DESIGN OF A DAILY-USER METHODOLOGY TO DETECT FUEL CONSUMPTION IN CARS WITH SPARK IGNITION ENGINE

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Abstract:
The article focuses on detection of fuel consumption in cars with the spark-ignition engine aiming to determine the most accurate way of daily-use fuel consumption through evaluation finding. To achieve relevant outcomes, different routes underwent experiments in multiple consumption modes. In particular, these encompass four circuits varying in length, speed limit, intersection number with significant waiting time and the route ratio city/highway. Each segment saw three measurings in terms of different consumption forms – standard, economical and dynamic. Apart from that, fuel consumption detection also takes into cosideration possible deviations from consumed fuel when automatically switching off the fuel pump pistol. Three methods contributed to achieving the findings; i.e. quantification method, the technique of data subtraction from the on-board computer (On-Board Unit) and method of amassing data from a phone application. Ultimately, compiled tables and detailed diagrams show outcomes demonstrating the most convenient way and approach of measuring fuel consumption for daily-users.

1. INTRODUCTION

Fuel consumption represents an important indicator of road motor vehicles in terms of its economy [1], technical condition [2] and exhaust gases emission [3-5], and requires careful monitoring. Fuel consumption varies according to the vehicle technical state [2], which makes technical certificate data insufficient calling for a regular check-up [6].

There are various methods of detecting fuel consumption available to daily-users. Firstly, it is a technique of subtracting data from the board computer or a simple quantification or an application to indicate fuel consumption. All these suggested methods accommodate daily-users, however not considering specific deviations that

may occur (i.e. discrepancies in the amount of consumed fuel when automatically switching off the pump pistol) [6].

The manuscript aims at suggesting a convenient method of reliably detecting fuel consumption in cars with spark ignition (SI) engine for daily-users. The methodology disregards laboratory technologies, however respecting common factors affecting the very fuel consumption [7].

2. DATA AND METHODS

With the intent to suggest the most reliable technique measuring fuel consumption in normal conditions [8], the individual steps were followed (Fig.1). As for the examination itself, we chose AUDI S5 passenger car SI engine. Fuel consumption

varies depending on specific circumstances. Therefore, the producer suggests three different consumption values based on the New European Driving Cycle (NEDC): urban operation consumption 18.1 l/100 km, extra-urban operation consumption 8.7 l/100 km and combined consumption 12.1 l/100 km.
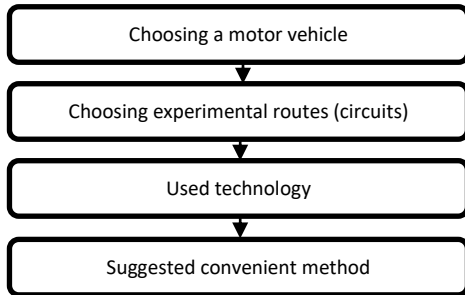

Fig. 1. Individual steps of the measuring technique. Source: authors

To this end, we chose four experimental segments of different parameters to achieve accurate research results [9]. The length of the route section (i.e. distance traveled) is the key parameter affecting the fuel consumption. In addition, individual routesections are highly specific about being situated either in the city or outside, which means further parameter involvement; the speed limit, intersection number and the city/highway ratio [10]. Table 1 summarizes individual specifications of certain routes.

Table 1. Specifications of selected routes. Source: authors

	Route designation	Distance [km]	Speed limit (km/h)	Number of intersections with significant waiting time	Ratio city/highway
Urban route	1	3.9	50–70	2	-
	2	8.8	50–80	1	-
Combined route	3	32.5	50–130	1	1:1
	4	61.7	50–130	-	1:3

The measuring process of fuel filled at the petrol station requires sophisticated technology [11]. For these purposes, the experiment used densimeters, a digital scale for gauging fuel density and weight, jerricans, a specially modified fuel filler neck of which the intent was to adjust the filling pistol and wireless adapters for detecting consumption [12].

Before the very fuel consumption investigation, measurements of deviations were needed to be carry out. Each measurement was executed on the same pump stand and by the same pump pistol with the aim to eliminate deviations which may occur due to using multiple fuel pump pistols [13].

