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Simultaneous application of exhaust gas recirculation and non-constant injection rates to reduce NOx and soot emissions in Diesel engines

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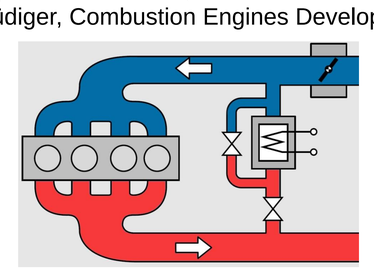
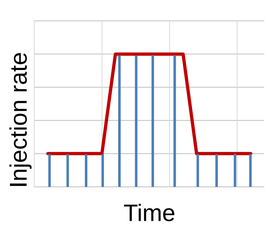
Introduction

Diesel engine: High thermal efficiency
Toxic emissions (PM, NOx HC, CO)

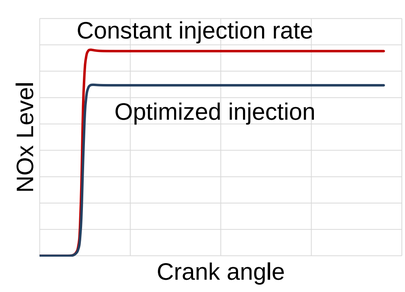
[2] Günter P. Merker, Christian Schwarz, Rüdiger, Combustion Engines Development

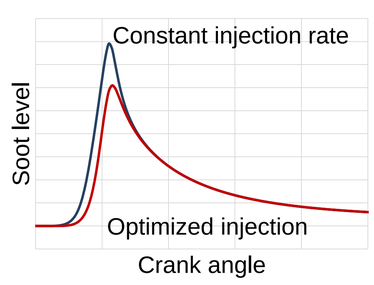




Application of Exhaust gas recirculation and optimization of injection profile

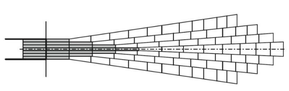
application of optimized injection profile, parallel with exhaust gas recirculation





Reduction of NOx and keeping soot emissions at an acceptable level

Methods

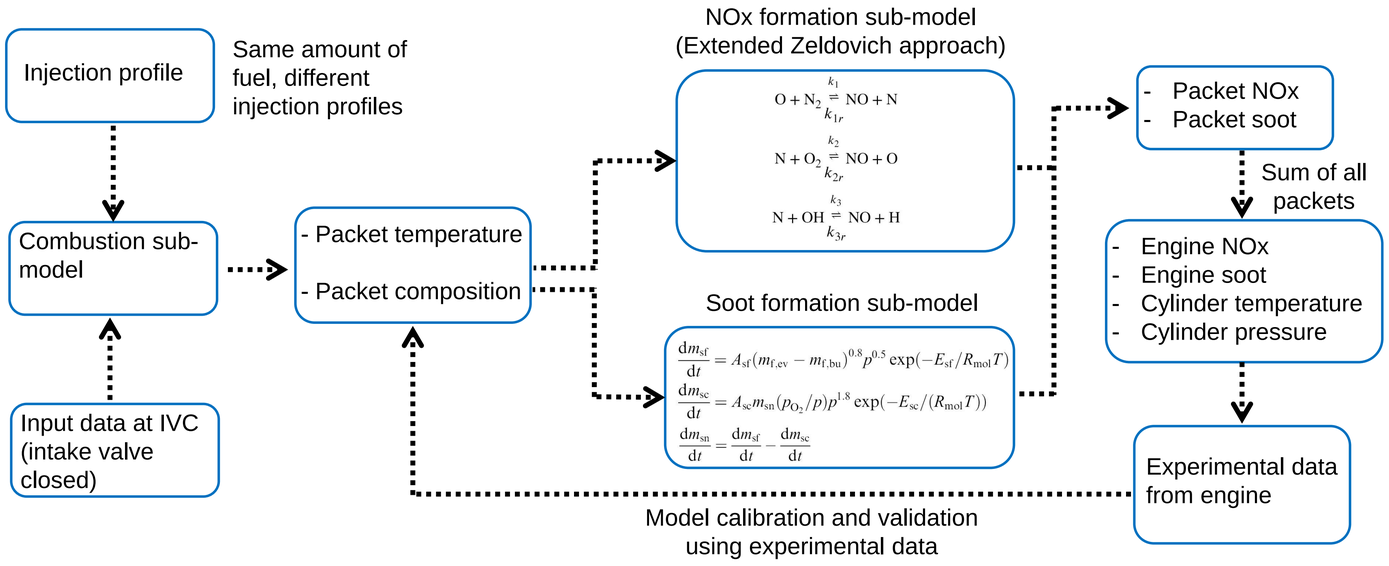


2D multi-zone phenomenological model (Packet model)

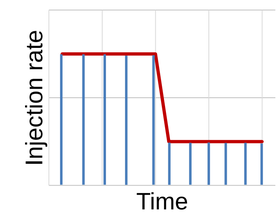
Each packet : considered as a thermodynamic control volume

