SIMULATION OF A PASSENGER CAR PERFORMANCE AND EMISSIONS USING THE AVL-CRUISE SOFTWARE

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Abstract: Lucrarea prezintă un studiu teoretic al emisiilor de gaze poluante pentru autoturisme. Au fost cercetate mai multe condiţii de exploatare, utilizând software-ul de simulare AVL-CRUISE, cu studiu de caz aplicat pentru un autoturism echipat cu motor cu aprindere prin scânteie. Programul de simulare poate fi utilizat pentru analiza parametrilor de funcţionare pentru întregul autovehicul, atât motorul, transmisia, cât şi sistemul de tratare a gazelor de evacuare, în toate fazele de proiectare. Astfel se obţine o reducere semnificativă a timpului alocat cercetărilor experimentale, ceea ce duce la o scădere a costurilor asociate dezvoltării prototipurilor şi o identificare rapidă a punctelor critice unde se pot obţine îmbunătăţiri semnificative în privinţa performanţelor.
Cuvinte cheie: Programul AVL-CRUISE, emisii poluante, autoturisme, motor, transmisie.

Abstract: This paper presents a theoretical study of emissions variation for passenger cars. Various situations were investigated by simulation using the AVL-CRUISE software applied for vehicles powered by spark ignition engines. The software can be used to analyze operational parameters for the entire vehicle, including the power unit, transmission and after-treatment system, throughout all the development phases. This greatly reduces the need for experimental trials and results in decreased development costs, with speedy identification of critical points where significant improvements can be achieved.
Keywords: AVL-CRUISE software, emissions, passenger cars, power unit, transmission.

1. INTRODUCTION

In the search for improved fuel economy and low emissions, several technological advances need to be evaluated, with respect to their potential of fulfilling these requirements. One way of studying this potential of improving vehicle operation is to simulate different working conditions using the AVL-CRUISE software. When considering the four AVL products specially designed for simulation purposes, Boost is the first choice for internal combustion (IC) engine thermodynamic cycle simulation, heat transfer and chemistry in exhaust gas after treatment systems and acoustic layout definition. AVL EXCITE is the leader in simulating dynamics, strength, vibration and acoustics of IC engines, transmissions, power units and drivelines under real operating conditions. AVL FIRE is a powerful multi-purpose fluid dynamics software with a particular focus on fluid flow applications related to internal combustion engines and power trains, while CRUISE is the prime tool for finding the right balance between fuel economy, emissions, performance and drive quality for conventional and alternative vehicle concepts [1]. Several studies have been undertaken to predict fuel economy and carbon dioxide emissions [2], or to optimize these parameters [3], as well as developing new strategies for alternative power train architectures [4]. Other studies even used these different modules to better predict performance and emissions during transient operation [5]. Such a study is developed in this paper, with the aim of evaluating emissions from a spark ignition (SI) engine powered passenger car. The results obtained using the AVL-CRUISE software were used to analyze experimental results obtained by performing measurements within the time interval between two periodical inspections.

2. THEORETICAL CONSIDERATIONS

SI engines exhaust gases are mainly constituted of nitrogen (N_2), carbon dioxide (CO_2) and water (H_2O). As these engines are rarely operated in the

lean range (of course, with direct injection SI engines this is no longer the case), very little oxygen (O_2) is found in the exhaust, as compared to compression ignition (CI) engines. The three regulated pollutant species, carbon monoxide (CO), unburned hydrocarbons (HC) and nitrogen oxides (NO_x), generally make up only around 1–2% of the total exhaust gas stream [6]. This proportion largely depends on the air-fuel ratio [7]. Other components such as particulate emissions are also present, but in much lower concentration compared to CI engines, where this requires a particulate filter to be fitted to the exhaust system, in order to fulfill pollution standards. One major drawback of SI engines is that they produce maximum power at slightly rich air-fuel mixtures, resulting in high CO and HC emissions. Another inconvenience is that maximum fuel conversion efficiency is obtained with slightly lean mixtures that lead to high NO_x production rates. A three way catalytic converter can be used to reduce al three regulated pollutant species (figure 1). However this technology requires that the engine is operated very close to a stoichiometric air-fuel ratio. Given the conditions of SI engines operation, several improvements can be identified by performing simulations. The AVL-CRUISE software is capable of simulating the operation of passenger cars in different conditions. In this way, critical points where significant improvements can be achieved are identified without the need for actual experimental trials, or a much smaller number of measurements performed just to validate the results obtained in a very short time by using the simulation software.

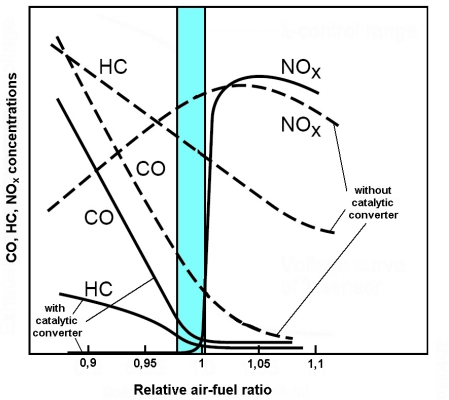


Fig. 1. Emissions concentrations for spark ignition engines exhaust [6].

