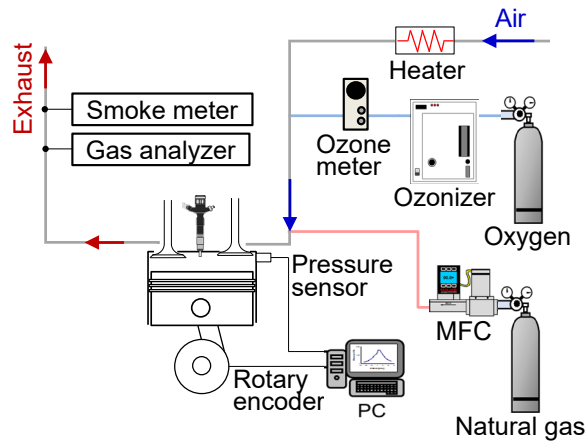


Figure 2 Schematic of the experimental setup with a single cylinder engine

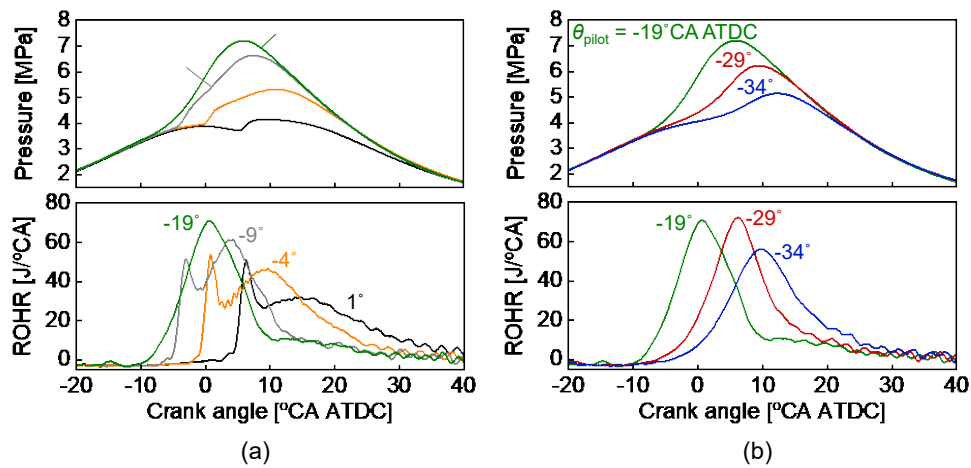


Figure 3 Changes in the profiles of the in-cylinder pressure and the rate of heat release (ROHR) with pilot injection timing of diesel fuel, θ_{pilot} ($\phi_{gas} = 0.42$).
 (a) $\theta_{pilot} = -19^\circ, -9^\circ, -4^\circ$ and 1° CA ATDC; (b) $\theta_{pilot} = -34^\circ, -29^\circ,$ and -19° CA ATDC

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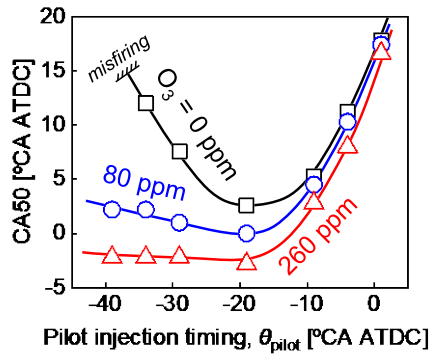


Figure 4 Effect of the ozone concentration on the fuel mass burned at 50% crank angle, CA50, at each pilot injection timing of the diesel fuel, θ_{pilot} ($\phi_{gas} = 0.42$)

