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Impact Attenuation for High-Speed Rail Fastening Systems according to EN 13146-3:2012

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Abstract

Imperfections in the perimeter of the wheels and on the running surfaces of the rails, combined with irregularities in the support system of the track superstructure, are the cause of the presence of impact loads on the track. This dynamic effect increases with increasing speed. In superstructures consisting of concrete sleepers, the fastening element responsible for damping the forces applied to the rail and transmitted to the sleeper is the elastic pad. Therefore, one of the requirements demanded of this element will be a good damping capacity in order to achieve a better conservation of the track elements located below, as well as to improve the comfort in the vehicle's operation.

The European standard EN 13146-3:2012 "Railway applications - Track - Test methods for fastening systems - Part 3: Determination of attenuation of impact loads", characterises the attenuation against impact loads of the support element. This standard sets out two possible procedures for determining attenuation, the so-called reference method and the alternative method. In both methods what is measured is the deformation of the sleeper when it is hit by a particular impact and the difference between methods lies in how the sleeper is placed. In the reference method, the sleeper rests on a ballast bed, without any additional load, while in the alternative method, the sleeper rests on an elastomeric mat of similar rigidity as the ballast and an additional load is applied to the system.

The problem arises when carrying out an intercomparison between two laboratories in which the results differed by more than 100 %. When analysing the results, it is verified that the test methods used are different and from this moment a research project begins by LADICIM, trying to justify this difference in the results.

The objective of this paper has been to verify that the two methods proposed by the Standard are not equivalent, so it may be necessary to reconsider the Standard to avoid possible errors in determining the attenuation of rail fastening systems.

Keywords: attenuation, impact, damping, high speed, fastening system, railway

1 Introduction

The fastening systems are designed to maintain the track gauge and to provide the required elasticity to the track assembly, an electrical insulation between rails and also, a comfortable rolling for the user.

Imperfections in the wheel circumference and in the rail running surfaces, combined with irregularities in the support system of the track superstructure are the cause of the occurrence of impact loads on the track. This dynamic effect increases with increasing speed. In concrete sleeper superstructures, the fastening element responsible for absorbing the forces applied to the rail and transmitting them to the sleeper is the rail pad. The rail pad is located to under rail (see Figure 1) and one of the requirements placed on this element is therefore a good damping capacity, in order to achieve better preservation of the track elements below, as well as to improve the ride comfort of the vehicle [1,2].

The elastic rail pad must guarantee high stability while maintaining its characteristics throughout the life of the track. The material used in its manufacture must guarantee good resistance to friction, adequate stiffness to withstand the vertical, longitudinal, and transverse stresses to which it will be subjected during its service. Also, the rail pad must resist to deterioration due to the surrounding environmental conditions [3]. Polymeric materials are currently being used to manufacture this component such as; EPDM, TPE, TPU, rubber... [4,5], and work is also underway to introduce other non-polymeric materials such as the metal pad made from stainless steel [6]. These last ones try to solve the problems that the polymeric materials present due to their stiffness can be altered by different environmental agents such as UV rays, temperature, humidity and the wear or deterioration suffered by the pads due to the continuous mechanical efforts of fatigue in compression, which increase the stiffness of the rail pad [7-8].

One of the existing procedures to evaluate the damping capacity of the rail pad is by means of determining the impact attenuation according to the methodology and requirements set out in the CEN Standards EN 13146-3:2012 [9] and EN 13481-2:2012+A1:2017 [10], respectively. The standard EN 13146-3:2012 proposes two different methodologies in order to determinate the impact attenuation value but the standard EN 13481-2:2012+A1:2017 stablishes the same requirements for both methods. In this sense, the results obtained by several laboratories using the both different test methods were very different. Therefore, this work focuses on analysing both methodologies by means of a comparative study and figuring out the sources of the discrepancy in the results obtained by these laboratories.

2 Methods

A fastening system (the type of fastening system cannot be indicated as it is confidential) was chosen to carry out the impact attenuation tests, mounted on a pre-stressed concrete monobloc sleeper and a 0.5 m long rail coupon (UIC60).

In order to be able to analyse the influence of the material used to manufacture the rail pad on the measurement of impact attenuation, rail pads with different stiffnesses and materials were chosen. The rail pads used are as follows:

- Reference solid EVA (Ethylene-vinyl acetate) pad. 5 mm thick. This pad shall be supplemented with aluminium plates of different thicknesses to match the thicknesses of the test pads.
- Solid EPDM (ethylene propylene diene monomer rubber) pad without studs, porous and 11 mm thick.
- Solid pad made of out-of-use tyres (NFU), with a grain size of less than 4 mm, bound with resin and with a thickness of 10 mm.
- EPDM Pad with circular studs (9 mm diameter) on both sides and 11 mm thick.
- Solid EPDM pad without studs and 7 mm thick. This is the solution adopted in the high-speed railway in Saudi Arabia.
- TPE (Polyester Elastomer Thermopolymer, Hytrel) pad with circular studs and 7 mm thick. Solution adopted in the Spanish high-speed rail system, PAE-2 [18]
- EVA pad with circular studs (13 mm diameter) and 10 mm thick.
- Solid rubber pad with textile reinforcement and 11 mm thick.

