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NUMERICAL CALCULUS FOR FUEL CONSUMPTION AND SOURCES OF ERRORS

Liviu Georgescu[1], George Dragomir[2], Mihai Cocosila[3],
1)University Politehnica Bucharest, liviugeorgescuro@yahoo.com, 2)Oradea University, georgedragomir@yahoo.com, 3) McMaster University, Hamilton, Canada, cocos40@yahoo.com

Abstract

Fuel consumption and exhaust gases analysis for automobiles may be determined for scientific purposes on special test benches. Precission of such apparatus is very high, in the field of 0.2%. In usual cases, however, errors occur, and precission of measurements is diminished. This paper intends to find sources of possible errors and its numerical calculus, for better improvement of methods for testing.

1. Scientific devices utilised

The automobile was placed on a roller bench Zöllner type and exhaust gases were anlysed, in a Pierburg bench model 1997, gas analyser AMA 2000, B type test system.

Data for testing cycle are presented in table 1, speed and distance versus time.

Table 1.

Data for testing cycle

T[s]	V[km/h]	D[km]	T[s]	V[km/h]	D[km]	T[s]	V[km/h]	D[km]
0	0	0	67	30	0,118	141	70	1,215
40	0	0	74	30	0,176	158	70	1,546
45	10	0,007	83	50	0,276	178	80	1,963
50	10	0,021	94	50	0,429	198	80	2,407
55	20	0,042	109	60	0,658	223	0	2,733
60	20	0,064	124	60	0,908	227	0	2,733

Data for selecting this kind of cycle were colected, from statistical point of vue concerning traffic in big towns in Romania, especially heavy traffic situations in Bucharest, capital of Romania [2]. At the beginning of the test, there were introduced 40 seconds with engine running at idle, as in general case for other tests. The speed is considered to increase in a linear manner (movement with constant acceleration), and fuel consumption was determined for acceleration between 0-10 km/h (first gear), 10-20 km/h (second gear), 20-30 km/h (third gear), 30-50 km/h (fourth gear), and finally 50-60, 60-70, 70-80 km/h (fifth gear) and for deceleration 80-0 km/h (fifth gear + neutral from speed below 50 km/h). Constant speed determination for fuel consumption was performed at speeds of 10 km/h (first gear), 20 km/h (second gear), 30 km/h (third gear), 50 km/h (fourth gear), 60, 70 and 80 km/h (fifth gear).

The cycle representing variation of speed versus time is presented in figure.1.

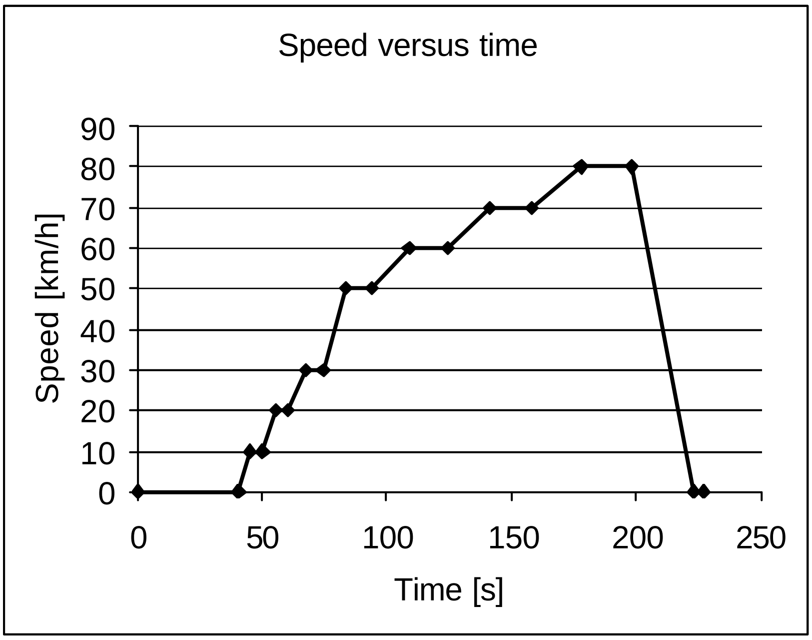

Fig.1. Dyagram of test cycle

2. Results obtained

Tests were performed upon a Romanian built automobile, a DAEWOO Cielo car, on the roller bench in Craiova for exhaust emissions and fuel consumption assesement. The device presents a precision of 0.2%, being a stientific and research device.