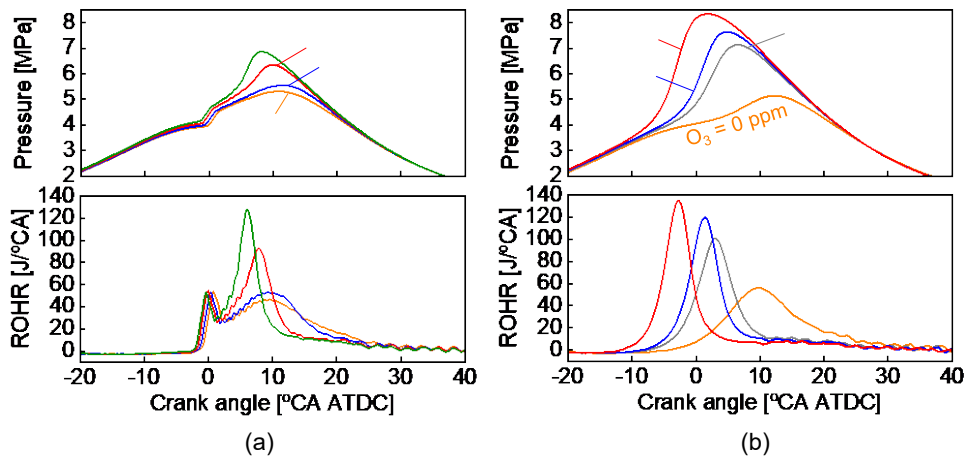


Figure 5 Changes in the profiles of the in-cylinder pressure and the rate of heat release (ROHR) with ozone concentration ($\phi_{gas} = 0.42$).
 (a) $\theta_{pilot} = -4^\circ$ CA ATDC; (b) $\theta_{pilot} = -34^\circ$ CA ATDC

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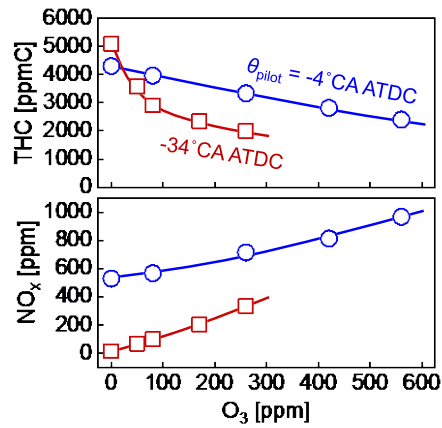


Figure 6 Comparison of the effects of the ozone addition on the THC and NO_x emissions between the pilot injection timings, θ_{pilot} , of -4°CA ATDC and -34°CA ATDC ($\phi_{gas} = 0.42$)

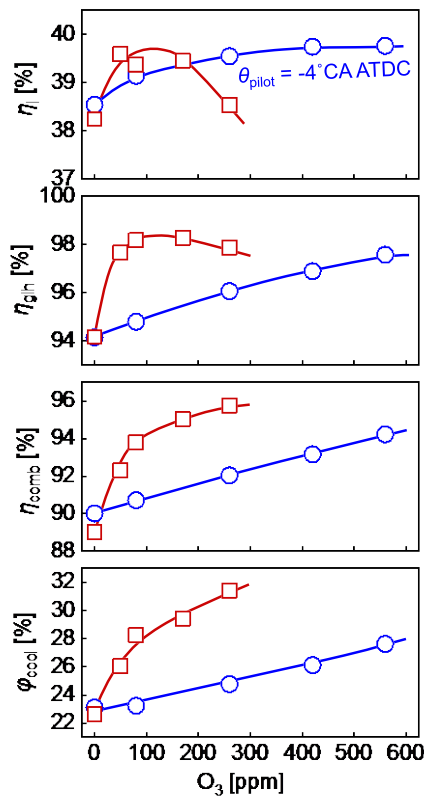
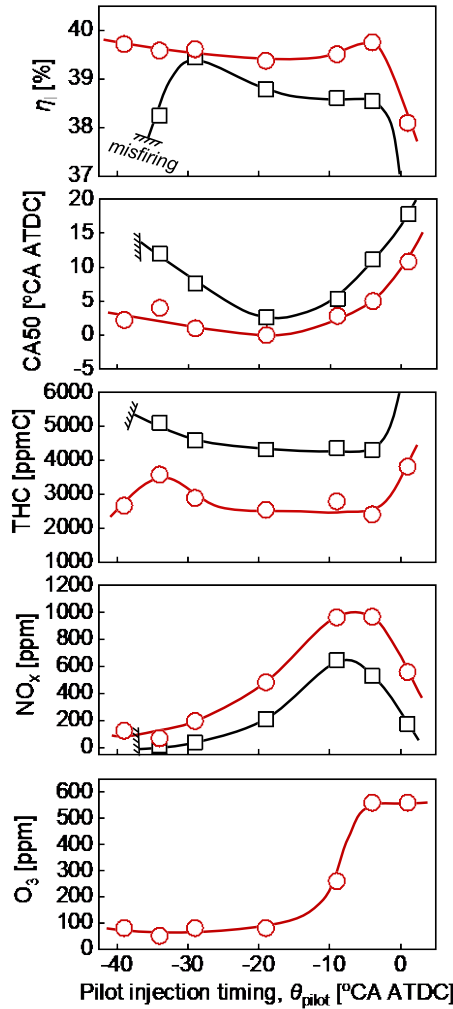


