A PROPOSAL FOR A HYBRID POWER TRAIN FOR A TRUCK

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ABSTRACT

Aiming at reducing the emission of pollutants from automotive vehicles, international commissions indicate, at each given period, a target of admissible values for these pollutants, to be implemented by the automakers. A case like the future implementation of EuroVII, from 2025, in European regions. In parallel to these conditions, there are many studies with the objective of seeking alternatives for the propulsion of these combustion vehicles, for example, the application of fully electric or hybrid vehicles. This article aims to develop and implement a mathematical model for a proposal for a hybrid engine, in a low-power truck, resulting in a small diesel engine, powering the vehicle's alternator and battery, generating the charging for use in a main electric motor, that is, to develop with a focus on energy conservation and the environment, with a reduction in the size of a combustion engine and its emissions.

Keywords: hybrid engine, electric vehicle, power train

NOMENCLATURE

(A)	Frontal Area
$(E_{tr})^{cicle}$	Total energy balance during the cycle
(C_d)	Aerodynamic drag coefficient
(C_{rr0})	Friction coefficient between tire and ground
$(\frac{dV}{dt})$	Derivative of velocity versus time (acceleration)
$(E_{acc})^+$	Electric energy consumed by vehicle accessories
$(E_{batt,int})^+$	Total energy delivered from the battery to the electric motors during acceleration
$(E_{batt,int})^-$	Energy consumed by the system while braking
$(E_{eng,fuel})^+$	Energy delivered by the internal combustion engine
$(E_{tr})^-$	Traction energy spent during acceleration
$(E_{tr})^-$	Energy dissipated during braking
$(E_{tr,credit})^{-/+}$	Energy recovered and supplied back to the battery
(F_a)	Aerodynamic drag force
(F_{tr})	Traction force required for the vehicle to move into motion
(F_{tr2})	Tractive force of electric motors
(g)	Gravity acceleration
(I_w)	Polar moment of inertia of the tire and wheel set
(VE)	Electric vehicles
(VEH)	Hybrid electric vehicles
(VEAE)	Extended Range Electric Vehicle
(KERS)	Kinetic Energy Recovery System
(MCI)	Internal combustion engine
(M)	Mass
$(P_{acc})^0$	Power of the accessories installed in the vehicle
(r_w)	Radius of the tire and wheel set
(t)	Time
(t_{idle})	Total time the vehicle is stopped
(η^+_{batt})	Battery efficiency
$(\eta^+_{dl,mot})$	Efficiency of mechanical components connected to the electric motor
(η^+_{eng})	Internal combustion engine efficiency
(η^+_{gen})	Alternator or generator efficiency
(η^+_{mot})	Electric engine efficiency
(ξ)	Energy separation factor

INTRODUCTION

With the advancement of technology for automobiles, and, along with it, the global demand for concern for the environment by greenhouse gas (GHG) emitters, the Paris Agreement intensifies, at each event. The message is that the world is willing to transform its way of generating and consuming energy, with investment through renewable sources and in technology so that consumption is more sustainable. In other words, decarbonizing the transport sector becomes fundamental part of achieving this goal (FGV ENERGIA, 2017).

In Brazil, CONAMA (National Council for the Environment) established the Air Pollution Control Program by Motor Vehicles (PROCONVE), which aims for the emission of pollutants from motor vehicles, maximum limits of CO, NOx values, among others, for domestic or imported. With that, the automakers started to establish stricter criteria in their developments.

In this scenario, Bartholomeu (2015) assesses and quantifies the potential for CO2 mitigation in road freight transport through the adoption of measures and technologies aimed at promoting a reduction in fuel consumption, as well as the gradual replacement of diesel with biodiesel. As a result, it was pointed out that an increase of 0.5 km/l in energy efficiency in a fleet of 145 vehicles as a sample leads to a reduction of about 20% in GHG emissions. However, the potential for mitigating emissions by increasing the biodiesel content is not so promising, due, in large part, to the drop in vehicle efficiency and, consequently, the increase in consumption.

