MEMBRĂ A

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Laboratorul de Testare, Cercetare și Certificare a Motoarelor cu Ardere Internă

TEST REPORT

Testing internal combustion engines to highlight the fuel cleaning effect and capturing combustion chamber images

July 2024

CUPRINS

1 INTRODUCTION

Evaluating diesel fuel is crucial due to the high number of vehicles using compression ignition engines that run on diesel. A high-quality diesel fuel is essential for achieving high engine performance, low fuel consumption, and reduced emissions. Consequently, each type of fuel must meet stringent standards regarding properties such as lower heating value, cetane number, density, viscosity, and surface tension, which significantly impact the combustion process within internal combustion engines (the conversion of chemical energy into mechanical energy that drives the engine).

Each fuel molecule contains chemical energy, released as heat (thermal energy) when it reacts with oxygen in the engine cylinder. This thermal energy is then converted into mechanical work through the motion of the piston. Given the requirements for the combustion process — to be as complete, fast, and efficient as possible, while ensuring a smooth pressure rise — the importance of fuel properties becomes clear. These properties are critical for developing new, efficient, and less polluting engine technologies.

This study seeks to determine the fuel coking/cleaning effect and the associated influence on engine performance when running with three different fuels: a standard (commercially available) Diesel, OMV Diesel and OMV MaxxMotion Performance Diesel. To have a correct analysis, and to draw pertinent conclusions, the evaluation of the deposits was done in real and controllable conditions.

The tests were done in the Internal Combustion Engines Certification, Homologation and Research Laboratory, on a 0,5 l single cylinder research engine.

2 EQUIPMENT

2.1 Engine

The engine used for the experiments is a single cylinder research engine developed by AVL, namely the AVL 5402 SCRED. The main characteristics of the engine are presented in table 2.1. In addition to intake/exhaust pressure and temperature monitoring the engine also allows for:

- control of injection quantity, timing, pressure and number of injections – for the current study the same setup has been used for all tested fuels;
- visualization of combustion chamber phenomenon via and endoscope.

Before each sequence of tests the engine oil and coolant were warmed up using the cooling and oil conditioning unit.

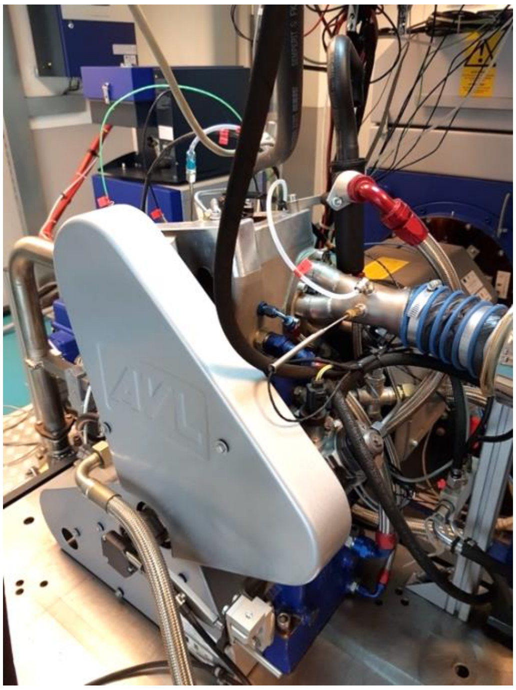


Fig. 2.1 AVL 5402 single cylinder research engine diesel

Table 2.1 Research engine data

Parameter	Value	M.U.
Bore x Stroke	85 x 90	mm x mm
Swept volume	510.7	cm^3
Compression ratio	17.1	-
Valves per cylinder	4 (2 inlet, 2 exhaust)	
Vlave train type	DOHC	
Fuel / Fueling system	Diesel / Direct injection	
Injection system / Injector	Bosch CRDI / Central injector (8 x 0.12 x 162°)	
Rated speed	4200	min^{-1}
Maximum Power (approx.)	6	kW

2.2 Pressure, temperature and humidity

The technical data of the sensors used to determine the intake pressure, and temperature, as well as the humidity are presented in table 2.2:

Table 2.2 Pressure, temperature and humidity sensor data

		Value	M.U.
Pressure	Measuring range	-1000 ... +2500	mbar
	Max. allowable uncertainty	0,2 MV	%
Temperature	Measuring range	-200 ... +800	°C
	Max. allowable uncertainty	0.15 MV	%
Humidity	Measuring range	0 ... 100	% RH
	Max. allowable uncertainty	2.0 MV	%

MV – Measured value

2.3 DynoRoad 202 Dynamometer

The DynoRoad 202 Dynamometer (Fig. 2.2) is driven by an asynchronous AC motor with an Insulated Gate Bipolar Transistor (IGBT) power module for direct connection to the power supply. The power module uses a hybrid interface that makes it easy to control the torque and speed of the tested engines. The technical specifications of the DynoRoad 202 dynamometer in generator mode and in motor mode respectively are shown in table 2.3.

Table 2.3 DynoRoad 202 dynamometer specifications

		Value	M.U.
Performance as a generator	Nominal Torque	525	[Nm]
	Nominal Power	220	[kW]
	Maximum Speed	12000	[rot/min]
Performance as a motor	Nominal Torque	473	[Nm]
	Nominal Power	198	[kW]
	Maximum Speed	12000	[rot/min]
Maximum allowable measuring uncertainty	Torque	0.2 MV	%
	Speed	0.2 MV	%

MV – Measured value

Fig. 2.2 DynoRoad 202 Dynamometer

2.4 Fueling map

In all test cases the following fuelling map was used by the engine control unit:

Table 2.4 AVL 5402 fueling map

Quantity limit [mm^3] \ Engine speed [1/min]	1600	1900	2200	2500	2800	3100	3500	4000
1	9.4	12.4	13.5	14.6	16.1	17.6	19.1	19.5
3	12.0	15.4	16.1	18.0	19.1	16.1	18.4	19.5
5	12.0	15.4	16.1	18.0	19.1	15.4	17.6	22.9
8	12.0	15.4	16.5	19.1	19.5	20.6	21.0	24.0
12	12.0	15.4	16.5	19.1	19.5	21.0	22.1	24.0
15	13.1	15.4	16.5	19.1	19.9	21.0	22.5	24.0
18	13.9	14.6	16.5	19.1	19.9	21.0	22.5	24.0
20	13.9	14.6	16.5	19.1	19.9	21.0	22.5	24.0
22		15.0	16.8	19.9	19.9	21.0	22.5	24.0
25		15.0	16.8	19.9	19.9			

The actual injected quantity for each relevant test cycle mode is presented in chapter 3.1.

2.5 Visioscope

The VISIOSCOPE system facilitates the measurement of the following parameters:

- temperature distribution and soot particle density – these are measured at seven defined points in the cylinder at different times during the combustion process set by the user;
- the program establishes a histogram of the images taken from the combustion chamber by making the ratio of the number of pixels having a given light intensity to the total number of pixels (cylinder area).

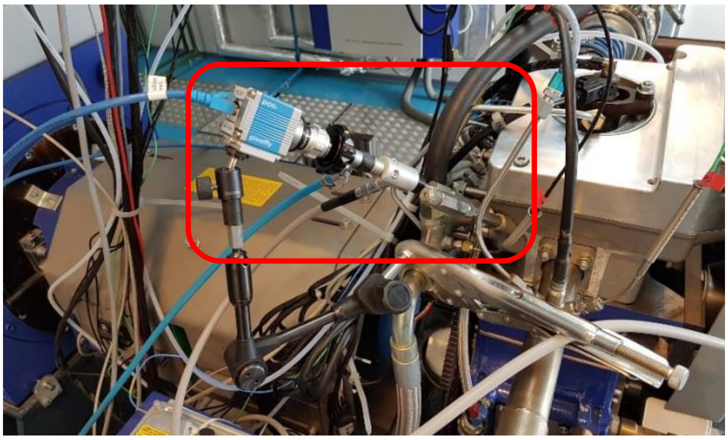


Fig. 2.3 Installation of the Visioscope equipment

Fig. 2.4 Combustion chamber with endoscope (setup example)

3 METHODOLOGY

3.1 Test cycle

To determine the fuel influence on engine operation and deposits/cleaning effect the engine was run for 32 hours with each of the following fuels:

- Standard Diesel – commercially available
- OMV Diesel – commercially available
- OMV MaxxMotion Diesel – commercially available

The 32 hours of testing consist of 32 one-hour cycles with 12 stages as specified by the CEC F-98-08 Direct Injection, Common Rail Diesel Engine Nozzle Coking Test.

Table 3.1 Test cycle and injected quantity for each mode

Mode	ID	Engine speed [1/min]	Load [%]	Mode duration [s]	AVL 5402 injected quantity [mg/cycle]
1.		1750	20	120	
2.	3000_60	3000	60	420	10.3
3.		1750	20	120	
4.	3500_45	3500	80	420	13.4
5.		1750	20	120	
6.	4000_60	4000	100	600	18.9
7.		1250	10	120	
8.	3000_60	3000	100	420	19.1
9.		1250	10	120	
10.	2000_60	2000	100	600	21.0
11.		1250	10	120	
12.	4000_60	4000	100	420	18.9
			TOTAL	**3600**	

3.2 Power correction

A power correction factor was used due to variation in atmospheric conditions. The power correction factor was calculated according to [1].

$$P_0 = CF \cdot P$$

where P_0 is the corrected power (with respect to the reference pressure - 0.990 bar and temperature – 298 K), CF the correction factor and P the actual measured power.
For the current study the intake pressure, temperature, and humidity were:

Table 3.2 Intake parameters

Parameter	Range	M.U.
Pressure	0.942 ... 0.963	bar
Temperature	300.3 ... 320.8	K
Humidity	11.3 ... 48.2	%

The calculated correction factor range was: 1.013 – 1.033.