Figure 7 Comparison of the effects of the ozone addition on the indicated thermal efficiency, η_i , the degree of constant volume heat release, η_{glh} , the combustion efficiency, η_{comb} , and the cooling loss, ϕ_{cool} , between the pilot injection timings, θ_{pilot} , of -4°CA ATDC and -34°CA ATDC ($\phi_{gas} = 0.42$)

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Figure 8 The indicated thermal efficiency, η_i , CA50, the THC and NO_x emissions, and the ozone concentration, at which the best η_i can be achieved. The results without the ozone addition are shown for reference ($\phi_{\text{gas}} = 0.42$).

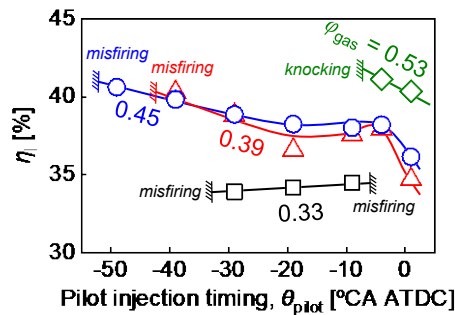


Figure 9 Comparison of the indicated thermal efficiency, η_i , among the equivalence ratios of the natural gas, ϕ_{gas} (without ozone)

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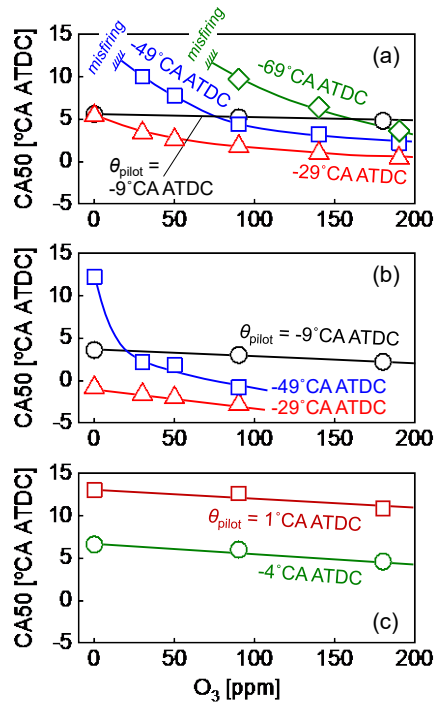


Figure 10 Effect of the ozone concentration on the fuel mass burned at the 50% crank angle, CA_{50} , over the range of equivalence ratios of the natural gas, ϕ_{gas}
 (a) $\phi_{gas} = 0.33$; (b) $\phi_{gas} = 0.45$; (c) $\phi_{gas} = 0.53$

