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Impact of Cold EGR on the Nitrogen Oxides Formation in a Diesel Engine Fuelled by Biodiesel B8

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Outline

- Background
- Experimental/Numerical setup
- Results
- Conclusion

Background – Dual-Injection

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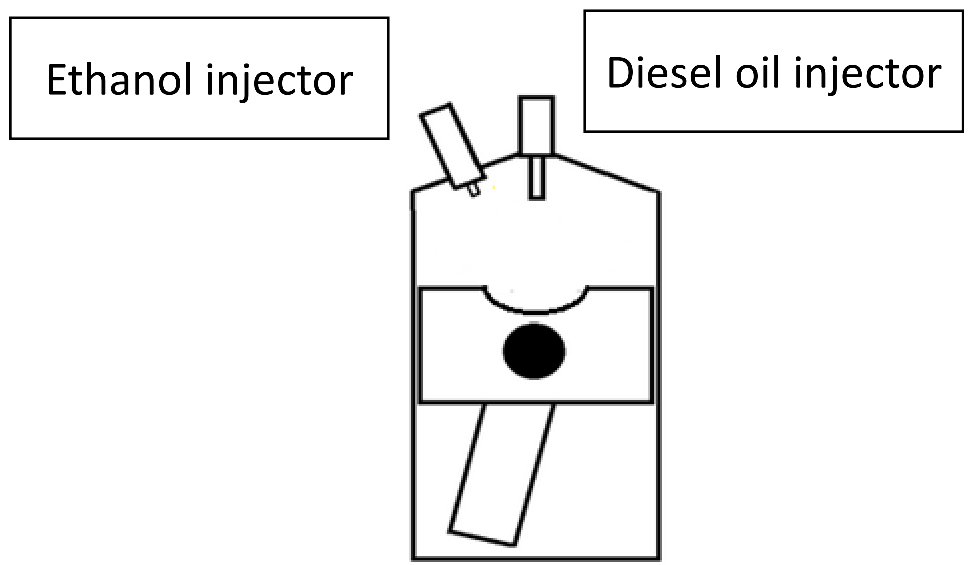
- To investigate the effects of the application of separate systems of direct injection of hydrous ethanol and commercial diesel oil (dual injection), containing 8% of biodiesel (B8), in a diesel engine.



State-of-the-art

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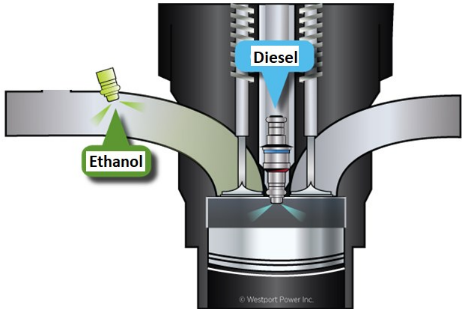
- Several studies showed the diesel engine performance and emissions using blends and fumigation technique:

- Ethanol-diesel blends technique
    - Up to 25% of diesel oil replacement;
    - **Limitation:** blends solubility and ethanol properties;
    - Reduction of NOx emissions in large operation range.

- Ethanol fumigation



- Up to 50% of diesel oil replacement;
- **Limitation:** knock ocurrence;
- Can reduce NOx emissions;
- Increase THC emissions;

State-of-the-art

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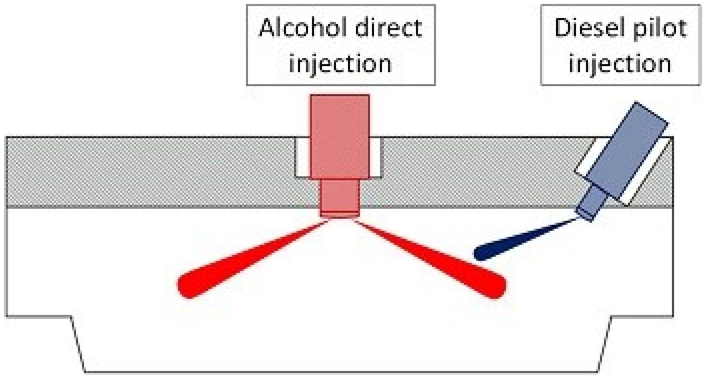
- There are few experimental works available in literature exploring the dual fuel technique, probably due to the difficulty in install the ethanol injection apparatus in an original diesel engine head.
- **Up to 90% of diesel oil replacement**
- By direct injecting both fuels, a more controlled distribution is possible through spray targeting, potentially reducing the amount of unburned fuel in crevice regions (REITZ and DURAISAMY; 2015).



Background – EGR, NOx and Soot

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- EGR has potential to reduce NOX emission of spark ignition and compression ignition engines and to realize low temperature combustion (LTC) technique
- Biodiesel and EGR have been studied in many researches, but the combination of these two technologies is relatively few.
- An improved understanding of the mechanisms responsible for the high NOX emissions generated during biodiesel and diesel oil combustion could lead to inexpensive and effective mitigation strategies.