3.3 Combustion chamber image analysis

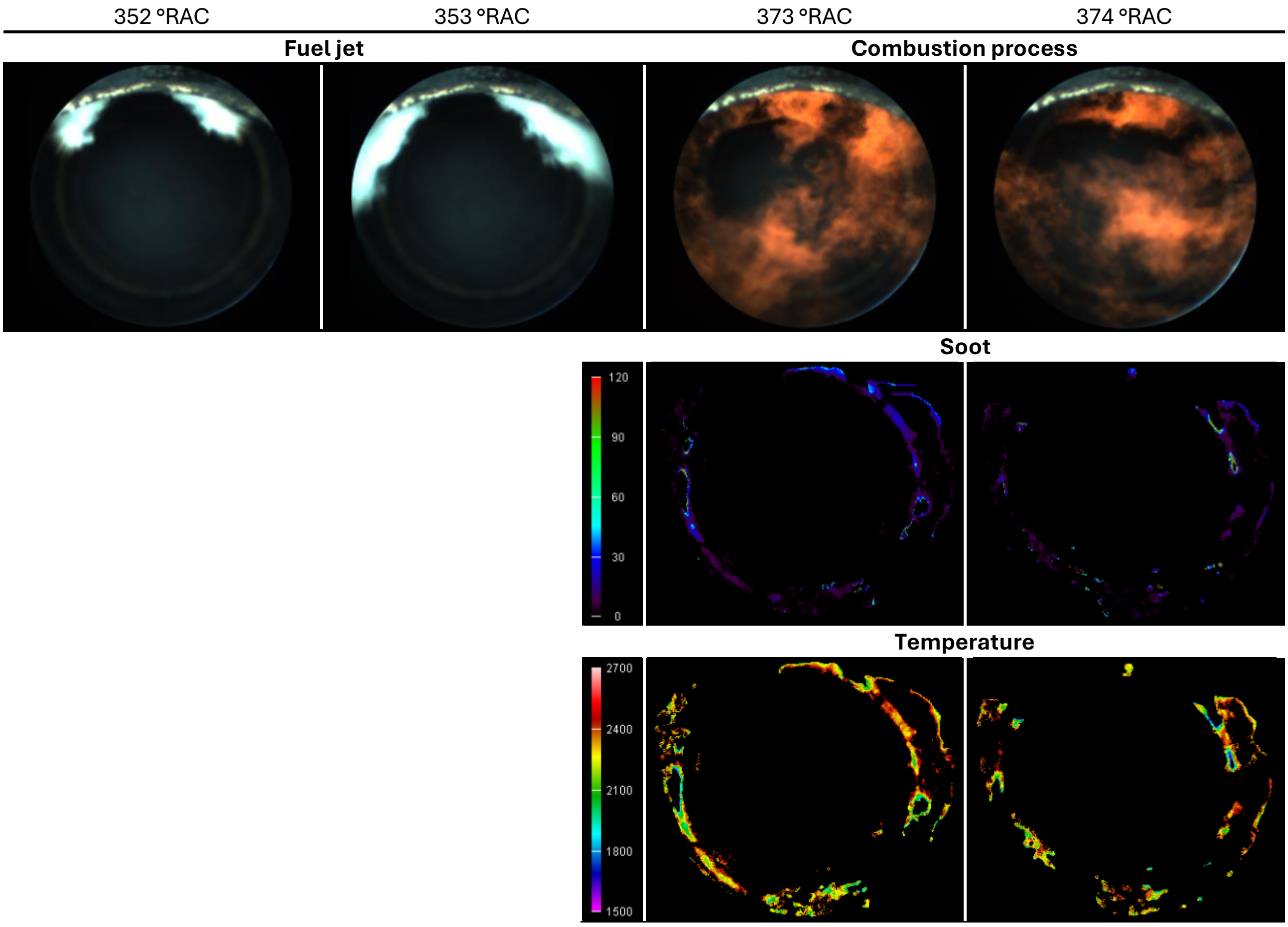
The combustion chamber image analysis was designed to highlight the influence of the fuel cleaning effect on the injection and combustion process. To this end, several aspects were analyzed (Table 3.3): fuel jet dispersion – determined by the angle between two fuel jets, soot area, combustion chamber temperature.

The images collected as described in Chapter 3.4 were initially processed using AVL ThermoVision Advanced software. After calibrating the entire image set, each image was compared to the first image in the set to obtain soot and temperature data.

Subsequently, a custom image processing software was employed to isolate and identify flame-related pixels by correlating thermal and RGB data. An in-depth data cleaning process removed any data points deviating more than 10% from the median, ensuring data reliability. With this refined dataset, the following analysis was conducted:

- soot area;
- combustion chamber temperature;
- flame area;
- flame average temperature;
- flame peak temperature.

Table 3.3 Sample images from the combustion chamber (fuel jet, combustion, soot, temperature)



3.4 Procedure and steps

For each test day, the following steps were followed:

Step 1. Check of all laboratory systems

Step 2. Following the warmup of the coolant and oil, the engine is started in motored mode.

Step 3. The test cycle presented in table 3.1 is selected together with the number of consecutive runs and the automatic test procedure is then started.

Step 4. After each one-hour cycle the engine is operated in motored mode at 1000 min^{-1} until the inlet coolant temperature drops to below 91 °C.

Step 5. As soon as the coolant inlet temperature drops below the set value, a new one-hour cycle is started until the number of specified cycles is reached.

After reaching a total of 32 one-hour cycles the combustion chamber image capture was started, and involved the following:

Step 1. Installation of visualization equipment.

Step 2. Start of engine in motored mode at 1500 min^{-1}.

Step 3. Set-up of injection control parameters:

Sequence	Quantity [mg]	Timing [°CA bTDC]	Pressure [bar]
Pilot	2	21.0	700
Main	10	11.6	

Step 4. Start of image capture.

Step 5. As soon as the measurement was finished the injection was stopped and the data saved.

Step 6. After steps 4 and 5 are repeated three times the engine is stopped, and the visualization equipment cleaned and refitted.

Step 7. Repeat Steps 1 – 6 eight more times, for a total of nine repetitions.

Step 8. Analysis of captured data to extract combustion chamber temperature and soot information.

Following the acquisition of the combustion chamber data, the fuel system was drained of the current test fuel and the new fuel was added.

This procedure was repeated for each test fuel.

4 RESULTS

4.1 Performance

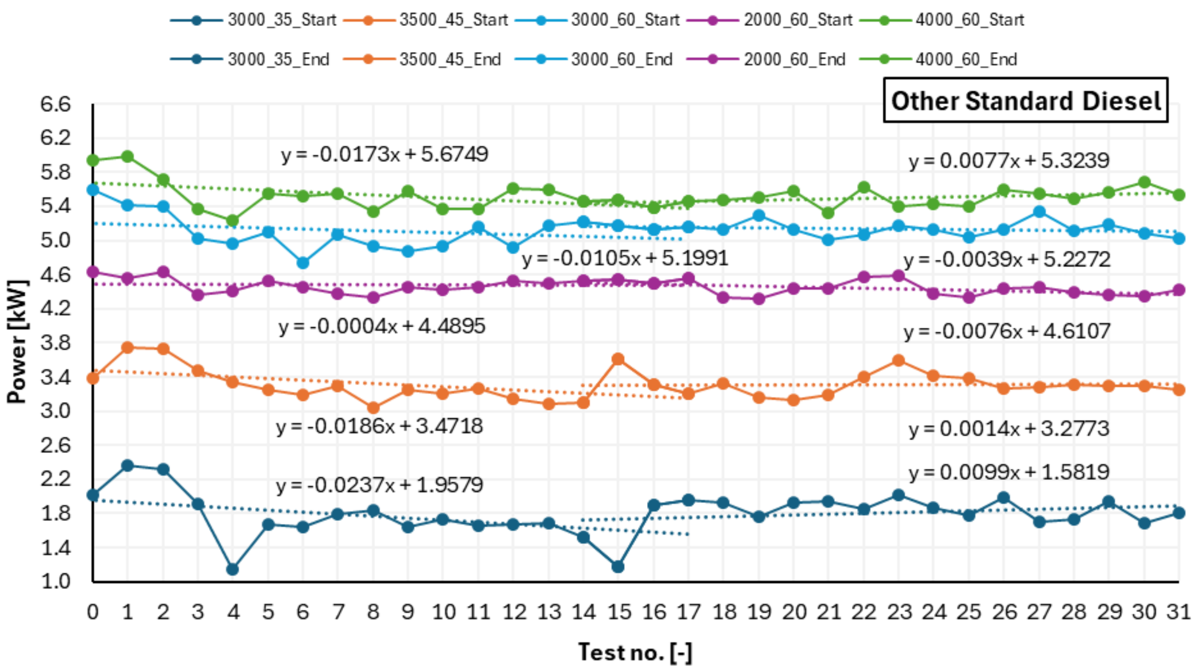
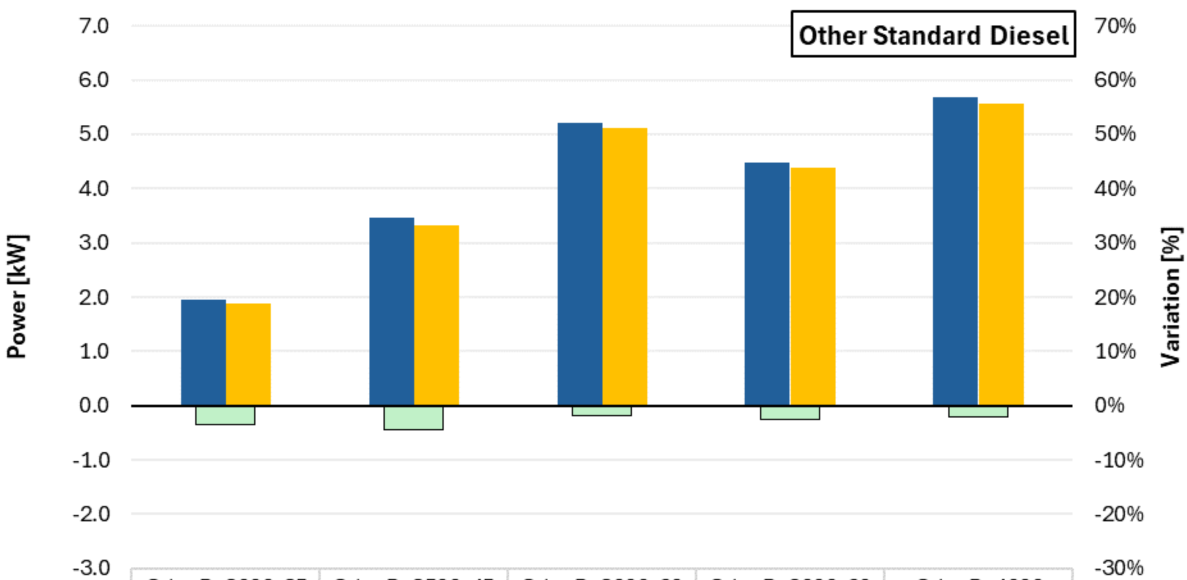


