THEORETICAL AND EXPERIMENTAL STUDY OF THE AUTOMOTIVE FUEL SAVING

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Abstract: *This paper presents some theoretical considerations concerning the energetic efficiency and fuel saving of the machines, as a general issue, and of the automotive as a specific issue. The paper also presents experimental aspects with respect to the vehicle's fuel consumption. The main assessment indices of the vehicle's and engine's fuel saving are stressed. Theoretical and experimental results, according to some test data are provided. The work also makes some connections to the fuel usage efficiency and the components of the energetic balance are presented. The work makes a comparison between the fuel consumption and the degree of the energy usage for different working conditions of the vehicles that have electronically controlled engines and mechanical transmissions.*

Keywords: fuel saving, energetic efficiency, power balance, fuel cyclic bulk volume

INTRODUCTION

Among the main requests a vehicle should accomplish there are those referring to fuel saving. In a narrow sense, fuel saving refers only to the fuel consumption expressed in different ways. In a wider sense, we should also cover other aspects as, for example, those referring to the energy consumption level given by the fuel, the efficiency of the engine and of the propelling system, etc. We should also make comparative studies concerning the fuel saving, for different kinds of engines, transmissions, propelling systems and for different kinds of fuel, classical or unconventional.

APPLICATIONS CONCERNING THE ECONOMIC EFFICIENCY OF AUTOVEHICLES

Like the vehicle as a whole, dynamics and fuel saving have developed in time. However, the car remains a means of transport with a weak energetic efficiency, as we can see in fig. 1 for a midsize car [1]; in fig. 1, the first figure refers to the urban European cycle, and the figure in brackets to the interurban European one. As we can notice in fig. 1, only 18.2% (25.6%) of the energy given by fuel is available for transmission. Moreover, only 12.6% (20.2%) of the energy is available for the propelling system, for the real movement.

Fig. 2 shows the variation of fuel saving and cost in 2003 for different classes of cars [2]. Frequently, fuel saving is appreciated through the number of miles driven with a gallon of fuel (mpg - mile/gallon) and cost in dollars.

For example, for a midsize car (a habitable volume of 3.11-3.37 m^3) we got a fuel saving of 12-32 mpg, and the fuel cost was 2062-725 $; expressed in number of kilometers driven with 1 liter of fuel, saving for this class of cars was 5.1-13.6 km/liter (1mpg = 0.425 km/liter) which means a fuel consumption of 7.35-19.6 liter/100 km.

A improvement of the fuel saving for all classes of cars is expected for the future [3]. For example, OTA (Office of Technology Assessment) considers that saving for the midsize cars will increase to 39-42 mpg in 2005 (5.6-6.1 liter/100 km consumption) and to 53-63 mpg in 2015 (3.7-4.4 liter/100 km).