Experimental Setup

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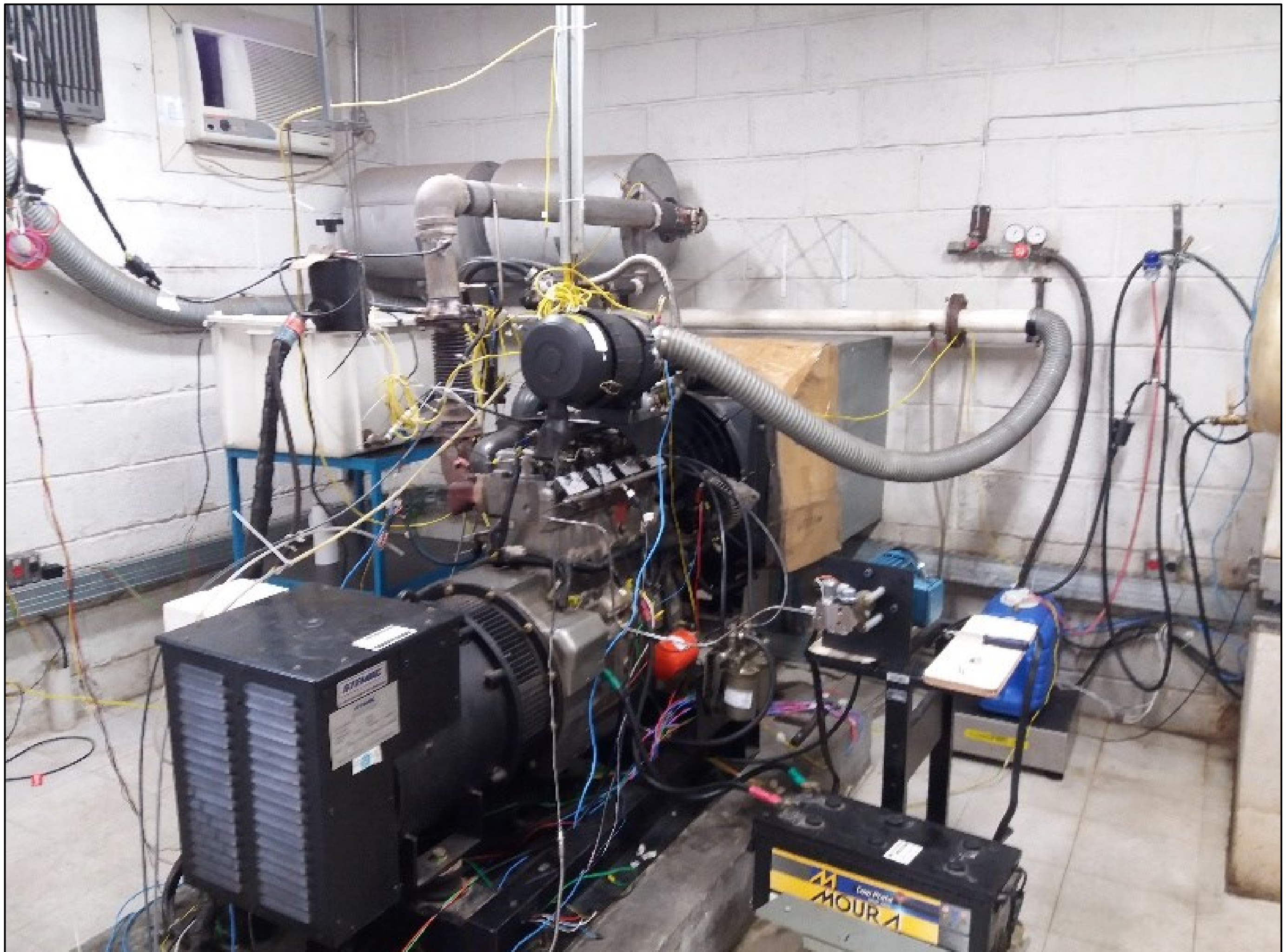
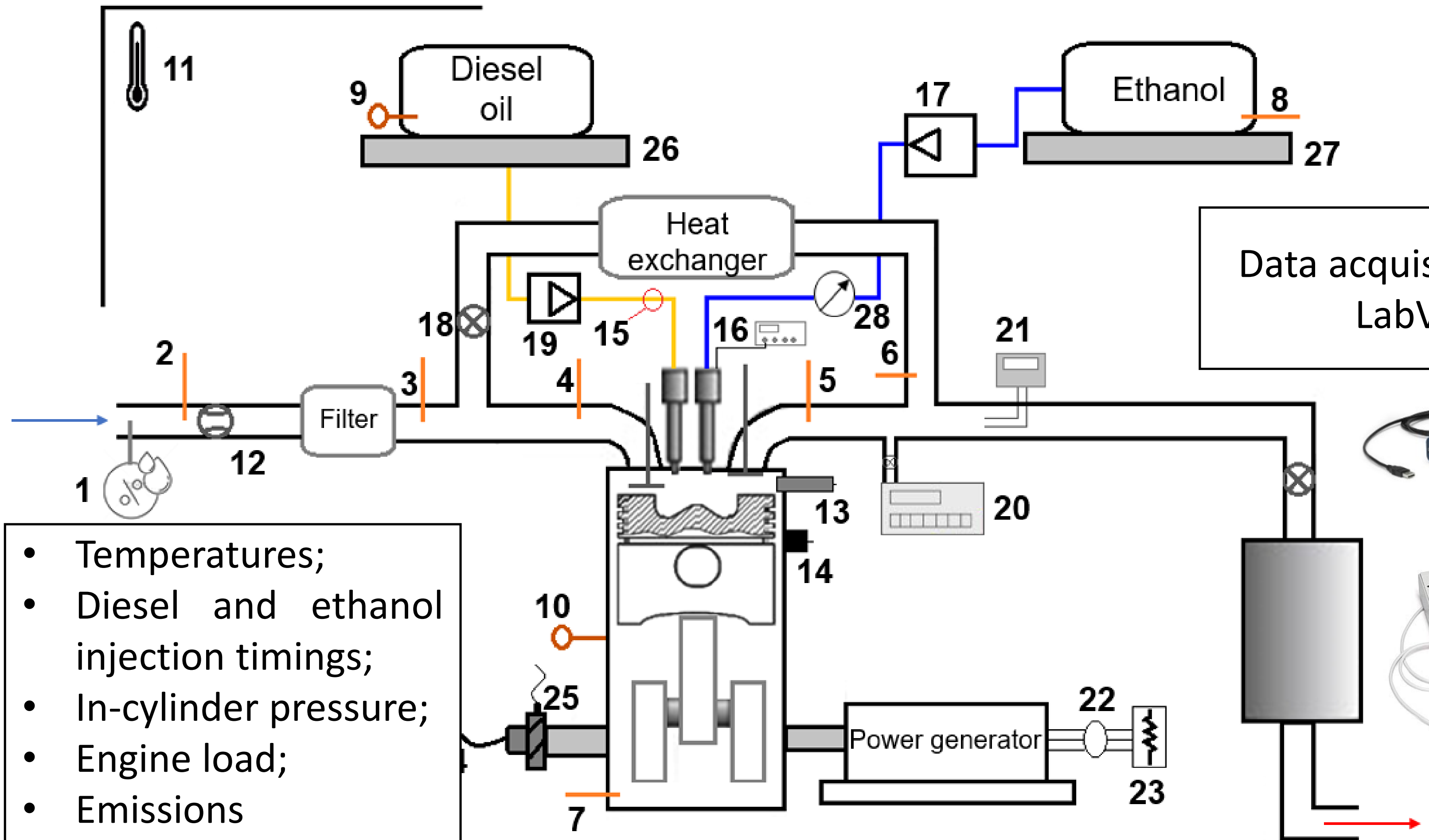


MWM 229-4 Diesel Engine Setup

Experimental apparatus



Data acquisition using LabView

- Temperatures;
- Diesel and ethanol injection timings;
- In-cylinder pressure;
- Engine load;
- Emissions composition;
- Fuel consumption;
- Etc.

EGR system

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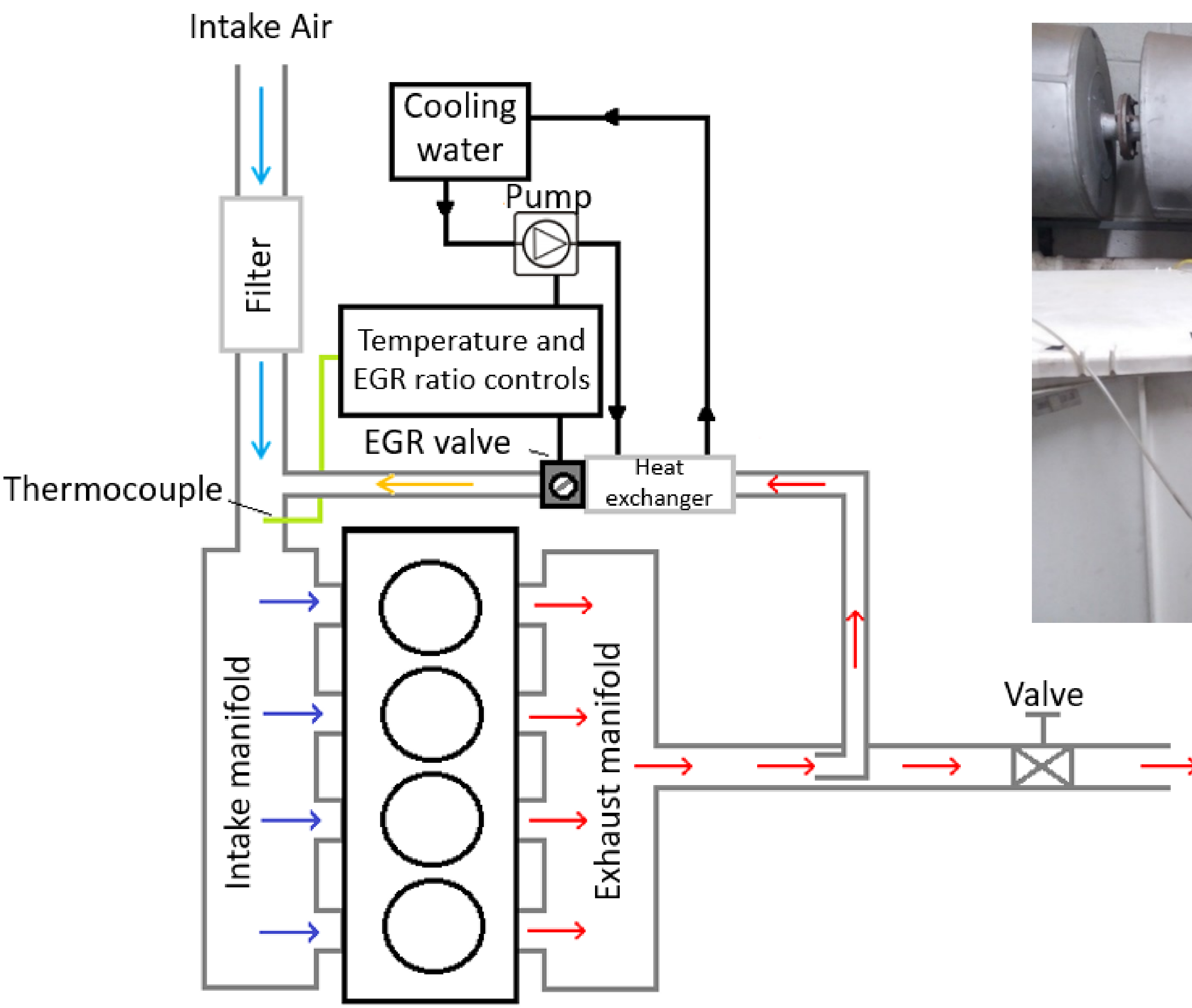

