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Assessment of Exhaust Emissions and Fuel Consumption from Means of Transport in Agriculture

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***Abstract*—**The paper discusses the problem of load transport using farm tractors and road tractor units. This type of carriage of goods is often done with farm vehicles. The tests were performed with the PEMS equipment *(Portable Emission Measurement System*) under actual traffic conditions. The vehicles carried a load of 20000 kg. This research method is one of the most desired because it provides reliable information on the actual vehicle emissions and fuel consumption (carbon balance method). For the tests, a route was selected that simulated a trip from a small town to a food-processing facility located in a city. The analysis of the obtained results gave a clear answer as to what vehicles need to be used for carriage of this type of cargo in terms of exhaust emissions and fuel consumption.

***Keywords*—**Emission, transport, fuel consumption, PEMS.

I. Introduction

TRANSPORT, one of the major sectors of the economy, remains a significant source of exhaust emissions and one o of the largest consumers of fossil fuels. An important component of the transport system is transit of food and agriculture produce necessary for its production. Such transport is very often realized with the use of farm tractors. This is particularly the case for carrying loads to food-processing facilities. When it comes to in-farm carriage, farm tractors are also used frequently.

Fuel consumption tests, including the measurement of the exhaust emissions, that heavy-duty vehicles and farm machinery are subjected to, are performed on engine dynamometers. They consist in testing the engines at certain operating parameters such as torque (engine load) and engine speed. The authors' previously performed investigations have proven that normative tests do not fully reflect the actual conditions of a vehicle operation [1]. Such a situation increases interest in worldwide vehicle energy-consumption research based on PEMS *(Portable Emission Measurement System*). Only tests with this type of equipment performed under actual operating conditions, characteristic of a given transport group, provide a reliable source of exhaust emissions data [2]. PEMS also allows measurement of the fuel consumption. In future, this type of research is to be used in the homologation procedures for heavy-duty vehicles.

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II. Research Objects and Measurement Equipment

Two vehicles carrying oversized loads were used for the tests. These were a Scania R420 tractor unit with a semi-trailer and a John Deere 7230R farm tractor with a dual-axle cargo trailer. Basic technical specifications of the tested objects have been shown in Table I.

TABLE I
BASIC TECHNICAL DATA OF THE TESTED VEHICLES [3]

Name	Scania R420	John Deere 7230R
Number of cylinders / displacement	6, inline/11.7 dm^3	6, inline/6.8 dm^3
Maximum power	309 kW at 1900 rpm	186 kW at 2100 rpm
Curb weight	7700 kg	10552 kg
Supercharging	Turbocharger (FGT)	Turbocharger (VGT)
Cooling	Forced circulation	Forced circulation
Injection system	Pump nozzle	Common Rail
Number of cylinders	24	24
Exhaust emission standard	Euro 3	Stage IIIB

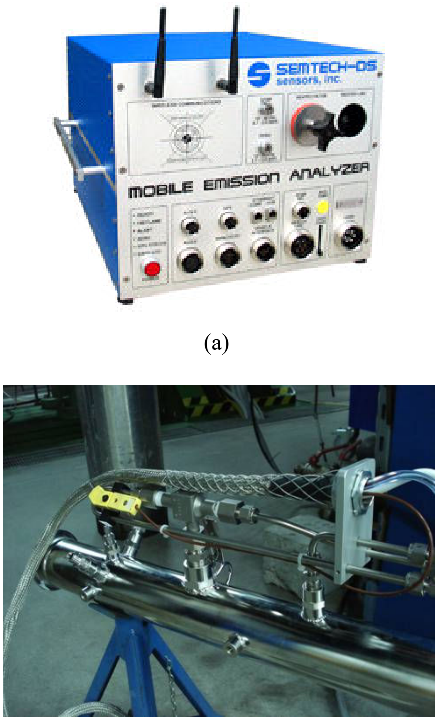
Both vehicles were fitted with diesel engines of the same number of cylinders (6) but different capacities, maximum power outputs and fuel injection systems. The view of the vehicles with the measurement equipment fitted has been shown in Fig. 1.

(a)

(b)

Fig. 1 View of the vehicles and the measurement equipment during the on-road tests

The assessment of the exhaust emissions level was performed with the PEMS equipment measuring the concentration of the exhaust gas components under actual conditions of operation. In the work described in the paper, Semtech DS - a portable exhaust emissions analyzer manufactured by Sensors Inc. was used (Fig. 2 (a)). The entire volume of the exhaust gas from the exhaust system of a farm tractor and the road tractor unit was sent to the mass flow meter (Fig. 2 (b)) and then through a measurement probe (maintaining the temperature of 191°C) to the analyzer (Fig. 3). The device filtered the exhaust gas to separate the particulate matter (PM). In the next step, the system measured the concentration of hydrocarbons in a FID (Flame Ionization Detector). The exhaust gas was then chilled to the temperature of 4°C and the concentrations of nitrogen oxides (NDUV, Non–Dispersive Ultra–Violet), carbon monoxide/carbon dioxide (NDIR, Non–Dispersive Infrared) and oxygen (electrochemical analyzer) were measured. The device is compatible with the vehicle's on-board diagnostic system (recording of the operating parameters - engine speed and load) and GPS (latitude and longitude for determining the vehicle speed).



