UTILIZATION OF OPERATIONAL PARAMETERS MONITORING TO ECONOMICAL AND SAFETY DRIVE OF VEHICLES

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The paper is focused on the issue of measuring the amount of fuel in the tank of truck, construction and agriculture machine. The gradual expansion of of the share of the biocomponent in diesel fuel results in greater measurement errors via the capacitive probe in the fuel tank. The proposed solution, which uses three electrodes leads to increased accuracy in measuring of the amount of fuel in the tank. According to standard EN 590, the measurement error of the new capacitive probe is only 1.5% when using diesel. The highest measurement error 4% is achieved when using neat rapeseed oil methyl ester. The previous solution of the capacitive probe when using diesel fuel according to EN 590 achieved a measurement error of 2.5%, but it increased significantly with the proportion of rapeseed oil methyl ester up to 70% when using neat rapeseed oil methyl ester. The new capacitive probe concept with two positive electrodes and higher accuracy can be used to evaluate driving style towards economical and environmentally friendly driving. It is also possible to focus on safe driving style of drivers using other operating parameters. The aim of the paper is to compare the capacitive probe with one and two positive electrodes and demonstrate their use in evaluating the driving style of drivers.

KEYWORDS

diesel., rapeseed oil methyl ether, biofules, capacitive probe, driving style of driver

1 INTRODUCTION

Currently, transport is facing major problems, mainly related to the way of traction of trucks and construction machine [Nag 2019, Chen 2019, Chu 2011, Zhang 2011]. An internal combustion engine that uses liquid or gaseous fuels is largely involved in the drive of vehicles. [Bugoslawski 2007, Goede 2018, Mattarelli 2014]. Today, internal combustion engine is gradually being replaced by an electric drive.

The internal combustion engine is criticized especially with regards to the issue of combustion of the fuel mixture, which subsequently releases components that are harmful to health and include carbon monoxide, hydrocarbons, nitrogen oxides, particulate matter and carbon dioxide, which contribute to global warming. [Dinc 2020, Anisur 2013, Acar 2020]. The gradual tightening of emission limits has led to the development of new systems that have reduced emissions from internal combustion engines. Recently, these systems predominantly include selective catalytic reduction and particulate filters. [Yang 2019, Kim 2022].

At first sight, the electric drive seems to be emission-free. However, it is necessary to realize, that the production of emissions is moved from the vehicle to the place where the electrical energy is produced. Then it is purely dependent on the energy mix, which is made up of non-renewable and renewable resources Except this main advantage, electric vehicles suffer problems with travel time, battery safety, weight and more.

The issue of life cycle analysis and CO_2 production is also very questionable. It always depends on who performs an analysis, what the analysis includes and what basic boundary conditions has been chosen. This then essentially predetermines the result, which is suitable for one or the other side. [Bilgilli 2021, Moosavian 2021, Fiaschi 2001, Bata 2019].

However, both sides have one thing in common, which is the driver who drives the vehicle. Today, the vehicles are equipped with a range of modern assistance systems, automatic multi-speed transmissions, modernized engine control units, but still the basic instructions for the operation of the vehicle are given by the driver and the systems adapt. [Wickramasinghe 2019, Muslim 2018, Fleming 2019, Yoon 2020]. However, as operational monitoring shows, only a very small percentage of drivers can use the potential of the vehicle in the ecological and economic area of its operation. [Rutty 2013, Rutty 2014, Negre 2017]. In the case of a truck, the difference in fuel consumption can be up to one third (one driver achieves an average consumption of 27 l/100 km and the other driver achieves 35 or more l/100 km on the same route).

In order to further reduce the impact of vehicle's operation on the environment, it is necessary to focus on educating drivers for economical, ecological and safe driving. One option is to take advantage of some of the leading vehicle manufacturers who already offer a basic driving style evaluation or choose an external company, which is not only intended for a specific vehicle brand, but can be used for any fleet. [Baric 2013, Seecharan 2015, Ayyildiz 2017] For the external evaluation system, it is important to obtain objective data to assess the driver's driving style, and therefore it is necessary to use independent sensors, such as capacitive probes to monitor the amount of fuel in the tank.

