Functioning Simulation of Logan Laureate Vehicle Based on Experimental Data Acquired from a Start-Up Test

Iulian-Leonard CUCU, Laszlo BAROTHI, and Ion COPAE

Abstract—**This paper presents a method of simulation of vehicle dynamics or engine efficiency based on a graphical programming language used in advanced research software. The obtained data allows the development of other comparative studies with other vehicles in the same range or the determination of mathematical models of some important parameters related to the operation of the vehicle. The simulation allows highlighting other data that could not be recorded in the start-up test, such as emissions.**

Index Terms — **traction forces, pollutant emissions, vehicle dynamics, start-up simulation.**

I. INTRODUCTION

In order to perform the simulation with CAE software, the initial data comes from a start-up test made with the Logan Laureate vehicle, equipped with a K7J engine with a 1390 cc engine, with a power of 55 kW at 5500 rpm and engine torque of 112 N·m at 3000 rpm. The recording of the two parameters, which are mandatory for simulation, is acquired with a specialized CLIP tester.

The two parameters are: variation of vehicle speed with time, and variation of the gearbox's number of gears with time. Obviously, other important parameters of the vehicle are introduced into the simulation software, such as: gear ratio, total cylinder capacity, caloric efficiency of gasoline, minimum engine speed, minimum rotational speed of the first shaft of the gearbox, performance level characteristic to gear ratios, width of the tire, height/width ratio of the tire, diameter of the wheel etc.

A very important library for the software to have the simulation for the paper is "IC Engine", which in its turn comprises the following sub-libraries: IFP drive, IFP engine, IFP exhaust, CFD-1D and C3D IFP. The components that can be analyzed by these libraries are: driver behaviour, gear box, camshaft, crankshaft, cylinder, fuel, heat transfer to the cylinder walls, airflow admitted, turbocharger, injectors, vehicle dynamics, etc.

The model represents the engine and vehicle behaviours without considering the clutch control for different operating cycles or for particular duty cycles entered by the user through the data file. The data file provides vehicle control information and contains information on vehicle speed and gearbox ratio variation, both based on time. The driver sub-model (DRVDRV00B) does not need engine speed as input. An engine speed sensor is used and is connected to the driver.

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II. SIMULATION CONFIGURATION STEPS

The vehicle simulation program is very easy to set up. In order to obtain credible and accurate data, it is important to take the following four important steps.

In the figure below, the print screen of the main window of CAE software is shown.
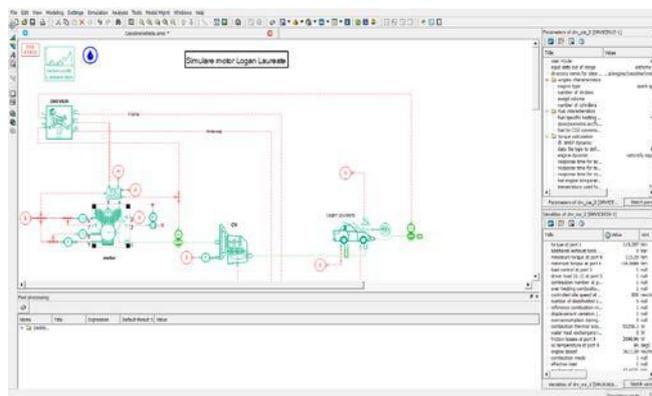

Figure 1. Software's print screen

The first step is to build the program's calculation scheme using predefined or user-created blocks. It is worth mentioning that the colour codes in the scheme are of major importance. For example, the elements and the circuits are marked with red; blue refers to hydraulic systems, turquoise is for simulation of mechanical (predefined) systems in the field of motor vehicle engineering and the green colour is associated with purely mechanical-based elements.

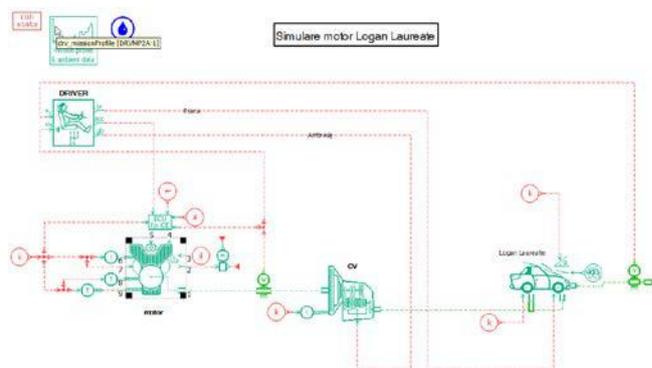Fig. 2 shows the graphical programming sketch for the given simulation.

