ON-ROAD COOLING SIMULATION TESTS OF COMMERCIAL VEHICLES PERFORMED BY A TRAILER WITH ELECTROMAGNETIC BRAKES

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1. ABSTRACT

Cooling tests of commercial vehicles are performed worldwide in a few big stationary installations provided with a chassis dynamometer and ventilators for simulation of the aerodynamic airflow. Those installations could not be built in Brazil due to economic reasons. Here, those tests are historically performed on-road (testing ground) by towing one or more trucks using their own brakes, with obvious operational problems during the tests. A Towing Trailer with an electromagnetic (EM) brake to simulate uphill, as reported before [1] and [2], was developed, partially supported by FAPESP, based on a sugarcane trailer. A laptop in the cockpit of the tractor truck registers and shows the electromagnetic (EM) brake parameters as rotation, electric voltage, current and temperatures. The force between tractor truck and the trailer measured by strain gauges in a bridge configuration as well as the speed and the position of the convoy captured by GPS are also registered and displayed on the laptop. Tests with this Trailer, performed at 20 km/h, speed usually used on cooling tests of commercial vehicles, prove the viability, the good handling and the rationality of using the Towing Trailer to test trucks up to 250 HP.

2. INTRODUCTION

Tests of commercial vehicle power trains as well as cooling systems can be performed on-road or on stationary testing equipment. Stationary chassis dynamometers for complete light vehicles with airflow simulation are found worldwide, some of them even with innovative systems, like the one developed by Jacobs for BMW in Munich with moving floor [3] and others [4]. That equipment should simulate the real condition of the airflow on the road, with the difficulties pointed out by some authors [5]. The unique stationary chassis dynamometer in Brazil with airflow simulation, from Denso in Santa Barbara do Oeste [6] does not allow tests of commercial vehicles.
Complete commercial vehicles can be tested worldwide on some few stationary chassis dynamometer, for example Mahle (former Behr) in Germany [7] or a simpler one like that in Asia [8]. Those systems could not be implemented yet in Brazil due to their high costs.

On-road tests are performed worldwide with towing trailers or semi-trailer. ATP in Germany presented a Push-Pull trailer to test vehicles up to 4.6 ton [9]. Towing Dynamometers are offered in the USA by Taylor [10], [11] and by Mustang [12], [13] for testing medium, heavy trucks and other commercial vehicles. Functional on-road tests such as cooling evaluation of commercial vehicles are difficult in Brazil due to the lack of towing dynamometers. The commercial vehicles here are normally tested on testing grounds simulating uphill by towing one or more trucks, with obvious difficulties as reported before. For the presented reasons, the use of the Towing Trailer developed in Brazil was therefore proposed in [1] and [2].

3. DEVELOPMENT OF A TOWING TRAILER

A towing trailer, based on a sugarcane trailer, with an EM brake, as reported before [1], [2], was developed and supported partially by FAPESP - Fundação do Amparo à Pesquisa do Estado de São Paulo [16]. A second hand sugarcane trailer with 8.2 m length and 2.6 m width, 2 axels and a lowered chassis in between the axles was prepared to receive the EM brake. On the trailer's front part, it was built the electro-electronic cab, the ballast (broken stones) was placed in the rear part as shown in Fig. 1.

![Fig. 1: The Towing Trailer being pulled by MB LS 2642 6 x 4 truck: side view showing lowered chassis between the axles, electro-electronic cab in front and ballast at rear.](image)

The original 8 tires 11.00R22 as well as the wheels, the suspension and the braking system were kept. The Trailer was licensed for running on open roads as a “Mecanismo Operacional” - Operational Mechanism by the Traffic State Authority CONTRAN - for 20 t gross weight [15]. Due to the strong structures and systems, the Trailer has great durability and can resist to heavy loads, with a road long life.
The trailer rear axle was changed by a truck rear traction axle with differential, which is connected by a drive shaft to an 8-gear truck transmission and the EM brake, supplied by DC-batteries and alternators, and cooled by fans (Fig. 2). This system, in opposition to the one that has an independent Diesel engine, absorbs the energy from the truck engine by EM braking and it is, therefore, ecologically correct.

