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CONDITION MONITORING AND COMPARISON OF BRAKING AND DYNAMICS IN RAILWAY FREIGHT WAGON

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ABSTRACT

In this paper the study and design of a monitoring system for intermodal freight wagons is presented. The prototype of the On Board Unit, realized within the research group of Railway Engineering of Politecnico di Torino is installed and tested on a intermodal freight wagon. Significant advances have been made in the field of freight train monitoring. In the last years many company have presented specific devices with the aim of monitoring the operating condition of good wagons. The developed prototype was tested on real track. The main vehicle parameters monitored during the tests were: the temperature of brake blocks, the operating pressures of the brake system and the vehicle accelerations. This paper present in particular the vertical and longitudinal accelerations monitored with the triaxial accelerometer installed on the chassis of the wagon. The significant amount of measured data is therefore used to develop diagnostic algorithms using the vibration analysis and to design an energy harvester to power the system.

Keywords: Freight train monitoring, vertical acceleration, vibration, condition-based maintenance.

INTRODUCTION

In recent years, the interest in monitoring the operating conditions of freight wagons has grown significantly as shown in numerous publications [1],[2],[3],[4],[5] and by the first devices dedicated presented on the market. Some solutions are focused on the bogie and its components while other on the transported goods.

The companies operating in this sector need to know the conditions of their wagons to be able to plan targeted maintenance and to reduce the costs connected with these operations. In the absence of continuous monitoring information, scheduled maintenance is realized to prevent faults that could lead at most to the discard of the wagon or, in the worst case, to derailments with serious consequences for the rail wagons and the infrastructure. Currently, the only information available is provided by the equipment installed along the railway network, separated by tens of kilometers. On the contrary, a good monitoring system should provide information on when and where you are experiencing a problem. The vibration value is the most commonly used parameter, along with the temperature, in the development of diagnostic and monitoring systems for different applications.

The acceleration values are studied in order to develop algorithms that can identify different type of problems such as derailment, wheels flat, bearings wear and faults and interaction with the railway track. Peter J Wolfs et al. [6] presented a prototype for online analysis of vehicle body motion signals to classify the vehicle response to the track and to detect potential derailments. Xiukun W.

[7] presented a wheel flat method based on the vehicle system acceleration, they used a SYMPACK model to analyze the fault signal. Shafiullah G.M. et al [8] developed a model using linear regression algorithms to predict vertical acceleration in the rear side of the wagon

THE MONITORING SYSTEM

The monitoring system (Figure 1) developed by our research group [12] [13] consists of a data acquisition system based on a microcontroller, a temperature sensor, three pressure sensors, a GPS module with external antenna, a SD memory and a triaxial accelerometer [9].

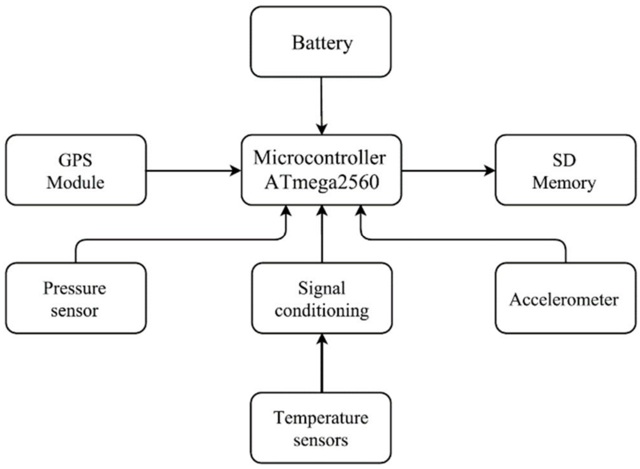

Fig. 1 - Monitoring system diagram

The wagon on which the developed monitoring device has been installed is an intermodal wagon, type “Sggmrs”, which is a special type of wagon used for container transporting. This is a two-unit articulate wagon with 3 bogies Y25 for a total of 6 axles (Figure 2).

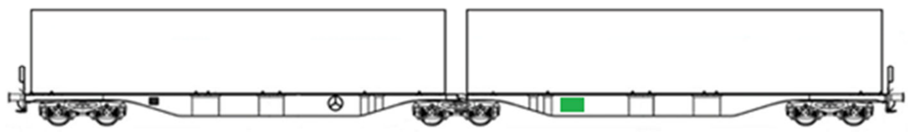

Fig. 2 - The wagon monitored

The monitoring system is installed in a box (protection degree IP66), schematized in Figure 2 with the green rectangle, fixed to wagon by threaded connections.