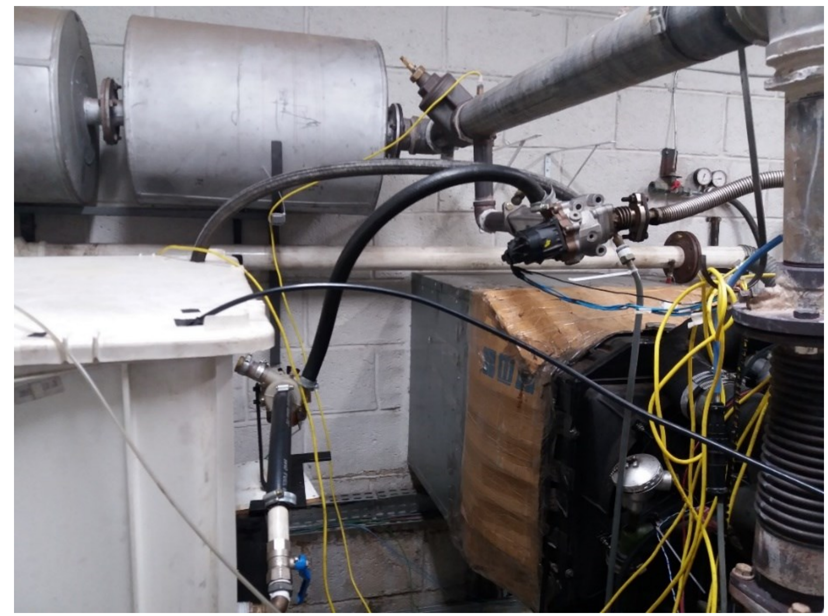

Table 1: Diesel engine specifications

Manufacture/Type	MWM 229/4
Cycle	Four strokes
Diesel oil injection	Direct
Bore × stroke	102 mm × 120 mm
Number of cylinders	4, in line
Compression ratio	17:1
Total displacement	3.922 L
Rated Power	44 kW
Intake system	Naturally aspirated
Start of injection	23°BTDC

Methodology - Dual injection

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- Use of EGR: combustion control and NOx reduction (10%);
- Use of diesel oil with 8% of biodiesel (B8);
- Diesel oil nominal replacement ratio of 60%.

Nomenclature	Biodiesel (%)	Ethanol (%)	EGR (%)
B8	8%	0%	0%
B8 + EGR	8%	0%	10%
B8E60	8%	60%	0%
B8E60 + EGR	8%	60%	10%

Numericla Experiment

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❖ **ANSYS Forte 18.1 was used to simulate the combustion process of a diesel engine**

Turbulence model	**RNG κ-ϵ model**
Breakup model	KH-RT coupled with gas-jet model
Collision model	Collision radius of influence model
Spray/wall interaction model	Naber and Reitz model
Heat transfer model	Improved law-of-the-wall
Evaporation model	Discrete multi-component
Combustion model	Detailed chemistry
Turbulence/chemistry interaction	Mixing time scale model
Soot model	Hiroyasu soot formation and Nagle/ Strickland-Constable oxidation models
NO_X formation model	Thermal and prompt NO

The submodels employed in the Ansys Forte software package

Numericla Experiment

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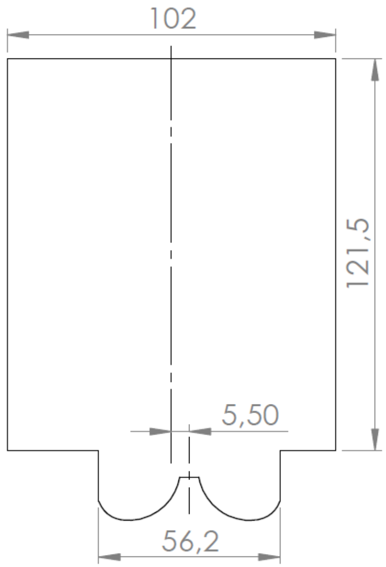
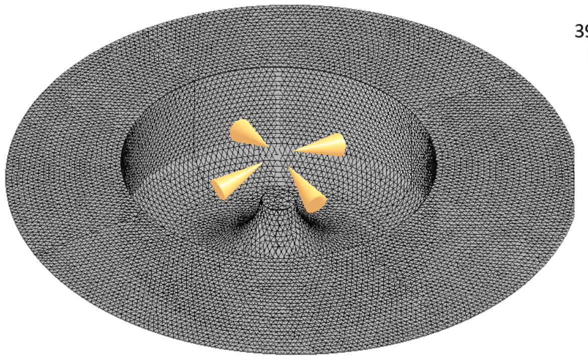
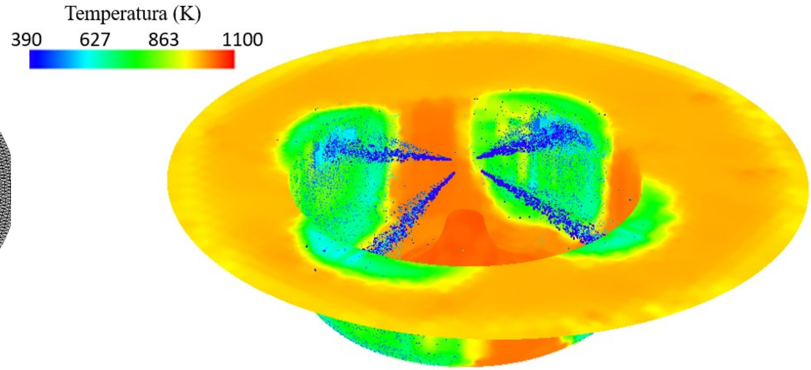
❖ **ANSYS Forte 18.1 was used to simulate the combustion process of a diesel engine**







Combustion chamber model (in mm), 440,000 structured cells at BDC, and 41,000 cells at the TDC

Results – Validation

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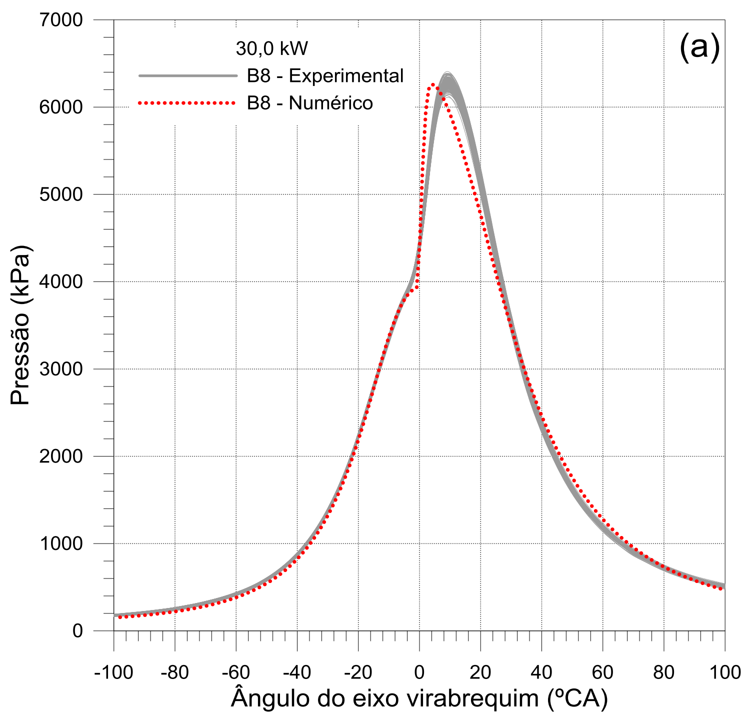
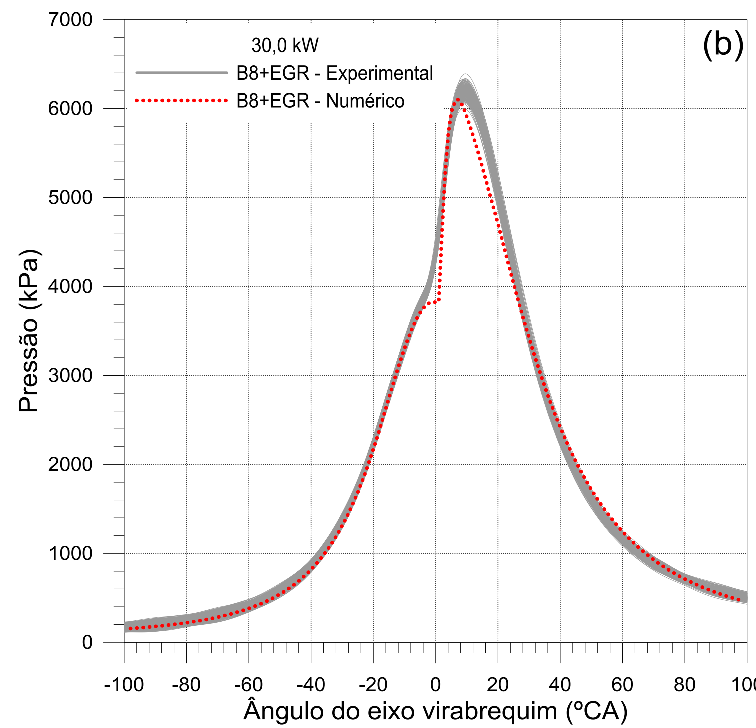
Comparison between numerical and experimental results – **In-cylinder pressure**.



