Development of an Innovative Fatigue Tests Profile for Three Axle Semi-trailers

H. Malon, L. Tello and C. Martin

***Abstract*—Nowadays, in the design of any type of vehicle, in particular of semi-trailers, the manufacture and testing of prototypes is essential. The fatigue tests on semi-trailers are almost non-existent because of the high costs and their duration, with the exception of those carried out in tests bench by LECITRAILER S.A. The aim of this paper is to show the process developed in the optimization of the innovative profile of fatigue testing developed by the University of Zaragoza in collaboration with the company LECITRAILER S.A., which is applied to the process of optimization of all the prototypes made by the company.**

I. Introduction

A fundamental aspect in the design of any type of vehicle, in particular of semi-trailers, is the development and testing of prototypes that confirm the correct performance of the vehicles before their launch into the market.

Currently, the world of vehicles is one of the major sectors of application of fatigue, vibration, and noise analysis, where a large number of tests for specific components and complete vehicles have been developed.

It is necessary to consider that some methodologies of applied design and testing in cars have not yet been developed or could not be applied to vehicles of great dimensions due to the differences in the existing requirements and the budget limitations in each sector of vehicle development.

At present, fatigue tests exist for different structural components from large machines to small components in vehicles [1]-[3], but up to now, there is no knowledge about fatigue tests of complete vehicles of large dimensions, with the exception of the fatigue tests of semi-trailers that are carried out by the company LECITRAILER S.A. under the supervision of the Transportation Engineering Area of the University of Zaragoza, in particular the research group VEHIVIAL.

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H. Malon is a Professor in the Mechanical Engineering Department of the University of Zaragoza, and is a researcher in the staff of the Mechanical Department of the University of Zaragoza, Spain (phone: +34/976761888; fax: +34/9762670; e-mail: hml@unizar.es)

L. Tello is a researcher in the staff of the Mechanical Department of the University of Zaragoza, Spain (phone: +34/976761888; fax: +34/9762670; e-mail: ltello@unizar.es).

Carlos Martin graduated in 1991 with a degree in mechanical engineering from the University of Zaragoza, Spain. Since 1995, Mr Martin has been Operation Director in Lecitrailer, Zaragoza. From 1992 to 1995 he worked in Leciñena, a semitrailer builder, in Zaragoza, and from 1991 to 1992 he worked for Neumin, a Spanish brakes builder. He has obtained the APICS Master (American Production Inventories Construction Systems) and EWE Master (European Welding Engineer) qualifications. (phone: +34/976462121; e-mail: martin@lecitrailer.es)

At present the majority of the tests that allow us to measure the characteristics of the behaviour of fatigue in semi-trailers are based on road tests, where the whole tractor and semi-trailer is tested, obtaining its fatigue life [4] [5].

This test technique presents a series of disadvantages mainly the duration of the test, for which several months are necessary, which in turn produces a long delay in launching the newly designed vehicle. In this case, it is necessary to prepare or to contract a test track and to employ one or several specialized drivers, who are able to reproduce the fatigue manoeuvres repetitively, an aspect in which the skill of the drivers is of utmost importance. Furthermore, it is also necessary to add the additional costs of maintenance of the vehicle, such as fuel and tyres, and the possible repairs to carry out in the tractor cabin or in the semi-trailer suspension systems.

As a result of these disadvantages in fatigue tests explained above, and the cost that they suppose, in the majority of the new designs of semitrailers, only resistance and rigidity tests are carried out. They are sufficient to validate the obtained results of the design and the optimization achieved by the Finite Elements Method, thus avoiding the fatigue tests.

The aim of this paper is to show the process used in the development of an innovative fatigue tests profile for three axle semi-trailers developed by the University of Zaragoza in collaboration with the LECITRAILER S.A. company, which allows fatigue testing of prototypes for a period of three months.

II. Fatigue test bench description [6] [7]

In the first place it is necessary to give a brief description of the fatigue bench used in the tests for three axle semi-trailer prototypes.

The bench dimensions are determined by the dimension of the large vehicle to test, in this case a three axle semi-trailer.

The bench of fatigue is made up of six vertical hydraulic actuators, one per wheel of the vehicle, and a seventh horizontal actuator, in the kingpin zone.

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Figure 1. Fatigue test bench.

The verticals actuators introduce vertical displacement onto each of the semi-trailer wheels, and the horizontal hydraulic cylinder introduces the transversal displacements generated by the tractor unit in the manoeuvres that these types of vehicles make.

III. Initial Hypothesis in the Optimization Process of Fatigue Test Profile [8] [9]

The initial hypotheses of the optimization process arises from the existing deficiencies detected in the fatigue test carried out on a reference vehicle.

