Development of trucks fuel consumption testing methodology on flat horizontal roads using a towing trailer with electromagnetic brake, simulating programs with different slope levels and gross weights.

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ABSTRACT

Global warming developments and legislations such as Euro 6, CONAMA and VECTO require truck on-road tests. These tests have issues such as traffic and long-term reproducibility. Tests with a Towing Trailer Prototype with electromagnetic brake were previously presented by the authors and highlighted in a review in SIMEA 2021.This present paper presents fuel consumption test performed with the Towing Trailer and a 440 HP tractor truck on flat horizontal road and on a road segment with a constant slope, measured by the effective consumed Diesel volume in a test tank. Test on horizontal road at maximum 60 km/h and without braking current present an autonomy of 1,92 km/l, (100%); at 78 km/h a lower autonomy of -27%. A -28% autonomy by maximal electromagnetic braking current. Tests on a road segment with constant slope showed an autonomy of - 5,5% by maximal speed of 60 km/h without braking current and an autonomy of -28 % by maximal test current and 35 km/h. It was possible to compare results on real road with slope and simulations on flat horizontal road. It is proposed therefore fuel consumption and also in future emission tests by simulation programs on horizontal test tracks. Braking torque measurement on the rear axle of trailer should be developed, to control those programs.

RESUMO EM PORTUGUES

"Desenvolvimento de metodologia de teste de consumo de combustível de caminhões em estradas horizontais planas, usando um reboque de arrasto com freio eletromagnético, simulando programas com diferentes níveis de aclives e pesos brutos."

Desenvolvimentos relativos ao Aquecimento Global e legislações como Euro 6, CONAMA e VECTO exigem testes de caminhão em estrada. Esses testes têm problemas como tráfego e reprodutibilidade a longo prazo. Os testes com um protótipo de reboque de arrasto com freio eletromagnético foram apresentados anteriormente pelos autores e destacados em uma revisão no SIMEA 2021.Este trabalho apresenta o teste de consumo de combustível realizado com o reboque de arrasto e um caminhão trator de 440 HP em estrada horizontal plana e em um segmento de estrada com aclive constante, medido pelo volume efetivo de Diesel, consumido em um tanque de teste. Testes em estrada horizontal com um máximo de 60 km/h e sem corrente de frenagem, apresenta uma autonomia de 1,92 km/l, (100%); a 78 km/h uma autonomia menor, de -27%; uma autonomia de -28% com corrente de frenagem eletromagnética máxima. Os testes num segmento de estrada com aclive constante revelaram uma autonomia de - 5,5% pela velocidade máxima de 60 km/h sem corrente de frenagem e uma autonomia de -28 % com corrente máxima de teste e 35 km/h. Foi possível comparar resultados em estrada real com inclinação e simulações em estrada horizontal plana. Propõe-se, portanto, testes de consumo de combustível e também em futuros testes de emissões por programas de simulação em pistas de ensaio horizontais. Deve ser desenvolvida a medição do torque de frenagem nos semieixos do eixo traseiro do reboque, para controlar esses programas.

INTRODUCTION

The whole world is concerned about the warning and energy efficiency, so that strategies and objectives are being defined until 2050 to avoid disastrous consequences.

The National Highway Traffic Safety Administration (NHTSA) and US Environmental Protection Agency (EPA) aim to the reduction of CO2 emissions and increase the energy efficiency of medium and heavy vehicles [1].

The European Commission defined in the EU Climate Strategies, targets for 2030 a climate & energy framework" [2], which was adopted by EU leaders in October 2014. It was defined at least 40% cuts in greenhouse gas emissions (from 1990 levels), at least 27%

share for renewable energy and at least 27% improvement in energy efficiency.

In Europe EURO 6 has been applied for trucks based on the European Commission's science and knowledge service [3].

Joint Research Centre VECTO [4] targets on the application in Commission Regulation (EU) 2017/2400 considering the determination of the CO2 emissions and fuel consumption of heavy-duty vehicles [4].

VECTO Workshop 2018 presented [5] "VECTO of pollution Control application in Commission Regulation (EU) 2017/240 consider the determination of the CO2 emissions and fuel consumption of heavy-duty vehicles, the main principles, Vehicle Segmentation and the Generic data".

Verification testing procedure (VTP). VECTO Workshop 2018 also presented [6] and consider "Possible options for HDV CO2 certification, On-road test with the remarks: Fuel consumption of entire vehicle [g/km], costs due to manifold combinations of engines, gearboxes, axles, tires."

VTP also consider "Poor reproducibility, Component tests plus vehicle simulation, Fuel consumption of the entire vehicle [g/km], Cost efficiency since measured component data can be applied in all vehicles, High reproducibility and flexibility. Regular updates of simulation tool necessary to cover relevant technologies."

In Brazil, RESOLUÇÃO Nº 490, DE 16 DE NOVEMBRO DE 2018, established the Phase P8 PROCONVE for the Program in Art. 12. [7], the requirement to measure the emission of pollutants in real traffic. The limits for the approval are shown in Table 1 attached to this Resolution.

History of the Introduction of the Resolution P8 is presented for example by Pedro Kutney [8].