The National Energy Plan (PNE) 2050 aims to discuss and identify uncertainties related to the automotive fuel market, providing the necessary information to make consistent and rational choices. He pointed out that there is no doubt that the future of this market and the automotive sector will be significantly different. Thus, it is considered reasonable to establish two narrative lines of electromobility scenarios, in which there is a long energy transition to progressive hybridization, and another alternative scenario for a short energy transition, with greater electromobility. With this trend, it is necessary to understand the definitions of hybrid and electric vehicle categories, the technological substitution processes and the associated opportunities and challenges (EPE, 2018).

Currently, vehicle assemblers and manufacturers have lines of research directly focused on hybrid proposals, and 100% electric proposals (EV, from the English term electrical vehicle) used to generically describe any type of electric vehicle (DENTON, 2018). The different ways or options of vehicle architecture and its assembly for a hybrid or electric, are distributed in variations such as a purely electric vehicle (Pure EV), whose power is supplied only by the battery as a source of electrical energy. Another vehicle architecture option is the so-called plug-in hybrid electric vehicle, or just plug-in hybrid vehicle, with a battery that can be connected to the electrical network and that has an internal combustion engine. A third option are extended-range electric vehicles (VEAE, or E-REV – Extended-Range Electric Vehicle), powered by a battery that receives power from a generator coupled to an internal combustion engine.

According to the International Energy Agency (2021), in 2020 there were about 10 million electric cars running around the world, representing a record increase of 41% in the year, where for buses and trucks (both electric) it also represented reaching global stocks of 600,000 and 31,000 vehicles, respectively. These numbers, punctuated by the need for alternative energy for automobiles and by the process of global awareness regarding emissions and the environment, seek alternatives with affordable cost options that are compatible with the reality of each country.

In the case of Brazil, where the production of trucks, according to the National Association of Automotive Vehicle Manufacturers (ANFAVEA, 2021), in 1957 6,843 diesel fuel trucks were manufactured, compared to 2020 a production of 94,809 vehicles, currently following the standard Euro V emission. However, there are still vehicles running in the country, with lower emission levels.

The European Commission set a target for a 15% reduction in CO2 emissions for medium and heavy transport vehicles, starting in 2025 (MONSALVE-SERRANO, 2020). With this, the next European standard (EuroVII) will impose a 50% reduction for NOx and particulates compared to the current EuroVI. Options such as changing cabin aerodynamics and improving vehicle power train efficiency are points to consider for manufacturers. As an alternative in the short and medium term, for city centers and mainly linked to the use of medium-sized trucks for deliveries, options are sought for this efficiency, aiming to conserve energy and the environment, with a reduction in the size of an engine. combustion and its emissions.

This research aims to propose, through simulation tools with a mathematical model, a simulation of a hybrid engine for use in a low-powered truck, with its application in an urban cycle. It also presents, as a specific objective, the analysis through the architecture of an extended range electric vehicle (E-REV).

THEORETICAL REFERENCE

The development process for the analysis of a hybrid engine consists of knowledge of mathematical modeling, covering references about the combustion engine, and concepts of the architecture used for electric/hybrid vehicles, currently arranged in different ways, for a better understanding of the “expected inputs” and “outputs” for the vehicle and project steps.

Internal combustion engine

Conversion of chemical energy into mechanical work is characterized as the process that an Internal Combustion Engine (ICE) undergoes when obtaining heat or performing work, through the burning of a fuel (BRUNETTI, 2017).

ICEs have different classifications as to how to obtain mechanical work. They are rotary engines, impulse engines, and the third classification, reciprocating engines, when it results from the movement of a piston with a connecting rod-crank assembly. This classification, in which the present article will work as a power supply reference for the electric motor.

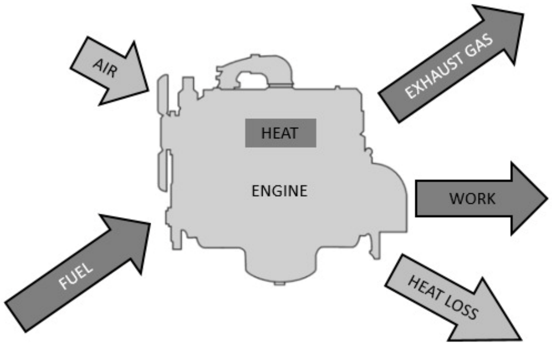

Figure 1. Mass and energy flows in an internal combustion engine – MCI. Adapted from Brunetti (2017).