B8 with 0% EGR



B8 with 10% EGR

Results – Numerical Validation

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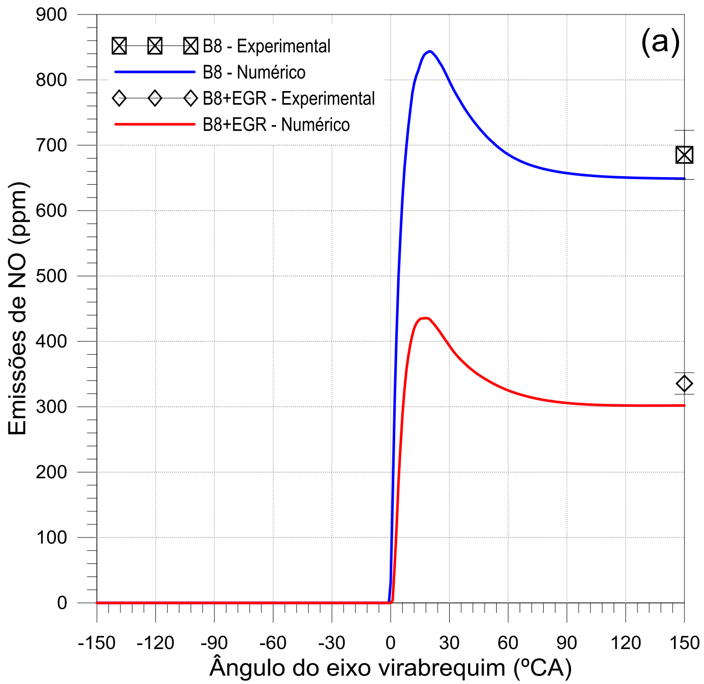
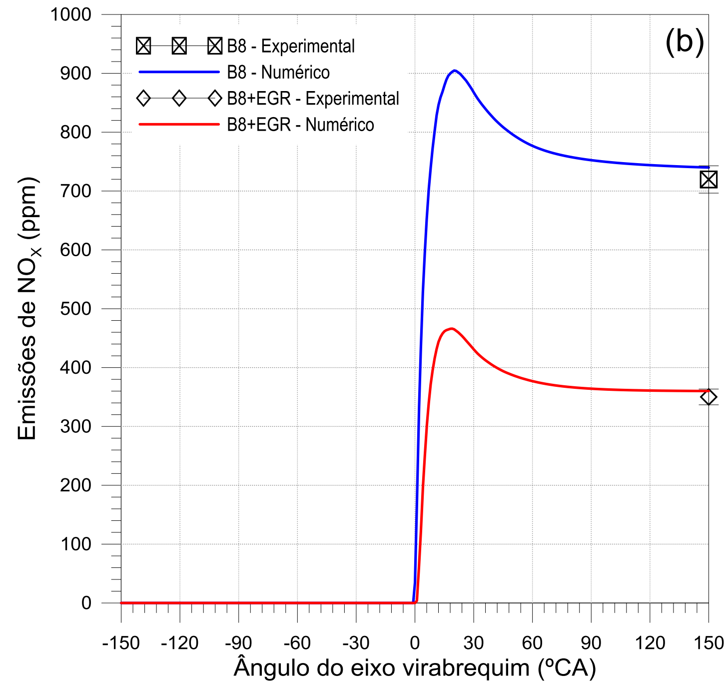
Comparison between numerical and experimental results – **NO** and **NO_X emissions**.



NO emission



NO_X emission

Results – spfc and fce

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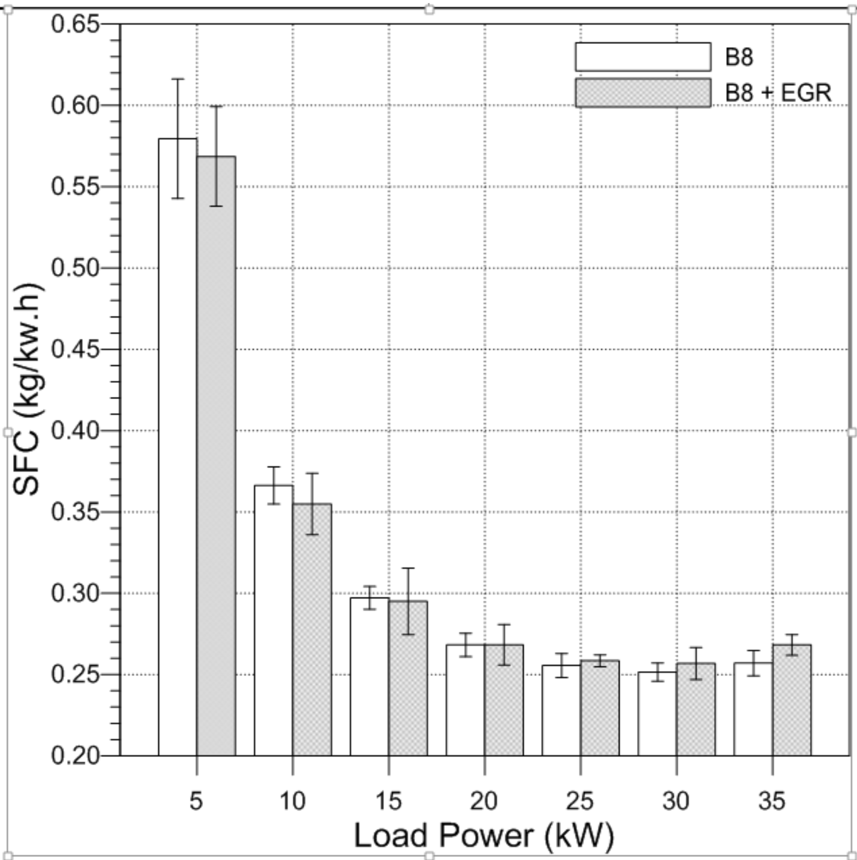
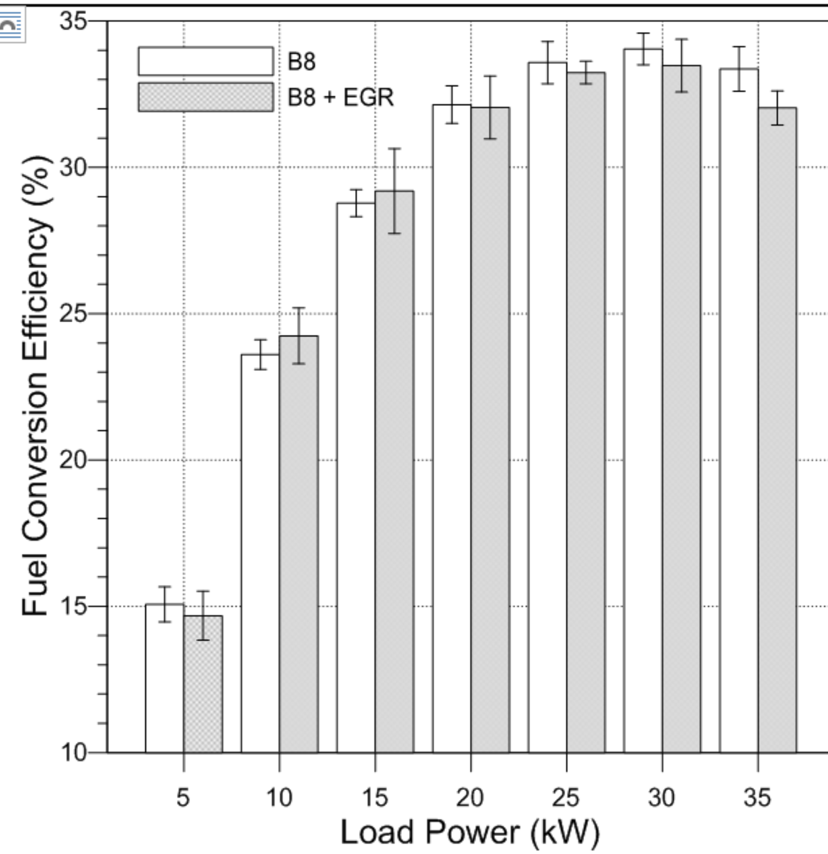
Specific fuel consumption and fuel conversion efficiency for different engine operating conditions