Presented by AEA in ROADMAP TECNOLÓGICO AUTOMOTIVO BRASILEIRO in Emissões e Eficiência Energética [9] indicate "With the entry of PROCONVE P8, scheduled for begin in 2022, and the definition of energy efficiency targets for this class of vehicles, expected to enter into force in 2032, new technologies will be introduced. Commercial vehicles should be treated by vehicle classes".

Presently in Brazil, there are several Programs promoting the development of vehicles involving emissions, energy efficiency and biofuels.

CONTEXTUALIZATION

Global Warming projects presently lead worldwide to the necessity to carry out final on-road tests of trucks and other heavy commercial vehicles, such as those foreseen and prescribed by Euro 6 and VECTO. These tests have issues mentioned before such as traffic and reproducibility. There will have necessity of a very high number of on-road testing of numerous vehicles from different manufacturers and types, different loading levels, uses and fuels. Repetition with reproducibility of tests should be performed during the whole vehicle life. This paper proposes a reproducible fuel consumption test methodology performed on flat road test-tracks with a towing trailer with electromagnetic brake simulating slope programs or gross weigh variation.

Worldwide there are some towing trailer manufactures such as Mustang [11] and Taylor [12]. The uses of towing trailer tests are also reported [13], [14] and [15].

Considering the tendency in future to develop its own projects using biofuels and vehicles application, the execution of tests in Brazil should be enhanced. The use of towing trailer with electromagnetic brakes and the already existing test tracks should be considered.

It is suggested in the present paper, the development of test methodologies of fuel consumption with towing trailer with electromagnetic brake, simulating slopes and different loadings on horizontal roads/testing tracks. In future, these methodologies could be applied to emission and other tests.

TOWING TRAILER PROTOTYPE

Developments and tests performed by the authors with the Prototype were describe in other papers [16 to 27]. Measurements and the control of the electromagnetic brake, as temperatures, rotation, braking current are sent wireless from the towing trailer to the laptop in the truck cabin.

The lap top placed in the truck cabin receives by wire the data from GPS positioned on the cabin roof, and wi-fi the other measured data from the trailer.

Force measurement between the truck and the towing trailer is also being sent wireless. The controls of braking current are still by cable.

TESTS WITH TOWING TRAILER PROTOTYPE-The Prototype was described in the previous mentioned papers, based on a trailer for crop of entire sugar canes with 2 axles, lowered in central part of the chassis, directional front axle and an adapted truck rear axle with differential. Tests were performed on the road with a 440 HP truck and the Trailer as shown in Figs. 1, 2 and 3.

Fig. 1: Tests on road on 24.03.2023, preparing measurements on Roundabout 1. Truck tractor pulling prototype. Side view.

Fig. 2: Tests on road on 24.03.2023, preparing measurements on Roundabout 1. Truck tractor pulling prototype. Front view

Fig. 3: Tests on road on 24.03.2023, preparing measurements on roundabout 1. Truck tractor pulling prototype. Back view.

Considered that the Prototype as well the truck tractor was prepared for measurements in a partner mechanic work shop in Araras, road segments for testing were chosen nearby, as shown in Fig. 4.

Fig. 4: Region where tests were performed. The defined test region is located among Araras (Cemitério Municipal), road to Usina São Joao and public road SP-291.

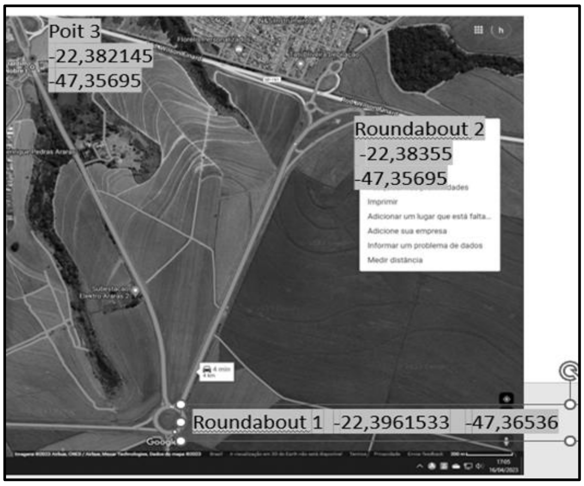


Fig. 5. Roads segments for testing in horizontal and sloped segment.

To simulate slopes on horizontal roads, it was defined 2000 m long on a two ways road segment as shown in Fig.5 with 2 Roundabouts (1. and 2.) on the edges. To measure on slope to compare with simulation on flat road, it was chosen the road departing from Point 3 to Roundabout 1, as shown also in Fig.5

TEST 1 (ONE LAP)

GPS MEASUREMENTS (EXEMPLE ONE LAP) – Test 1 on 24.03.2023 on a horizontal flat segment, 60 km/h max. The test was performed as shown in Fig.1 on a 2000 m two ways horizontal road segment, with two roundabouts at the edges. Test starts from 0 km/h from Roundabout 1 to Roundabout 2, with 60 km/h maximum speed, then reducing the speed to 25 km/h and returns on roundabout 1, with 60 km/h maximum speed.

Longitude and Latitude and the convoy speed were measured by GPS and registered by the laptop as shown in Figs 6 and 7, convoy speed in Fig. 8. Test distance was calculated by laptop through the Latitude and Longitude data, as shown in Fig. 10.