Fig. 4.1 Other Standard Diesel – 32 h power evolution



	OtherD_3000_35	OtherD_3500_45	OtherD_3000_60	OtherD_2000_60	OtherD_4000
Start	1.96	3.47	5.20	4.49	5.67
End	1.89	3.32	5.11	4.38	5.56
Variation	-3.53%	-4.35%	-1.78%	-2.55%	-1.98%

Fig. 4.2 Other Standard Diesel – 32 h Start-End power variation

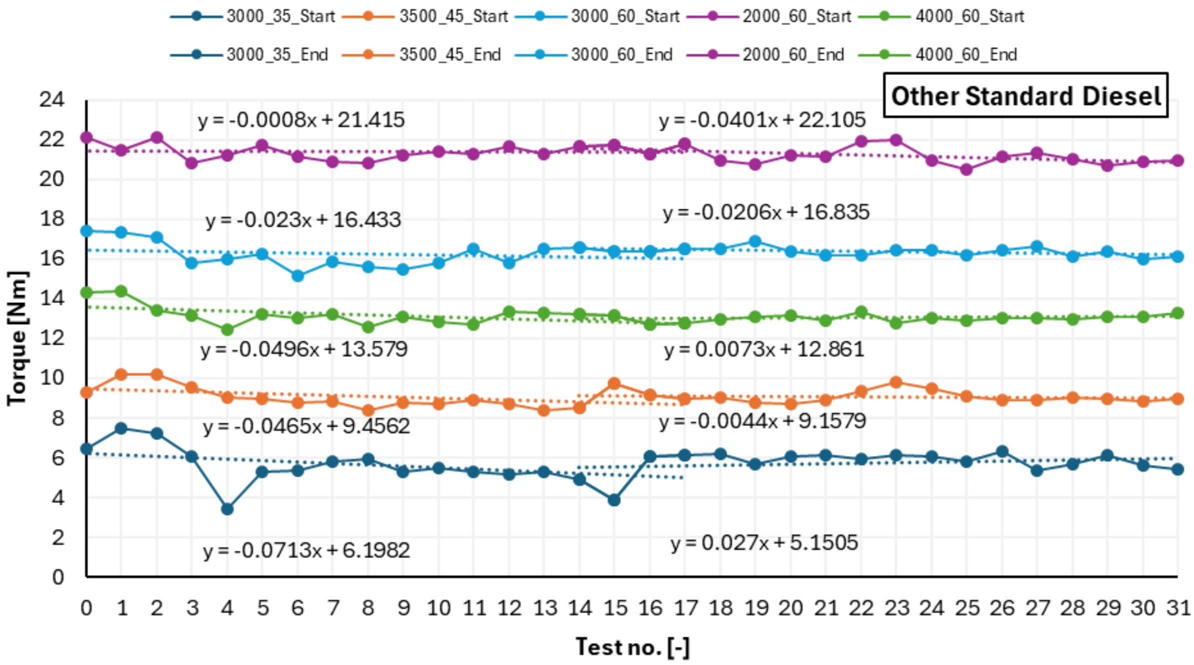
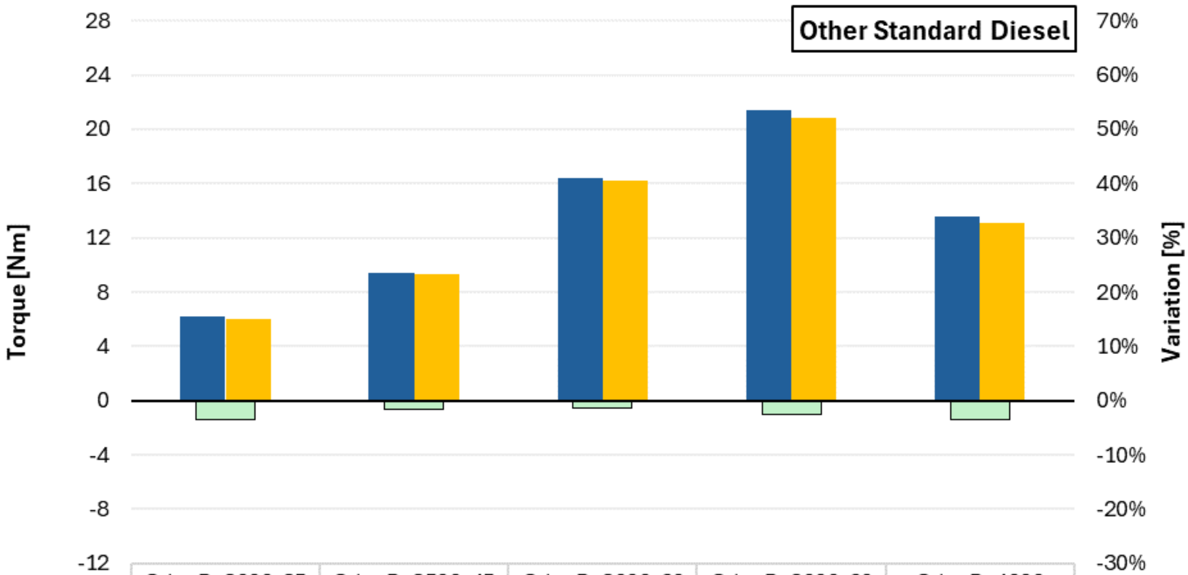


Fig. 4.3 Other Standard Diesel – 32 h torque evolution



	OtherD_3000_35	OtherD_3500_45	OtherD_3000_60	OtherD_2000_60	OtherD_4000
Start	6.20	9.46	16.43	21.42	13.58
End	5.99	9.29	16.20	20.86	13.09
Variation	-3.40%	-1.71%	-1.44%	-2.58%	-3.62%

Fig. 4.4 Other Standard Diesel – 32 h Start-End torque variation

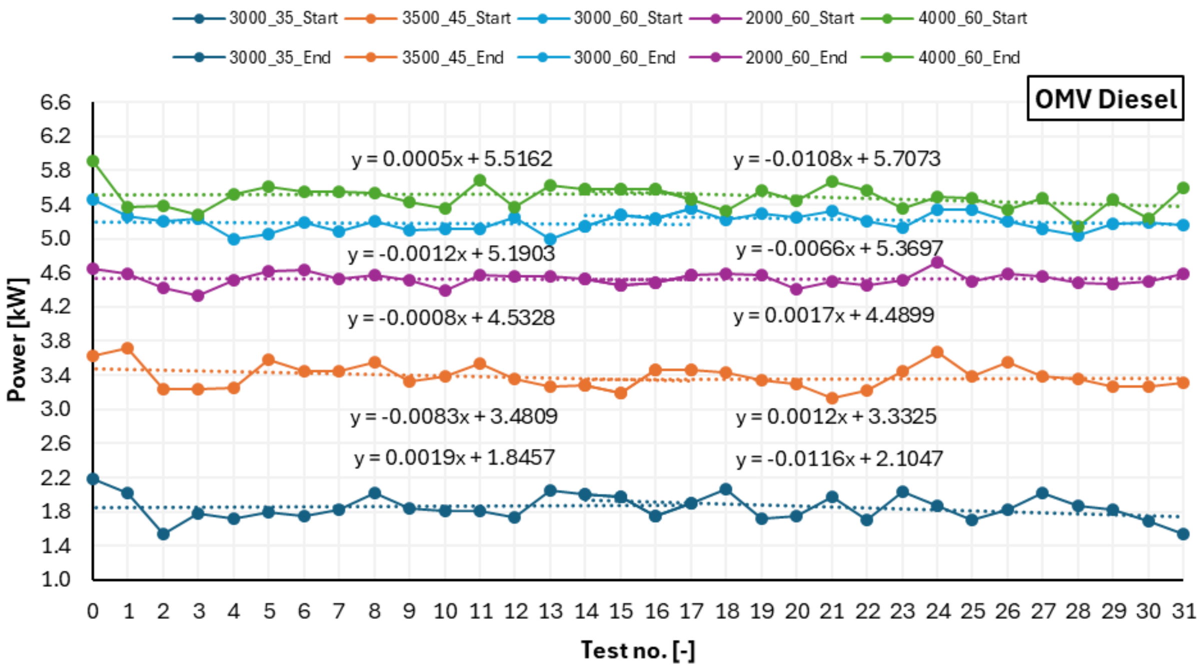
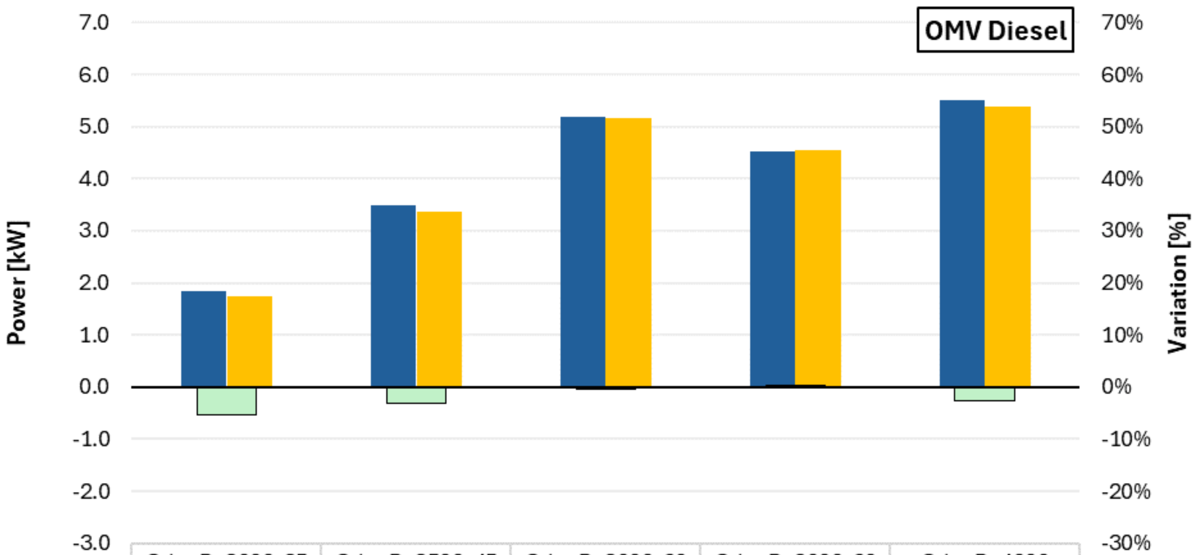