Figure 2. Simulation sketch

The second step is to choose sub-models for each block. With the help of the sub-models, the calculation of the differential equations is chosen. For example, in the present paper the driver model is commanded by a data file. The data is taken from a pre-registered start-up on the Logan Laureate with a direct injection gasoline engine. This file

contains data grouped in three columns: time, vehicle speed, and gear number at each time point.

In the third step, the software operator has to set up the main parameters of the vehicle, which are: gear ratio, total cylinder capacity, caloric efficiency of gasoline, minimum engine speed, minimum rotational speed of the first shaft of the gearbox, performance level characteristic to gear ratios, gear ratios, width of tire, height/width ratio of the tire, diameter of the wheel, etc.

Figure 3. Parameters setting up screen

The fourth step is to run the calculation program and present the results in graphic form.

III. SIMULATION RESULTS

The results of the simulations can also be presented in this software. In Fig. 4, the vehicle speed variation and the engine speed variation are presented as they are given by the software.
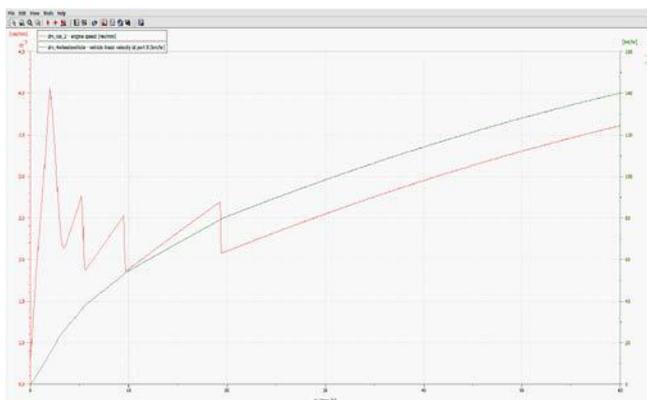

Figure 4. Print screen of results from CAE software

In the following, several parameters of the gasoline direct injection engine of the Logan Laureate are highlighted. All the figures below are made and processed with another CAE software for better representation.
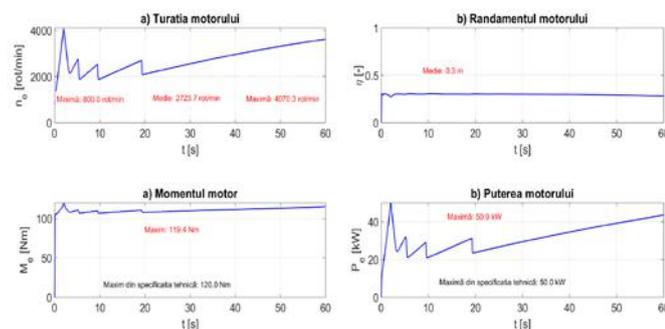

Figure 5. Main simulated start-up parameters (engine speed, energy efficiency, engine torque, engine power)

The figure below shows the simulated data of vehicle's start-up. In the figure below in left side the variation of engine speed is presented. The shifting moments can be observed easily from graphs. The maximum engine speed is 4070.3 rpm, which was reached in the first gear. And this graph shows that the car is equipped with a 5-speed gearbox. The minimum speed is 800 rpm, which is the minimum stable engine speed and is set in the software. The thermal efficiency of the engine is simulated in figure b) and has an average value of 30%. Due to the starting-up test, the engine torque is high and very close to the maximum value given in the technical specification. Also, on the variation of these parameters the gear shifting moments can be observed. The maximum theoretical value of the engine torque is 119.4 N·m. In the last figure there is a simulation of the engine power variation. The power variation is higher than the torque variation. The maximum value is higher than the one given in the technical specification and is 50.9 kW. It can therefore be concluded that the calculation error for the engine power simulation is 1.8%.