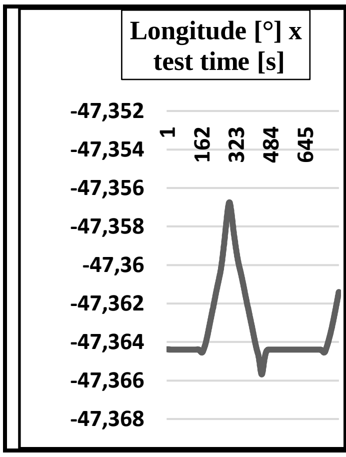


Fig 6: Tests on 24.03.2023 on a horizontal plane road. Longitude

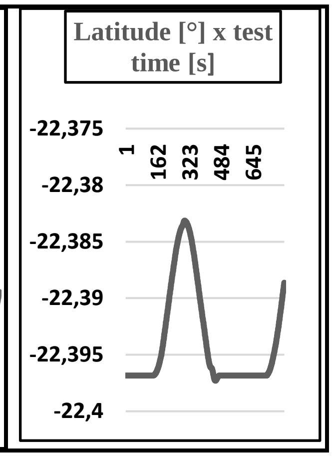


Fig 7: Tests on 24.03.2023 on a horizontal plane road. Latitude

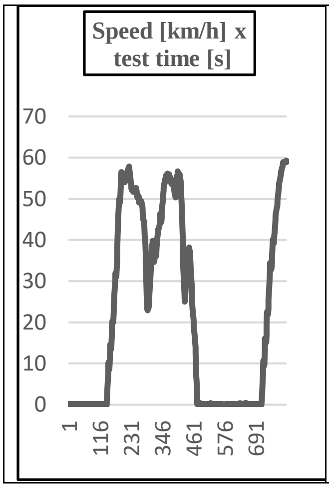


Fig 8: Tests on 24.03.2023. Convoy speed.

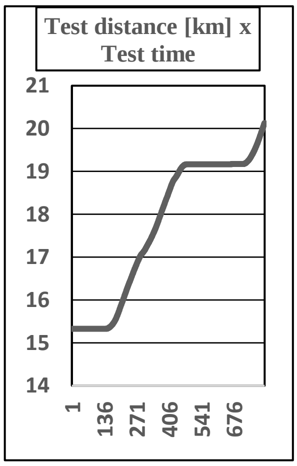


Fig 9: Tests on 24.03.2023. Test distance

TEST ROUTE DEFINITION (ROUNDABOUTS 1 TO 2) - Through Latitude and Longitude, the test route of this road segment can be defined as in Fig.10, calculated by a dispersion graphic.

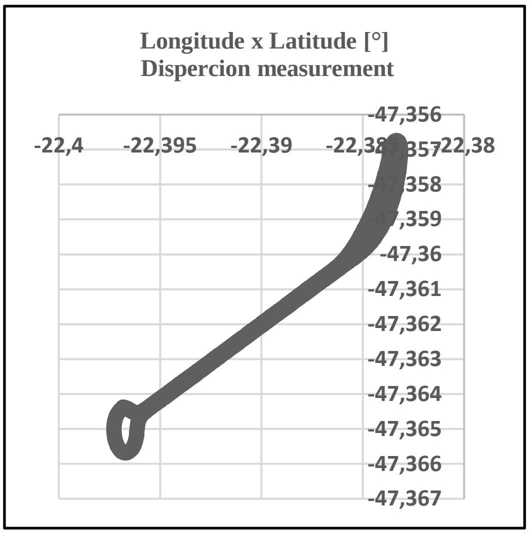


Fig. 10: TEST 1. One lap route on horizontal road segment, test distance of 4 km between Roundabouts 1 – 2 and return to Roundabout 1.

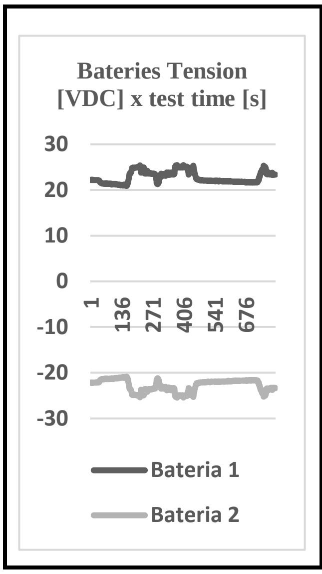
CURRENT, BATTERIES CHARGE AND TEMPERATURES (TEST 1) – The control data from the electromagnetic brake were measured by the laptop and shown in Figs. 12, 13 and 14.

The braking current, and so the braking torque are easily set by a rheostat controlled by a PWM System (Pulse Width Modulation). System is controlled by a testing engineer in the truck cab. In future it will be possible to develop a testing system with a testing automatized program.

Fig. 12 shows one lap, up and down of the braking current around 6,0 A. On Roundabout 2, (at 291 s) and Roundabout 1 (at 771 s), due to the quick change of convoy speed, occurs oscillation of the current signal shown on the laptop screen of Fig.16.

Fig 12: One complete lap between 125 s and 497s during convoy movement.

Fig. 14 shows the tension of the Batteries Set 1 and 2. Fig. 15 shows the temperatures of the electromagnetic brake (inside), cooling exhaust air and alternator temperatures. Former tests showed the capacity of batteries charges and the cooling capacities of the 3 brake ventilators.