Fig. 4.5 OMV Diesel – 32 h power evolution



	OtherD_3000_35	OtherD_3500_45	OtherD_3000_60	OtherD_2000_60	OtherD_4000
Start	1.85	3.48	5.19	4.53	5.52
End	1.75	3.37	5.17	4.54	5.37
Variation	-5.45%	-3.19%	-0.49%	0.22%	-2.61%

Fig. 4.6 OMV Diesel – 32 h Start-End power variation

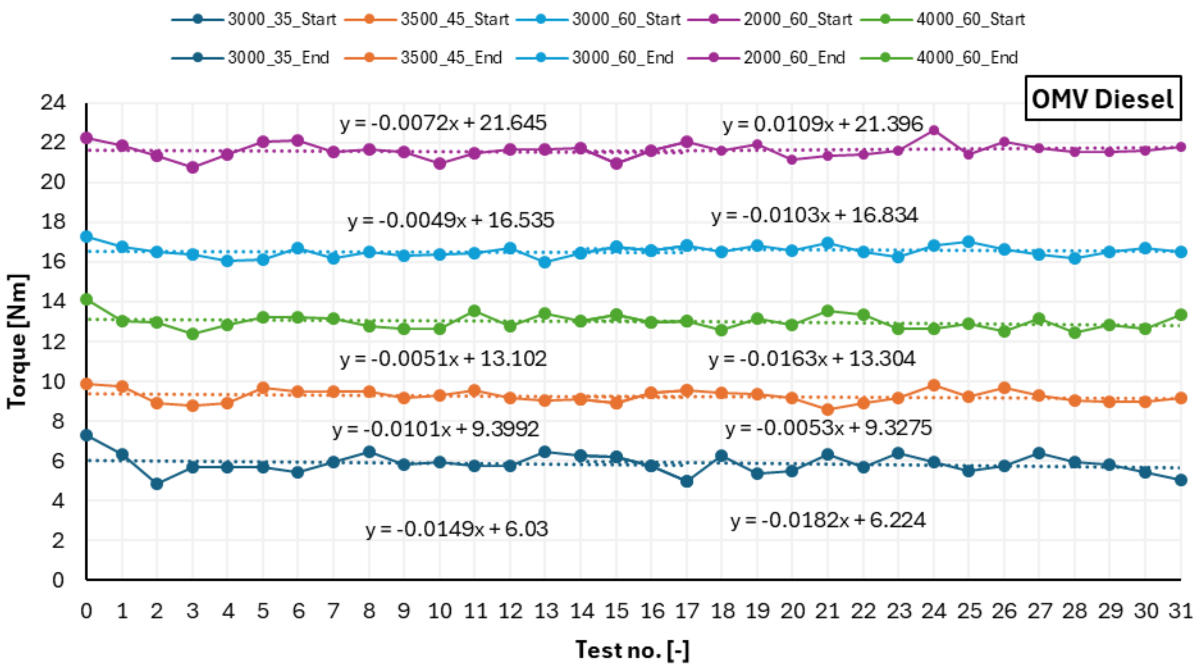
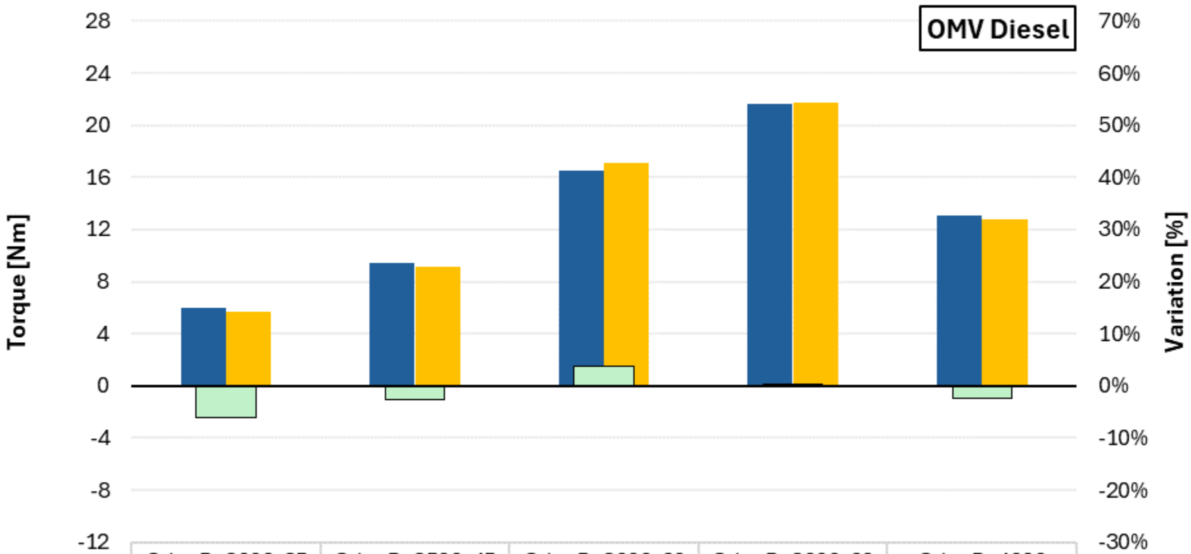


Fig. 4.7 OMV Diesel – 32 h torque evolution



	OtherD_3000_35	OtherD_3500_45	OtherD_3000_60	OtherD_2000_60	OtherD_4000
Start	6.03	9.40	16.54	21.65	13.10
End	5.66	9.16	17.15	21.73	12.80
Variation	-6.14%	-2.51%	3.74%	0.41%	-2.31%

Fig. 4.8 OMV Diesel – 32 h Start-End torque variation

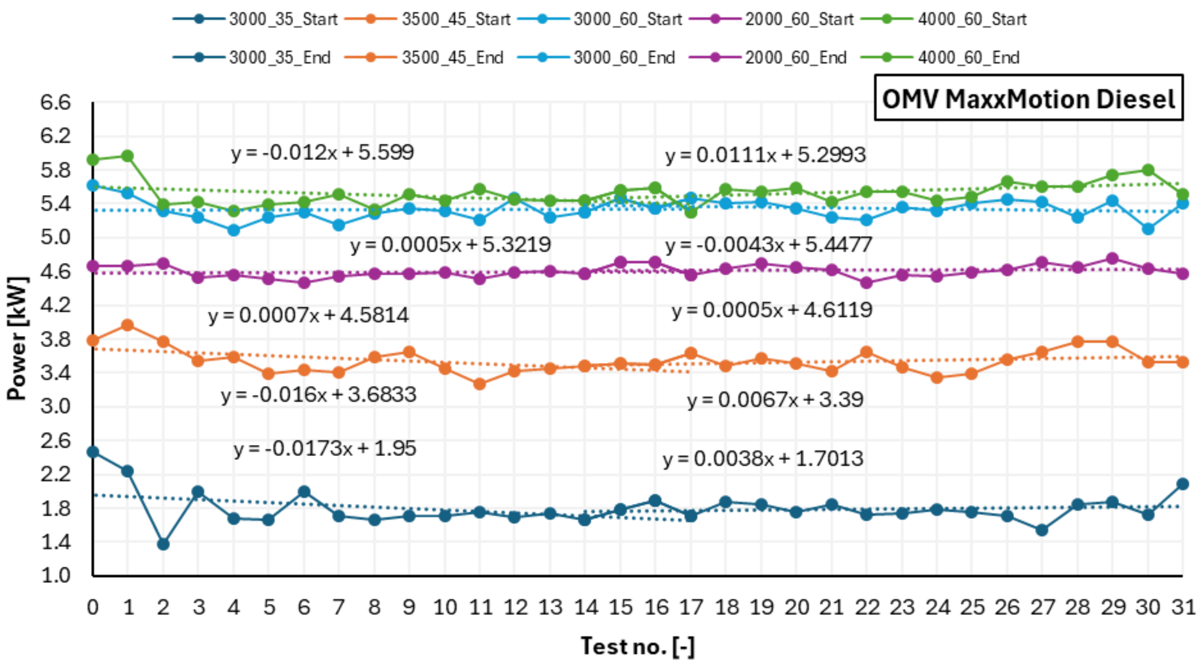
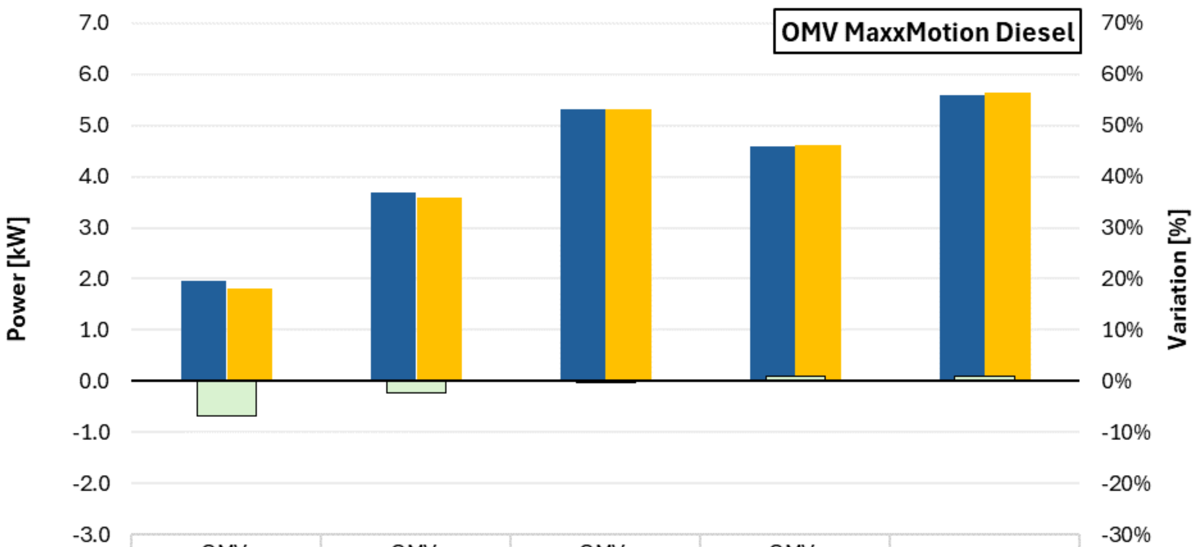