Each investigation was performed three times on each route section. Each route section was accomplished under various driving technique; economical, then regular and finally dynamic technique of driving. Thereafter, the next investigation was realized once on all the route sections only under regular technique of driving. Fuel was added almost to the edge of the fuel tank neck [14].

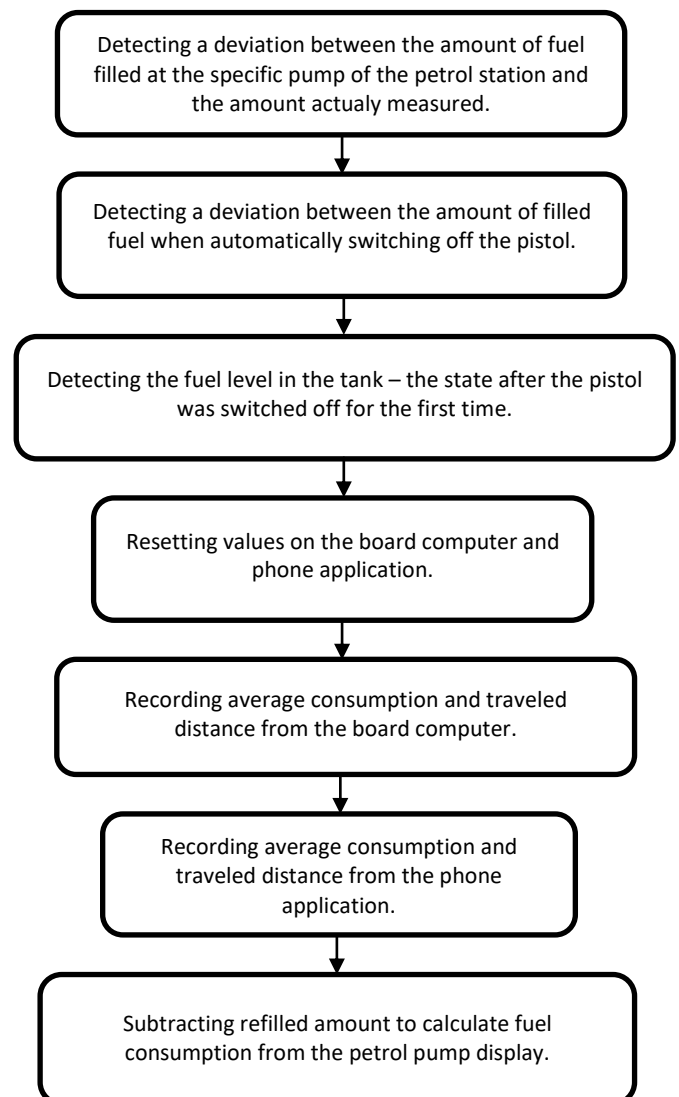A designed flowchart of the fuel consumption examination process is depicted in Fig.2.

Fig. 2. The methodology of the fuel consumption detection. Source: authors

3. ACHIEVED RESULTS

At the beginning of the detection procedure, the quantified standard value of fuel consumption was stipulated to be a initial value. Based on this value, other types of consumption investigation were then compared [15].

3.1 Accuracy and deviation examination of the amount of consumed fuel

As far as the first investigation went, the maximum permissible error, in order to specify dispensed fuel accuracy, was obtained of (+/-) 0.5% of the dispensed quantity. In practice, this means of (+/-) 0.1 l per 20 l of filled fuel.

The very fuel consumption examination was conducted by obtaining fuel weight values detected at laboratory scales and fuel quantity dispensed at the fuel station [16]. Such values were compared with quantified values (based on the detected weight and fuel density). In the following table (see Table 2), all the measured deviations are listed.

Table 2. Accurate numbers of consumed fuel at petrol pump (Petrol 95 octane). Source: authors

Amount petrol pump (l)	Weight (g)	Volume (m³)	Calculated amount (l)	Deviation (l)	Deviation (%)
5.03	3770.2	0.00498	4.98044	0.0496	0.99
10.33	7741.4	0.01022	10.22642	0.1036	1.01
5.11	3833.9	0.00506	5.06459	0.0454	0.90
10.47	7848.5	0.01036	10.36789	0.1021	0.98
			Ø deviation	0.0752	0.97

The second measurement focused on detecting the deviation of filled fuel caused by the pump pistol switch-off. For this purpose, we used a fuel filler neck of Škoda Felicia with the adjustment to fully adapt to the vehicle position so that the experiment proceeds in the same position.