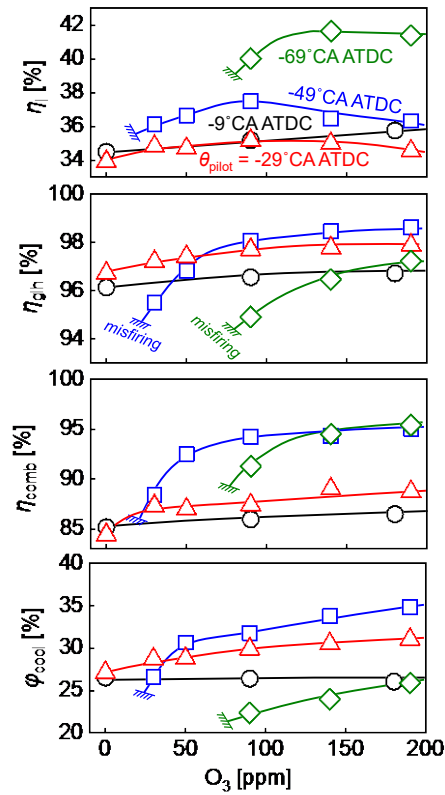


Figure 11 The indicated thermal efficiency, η_i , the degree of constant volume heat release, η_{glh} , the combustion efficiency, η_{comb} , and the cooling loss, ϕ_{cool} , at the various pilot injection timings, θ_{pilot} with the equivalence ratio of the natural gas, ϕ_{gas} of 0.33

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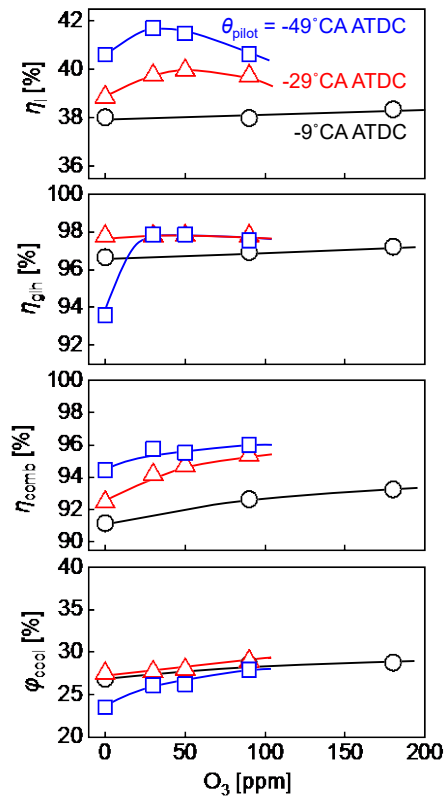


Figure 12 The indicated thermal efficiency, η_i , the degree of constant volume heat release, η_{glh} , the combustion efficiency, η_{comb} , and the cooling loss, ϕ_{cool} , at the various pilot injection timings, θ_{pilot} with the equivalence ratio of the natural gas, ϕ_{gas} of 0.45

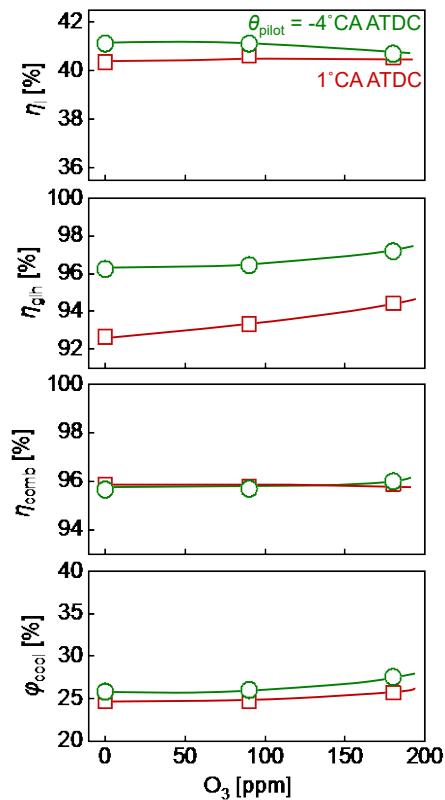


Figure 13 The indicated thermal efficiency, η_i , the degree of constant volume heat release, η_{glh} , the combustion efficiency, η_{comb} , and the cooling loss, ϕ_{cool} , at the various pilot injection timings, θ_{pilot} with the equivalence ratio of the natural gas, ϕ_{gas} of 0.53

