

A new weigh-in-motion and traffic monitoring system

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Abstract

The new weigh-in-motion (WIM) system, presented in this paper, is able to give not only the load, but also an extension of the information supplied by traditional WIM technology, such as dimensions of the tire footprint. It has a smaller cross section in comparison with those of load cells and a better endurance comparing with piezoelectric sensors. The results obtained by Finite Elements Analysis (FEA) have been checked by calibration test, performed on a spring/elastic element made by aluminum alloy.

Key Words: weigh-in-motion system, elastic element, strain gauges, design, FEA

1. Introduction

Weigh-in-Motion is a major tool used to collect traffic data. WIM is described as “the process of measuring the dynamic tire forces of a moving vehicle and estimating the corresponding tire loads of the static vehicle” in the standard specification [1]. There are intrusive devices, because they are embedded into the roadway. High-speed WIM systems collect continuous data that can be used for statistical purposes, while minimizing traffic disturbance. WIMs typically accompany double inductive loop detectors to collect the data set [2]. Although static and portable scales have a better accuracy [3], WIM systems are very important topics with important benefits in traffic monitoring [4]: reduction of accident frequency rates, reduction of pavement damages, reduction of noxious emission and fuel consumption, etc. Truck weight data is important for pavement management because especially heavy trucks deteriorate the pavement. An approximation derived from extensive tests conducted in the 1950's suggests that pavement damage increases exponentially with axle weight to a power of four – the so called “fourth power” rule. An obvious disadvantage of this too restrictive approximation is: it doesn't take account of some important parameters as temperature of the road, the contents of moisture in soil, the dimensions and area of the tire footprint, the contact pressure between tire and road etc. Trucks carrying legal weight loads over weakened surfaces (in the time of spring, when the soil has too much water) do the damages of the roads too.

Today, the most used commercial WIM systems are: bending plates, load cells and piezoelectric sensors [5 – 7]. Designers from many countries are working now

at the WIM devices of a new generation, with better performances and able to give more parameters such as the tire footprint dimensions.

2. Objectives

The new WIM measuring system presented in this paper try to demonstrate the possibility to obtain more information using a smaller cross-section area. The target of the project is to design and to test a WIM device with the following parameters:

- Good accuracy,
- Smaller cross section area,
- Smaller initial installation cost,
- Capacity to give some additional data as dimensions of the footprint of the tire, identification of the type of tire wheel (single tire wheel or twin wheels),
- Capacity to detect under-inflated tires,
- Better endurance.

3. Description

In order to have accuracy as good as possible, the solution based on strain gauges was adopted. The idea is to use a *sensitive carpet* of small transducers (working in compression or bending, for example), put in a matrix network. A bigger number of transducers will give a bigger volume of data (about tire print, pressure distribution between the tire and the road etc.). The actual WIM systems can't supply this important information. The new WIM design is presented in the following pictures. The solution with some leaf spring/elastic elements (Figure 1), mounted on the base plate, was adopted and the sensor has a comb shape (Figure 2). This new design ensures a smaller cross section of the strain gauged transducer.

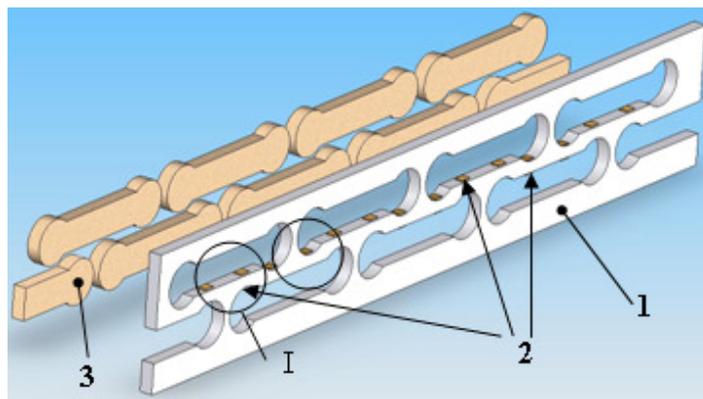


Figure 1. WIM principle: 1 - spring element; 2 - strain gauges; 3 - soft foam.
I - seven full bridges (inside of circles etc.)

