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NOx emission measurement

of a passenger car

Opel Zafira Diesel, Euro 6b

on the roller dynamometer

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1. SUMMARY

The German Environmental Aid Association (DUH) charged the exhaust emission control laboratory of the University of Applied Sciences in Bern to examine the NOx emissions of a passenger car – an Opel Zafira (EURO 6) – on the roller dynamometer. The measurement results show that the vehicle behaves differently when the dynamometer is operated in the 4- or 2-wheel mode.

2. TEST VEHICLE

The vehicle's most important technical parameters tested are listed in the table below. The vehicle has a diesel engine and a particulate filter and SCR system for exhaust gas treatment.

Fig. 1: OPEL Zafira CDTi 1.6 on the 4x4 roller dynamometer at the exhaust emission control lab

Model/year	OPEL Zafira 16 CDTi/2015
Engine type	B16DTH
Number of cylinders	4-series
Cubic capacity	1598 cm^3
Performance	100 kW @ 4000 rpm
Torque	320 Nm @ 2000 rpm
Fuel/injection	Diesel /DI common rail
Charger	VTG
Kerb weight	1650 kg
Gross vehicle weight	2410 kg
Drive	Front-wheel drive
Gearbox	Manual 6 gear
Year of first registration / mileage	08.2015 / ~ 6000 km
Emission standard complied with	EURO 6b
Exhaust gas treatment	DPF, SCR
VIN	W0LPD9E38F2008269

Table 1: Specifications of the test vehicle

3. MEASUREMENT TECHNOLOGY

3.1. Roller dynamometer test bench

• Type:	AFHB GSA 200
• Roller diameter:	502 mm
• Driver control station:	Tornado, Version 3.3
• CVS dilution system:	Control System R03-700 with roots blower
• Ambient conditions of test hall:	Control for intake and dilution air Temperature: 20 - 30°C Humidity: 5.5 – 12.2. g/kg

For all measurements carried out on the above-mentioned vehicle, the roller dynamometer was adjusted according to the manufacturer's instructions.

3.2. Measurement instruments for limited emissions

The following devices meet the technical requirements of ECE Regulation No.83. They are suitable for measuring vehicle exhaust emissions in Switzerland and the European Union.

• exhaust components measured:

Exhaust gas measurement technology gaseous: Horiba MEXA-7200

CO, CO2…	infrared spectroscopy (NDIR)
HC...	flame ionization detector for total HC (FID)
CH4...	flame ionization detector only for HC4 (FID)
NO/NOx...	chemiluminescence analyzer (CLA)

The dilution ratio in the CVS system is variable and can be checked by means of CO2 analyzers.

3.3 Exhaust gas temperature measurement

To determine the exhaust gas temperature, a type K thermocouple was mounted at the exhaust pipe end of the exhaust system. This temperature does not correspond to that of the exhaust aftertreatment system, but nevertheless permits a comparison between the various measurements to be made.

4. TEST METHOD

During the tests, the following parameters were changed or varied:

. SCR – dosing unit (AdBlue injection):
During two measurements, the AdBlue dosing unit was electrically disconnected. Thus, AdBlue dosing was interrupted during the whole measurement. This manipulation did not cause any OBD efaults to be stored in the control unit during the measurement.

. Roller dynamometer test bench mode:
The roller dynamometer can be operated in two different modes: 2WD or 4WD.

In the 4-wheel drive mode (4WD), the rear wheels rotate at the same speed as the front wheels. In 2-wheel drive mode (2WD), the two rear wheels are stationary.

. Electrical consumers in the vehicle:
The following electrical appliances were connected to the engine for the duration of each cycle: air conditioning, heated seats, heated steering wheel, radio, high beam, fog lamps, rear fog lights, rear window defroster.

. Engine condition cold / hot:
Measurements were performed with cold and warm engine states.
To measure the NEDC cold, the vehicle was conditioned the day before.

4.1 Test cycles

The following driving cycles were used during the tests:

New European Driving Cycle (NEDC)

The NEDC is the current test cycle for passenger vehicle homologations (EUR 6) in the EU.

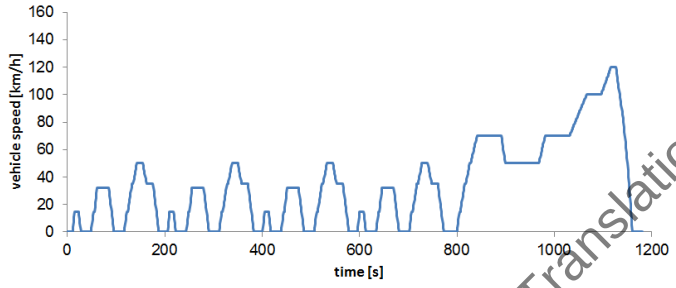

Fig. 2: NEDC

Driving cycle 1

This cycle consists of a warm-up phase of 7.5 minutes at a speed of 80 km/h; then the target speed is continuously increased to 150 km/h. The maximum speed of 150 km/h is kept constant for 90 seconds.

