Driving Style Influence on Vehicles Performances

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***Abstract*—Vehicle dynamics and fuel saving performances are largely influenced by the driving style of the driver. This paper will give an account of this important aspect mentioned in specialty literature, defining some driving style assessment criteria and setting their values based on the experimental data obtained from the tests conducted on a Logan Laureate. The experimental data corresponds to 50 starting samples and 50 normal movement samples, the latter being called “non-starting” in the paper.**

***Index Terms*—car engine, fuel saving, aggressive factor, engine power, engine torque.**

I. Introduction

In specialty literature it is shown that driving style has great influence on vehicle dynamics and fuel efficiency [1-4]. In this sense, some criteria for assessing driving style are proposed, which concern either the vehicle dynamics, or its fuel economy, or both, the latter being the correct one from the customer’s point of view.

II. Appreciation Criteria of Driving Style (Driving Style Assessment Criteria)

In order to highlight the influence of the comparative driving style on both types of motion, we labeled 50 starting and 50 non-starting available samples (normal displacement); starting samples are labeled LD1-LD50, and non-starting samples, LN1-LN50. Thus, in order to target the dynamics, in Figure 1 the percentage variation of the speed ΔV [%] is presented compared to its average value over all 100 samples ($V_m = 87.4\ km/h$). In function of this variation, there we have 54 samples with sportive driving style (where $\Delta V > 0$) and 46 samples with moderate driving style (where $\Delta V < 0$). In this chart and in the following, starting samples are numbered 1-50, and non-starting samples, 51-100.

As can be observed in Figure 1, all of the 50 starting samples are from sportive driving style (which was expected), plus 4 non-starting samples (LN55, LN56, LN69, LN84); the other 46 non-starting samples (normal movement) are part of the moderate driving style.

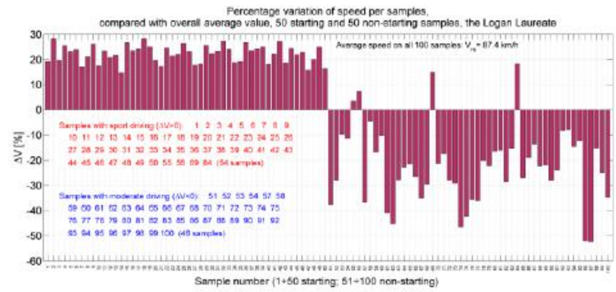

Figure 1. The percentage variation of the speed

To target the fuel saving, in Figure 2 the percentage variation on samples of fuel consumption at 100 km ΔC_{100} [%] is presented to average their values on all of the 100 samples (C_{100m}=7.49 liters/100 km). In function of this variation, there we have 55 samples with non-economic driving style (where $\Delta C_{100} > 0$) and 45 samples with economic driving style (where $\Delta C_{100} < 0$).

As it can be observed in Figure 2, all of the 50 starting samples are from non-economic diving style (which was expected), plus 5 non-starting samples; the other 45 non-starting samples (normal movement) are from economic driving style.

In order to simultaneously target dynamics and fuel economy (named eco-dynamics), in Figure 3 the percentage variation of speed ΔV [%] and fuel consumption at 100 km ΔC_{100} [%] is presented in comparison to their average value over all 100 samples; as in the two previous graphs, positive values mean increases toward average values of samples, and negative values show decreases toward them.

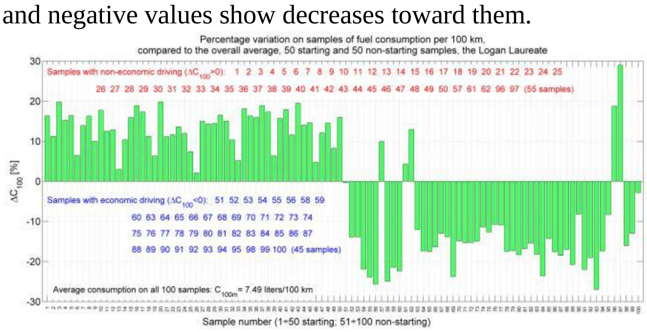

Figure 2. Percentage variation on samples of fuel consumption per 100 km compared to the overall average, 50 starting and 50 non-starting samples, the Logan Laureate

As shown in Figure 3, there are 4 rational driving tests depending on these two variations, all of which are non-starting, $\Delta V > 0$ and $\Delta C_{100} < 0$, where the increase in speed

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Digital Object Identifier 10.32754/JMT.2018.1.07

toward its average values decreases the fuel consumption compared to its average on the whole.

