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COMPARATIVE ANALYSIS OF OPERATING PARAMETERS OF MEDIUM-SPEED DIESEL, GAS DIESEL AND GAS ENGINES

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Basic advantages of using gas fuel in medium speed IC engines

- *Less expenses for fuel*
  - Gas fuel is cheaper than diesel
  - Lower consumption of gas fuel
  - Price difference between gas and oil will grow
- *Less CO_2 emissions*
  - Lower content of C in natural gas
  - Lower consumption of gas fuel
- *Possibility to avoid using aftertreatment systems*
  - No particles emissions (cancerogene, important for megapolice)
  - Less NOx emission
- *Less noise, longer intervals between oil replacement*

Methods of medium-speed diesel engines conversion for operation on natural gas

- *Spark ignition gas engine with lean gas-air mixture*
  - high fuel efficiency
  - low NO_x emissions
  - only one fuel system and only one fuel used
  - combustion chamber shape has to be changed to reduce the compression ratio
  - needs special measures to avoid knock

- *Gas diesel engine with minimized portion of diesel fuel injected by a high pressure fuel supply system (Common Rail, unit injector, etc.).*
  - high engine power augmentation, any engine size because there is no problem of knock
  - high fuel efficiency
  - high % of diesel fuel substitution by gas (about 5% of diesel fuel at full loads)
  - the need to have two fuel systems and refuel the vehicle with gas and diesel fuel
  - problem of injectors overheating when injecting small portions of fuel

Main parameters of the engines investigated

Engine	Number and arrangement of cylinders	Cylinder diameter (mm)	Cylinder stroke (mm)	Rated speed (rpm)	Rated break mean effective pressure (MPa)	Comp-ression ratio
D200 diesel engine	L6	200	280	1000	2.00	15.0:1
D200 gas diesel engine	L6	200	280	1000	2.00	15.0:1
D200 gas engine	L6	200	280	1000	2.00	10.0:1

Engine parameters simulation

Two models were used:

- One-zone model of diesel/gas diesel/gas engine developed in MADI
- Multi-zone FIRE model of the AVL company

Simulation method

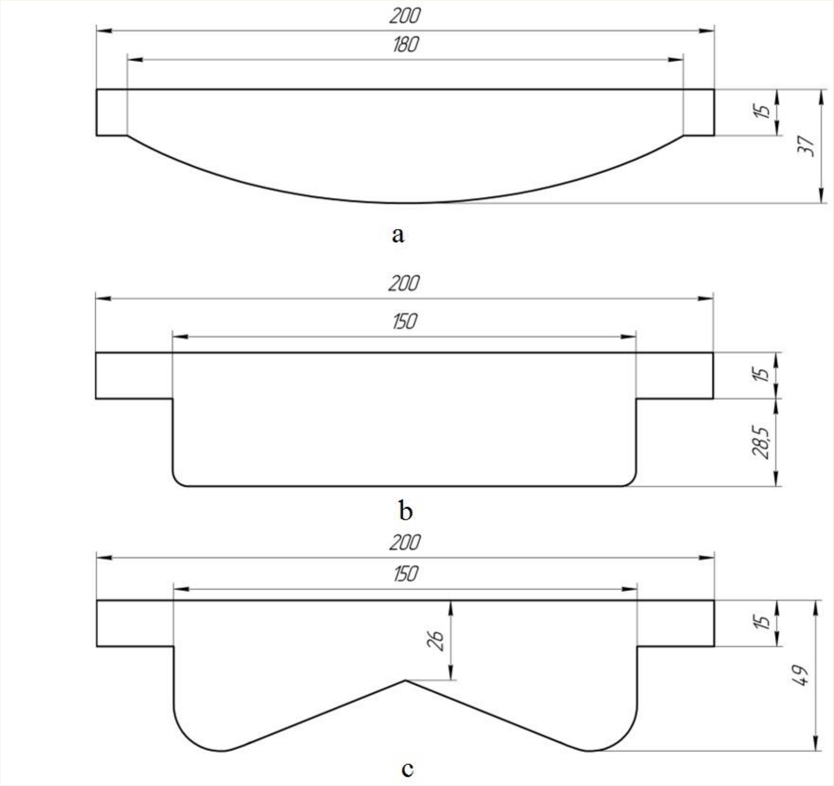
1. Calculations of the 4-stroke cycle of the D200 diesel/gas diesel/gas engine by the one-zone MADI model using the approximate values of the I.Viebe formula parameters (heat release duration φ_z and heat release law *m*) to get the boundary conditions at the inlet to the cylinder and outlet from the cylinder. The boundary conditions are required for calculations by the FIRE model.

