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A Fast and Economical Method to Measure Force Distribution over Radial Tires by Means of Optical Vision

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ABSTRACT: *For educational purposes, it is very important for the students of engineering to understand how external forces are distributed along a radial tire. This paper presents a novel and cheap device that, by the use of a simple vision system made with an economic webcam, a handmade metallic box and homemade simple software, measures and shows how a force is distributed along the length and wide of the reposed surface of the tire over a rigid floor. The 2D and 3D design of the device, a simulation of its functionality and the results of force distribution obtained by the application of the device are presented in this work. For industrial matters, a more detailed device, based on this idea, would be a very interested purpose of a non-invasive method for studying force distribution on tires.*
KEYWORDS: *radial tires, deformation measurements, novel device.*

I. INTRODUCTION

An area of continuous interest within automotive engineering and the tire industry is the analysis, modeling and design of tires subject to a large variety of general loading conditions, it is implied that the model will reliably predict both the global and local response of the tire under these loading conditions. Over the time, a different amount of models have been proposed with a serial number of problems and limitations. The simplest of the proposed models consists of joining two concentric elastic rings by numerous springs and dampers; this model predicts only some particular behavior but presents difficulties in determining the equivalent material properties. Another model is the two-dimensional axisymmetric finite element which is incapable of representing the anisotropy of the tire in the circumferential direction and is also restricted to axisymmetric loading conditions. For the comprehension of how the loading conditions affect directly over a tire, there are some professional equipment that, due to their cost, could be impossible to arise and get used for an engineering student. Compering to other optical measurements done by the authors [1-4], this paper presents a novel and economic idea of a device that allows us the study of how a load is distributed along the wide and length of the reposed surface tire over a rigid floor.

II. THEORETICAL DESCRIPTION

To analyze the resulted force and momentum components that act over the tire, as a result of their interaction with the rigid floor, there have been defined by the Society of Automotive Engineersthe x, y and z axis to be used in a 3D graph shown in figure 1.

The x-axis is the intersection of the medium plane of the tire and the plane of the rolling surface. The positive direction coincides with the movement of the vehicle. The z-axis is perpendicular to the plane of the rolling surface and its positive direction coincides with the resistance force of the floor. The y-axis is perpendicular to the x-and z-axis.

The origin of the system is found in the center of the contact of the tire over the rigid floor. The flexibility of the tire is the cause of the deformation with the contact rigid floor, when a force in the origin to z-axis direction exists; this force generated a distributed system of forces along the wide and length of the tire reposed over the floor. This allows doing a pressure measurement in different contact points. Figure 1 shows a pressure distribution along the x, y and z axis.

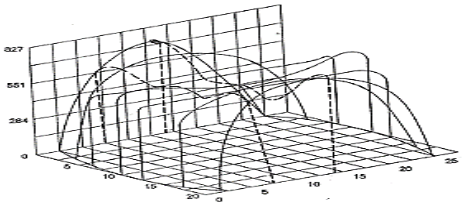


Figure 1. Pressure distribution along the wide and length of the tire reposed over a rigid floor.
The x-axis shows the contact length (cm), the y-axis shows the contact wide (cm) and the z-axis shows the pressure contact (KPa).

As it is shown in figure 1, the pressure is distributed along the wide and length of the tire surface reposed over a rigid floor, just as is shown in the system of figure 2.

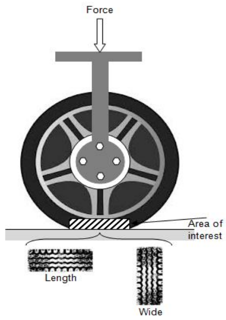


Figure 2. A force is applied to a tire in order to generate a wide and a length deformation.
The area of interest for this work is the surface reposed along a rigid floor.

III. PROPOSED DEVICE

The main objective of this work is to find an easy way to understand and to measure how loading forces deform the wide and length of a tire, in other words, an easy way to measure pressure along the deformed tire due to static loads.

For this purpose, the setup proposed is shown in figure 3.

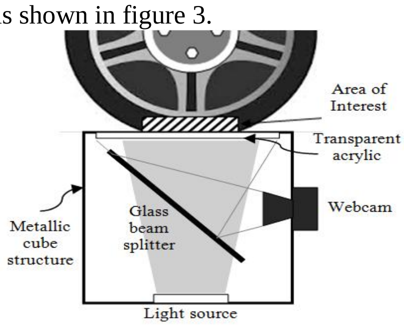


Figure 3. Proposed set up for measuring wide and length deformations over a tire.

A light source illuminates all the time the area of interest. A webcam is placed in order to observe in a computer the whole area of interest. A glass is used as a beam splitter in order to ensure that the complete area of interest is showed in the computer. All the system is enclose by a metallic structure leaving only the superior side uncovered with the objective of placed a transparent acrylic that will allow to the system to do the measurement.

In order to measure the deformation mentioned above, a pattern of ink points, perfectly distributed, is placed over the transparent acrylic, as it is shown in figure 4, on a simulation manner.

