PORTABLE DIAGNOSTIC SYSTEM FOR THE METRO TRAIN

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Summary

In this article it's present the results obtained during the implementation of a portable diagnosis system to the maintenance routines of the passengers vehicles and permanent track of the Metro de Medellín Ltda. Company, that allowed to evaluate the aspects as: safety, comfort and technical condition of the track-vehicle interphase.

The reports given in of this evaluation allowed to identify and to arrange the track sections according to its technical condition, associating in this way the track condition parameters and the vehicle with the estimators associated to the passengers vehicles dynamics.

Key words: diagnostic system, technical condition, safety, comfort, dynamic state.

PRZENOŚNY SYSTEM DIAGNOSTYCZNY POCIĄGÓW METRA

Streszczenie

W pracy przedstawiono wyniki badań prowadzące do konstrukcji przenośnego urządzenia diagnostycznego dla potrzeb utrzymania zdatności pociągów Metra w Medellin – Kolumbia. Badania obejmują zagadnienia z zakresu bezpieczeństwa jazdy, komfortu i zmian stanu na granicy tor - pojazd.

Słowa kluczowe: system diagnostyczny, stan techniczny, bezpieczeństwo, komfort, stan dynamiczny.

1. INTRODUCTION

In the internacional field standards exists for the rail road, which determine the procedures and tests that must be realized to evaluate the different railway components. The Metro de Medellín company and the investigation group GEMI (Group of Studies in industrial Maintenance) of the EAFIT University with COLCIENCIAS's support they realized a study of the passengers vehicles dynamical behavior taking as a base the UIC 518 international norm (International Union Of Railways), with the goal to check the current operation condition of the railway system.

This internacional norm contains all the indications to realize the railway rolling stock tests from the point of view of its dynamical behaviour, with the goal of evaluate the safety aspects, track fatigue and the running onditions (stability, comfort, etc.).

It stablishes besides, the measurement conditions of the track condition parameters in the different test zones (tangent and small and large radius curves) such as horizontal and vertical alignment, cant insufficiency, and other ones.

Additional it was considereted operation variables as the speed passengers vehicle. The measurement points, the automatic and data stadistics processing conditions, the quantities measured evaluation with its respective limits values were fixed according to the norm.

2. PORTABLE DIAGNOSTIC SYSTEM

To fulfill with the requirements that the norm demands, a Portable Diagnostic System is developed (see fig. 1) for the track-vehicle interphase of the Metro de Medellín system.

Fig. 1. Executors of project Portable Diagnostic System

The Portable Diagnostic System (SPD) is constituted by modules that allow to evaluate the safety aspects, comfort and track-vehicle interphase state condition (fig. 2), besides it offers recommendations to determine the following diagnosis term.

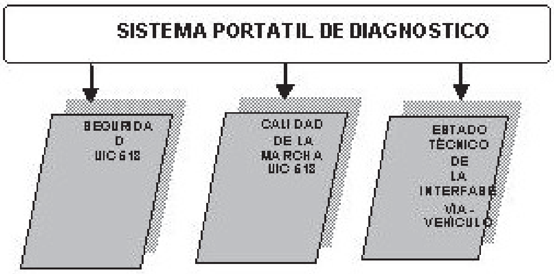

Fig. 2. Portable diagnostic system - SPD

The portable diagnostic system (SPD) have an equipment of the HBM company named MGCplus that acquire and include physical variables as forces and accelerations, which ones are acquired in the railroad different typical points by means of force transducers, unidirectional and triaxials acelerometers. The sampling frequency of the system is equal to 400Hz. The hardware is configured through a specialized software for this application type, which allows to configure the capture parameters, register and data processing, as well as to recalibrate instruments, to store measurements, to processing data (signals filtered and window) and to draw the results. In the figure 3 appears the acquisition system SPD configuration, is observed the forces and accelerations transducers, the data processor and the computer to realize the respective configuration from the software.