At this research stage only the central bogie has been sensorized because, being the most heavily loaded, it is the most stressed during the braking operations. The installation of the monitoring device is made following a complete inspection of the wagon in such a way that the data recorded during the monitored installation are not influenced in any way by faults or malfunctioning. The information thus obtained made it possible to establish what levels of temperature, pressure, and acceleration characterize the operation of this type of wagons in optimum conditions.

PRESSURE SENSORS

In accord with the operating pressure of the braking system, we decided to install three pressure sensors with a measuring range from 0 to 7 bar. The resolution of the pressure sensor obtained by our monitoring system is 7 mbar. The system pressure is obtained by connecting the sensors in the same attachment points used during the periodical brake tests. It is possible to monitor the pressure of the brake pipe, the brake cylinder, and the weighing valve of the central bogie. The pressure value of the weighing valve is essential to correctly estimate the mass of the load transported.

The pressure sensors, after having been calibrated in the laboratory, were tested in the maintenance workshop connecting them to the braking system. To make this link, we used the diagnostic connection on the braking system. With the brake tester equipment, we supplied known value of pressure to the braking system. Then this data were compared with those provided by the monitoring system. The mean of the relative errors of the various measurements is 3.2%.

ACCELEROMETER

The acceleration values shown in this paper are recorded with a triaxial accelerometer mounted inside the box. For this sensor we adopted a measurement range of ±16 g. We acquired the data with a sample rate of 200 Hz and every second we save on the SD memory the RMS (Root Mean Square) value with the maximum and minimum value measured for each axis.

The RMS values are calculated with the equation (1):

$$x_{rms} = \sqrt{\frac{1}{n}\left(x_1^2 + x_2^2 + \cdots + x_n^2\right)} \tag{1}$$

The vertical acceleration value, in addition to providing an important information on the interaction of the wagon with the railway track, represents an excellent basis for the correct dimensioning of an energy harvester device [10] able to satisfy the energy consumption of the system.

RAILWAY LINE MONITORED

The railway line traveled by the freight wagon, owned by the intermodal transport company Ambrogio Trasporti S.p.a., connects the terminal of Turin (IT) to the one in Mouguerre (FR), for a total length close to 1400 km, as shown in Figure 3.

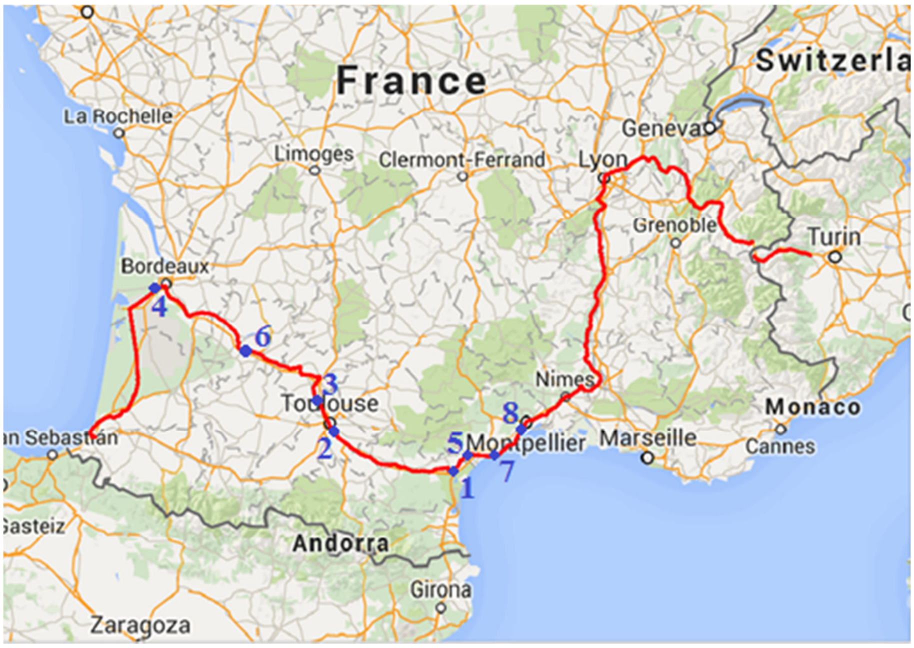

Fig. 3 - The monitored railway line

During the measurement campaigns, we monitored a total of about 28000 km on the same line. This data represented a large database for the development of monitoring and diagnostic algorithms.