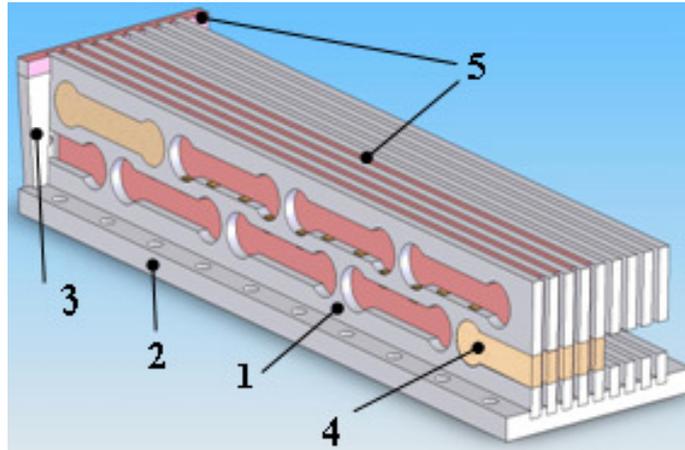


Figure 2. WIM system (without three sides of the box): 1 - spring element, 2 - basic plate; 3 - lateral plate; 4 - soft foam; 5 – rubber

4. Methodology

The stresses and strains in any elastic element were studied using the Finite Elements Analysis (FEA). Seven groups of four strain gauges, glued on the spring element, will be mounted in a full Wheatstone bridge (Figure 1). The positions of strain gauges on the spring element were also determined using FEA data, using the *Abaqus* software (Figure 3). The mesh has 166,232 finite elements (Hex type). Every elastic element is loaded with 2 MPa load on the top and embedded into the bottom part. Using FEA, the full bridges outputs have been simulated (Figure 4), tacking account of the integration tendency of the strain gauges. The spring element cavities, with the strain gauges mounted inside, are filled with soft foam. A model of the elastic element, made by aluminum alloy, has been realized and all strain gauges have been glued on it (see Figure 1). It was loaded with known weights, applied in every section of the seven full bridges. Although the real spring element will be made by stainless steel, aluminum alloy has been preferred for this test, in order to apply smaller forces.

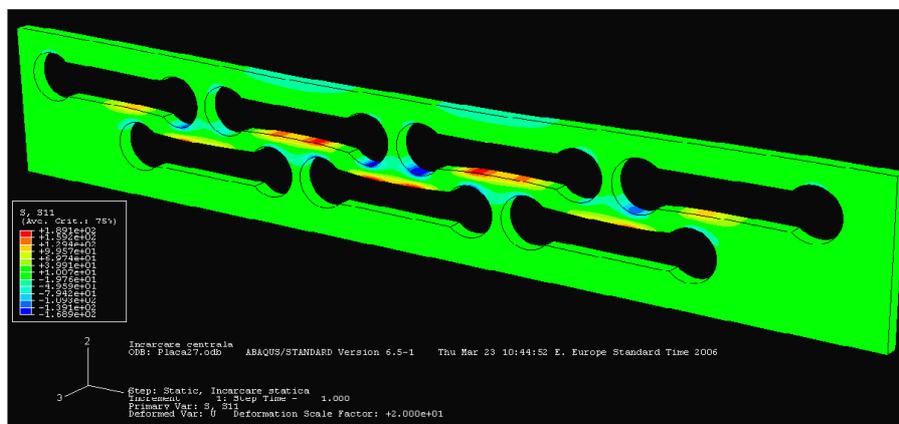


Figure 3. Normal stress σ_{11} distribution in the spring element (simulation by FEA)

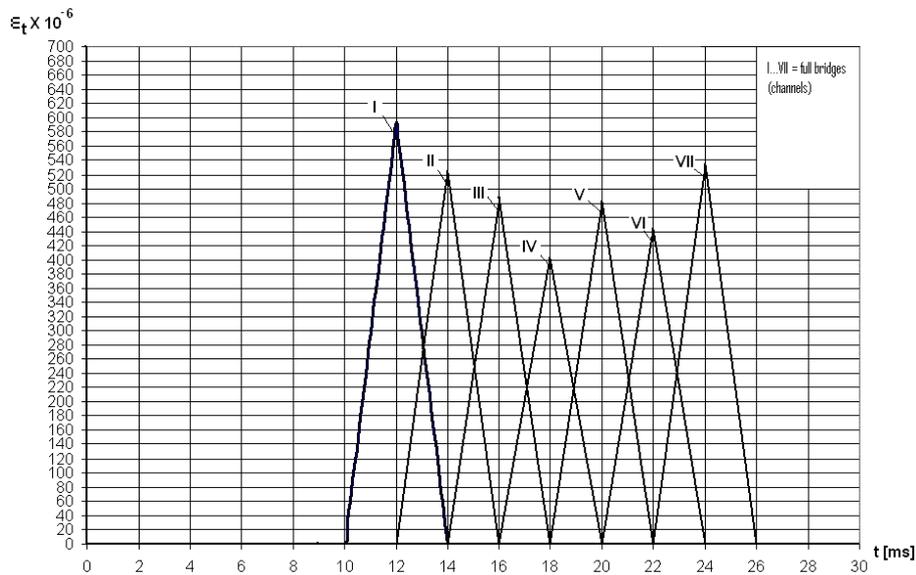


Figure 4. The output signals of the seven full bridges mounted on a spring element, traversed by a load of 2 MPa, with 60 km/h speed (FEA simulation)

The target of the test was to check the results obtained by FEA and the linearity of the calibration procedure. Figure 5 presents the calibration diagram. One can see that all ten points are on the same line, confirming the predictions made using FEA. The calibration line does not traverse exactly the zero point, but one can do the corrections using the above-mentioned diagram.