Also there are 5 samples with irrational driving, all labeled non-starting, where $\Delta V < 0$ and $\Delta C_{100} > 0$, meaning that compared to the average overall results an increase in fuel consumption in comparison to its average overall when speed decreases.

Finally, there are 91 samples with normal driving, out of which 50 are starting samples and 41 non-starting samples, where the speed increases with the increase of fuel consumption, and the reduction in speed takes place with lower fuel consumption.

As shown in Figure 3, if dynamics and fuel economy are concomitantly aimed at, starting is part of the normal driving range; therefore increasing the fuel consumption is justified by increasing the dynamics. At the same time, no starting evidence is part of the rational driving category, which means that during this type of movement one cannot get a high dynamics without consuming more fuel; at the same time nor starting does not make part of irrational driving, which means that in this movement type does not consume more unnecessarily fuel.

Also, in Figure 3 it is found that from the category of non-rational driving there are only non-starting samples, which means that unnecessary fuel consumption exists only on normal movement.

Apart from these aspects, which refer to dynamics and fuel economy (separately or simultaneously), some quantitative criteria defining driving style are also used in the specialty literature. These criteria refer either to the driver directly or indirectly to the effect on the dynamics of the vehicle.

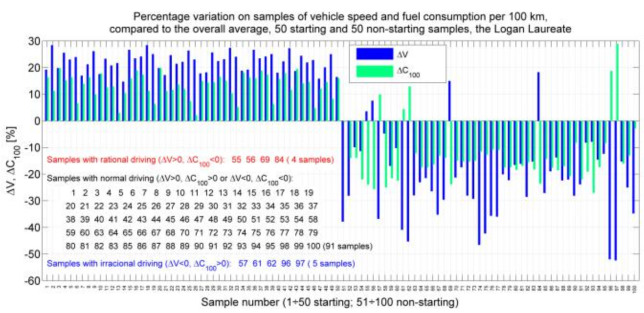

Figure 3. Percentage variation on samples of vehicle speed and fuel consumption per 100 km, compared to the overall average, 50 starting and 50 non-starting samples, the Logan Laureate

Thus, the criterion which refers directly to the driver is called aggressive factor of the driver f_s, and is defined by the expression [5], [6]:

$$f_s = 2p\frac{\mathrm{d}p}{\mathrm{d}t}, \quad (1)$$

where p is throttle pedal position, and $p' = dp/dt$ its time derivative.

For the gasoline engine, the accelerator pedal position p may be considered to be the same as throttle position ξ. For the 50 starting samples and 50 non-starting samples of the Logan Laureate, the values of pedal position and its derivative are presented in Figure 4. As expected, the pedal position at starting tends toward the maximum value of 100% towards the end of the process (Figure 4a), and the pedal derivative toward the null value (Figure 4c).

From the presented graphs it is also found that the mean value on all of the samples of the pedal and its derivative are bigger on starting samples.

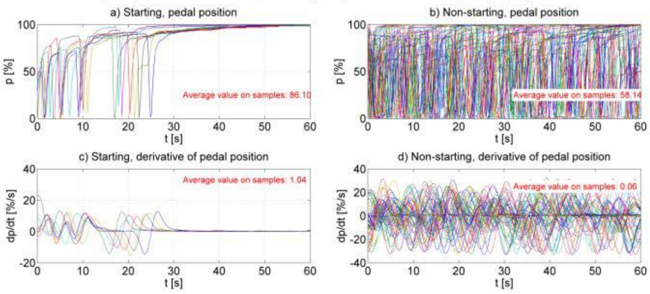

Figure 4. Throttle position and its derivative, 50 starting and 50 non-starting samples, the Logan Laureate

Similarly, along with the aggressive factor of the driver, in specialty literature it is also defined the aggressive factor of the vehicle [3], [4], defined with a similar relation by the expression (1):

$$f_a = 2v\frac{\mathrm{d}v}{\mathrm{d}t}, \quad (2)$$

where v is speed, and $v' = \mathrm{d}v/\mathrm{d}t$ derivation in time of it.

For those 50 starting samples and 50 non-starting samples of Logan Laureate, the values of speed and its derivative are shown in Figure 5.

From the graphs shown, we can see that the average values of speed and its derivatives on the samples are higher at the starting samples.

Based on the two previous criteria, the aggressive factor of the driver-vehicle is [5], [6]:

$$f_{sa} = \sqrt[4]{f_s} + \sqrt{f_a} \quad (3)$$

In specialty literature there are two driving style assessment criteria by which to define the aggressive factor of driver-vehicle.