Fig. 4.9 OMV MaxxMotion Diesel – 32 h power evolution



	OMV-MMD_3000_35	OMV-MMD_3500_45	OMV-MMD_3000_60	OMV-MMD_2000_60	OMV-MMD_4000
Start	1.95	3.68	5.32	4.58	5.60
End	1.82	3.60	5.31	4.63	5.65
Variation	-6.71%	-2.32%	-0.14%	1.00%	0.84%

Fig. 4.10 OMV MaxxMotion Diesel – 32 h Start-End power variation

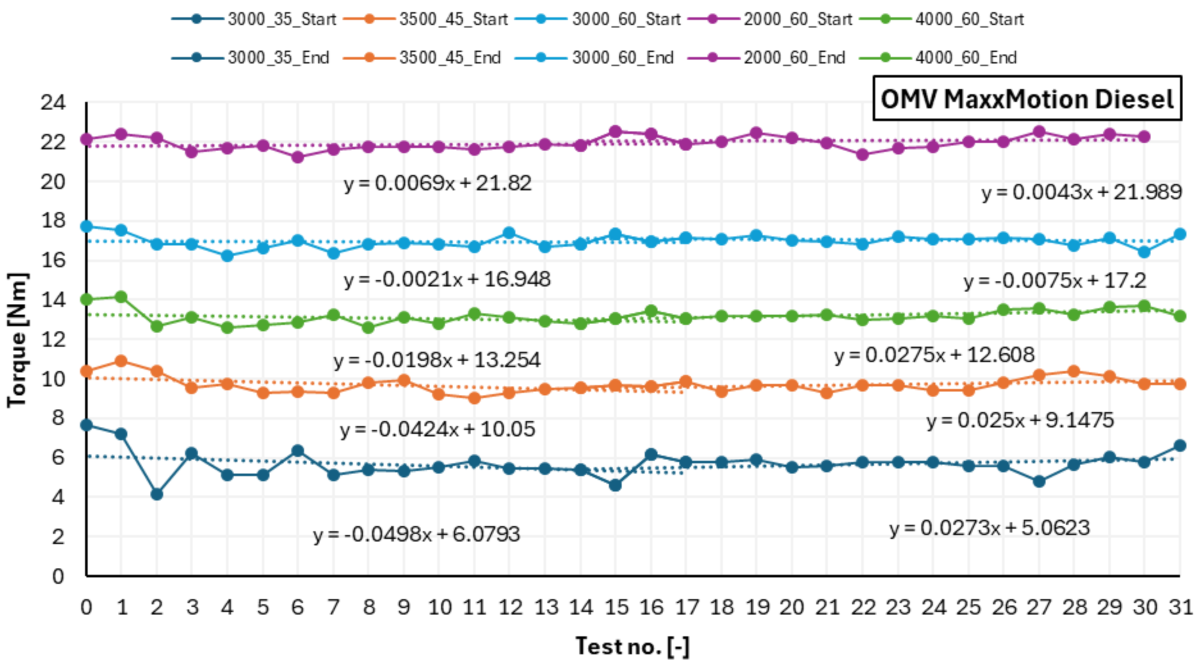
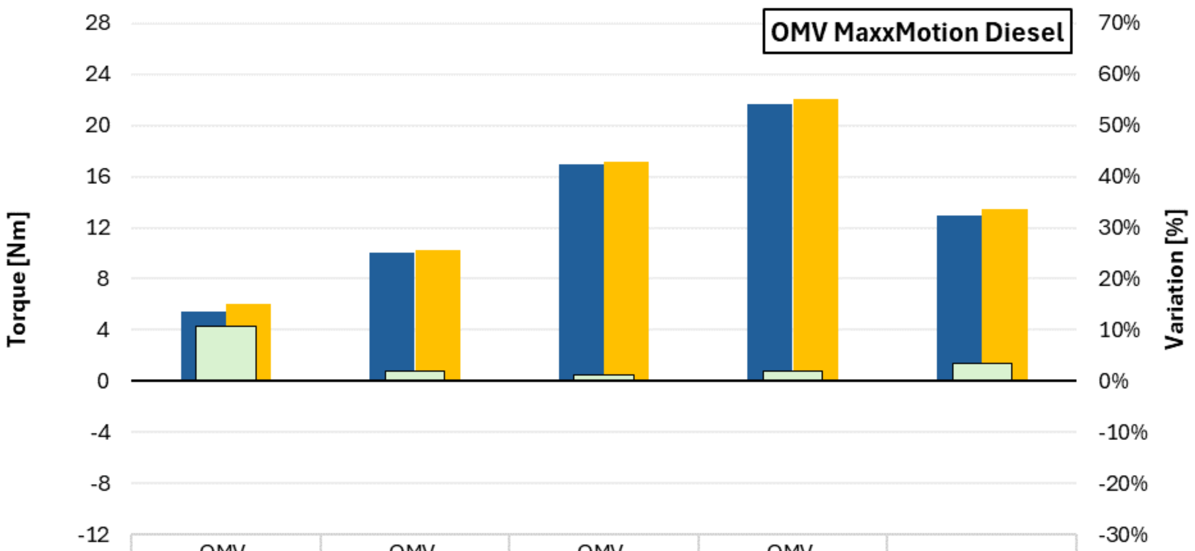
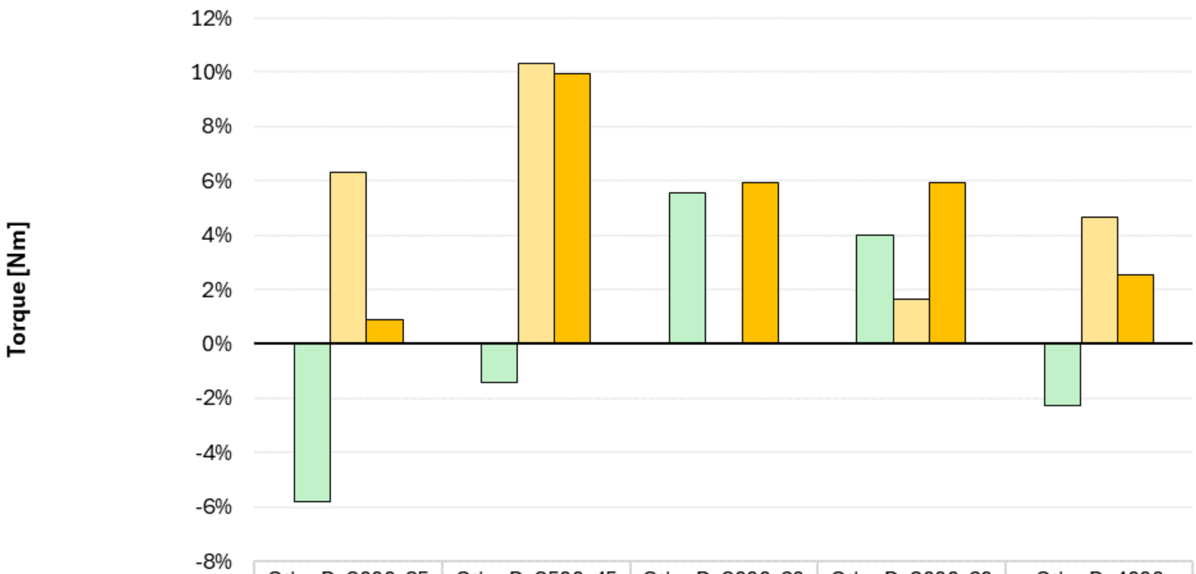


Fig. 4.11 OMV MaxxMotion Diesel – 32 h torque evolution



	OMV-MMD_3000_35	OMV-MMD_3500_45	OMV-MMD_3000_60	OMV-MMD_2000_60	OMV-MMD_4000
Start	5.45	10.01	16.94	21.68	12.98
End	6.04	10.22	17.16	22.10	13.42
Variation	10.74%	2.07%	1.29%	1.92%	3.43%