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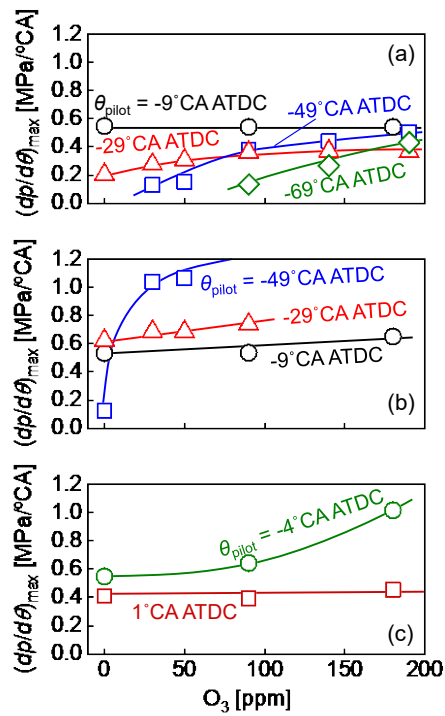


Figure 14 Effect of the ozone concentration on the maximum rate of pressure rise, $(dp/d\theta)_{max}$, over the range of equivalence ratios of the natural gas, ϕ_{gas}
 (a) $\phi_{gas} = 0.33$; (b) $\phi_{gas} = 0.45$; (c) $\phi_{gas} = 0.53$

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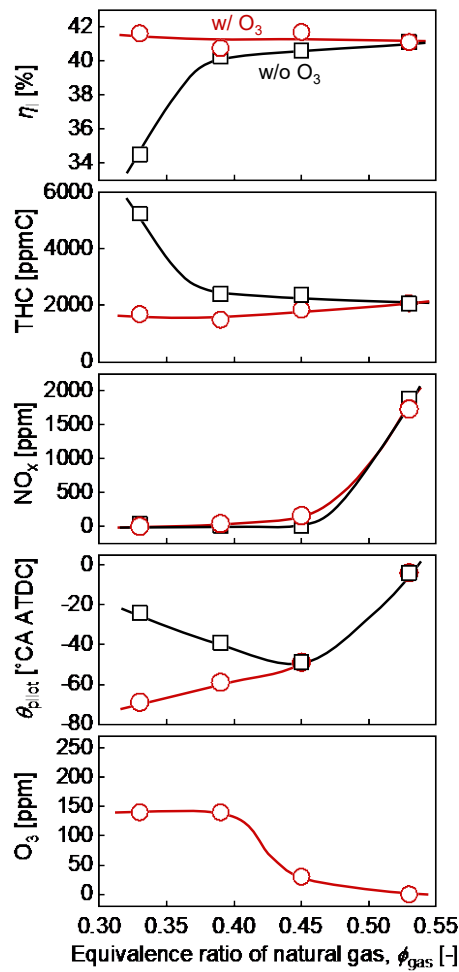


Figure 15 The indicated thermal efficiency, η_i , the THC and NO_x emissions, the pilot injection timing, θ_{pilot} , and the ozone (O₃) concentration at which the best η_i can be achieved over a range of equivalence ratios of the natural gas, ϕ_{gas} . The results without the O₃ addition are shown for reference.

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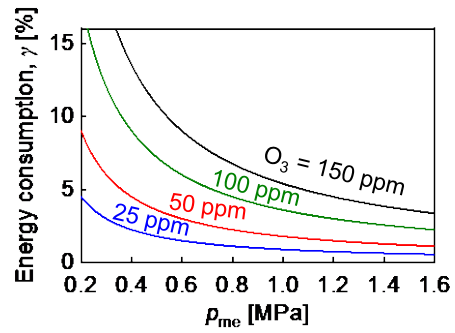


Fig.A-1 Ratio of the energy consumption caused by the ozone production, γ , versus the mean effective pressure, p_{me}