The paper deals with the use of monitoring of operational parameters from on-board system of vehicles and modernized capacitive probe for monitoring the fuel level in the tank. This modernized capacitive probe solves a significant problem, which lies in the different proportions of the biocomponent added into the fuel, which is in the fuel tank and affects the accuracy of the method used.

2 MATERIALS AND METHODS

In order to monitor and evaluate the operation of the vehicle and the driver's driving style, it is necessary to obtain some important operating parameters from the truck. These important operational parameters include information on:

- fuel consumption from FMS (Fleet management system) and capictance probe, refueling and vehicle position,
- driving speed, gearshifting and engine speed,
- use and handling of the braking systems of vehicle,
- steering wheel position and use of safety assistants.

Information about the amount of consumed fuel and position of vehicle is obtained from processed data from capacitive probe, which is also equipped with a GPS reciever.

Scheme of capacitance probe is shown in Figure number 1.

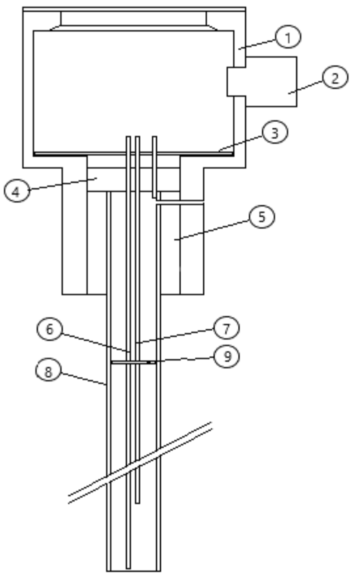

Figure 1 Scheme of capacitive probe

1 Head of capacitive probe
2 Cable bushing
3 Printed circuit board
4 PTFE liner
5 Insulating insert
6 First positive electrode
7 Second positive electrode
8 Negative electrode
9 PTFE liner

The diesel permittivity change with the rapeseed oil methyl ester content in the diesel. This aspect affects the accuracy of the measurement and therefore the single positive electrode concept is not suitable. Following options can be used to eliminate these problems.

- use of two capacitance probes of different lengths - this solution is not suitable - difficult installation in operation and increased costs,
- use of one probe with two electrodes:
  a) use of one probe which has two electrodes with the same length with different capacitive dependence (linear x nonlinear),
  b) The capacitance probe contains two positive electrodes of different lengths (Fig. 2)

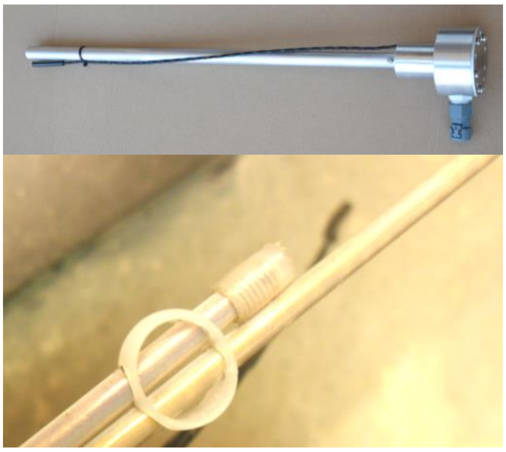

Figure 2 Capacitance probe with two positive electrodes of different lengths

The measured capacitance *C* (equation no. 1) is a function of the tank filling and permitivity of the liquid in the tank, where *V* is the tank filling, *P* is the permitivity of the liquid in the tank and *f* is the sensing function given by the shape of the electrodes. In the case that the positive electrode is paralell with the negative electrode, this function is linear.

$$C = f(V,P) \qquad (1)$$

C – measured capacitance of the probe (F)
V – volume of the tank filling (m^3) expressed as the level in the tank (m)
P – permitivity of the liquid in the tank ($F \cdot m^{-1}$)

Telecommunication unit (Fig. 3) is connected to the vehicle control unit in order to obtain the remaining operational parameters of the vehicle. The unit collects the defined data from FMS. This data are processed and sent to the server, where the data is provided to the driver so that he can focus on improving driving style. Also, the data can be used by the company's management to compare the whole group of drivers.