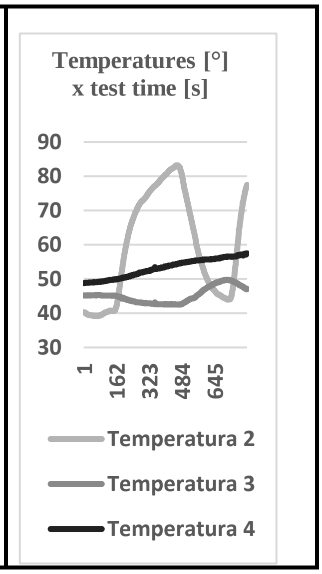


_Fig 13: Electromagnetic Brake batteries tension in VDC

Fig 14: Temperatures in one complete lap between 125 s and 497 s.

TEST 2 WITH 4 LAPS

LAPTOP SCREEN VIEW (EXAMPLE 4 LAPS) - The lap top placed in truck cabin receives by wire the data from GPS positioned on the cab roof, and wi-fi the other measured data from the trailer. Fig 15. shows as example TEST 2, an extract of laptop screen view, for four complete laps, maximum 60 km/h, two laps with braking current and two laps without braking current.

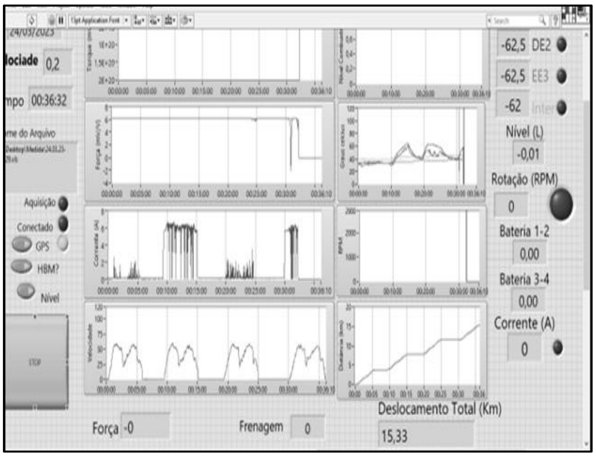


Fig. 15: TEST 2. Example of laptop screen view. Four completes, max 60 km/h, two laps with braking currant and two laps without braking current. Do not consider Braking Force, Braking Torque, rpm and fuel level measurement.

GPS MEASUREMENTS (TEST 2 / 4 LAPS) – GPS measurement results of longitude and latitude were registered in the laptop and the diagrams shown as following in Figs. 16 and 17.

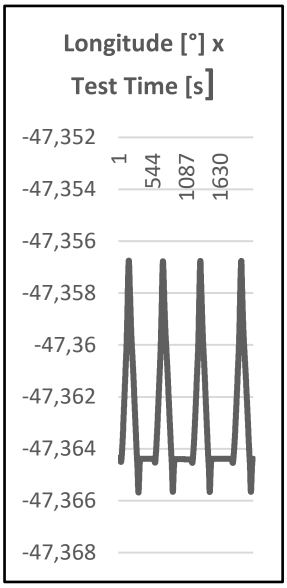


Fig. 16. Test 2. Longitude in function of Test Time, 4 laps

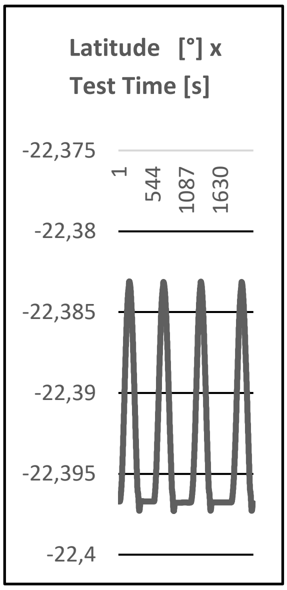


Fig. 17. Test 2. Latitude in function of Test Time, 4 laps

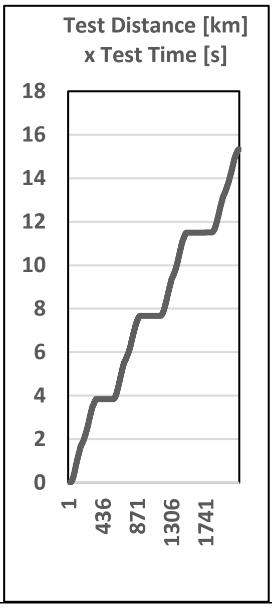


Fig. 18: Test distance in function of test time

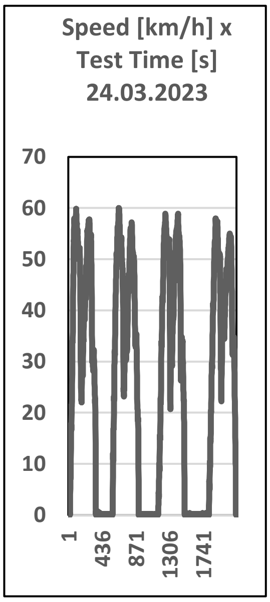


Fig. 19: Convoy speed.

Test distances measured by GPS by longitude and latitude and convoy speed were registered in the laptop and the diagrams shown as in Figs. 18 and 19.

