

MATCEL-PROP, A SIMULATION FOR AN OPTIMAL POWERTRAIN USED FOR ROAD VEHICLES

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Abstract—By customizing a mathematical model, previously developed by the authors, has done a simulation to define a completely stabilized operating modes of propulsion systems and their dynamic, economic and pollution parameters. This provides, even the design phase, definition of additional constructive and functional criteria against the current, to ensure stable and economic operation, in an area as extensive.

Keywords—road vehicles, powertrain, simulation, optimal.

I. INTRODUCTION

A complex simulation of the propulsion system behavior in various constructive-functional situations, called *MATCEL-PROP*, has done by customizing a mathematical model, previously developed by the authors.

The basic parameters required for simulation was determined for a typical car; significant values are highlighted in Fig. 1.

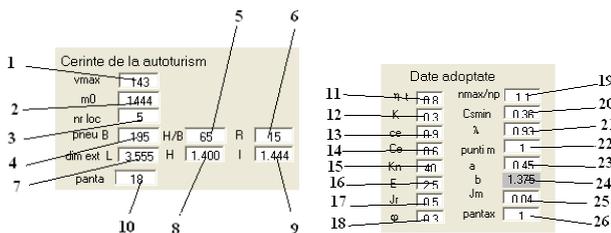


Fig. 1. Basic parameters related coefficients picture

Fig. 2 highlights *characteristic* of the propulsion system model; it is the actual power and timing variations in the unmodified engine propulsion system obtained by simulation, in the form of an executable.

II. SIMULATION AND RESULTS

From these raw elements, further presented the most significant results of simulation *MATCEL-PROP*, looks especially the problem of propulsion system stability. Were considered, in particular, common situation of equipment for the real propulsion system model of car

chosen, designed to lead to some conclusions with applicative features, useful in terms of its mechanical and functional optimization [1].

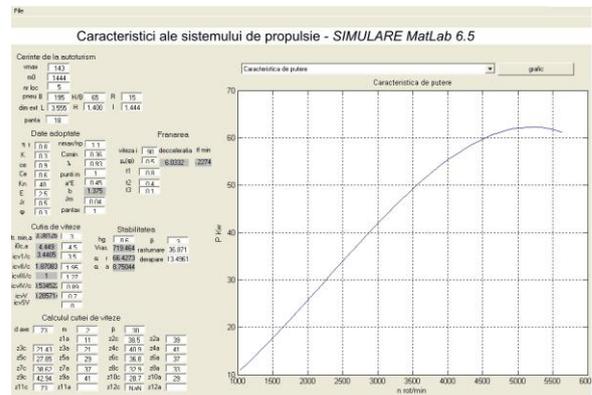


Fig. 2. Characteristic of the propulsion system

Results are summarized using the variation diagrams of engine torque, M_m , resistant torque reduced to motor shaft, M_{rr} and specific fuel consumption, c_e , depending on the angular velocity ω of motor shaft, presented in figures below [2]. For each case, algorithm simulation allows determining the position of the system operating point corresponding to maximum speed of the car. On the other hand, in order to emphasize the stability of propulsion, these diagrams contain the tangent lines to variation curves of torques in the operating point, $Fct.tan.M_m$, respectively, $Fct.tan.M_{rr}$.

Defining the *stability parameter* Δ we can evaluate the stability of the vehicle propulsion system operation:

$$\Delta = |slope(Fct. \tan .M_r)| - |slope(Fct. \tan .M_m)| \quad (1)$$

In this respect, a *first case* simulated and analyzed (*ESI*) with *MATCEL-PROP* considers basic equipment of the propulsion system, which includes an engine having the effective power value 64 (kW), assimilated in the model with an engine power ($P_e=P_m$), and a 15" wheel diameter. By assigning the value 4 for main gear ratio, i_0 , variations in Fig. 3 shows a *stable operating point* at maximum speed of 149 (km/h), and further characterized by an acceptable specific effective fuel consumption, respectively 173 (g/kWh).

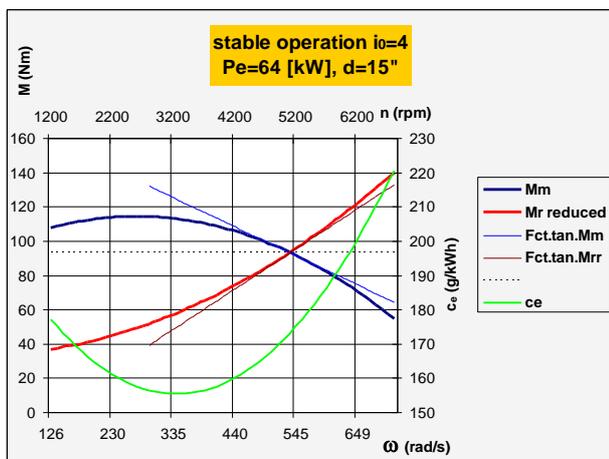


Fig. 3. Conditions for stable operation of the propulsion system - highlighted by the simulation phase *ESI*

Still increasing main gear ratio by only 0.5, thus leading to the value $i_0=4.5$, the propulsion system behavior becomes *unstable*, speed decreases slightly the value of 148(km/h), there the premises so that it can not be kept constant, while the value of specific effective fuel consumption rises to 173 (g/kWh) to 186.4 (g/kWh), situation highlighted by the diagrams in Fig. 4.