SIE or Spontaneous Ignition Engines or Diesel, do not have the need to spark their spark, only through the compression and increase in cylinder temperature. The air temperature necessary for the fuel to react spontaneously is called the "auto-ignition temperature (AIT)". The differences in temperature values compared to other fuels in spark ignition engines are indicated in Tab. 1.

Table 1. Auto-ignition Temperature (AIT) typical values.

Auto-ignition Temperature - AIT (°C)			
Diesel	Hydrous ethanol	Methanol	Gasoline E22
250	420	478	400

Hybrid Electric Vehicles

Hybrid Electric Vehicle (HEV) are presented as a viable alternative when the issue is related to autonomy or battery recharge time. It is considered as a main feature of the HEV, the combined use of an ICE power source and an electric motor. Peres and Souza (2007) mention that for HEV internal combustion, two options are offered, one parallel and the other in series. In the first, in parallel, the drive together for vehicle traction occurs through the ICE and the electric engine (EE), as opposed to the series operation, in which only the EE generates traction to the vehicle. Unlike battery-only EV, HEV has atmospheric emissions, but it offers lower fuel consumption and, consequently, a reduction in atmospheric gases such as CO2 and CH4, and pollutants such as NOx, SOx , CO, particulate and others.

Parallel Hybrid Electric Vehicle

In parallel configuration, it allows different ways to couple the engines (combustion and electric). It is exemplified that, through Fig. 2, the mechanical energy generated by the MCI and the energy generated by the ME are transmitted to the wheels, through gears, not performing, therefore, in this situation, the assembly of both motors on the same axis, and thus, it can have an architecture with varied dispositions.

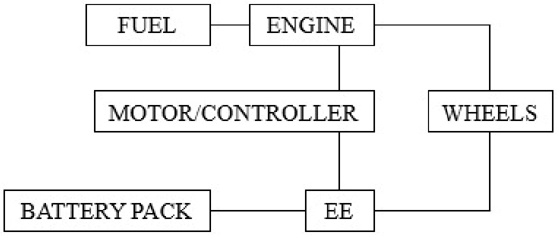

Figure 2. Parallel hybrid electric vehicle schematic. Adapted from Peres e Souza (2007).

Because the electric motor also transmits mechanical energy to the gears, the determination of the amount of energy that each motor will supply to the wheels and in the performance of regenerative braking providing energy to the battery, is performed through the controller, which also transmits to the clutch, the information to actuate the coupling or decoupling. For regenerative braking situations, only the electric motor is coupled to the gear, which allows the motor to act as a form of generator, transmitting energy to the batteries. In this way, if the energy demand is low, the MCI has the possibility of being turned off, reducing noise and fuel consumption, in addition to emission.

Hybrid Electric Vehicle Series

In the series configuration, the vehicle's traction is generated only by the electric motor. The process, as illustrated in Fig. 3, occurs through the mechanical energy of the MCI transmitted to an electrical generator (alternator), transforming the mechanical energy into electrical energy. With a rectifier, the output voltage is changed to continuous, direct current (DC), enabling connection to the batteries. This energy from the MCI and stored by the rectifier, generates through the controller, the division of which will be the amount distributed to the electric motor and batteries. Thus, in cases where a greater vehicle traction effort is required, both batteries and combustion engine energy may be used.

In this case, the electric motor starts to transform electrical energy into mechanical energy, resulting in wheel movement, and again during regenerative braking, the traction electric motor will be responsible for generating electrical energy through the mechanical energy of the wheels, to recharge the batteries. As in the parallel configuration, for the series configuration there is the possibility of the internal combustion engine being switched off at low energy demands, also not consuming fuel, generating noise and emissions.

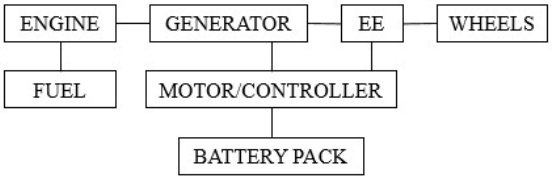

Figure 3. Series Hybrid Electric Vehicle Schematic Adapted from Peres e Souza (2007).