2. Calculations of the compression-combustion-expansion processes of the D200 diesel/gas diesel/gas engine by the multi-zone FIRE model to get more precise values of the heat release rate parameters φ_z and *m* for the I.Viebe formula and toxic emissions.

3. Calculations of the 4-stroke cycle of the D200 diesel/gas diesel/ gas engine by the one-zone model using more precise values of heat release rate parameters φ_z and *m* for the I.Viebe formula to get indicated and efficient parameters of the engine.

Three variants of combustion chambers of the D200 gas engine were analyzed using simulation by the multi-zone FIRE model.

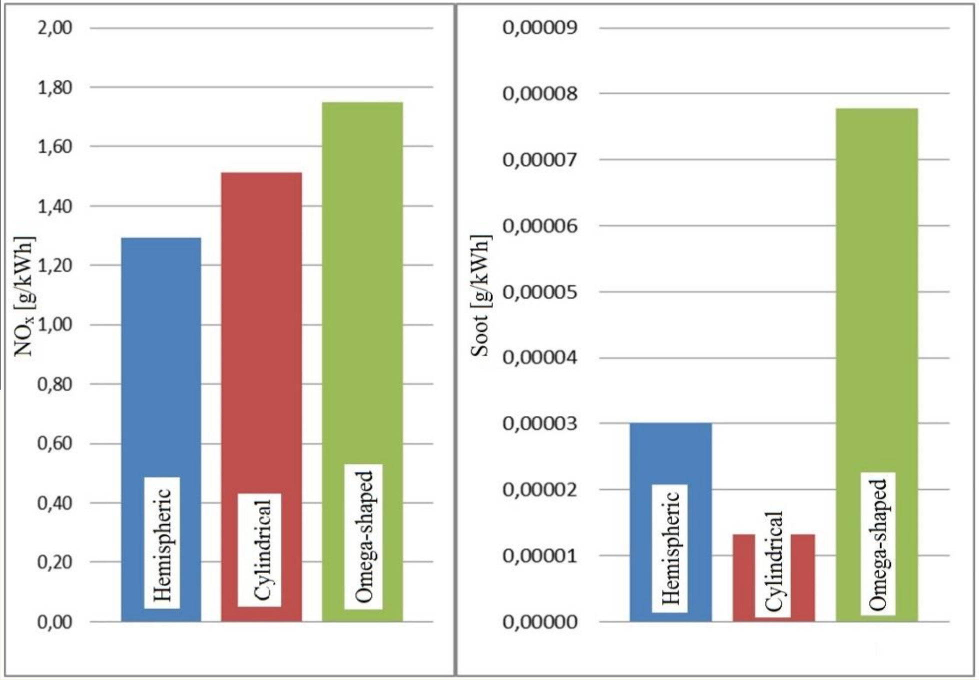
Schematics of the combustion chambers :
a) hemispheric; b) cylindrical; c) ω-shaped



Emissions of NO_x and soot by the D200 diesel, gas diesel and gas engines calculated by the FIRE model