Figure 3 Telecomunication unit

3 RESULTS AND DISCUSSION

Calibrated measuring cylinders and several basic types of fuel (100 % diesel – 100 D, 3.9 % RME – 3.9 M, 30 % RME – 30 M, 100 % RME – 100 M) were used to verify the difference in accuracy of the capacitive probe with one and two electrodes. The measurement was performed at room temperature. The results are given in the percentage expression of the calibrated measuring cylinder filling and shown in the Figures 4-7. The probes were firmly connected with the calibrated measuring cylinder and the selected fuels were repeatredly refilled using a small electric pump. The probes with the lenght of 530 mm were placed in the measuring cylinder. The probe with two positive electrodes had a length of one 530 mm and the other 500 mm. The default settings of the probes was calibrated using 100 D with the use of device Saluda Ltd.

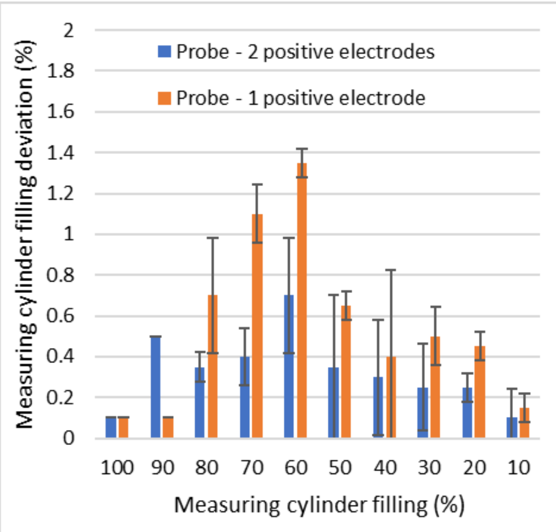

Figure 4 Measuring cylinder filling deviation –100 D

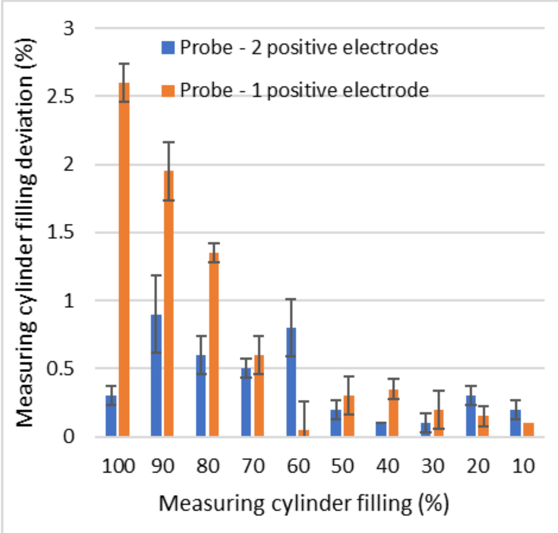

Figure 5 Measuring cylinder filling deviation – 3.9 M

From the measured values for the probe with one and two positive electrodes, it can be stated that due to the small standard deviation, the repeatability of the measurement is ensured.

However, large differences occur in deviation from the actual value. The single positive electrode concept achieves acceptable maximum deviations when using 100 D (approx. 1.4%) and 3.9 M (approx. 2.5%) fuel. With 30 M (approx. 22.5%) and 100 M (approx. 70%) fuel used, the maximum deviations are completely unacceptable.