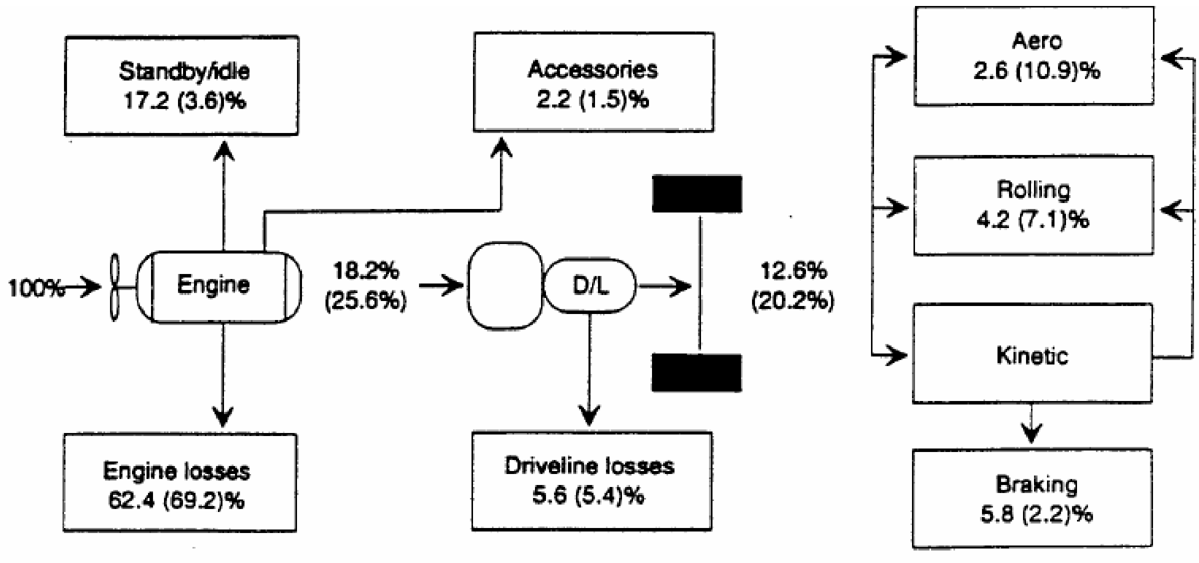

Fig. 1. Energetic efficiency for a midsize car

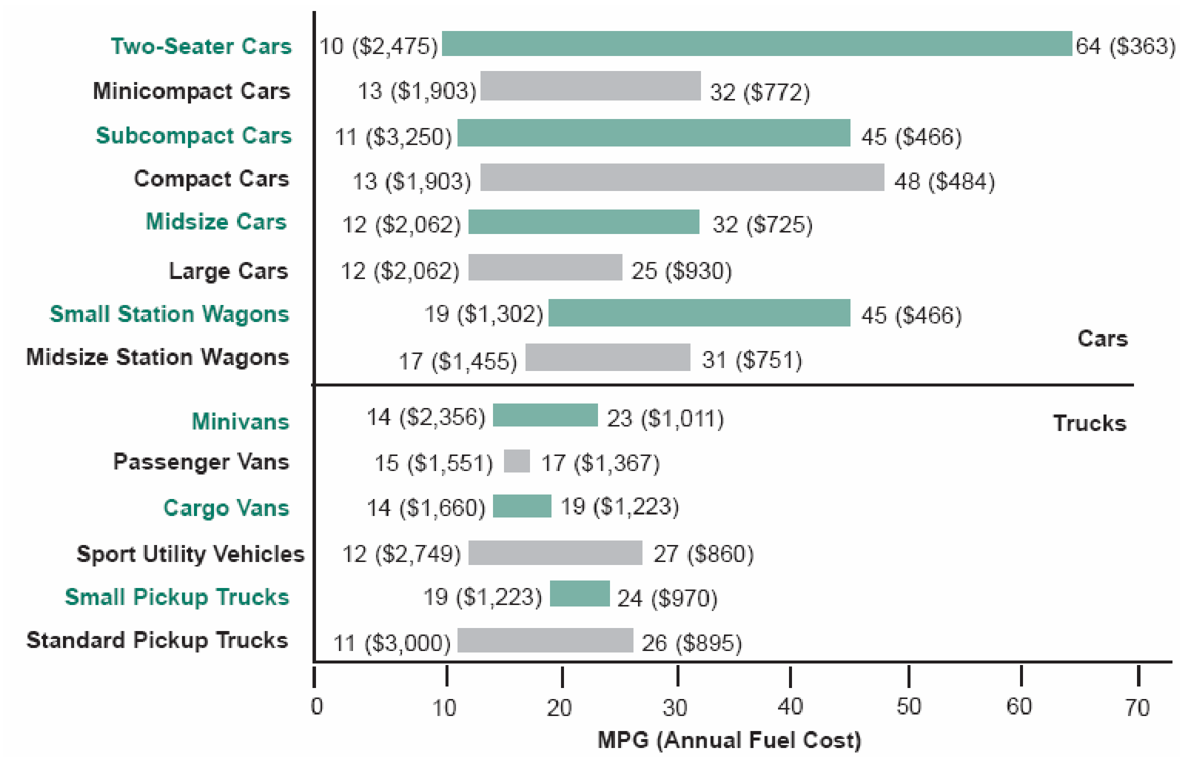

Fig. 2. Fuel saving and cost variation for class of cars

There is a continuous demand to decrease the fuel consumption and that is due to saving the natural oil resources, which are limited and better used in other domains; even non-conventional fuels are used, they are considered just as a local choice, so they won't solve the worldwide problem. There should be noticed from the very beginning that a theoretical limit of the minimal fuel consumption works as a threshold [4].