Specific fuel consumption vs. Engine Loads



Fuel conversion efficiency vs. Engine Loads

Results – Pressure, RoHR

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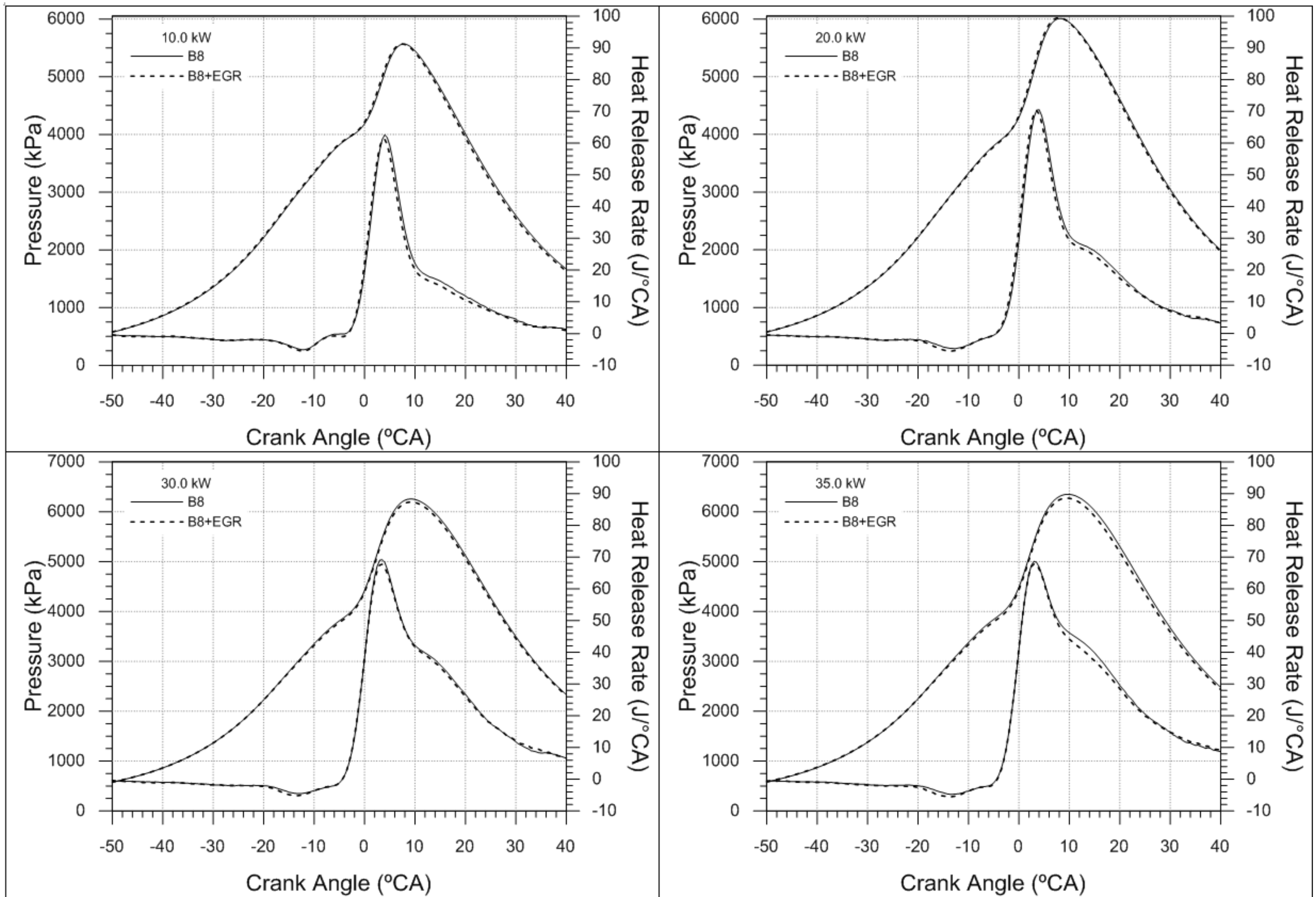

Results –CO_2 and CO

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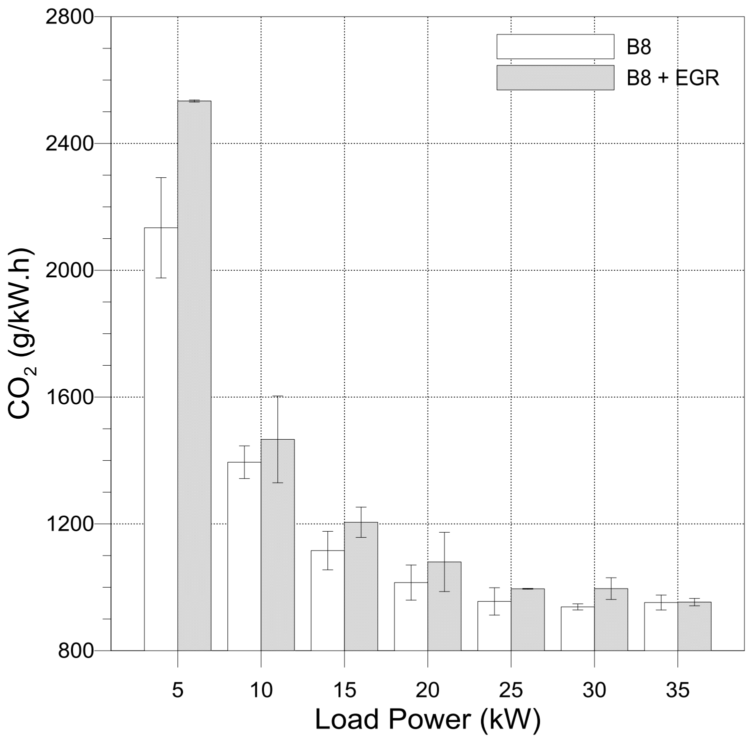
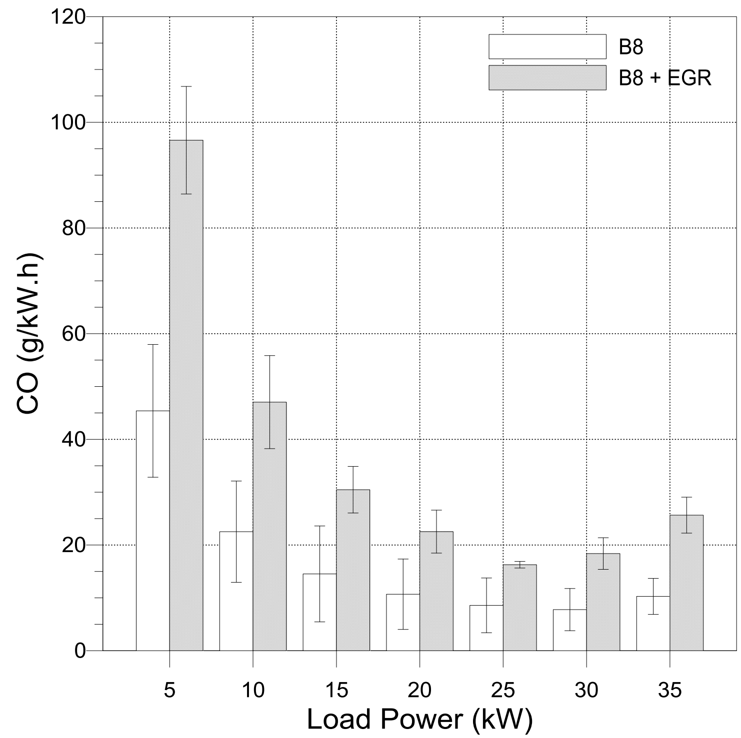