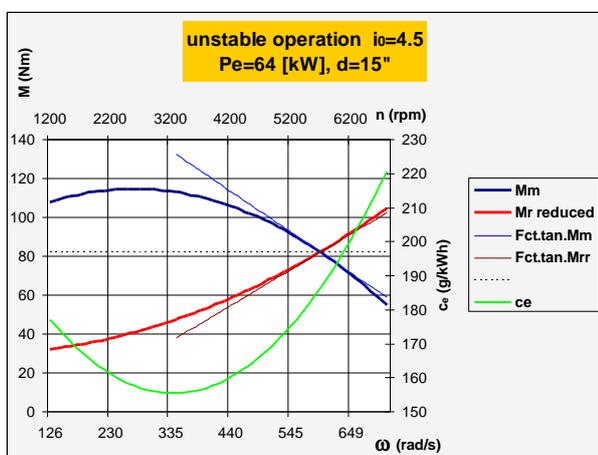


Fig. 4. Conditions for unstable operation of the propulsion system - highlighted by the simulation phase *ESI*

On the other hand, from baseline, summarized in Fig. 3, reducing by 0.5 the ratio main gear i_0 , it reaches $i_0=3.5$, achieve a *very stable* operating point, leading to maximum speed 146.9 (km/h), very stable value, made with a specific effective fuel consumption of 162 (g/kWh), which confirms the downward trend of this important parameter, with increasing stability of the system drive. This condition simulated propulsion system is presented through results obtained in Fig. 5.

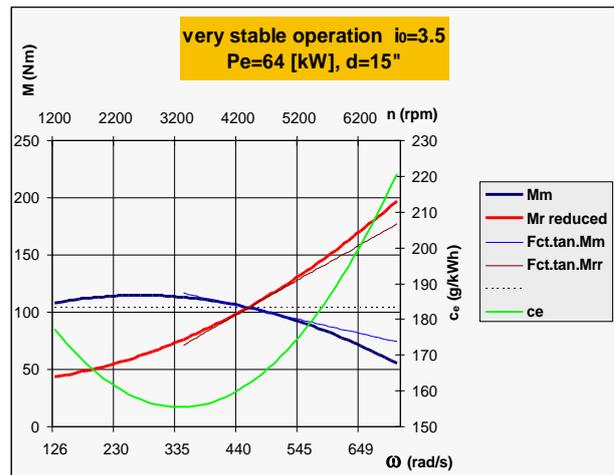


Fig. 5. Conditions for very stable operation of the propulsion system - highlighted by the simulation phase *ESI*

Continuing the iteration of the *MATCEL-PROP*, the main gear ratio value $i_0=3$ is reached *extremely stable* operation of the propulsion system, characterized by a maximum speed value of 136.3 (km/h), in turn extremely constant value, in fact the smallest of speed values highlighted in this stage of the simulation and effective specific fuel consumption decreased to 155.6 (g/kWh), situation presented in Fig. 6.

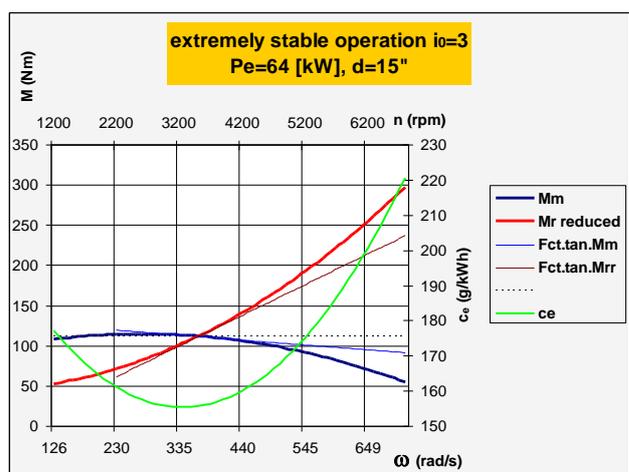


Fig. 6. Conditions for extremely stable operation of the propulsion system - highlighted by the simulation phase *ESI*

Simulate a situation leading to opposite results as shown in Fig. 7, the $i_0=5$ value ratio of the main gear reach a *very unstable* operation, the operating point is characterized in this case by the speed increased to 144.9

(km/h), but can not be maintained, obtained at engine speed of 6200 (rpm) and effective specific fuel consumption increased to a value of 200.4 (g/kWh).