For instance, an Otto engine having a compression ration of ε=10 has a theoretical (possible) minimal specific fuel consumption of c_t=125 g/(kWh) that corresponds to a theoretical efficiency of η_t=60%. Obviously, in the real world the ideal values would be never approached. Figure 3 gives, as an example, the results that have been obtained for 6 tests of a DAEWOO Nubira passenger car (symbolized as I1…I6); the real values of the efficiency can be seen in fig. 3a, and as noticed, they merely exceed 30%.

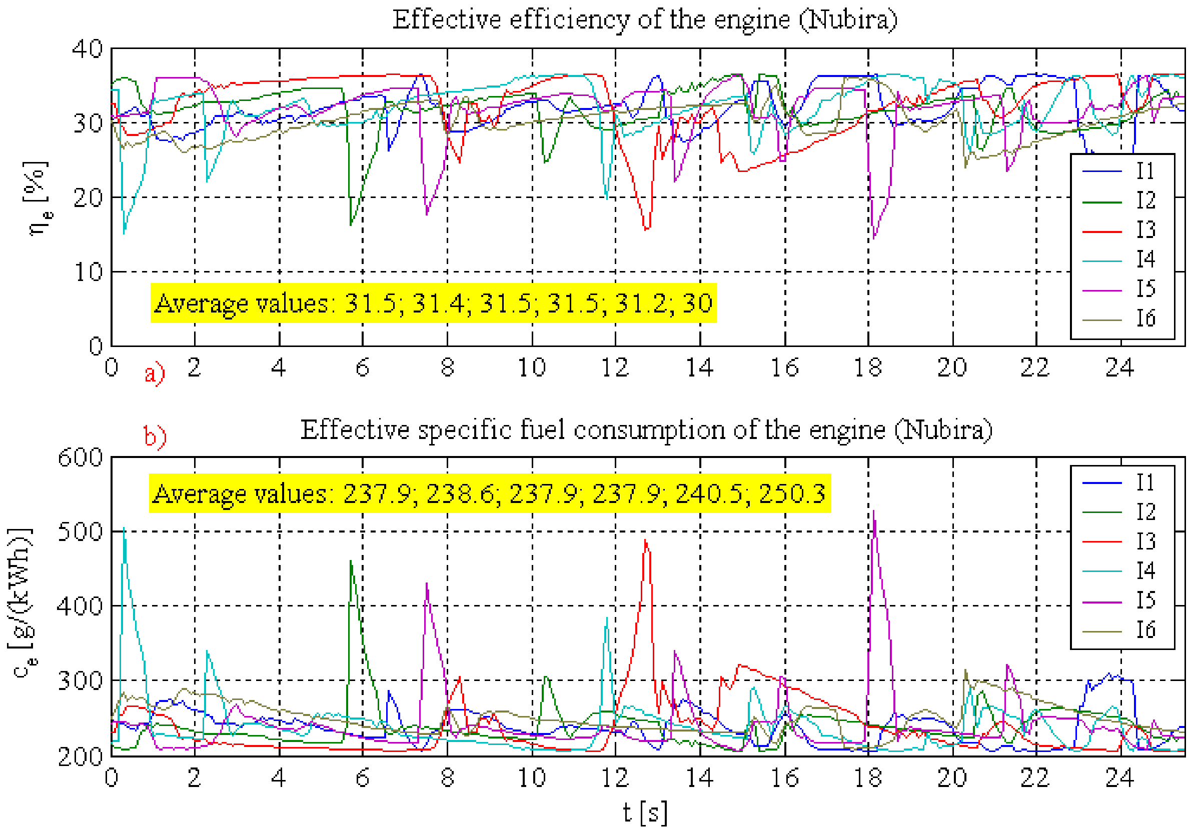

Fig. 3. Fuel saving assessment indices

THE FUEL CONSUMPTION USED IN THE STUDY OF ECONOMIC EFFICIENCY

The references for passenger cars gives as the most usable index for the fuel consumption the fuel consumption for 100 km; frequently, the volumetric consumption is used (give in [liter/100 km]), but sometimes the mass fuel consumption is also suitable (given in [kg/100 km]). Both cases are completed with the fuel consumption per hour (C_h); hence, the fuel consumption given in [liter/100 km] can be computed with the well-known relation:

$$C_{100}^{l} = \frac{100 C_h}{\rho V} \tag{1}$$

where ρ is the fuel density and V [km/h] represents the car's speed.

