SENSIBILITY ANALISYS OF A BICYLE PEDAL PLATFORM TO USE IN BIOMECHANICS

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Abstract. *The subject of this study is analyzed a pedal force platform behavior during the change of the values of four variables, it was numerical simulation using a finite element method software. A parametric model was developed to numerical simulation using finite element method where twenty eight different geometric models are simulate and analyses using strain graphics on selected regions to defined the final form platform.*

***Keywords**: Biomechanics, force platform, pedal force*

1. INTRODUCTION

Biomechanics of human movement can be defined as the interdiscipline which describes, analyzes and assesses human movement (Winter, 1991). In order to obtain quantitative measures of the forces associated with a wide variety of activities, the force platforms have been developed to quantify the forces in gait and human locomotion studies, time motion studies for industrial activities, development of prosthetic devices, military applications, human rehabilitation research, sports activities, and motor skills testing (Ramey, 1975). To measure a force it is necessary to obtain its magnitude in an indirect manner by observing the response of some device to the presence of the force. To indicate the magnitude of the imposed force, the force platform has sensing elements a measure of the force being applied. The sensing element is chosen such that the force acting of the element is directly proportional to the displacement of the element. The most versatile and widely used system of force measurement in force plate design is the electric resistance strain gage where the electric resistance is proportional to the deformation. The force platform takes a wide variety of shapes depending on the use, desired sensitivity, and dynamics characteristics (Nabinger, 1997).

The force applied on pedal by cyclist can be represented by force components in a triaxial coordinate system and respective moments. (Fig. 1).

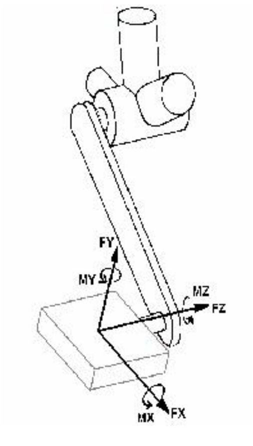

Figure 1. Coordinate system force and moments on pedal bicycle.

Force platforms can be classified by sensor type using to measure, the piezoelectric sensors and strain gauges sensors are more used. Forces platforms that using sensors type strain gauges present a low cost manufacture, but needs a complex geometry for decoupling forces. These platforms present a low rigid and can present crosstalk, when have interference between applied forces and measure forces and was based in Roesler and Fonseca (1998). Forces platforms using strain gauges are based on beam flexion, there are many designs of force platforms developed and used in biomechanics (Winter, 1991).

This pedal platform design not presents a final interference, it was verifying theoretically the decoupling and the crosstalk was reduced putting the sensors in the ideal position in the platform, the correct position of sensors in Wheatstone bridge and by software using a calibration matrix. (Nabinger, 2002)

The platform design has four parts, the first part is the top base for support the bearings and it is connected with central beam, the second part is the four central beam which function is be able measure the lateral force (Fz) and vertical moment (My), the third part is four principal beam force which function is measure the frontal force (Fx), vertical force (Fy), frontal moment (Mx) and lateral moment (Mz). The fourth part is the top base, which connect the four principal beams and fixed shoes on pedal using toe clip.

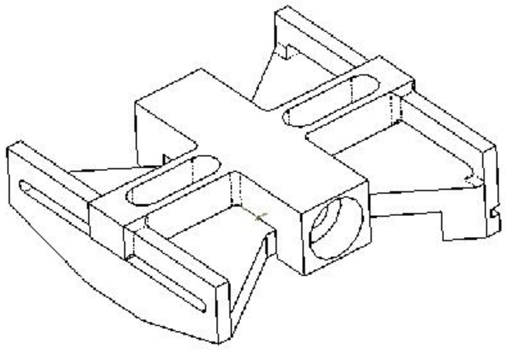

Figure 2 – Platform bottom view, where a) central base, b) top base, c) central beam e d) principal beam.

The platform design has some aspects that one available material, low weight, load capacity, compatible fundamental frequency, commercial fixation system, permit measure pedal angle and crank arm pedal, compatible with normal crank arms, low crosstalk, low costs using the geometrical limits.

To obtain the design pedal platform the maximal load and flexibility are compared with strain data on interests regions where the sensors are applied. The pedal platform has eight instrumented beams. The beam length is limited by platform size and beam section is function of the optimal strain to use sensors. The beam strain is function the load force, force direction, length, section and material.

The load force is applied simultaneous in all directions, an analytical beam model can show the relation between forces (Fx and Fy), cross sections of beam and local strain, illustrated in Fig. 3, this relation is describes in Eq. 1 and Eq. 2.