The obtained results for fuel consumtion (liters per hour) are presented in table 1. There were performed 2 identical tests in order of observing the repetability of the measurement process and the possible sources of errors. The engine of the automobile was warmed up previously tests were performed.

Table 2. **Fuel consumption per hour, Cielo car without AC, fueled LPG**

No.	V average [km/h]	$C_h$warm1 [l/h]	$C_h$warm2 [l/h]	Relative error column 3/2 [%]
0	1	2	3	4
1	0 (idle)	1.030	1.335	+29.6
2	5	0.9911	1.523	+53.7
3	10	1.6549	1.7564	+6.1
4	15	1.8429	1.7513	-5
5	20	2.028	1.916	-5.5
6	25	2.123	2.022	-4.7
7	30	1.950	2.1465	+10.1
8	40	3.0048	3.0128	+2.7
9	50	3.356	3.378	+0.6
10	55	2.8039	2.9799	+0.6
11	60	2.9766	2.829	**+6.3**
12	65	3.297	3.5269	-5
13	70	3.325	3.2676	+6.9
14	75	3.930	4.1198	+4.8
15	80	3.811	3.9168	+2.8

Average value for column 4 in table 2 is +6.93% and standard deviation is 15.59.
Considering only from line 3 and below, average value for column 4 in table 2 is +1,59% and standard deviation is 5,28. At low speeds (no.1 and 2) error values are high.

Table 3.

Fuel consumption per hour, Cielo car with AC, fueled LPG

No.	V average [km/h]	$C_h$warm1 [l/h]	$C_h$warm2 [l/h]	Relative error column 3/2 [%]
0	1	2	3	4
1	0	1.869	1.7463	-6.6
2	5	2.16235	2.4137	+11.6
3	10	2.3132	2.,6391	+14.1
4	15	2.20095	2.21415	+5.9
5	20	2.5958	2.5236	-2.8
6	25	2.56675	2.66975	+4
7	30	2.577	2.6976	+4.7
8	40	3.7728	3.5692	-5.4
9	50	3.995	3.616	-9.5
10	55	3.73945	3.6476	-2.5
11	60	3.2028	3.321	**+ 3.7**
12	65	4.07745	4.043	-1
13	70	3.8205	3.8542	+0.9
14	75	4.5645	4.71225	+3.2
15	80	4.4528	4.5776	+2.8

Average value for column 4 in table 3 is +1.54% and standard deviation is 6.443.
Considering only line 3 and below, average value for column 4 in table 3 is +1.39% and standard deviation is 5.87. At low speeds (no.1 and 2) relative errors are also high.

In general, measuring errors are interpreted from relative error point of vue. Qualitative interpretations are presented in table4.

Table 4.

Measuring errors for different determinations ant qualitative interpretation

No	Relative error %	Precision assesement
0	1	2
1	0…1	Laboratory
2	1…3	Technical
3	3…5	Brute
4	> 5	Uncceptable

From this point of vue, results in table 1 and 2 may be considered as acceptable, being between the field of 1...3%, corresponding to technical precision.

3. Sources of errors

Tests number 008 and 009 were selected and represented in fig.2 and 3 by the aid of programme graphic facilities for Pierburg system.

With different colours there were represented V_TARGET in km/h and V_ACT in km/h, as it was realised by the human operator. Diagrams are reproduced from [1].