An impact load is applied by dropping a mass onto the head of a rail fastened to a concrete sleeper. The effect of the impact is measured as strain in the concrete sleeper. The impact attenuation of a fastening system is assessed by comparing the strains induced with a low attenuation reference rail pad and the rail test pad in the fastening system. With the reference pad in the system, the deformation produced by the impact load must not exceed 80 % of the resistant moment of the sleeper of the low rail section at measuring points. The mass that falls, the drop height and elasticity of the hammer head are adjusted to ensure that the deformation limit is not exceeded. The procedure is repeated with the test pad, with no subsequent change of falling mass, fall height or hammer head.

The standard proposes two different methods, the reference and the alternative. The only differences lie in the support on which the sleeper is supported and the load condition applied. In the reference method the support is a bed of crushed stone and no external load is applied to the system. Whereas, for the alternative, the sleeper is placed on a rubber mat on a firm base and the fastening system is preloaded during the test.

3 Results

Figure 1 shows the results obtained in the attenuation tests using the two methods. It can be seen that the results obtained by the two methods are very disparate, the values obtained by the reference method are higher than those obtained by the alternative and the variations between the methods in some of the rail pads reaches values of 97 %.

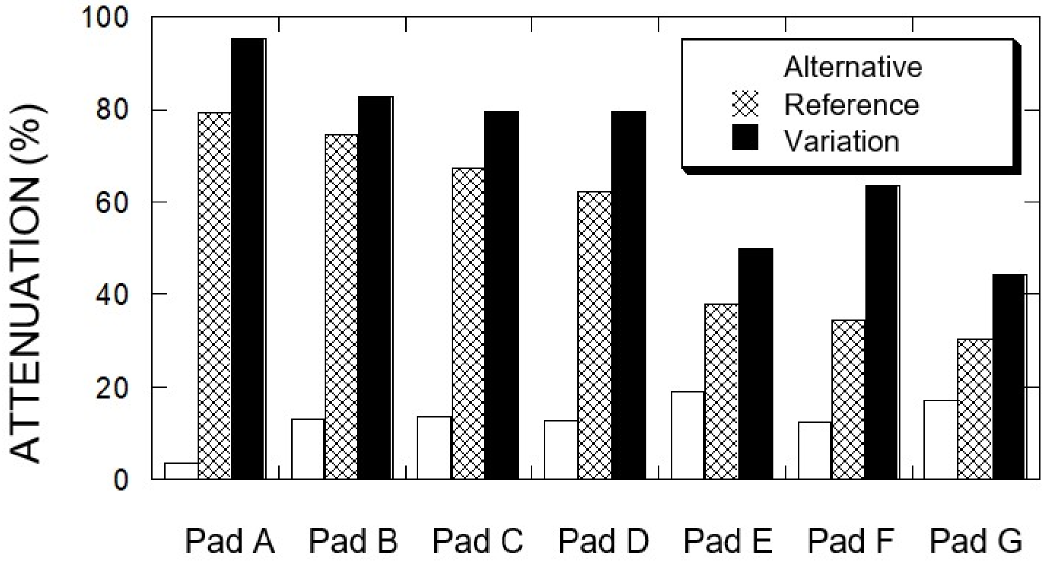

Figure 1: Impact attenuation results.

As Carrascal et al. [26] concluded in previous studies the relationship between impact attenuation and the mechanical properties of the rail pad. The results show that the attenuation decreases with increasing rail pad stiffness if the reference method is used, in contrast, the attenuation increases with increasing rail pad stiffness if the attenuation is measured with the alternative method.

Independently of rail pad geometry, analysing the hardness of the rail pad, the result show how for the reference method the attenuation tends to decrease with increasing rail pad hardness, while for the alternative method the opposite happens, the attenuation increases with rail pad hardness, but in lower absolute values.

This difference between the two methods is the pre-loading, since the impact device is the same (height and mass) and the stiffness under the sleeper is similar since they meet the same deformation criteria despite being different in nature. For this reason, impact tests are carried out, but the preload is modified. The results show that as the preload is reduced, the attenuation values are increased, getting closer to the values measured by the reference method. It can be seen that below 5 kN the attenuation values lose their upward trend, possibly due to the lack of clamping of the sleeper, as it is only supported by the resilient mat and this can slightly influence the strain gage measurements

4 Conclusions and Contributions

The following conclusions have been drawn from the analysis of the results obtained in this study:

- The two methods defined in EN 13146-3:2012 give very different impact attenuation results. The variation between the two methods increases as the stiffness of the base rail pad is reduced.
- The attenuation values measured with the reference method tend to decrease with increasing the rail pad static stiffness and hardness, while the opposite happens for the alternative method. For the rail pads analysed the relationship between the results obtained by both methods is inverse.
- With the alternative method the attenuation values increase by reducing the test preload.
- When comparing the two methods' results, the values obtained with the reference method tend to those obtained with the alternative method for a preload of 0 kN.
- When reporting an impact attenuation result, it will be necessary to indicate the method used for its determination. In the same sense, the standard UNE-EN 13481-2:2012+A1:2017, when establishing a classification of fasteners according to their attenuation, will have to indicate two different criteria depending on the type of method used for their determination.

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