Fig. 4.12 OMV MaxxMotion Diesel – 32 h Start-End torque variation

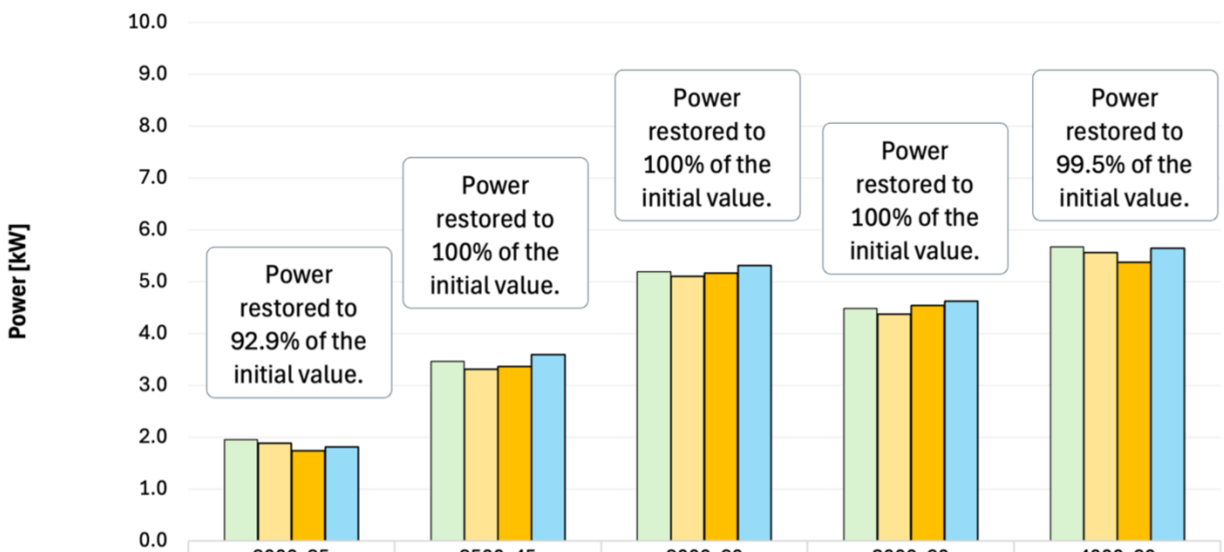


	OtherD_3000_35	OtherD_3500_45	OtherD_3000_60	OtherD_2000_60	OtherD_4000
OMV-D vs. OtherD	-5.8%	-1.4%	5.6%	4.0%	-2.3%
OMV-MMD vs. OMV-D	6.3%	10.3%	0.0%	1.6%	4.7%
OMV-MMD vs. OtherD	0.9%	10.0%	6.0%	5.9%	2.6%

Fig. 4.13 Comparison of end torque values between the 3 tested fuels

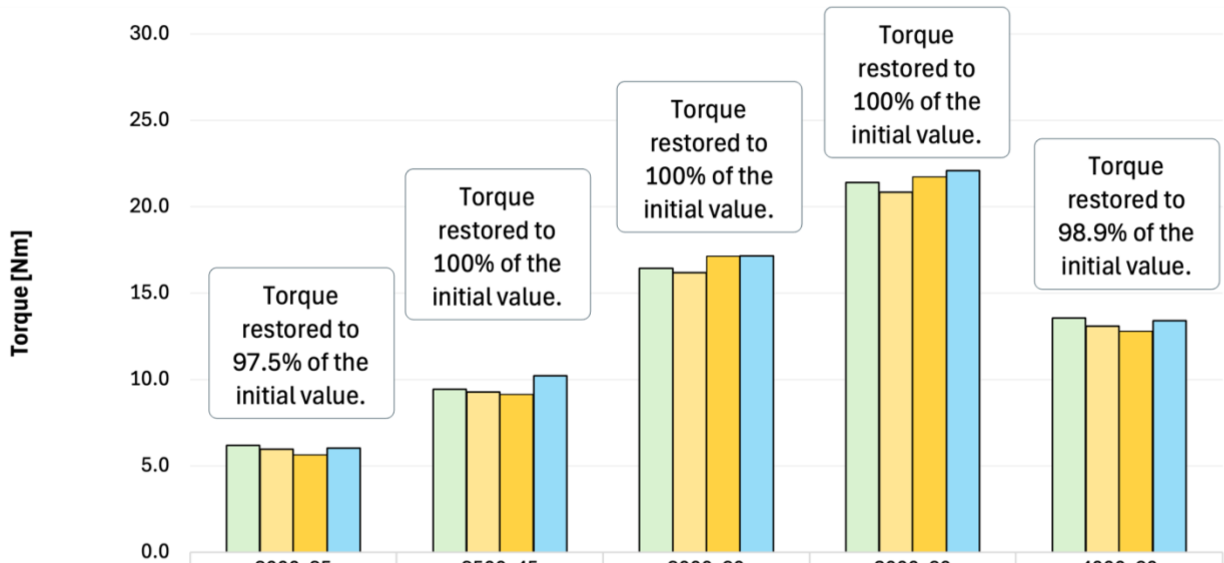
	OtherD_3000_35
OMV-D vs. OtherD	1.1%
OMV-MMD vs. OMV-D	-0.7%
OMV-MMD vs. OtherD	0.5%

Fig. 4.14 Comparison of end exhaust gas temperature values between the 3 tested fuels



	3000_35	3500_45	3000_60	2000_60	4000_60
Start	1.96	3.47	5.20	4.49	5.67
After OtherD	1.89	3.32	5.11	4.38	5.56
After OMV-D	1.75	3.37	5.17	4.54	5.37
After OMV-MMD	1.82	3.60	5.31	4.63	5.65

Fig. 4.15 Power restore after OMV MaxxMotion Diesel compared to the initial value for Other Standard Diesel



	3000_35	3500_45	3000_60	2000_60	4000_60
Start	6.20	9.46	16.43	21.42	13.58
After OtherD	5.99	9.29	16.20	20.86	13.09
After OMV-D	5.66	9.16	17.15	21.73	12.80
After OMV-MMD	6.04	10.22	17.16	22.10	13.42

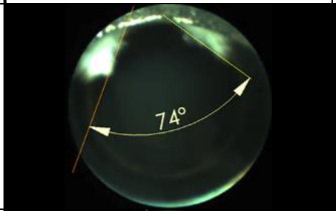
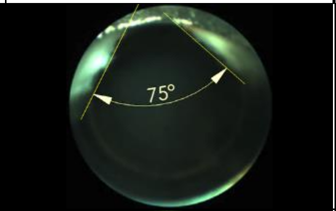
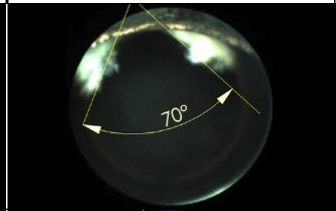
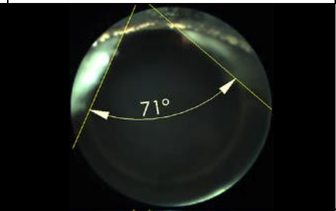
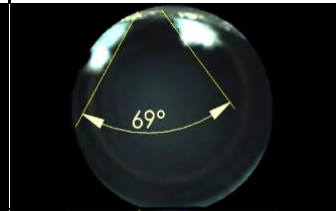
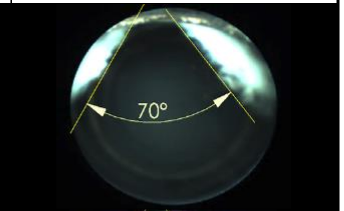
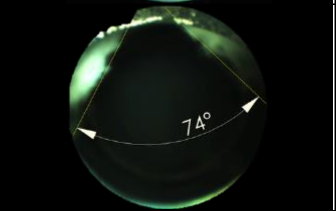
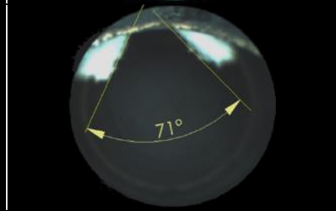
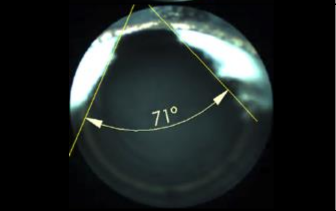
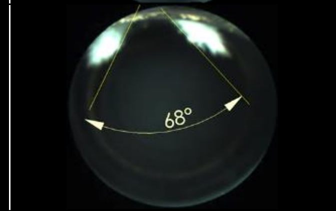
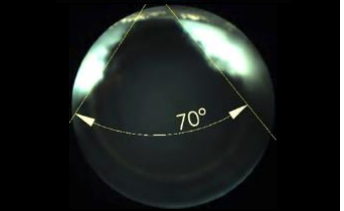
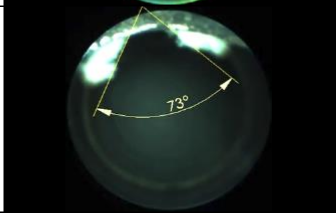
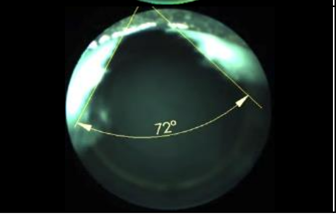
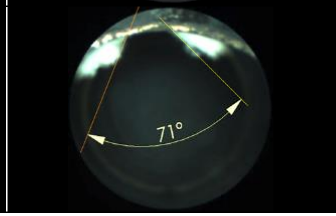
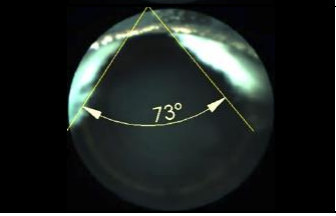
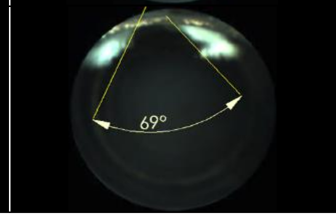
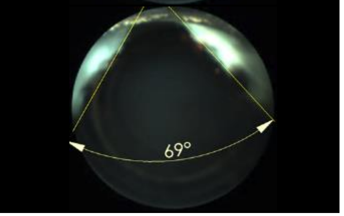
Fig. 4.16 Torque restore after OMV MaxxMotion Diesel compared to the initial value for Other Standard Diesel

Analysis

- Compared to the Start performance (power, torque) the use of "Other Standard Diesel" fuel during the 32 h test cycle (Table 3.1) has led to a lower End performance values. Considering the employed test cycle (CEC F-98-08 Direct Injection, Common Rail Diesel Engine Nozzle Coking Test), this decrease can be attributed to a coking effect;
- Compared to the Start performance (power, torque) the use of "OMV Diesel" fuel during the 32 h test cycle (Table 3.1) has led to a slightly improved End performance values for some of the test points, and a decrease for the others. Considering the employed test cycle, it can be concluded that the "OMV Diesel" does not add to the coking effect, thus maintaining the engine performance values;
- Compared to the Start performance (power, torque) the use of "OMV MaxxMotion Diesel" fuel during the 32 h test cycle (Table 3.1) has led to improved End performance values. Considering the employed test cycle, this decrease can be attributed to a cleaning effect;
- Compared to the "Other Standard Diesel" fuel, at the end of the corresponding 32 h cycle (Table 3.1) the use of "OMV Diesel" and "OMV MaxxMotion Diesel" led to an increase in exhaust gas temperature (in spite of the lower intake air temperature values), which can be attributed to the improved combustion process and cleaning effect of the fuel (considering the employed test cycle);
- The conclusions for "OMV MaxxMotion Diesel" are in agreement with an independent test performed on a 4-cylinder by DTC Testing GmbH [2].