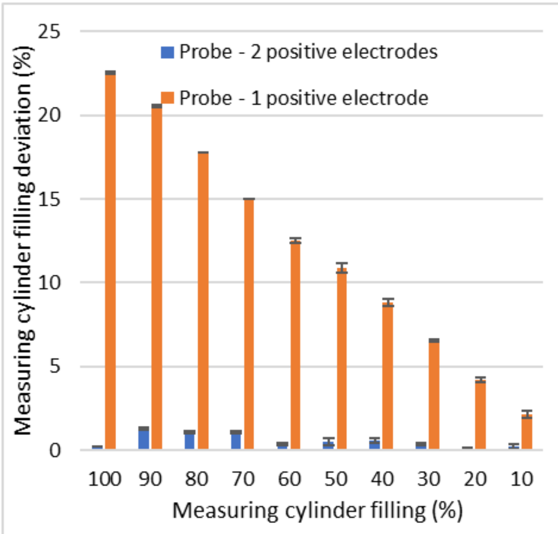

Figure 6 Measuring cylinder filling deviation – 30 M

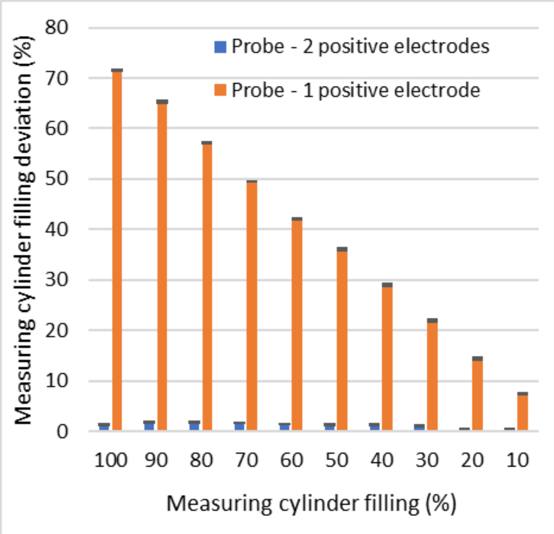

Figure 7 Measuring cylinder filling deviation – 100 M

On the other hand, the capacitive probe, which contains two electrodes, reached maximum deviations at 100 D (approx. 0.7%), 3.9 M (approx. 0.9%), 30 M (approx. 1.3%) and 100 M (about 1.9%). From the overall view in Figure 8, it can be stated that the capacitive probe with two positive electrodes does not have a deviation of more than 2% in the whole measurement range and different ratios of diesel and rapeseed oil methyl ester.

When using the probe with one positive electrodes the result is directly dependant on the permitivity of the liquid in the tank. Accuracy of the measurement is then given by the performed calibration. For the used example the calibration is performed using 100 D, in praxis a value close to 3.9 M is usually used, since it is the average value based on the standard EN 590. When using the probe with two positive electrodes the result is also dependant on the liquid permitivity, but in this case the permitivity is not given as a constant, as in the case of probe with one positie electrode, but it is a result of the measurement.

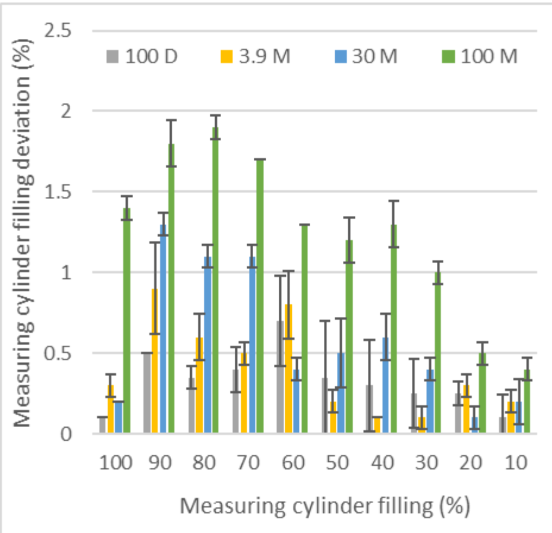

Figure 8 Capacitive probe with two positive electrodes

In terms of measurement accuracy (Fig. 8), it can be stated that the new probe with two positive electrodes achieves measurement error below 2% in the normal range of rapeseed oil methyl ester (up to 30% biodiesel). With standard diesel according to EN 590, the measurement error does not even exceed 1.5%. If there is a higher proportion of rapeseed oil methyl ester in diesel, there is also a higher measurement error, which reaches up to 4% when using 100 % rapeseed oil methyl ester, especially with a lowe tank filling. With a probe filling in the range of 50 to 100%, the measurement error is below 2.5% in this case as well.

The use of the capacitive probe in real operation is already common. Figure 9 shows the installation of the capacitive probe in the fuel tank of the MAN truck and Figure 10 shows the installation of the telecomunication unit.