In Figure 6, a line of WIM devices mounted into the road is presented. When this line is traversed by a tire, all seven full Wheatstone bridges mounted on loaded spring elements will produce output signals. Knowing the simulation by FEA (see Figure 4) and calibration diagrams, we can have information about the tire load and length of tire footprint. The number of loaded spring elements gives information about the width of tire footprint.

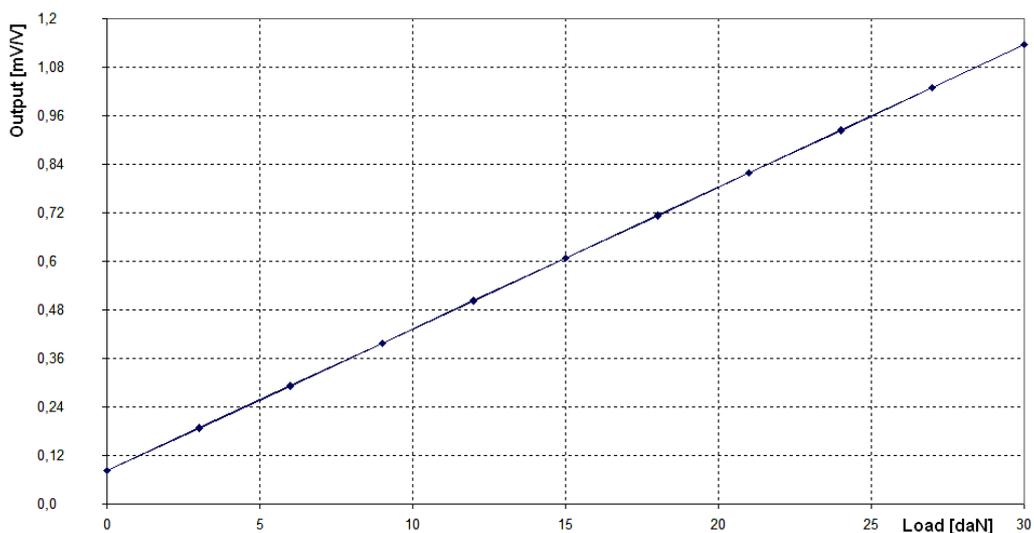


Figure 5. Calibration diagram: the full bridge output versus load

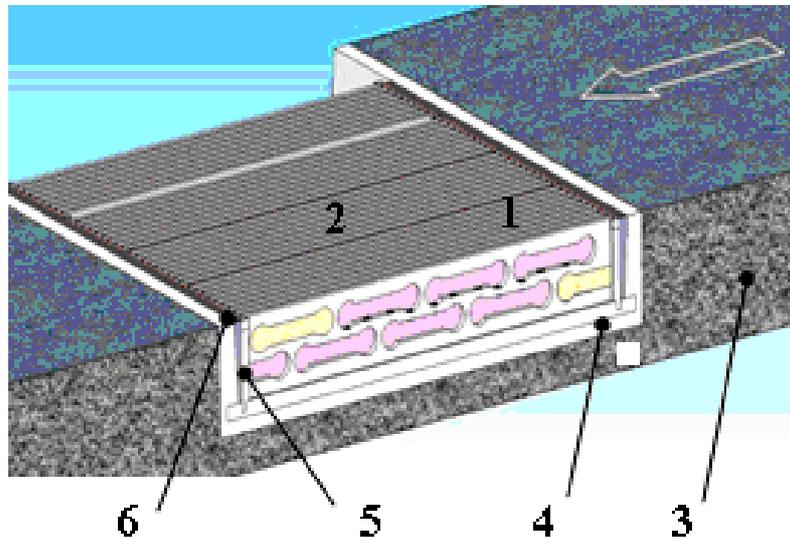


Figure 6. WIM devices embedded in a roadway: 1 - first WIM device; 2 - second WIM device etc. 3 - road; 4 - sand/epoxy; 5 - lateral plate; 6 - rubber layer

5. Conclusions

1. The new WIM system presented in this paper gives an extension of the information supplied by traditional WIM technology, as the tire footprint dimensions (length and width). It has a smaller cross section in comparison with the actual sensing devices realized with strain gauges technique (single load cell and bending plate, respectively) and, hopefully, a better endurance (comparing with piezoelectric sensors);

2. A model of the spring element, made by aluminum alloy, has been realized and loaded with known weights. The calibration tests are in good agreement with the predictions made using FEA. Calibration diagrams (full bridge output versus applied load) prove a satisfactory linearity.

3. Design and simulation of the new WIM measuring device, traversed by a load of 2 MPa with 60 km/h speed, have been achieved by FEA. The authors hope the design of the new WIM system will determine also an improvement of accuracy, in comparison with the actual sensors.

Acknowledgements

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