CO_2 *vs.* Engine loads



CO *vs.* Engine loads

Results – O_2 and THC

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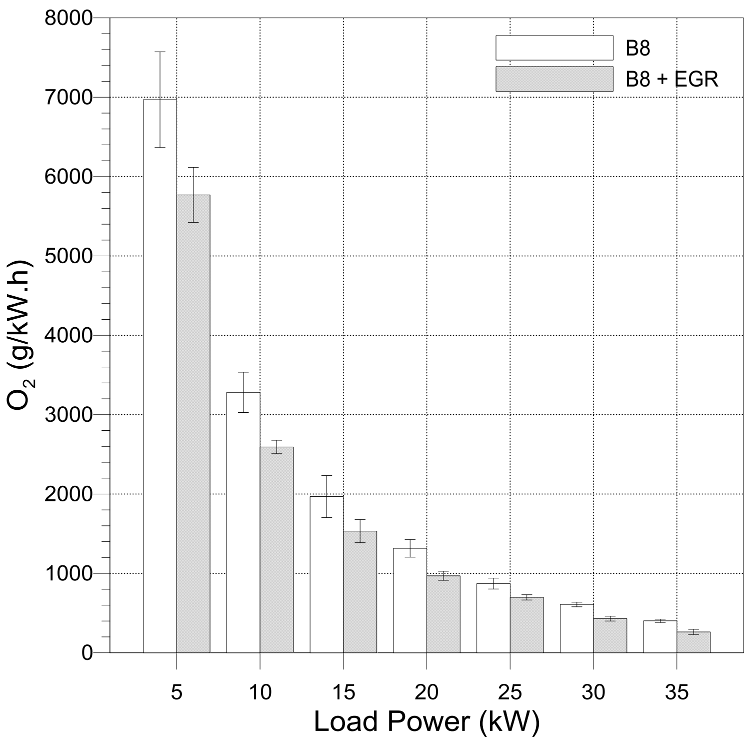
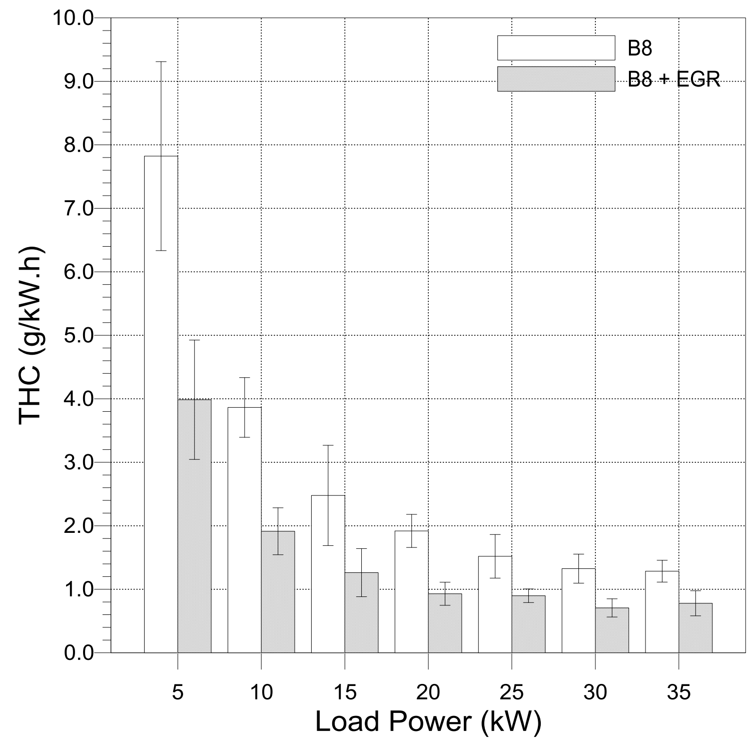
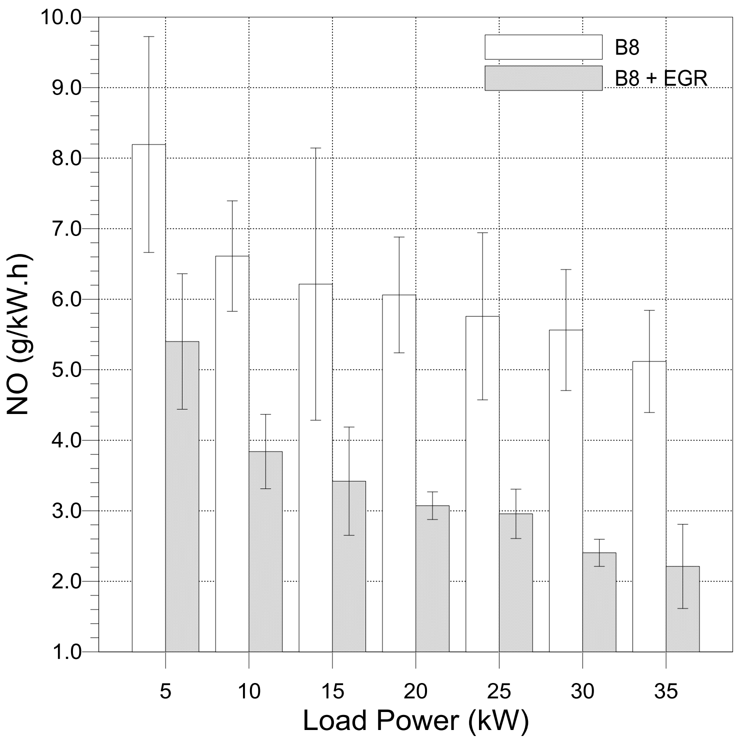