TEMPERATURES MEASUREMENTS–Temperatures from the electromagnetic system were presented in Fig. 20. In future, ventilation set up will be optimized to achieve higher test performance of the towing trailer Prototype.

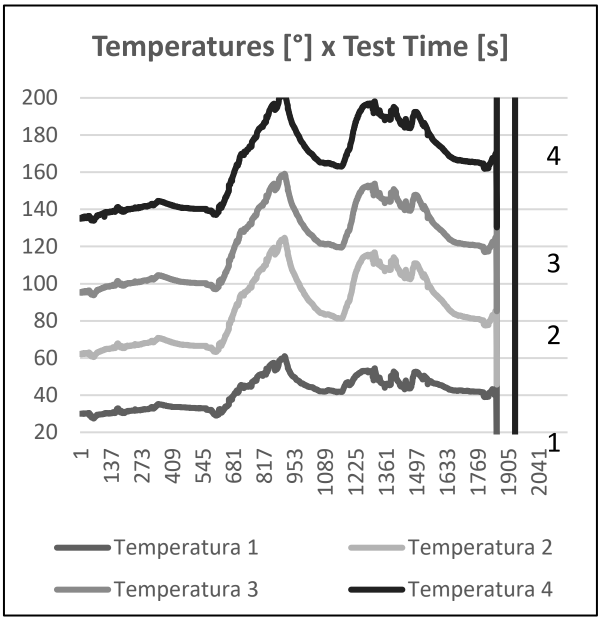


Fig. 20. Test 2. Electromagnetic Brake Temperatures.
Temp. 1 = DE2 Exhaust air, right side
Temp. 2 = EE3 Exhaust air, left side
Temp. 3 = brake intern Temp.
Temp. 4 = Alternator

TEST 3 IN HORIZONTAL AND SLOPED ROAD

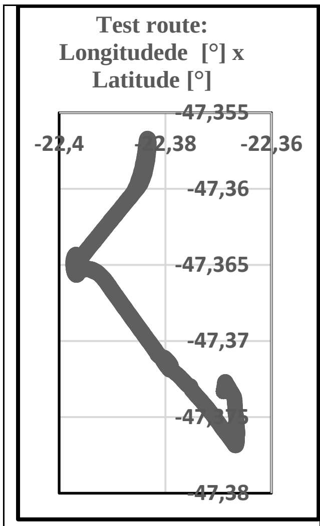


Fig. 21: Test routes. Longitude in function of latitude.

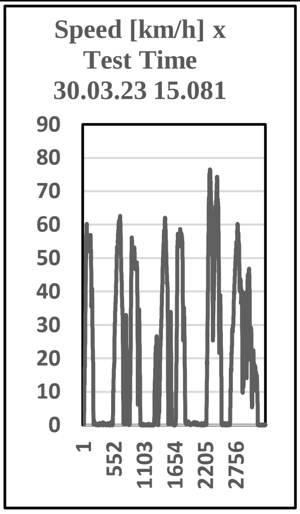


Fig. 22: Speed in function of test time. Last lap max. 78 km/h.

Measurements were performed as shown in Fig. 21 and 22. on the horizontal road segments from Roundabout 1 to 2 and returned to Roundabout 1, at maximum 60 km/h and repeated at maximum 78 km/h on the last lap.
Fig. 21 shows test route and Fig. 22 the convoy speed. Measurements were performed also on the sloped road segment between Point 3 and Roundabout 1, without electromagnetic braking and repeated with 6,5 A and 5,8 A, simulating higher level of slope or higher level of TGW.

FUEL CONSUMPTION MEASUREMENTS

Performance of the truck/convoy can be evaluated in real road application. Tests of cooling, acceleration curves, noise, vibrations, durability, were proposed in former papers. Fuel measurements and future emission tests were already proposed. Simulations on horizontal road with a towing trailer with electromagnetic brake are being testing in this paper. Those tests show that it is possible to simulate slopes, various PBTC and speeds by using Towing Trailer with electromagnetic brake on horizontal roads.

Fuel measurement consumption using a test tank as described on former presentation in SIMEA 2022 [27] was chosen in this paper, as a criterion for evaluation of simulation test on a horizontal road. The effective measurement volume of consumed fuel in each road segment will supply the consumed data, independently of the truck engine electronic data. The simulation methodology can be used for different fuels and trucks and compare the results of different trucks.

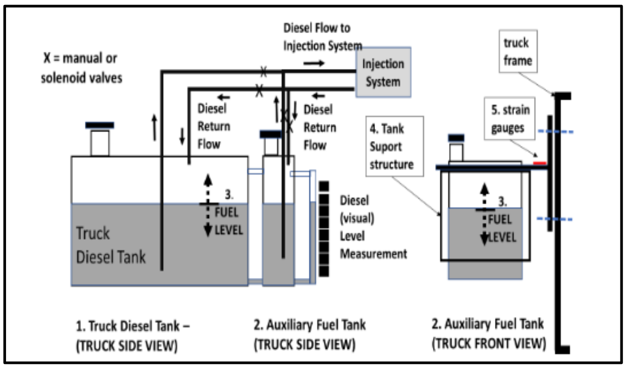


Figure 23. Schematic view of auxiliary tank and truck fuel tank for short distances (only auxiliary tank) and truck tank for longer distances fuel measurement.