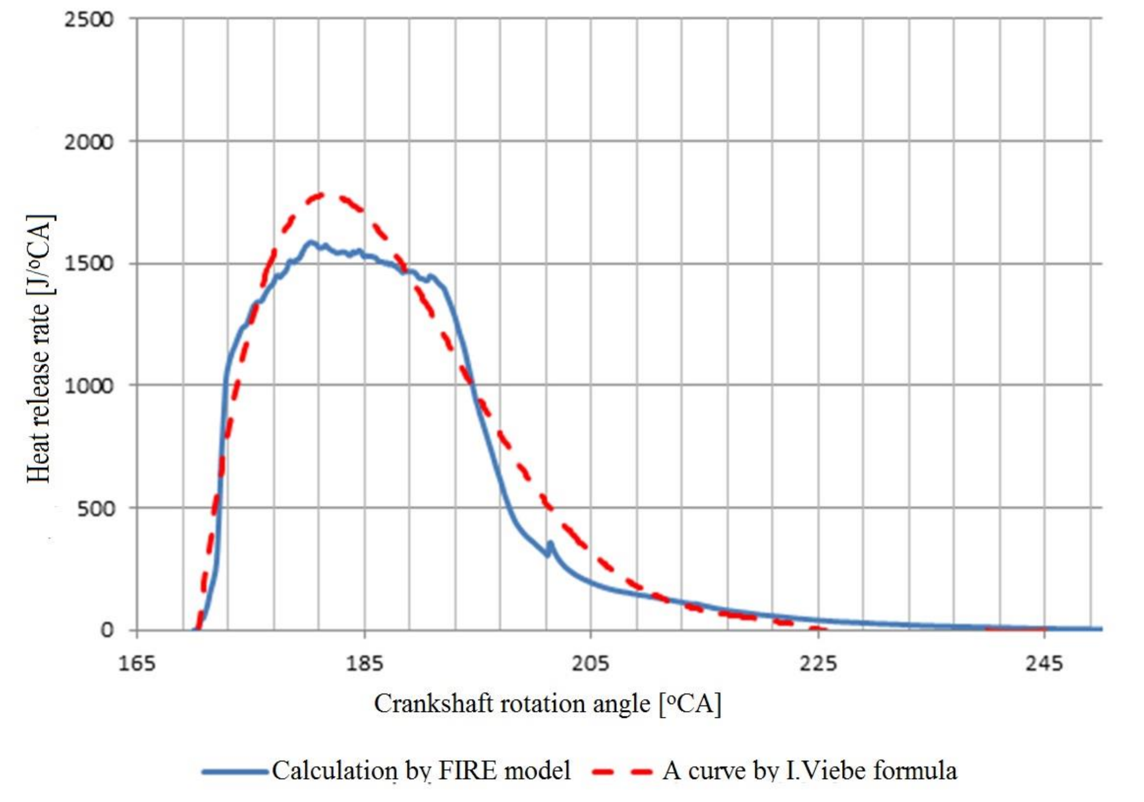
	NOx (g/(kW·h))	Soot (g/(kW·h))
Diesel engine	17.742	0.0089
Gas diesel engine	5.743	5.3492·10-5
Gas engine with different combustion chambers		
Hemispheric *	1.2945	3.0173·10-5
Cylindrical	1.5146	1.3243·10-5
ω-shaped	1.7481	7.7823·10-7