Fig. 4 provides a good example, using the results of 8 tests developed with a DAEWOO Nubira passenger car. The picture depicts the average speed and the throttle's position versus fuel consumption. The diagram enhances the fact that the car's fuel consumption won't strictly obey to the order of the speed hierarchy (e.g. tests I4 and I5), and that confirms the complexity of the processes. Hence, when analyzing them, intimate dynamic aspects should be considered.

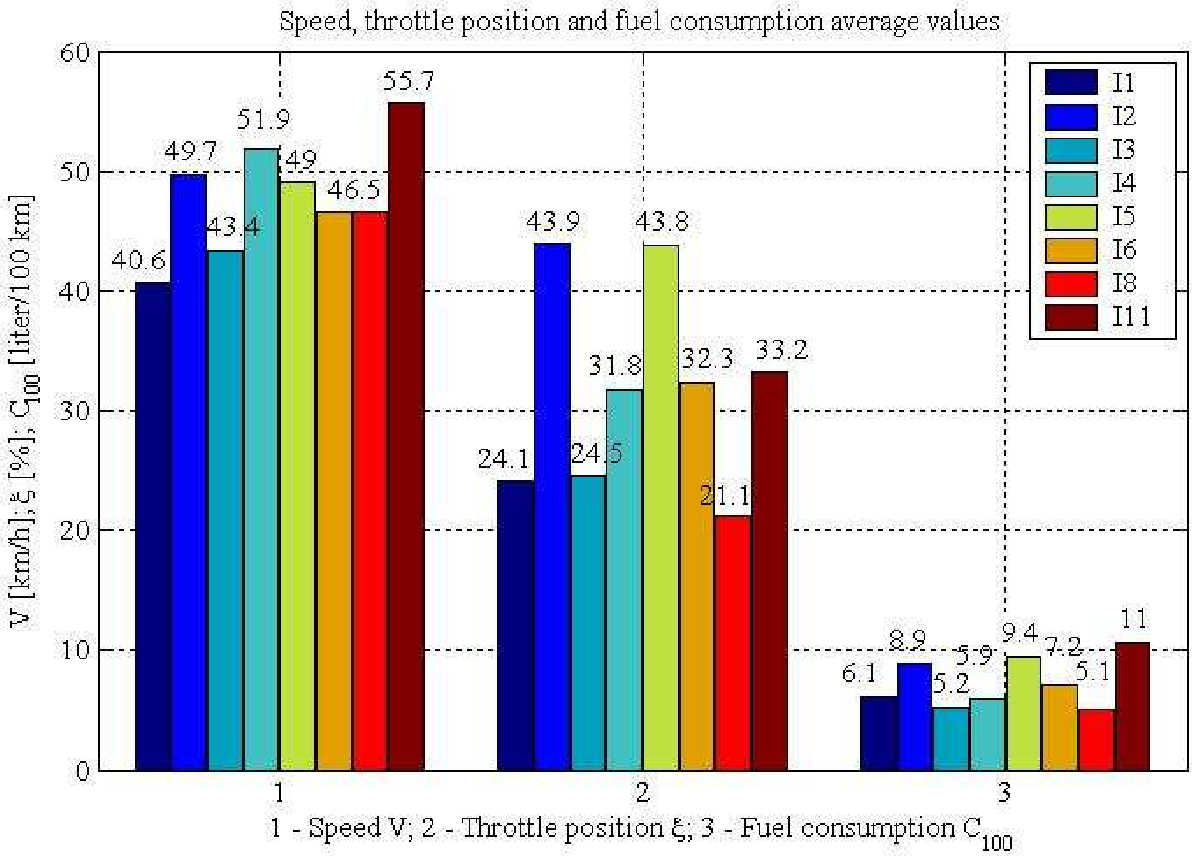

Fig. 4. Average values

THE EVALUATION CRITERIA FOR ECONOMIC EFFICIENCY

Another fuel saving criterion, which is rather rarely used, is the fuel consumption per distance unit, C_{km} [kg/km]; since the mass fuel consumption is involved, then:

$$C_{km} = \frac{C_h}{V} \tag{2}$$

On the other hand, the reverse of the previous ratio (i.e. the distance that can be traveled with one unit of fuel) is intensely used, especially when talking about passenger cars. Moreover, the distance unit is not the kilometer, but the mile (1 ml = 1,609 km) and the volumetric fuel consumption is also used.