RESULTS

The triaxial accelerometer mounted inside the box installed on the freight wagon chassis allowed to monitor the vertical and longitudinal acceleration of the wagon.
During the activation of the brake it is possible to synchronize the measurement of the brake cylinder pressure variation with the longitudinal deceleration and with the increase of temperature of the brake blocks.

Kwowing the geometric dimensions of the braking cylinder that acts on the central bogie and monitoring the pressure values during the braking phases was possible to define the total braking force (*H*) that act on the central bogie monitored. The formula (2) used is the following:

$$H = p\,A\,\beta \tag{2}$$

Where p is the pressure inside the brake cylinder, A is the brake cylinder area and β is the multiply coefficient obtained by the brake lever. In this braking system β is equal to 2.

In order to characterize the intensity of each individual braking it was calculated the integral mean of the force *H*, for all the braking of the different journey, with the following formula (3):

$$H_{mean} = \frac{1}{t_f - t_s} \int_{t_s}^{t_f} H(t)\, dt \tag{3}$$

The information related to the position of the train, collected using GPS, is extremely important because it allows to know the position and speed of the train and to correlate the parameters measured. We used it to obtain the braking distance (*d*) and to calculate the mean deceleration a_b during braking (4):

$$a_b = \frac{s_s^2 - s_f^2}{2\,d} \tag{4}$$

Where s_s represent the speed of the wagon when the braking start, s_f the speed at the end of the braking and d is the braking distance. In this analysis, we take into account only braking in plain. The results obtained are synthetically shown in Figure 4.

The previous figure summarise the results of four different journeys. It is possibile to notice, as planned, the linearity relationship between the two physical quantities. The value monitored and presented are in line with those reported in literature [11]. The correct operation of the braking system has allowed to obtain extremely repeatable measurements.

Figure 5 - 8 shows the trend of the longitudinal acceleration of the wagon in relation to the brake cylinder pressure. As can be seen in the RMS value of the longitudinal deceleration present the same trend of the pressure in the brake cylinder. In the figures are reported partial braking to modulate the speed of the train, so the maximum pressure value reached in the following figure is 1.5 bar.

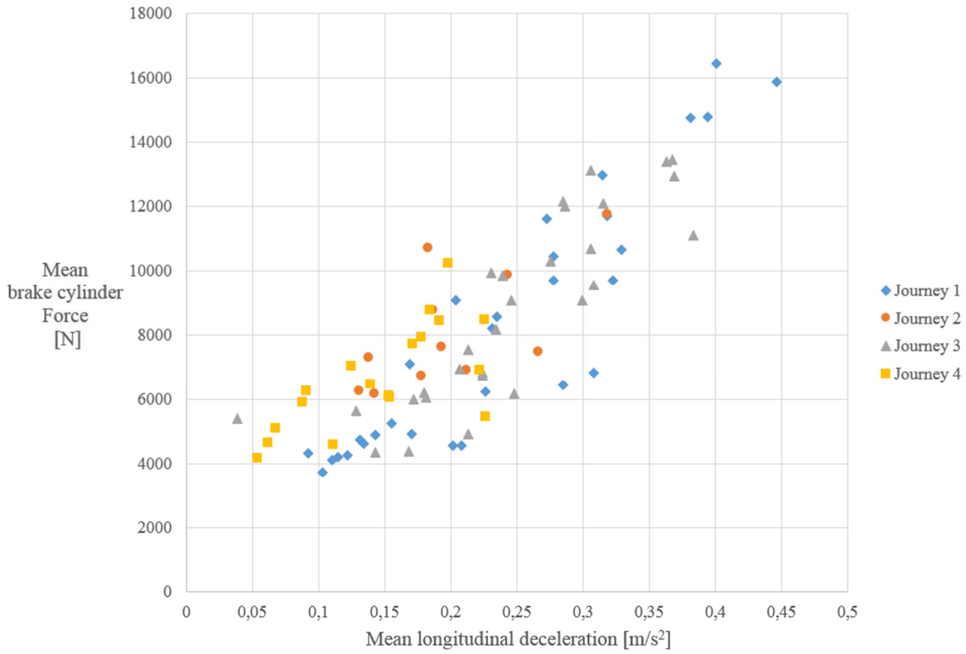

Fig. 4 - Mean longitudinal deceleration during braking

The numbers reported in Figure 3 are referred to the cases analysed in Figure 5 - 8 in order to allow the reader to understand the position of the different braking events along the monitored railway line.