4.2 Fuel jet dispersion

Table 4.1 Comparison of fuel jet dispersion for the three analyzed fuels

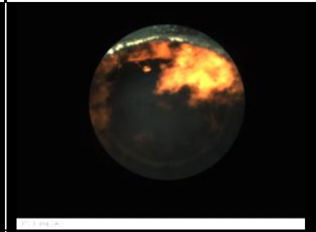
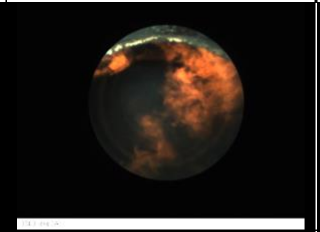
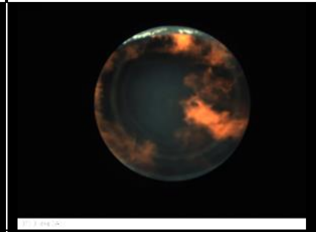
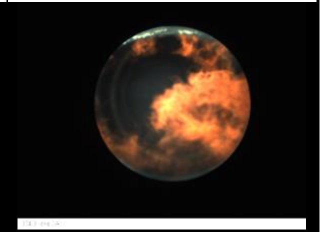
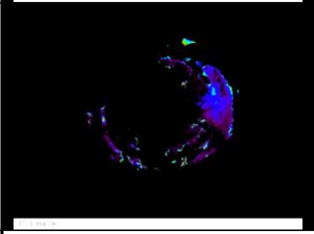
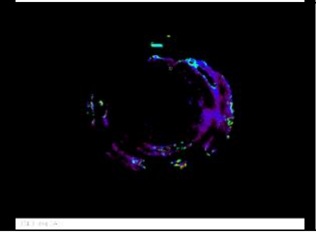
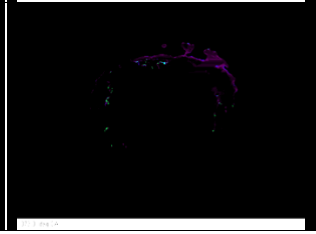
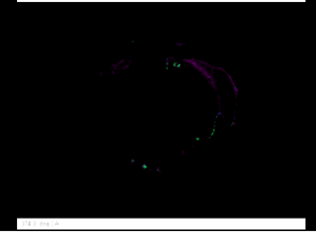
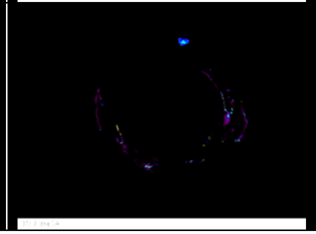
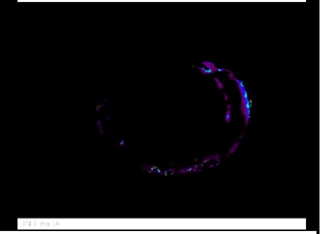
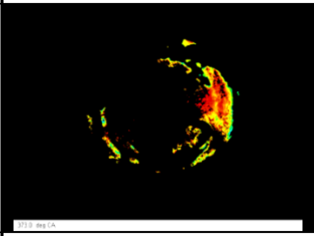
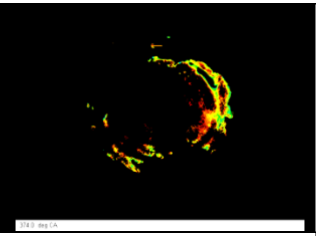
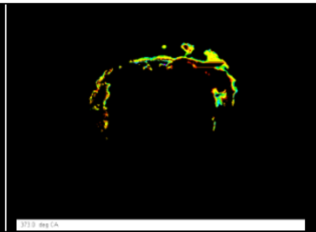
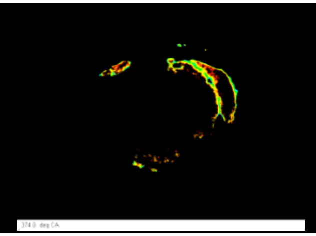
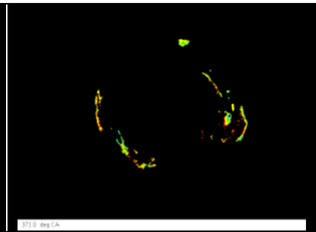
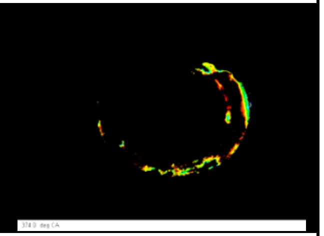
No.	Other Standard Diesel		OMV Diesel		OMV MaxxMotion Diesel	
	352 ° RAC	353 ° RAC	352 ° RAC	353 ° RAC	352 ° RAC	353 ° RAC
Median	74	74	71	72	70	70
1						
2						
3						

Analysis

- Compared to the "Other Standard Diesel" fuel, at the end of the corresponding 32 h cycle (Table 3.1) the use of "OMV Diesel" and "OMV MaxxMotion Diesel" led to smaller angles between jets as compared to the other Standard Diesel fuel tested;
- A smaller angle between jets is equivalent to an increased jet dispersion angle and consequently, an improved fuel distribution in the combustion chamber;
- The fuel jet dispersion angle is affected, among other factors, by injector nozzle deposits (in this case injection parameters were identical for all fuels).

4.3 Soot and temperature

Table 4.2 Comparison of soot and temperature data for the three analyzed fuels

	Other Standard Diesel		OMV Diesel		OMV MaxxMotion Diesel	
	373 ° RAC	374 ° RAC	373 ° RAC	374 ° RAC	373 ° RAC	374 ° RAC
Raw image						
Soot						
Area Median	4128		721		948	
Temperature						
Peak Median	2692		2689		2687	
Average Median	1784		1782		1780	

Analysis

- Compared to the “Other Standard Diesel” fuel, at the end of the 32 h cycle (Table 3.1) the use of “OMV Diesel” and “OMV MaxxMotion Diesel” led to smaller soot areas (in agreement with the fuel distribution observations) and consequently less deposits;
- The temperature values (peak and average) in the analyzed images are similar between the three fuels.

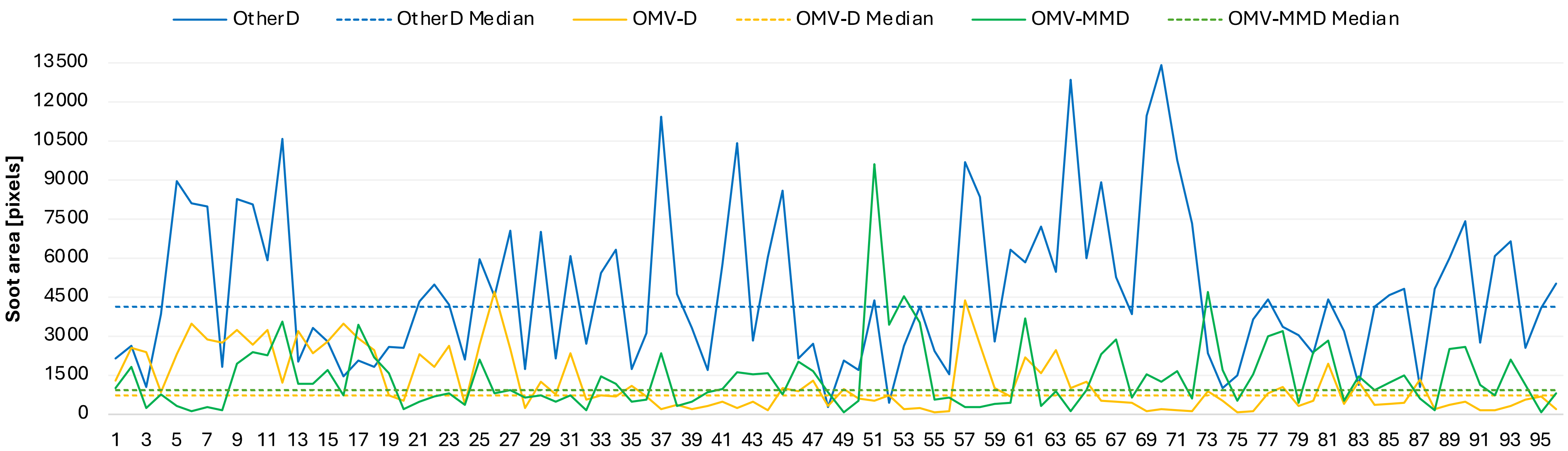


Fig. 4.17 Evolution of soot area for the analyzed images

5 CONCLUSIONS

For this study the CEC F-98-08 Direct Injection, Common Rail Diesel Engine Nozzle Coking Test was employed to determine the coking/cleaning effect of three different fuels. This test was specifically designed by The Coordinating European Council for the Development of Performance Tests for Fuel, Lubricants and other Fluids to highlight the coking propensity of a fuel. To this end, if the engine power after 32 one-hour test cycles is lower compared to the initial value, it is concluded that the fuel has a coking effect. However, if the engine power after 32 one-hour test cycles is higher compared to the initial value, it is concluded that the fuel has a cleaning effect.