The optimal rotation range of the EM brake is from 1200 to 1600 rpm. Depending on the testing speed of the commercial vehicle, it is possible to set (not in movement) the gears’ range of the transmission and the Trailer to reach speeds from 8 km/h up to 80 km/h.

A Patent of the concept of the Towing Trailer was requested to the NPI – Brazilian Institute of Intellectual Property, which was published in RPI - Revista da Propriedade Industrial [16].

4. CONTROL AND MEASUREMENT SYSTEMS

In the truck cab, there are the breaking level control and a laptop (Fig. 4), which receives and registers the operational parameters of the Towing Trailer. The GPS in the truck cab supplies information such as time, speed, latitude and longitude allowing the control of the route during the test. To supervise the Towing Trailer from the truck cab a wireless camera is placed inside the Trailer and a monitor with LCD screen in the truck cab (Fig. 5 and 6).

The EM braking level can be measured by strain gauges in bridge configuration, glued on the traction rod between the truck (commercial vehicle) and trailer.

The voltage variation in mV/V measured by the strain sensor, after amplification and treatment, were converted to kgf. A static gauge with an analogue mechanical dynamometer and mechanical hoist was used to perform this calibration: 1000 kgf corresponds to 0.01075 mV/V.
The EM braking forces can be adjusted in the truck cab by regulating the current that passes through the brake. A potentiometer connected by wires, up until now, is used to control the current intensity. Wireless control system will be implemented in the near future.

The operational parameters of the EM brake (rotation, current, voltage and temperatures) as well as the forces between truck and trailer and the convoy speed can be visualized on the laptop screen (Fig. 4) in the truck cab. The testing set up is simple and operation of the Towing Trailer easy.

5. FIRST COOLING SIMULATION TEST (31.03.2015)

The cooling test simulation was performed on an almost flat road, 1.6 km-long, with a MB 2642 6 x 2 truck pulling the Towing Trailer at 20 km/h. At the beginning and at the end of this road segment, the convoy reduced the speed on roundabouts.

The measured data were received in real time by the laptop, sent from the acquisition system in the electro-electronic cab in the Trailer. The laptop screen is shown in Fig. 5, with the diagrams during the test.

The first cycle was performed with 85% (8.5 A) of the maximum EM braking current, the second without current and the last 4 cycles with 45% (4.5 A) of the current.

The 5th gear was set on the transmission on the Trailer during the first Cycle and the 4th gear during the remaining cycles; the EM Brake rotation was respectively 1250 rpm and 1460 rpm (at 20 km/h speed).

The batteries voltage were maintained on a satisfactory level.

The internal temperatures of the EM brake (1 and 4) did not reach high values. The exhaust temperatures (2 and 3), however, reached the limit and should be checked and the system optimized if necessary.
The forces between truck and Trailer measured in mV/V by the strain gauges will be discussed in the Section 7.

As examples, an extract (14 seconds) of the data from measurements (31.03.2015) is presented in Table 1 and diagrams of data corresponding to 1000 seconds are shown in Fig. 5 to Fig. 11.

Table 1: Data from measurements (31.03.2015)

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Fig. 6: Speed [km/h] x Time [s]

Fig. 7: Temperatures [°C] x Time [s]

Fig. 8: Current [A] x Time [s]

Fig. 9: Batteries voltage [V] x Time [s]

Fig. 10: Force measurement [mV/V] x Time [s]

Fig. 11: Rotation [rpm] x Time [s]
6. SECOND COOLING SIMULATION TEST (09.04.2015)

In the cooling simulation test, the conditions, truck and equipment were similar to the first test. Fig. 6 shows the complete test, including the route on-road with varied slopes until the testing point. A speed graph was added in the control program displayed on the laptop. Cycle 6 was performed without EM braking. A short stop during the test was used to check the system.

Cycle 1 was performed without EM braking and will be considered as a reference for the traction forces. Cycles 2 to 5 were performed without stops and can be considered as a cooling test simulation.