The fuel level can be measured directly in a scale or by a capacitive fuel level sensor on the fuel tank filler neck. The present measured data with the convoy standstill, are sent to the laptop and presented on the desktop of the laptop, as shown in a static calibration in Figure 23.

The analysis of the measured fuel consumption data of Table 1 shows the following described results.

Test 1.1 and 1.3 – Consumption tests on horizontal road at maximum speed of 60 km/h and without electromagnetic braking, present a fuel autonomy of 1,941 km/l (considered 100 % as reference) and a fuel consumption of 0,507 l/km (considered 100 % as reference).

Tests 1.2 and 1.4 - At the same condition of 1.1 and 1.3 but with a braking current of 6,5 A (adopted as 100 %) presents a fuel autonomy of 1,391 km/l (71,7 %) and a consumption of 0,796 l/km (155 %). The braking current increases therefore 55 % of consumption.

Tests 2.1 - At the same condition of 1.1, without braking but at a maximum speed of 78 km/h presents an average autonomy of 1.60 km/l (82,4 %) and a consumption of 0,625l/km (123 %). The higher speed increases 23 % the consumption.

0,813 l/km (143 %). The higher speed plus the braking increases 43 % of consumption.

Tests 3.1 to 3,3 – The measurements were performed on the sloped road segment of 2.000 m without current / with 3,5 A / 6,5 A presenting autonomy of 1,834/1,78 /1,60 l/km and fuel consumption of 1.09 / 1,186 and 1,25 km/l.

Test 4.1 - At the same condition of 1.1, with of 6,5 A braking but at a maximal speed of 78 km/h presents an average autonomy of 1,23 km/l (63,4) and a consumption

Tests 3.1 to 3,3 – The measurements were performed on the sloped road segment of 2.000 m without current / with 3,5 A / 6,5 A presenting autonomy of 1,834/1,78 /1,60 l/km and fuel consumption of 1.09 / 1,186 and 1,25 km/l.

Table 1: Measurements of fuel consumption on 24.03 and 30.03.2023 with towing trailer Prototype on horizontal and road segment with slope.

Test Number	Data / hour	Horizontal road (H)	Sloped road (S)	Current [%]	Max. Speed [km/h]	Distance performed [m]	Fuel consumed [l]	Fuel consume [l/km]	Mean consumption [l/km] / (% to refence)	fuel autonomy [km/l]	Mean autonomy [km/l] (% to refence)
1.1	24.03 9h58	H	no	0	60	4.000	2,00	0,5	0,507 (100 %)	2,00	1,941 (100 %)
1.3	24.0 3	H	no	0	60	4.000	2,125	0,513		1,88	
1.2	24.03 9h48	H	no	100	60	4.000	2,875	0,796	0,796 (155 %)	1,391	1.391 (71,7 %)
1.4	24.03 10h1	H	no	100	60	4.000	2,875	0,796		1,391	
2.1	30.03 14;59	H	no	0	78	4.000	2.50	0,625	0,625 (123 %)	1.60	1,60 (82,4 %)
4.1	30.03 15.54	H	no	100	78	4.000	3,25	0,813	0,8 (143 %)	1,23	1.23 (63,4 %)
3.1	30.03 14h59	no	yes	0	60	2.000	2,125	1,06	1,09 (215	1,834	1,834 (94,5
3.2	30.03 15h29	no	yes	50	45	2.000	2,2	1,125	1,125 (234 %)	1,78	1,78 (91,2 %)
3.3	30.03 15h44	no	yes	100	30	2.000	2,5	1.25	1,25 (246 %/)	1.60	1,60 (82.4 %)

The tests showed fuel consumption autonomy on horizontal and sloped road, different speeds and different braking current as shown in short in Table 2. Test on horizontal road at maximum speed of 78 km/h showed a lower autonomy of -27% (1,60 km/l) and a -28% (1,39 km/l) autonomy by maximal electromagnetic braking current. Tests on a road segment with constant slope showed an autonomy of -5,5% by maximal speed of 60 km/h without braking current and an autonomy of -28 % by maximal test current and 35 km/h. It was possible to compare results on real road with slope and simulations on flat horizontal road.

Table 2: Resume of results of Autonomy

Road	Curent [%]	Speed max. [km/h]	Autonomy [km/l]	Autonomy [%]
Horizontal	0	60	1,94	100
	100	60	1,39	71,7 (-28,3)
	0	78	1,60	82,4 (-17,6)
Sloped	0	60	1,23	63,4 (-36,60)
	50	45	1,78	91,2 (-8,8)
	100	30	1,60	82,4 (-18,6)

Those results indicate that it was possible to verify the influence of speed, brake current, maximum speed and slope. The influence factors of the autonomy in relation of the reference of 100 % on horizontal road, 60km/h and without braking current are:

- **Speed of 78km/h on horizontal road: -17,6%**
- **Current on horizontal road: - 28,3 %**
- **Slope without current: -36,6 %**
- **Slope with maximal current at 35 km/h: - 18,6 %**

Those results indicate the possibility of simulating measurements of fuel consumption at different testing conditions on horizontal roads/ testing tracks. It is possible to simulate higher TGW and/or higher slopes by testing with towing trailer

SIMULATION PROGRAMES

DEFINITION OF TESTING OBJECTIVES – It is necessary to understand and define the region and the application of the truck/ convoy. For example, São Paulo State with almost 30% of the Brazilian GDP (Gross Domestic Product), has a very important economic role on the road transport. Fig. 24 presents the Altimetric Map of São Paulo State [9], indicating the topography of the state. Five main regions can be highlighted:

- flat plains at sea level,
- plains and valleys formed by the Paraná River and affluents in the east region of São Paulo,
- medium high plateaux,1396 m
- high plateau,
- high mountains, up to 2.792 m, (dark).