Overall, we conducted 9 measurements and achieved 9 values of refilled fuel (from 0.87 to 0.94 l). Values were subsequently set out as follows:
- mean with the value of 0.9055 l,
- standard deviation with the value of 0.02297 l,
- the deviation caused by the pump pistol switch-off, of which the value may equal to 0.07 l.

3.2 Fuel consumption detection

First of all, we refilled fuel no sooner than after the pump pistol had switched off. The procedure began by resetting measured values of consumed fuel and traveled distance on the board computer (referred to as PC) and specific smartphone application. Experimental routes consecutively saw an economical, standard and dynamic driving technique [17].

The examining process involved OBD apps data (or Torque) along with Vgate iCar Pro Wifi Adapter. Table 3 lists findings of the first experiment.

Table 3. Results of the first investigation of fuel consumption of SI engine. Source: authors

No.	Circuit	Drive mode	Distance PC (km)	Distance OBD apps data (km)	Consumption PC (l/100 km)	Consumption OBD apps data (l/100 km)	Amount refilled (l)	Consumption calculated (l/100 km)
1	1	E	3.8	3.77	13.0	9.5	1.45	38.158*
2	1	S	3.9	3.85	15.6	14.7	1.05	26.923*
3	1	D	3.9	3.82	18.8	20.1	1.18	30.256*
4	2	E	8.8	8.69	10.2	10.6	1.06	12.045
5	2	S	8.8	8.69	11.6	11.9	1.12	12.727
6	2	D	8.8	8.69	14.6	14.2	1.32	15.000
7	3	E	31.9	31.57	9.5	9.7	2.97	9.310
8	3	S	31.9	31.57	11.2	11.5	3.78	11.850
9	3	D	31.9	31.57	13.5	12.7	4.28	13.417
10	4	E	57.7	57.01	9.4	10.1	5.82	10.087
11	4	S	57.6	57.06	11.2	11.3	6.71	11.649
12	4	D	57.6	56.95	15.6	14.9	8.97	15.573

*higher values of fuel consumption were achieved because of fuel overflow through the tank cap

The next measurement method of fuel consumption focuses on refilling fuel up to a specific point. This point almost reaches the tank lid, allowing an easy visual accuracy check. These experiments were conducted on all the route sections.

Table 4 shows the results of the second experimental detection of fuel consumption.

This experiment investigates the first route section twice. The whole process had to be repeated with the intent to remove potential air bubbles in the tank since it was almost empty before the measuring took place.

Table 4. The results of the second investigation of fuel consumption of SI engine. Source: authors

No.	Circuit	Drive mode	Distance PC (km)	Distance OBD apps data (km)	Consumption PC (l/100 km)	Consumption OBD apps data (l/100 km)	Amount refilled (l)	Consumption calculated (l/100 km)
1	1	S	3.9	3.81	14.3	13.7	0.99	25.38
2	1	S	3.9	3.81	12.7	12.3	0.79	20.26
3	2	S	8.8	8.67	12	11.75	1.2	13.64
4	3	S	31.9	31.54	12.2	10.9	4.2	13.17
5	4	S	57.6	55.91	13.4	11.2	8.04	13.96

4. DISCUSSION

The diagram below (Fig.3) illustrates the comparison of achieved values of the first experiment, showing inaccuracies in fuel consumption quantifications that occur mostly on the shortest route. In this case, these mistakes were caused by fuel foaming and the deviation of the pistol switch-off [18]. These faults emerge throughout the experiment, which seems to be the most significant on the shortest route. The inaccuracies appear due to the approximately equal deviation after refilling, however being the most material on the shortest circuit (3.9 km), where the influence on the calculated consumption is the greatest [19]. This fact is caused by fuel overflow through the tank cap.
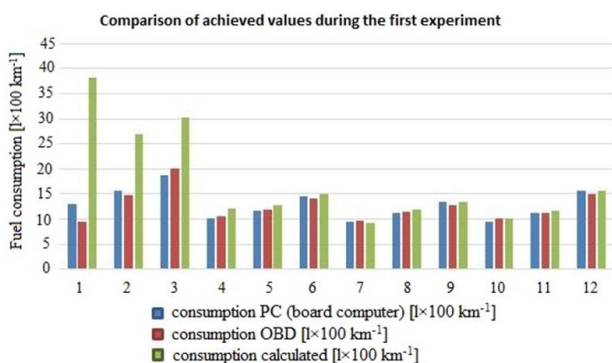