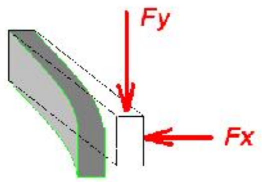

Figure 3. Force applied on bending beam in two directions simultaneous.

$$\varepsilon = \frac{6Fx}{Ebh^2} \tag{1}$$

$$\frac{\varepsilon_y}{\varepsilon_x} = \frac{F_Y}{F_x}\frac{b}{h} \tag{2}$$

The ratio between vertical force and horizontal force is proportional the ratio between beam section (Eq.2). The platforms beams have a restriction and are represented by a structure with two beams with bending restriction (Fig. 4).

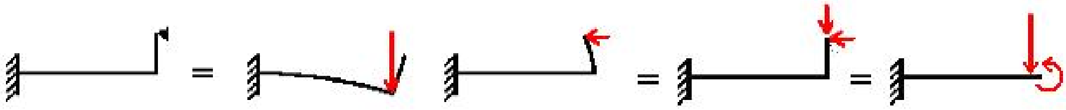

Figure 4. Principal beam model.

$$M_X = Fl - M_A \tag{3}$$

$$M_A = F_Y L_1 - F_{apoio} L_2 \tag{4}$$

$$\theta_B = \frac{FL_1^2}{2EI_1} \tag{5}$$

$$\delta x = sin(\theta)L_2 \tag{6}$$

$$F_{apoio} = \frac{\delta_x 3EI_2}{L_2^3} \tag{7}$$

$$\varepsilon_A = 6\frac{F_y L_1}{Ebh^2}(1 - \frac{3L_1c^3}{2h^3L_2}) \tag{8}$$

For obtain the relation between the beam height and width with the forces (Fx and Fy) and the local deformation (εx and εy) on principal beam, it was use the equation 3 and 4, obtain by the combination of effects of set showed in the Fig. 3 and the Fig. 5 describe the principal beam geometry.

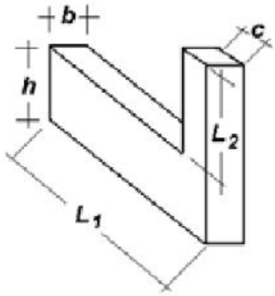

Figure 5. Principal beam model.

The goal of the presents work analyzes of sensibility for defining the ideal dimensions of the tri-dimensional pedal force platform. The parametric study of the force platform allows us to analyze the influence of the geometry and the performance relation, sensibility and dynamic response. Finally are present the conclusions about the force platform performance and advantage this methodology in project the mechanics transducers based in strain gauges.

2. METHODOLOGY

For evaluate a static behavior of the force platform under maximal triaxial loads and the influence of section beams on local strain in selected regions using the finite method element in a parametrical model. The base platform model was design using an analytical model, four design components was selected for change the basic parametrical model in four cases, after analyses the each case the basic parametrical model is changed. The platform has geometric limit defined by 106x95 mm. The maximal forces are 1200 N to vertical force and 600 N to frontal and lateral forces; the ideal strain is 2000 µm/m.

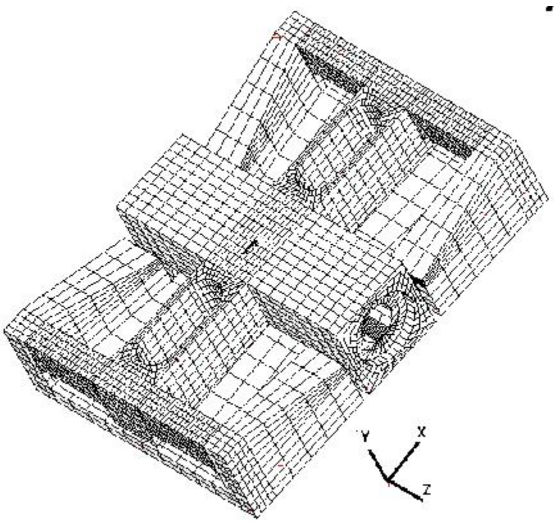

Figure 6. Meshed model using for finite element analysis.

The numerical analysis of strain was use the ANSYS software, with a tri-dimensional parametric model be able different shapes with same numbers of elements and node numbers, because each volume is divided the same form. The model was represented by 12448 elements type SOLID45 (Fig. 4), and each case is applied three loads on different directions.