The considered initial hypotheses in the development process are the following:

1) **To obtain an increase of the torsional strain in the semitrailer chassis metallic structure.** The experience of the LECITRAILER S.A. Company and the Transportation Engineering Area of the University of Zaragoza in semi-trailers, indicates that the early fatigue failures that occur in this type of vehicles occur in the welded joints, mainly in the welded joints of the axle supports and in the change of section of the stringers. These fatigue failures are produced due to the chassis torsion.
2) **Symmetrical cycle.** The manoeuvre to simulate must be symmetrical in order to avoid permanent deformation in the chassis structure, modifying the initial state and the repetition of the test.
3) **Absence of sliding in the vehicle wheels.** When sliding takes place, the friction coefficient falls and loads are partially transmitted to the structure, diminishing the tensional state and deformations of the vehicle. In addition, when the wheels slide, as the test progresses, there is a change in the vehicle position that will make difficult to compare results between different fatigue tests.
4) **Reduction of the time of highway test.** The obtained results of the fatigue test show that the part of the test corresponding to the highway section presents a lower variation of stress and deformation compared with the part of the test corresponding to critical manoeuvres. Therefore the time of the section of the highway test is reduced, and at the same time it is modified in order that this part of the test corresponds to one of the critical situations that a semi-trailer can face when travelling on a highway.
5) **Reduction of the duration of fatigue cycle.** It is necessary to consider that this is a fatigue test of a quasiestatic manoeuvre, which implies that the total time of each cycle will be quite long. Therefore it is necessary to develop a cycle with the minimum duration of time, fulfilling the previous requirements, and in addition, assuring that the input signal generated by the controller is reproduced faithfully by the actuators.

IV. Optimization Process [10]

Once the initial hypotheses of the fatigue profile to develop have been defined, it is now necessary to analyze diverse configurations of the positioning of the actuators of the fatigue test bench with the purpose of determining the more unfavorable combination of displacements in the hydraulic cylinders for the semitrailer chassis structure.

In this optimization process of the fatigue manoeuvre 14 fatigue profiles have been developed and tested, besides the initial ones. In the first place, strains and stresses that are generated in the chassis structure have been analysed by means of extensiometric techniques. In the second place displacements have also been analysed, these displacements are mainly generated by the sliding of wheels.

The obtained results of the extensiometric measurements of nine critical zones of the chassis structure allow us to compare the developed profiles, and to obtain the critical positioning of the hydraulic actuators for three axle semi-trailers.

In the process explained above to obtain the critical positioning of the hydraulic actuators, only three of the five initial hypotheses have been considered; to obtain an increase of the torsional strain in the semi-trailer chassis metallic structure, a symmetrical cycle and the absence of sliding in the vehicle.

The development of the final fatigue profile must consider the obtained results of the optimization process, as well as the displacement speed limitations of the hydraulic actuators, at the same time as fulfilling the two remaining hypotheses, reducing the time of the highway section test and to ensure a cycle with the smallest possible duration.

Initially, a cycle in which the actuators move in pairs on the same axle of the vehicle is implemented. This cycle is based on the cylinders positions obtained previously and will allow obtaining maximum ascent speed and descent speed of wheels of 42 mm/s and 33 mm/s respectively. These speeds are the maximum that allow the actuators to follow the input signal, once it have been regulated by a PID controller.

The maximum velocity of displacement in the horizontal cylinder is 30mm/s, which is determined by the most restrictive speed, which is the backward movement of the hydraulic actuator.

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Starting from the knowledge that highway driving do not usually generate structural damages, a combination of two unfavourable conditions has been considered for the highway profile developed: a very short duration and an uneven highway section profile.

With these hypotheses, it has been developed a highway section profile that reproduces the passing of the vehicle through three consecutive potholes in 10 seconds. It has been considered a pothole depth of 35 mm. Although a pothole of these characteristics is unlikely on a highway, it is considered a serious risk when travelling at high speeds.

V. INNOVATIVE FATIGUE TEST PROFILE FOR THREE AXLE SEMITRAILER

The innovative profile developed, showed in fig 2, displays a total duration of 70 seconds and it can be divided into two phases. The first corresponds to a section of 58 seconds which represents the developed critical manoeuvre, which is the cause of the failure through fatigue of the structural components of the semitrailer chassis structure. The test phase of 12 seconds after the critical manoeuvre, corresponds to a section of travelling on a highway, which structurally does not affect the vehicle, but can produce the failure through fatigue of auxiliary components in a semi-trailer.

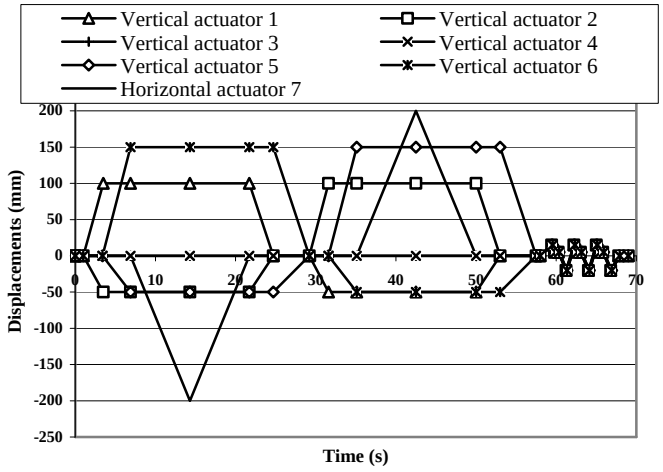

Figure 2. Innovative fatigue test profile for three axle semi-trailers.

VI. CONCLUSIONS

This paper shows the process developed in the optimization of a fatigue tests profile for three axle semi-trailers, which is able to generate the maximum torsion in the vehicle without the sliding of the wheels. The duration of the cycle is the least possible, limited by the maximum speeds of displacements of the hydraulic actuators.

The designed profile permits reducing the duration of the fatigue test from several years to three months, with a considerable cost reduction of tests in comparison with the present techniques of circuit testing.

At present LECITRAILER S.A. company uses the innovative profile developed by VEHIVIAL group of the University of Zaragoza, in the fatigue analysis of its prototypes.

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