Fig. 3. Comparison of achieved values during the first experiment. Source: authors

Table 5 shows only a negligible difference between the consumption quantified by the On-board computer and smartphone application (1.61%), with respect to the ratio between the consumption and both experimental devices [20].

The most considerable deviation appeared during the experiment on the first route, requiring completion of the last row in the table, which compares anomalies without specifying the experimental track. These figures show a dramatic reduction in deviation values. The average rate of OBD apps with a deviation of 4.26% is the closest to the estimated consumption; nevertheless, it should further grow by 0.97% (the average deviation from the accuracy of the petrol pump BA 95), while taking into account pump pistol switch-off difference ranging from (+/-) 0.023 l.; i.e. the resulting inconsistency between the calculated consumption and smartphone application will be of 5.23% (+/-) 0.023 l.

Table 5. Comparison of deviations of the first experiment Source: auhtors

No.	Deviation PC and calculated (l/100 km)	Deviation OBD and calculated (l/100 km)	Deviation PC and OBD (l/100 km)	Deviation PC and OBD (%)	Deviation OBD and calculated (%)	Deviation PC and calculated (%)
1	-25.16	-28.66	3.50	26.92	-301.66	-193.52
2	-11.32	-12.22	0.90	5.77	-83.15	-72.58
3	-11.46	-10.16	-1.30	-6.91	-50.53	-60.94
4	-1.85	-1.45	-0.40	-3.92	-13.64	-18.09
5	-1.13	-0.83	-0.30	-2.59	-6.95	-9.72
6	-0.40	-0.80	0.40	2.74	-5.63	-2.74
7	0.19	0.39	-0.20	-2.11	4.02	2.00
8	-0.65	-0.35	-0.30	-2.68	-3.04	-5.80
9	0.08	-0.72	0.80	5.93	-5.65	0.62
10	-0.69	0.01	-0.70	-7.45	0.13	-7.30
11	-0.45	-0.35	-0.10	-0.89	-3.09	-4.01
12	0.03	-0.67	0.70	4.49	-4.52	0.17
Ø	-4.40	-4.65	0.25	1.61	-39.48	-30.99
Ø w/o 1st track	-0.54	-0.53	-0.01	-0.72	-4.26	-4.99

The following diagram (Fig.4) depicts the average fuel consumption values of individual routes and their standard deviations for all the experimental techniques. The diagram illustrates the enormous influence of inaccuracies on the shortest experimental segment [21].
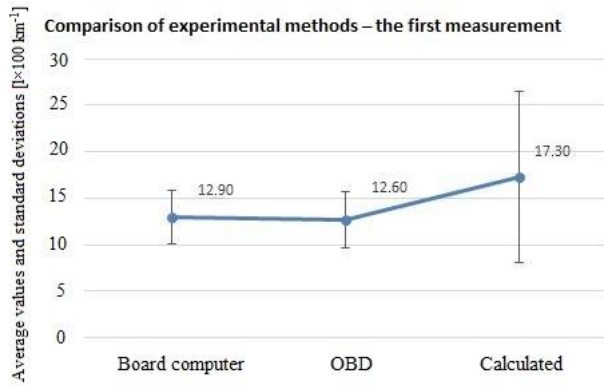
Fig. 4. Schematic comparison of individual experimental methods; the first measurement. Source: authors

The following figure (Fig.5) represents a comparison of detected values of the second investigation.
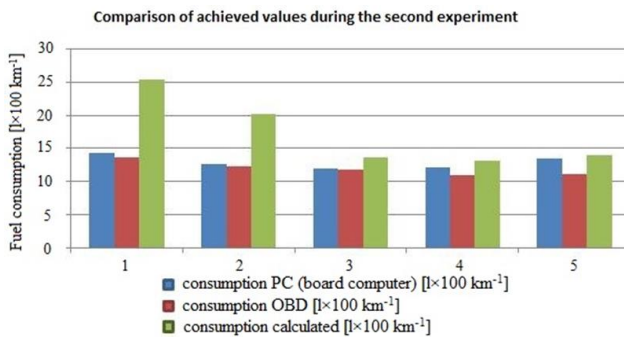

Fig. 5. Comparison of achieved values during the second experiment. Source: authors

The following statistics (see Table 6) summarize deviation values of the second measurement.