Conservation of mass and energy for each packet

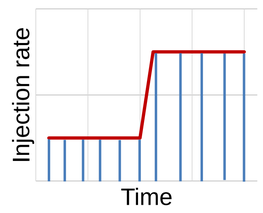
History of composition and temperature for each packet



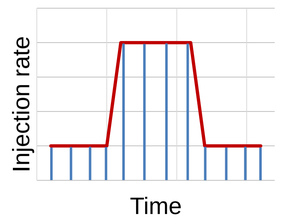
Injection profiles used



Downward profile:
First injecting at a higher rate and then at a lower rate



Upward profile:
First injecting at a lower rate and then at a higher rate



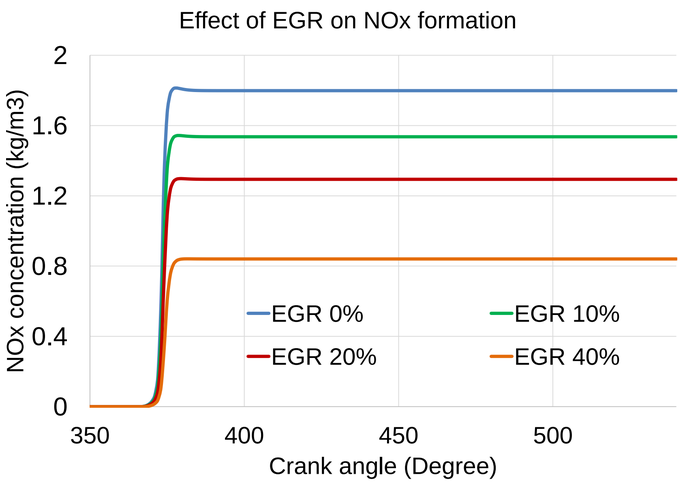
Upward-Downward profile:
First injecting at a low rate and then at a higher rate and finally at a lower rate again

Downward profile: More fuel at the beginning → Higher peak cylinder temperature → Higher NOx, lower soot

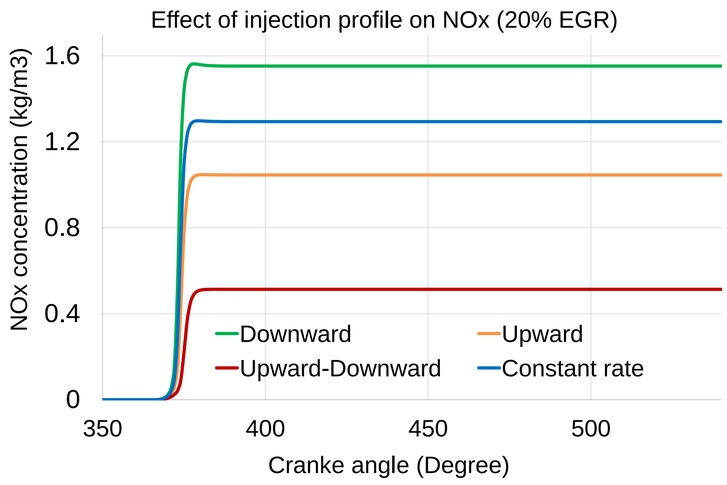
Upward profile: less fuel at the beginning → Lower cylinder peak temperature → Lower NOx, higher soot

Upward-Downward profile: less fuel at the beginning → Lower cylinder peak temperature → Lower NOx
Longer injection duration → Better oxidation of soot