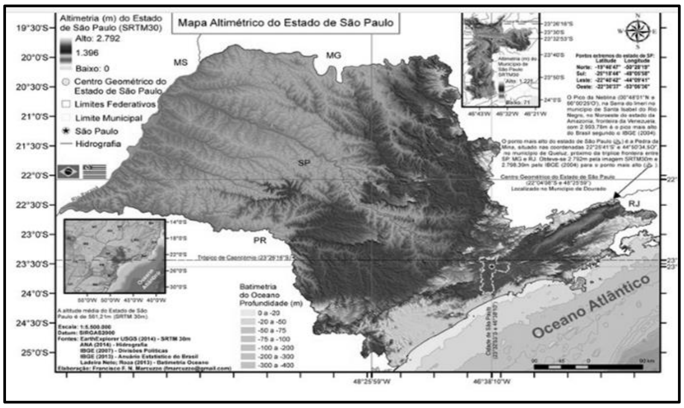


Fig. 24: Altimetric Map of São Paulo State presents the main regions of the State.

InterCity Transport in Brazil has an important truck participation, today almost with Diesel engines. A great part of the main transport occurs on the Central Plateau, where the roads present successive up and down slopes.

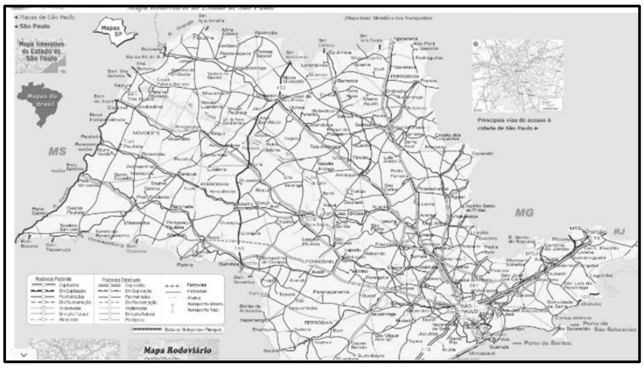


Fig. 25. São Paulo State roads and highways

The main highways have normally 2 or 3 lanes in each direction, with low slopes, except for the mountain segments. and the flat plains, with low slopes.

The secondary roads are normally with successive up and down slopes, with higher slops values.

The medium high plateau can be assumed as an example model for this transport. So, the highways Via dos Bandeirantes and Via Anhanguera between São Paulo City and Ribeirão Preto were chosen, see Fig.26, to prospect road segments to be evaluated.

Fig. 26: Highway from Sao Paulo City to Ribeirão Preto, 315 km, crossing Araras City. Google Map image.

ROADS ALTIMETRIC VALUES – To evaluate the altimetrical values of the roads, it is possible to use the Google Earth Pro. Based on this system it was shown the altimetric values as indicated by Fig. 27 [11] of highways Via dos Bandeirantes and Via Anhanguera between São Paulo City and Ribeirão Preto, to prospect road segments to be evaluated.

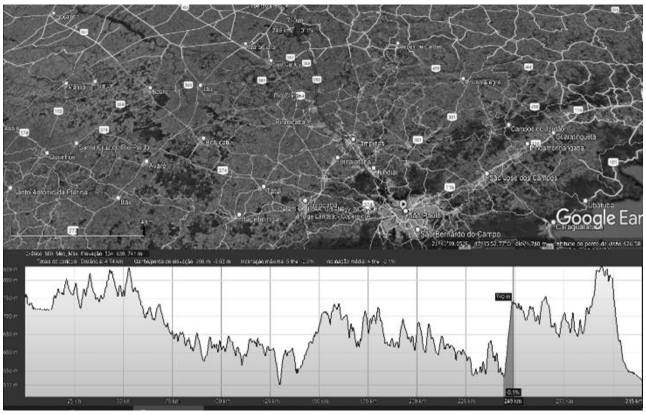


Fig.27. Highways altitudes of Via dos Bandeirantes and Anhanguera, from São Paulo City to Ribeirao Preto, indicating the upslope test segment in dark. Google Earth pro image. Based on the Altitude profiles, it can be chosen as the example a road segment with 4,7 % slope of five kilometers, length, shown in Fig. 28