In this configuration, the ICE allows it to be operated at practically constant rotation, which corresponds to a curve of torque versus engine speed with greater efficiency, that is, as a consequence, consumption and emissions are reduced, compared to an ICE not hybrid. It should be noted that the absence of gears in this configuration allows for the reduction of assembly complexity, however, the processes of converting mechanical to electrical energy, and subsequently the conversion of electrical to mechanical energy, reduces the efficiency of the series-type HEV . The existence of the motor-generator results in obtaining electrical energy to be used in other functions, when the vehicle is parked.

Mathematical Models

To enable the design and study of the vehicle system, the acting forces must be considered, so that it can stand out and generate movement. The quantitative analysis of force, indicated by Sovran and Blaser (2003) and Alley (2013) for the opposing forces acting on the vehicle, can be indicated by the free-body diagram in Fig. 4 and Eq. (1)

Being the traction force F_{tr} for the movement of the vehicle equivalent to the sum of the aerodynamic drag force of the vehicle F_a and the friction force F_R between the tire and the ground.

By multiplying the value of the vehicle's traction force with the total distance “x” of the cycle, it will result in the total net energy needed and, Eq. (2), for the realization of this.

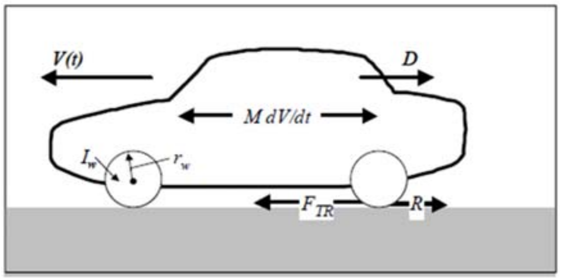

Figure 4. Diagram of force-free body acting on a vehicle in the absence of ambient wind. Adapted from Sovran e Blaser (2003).

$$F_{tr} = F_a + F_R \tag{1}$$

$$F_{tr} \, . x = e \tag{2}$$

To calculate the tractive force provided by electric motors F_{tr2}, the relationship present in Eq. (3) is considered between the number of motors Q_M and driven wheels Q_R, the reduction ratio for increasing torque R_m, the torque of each electric motor T_m, drivetrain efficiency n_{dl} and wheel and tire set radius r_w.

$$F_{tr2} = Q_m Q_r \frac{(R_m T_m n_{dl})}{R_w} \tag{3}$$

$$(E_{tr})^+ = \left[C_{rr0} Mg + C_d A \frac{V^2}{2} \rho + \left(M + 4\left(\frac{I_w}{r_w^2}\right)\right)\left(\frac{dV}{dt}\right)\right] Vt \tag{4}$$

$$(E_{tr})^- = \left[C_{rr0} Mg + C_d A \frac{V^2}{2} \rho - \left(M + 4\left(\frac{I_w}{r_w^2}\right)\right)\left(\frac{dV}{dt}\right)\right] Vt \tag{5}$$

Where C_{rr0} is the friction coefficient between the tire and the ground, C_d is the aerodynamic drag coefficient, I_w the polar moment of inertia of the tire set.

It is then considered that the total energy balance during the cycle is represented by the sum of the above equations:

$$(E_{tr})^{cicle} = (E_{tr})^+ + (E_{tr})^- \tag{6}$$

It can be interpreted that, $(E_{tr})^+$ is the energy generated by the electric motors to drive the vehicle and $(E_{tr})^-$ the energy dissipated during braking.

Once the necessary impulse energies has been calculated, the sequence is for the dimensioning of the necessary battery that will result in the electric motor supply. Here, the energy that the vehicle accessories consume is necessary, as well as the efficiency parameters of the power train components. Thus, in order for the battery to deliver the total energy needed to complete the complete cycle to the electric motors during acceleration, this energy is calculated by:

$$(E_{batt,int})^+ = \frac{1}{\eta_{batt}^+} \left\{ (E_{acc})^+ + \left[\frac{(E_{tr})^+}{(\eta_{mot}^+)(\eta_{dl,mot}^+)} \right] \right\} \tag{7}$$

The battery efficiency represented by η_{batt}^+, the efficiency of the electric motor represented by η_{mot}^+, the efficiency of the mechanical components connected to the electric motor by $\eta_{dl,mot}^+$and the total amount of energy in which the vehicle accessories consume by $(E_{acc})^+$.