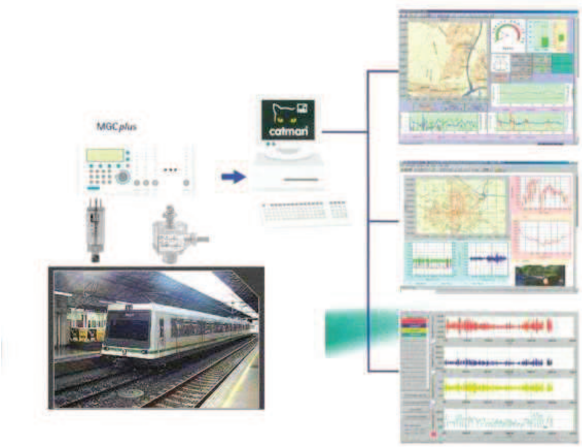

Fig. 3. Adquisition system of the SPD

In the fig. 4 a force signal measured in the motor vehicle axle top appears.This signal allows to calculate the lateral forces sumatory that are generated in the vehicle along the track which are necessary for the safety evaluation.

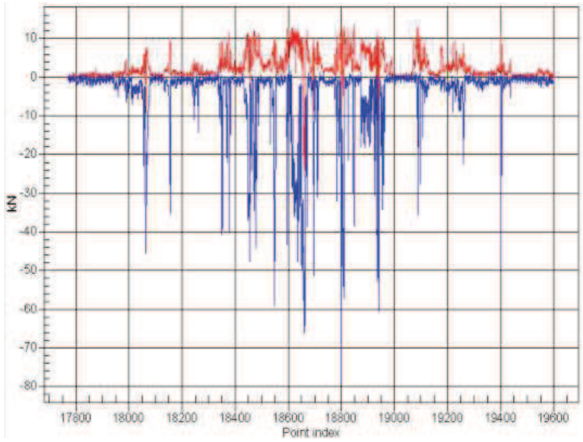

Fig. 4. Force signals measured in passengers vehicle

In the fig. 5 an acceleration signal appears, which is measured in the vehicle box front part during a test route, this sign allows to the SPD to create the necessary estimators to evaluate the running quality or the comfort in the passengers vehicle.

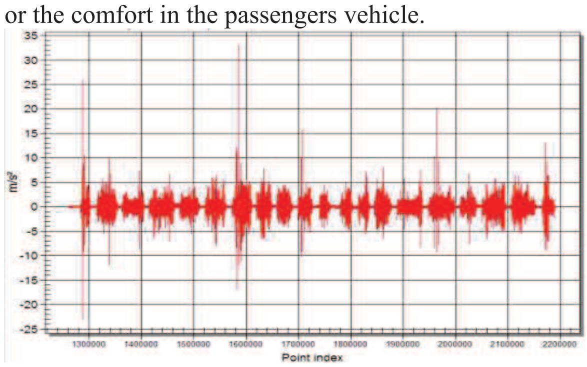

Fig. 5. Acceleration signal measured in passengers vehicle

The difference force and acceleration sensors are located in the vehicle load points following the norm guidelines, for this were made devices that allowed the sensors installation, without affecting the vehicles normal operation in the moment of the tests.

The fig. 6 illustrates the axle top where the force and acceleration transducers are installed under the UIC 518 norm criteria.

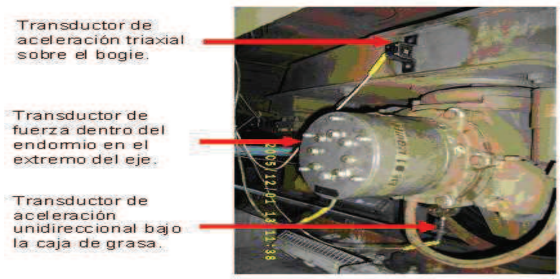

Fig. 6. Transducers installation in the passengers vehicle axle top

The UIC 518 norm establishes two test methods to evaluate the railway systems rolling stock conditions; simplified and normal method., this last was the implemented one Sistema Metro.

The system SPD registers the operation speed and generates the train position vector in the track, indispensable data to determine the sections length and location (the levels or railway geographical) that expires with the norm. requirements.