Histogram of NO_x and soot emissions by the D200 gas engine



* Was selected for further investigations

Heat release rate for the D200 **diesel engine**

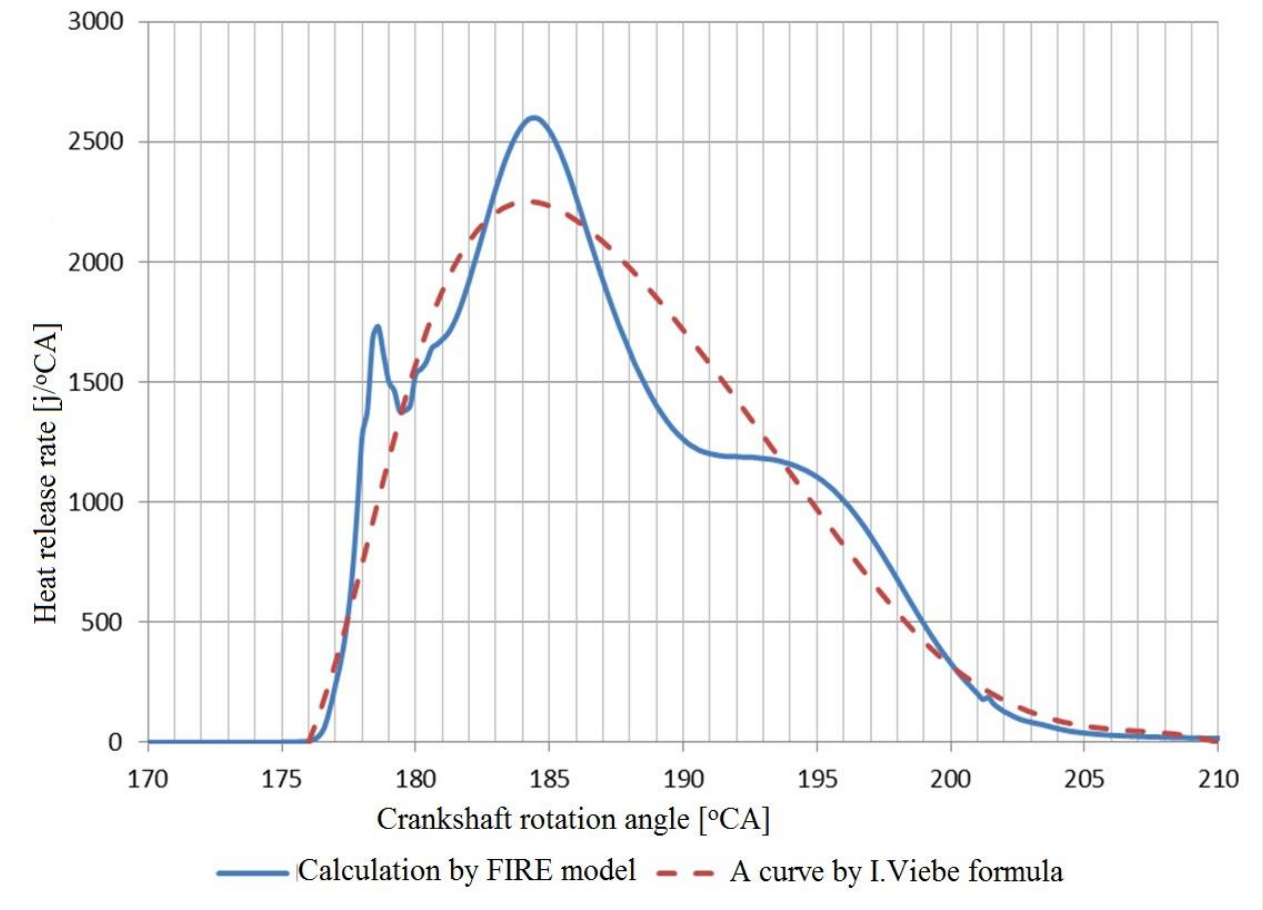


Parameters by the I.Viebe formula:

m=0.5, φ_z =70°CA

Experience of Diesel Engines Conversion for Operation on Natural Gas Obtained in MADI

Heat release rate for the D200 **gas diesel engine**:



Parameters by I.Viebe formula:

m=1, φ_z =36°CA

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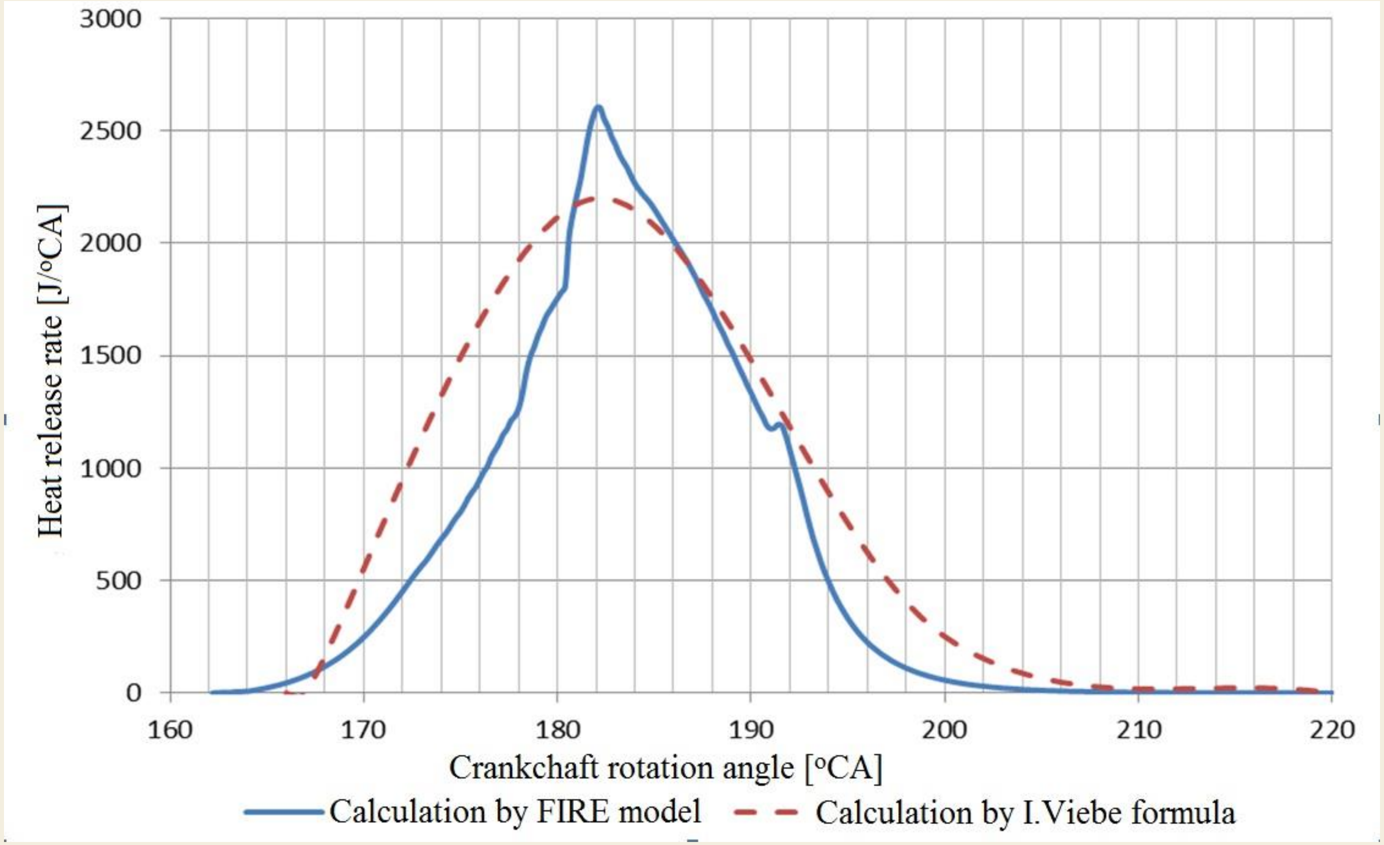
Heat release rate for the D200 gas engine



Heat release law and duration parameters by I.Viebe formula:
m=2, φ_z =40°CA

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Parameters of the D200 diesel/gas diesel/gas engines at rated mode

Engine	g_e	η_i	λ	p_z	T_{res}	α_{av}	$T_{res} \cdot \alpha_{av}$	Q_b	Q_w	Q_w/Q_b	T_t	p_c
	g/kW·h	-	-	MPa	K	W/m²·K	kW/m²	kJ	kJ	-	K	MPa
Diesel	188.9	0.503	2.10	20.6	1110	759	842.5	390	46.50	0.119	0.283	0.317
Gas diesel	162.1	0.507	2.04	20.7	1100	752	834.7	390	47.10	0.121	0.282	0.315
Gas	171.7	0.475	2.15	16.3	1040	705	733.2	415	39.00	0.094	0.309	0.355

Nomenclature

g_e - brake specific fuel consumption

η_i - indicated efficiency

λ - air excess coefficient

p_z - peak combustion pressure

T_{res} - resulting by heat exchange temperature

α_{av} - average heat transfer coefficient

$Q_{в}$ - heat supplied in the cycle

Q_w - heat losses into walls

T_t - exhaust gases temperature

p_c. - compressed air pressure

Experience of Diesel Engines Conversion for Operation on Natural Gas Obtained in MADI

CONCLUSIONS

1. Analysis performed demonstrates that medium-speed gas engines are most suitable for stationary application, first of all, energy generation because operation at a constant high speed minimizes the risk of knock. Gas diesel engines can be successfully used for transport because they do not have knock problems.

2. Calculation of compression-combustion-expansion processes by the multi-zone FIRE model enabled to obtain parameters of the I.Viebe heat release rate formula for diesel/gas diesel/gas required for calculation of the 4-stroke cycle parameters of these engines by a one-zone model.

3. Calculated comparison of operation parameters of diesel/gas diesel/gas engine by the MADI one-zone model in maximally close operation condition showed that compared to the base diesel engine, the gas diesel and gas engines had, correspondingly, by 14.2% and 9.1% lower brake specific fuel consumption, as well as 3.09 times and 13.7 times lower NO_x emissions. Soot emissions of the gas diesel and gas engines were negligibly low. Thermal strength of the gas engine was by 26% lower than that of diesel and gas diesel engines.

Thank you