For braking, two situations are considered for calculations, the first by calculating the energy still consumed by the system during braking, through Eq. (8), and the second situation, if a kinetic energy recovery system is used , calculate the amount of energy that can be recovered, Eq. (9).

$$(E_{batt,int})^{-} = \eta_{batt}^{-}\{(E_{tr})^{-}(\zeta)(\eta_{mot}^{-})(\eta_{dl,mot}^{-}) + (E_{acc})^{-}\} \tag{8}$$

$$(E_{tr,credit})^{-/+} = -(E_{batt,int})^{-}(\eta_{batt}^{-/+})(\eta_{mot}^{-/+})(\eta_{dl,mot}^{-/+}) \tag{9}$$

Where ζ is the energy recovery fraction.

For the case of a stationary vehicle, in "idle", the battery sizing for the energy consumed by it will be given by Eq. (10):

$$(E_{batt,int})^{0} = \frac{(t_{idle})(P_{acc})^{0}}{\eta_{batt}^{0}} \tag{10}$$

Where (t_{idle}) is the total vehicle stopped time during the cycle, and $(P_{acc})^{0}$ is the power of the accessories installed in the vehicle.

Finally, for this project there is no consideration of a kinetic energy recovery system, commonly known as KERS (Kinetic Energy Recovery System), which, for the total sizing of the battery charge, just add up all the energy consumptions during the cycle, ie electric motors and vehicle accessories.

So, the amount of total energy needed by the ICE and its dimensioning will be given through Eq. (11):

$$(E_{eng,fuel})^{+} = \frac{(E_{batt,int})^{+}}{(\eta_{eng}^{+})(\eta_{gen}^{+})[\xi+(1-\xi)(\eta_{batt}^{+})]} \tag{11}$$

Where (η_{eng}^{+}) represents the internal combustion engine efficiency, (η_{gen}^{+}) the alternator/generator efficiency and ξ the energy separation factor.

The indication of the equations above, represent the calculation of energy consumption of the proposed truck and its estimate of average fuel consumption. However, to simulate its performance and the dimensioning of its components, it is necessary to quantify the torque exerted by the electric motors, as well as the forces that oppose the vehicle.

Thus, for this simulation, equation (1) is expanded, resulting in the tractive force required to move the vehicle, Eq. (12):

$$F_{tr} = \left[C_{rr0}Mg + C_{d}A\frac{V^{2}}{2}\rho + \left(M + 4\left(\frac{I_{w}}{r_{w}^{2}}\right)\right)\left(\frac{dV}{dt}\right)\right] \tag{12}$$

Where this equation makes it possible to compare the linear force provided by the electric motors, with the traction needed to submit the vehicle to a requested condition (speed). The initial condition of this equation denotes the vehicle in the plane. For ascents, the slope is then added together with the mass. Based on this equation, the torque required by these motors is then calculated, and also resulting in the calculation of the power delivered by them. With the measured power, the plotted test cycle, and the equations mentioned above, it becomes possible to calculate the power of the other components, as well as the total energy consumption, making it possible to estimate, for the cycle, the average fuel consumption.

METHODOLOGY

With the proposal of a hybrid truck engine, the vehicle considered for study presents its focus and its main applications in urban routes, aiming at deliveries, for example, of beverages and food. The input parameters for calculation, such as drag coefficient, mass, radius of the tire and wheel set, and others, will be adopted from the base model for the study, in this case a rigid Volvo VM 4x2 with a 220hp engine.