3. OPERATIONAL PARAMETERS

Several parameters are needed for simulating the operation of SI engine powered passenger cars. These parameters were introduced within the software's block diagram, using the user interface (figure 2):

- vehicle geometrical parameters (L, l, h, Mpr, Amp),
- power train parameters (displacement, torque, power, gear box, differential etc).

Other input data such as engine speed, torque, fuel properties, working temperature and so on, was also required.

The passenger car considered for simulation was a 928 GTS type Porsche, with the following specifications:

- displacement, cylinders, valve train: 5,4 liters, V8, Twin cam,
- engine code: M 28.50,
- rated power: 257 kW @ 5700 rev/min,
- displacement: 5,400 liters,
- transmission: CVA 4,
- vehicle mass: 1620 kg.

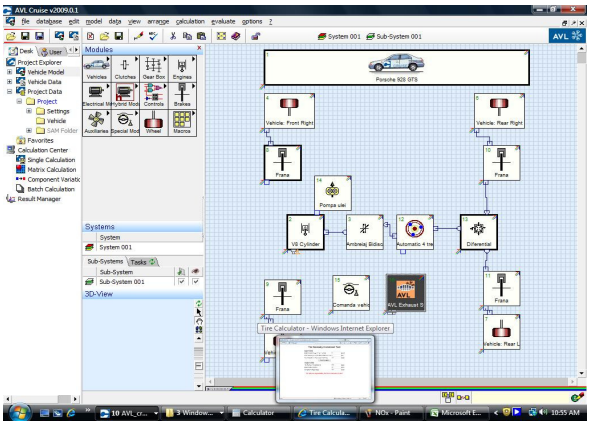


Fig. 2. Input parameters block diagram and simulation algorithm

4. RESULTS AND DISCUSSIONS

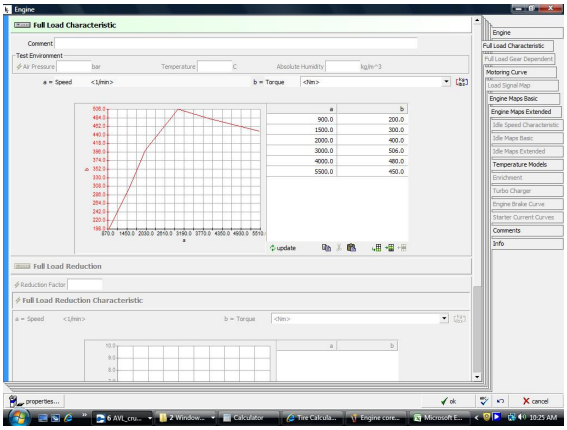


Fig. 3. Calculated torque during full load operation.

The software calculates full load engine torque based on the input data (figure 3). Maximum engine power is the main value used for calculating full load torque. After the full load characteristic is available, several other parameters such as air-fuel intake can be calculated and plotted (figure 4). These values can be plotted in three dimensional or isometric charts.

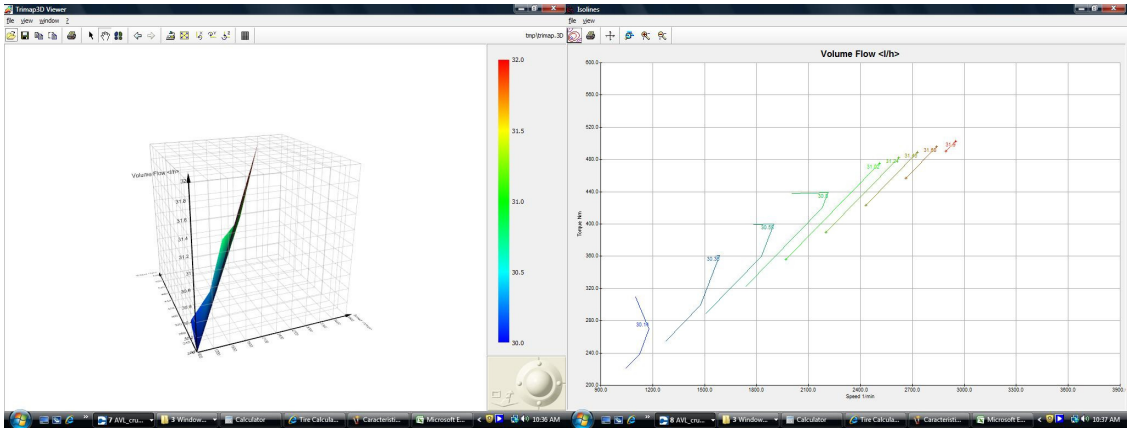


Fig. 4. Air-fuel intake plotted in 3D (left) and isometric (right) charts.