Thus, the first defines the aggressive factor of the driver-vehicle assembly, which takes into account the acceleration a, deceleration d and travel speed v [5], [6]:

$$f_{sa} = \frac{2a - d}{0,8v + 1} \quad (4)$$

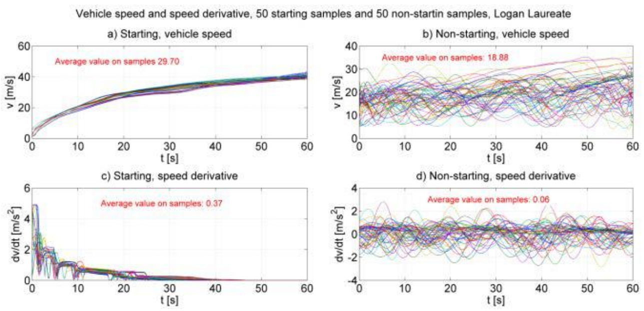

Figure 5. Vehicle speed and speed derivative, 50 starting and 50 non-starting samples, the Logan Laureate

A second criterion in specialty literature defines the value of the aggressive factor of the driver-vehicle which takes in account the force in the wheel F_r and the mass of the vehicle m [5], [6]:

$$f_{sa} = \frac{F_r}{m} \quad (5)$$

The values of the wheel force are shown in Figure 6.

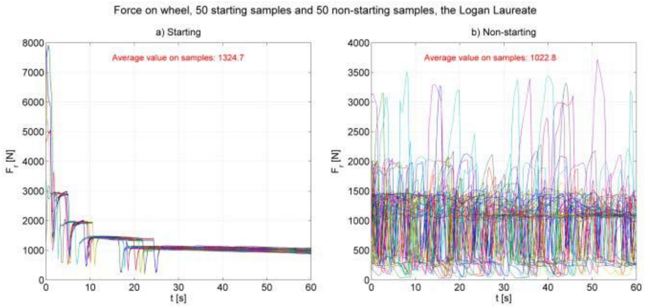

Figure 6. Force on wheel, 50 starting and 50 non-starting samples, the Logan Laureate

Figure 6 presents the instantaneous values of the wheel force F_r in the case of starting and non-starting of the Logan Laureate, which shows specific variations for the two types of movement.

It is also clear from these graphs that in the case of starting, the mean value on all the traction force samples is over 1.29 times higher than in the case of non-starting.

It should also be noted that in order to appreciate the aggression on the samples (i.e. a single value), we can use the average values of the respective factor, or the mean quadratic root (RMS – Root Mean Square).

III. Comparative Study on Driving Style Influence

Below are presented the values of the criteria using experimental data and some information about the impact of the driving style.

So, in Figure 7 are presented the instantaneous values of the aggressive factor of the driver f_s as defined by (1), and the aggressive factor of the vehicle f_a as defined by (2), for the 50 starting samples (superior graphs) and the 50 non-starting samples (inferior graphs). Based on these and using (3), in Figure 8 is represented the instantaneous values on samples of the aggressive factor of the driver-vehicle f_{sa}.

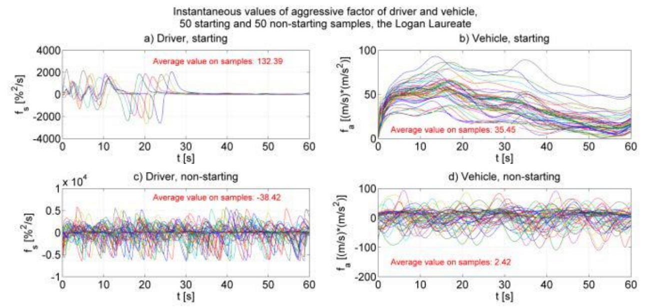

Figure 7. Instantaneous values of aggressive factor of driver and vehicle, 50 starting and 50 non-starting samples, the Logan Laureate

The graphs in Figure 7 show that the mean value on the whole sample of the aggressive factor of the driver is much higher in the case of starting than the non-starting (graphs on left side). Moreover, in starting it has positive value, and in non-starting it has negative value, which means, according to (1) that in the first case the pressure on the accelerator pedal is preponderant, and, in the second case, its release is preponderant; if the RMS value (with positive values only) is used, this aspect cannot be perceived.

Graphs from Figure 8 show that mean value of the aggressive factor of the driver-vehicle on all of the samples is 1.12 times higher than in case of starting, compared with normal movement.