To develop this VEH feasibility study, data were obtained from the vehicle's technical file and, from a simplified model, these data were transferred to the numerical calculation software tool, where a simulation analysis of the data was performed with a mathematical model that allows the simulation and operation of the system in the cycle, and speed. This model takes into account the truck's idle time, resulting in the quantitative energy it needs to travel, and which electric motor must be dimensioned to meet this demand. It is noteworthy that the electronic control of the system was not addressed, as well as: supports, structures to fix this system and other vehicle installation parts.

In calculating the mathematical model, route data from the United States Environmental Protection Agency (EPA) were used, which maps and controls vehicle emissions in metropolises in the United States, and also controls the behavior of drivers using GPS installed in vehicles. Routes are defined as urban when there are several stops, with an average speed of 34 km/h and more aggressive accelerations. As for highway routes, the direction is more linear and speeds higher. The study will be based on the urban route, where the vehicle in question is a distributor, and the cycle used for this test is called EPA75, as the agency calls the test procedure, Fig. 5, with speeds, travel time and distance stipulated.

From the analyzed and collected data, a distribution route that is more similar to the transit of Brazilian capitals was chosen, using it to certify the diesel engine that will supply energy to the alternator, the battery that will store this energy. , and consequently, the proposal for the electric motor to be directly connected to the truck's wheels will be generated, transmitting the necessary power that will be needed for the application. All of this, in accordance with CONAMA (National Council for the Environment) and IBAMA (The Brazilian Institute for the Environment and Renewable Natural Resources) standards, which certify vehicles according to their emission of pollutants.

Thus, after data analysis and simulations, the quotation of commercial models of the system components is carried out, which are compatible with the requests, analyzed for the feasibility of installation, and then the coupling between the components will be developed, resulting in the obtaining the final value of the project and checking its feasibility as to the possibility of production and technical and financial specifications.

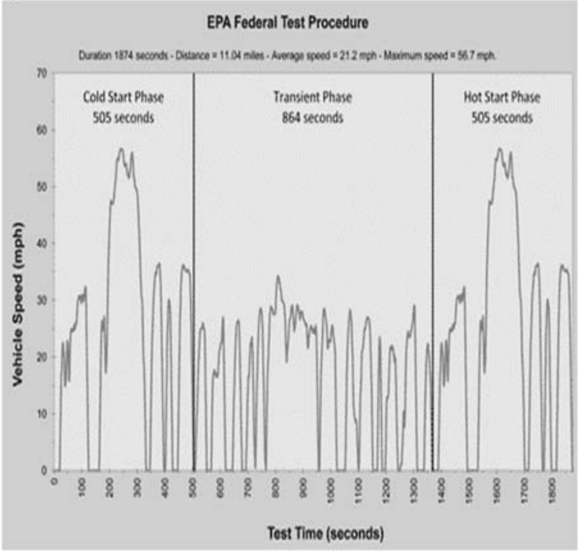

Figure 5. EPA test procedure.

RESULTS AND DISCUSSIONS

After defining the equations for sizing the system, the calculations were developed by obtaining the technical file parameters of the proposed vehicle, indicated by Tab. 2.

Table 2. Vehicle parameters. Adapted from Monsalve-Serrano (2020).

Parameter	Symbol	Value
Coefficient of friction	C_{rr0}	0.013
drag coefficient	C_d	0.65
Mass (vehicle + cargo) [kg]	M	10000
Front area [m²]	A	5.52
Air density [kg/m³]	ρ	1.2
Radius of the tire + wheel set [m]	r_w	0.59

To start and carry out the movement of the vehicle, the minimum torque required for the electric motor was calculated through equation (12) and parameters in Tab. 2, resulting in the need for at least 4,184.1Nm.

With the minimum torque, the survey of electric motor powers present in the market was then carried out for the sequence of sizing the set, through the addition of new parameters indicated by Tab. 3 extracted and used as a reference by Alley (2013).

After extracting the above data, the minimum battery power (P_{bat}) was calculated, resulting in 234.97kW, which the internal combustion engine power (P_{eng}) was calculated using equation (11), with an alternator with 95% efficiency, totaling 332.38HP. It is noteworthy at this point that this value refers to calculations with continuous speed of 80km/h (maximum speed stipulated). For the values mentioned above, continuous and static operation of its components, with an electric motor and without reduction, was considered.

Table 3. System Component Parameters. Adapted from Alley (2013).