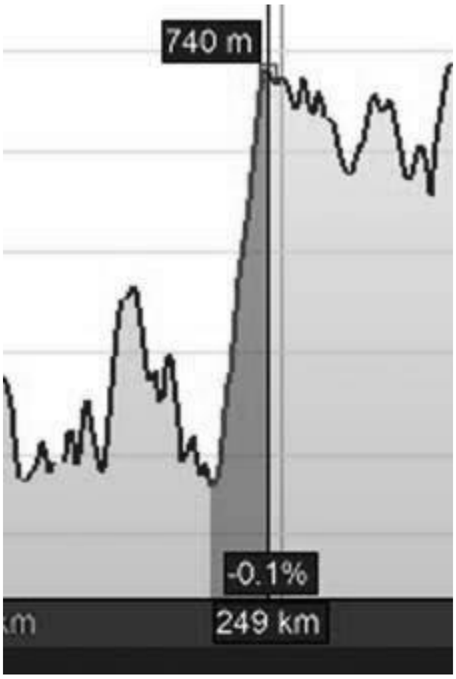


Fig. 28. Highways altitudes of Via Anhanguera around km 249, indicating the 4,7 % up slope segment in dark. Google Earth pro image.

BRAKING TORQUE MEASSUREMENTS – Earlier tests describe the difficulties of the electromagnetic braking torque measurements, for example on [27].

Forces measurement on traction rod - Forces between truck and the towing trailer can be measured by the traction rod by a strain gauge sensor developed by the authors. It is possible to measure the traction forces of the electromagnetic braking forces only during a constant running condition. During convoy accelerations or breakings, those vehicular dynamic forces are very high and very quick, so that the values of the electromagnetic braking torque can't be easily measured and defined.

Torque measurements in the electromagnetic brake - Measurements in earlier tests of the torque in the electromagnetic brake input present also measurements instability due to the dynamic forces between truck and Trailer. The torque was measured on the input shaft of the brake by a strain gauges sensor, developed by the authors.

Torque measurement on the semi axles - For future measurements, it is proposed to use strain gauge sensors on the two semi axels, which send wi-fi to the laptop in the truck cabin the effective measured braking torque by the tires. The effect of the electromagnetic braking can thus be measured by the lap top and calibrated statically in the mechanic shop.

Testing program - The testing program defined as explained above, can be controlled by the current of the PWM system. The laptop in the Prototype can already receive the sensor signals.

A closed loop system composed by the braking program (torque/current) and the real torque by the tires regulates the simulation program in function of the test distance.

TESTING SIMULATION PROGRAM - Based on the above explained points, it is suggested to define a simulation program based on the following steps:

Tests objectives – Definition of vehicles, vehicle application, loads

Location - Definition of the geographic region, roads (google maps)

Altimetry- Definition of the altimetric data from the selected roads by google earth pro. Select and discard irrelevant segments for the tests: down-slopes, horizontal road segments or with light climbs. Note that the tested trailer prototype does not simulate yet down slopes.

Manual Testing Program - Choice of road segment(s) to be simulated. Define a test program: distance x slope.

Braking current measurements – Set the electromagnetic brake torque by the braking current, simulate the slopes, and the distances. The braking current and the testing program should be set initially manually through the potentiometer (PWM system) in the cabin.

Braking torque measurements – Set the electromagnetic brake torque by testing current. It is proposed to use strain gauges sensor on both semi axle of the trailer to measure and calibrate the braking torque.

CONCLUSIONS

Global Warming forces worldwide development programs and legislation for the reduction of emissions and consumption of fuel with the need to carry on-road tests of trucks and other heavy commercial vehicles, such as those planned and prescribed by Euro 6, CONAMA and VECTRO. There is, therefore, a great need of on-road testing due to the huge number of vehicles of different manufacturers, different loading levels, vehicle variants, different applications, fuels, and repeated tests during truck lifetime and other conditions.

The present tests showed fuel consumption autonomy on horizontal and sloped road, different speeds and different braking current as presented in Table 2 and summarized here:

- Test on horizontal road at maximum speed of 60 km/h and without braking current presented an autonomy of 1,94 km/l, considered as 100%.
- Test on horizontal road at maximum speed of 78 km/h and without braking current, showed a lower autonomy of 1,60 km/l, -27% compared to 60 km/h.
- Test on horizontal road at maximum speed of 60 km/h showed at maximum current, considered as 100%, a lower autonomy of 1,36 km/l, -28% compared to without current.
- Tests at maximal speed of 60 km/h on a road segment with a constant slope showed an autonomy of 1,6 km/l, - 5,5% without braking current.
- Tests showed on a road segment with the constant slope an autonomy of -28 % by maximal test current and 35 km/h.

It was therefore indicated that it is possible to compare results on real road with slope and simulations on flat horizontal road. Extension of the test should be performed in future. These results indicate that it was possible to verify the influence of speed, brake current, maximum speed and slope. The influence factors of the autonomy are:

- Speed on the horizontal road: - 27%
- Current on horizontal road: - 28 %
- Slope without current: - 6 % %
- Slope with maximal current at 35 km/h: - 18 %

It is proposed to continue the development of a methodology to simulate tests program on horizontal road with a towing trailer considering 4 steps:

- Analysis of the topography (map) of the region to simulate the tests
- Define the roads to be simulated and the road altitude profile
- Define a testing program slope x slope length. Slope calculated through altitudes.
- Test performed following the program on horizontal road/ track. At the beginning, the program will be set manually by the test engineer. In future a computer program should be developed.

It will be necessary to develop sensors on the semi axles of the trailer rear axle, to measure the real braking torque.

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