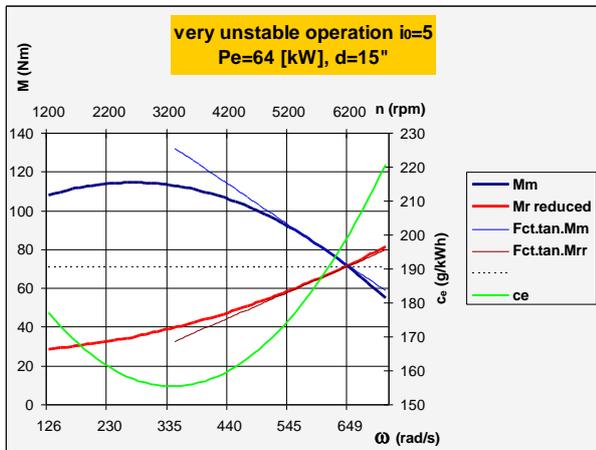


Fig. 7. Conditions for very unstable operation of the propulsion system - highlighted by the simulation phase *ES1*

Simulation performed with *MATCEL-PROP* include a *second phase* of study (*ES2*), which takes into account the above stable conditions, characterized by the motorization of 64 (kW) and the main gear ratio value $i_0=4$, but with two-stage change diameter wheels. Thus, a diameter of 15" was increased to 16".

The *third phase* of study (*ES3*) addressed through simulation *MATCEL-PROP* envisages an engine characterized by increased power to 74 (kW), keeping the basic diameter of the wheel motors, thus is 15", but with the i_0 main gear ratio change, with steps of 0.5 in the range of normal values. *Stable* operation is achieved with the main gear ratio $i_0=3.7$.

The simulation is *MATCEL-PROP* addresses equally the *fourth stage* of the study (*ES4*), leaving, primarily from reduced engine power, thus is 54 (kW) and secondly, as described above, driving wheel diameter 15". Also, in this case is considered the i_0 main gear ratio change with steps of 0.5. Initializing the study from $i_0=4.2$ is reached to a *stable* operating state. The results obtained in the *four stages of the study* are summarized in Fig. 8, Fig. 9, Fig. 10 and Fig. 11, actually describing simulated behavior of the propulsion system, assessed by the stability parameter variation Δ as we define in (1).

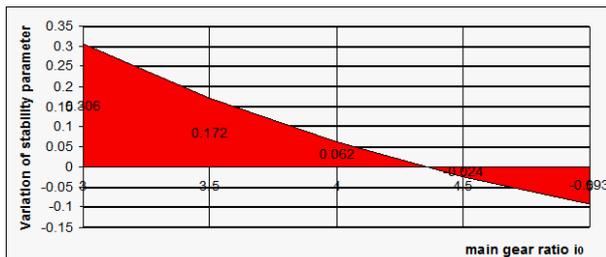


Fig. 8. Variation of stability parameter with main gear ratio change obtained by simulating *MATCEL-PROP* for propulsion engine power of 64 (kW)

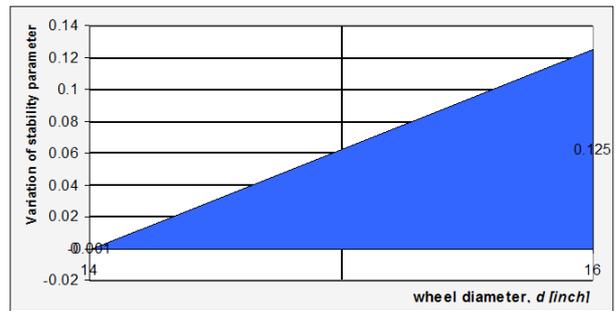


Fig. 9. Variation of stability parameter obtained by simulating *MATCEL-PROP* for changing wheel diameter

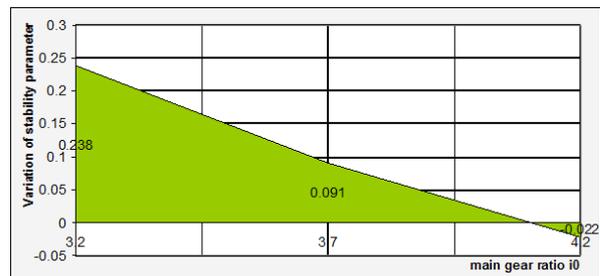


Fig. 10. Variation of stability parameter with main gear ratio change obtained by simulating *MATCEL-PROP* for propulsion engine power of 74 (kW)