Parameter	Symbol	Value
Power for accessories [kJ]	$(E_{acc})^+$	600
Battery efficiency [%]	η^+_{batt}	99
Electric motor efficiency [%]	η^+_{mot}	86
Mechanical efficiency between electric motor and wheels [%]	$\eta^+_{dl,mot}$	92
Internal combustion engine efficiency [%]	η^+_{eng}	32

However, to simulate a more refined path and closer to a city and delivery route, the official route cycle was used, in the case EPA FTP75 Urban.

Table 4. Obtained results

Parameter	Results			
Number of Electric Motors	4	4	6	6
Driven wheels	2	2	2	2
Reduction	1	2	1	2
Acceleration 0 to 45 km/h (s)	23.39	8.39	12.35	10.57
Acceleration 0 to 100 km/h (s)	56.59	19	28.42	23.71
Maximum Speed (km/h)	183	304	251	362
Power Consumed by M.E. at 80 km/h (kW)	51.29	102.58	51.29	102.58
Battery Power (80 km/h) (kW)	234.97	469.62	352.29	704.26
MCI power at 80 km/h (HP)	332.38	664.3	498.34	996.23
Vehicle Mass (kg)	10000	10000	10000	10000
Effective Torque (Nm)	2907.2	5814.4	4360.8	8721.6
Autonomy (km/L)	10.45	5.25	4.67	2.34

For an analysis of autonomy and accelerations/speed, diversification in parameters such as the number of electric motors, with or without transmission reduction, climbs, adding the inclination to the vehicle mass together with equation (12). Analyzes obtained and expressed in Tab. 4, considering then electric motor Yasa P750R, batteries A123, MCI Jeep Diesel 2.0 with 170hp power and 75kgf.m torque, in addition to the acceleration curve results for each simulation, indicated in Fig. 6 to Fig. 9, according to the percentage of inclination supported by the vehicle in its condition, and the autonomy simulated during the cycle, Fig. 10. The model assigned to the battery can be changed as needed by the vehicle.

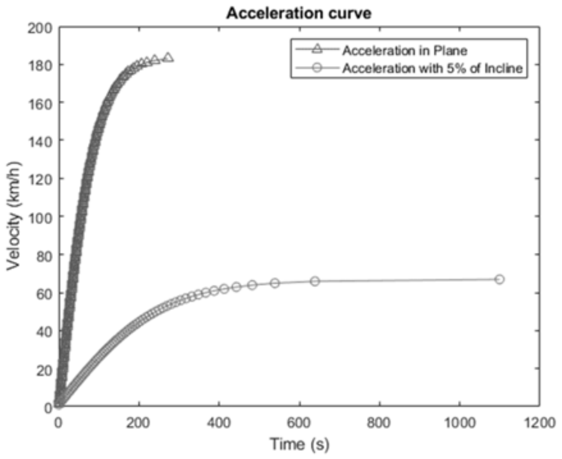

Figure 6: Acceleration Curve Truck with 4 electric motors without reduction.

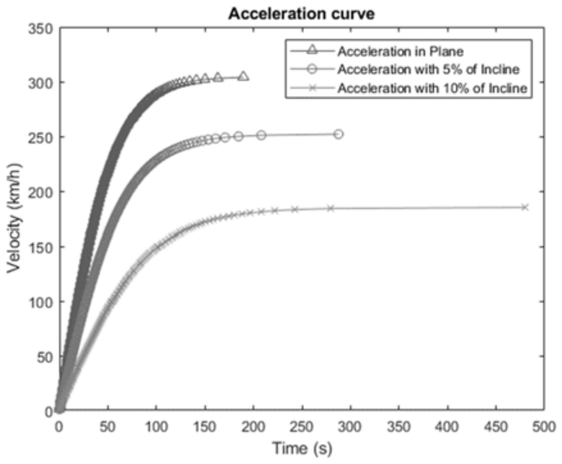

Figure 7: Acceleration Curve Truck with 4 electric motors with reduction.