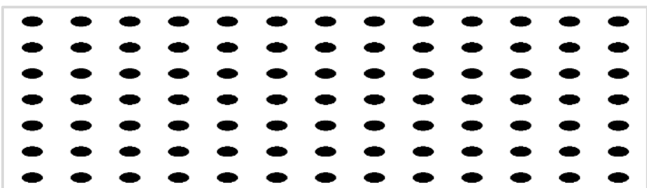


Figure 4. Simulated ink pattern to be deformed by a force applied to the tire.

Suppose, for example, that there is a spherical object reposed over the device surfacemodifying with this the area of the ink point's pattern due to an applied force. Figure 5 shows the supposition.

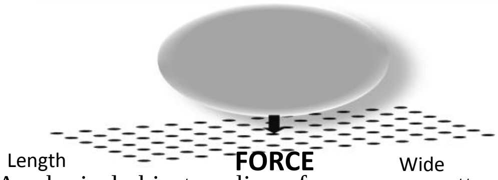


Figure 5. A spherical object applies a force over a pattern of ink points

Once the force is applied, the ink will change its size and shape, this chance or deformation can be understand as the deformation in different points of the surface reposed over the rigid floor, as shown in figure 6.

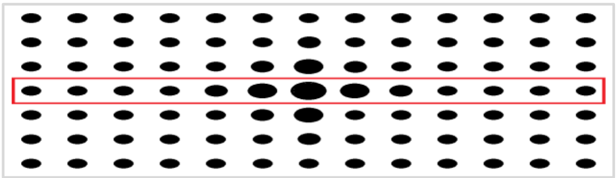


Figure 6. Deformation of the area of some of the ink points due to the applied force.

Selecting a horizontal line, as it is shown in figure 6, it could be possible to plot the subtraction of areas of the points before and after deformation, showed in figure 7.

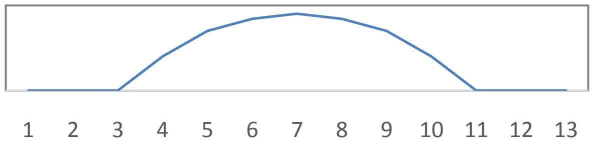


Figure 7. Deformation over the ink pattern as a result of applying a force over it. This profile can be approximated to a function in order to quantify the measurement. X-axis is the position on the area detected (meters) and y-axis represents the deformation.

As it is seen in figure 7, the plotted deformation can be approximated to a second order function.
All over each of these points can also be calculated the presents due to the applied force and the deformed area, getting a multisensory device.

IV. RESULTS

In figure 8 there is shown the pattern that has been used in the experiment. There are 9 horizontal lines and 22 vertical lines of ink points.

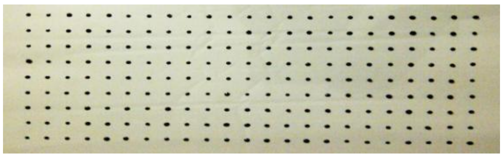


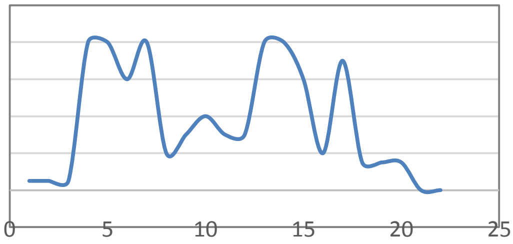
Figure 8. Ink pattern applied in the experiment.

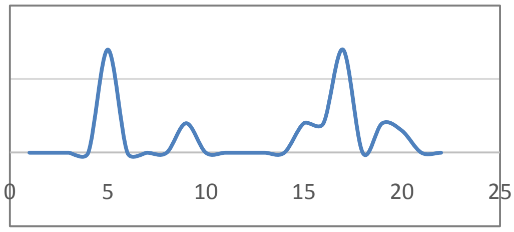
This pattern is placed between the acrylic and the tire in order to measure the deformation applied to the tire due to a force and pressure.

After the application of the force, the pattern is deformed in some points, which are the contact points between the tire and the surface (Figure 9)

Figure 9. Ink pattern after force application over the tire. Only some of the points of the pattern are deformed, these points are in contact with the surface and the tire.

Selecting, for example, line 1 and line 6 (coming from the top of the pattern), the resulted plotted is shown in figure 10.





(a) (b)

Figure 10. Profiles of the deformation of the tire surface under force conditions. a) for line 1, b) for line 6. x-axis is the position of the point, y-axis is the deformation of the point that can be written also as a pressure

It can be seen as the technique of ink pattern matrix proves to be useful for the purposes sought in the study of the behavior of the pressure distribution in the contact area between the tire and a rigid surface, and hence an understanding factors influencing the vehicle dynamics. The distribution of forces in the plane of the contact surface is closer to the theoretical reference. However, this results useful for academic understanding and design of these components.

V. CONCLUSIONS

Making measurements of deformation over tires due to the application of forces can be easily done. In this paper we show an economic and simple device that can be developed in order to understand how the load is distributed. The ink pattern used in this paper can be perfectly calculated in order to cover as much as the possible area of interest. For academic purposes, this project can be very efficient.

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