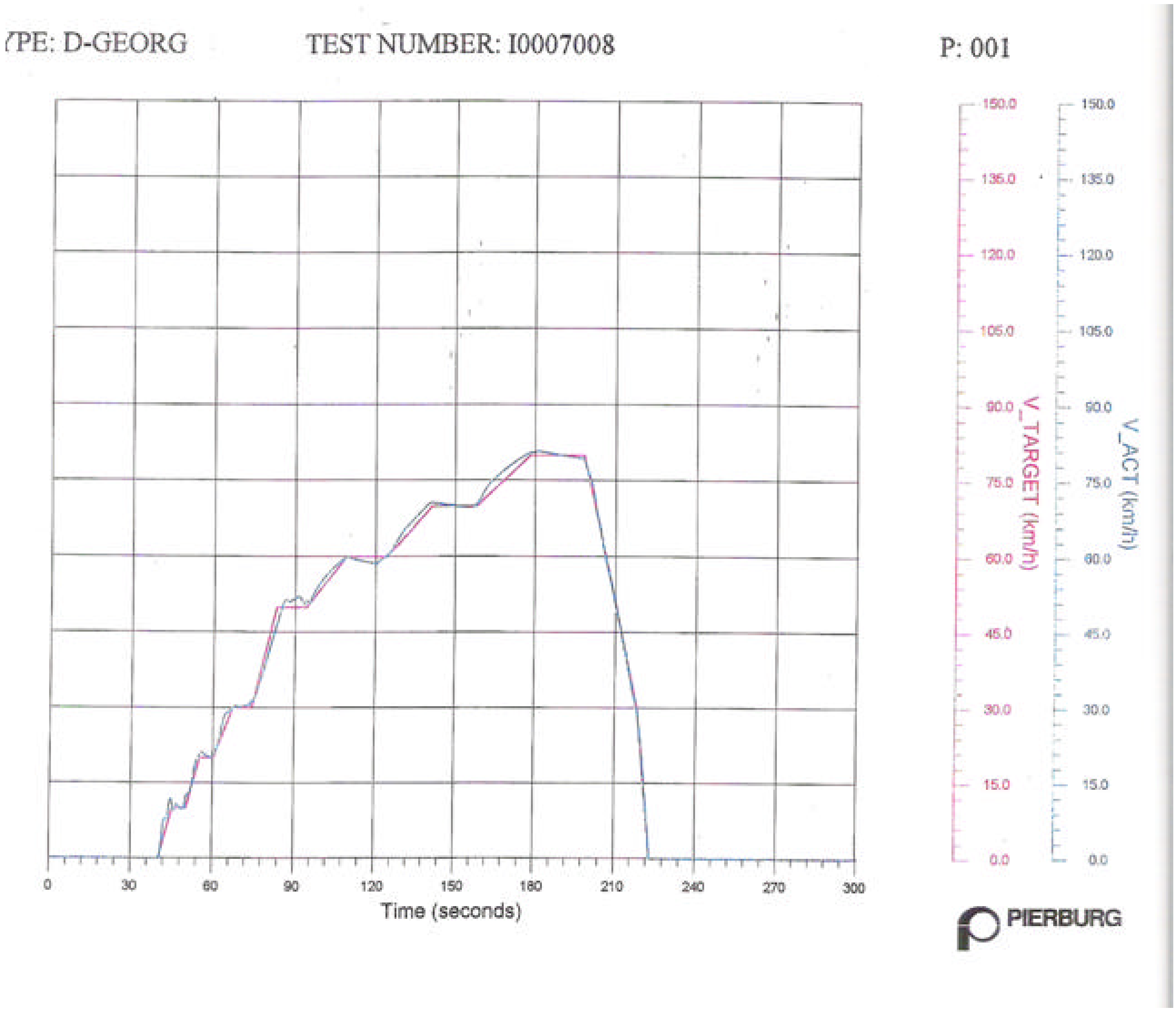

Fig.2. Test 008

As it is easy to notice, test driver is not able to obtain quite the specific value of the speed. In fig.2 representing test 008, speed is generally higher than indicated speed, and some other areas speed is lower. As an example, speed in gear 5 at test 008 is considered 2.5 km/h.lower (-4.16%) than the indicated one.