Based on the above, the main conclusions after the 32 h test cycle are:

Other Standard Diesel (OtherD)

- Decreases engine performance (power, torque):
  The power and torque values dropped to

Test point	3000_35	3500_45	3000_60	2000_60	4000_60
Power	96.5%	95.6%	98.2%	97.5%	98.0%
Torque	96.6%	98.3%	98.6%	97.4%	96.4%

  of the initial values;
  Compared to the initial values
  - For the 3000_35 test point
    - the power <u>decreased</u> from 1.96 kW to1.89 kW kW (3.7%),
    - the torque <u>decreased</u> from 6.20 Nm to 5.99 Nm (3.4%);
  - For the 3500_45 test point
    - the power <u>increased</u> from 3.47 kW to 3.32 kW (4.6%),
    - torque <u>decreased</u> from 9.46 Nm to 9.29 Nm (1.7%);
  - For the 3000_60 test point
    - the power <u>increased</u> from 5.20 kW to 5.11 kW (1.8%),
    - the torque <u>increased</u> from 16.43 Nm to 16.20 Nm (1.4%);
  - For the 2000_60 test point
    - the power <u>increased</u> from 4.49 kW to 4.38 kW (2.6%),
    - the torque <u>increased</u> from 21.42 Nm to 20.86 Nm (2.6%);
  - For the 4000_60 test point
    - the power <u>decreased</u> from 5.67 kW to 5.56 kW (2.0%),
    - the torque <u>decreased</u> from 13.58 to 13.09 Nm Nm (3.6%);

- Decreases the fuel jet dispersion angle, thus hindering fuel distribution. As a result the coking effect and soot emissions increase;
- The fuel appears to have a coking effect.

OMV Diesel (OMV-D)

- Maintains engine performance (power, torque):
  The power and torque values increased for some test points and decreased for the others, leading to

Test point	3000_35	3500_45	3000_60	2000_60	4000_60
Power	89.1%	97.1%	99.3%	101.2%	94.7%
Torque	91.3%	96.9%	104.4%	101.5%	94.3%

  of the values at the beginning of “Other Standard Diesel”;

Compared to the end values for "Other Standard Diesel"

- For the 3000_35 test point
  - the power decreased from 1.89 kW to 1.75 kW (8.2%),
  - the torque decreased from 5.99 Nm to 5.66 Nm (5.8%);
- For the 3500_45 test point
  - the power increased from 3.32 kW to 3.37 kW (1.5%),
  - torque decreased from 9.29 Nm to 9.16 Nm (1.4%);
- For the 3000_60 test point
  - the power increased from 5.11 kW to 5.17 kW (1.1%),
  - the torque increased 16.20 Nm to 17.15 Nm (5.6%);
- For the 2000_60 test point
  - the power increased from 4.38 kW to 4.54 kW (3.7%),
  - the torque increased from 20.86 Nm to 21.73 Nm (4.0%);
- For the 4000_60 test point
  - the power decreased from 5.56 kW to 5.37 kW (3.5%),
  - the torque decreased from 13.09 Nm to 12.80 Nm (2.3%);

- Increases the fuel jet dispersion angle, thus improving fuel distribution. As a result the coking effect and soot emissions are reduced (compared to "Other Standard Diesel");
- The fuel appears to have a neutral cleaning-coking effect.

OMV MaxxMotion Diesel (OMV-MMD)

- Reestablishes engine performance (power, torque):
  The power and torque values increased to

Test point	3000_35	3500_45	3000_60	2000_60	4000_60
Power	92.9%	103.6%	102.2%	103.1%	99.5%
Torque	97.5%	108.1%	104.4%	103.2%	98.9%

of the values at the beginning of "Other Standard Diesel";
Compared to the end values for "Other Standard Diesel"

- For the 3000_35 test point
  - the power decreased from 1.89 kW to 1.82 kW (3.7%),
  - the torque increased from 5.99 Nm to 5.66 Nm (0.9%);
- For the 3500_45 test point
  - the power increased from 3.32 kW to 3.60 kW (8.3%),
  - the torque increased from 9.29 Nm to 10.22 Nm (10.0%);
- For the 3000_60 test point
  - the power increased from 5.11 kW to 5.31 kW (4.1%),
  - the torque increased from 16.2 Nm to 17.16 Nm (6.0%);
- For the 2000_60 test point
  - the power increased from 4.38 kW to 4.63 kW (5.8%)
  - the torque increased from 20.86 Nm to 22.10 Nm (5.9%);
- For the 4000_60 test point
  - the power increased from 5.56 kW to 5.65 kW (1.5%)
  - the torque increased from 13.09 Nm to 13.42 Nm (2.6%);

- Increases the fuel jet dispersion angle, further improving fuel distribution. As a result the coking effect and soot emissions are further reduced (compared to "Other Standard Diesel" and "OMV Diesel");
- The fuel appears to have a cleaning effect (compared to "Other Standard Diesel" and "OMV Diesel") – this is in agreement with a previous test by DTC Testing GmbH.

Project director
Assoc. Prof. PhD. Eng. Nicolae Vlad BURNETE

BIBLIOGRAPHY

[1] Regulation No 85 of the Economic Commission for Europe of the United Nations (UN/ECE) — Uniform provisions concerning the approval of internal combustion engines or electric drive trains intended for the propulsion of motor vehicles of categories M and N with regard to the measurement of net power and the maximum 30 minutes power of electric drive trains, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A42014X1107%2801%29&qid=1720010989413, accessed 4 July 2024

[2] DTC Testing GmbH, *Test report. Direct Injection, Common Rail Diesel Engine Nozzle Coking Test According to Dirty-Up and Clean-Up Test Procedure CEC F-98-08 PSA DW10 Engine*. Austria, January 2024

ANNEXES

Fuel purchase receipts


S.C. LUKOIL ROMANIA S.R.L.
CLUJ-NAPOCA, FABRICII NR. 147/A
STATIA CLUJ 7, JUD. CLUJ
COD IDENTIFICARE FISCALA: RO10547022
NUMAR BON: 209
OPERATOR: C.#. IRIMIA
EURO 1 DIESEL (PMP 6)
7.00 X 21.43 L 150.01 D
TOTAL 150.01

S.C. LUKOIL ROMANIA S.R.L.
CLUJ-NAPOCA, FABRICII NR. 147/A
STATIA CLUJ 7, JUD. CLUJ
COD IDENTIFICARE FISCALA: RO10547022
NUMAR BON: 260
OPERATOR: I. ONOFREI
DIESEL (PMP 6)
7.00 X 20.26 L 141.82 D
TOTAL 141.82

S.C. LUKOIL ROMANIA S.R.L.
CLUJ-NAPOCA, FABRICII NR. 147/A
STATIA CLUJ-7, JUD. CLUJ
COD IDENTIFICARE FISCALA: RO10547022
NUMAR BON: 232
OPERATOR: S.#. COC
EURO 1 DIESEL (PMP 6)
7.00 X 20.38 L 142.66 D
TOTAL 142.66
CREDIT 142.66
REST PLATA 0.00
TOTAL TVA D(19.00%) 22.78
TOTAL TVA 22.78
VISA&MASTERCARD S 142.66
#357700
2114459297299695
NUMAR POS: 3
DATA: 13/06/2024 ORA: 10:16:28
BON FISCAL
2000512795

S.C. OMV PETROM MARKETING S.R.L.
OMV CLUJ RING ROAD
STR. PRINCIPALA, NR 60/A
SUB COASTA, COM APAHIDA, JUD. CLUJ
C.I.F.: RO11201891
BON FISCAL
NUMAR POS: 1
NUMAR TRANZACTIE: 1200701/1/240618/103
* 5 OMV DIESEL
0,6765 L X 7,11 4,81 A

S.C. OMV PETROM MARKETING S.R.L.
OMV CLUJ RING ROAD
STR. PRINCIPALA, NR. 60/A
SUB COASTA, COM APAHIDA, JUD. CLUJ
C.I.F.: RO11201891
BON FISCAL
NUMAR OPT: 21/1
NR. TRAN.: 1200701/21/240618/00003
* 3 OMV DIESEL 20,0098 L X 7,11 142,27 A
TOTAL 142,27

S.C. OMV PETROM MARKETING S.R.L.
OMV CLUJ RING ROAD
STR. PRINCIPALA, NR 60/A
SUB COASTA, COM APAHIDA, JUD. CLUJ
C.I.F.: RO11201891
NEFISCAL
DOCUMENT NEFISCAL
NUMAR POS: 1
NUMAR TRANZACTIE: 1200701/1/240618/102
* 5 OMV DIESEL
42,1940 L X 7,11 300,00 A
CUPON 300,00
TICHETE UTILIZATE: 6
VALOARE TICHETE: 300,00
ADUNA PUNCTE IN OMV MYSTATION
SI TRANSFORMA-LE
IN PRODUSE SI SERVICII!
CASIER: LAPADEAN MARIA 001
18.06.2024 09:07:21 NF-2422-00029
NEFISCAL

S.C. OMV PETROM MARKETING S.R.L.
OMV CLUJ RING ROAD
STR. PRINCIPALA, NR.60/A
SUB COASTA, COM APAHIDA, JUD. CLUJ
C.I.F.: RO11201891
BON FISCAL
NUMAR OPT: 21/1
NR. TRAN.: 1200701/21/240702/00008
* 3 OMVMAXXD 21,3797 L X 8,19 17[illegible]
TOTAL

S.C. OMV PETROM MARKETING S.R.L.
OMV CLUJ RING ROAD
STR. PRINCIPALA, NR 60/A
SUB COASTA, COM APAHIDA, JUD. CLUJ
C.I.F.: RO11201891
BON FISCAL
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* 8 OMV MAXXMOTION DIESEL
23,7739 L X 8,23 195,[illegible]

S.C. OMV PETROM MARKETING S.R.L.
OMV CLUJ RING ROAD
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NEFISCAL
DOCUMENT NEFISCAL
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18,2260 L X 8,23 150,00

S.C. OMV PETROM MARKETING S.R.L.
OMV MARASTI
PTA. MARASTI, F.N.
MUN. CLUJ-NAPOCA, JUD. CLUJ
C.I.F.: RO11201891
BON FISCAL
FUEL THE FUN AT ELECTRIC CASTLE!
PLATESTE CU MASTERCARD LA OMV,
INSCRIE BONUL PE WWW.OMV.RO
SI POTI CASTIGA UNUL DIN CELE 150X
PREMIUM PASS.
NUMAR POS:
NUMAR TRANZACTIE: 5200413/2/240610/1[illegible]
* 4 OMV MAXXMOTION DIESEL
20 L X 7,61 152,[illegible]
TOTAL: 15[illegible]
NUMERAR 15[illegible]
ADUNA PUNCTE IN OMV MYSTATION
SI TRANSFORMA-LE
IN PRODUSE SI SERVICII!