(a)

(b)

Fig. 2 Semtech DS analyzer and the exhaust gas mass flow meter by Sensors Inc. [4]

The authors used Semtech LAM (*Laser Aerosol Monitor*) by Sensors Inc. (Fig. 4) for the measurement of particulate matter. The device uses laser light dispersion triggered by particulate matter contained in the exhaust gas. Semtech LAM can determine the real time concentration of PM in the exhaust gas.

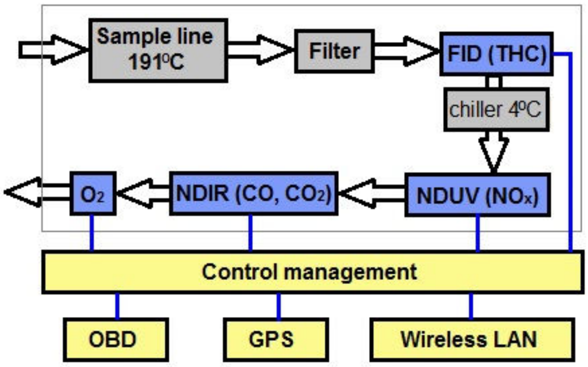


Fig. 3 Diagram of the portable exhaust emissions analyzer (SEMTECH DS) with the exhaust gas flow and electrical connections marked [4]

Fig. 4 Semtech LAM Sensors Inc

III. Research Methodology

A reliable exhaust emissions measurement requires selecting a test road portion, typical of a given group of vehicles. During the tests, the vehicles covered a distance in a rural area from the town of Dabie to the town of Kolo. The route has been shown on the map in Fig. 5.

The length of the route was 22.3 km. The task of the tested vehicles was to carry 20000 kg of cargo. During the tests, the PEMS equipment measured the exhaust components (CO, HC, NO_x, CO_2 and PM) and fuel consumption (carbon balance method).

IV. Results

Based on the exhaust emissions measurements performed under actual conditions of operation, it has been observed that the road emission of CO for the farm tractor was 3 g/km and was by 1.5 g/km higher than that of the truck (Fig. 6). The road emission of NO_x, HC and PM was also higher for the farm tractor, but the percentage differences were smaller than for carbon monoxide.

In order to ensure clarity of the results they were compared in a relative form against the emission of the road tractor unit, which equaled 1 (Fig. 7). The smallest relative differences in the road emissions were recorded for HC and NO_x, which were 26% and 18% respectively. For CO and PM these values were greater – 50% and 46% respectively.