With the CAE software, losses due to friction and loss due to the heat exchange inside the engine can also be simulated.
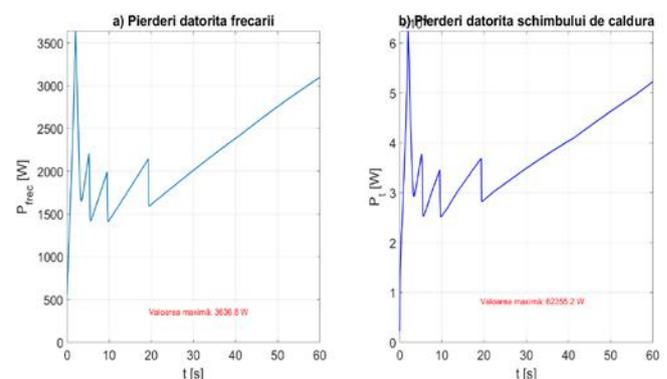

Figure 6. Main simulated start-up parameters (friction losses, heat losses)

It is noted that the two types of losses are very close and are directly proportional to the engine speed. The maximum power lost due to friction between the motor mechanisms is 3636.8 W. It is noted that the maximum friction value is also reached in the first gear. The maximum loss due to heat exchange is 62.35 kW.
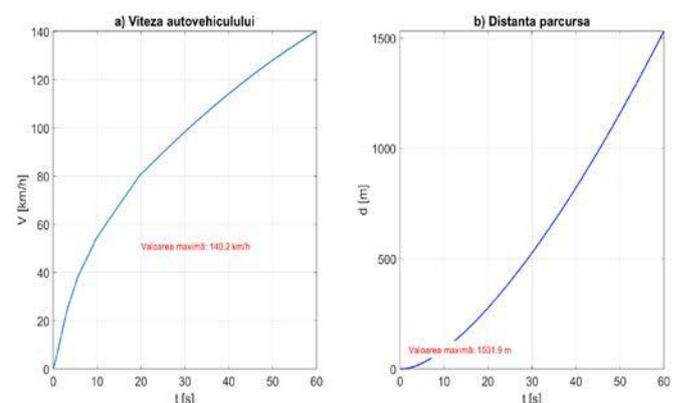

Figure 7. Main simulated start-up parameters (vehicle speed, travelled distance)

Another example for highlighting the simulated data is given in the graph above, showing the variation of two kinematic parameters of the vehicle. In the figure above, in the right side is shown the variation of the vehicle speed during the start-up test. The maximum speed achieved in 60 seconds is 140.2 km/h. On the simulation of the speed graph it is easy to observe the gear shifting moments. And the figure on the left side shows that in 60 seconds the vehicle travels 1531.9 meters.

The change in traction force, shown in the figure below, illustrates that there is a calculation error. The maximum value is 3636.8 N, obviously in the first gear. From the variance of the forward resistances, it is observed that this is a first level function. In contrast, in the specialty literature [1-3], the total displacement resistance is a second degree function due to the air resistance.
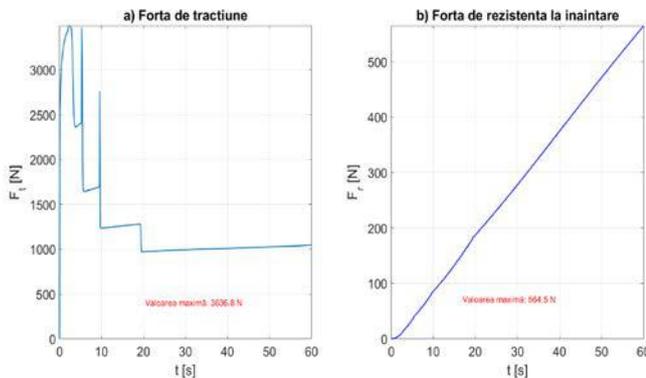

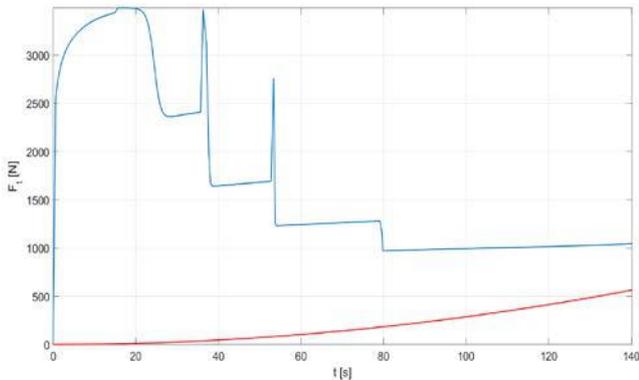Figure 8. Main simulated start-up parameters (vehicle speed, travelled distance)

Figure 9. Traction and resistance forces

The figure above shows the traction forces variation, which emphasizes that the vehicle didn't reach its maximum speed at 140 km/h. It is not shown where the two charts intersect because simulation in the CAE software was done in up to 60 seconds while the vehicle reached about 140 km/h. At this speed, the difference between the traction force and the resistant forces is 481.3 N, which is the surplus force, or hook force at 140 km/h.