O_2 *vs.* Engine loads

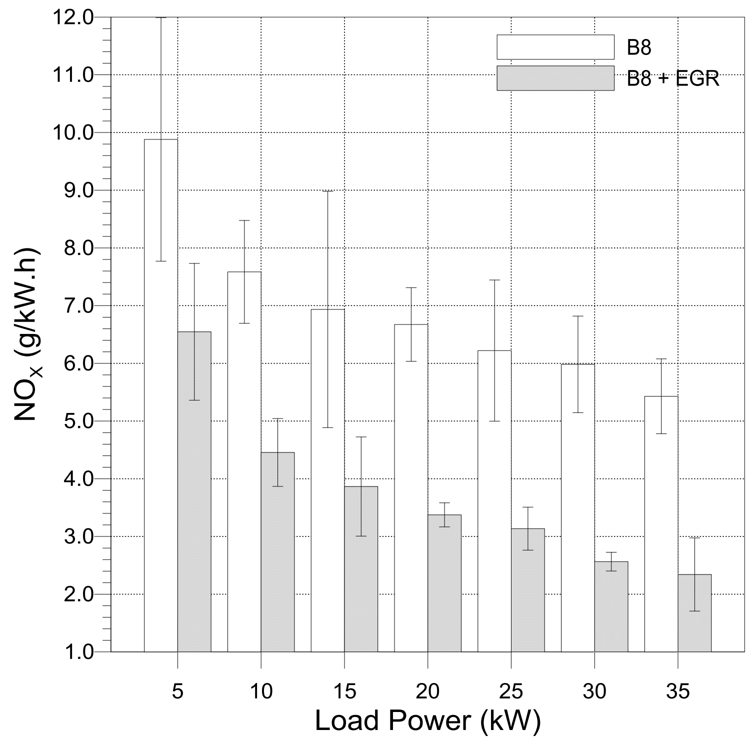


THC *vs.* Engine loads

Results –NO and NOx



NO *vs*. Engine loads



NO_x *vs*. Engine loads

Results – Numerical Experiment

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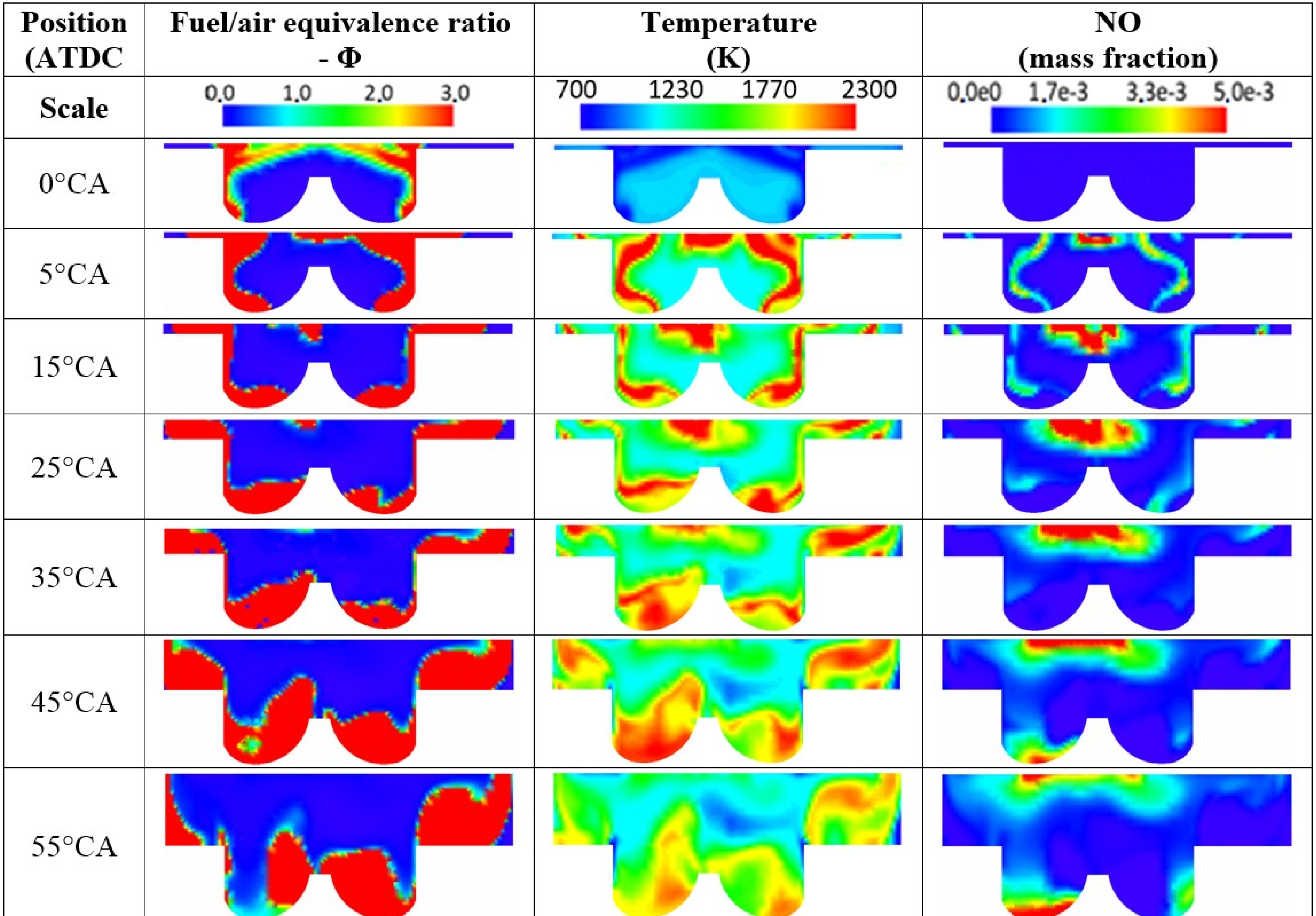

Results – Numerical Experiment

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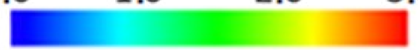
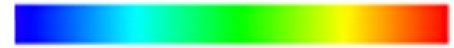
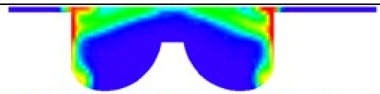
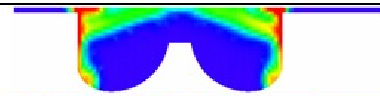
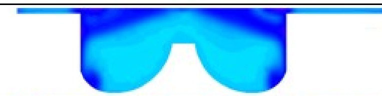
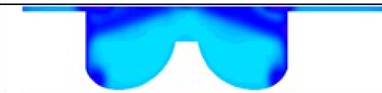
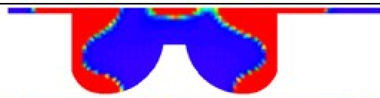
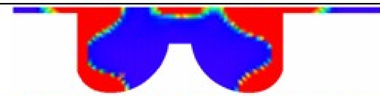
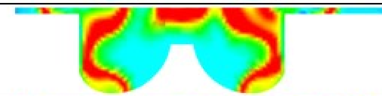
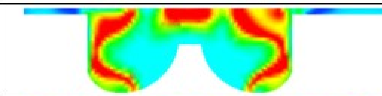
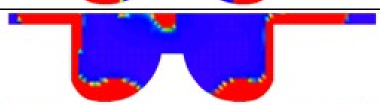
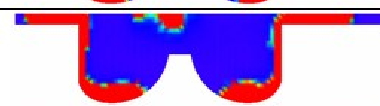
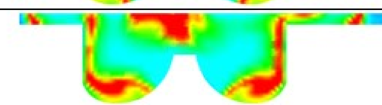
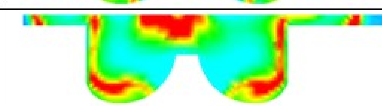
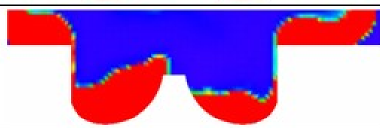
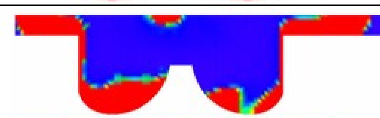
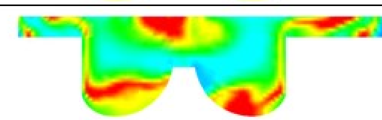
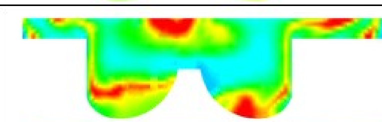
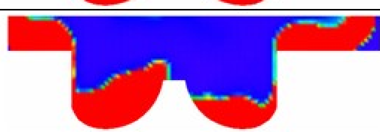
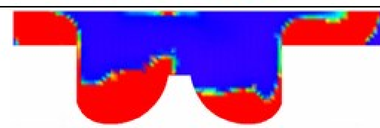
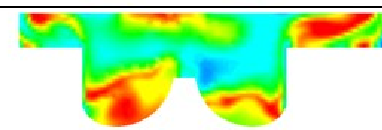
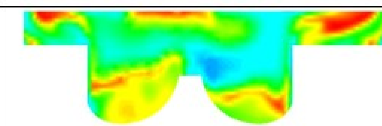
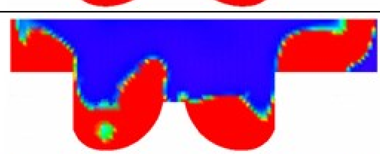
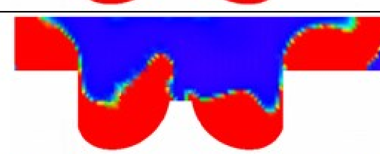
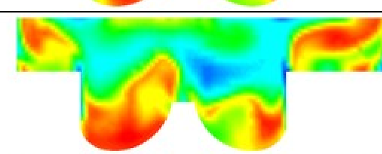
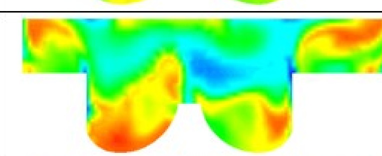
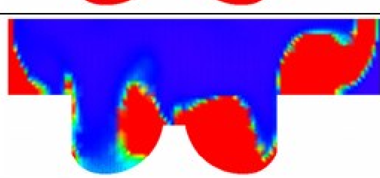
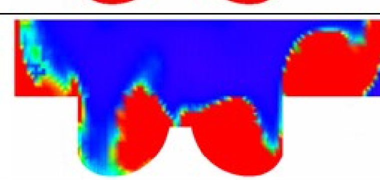
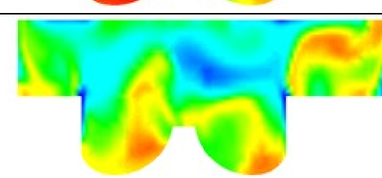
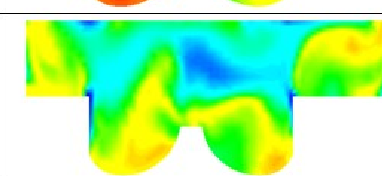
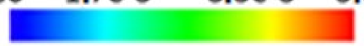
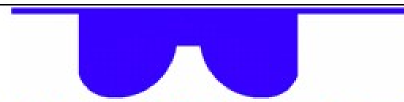
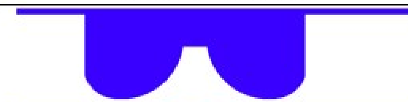
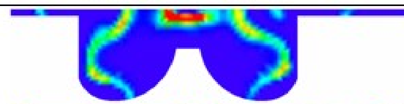
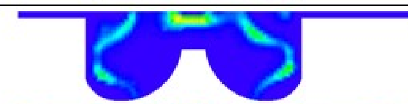
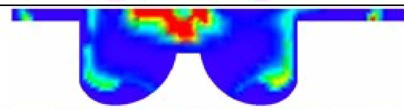
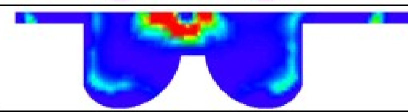
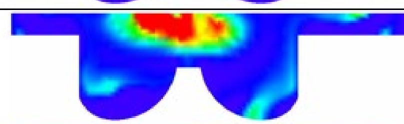
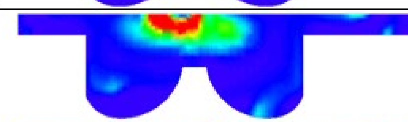
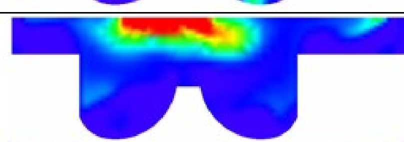
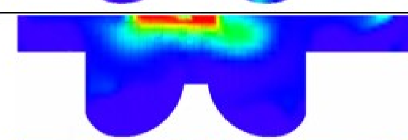
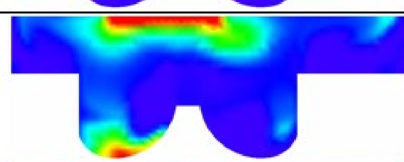
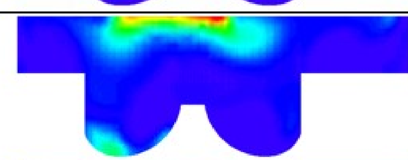
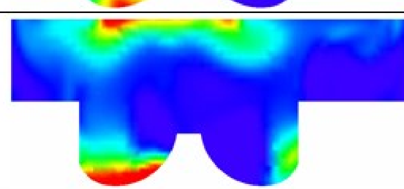
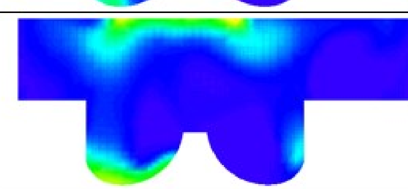
Parameter	Φ		Temperature (K)	
Scale	0.0 1.0 2.0 3.0 		700 1230 1770 2300 	
Position (ATDC)	B8	B8 + EGR	B8	B8 + EGR
0°CA				
5°CA				
15°CA				
25°CA				
35°CA				
45°CA				
55°CA				