For analysis tree path on central line of selected surface (c1, d2 and c1) was selected and the results are plotted. The paths are located on top and front of principal beam and top of central beam (Fig. 6a). Four cases to analysis was defined, analyzed and incorporated to the model base. The first case consist in analyze the influence the size of column between top base and principal beam, result the changed the column (c) of base model, the second cases analyze a local strain of principal beam on nine different sections (b1 x h1), result the changed principal beam section, the third cases analyze a local strain of central beam on twelve different sections (b1 x h1), result the changed central beam section and the fourth cases analyze a local strain of central beam on four different central distances (l) (Fig. 6b)

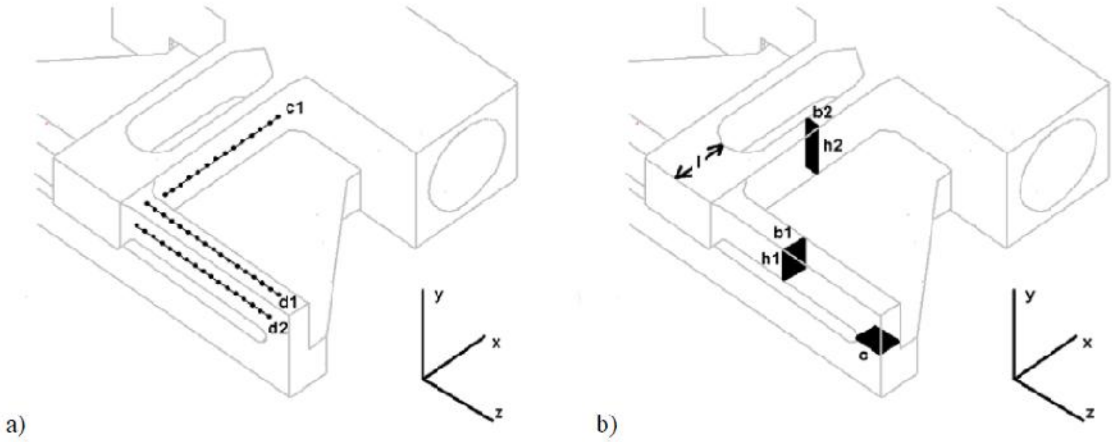

Figure 7. Select regions to analyses and variables regions. a) Tree paths to strain analyze c1 on central beam, d1 on top of principal beam top area and d2 on principal beam frontal area. b) Variables c to section column, b1 and h1 to section principal beam and b2 and h2 to central section and l to central distance.

3. RESULTS

Twenty eight simulations results are showed in four defined cases. Table 1 describes the variables the cases and the simulations.

Table 1 – Tables describe the four cases and twenty eight simulations

	Coluna	**Principal**	**Central**	**Vão**
Case 1	4 5 6	4 x 8	3 x 12	40
Case 2	5	6 x 4 7 x 4 8 x 4 6 x 4.5 7 x 4.5 8 x 4.5 6 x 5 7 x 5 8 x 5	3 x 12	40
Case 3	5	8 x 5	16 x 3 14 x 3 13 x 3 16 x 3.5 14 x 3.5 13 x 3.5 16 x 4 14 x 4 13 x 4 16 x 4.5 14 x 4.5 13 x 4.5	40
Case 4	5	8 x 5	3 x 13	40 30 20 10

The simulations results presented below are strain in the same directions of sensors

CASE 1

Using a basic model, it was analyzed three different column size, the column is localized between top base and principal beam. Using a vertical load it was obtained the strain results on central line of principal beam top area (d1); it is presented in the Fig. 7a.

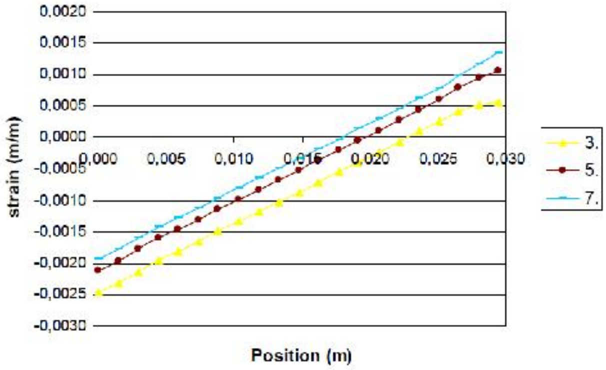

Figure 8. Three strain path results on central line of principal beam top area using vertical load (Fy), using different size of column.

The variation of the size of column influence the strain on principal beam top area (Fig. 8), this modify move the position of null strain on bending. This figure was analyzed and defined this dimension on a new base model.