The software also allows simulating the amount of burned gas as well as its composition. So, below there are: the variation in fuel consumption, total fuel consumption, carbon dioxide emissions and total carbon dioxide emissions. The fuel consumption, as simulated, is directly proportional to engine speed. The average consumption per second is 2.5 g/s of petrol. In 50 seconds, the engine consumed 150.2 g of petrol. It means that the car at this

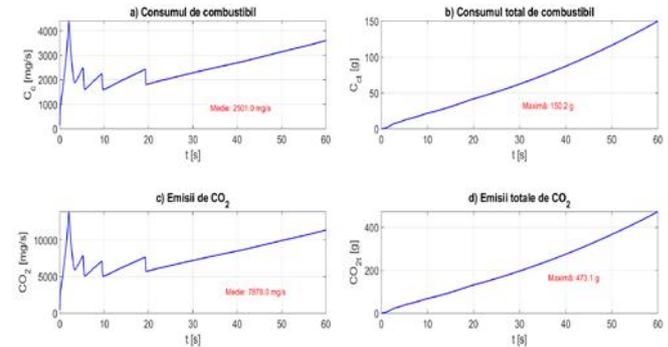start-up test consumed 0.2 litres of fuel.

Figure 10. Main simulated start-up parameters (fuel consumption, total fuel consumption, CO_2 emissions, and total CO_2 emissions)

Fig. 10d shows that the amount of CO_2 emissions is directly proportional to the fuel consumption and, implicitly, to the engine speed. The average consumption for 60 s is 7.8 g/s. If the vehicle has travelled 1.53 km in 60 s it results that the engine's carbon dioxide pollution at start-up is 309.21 g/km.

To exemplify, the variation of carbon monoxide (Fig. 10a), hydrocarbons (Fig. 10b), NOx (Fig. 10c) and burned gas flow (Fig. 10d) are presented below.

Fig. 10d shows that the engine emits 2501 mg/s as an average amount of carbon dioxide during start-up. It also follows from this figure that the maximum emission per second is 2664.9 mg/s when leaving the scene. Towards the end of the simulation, carbon monoxide emissions are gradually increasing. This can be explained by the fact that the engine speed increases and the firing becomes deficient.

From the simulated uncharged hydrocarbon (HC) emissions, it can be observed that this is similar to the variation of the engine speed. The maximum emission value is reached at the beginning of the test in the first gear. On average, the engine emits 67.2 mg/s during the start-up test. Instead, the pollutant emissions have higher values, 132.1 mg/s. The burned gas flow has a maximum value of 67.7038 g/s.
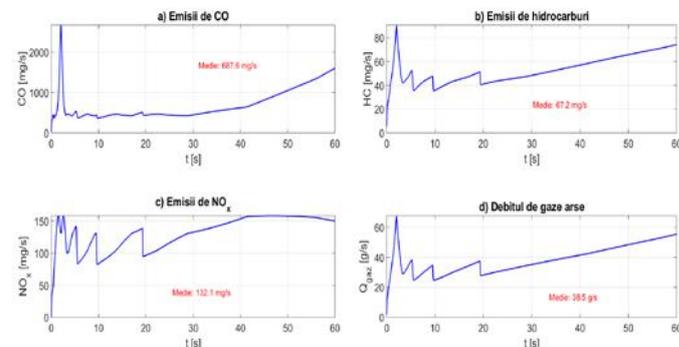

Figure 11. Main simulated start-up parameters (CO emissions, HC emissions, NOx emissions and burned gas flow)

IV. CONCLUSION

In conclusion, the DRVDRV00B sub-model, which governs driver behaviour and vehicle control, also provides plausible information about the operation of the gasoline engine fitted to the Logan Laureate vehicle.

It is noticeable that each graph leaves from zero, which, for example, in pollutant emissions is not the case because the car's engine at the time of departure is running. This inconvenience derives from the initial conditions set at the beginning of the simulation, from the files provided by the user. Since a file contains time related data and the speed of the car starts from zero, the first value in any simulation is zero.

Almost all of the simulations are dependent on and directly proportional to the engine speed.

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