Figure 9 Installation of the capacitive probe in the fuel tank – MAN truck

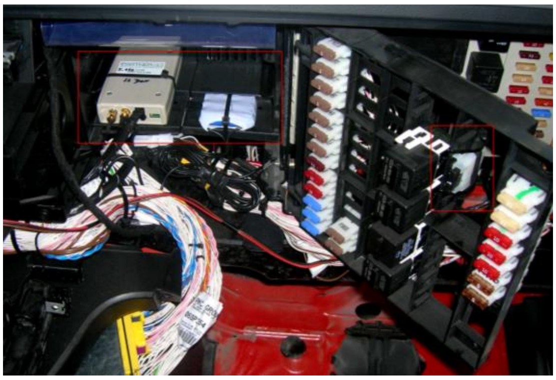
Figure 10 Installation of the telematics unit – MAN truck

Drive of the vehicle in real conditions differ from the measurement in laboratory conditions mainly in drive dynamics and inclination. For elimination of these effects the probe is equipped with inclinometer (gyroscope) and GPS locator.

For practical comparison of the tank filling the flowmeter with oval wheels and fuel 100 D were used (Table 1).

Table 1 Comparison of the fuel tank filling

Volume of the fuel, measured by means of flowmeter	Volume of the fuel, measured by means of probe with two positive electrodes
278 l	278 l
160 l	160 l
323 l	322.8

A comparative measurement during real operation was also performed using calibrated refueling equipment of public fuel sellers (Table 2).

Table 2 Refueling of the vehicle – comparison of the flowmeter on the tank stand and the capacitive probe in the tank

Refueling number	Volume of the fuel from the accounting documents (l)	Volume of the fuel from the capacitive probe (l)	Difference in the volume (l)	Relative error (%)
1	680	677.74	2.26	0.33
2	444	442.12	1.88	0.43
3	552	550.06	1.94	0.35
4	410	409.77	0.23	0.06
5	395	393.77	1.23	0.31
6	460	459.62	0.38	0.08
Total	**2941**	**2933.08**	**7.92**	**0.27**

From the Table 2 it can be seen that a total of 2941 liters of diesel were refueled according to the accounting documents and the capacitive probe measured 2933.08 liters, which represents the deviation of 0.27 %. This comparison is partly burdened by the measurement error, which is given by the measurement principle of the tank stand. This consists mainly of the unknown filling of the hydraulic parts of the refueling circuit (especially the filling hose) and the unknown temperature of the fuel in the underground tank.

4 CONCLUSIONS

In order to monitor the operation of the vehicle it is possible to use a number of its operating parameters, but it is advisable to supplement them with externally obtained data for example the amount of fuel in the tank combined with vehicle position information. This information can be used, for example, to automatically fill in the logbook or also to evaluate the driver's driving style.

It is possible to use a capacitive probe to monitor the amount of fuel in the tank. If the capacitive probe has only one positive and one negative electrode, it is less sensitive when using rapeseed oil methyl ester in diesel. To eliminate this problem, it is possible to use capacitive probes with two electrodes and one negative electrode.

1. When using neat diesel, the maximum deviation when filling a calibrated measuring cylinder is 1.4% for a probe with one positive electrode and 0.7% for a probe with two positive electrodes.

2. When using diesel fuel with 3.9% rapeseed oil methyl ester the maximum deviation from the calibrated measuring cylinder is 2.5% for a probe with one positive electrode and 0.9% for a probe with two positive electrodes.

3. When using diesel fuel with 30% rapeseed oil methyl ester is maximum deviation of the calibrated measuring cylinder 22.5% for a probe with one positive electrode and 1.3% for a probe with two positive electrodes.

4. When using 100 % rapeseed oil methyl ester the maximum deviation from the calibrated measuring cylinder is 70% for a probe with one positive electrode and 1.9% for a probe with two positive electrodes.

5. The accuracy of a capacitive probe with two electrodes is 1.5% in the normal range of a mixture of diesel and rapeseed oil methyl ester which is given by the EN 590 regulation. If there is a larger proportion of rapeseed oil methyl ester in the tank, the measurement error of the capacitive probe with two electrodes will increase to a maximum of 4%.

Monitoring of vehicle operating parameters via sensors located in the vehicle and suitably supplemented by external sensors (capacitive probe, GPS locator, accelerometer) is suitable for evaluation economic, environmental and safe driving. Drivers can be trained to reduce fuel costs, reduce the environmental impact and increase road safety through a suitable remote monitoring system. It is also possible to use the operational parameters of the truck to specify the preventive periodic and diagnostic maintenance and, when using a suitable algorithms, also to predictive maintenance.

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