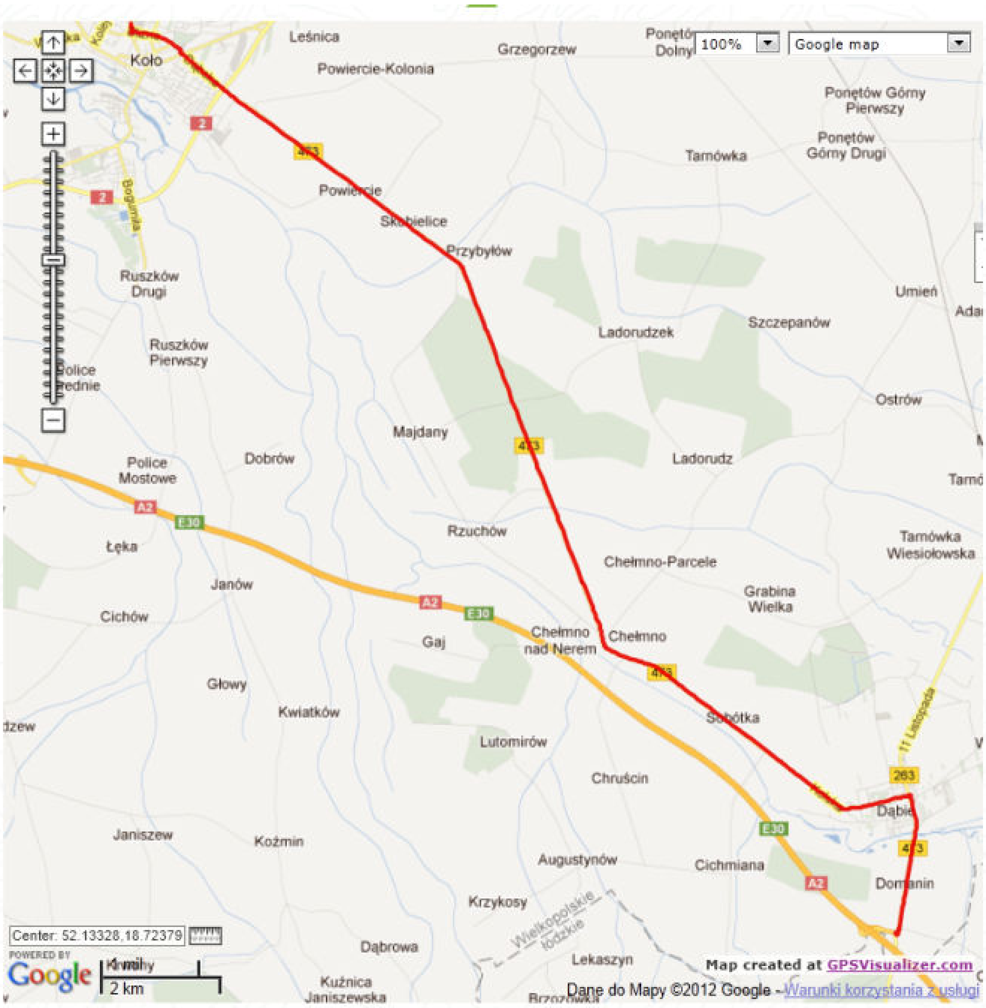


Fig. 5 The route on which the 20000 kg of load was carried (map created on [5])

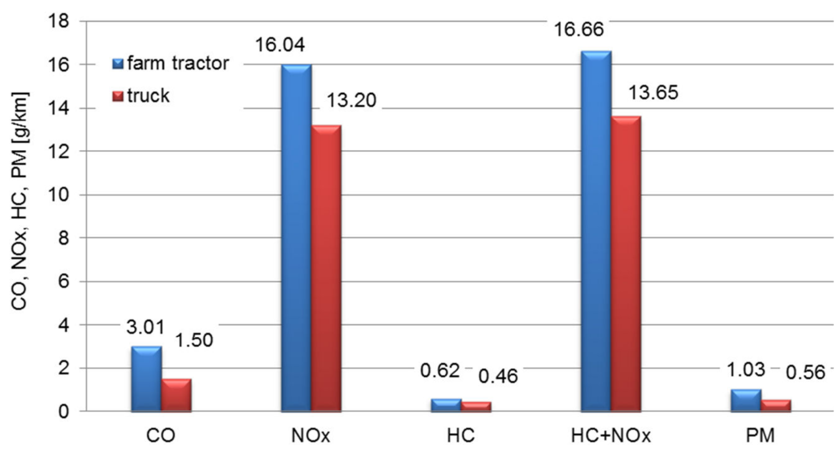


Fig. 6 Comparison of the road emission of the tractor and the truck during the test under actual operating conditions

The analysis of the obtained values of the exhaust components containing carbon (HC, CO and CO_2) determined the fuel consumption (carbon balance method, Fig. 8). The farm tractor used more than 64 dm^3 of diesel fuel per 100 km, which was almost twice as much compared to the truck.

Such a significant difference results mainly from the drivetrain design that was inappropriate for road transport (gear ratios, large tires) and higher motion resistance (difference of curb weights of the tested vehicles). These factors also contributed to the fact that the truck had higher average speed during the test run, which was 52.2 km/h

(Fig. 9 (a)) i.e. 46% higher than the speed of the farm tractor. This reduced the time needed to cover the distance by 61% (Fig. 9 (b)).

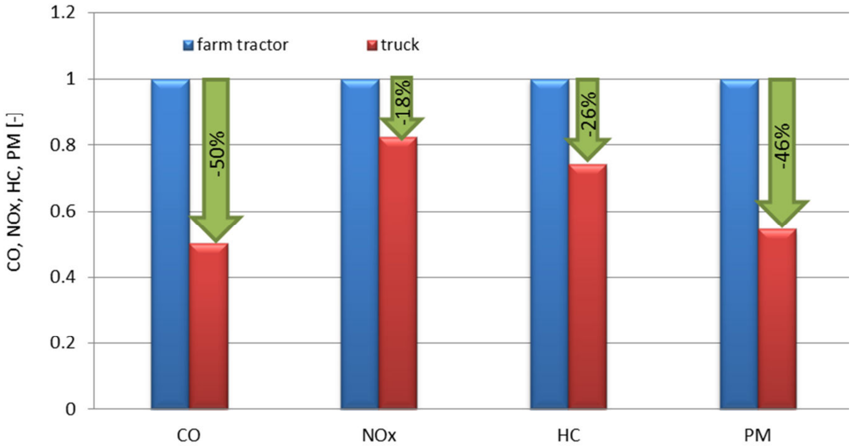


Fig. 7 Comparison of the relative road emission of the tractor and the truck during test under actual operating conditions