To completely describe the power train, other data referring to transmission gear ratios, differential ratio and so on was needed. Based on this information the software calculated the torque transmitted by the clutch (figure 5). With all parameters properly defined, simulating the vehicle operation was possible, along with calculating HC and NO_x emissions. These values were compared to measurements performed according to the specifications of periodical technical inspections procedure. Volumetric concentrations of CO, HC and O_2 in dry exhaust gases are routinely performed to evaluate the effectiveness of pollution control devices fitted to SI engines powered passenger cars. These concentrations need to be below certain thresholds at idle and accelerated idle, with the engine warmed-up. Nitrogen oxides emissions are not required to be measured, but all standard emissions testing equipment can be provided with this optional component. Calculated values for HC and NO_x emissions were compared to the ones measured during engine operation as described above, and were found to be in good accordance with the experimental data. As a result, the results provided by the AVL-CRUISE software can be successfully used to simulate SI engines emissions for different vehicle operational parameters.

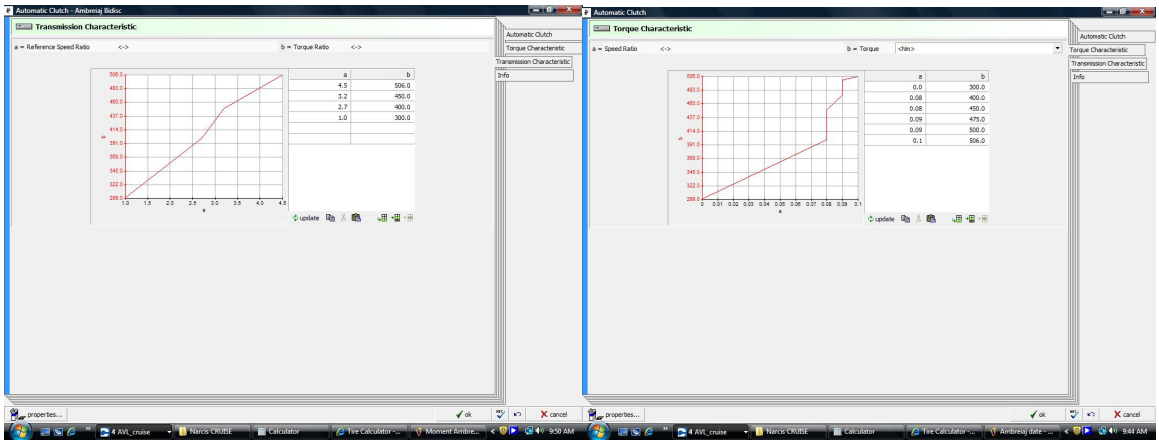


Fig. 5. Transmission characteristic (left) and calculated torque transmitted by the clutch (right).

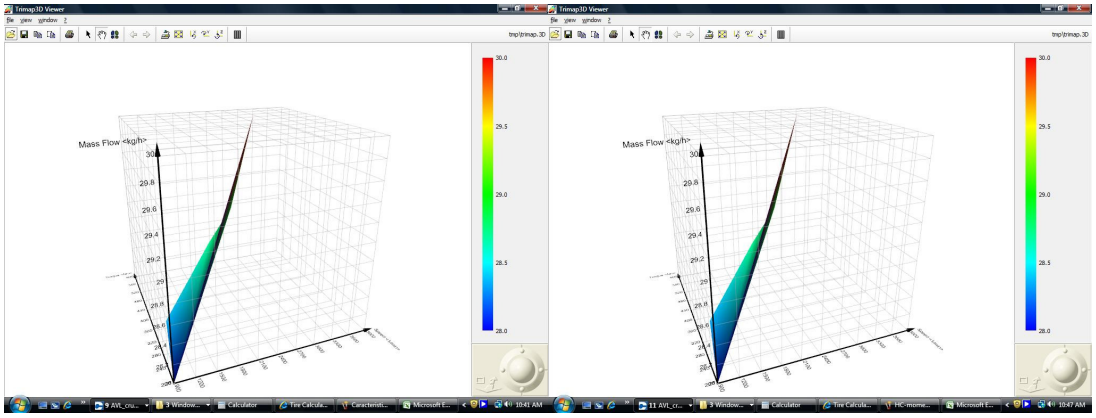


Fig. 6. Calculated HC (left) and NO_x (right) emissions.

5. CONCLUSIONS

Simulation software can significantly reduce the time required for developing new technologies and control strategies in the automotive field. Therefore, the possibility of simulating vehicle operation using the AVL-CRUISE software was investigated. As the results obtained by running the software were found to be in good agreement with experimental data, the simulation program can be effectively used to develop new automotive technology.

ACKNOWLEDGMENT

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