As a result, an assessment index for fuel consumption, the [mpg] (mile per gallon) came into being. It will be further referred as S_m [mpg]; since there is a correspondence of 1 gallon = 3.785 liters, then 1 mpg=0,425 km/liter. Hence, the next computation equation results as follows:

$$S_m = \frac{\rho V}{0,425 C_h} \tag{3}$$

Fig. 5 depicts this amount for 4 tests developed with a DAEWOO Nubira passenger car; the graphs give the distance (in km) traveled using a single liter of fuel S_{km} [km/liter], which is computed using:

$$S_{km} = \frac{100}{C_{100}} \tag{4}$$

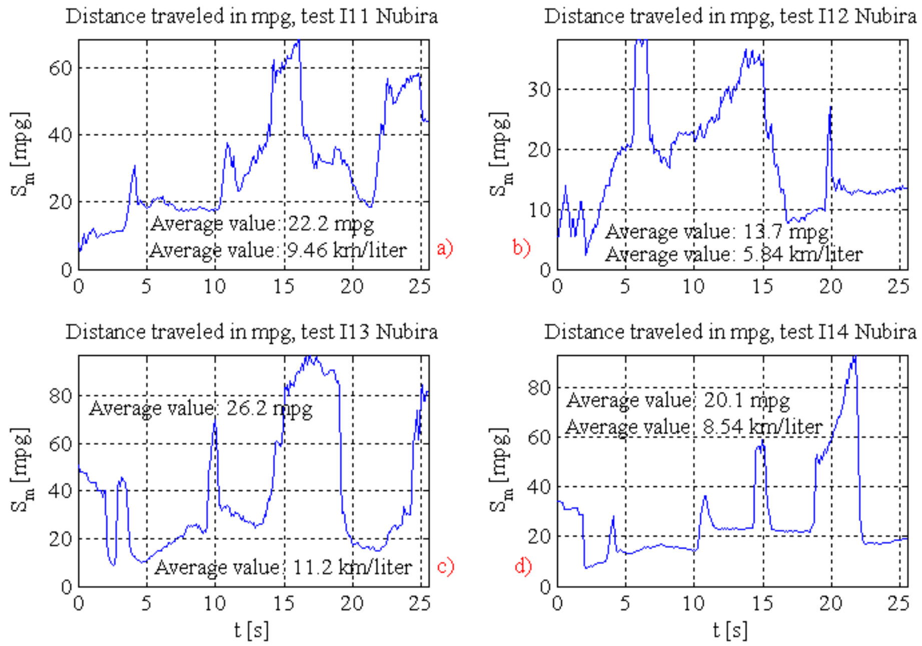

Fig. 5. Fuel saving assessment indices

CONCLUSIONS

According to what I have previously shown through experimental exemplifications, an improvement in the dynamics of the automobile usually leads to a decrease of its fuel saving efficiency. It would be, therefore, extremely beneficial to determine exactly how much can be gained in dynamics and at what costs in terms of fuel economy. All in all, we should be able to establish this relation of inverse proportionality and its effect on eco-dynamics. The gain and the loss were compared to the first sample (C5), with the highest and the lowest dynamic value. Thus we can obtain the graphic shown in figure 7a (the dynamic increment) and figure 7b (the economic loss), both calculated in percentage.