The coordinates system used is the proposed one in the UIC norm. The axle X becomes positive in the running direction; the Z axle becomes positive vertically up and the Y axle is orthogonal to the other two, it means in transverse direction (fig. 7).

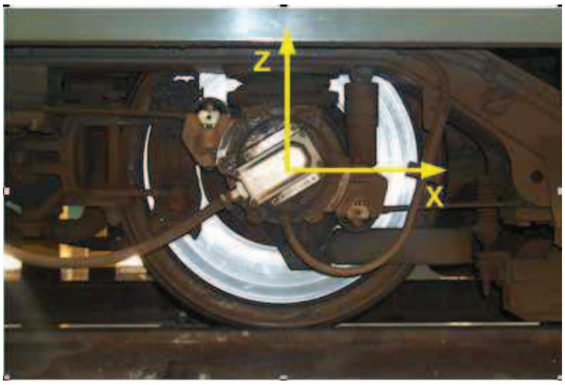

Fig. 7. Coordinates system of according to the UIC 518 norm

To implement the norm, it became necessary to recognize the different sections in tangent tracks, small and large radius curves, which were checked according to the norm requirements in what concerning lengths, contact geometry (cant, alignment, equivalent conicity, etc.) and operation speeds; giving as a result the zones test with its respective speeds and radius, as the fig. 8 illustrates.

The cant track insufficiency (see fig. 9) is reflected in the evaluation reports of the curves in the vehicles tests.

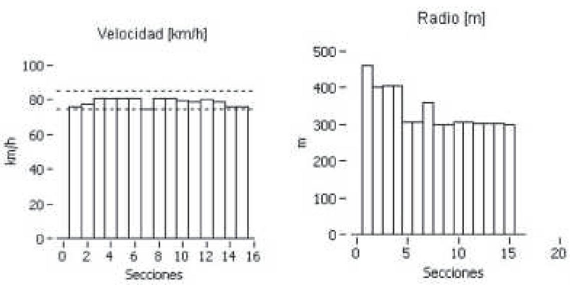

Fig. 8. Track sections according to speed and radius curves

The cant insufficiency in the curves is defined as the balance between the theoretical cant (design) and the real cant according to the relation:

$$Preal = Pdesign - P_{insufficiency}. \qquad (1)$$

$P_{insufficiency}$= 2 Dcontact * ay/ g
$P_{insufficiency}$ = Insufficiency cant
Rcontact = Wheel contact radius
g = Gravity constant.

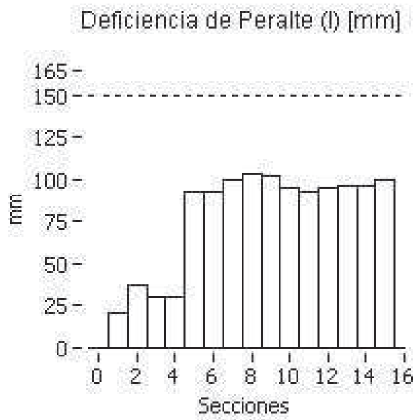

Fig. 9. Insufficiency of cant of the road

In the figures 10 and 11 appear the different recommended values in the norm as for the cant insufficiency and alignment that must fulfill the tests zones.

Categoría de tren		Velocidad (km/h)	I_{adm} (mm)
Ia - Trenes de carga (diseño convencional)		V ≤ 120	130
Ib - Trenes de carga (diseño apropiado)		120 < V ≤ 140	130
Ic - Trenes de carga (diseño apropiado) también permitiendo el uso de rutas de trenes de pasajeros		140 < V ≤ 160	150
II - Trenes de pasajeros (diseño convencional)		V ≤ 230[a]	150
III - Múltiples unidades sin inclinación y carros de riel con diseño especial (ej, centro de gravedad bajo, cargas axiales mas bajas)	Líneas convencionales	0 < V ≤ 160	165
		160 < V ≤ 230	150
	Líneas de alta velocidad	200 < V ≤ 250	150
		250 < V ≤ 300	130[b]
IV - Trenes/ Vehículos inclinados		0 < V ≤ 300	c

Fig.10. Permissible values of cant insufficiency for railroad type

In order to obtain homogeneous data in the different test zones, the norm suggests to classify the track state condition, for this indicators associated with the standard deviation of the vertical and horizontal track alignment are in use (see fig. 11).