![Fig. 6: Laptop screen showing 6 cycles of a cooling test simulation (31.03.2015).](image)

The test was performed at 20 km/h, 1460 rpm EM brake rotation, 4th gear of the transmission on the Trailer and at 4.5 A (45 %). The voltage of the batteries maintained a satisfactory level during the test, indicating that the alternator was able to recharge them and the test could be ran continuously.

The internal EM brake temperatures (I1 and I4) were low and the exhaust air temperatures (DE2 and EE3) reached an acceptable equilibrium around 100ºC. Actions in future for lowering those exhaust temperatures are desirable in order to increase the EM force.

EM braking force demonstrated the good performance of the EM braking system under those test condition, confirmed by the driver and testing engineer perception. The braking levels will be discussed in Section 7.
7. EM BRAKING PERFORMANCE

The test results in Section 5 and 6 were jointed in table 2, based on the relationship 1000 kgf that corresponds to 0.01075 mV/V, defined by calibration already presented in Section 4.

Table 2: Data from measurements Test 1 (31.03.2015) and Test 2 (09.04.2015)

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Without applied force, at “0 kgf”, of the strain gauge measured a value of 0.20 mV/V, and this value was applied to the two measurements (31.03.2015 and 09.04.2015). The differences of values during the test with a stopped convoy were caused by the different positions between the truck and the Trailer, with residual traction forces between both vehicles during each stop.

Theoretic calculations of the EM braking forces (Item 12 of table 2) and EM braking power (Item 13) were obtained based on the EM brake technical data. The EM measured force at 8.5 A during Cycle 1 - 31.03.2015, was higher than those calculated and presented in table 2 (Item 12 and 13), due to the higher cooling effect of the 3 fans. The original data from the manufacturer foresaw only 1 fan. The other calculated EM forces are according to the measurements.

The measurements with 5 A and 4th gear resulted in a EM performance better than the one with 5th gear and 8.0 A applied in tests 09.04.2015. Internal temperatures of the EM brake were acceptable (low) in all cases (80 ºC). The air exhaust temperatures around 100 ºC were in the limit and optimizations should be tested in future.

The alternators and batteries performance were good, the additional mounting of 2 more batteries, especially for other tests, brought an additional safety to the energy balance.

The tests and calculations pointed to an application for commercial vehicles up to 250 HP. Considering that the vehicle losses (power without EM braking) should be 30%, the braking power could reach vehicles of 230 HP + (30% *230 HP) = 299 HP. New tests should confirm the limit of the Towing Trailer. The applicability of the Trailer on buses and tractors can be evaluated too.
8. CONCLUSIONS AND SUGGESTIONS

1. The developed Towing Trailer at 20 km/h has a good performance on-road (testing fields) cooling simulation test for trucks up to 250 HP. Applicability to busses, tractors and trucks up to 300 HP, should be tested. Tests with other speeds can be performed by changing the gear of the transmission on the Trailer.

2. The Towing Trailer is easy to couple with the truck and during, in tests, only the truck driver and one testing technician/engineer is needed. There is no need of other trucks / drivers. Relevant cost reductions therefore are expected, due to reduction of investment (in loaded trucks), with employees and with testing ground costs (paid per axle /test hour).

3. The EM brake is easily controlled and its parameters can monitored by a laptop, both in the truck cabin. In the future, data from the truck under test will also be registered in the laptop, and the experimental truck engine can also control the Towing Trailer.

4. Future tests should be performed with commercial vehicles and system producers to adapt the Towing Trailer to their necessities.

5. A semi-trailer for testing 600 HP vehicles is being planed. New support of government and participation of automotive industry will be welcomed.

REFERENCES


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[14] REHDER, H., Testes de caminhões leves até semipesados com um reboque de arrasto inovador com freio eletromagnético para simulações on road de alices, project supported by FAPESP – Fundação do Amparo à Pesquisa do Estado de São Paulo (Supporting Research Foundation of São Paulo State), project PIPE 12/7 50992 approved on Dec. 2012 and Final Technical and Financial Report approved in 2014.