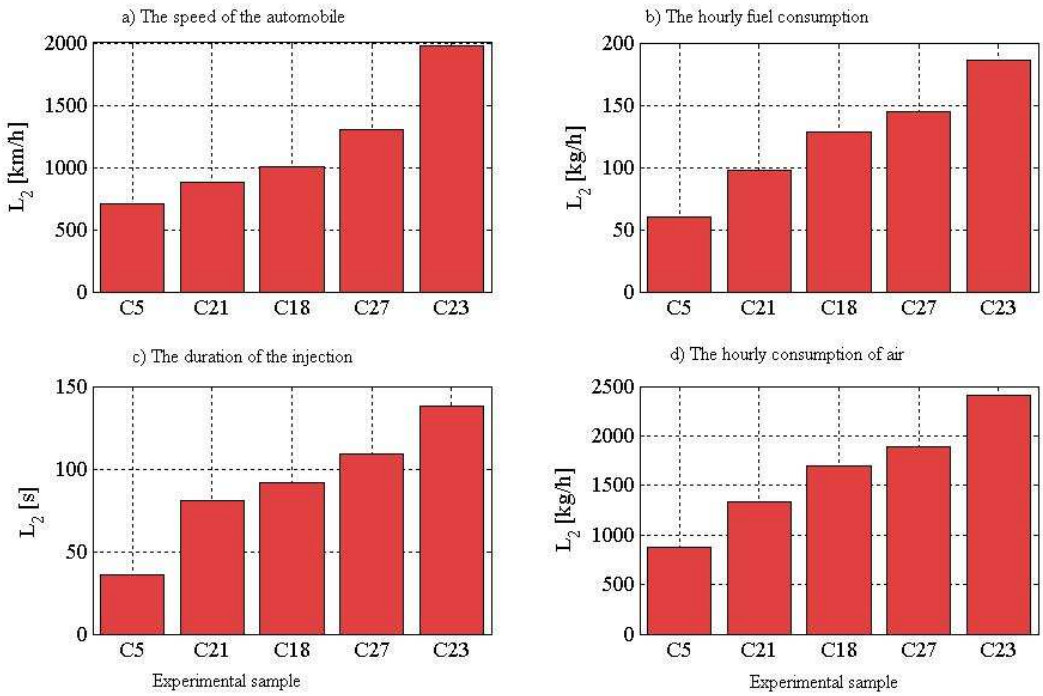

Fig. 6. Indexes for some functional characteristics of the Cielo vehicle

If we assign the same significance to both the dynamics and the fuel saving, we can consider that the eco-dynamics reside in establishing the differences between the losses in economy and the gain in dynamics, as shown in (1) for C21 sample. Therefore the data graphic in figure 7c shows the losses in eco-dynamics of all four samples compared to the C5 sample. As one can observe in the (1) relation, the C21 sample has an increment in dynamics of 24%, while the decrease in eco-dynamics is 26,8% compared to C5 sample.

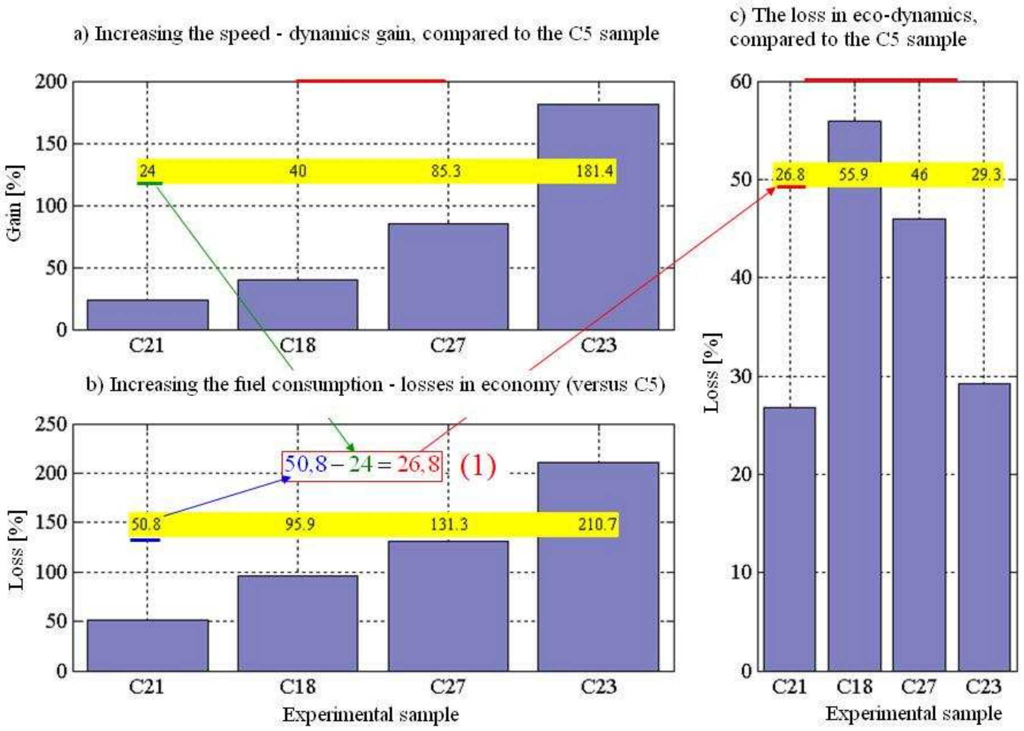

Fig. 7. The study of eco-dynamics for five experimental samples (Cielo vehicle)

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