On the contrary, in fig.3 representing test 009, in which AC was ON, in gear 4 speed is lower than the indicated one, due to the extra resietence induced by the compressor of the AC instalation, but at some other speeds actual speed is higher. At speed 60 km/h, actual speed is 2 km/h higher (+3.33%) than the indicated one.

These differences induce difference in fuel consumption.

For constant speeds, fuel consumption per hour, may be expressed, for Cielo car, by the following equation, no AC, warm engine [2]:

$$C_h=0,0004 * V^2+0,06 * V+1.6378 \qquad [1]$$

and, in case of AC ON,

$$C_h=0,0002*V^2+0,0512*V+1.7269 \quad [2]$$

Difference of fuel consumption, calculated with formula 1 (AC is OFF), due to the decrease with 2.5 km/h of speed,in test 008, at speed 60 km/h, will be equal to 0.1524 l/h reported to the value of 2.976 l/h, or relative difference of -5,12%. In table 2 difference between the two identical determinations is **6,3**%.

By example, with formula 2 (AC is ON), difference in fuel consumption due to the speed increase by 2 km/h in test 009, at speed of 60 km/h, will be equal to 0.10765 reported to the value of 3.2028 l/h, or relative difference of +3,36%. In table 3 difference between the two identical determinations is **3,7**%.