CASE 2

From the new base model were analyzed nine sections of the principal beam by using a vertical and horizontal load it was obtained the strain on a central line of the principal beam frontal and top area to each load. The variation of principal sections under vertical load (Fy) influence the strain on the principal beam top area (Fig. 9) and the variation of principal sections under frontal load (Fx) influence the strain on the principal beam front area (Fig. 10). Based on Fig. 10 and Fig. 11 was defined the new basic model.

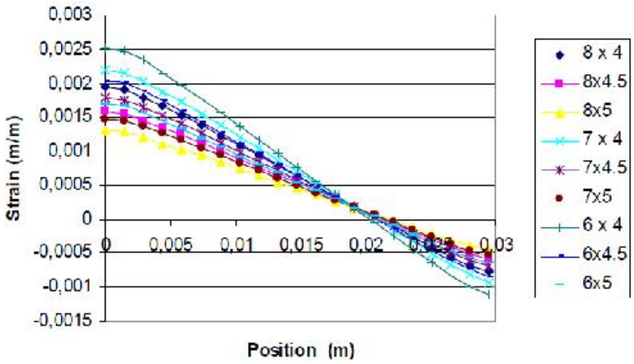

Figure 9. Nine strain path results on central line of front principal beam top area using frontal load (Fx), using different principal beam section size.

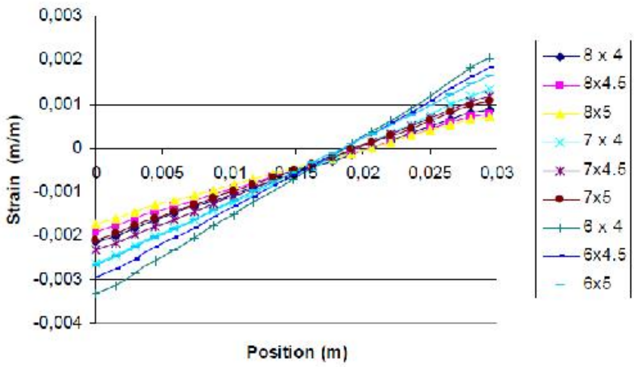

Figure 10. Nine strain results on central line of principal top beam using vertical load (Fy), using different principal beam section size.

CASE 3

From the new base model were analyzed twelve sections of the central beam by using a lateral load (Fx) it was obtained the strain on a central line of central beam lateral area (Fig. 11) and the new base model was defied.

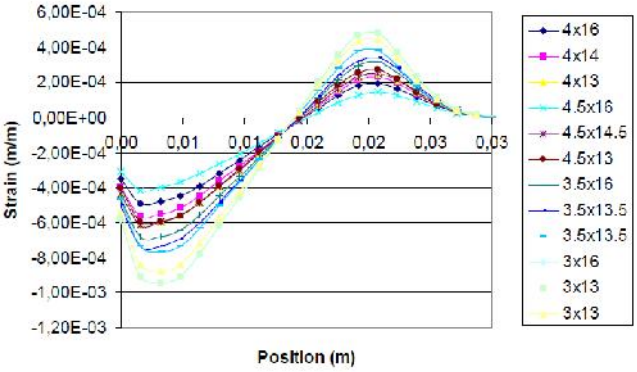

Figure 11. Twelve strain results on central line on central beam top area using lateral load (Fx), using different central beam section size.

CASE 4

From new the base model were analyzed four central distances using a lateral load (Fx) it was obtained the strain on a central line of central beam lateral area (Fig. 12) end defined the final model.

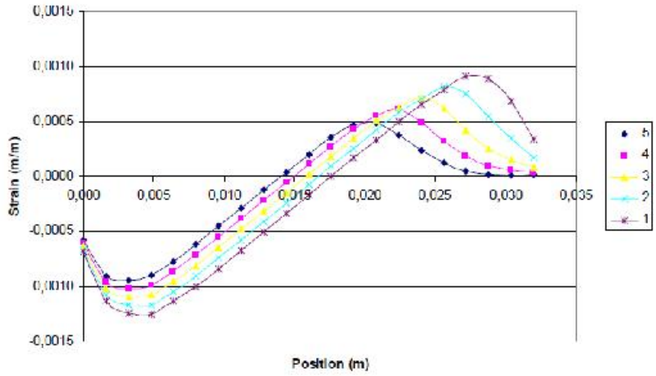

Figure 12. Strain results on central line of lateral area of central beam using lateral load (Fx).

5. CONCLUSIONS

This method of analyze permit verify the sensibility of a complex structure and define the best dimensions of a platform based in beams.

6. REFERENCES

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