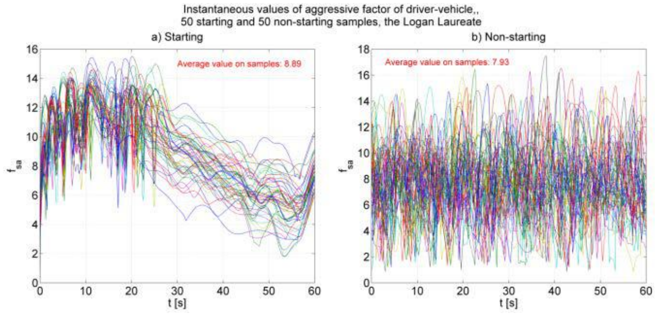

Figure 8. Instantaneous values of aggressive factor of driver- vehicle, 50 starting and 50 non-starting samples, the Logan Laureate

In Figure 9 are presented instantaneous and mean values on samples of the aggressive factor of the driver-vehicle f_{sa} defined by (4).

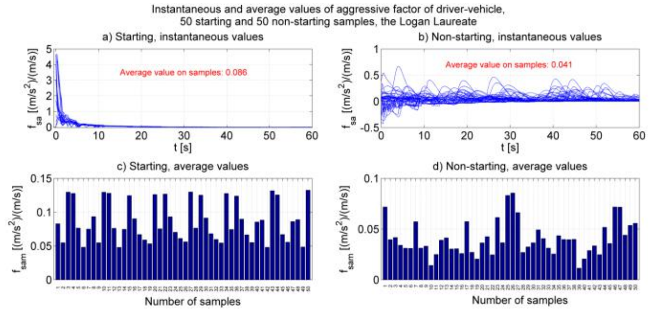

Figure 9. Instantaneous and average values of aggressive factor of driver-vehicle, 50 starting and 50 non-starting samples, the Logan Laureate

As can be seen in Figure 9, in the case of starting, the mean value on all samples of this factor is almost 2.1 times higher.

Figure 10 shows the dependence of the average values on the f_{sam} of the aggressive factor of the driver-vehicle, in Figure 9 and the average values on the samples C_{100m} of fuel consumption per 100 km.

As can be seen from the evolution trend marked on the graphs, fuel consumption increases as the aggressive factor increases, which was expected.

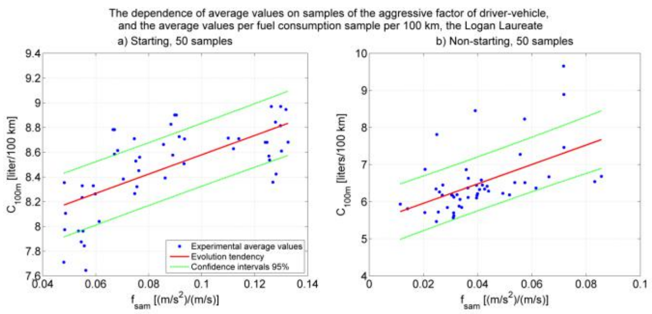

Figure 10. The dependence of average values on samples of the aggressive factor of driver-vehicle, and the average values per fuel consumption samples per 100 km, the Logan Laureate

The graphs in Figure 11 represent the instantaneous values and mean values of the aggressive factor of the driver-vehicle assembly, defined by (4) and (5).

As can be seen in Figure 11, in the case of starting, the mean value on all samples of this factor is 1.3 times higher.

In Figure 12 is presented the dependence of the instantaneous value of the aggressive factor of the driver-vehicle from Figure 11 and the instantaneous values of fuel consumption per probe at 100 km.

As can be observed in Figure 12, fuel consumption increases with the increase of the aggressive factor, inclusive of average values, which was expected. Thus, in case of starting, the average values for all the aggressive factor and fuel consumption samples are 1.3 times higher than those for normal movement.

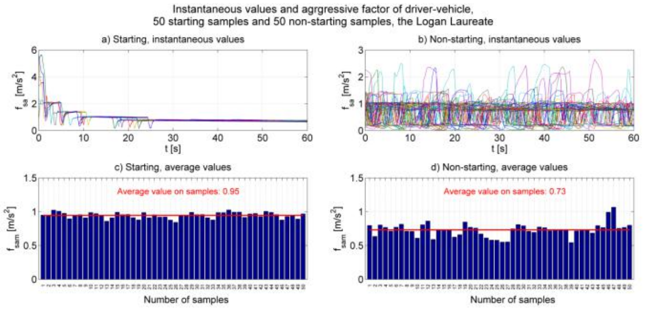

Figure 11. Instantaneous values and aggressive factor of driver- vehicle, 50 starting and 50 non-starting samples, the Logan Laureate

In Figures 13 and 14 the dependences between instantaneous values of the aggressive factor of the driver-vehicle are presented on the samples from Figure 11 and the instantaneous values on the samples of engine torque M_e (Figure 13) and engine power P_e (Figure 14). As can be seen from these graphs, the engine torque and engine power increase with the increase of the aggressive factor, including its average and maximum values, as it was expected.