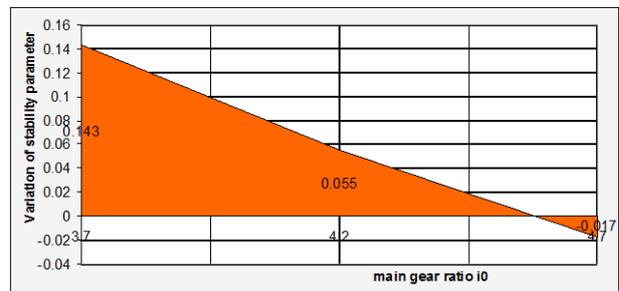


Fig. 11. Variation of stability parameter with main gear ratio change obtained by simulating *MATCEL-PROP* for propulsion engine power of 54 (kW)

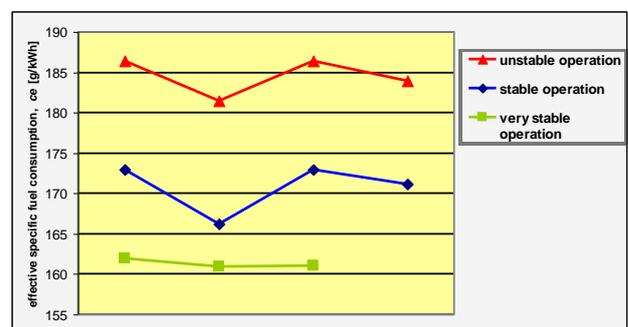
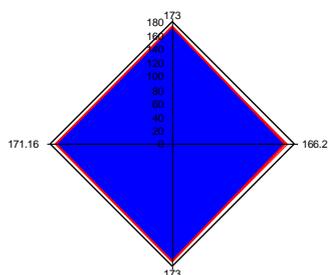


Fig. 12. Evolution of effective specific fuel consumption values for different states of the propulsion system

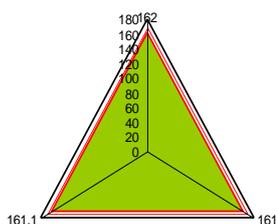
The evolution of specific fuel consumption values for different states of the propulsion system is highlighted in Fig. 12.

Using the Fig. 13 a,b,c shown the variation of these inputs for the three states of the system, and that each state consumption values are very close together, being

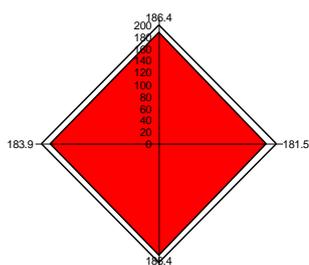
practically constant regardless of equipment and characteristics of propulsion system that obtains the condition of its.



(a)



(b)



(c)

Fig. 13. The range of values of effective specific fuel consumption corresponding of the three states of propulsion system

Based on *MATCEL-PROP* simulation, design using *CATIA V5R16* [3] environment has created a *virtual model of transmission* [4], [5] as a complex part of the propulsion system for the most stable operating situation highlighted. It was also considered the modeling of dynamic phenomena mainly in order to validate *the equivalent mechanical model of the propulsion system*.

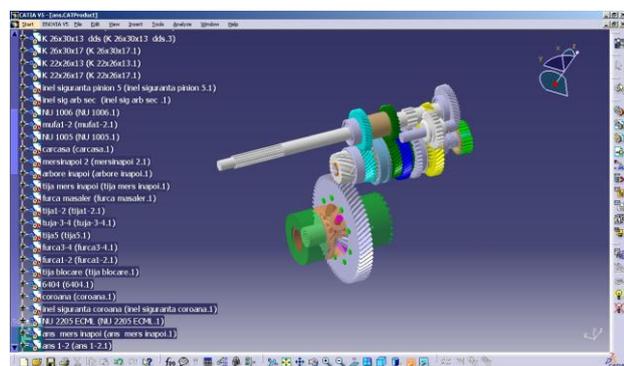


Fig. 14. Virtual model for meshing the principal elements of propulsion system based on the simulation performed

Since the equivalent model substitute the presence of trees, gears and other rotating masses, specific to propulsion system, also was considered useful an evaluation of a discrete model of the propulsion system, encompassing such elements assimilated in mechanical model [6], [7].

Thus, the Fig.14 is presented all the rotating masses of real gearbox model consisting of a mechanical gearbox with fixed axes, with 5-speed synchronized [8].

III. CONCLUSIONS

In this work a model study was performed, which allows to define more completely stabilized operating modes of propulsion systems and their dynamic and economic parameters.

The increased stability of the propulsion system during operation led to lowering the specific fuel consumption which is very advantageous.

This model provides an early-phase design recommendation in addition of existing construction and functional criteria.

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