Desviación Estándar : Alineamiento Lateral	QN1 (mm)	QN2 (mm)
V ≤ 80 km / h	1.5	1.8
80 < V ≤ 120 km/h	1.2	1.5
120 < V ≤ 160 km/h	1	1.3
160 < V ≤ 200 km/h	0.8	1.1
200 < V ≤ 300 km/h	0.7	1

Desviación Estándar : Alineamiento Vertical	QN1 (mm)	QN2 (mm)
V ≤ 80 km / h	2,3	2,6
80 < V ≤ 120 km/h	1.8	2.1
120 < V ≤ 160 km/h	1.4	1.7
160 < V ≤ 200 km/h	1.2	1.5
200 < V ≤ 300 km/h	1	1.3

Fig. 11. QN1 and QN2 indicators of the track alignment state, according to the UIC 518 norm.

The lateral and vertical alignment recorded in the SPD reports is obtained of the machine records that realizes the alignment activities in the permanent track of the system Metro.

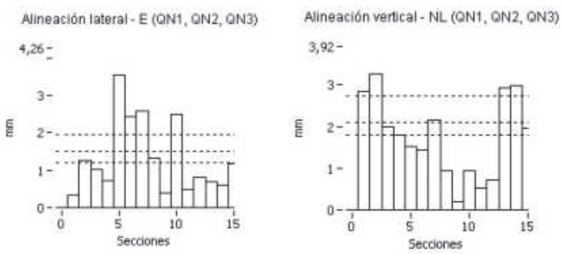

Fig. 12. Track alignment, for the sections where the UIC norm is implemented

For normal approval purpose of the vehicles, the geometric quality is based on the track maintenance criteria, represented in two quality levels:

QN1 – It refers to the value that needs observation of the track condition or measurements acquired as a part of the maintenance actions usually planned.

QN2 – It refers to the value for which is require short term maintenance actions.
The Metro de Medellín system applies for the values that corresponds to minor or equal speeds to 80 km/h.

For the evaluation of the safety aspects, running behaviour and track fatigue, it's calculated a serial estimators from the and acceleration forces measurements previously described. For the different tests zones, there is defined a maximum value estimated, which represents the railway system state condition once it is compared with its respective limit value. It's as follows:

$$\hat{x}_{\max} = \bar{x} + k \cdot s \qquad (2)$$

where:
$\bar{x}$: arithmetical average,
s : standard deviation,
k : confidence level factor selected, like that:

k = 3 for the safety aspect.
k=2.2 for the track fatigue and the running behavior
k = 0 for quasi-static quantities.

In the evaluation reports of the Portable System of Diagnosis one finds a value named coefficient λ, which is the relation between the limit value and the maximum estimated value, according to the following relation:

$$\lambda = \min\left(\frac{\text{Limit Value}}{\text{Maximum Estimated Value}}\right) \qquad (3)$$

In the fig. 13 is shown an example about the measured values in the small curves test zones, in this figure are observed the different defined variables in the previous paragraphs.

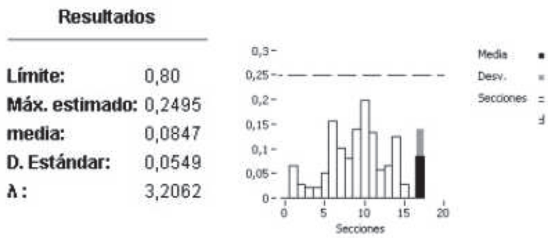

Fig. 13. Reports presentation

3. RESULTS OF THE PORTABLE SYSTEM OF DIAGNOSIS – SPD IMPLEMENTATION

Next the results obtained of the UIC 518 norm implementation in the passengers vehicles fleet of the Metro de Medellín are shown, using a sample of eighteen vehicles.