Table 6. Comparison of fuel consumption deviations of SI engine in the second experiment. Source: authors

No.	Circuit	Deviation PC and calculated (l/100 km)	Deviation OBD and calculated (l/100 km)	Deviation PC and OBD (l/100 km)	Deviation PC and OBD (%)	Deviation OBD and calculated (%)	Deviation PC and calculated (%)
1	1	-11,08	-11,68	0,60	4,20	-85,29	-77,51
2	1	-7,56	-7,96	0,40	3,15	-64,69	-59,50
3	2	-1,64	-1,89	0,25	2,08	-16,05	-13,64
4	3	-0,97	-2,27	1,30	10,66	-20,79	-7,92
5	4	-0,56	-2,76	2,20	16,42	-24,63	-4,17
Ø		-4,36	-5,31	0,95	7,30	-42,29	-32,55
Ø w/o 1st track		-1,05	-2,73	1,68	12,88	-24,22	-8,26

In this case, the board computer (PC) showed higher accuracy with a deviation of 8.26%. This experiment had to take into consideration an accuracy deviation of the petrol pump of 0.97% for petrol 95 octane. The anomaly resulting value is approximately 7.29 % [22].

The following chart (Fig.6) illustrates mean (average) values and their standard deviations of each of the routes being examined.
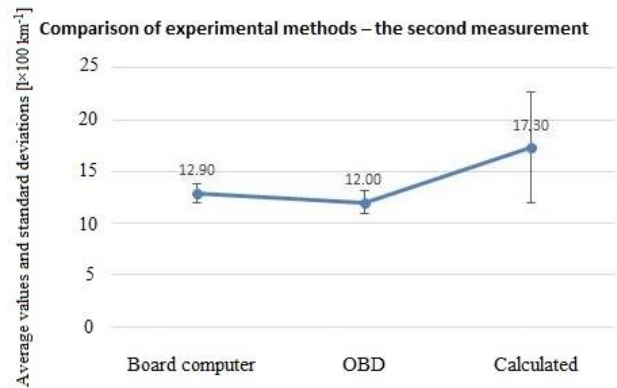

Fig. 6. Schematic comparison of individual experimental methods; the second measurement. Source: authors

5. CONCLUSION

The manuscript focused on searching for the most accurate daily-user method of detecting fuel consumption. The experiment aimed at recommending a convenient technique to achieve the specific objective using a car with the spark-ignition engine AUDI S5. The vehicle underwent tests on four predesignated routes. Each circuit showed particular parameters such as length, speed limit, number of intersections with significant waiting time and the city/highway drive ratio. The specific technique of driving also affects the very fuel consumption. The experimental research comprised in total 12 journeys to meet this specification with each journey taken in three different forms on all four routes; standard, economical and dynamic mode as separate styles to a great extent impact on fuel consumption. The experiment implementation and resulting evaluation of fuel consumption followed three different approaches; calculation (quantification) method, the method of subtracting data from the on-board computer (PC) and OBD apps, which required the use of special measuring technology.

Apart from the fuel consumption experiment, the detection of the amount of consumed fuel and its deviation when automatically switching off the pump pistol constituted an integral part of the research. Resulting tables and detailed diagrams

depict the evaluation of the amassed data. The findings recommended the use of the first of the adopted measurement (detection) methods, suggesting that the experiment may regard the deviation caused by the pump pistol automatic switch-off. Accuracy of this method is increasing by higher amount of consumed fuel or driven distance. This method is not suitable for fuel consumption calculation on short tracks (over 10 km).

Repeated investigation and proper modification of vehicle drive style (technique) provides a daily-user with more precise information on the fuel consumption of a specific vehicle.

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