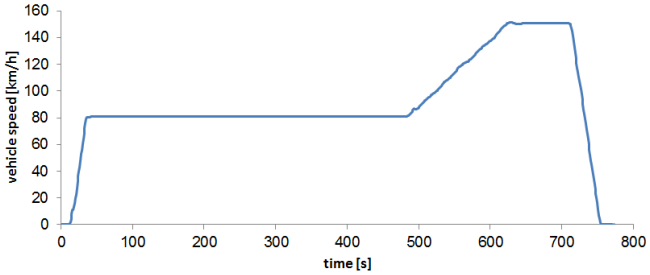

Fig. 3: Driving cycle 1

Driving cycle 2

This cycle starts with 3 low-speed levels. In this case, the velocities of 20, 35 and 45 km/h were kept constant for 5 minutes each. The speed is then accelerated to the final speed of 150 km/h with the same constant acceleration as shown in cycle 1. This speed is maintained for of 120 seconds. The speed is, however, reduced like the starting procedure but in reverse order, with the same speeds levels.

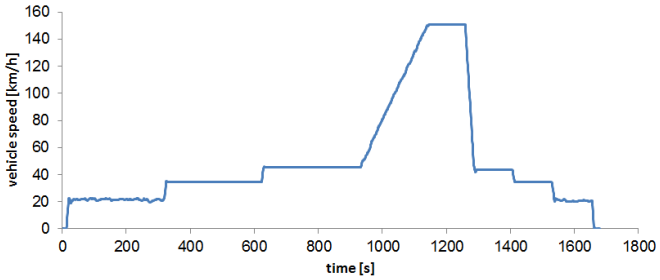

Fig. 4: Driving cycle 2

5. RESULTS

The list of all the measurements taken can be found in Fig.6. Several experiments were carried out in the respective cycles; in each case their results are represented as a function of time in Fig. 7 to Fig. 23.

The next section documents only the key findings.

5.1 Results in the NEDC

The cycle was repeated six times in total: three times in the 4-wheeled drive mode and three in the 2-wheel drive mode. The behaviour of the engine was also observed in the hot and cold (conditioned) state.

The NOx results of all the NEDCs completed are listed in Fig. 5.

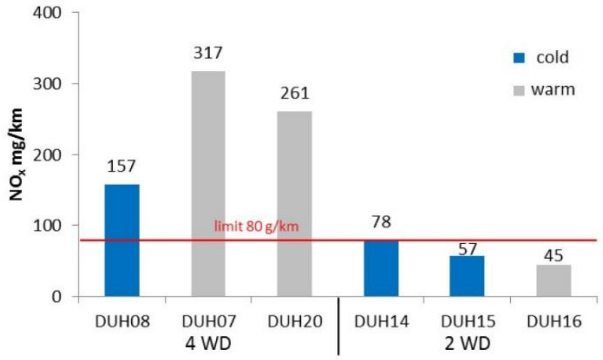

Fig. 5: Results of the NEDC (raw results without deterioration factor)

RESULTS NEDC			CO mg/km	NOx mg/km	CO2 mg/km
DUH08	4WD	cold	264.6	157.0	138.1
DUH07	4WD	warm	10.7	317.3	128.0
DUH20	4WD	warm	9.7	260.7	114.8
DUH14	2WD	cold	196.4	78.4	128.4
DUH15	2WD	cold	8.9	56.9	126.1
DUH16	2WD	warm	13.4	44.8	121.2
Limit values			*500*	*80*	*170*

Table 2: Results of the NEDC (raw results without deterioration factor)

The NOx values of all three measurements in 2-wheel drive mode were below the prescribed limit of 80 g/km in each case. The opposite behaviour is observed among three measurements in the 4-wheel drive mode. In the process, the threshold value was exceeded by a factor of 2-3.
It is apparent that the initial state of the vehicle is not as critical as the drive mode of the test stand.

5.2 Results in cycle 2

Fig. 25 shows the comparison of NOx emissions during the two cycles in the 4- and 2-wheel drive modes.

The first three speed levels in these measurements show that the vehicle emitted less NOx when the roller dynamometer was operated in the 2-wheel drive mode. This behaviour could be associated with greater SCR activity.

NOx emissions suddenly rose abruptly on the speed ramp in 2-wheel drive mode. The emission level exceeded the set measuring range of the instrument. The behaviour could be explained by a shutdown of the AdBlue dosing unit. Similar behaviour was not detectable when operated in the 4-wheel drive mode.

6. CONCLUSION

The measurements carried out showed the following trend:

. The NOx emissions in the NEDC cycle depend on the test mode of either 2WD or 4WD.

. In the 2-wheel drive mode, the vehicle met the NOx regulations.

. At low speeds, NOx emissions are not always identical and are likely to depend on the activity or the storage effect of the SCR system.

. The behaviour of the SCR system seems to be dependent on the test mode, since the NOx courses are different in the two test stand modes of operation.

7. DOCUMENTATION

The original data are archived at the Laboratories for IC-Engines and Exhaust Emission Control at the University of Applied Sciences Biel and represent confidential material.

8. LIST OF FIGURES

9. ABBREVIATIONS

AFHB	Laboratories for IC-Engines and Exhaust Emission Control at the University of Applied Sciences Biel, CH
CLD	Chemiluminescence detector
CVS	Constant Volume Sampling: Dilution Tunnel for Regulated Emission Measurement
DF	Dilution factor
DI	Direct Injection
DPF	Diesel Particle Filter
ECU	Electronic control unit
EU	European Union
FID	Flame ionization detector
NDIR	Non-dispersive infrared
NEDC	New European Driving Cycle
OBD	On board diagnosis
PM	Particulate matter, particle mass
VIN	Vehicle identification number