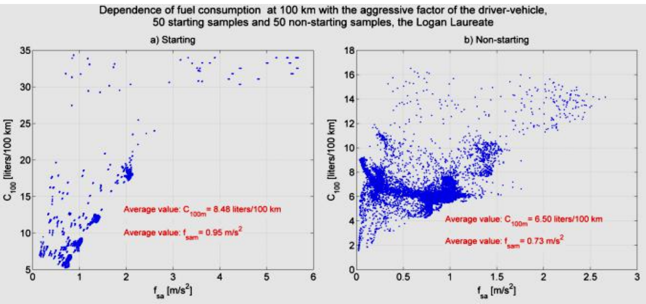

Figure 12. Dependence of fuel consumption at 100 km with the aggressive factor of the driver-vehicle, 50 starting and 50 non-starting samples, the Logan Laureate

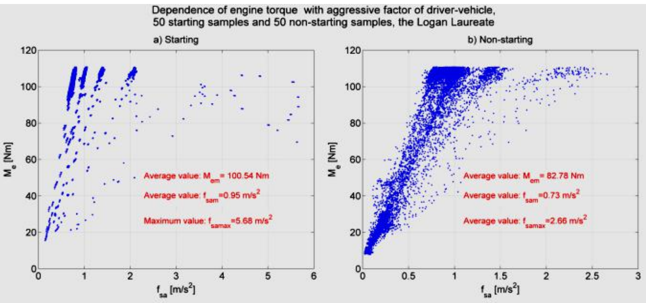

Figure 13. Dependence of engine torque with the aggressive factor of the driver-vehicle, 50 starting and 50 non-starting samples, the Logan Laureate

In the case of this criterion too the evolution tendency of a certain value can be determined depending on the factor of aggression.

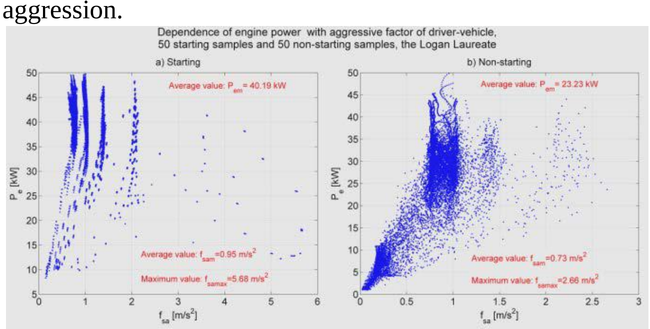

Figure 14. Dependence of engine power with the aggressive factor of the driver-vehicle, 50 starting and 50 non-starting samples, the Logan Laureate

For example, in Figure 15, the dependence of the average value on the samples of fuel consumption at 100 km is presented in function of the average value on the samples of the aggressive factor of the driver-vehicle in case of starting (data from Figure 12a).

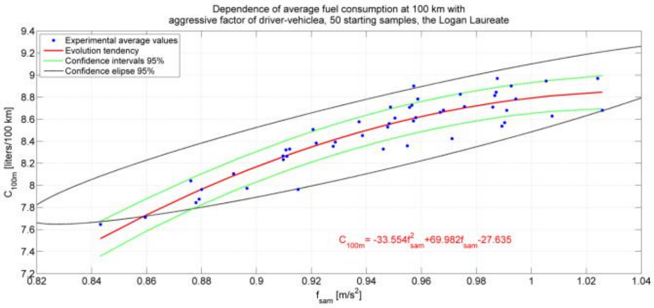

Figure 15. Dependence of average fuel consumption t at 100 km with aggressive factor of the driver-vehicle, 50 starting and 50 non-starting samples, the Logan Laureate

Experimental values, trend of evolution (second order parable), 95% confidence intervals, and 95% confidence ellipse are presented in the graph; as can be seen, it can be assumed that the 95% confidence ellipse includes practically all experimental values.

As the chart shows, the trend of evolution is given by the second degree parabola:

$$C_{100m} = -33.554\, f_{sam}^{2} + 69.982\, f_{sam} - 27.635 \quad (6)$$

This offers average values of the fuel consumption at 100 km in function of the average values of the aggressive factor of the driver-vehicle in case of starting.

IV. Conclusion

Quantitative appreciation of the influence of the driving style can only be obtained based on experimental data.

Equipping today's vehicles with control systems, transducers, actuators and on-board computers enables a thorough study of engine operation and provides data on the influence of various factors.

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