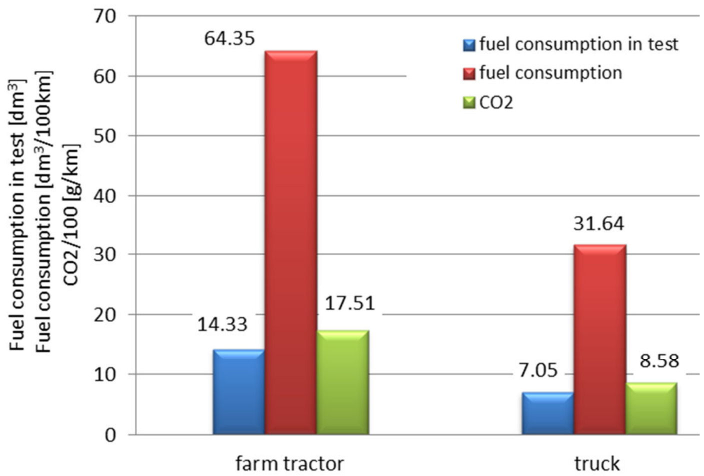
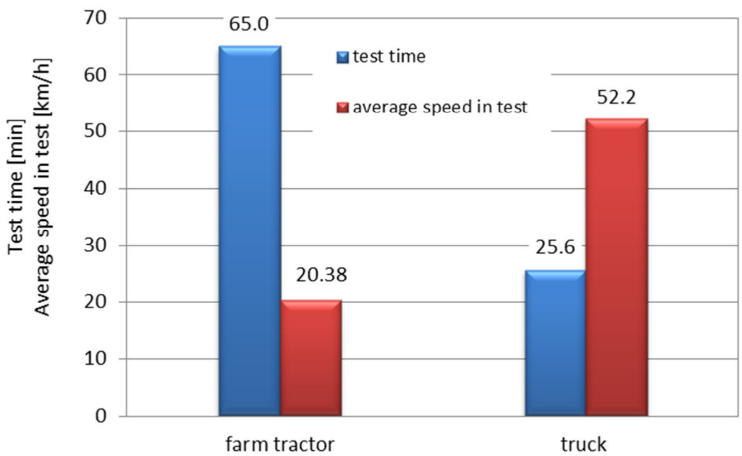
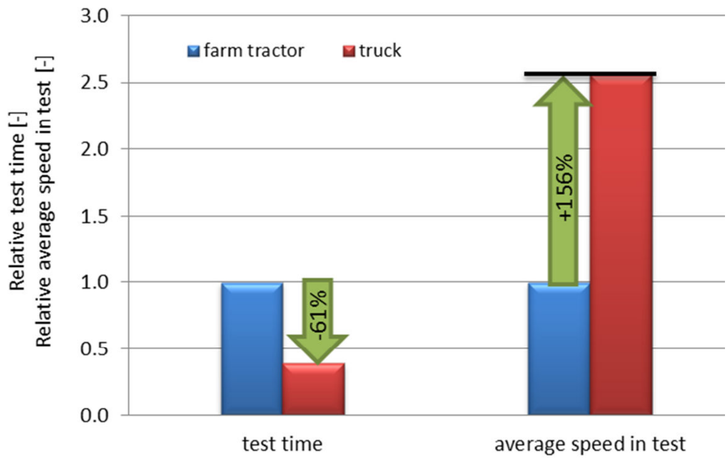


Fig. 8 Fuel consumption during the test under actual conditions of operation



(a)



(b)

Fig. 9 (a) Time and average speeds of the test run during the tests under actual conditions of operation, (b) relative time and speeds of the test run

V. Conclusion

The presented results confirm the need of carrying goods on public roads by road trucks rather than farm tractors. Using farm tractors for carriage of goods on public roads significantly exposes the natural environment to excessive exhaust emissions to a much greater extent than it is in the case of heavy-duty trucks and increases the operating costs due to increased fuel demand. The differences shown in the investigations in both, exhaust emissions and fuel consumption were significant. Load carriage by heavy-duty trucks also reduces the time consumption.

While performing the investigations, the authors' attention was drawn to certain traffic safety issues. The problem has not been addressed in this paper, but it is rather obvious that farm tractors slow down the traffic and expose the road users to a variety of hazards.

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