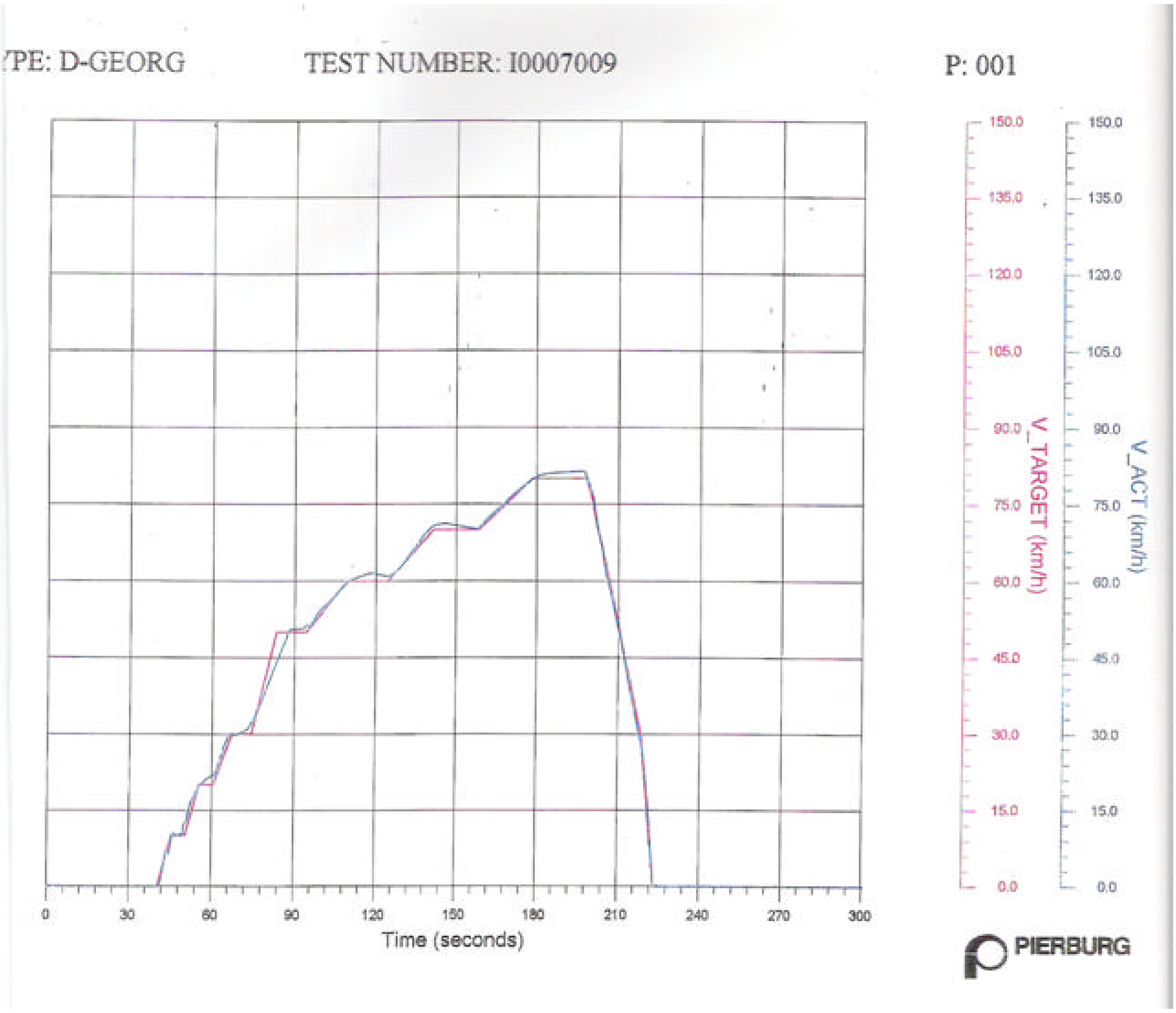

Fig.3. Test 009

4. Discussions

Errors obtained in the case of the two identical tests numbered 008 and 009, are presenting higher values than would be accepted for technical purposes. It is important to emphasize that these errors are not due to the stientific devices, but they are induced by human errors, driver being not able to follow exactly the target speed imposed in the test.

5. Conclusions

It was important to observe that errors in determining fuel consumption, were in the same range of ± 5% as errors in table 2 and 3. Difference in fuel consumption values were due to the fact that driver could not follow the exact speed inposed as it was stipulated in the protocol. It is important to know that such errors would occur always, by example it is impossible from technical point of vue that speed abruptely changes from accelerated movement, to instant constant speed as imposed in fig.1 (fraction of total European cycle).

Exterior urban cycle

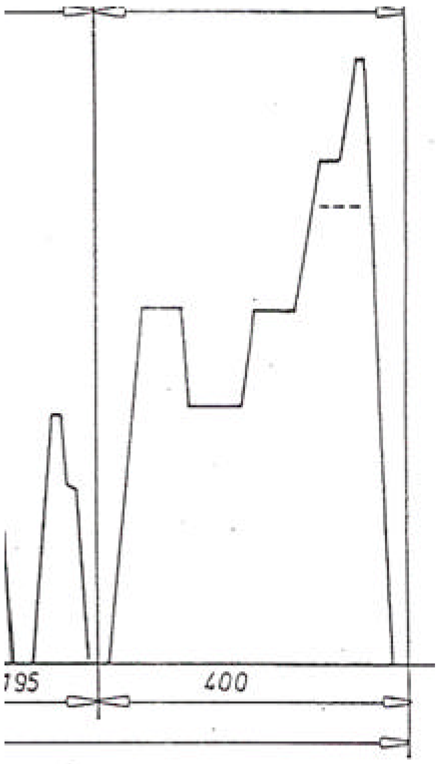

Fig.4. Test CEE-UN no.83.0

Same sources of errors would be encountered in others tests, as shown in fig.4, which represents the extraurban cycle of poluttant emission test in CEE-UN-no.83. For higher rate of repetability, some automated robotics actioning controls of the tested vehicle, would insure speed values closer to the imposed one. Costs for such devices are however very high, as actuators for throttle pedal, clutch, gear lever (manual transmission case involved), brake and AC actioning, as well as sensors for actual simulated speed of the car, with a special designed software to be implemented to the test bench.

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