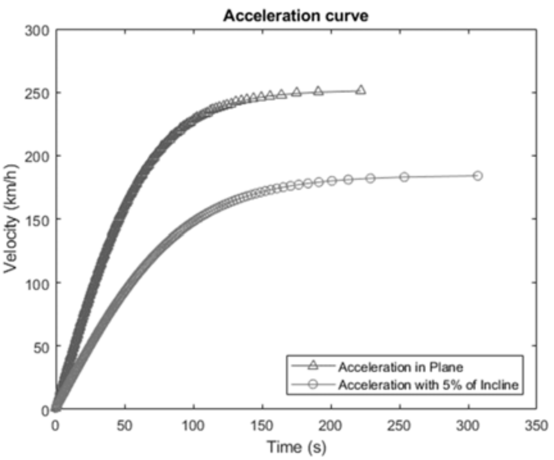

Figure 8: Acceleration Curve Truck with 6 electric motors without reduction.

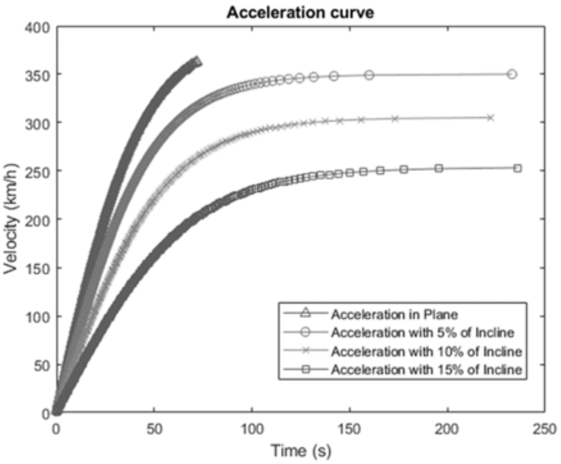

Figure 9: Acceleration Curve Truck with 6 electric motors with reduction.

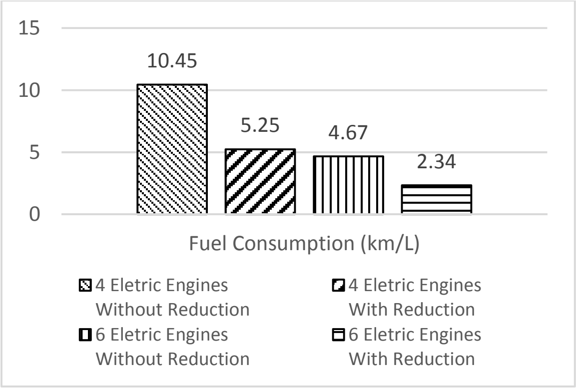

Figure 10: Autonomy during the EPA FTP75 Urban Cycle.

After extracting the data and analyzing the results of the simulation of the hybrid truck for the route of the EPA FTP75 Urban cycle, it was noted that with the increase in the combination between the number of engines and reduction, there was a direct impact on increased consumption, but higher returns in terms of torque response and acceleration, always enabling an improvement in the calibration of this configuration of electric motors. However, it should be taken into account that, in cases where there is high torque delivery, the actuation of pedals, for example, is a point where calibration must be performed so that displacement smoothing occurs, as it deals with if a vehicle considered to be loaded with a load totaling 10 tons. Points such as an improvement in performance in terms of correct charging of the batteries during their cycle, or the recovery of energy dissipated during braking together with a kinetic energy recovery system were not part of the scope of this project, which can then be refined and related to future studies.

CONCLUSIONS

Taking into account the data extracted from the obtained results, the proposed hybrid power train system proved to be satisfactory by choosing the ICE containing 170hp, considering that it would support the load required by the electric motors.

In the case studied, where the hybrid architecture is in series, that is, in which the ICE does not exert wheel traction, it presented an autonomy of up to 10.5 km/L. That makes a good economy considering the weight and size of the vehicle presented, compared to vehicles currently powered by only ICE, exercising the same delivery function in an urban cycle, thus making the simulated proposal feasible, reaching its objectives.

There must be a caveat for input parameters. For future projects, the development of an electronic control for the battery and electric motors is expected, in addition to optimizing the functioning of the internal combustion engine for an eventual improvement in consumption and autonomy (an important point today in terms of electric vehicles).

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