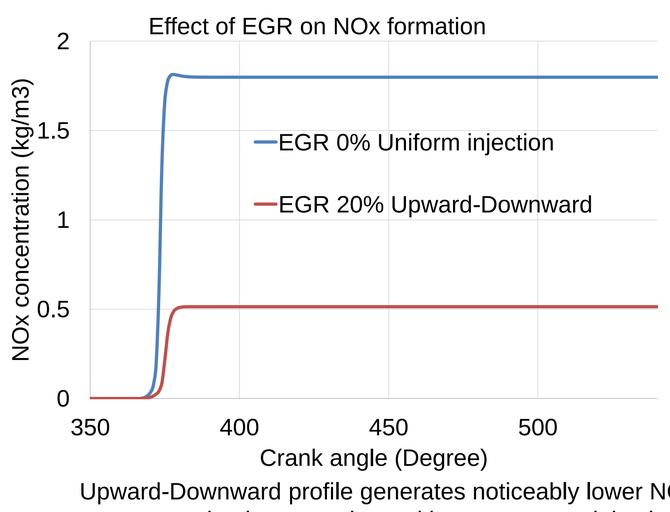
Results



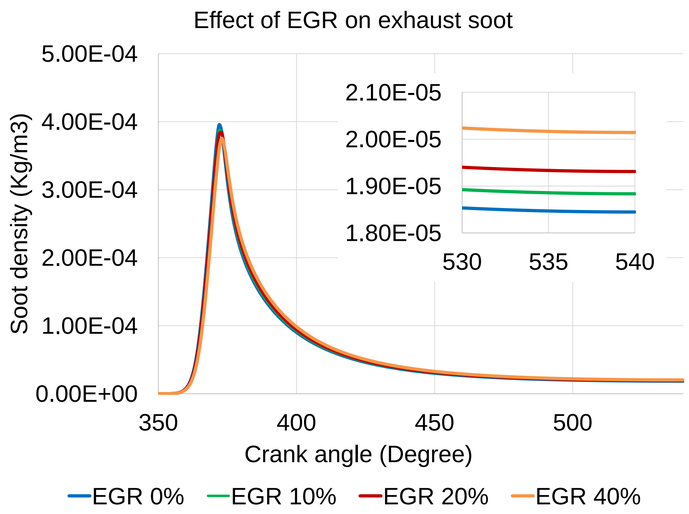
Increasing EGR rate → Lowering cylinder temperature → Reduction of NOx emissions



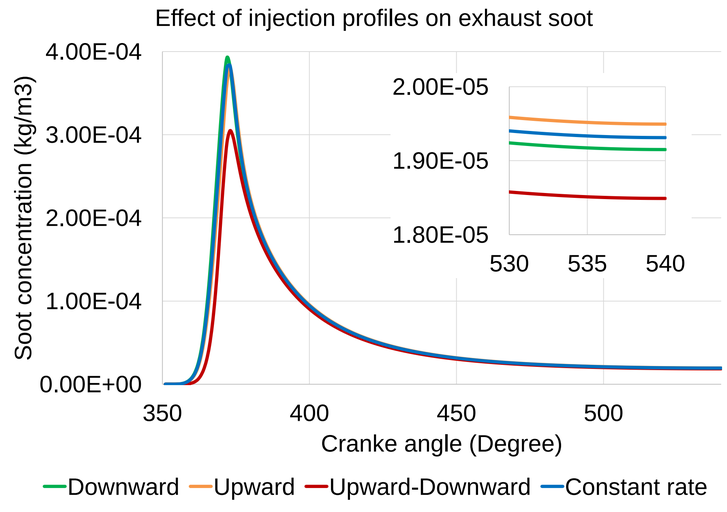
Upward-Downward profile generates the lowest NOx concentration at the same EGR rate



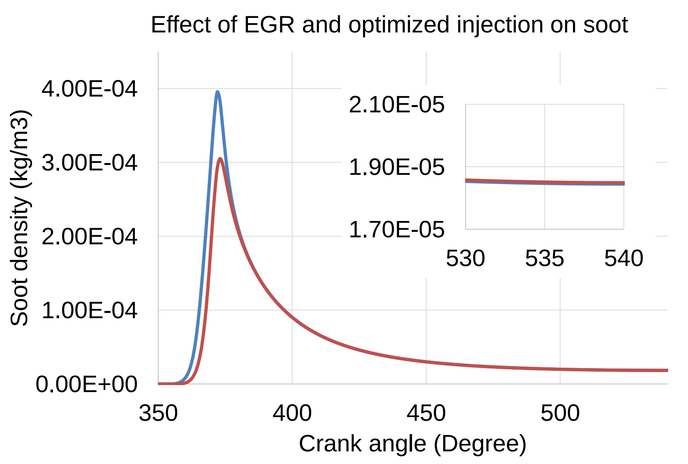
Upward-Downward profile generates noticeably lower NOx concentration in comparison with constant rate injection and no EGR



Increasing EGR rate → Lowering cylinder oxygen content → Increasing exhaust soot



Upward-Downward profile generates the lowest exhaust soot concentration at the same EGR rate



Upward-Downward profile: lower soot formation and the same exhaust soot concentration in comparison with constant rate injection and no EGR

Conclusion

- Using upward injection profile reduces NOx emissions, as lower amount of fuel in compression phase leads to lower peak temperatures, but increases soot emissions, because of lower oxidation rate of soot.
- Using downward injection profile results in higher peak temperatures, generating more NOx emissions, but lower soot, as the oxidation rate of soot is increased
- The application of exhaust gas recirculation and upward-downward injection profile at the same time could reduce NOx and keep soot emissions at an acceptable level.

References

[1] Heywood, J. B. (1988), Internal Combustion Engine Fundamentals, McGraw-Hill

[2] Günter P. Merker, Christian Schwarz, Rüdiger Teichmann (2012), Combustion Engines Development, Springer

[3] Colin R. Ferguson, Allan T. Kirkpatrick (2016), Internal Combustion Engines Applied Thermosciences, Wiley

[4] C.D. Rakopoulos, K.A. Antonopoulos (2007), Development and application of multi-zone model for combustion and pollutants formation in direct injection diesel engine, Energy Conversion and Management 48 (2007) 1881–1901

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