In the fig. 14, is observed the RMS maximum value estimated of the guide forces sumatory obtained in the different passengers vehicles. It is possible to deduce that this estimator is changeable in the different vehicles, because of the condition of the track-vehicle interphase properties, such as: thickness and wheel flange height and diameters differences in the same unit and others.

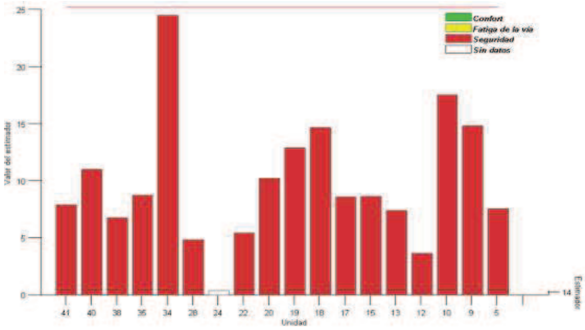

Fig. 14. Safety results compared with UIC 518 norm criteria

In the fig. 15 and 16 the different needed estimators in a three-dimensional way are shown to evaluate the comfort in the passengers' vehicles and the track fatigue. The surface that is over the values, represents the limit value established by the norm. In the same way due to the vehicles exploitation record, it shows different results.

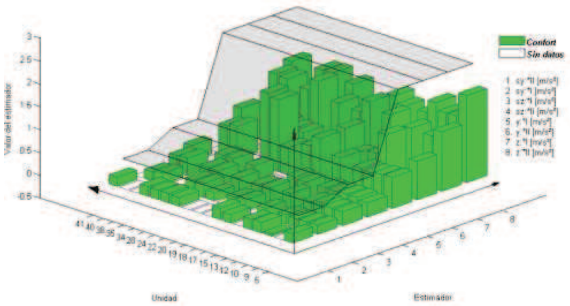

Fig. 15. Comfort results compared with UIC 518 norm criteria

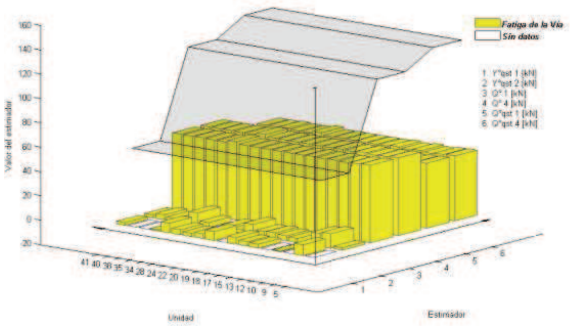

Fig. 16. Fatigue results compared with UIC 518 norm criteria

In the final investigation report analyses, all the estimators concerning to the safety, comfort and fatigue evaluation for passengers vehicle are grouped, as the fig. 17 shows.

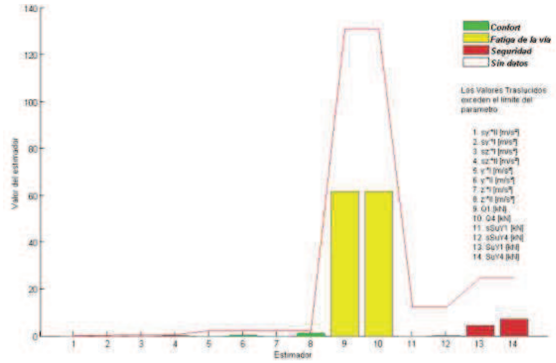

Fig. 17. Grouped results compared with UIC 518 norm criteria

4. CONCLUSIONS

1. The implementation of UIC 518 international norm in the passengers vehicles took place in real exploitation conditions of Metro trains. The innovation of these norms are principally associated with rolling elements and special conditions of measurement.
2. The sections associated with the norm evaluation, will allow to establish new political maintenance based on the technical condition of the track-vehicle interphase.
3. The results of investigations allow to the Metro company the improvement of safety, comfort and quality service during exploitation.
4. The information recorded in the final investigation report, is the way to define new challenges in the maintenance of technical complex systems.
5. This type of investigation aims the academic and industrial development in our country.

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