Results – Numerical Experiment

Parameter	NO (mass fraction)	
Scale	0.0e0 1.7e-3 3.3e-3 5.0e-3 	
Position	B8	B8 + EGR
0°CA		
5°CA		
15°CA		
25°CA		
35°CA		
45°CA		
55°CA		

Results

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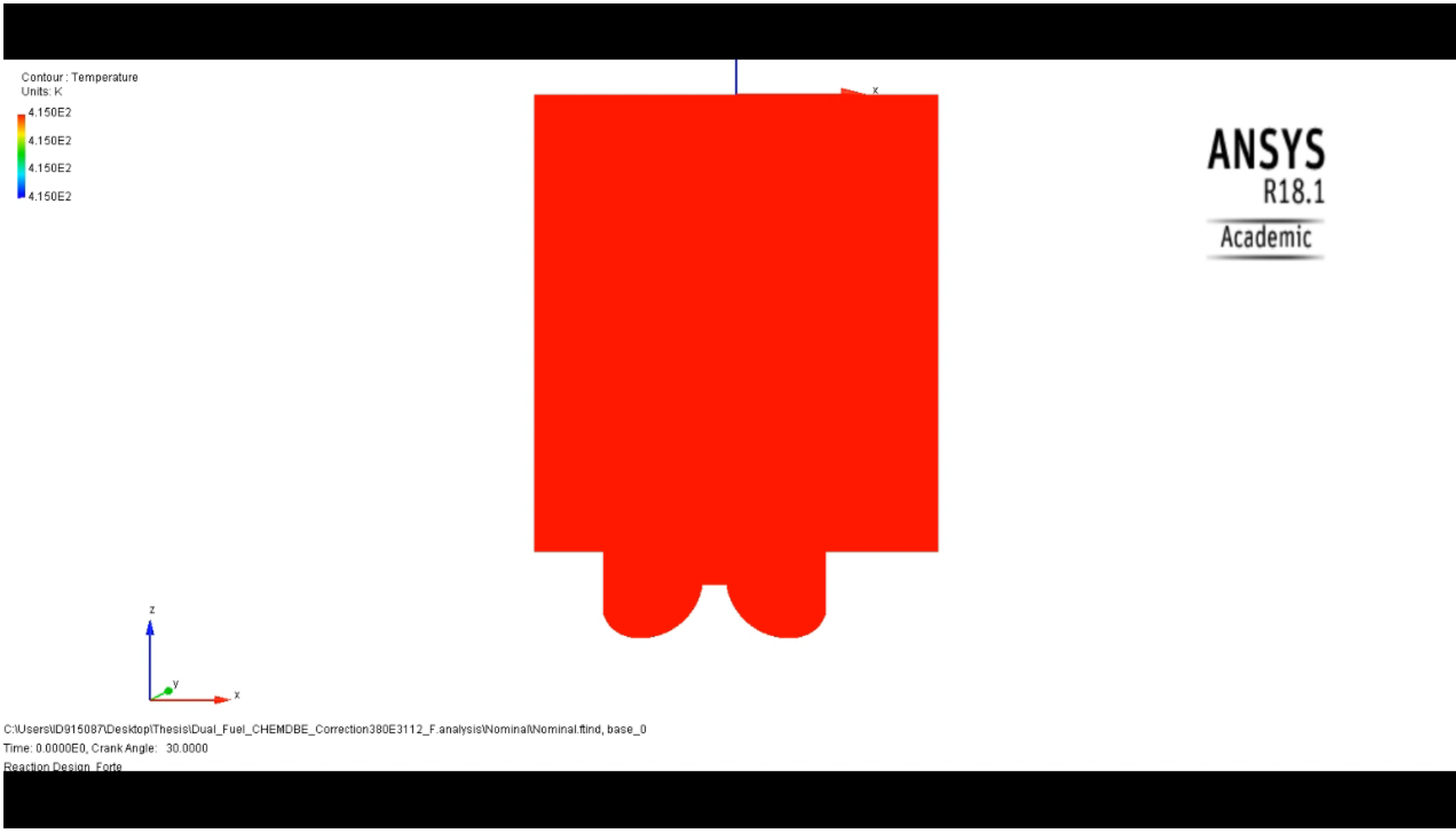

Conclusions

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- 10% cold EGR slightly affected the engine specific fuel consumption, and proved to be effective in reduce the NOX emissions, up to 56%.
- The numerical study showed that the NO formation in the engine is mainly due to the thermal mechanism and that the EGR use inhibits the NO formation by the reduction of the in-cylinder temperature and O_2 concentration.
- The EGR use reduced THC emissions up to 52%. However, CO_2 and CO emissions increased when using EGR, up to 19% and 155%, respectively.

Acknowledgment

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