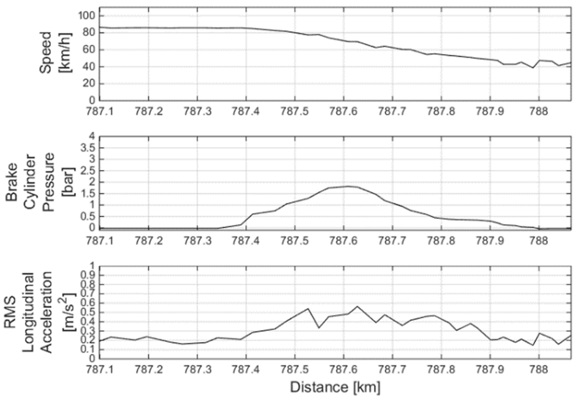

Fig. 5 - Case 1 - Outward Journey A

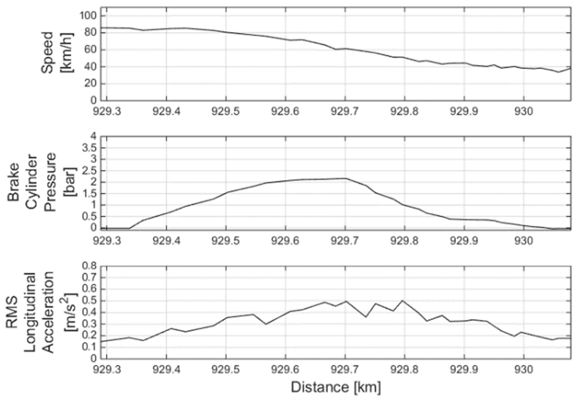

Fig. 6 - Case 2 - Outward Journey A

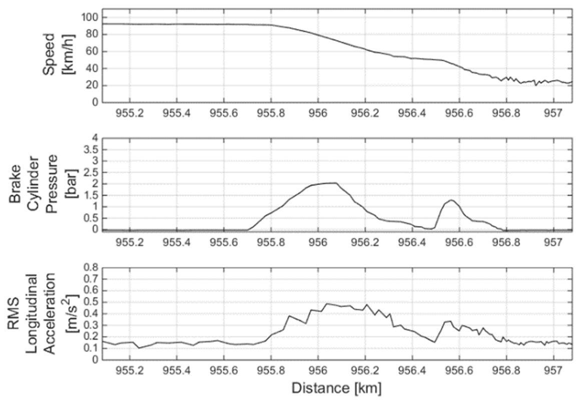

Fig. 7 - Case 3 - Outward Journey A

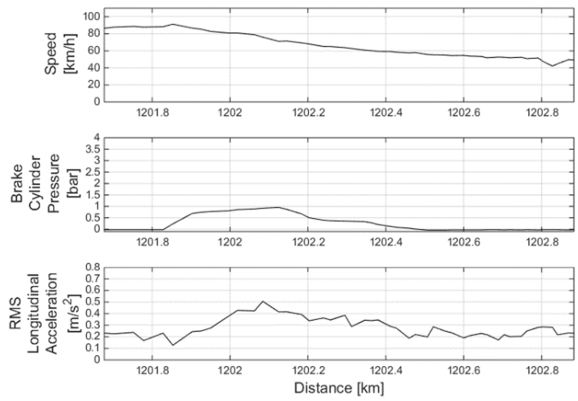

Fig. 8 - Case 4 - Outward Journey A

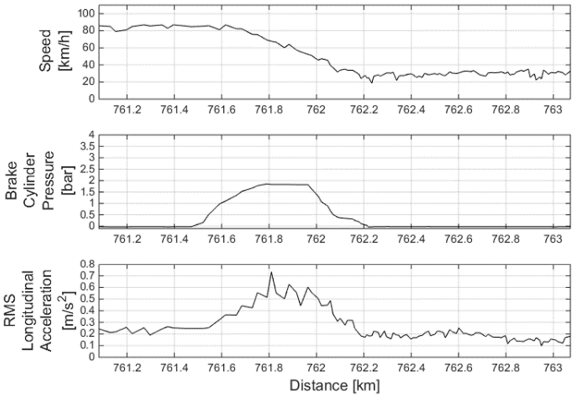

Fig. 9 - Case 5 - Outward Journey B

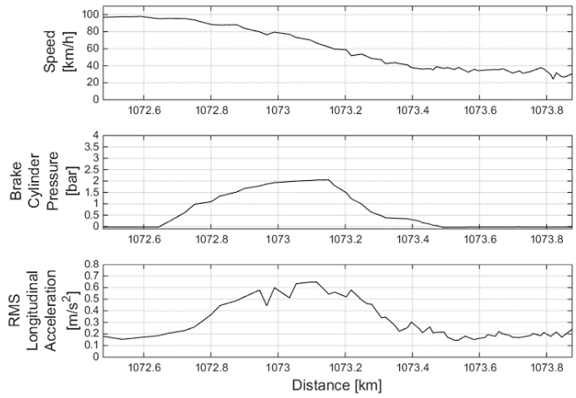

Fig. 10 - Case 6 - Outward Journey B

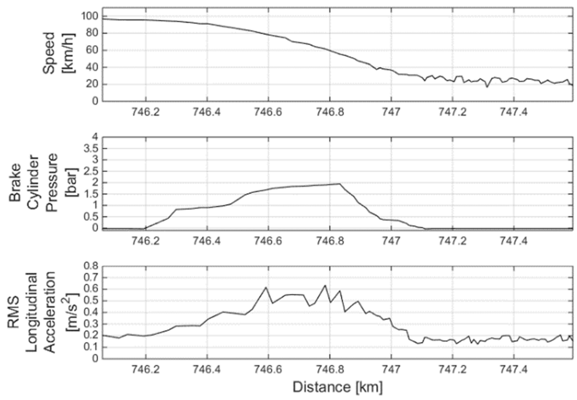

Fig. 11 - Case 7 - Outward Journey B

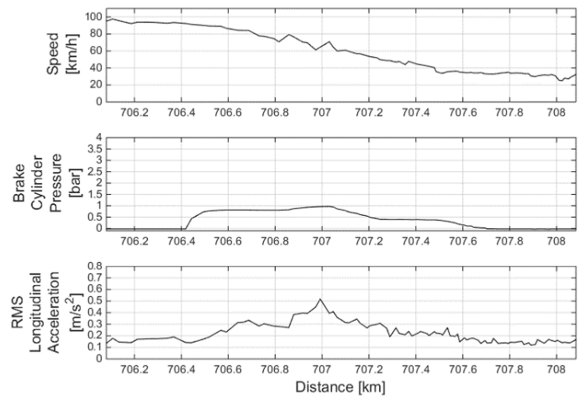

Fig. 12 - Case 8 - Return Journey B

The value of the accelerations, showed in the graphs, are summarized in Table -1:

Table 1 – Summary of accelerations

Case	Mean Longitudinal Deceleration [m/s^2]	Mean Longitudinal RMS [m/s^2]
1	0,32	0,35
2	0,31	0,33
3	0,28	0,30
4	0,31	0,33
5	0,38	0,40
6	0,37	0,40
7	0,32	0,36
8	0,22	0,25

The values of the first coloum are calculated with the formula (4) while the secondo coloum are calcolated as mean of the RMS value calculated and saved by the monitoring system during the braking.

CONCLUSION

In this paper, we presented the realization, the installation, and the first results obtained from the modular monitoring system dedicated to intermodal freight wagons developed by the Politecnico di Torino. The data collected made it possible to obtain information on the dynamics of the train during braking.

This first data represent an initial database for the future development of diagnostic and monitoring algorithms for the dynamics of the freight wagon.

The RMS longitudinal acceleration is compared with the GPS velocity deceleration data. The pressure signal measured by means of on sensorized on board unit is correlated with the longitudinal deceleration. Comparing different journey in different days a bid data set confirm that deceleration trend could be directly linked with the breaking pressure signal. This measurements dataset give the possibility to develop a more simplified On board Unit in order to derive the breaking behavior by means of imitated number of sensors.

The next data analysis will focus on the study of the impact of the high temperature of the brake blocks on the braking force and braking distance.

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