Construction of Low Cost Force Plate Instrument for Gait Pattern Analysis

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ABSTRACT:

To analyze the kinematics and kinetics of the different joint many instruments are required, such as force plate. Force plate is used to measure the Ground reaction force which is the force exerted by body over the ground during locomotion. Using inverse dynamics approach we can measure the moment across the joints through the use of ground reaction forces. In the present study we have tried to develop a low cost strain gauge based force plate instrument. We have constructed a force plate of 30 *30 cm size. Four corner of the force plate are suspended through the cantilever. Each cantilever is consisted of two spring blade; one for vertical and another for horizontal force measurement. Strain gauge is attached to spring blade. When spring blade gets deflected, there is a change in the resistance of strain gauge. Change in resistance of strain gauge is measured with the help of Wheatstone bridge. So the output of the Wheatstone bridge is directly proportional to the weight.

Keywords: Gait Analysis, Force plate, Instrumentation, Strain Gauge.

1. INTRODUCTION

Health related problems are one of the most challenging problems to be solved, in which gait related problems are of great importance. Gait is the repetitive sequence of lower limb movement so that a person can walk with minimum energy expenditure [**1**].For proper execution of gait there should be good co-ordination between central nervous system and neuromuscular system. In some pathological condition deviation in gait pattern is found. Gait analysis is the study of locomotion of human. The study includes quantification of measurable parameters of gaits, as well as drawing interpretation about the subject (health, weight, speed, etc.) from his/her gait. According to **Brand et al [2]** Gait analysis is done for two purposes either for clinical research or clinical testing. Clinical research differs from clinical testing because the reason is not to make clinical decisions for the individual patient, but to gather data about a pathological condition affecting a group of individuals . The main aim of most gait analysis is the study of joint kinematics and kinetics; other measurements are electromyography (EMG), oxygen intake and foot pressures **[3, 4, 5]**. For foot pressure measurement either force plate or pressure foot is used, Force plate gives information about ground reaction force **[6]** while pressure foot gives force field distribution of foot. Gait analysis can be used to extract the information about the pathological conditions affecting the pattern of gait. Not only it has application in rehabilitation engineering for new prostheses development but also in the field of biometrics, individual gait information can be used for identifying individuals. In the present study we are trying to make a low cost force plate which is capable of giving information about force field distribution as well as Ground reaction forces. Our cantilever designs are inspired from **Heglund et al [7]** cantilever design.

2. MATERIAL AND METHODS

2.1 Methodology

First of all we have Designed (Shape and Dimension) the Cantilever and Force Plate. Then we have constructed the Cantilever from stainless steel cantilever and constructed the Force plate according to the design, by attaching the one ends of cantilever at force plate surface and other end at fixed base end. Then we attached the strain gauge to cantilever. The cantilever with attached strain gauge acts as sensor. Strain gauge gives signal when undergoes deflection due to load, these signal are then filtered and amplified and then passed to analog to digital converter, which convert the analog signal to digital signal. These digital signal are transferred to PC where further processing of signal will done and then force plate Instrument will be calibrated and standardized [Fig.1].

2.2 Cantilever Design

Design is based on the formula which is used by **Heglund et al [7]** for determining the cantilever dimension

Beam flexure = $\mathbf{S = MC / I}$ ------------ **(1)**

Where
S = Stress on any fiber (N/M$^{2)}$
M = Bending moment (Nm)
C = Distance from the fiber to the neutral axis (m)
I = Moment of Inertia (m^4)

For a cantilever with the load concentrated at the distal end

$\mathbf{I = bh^3 / 12}$-- **(2)**
(Where b = width and h = height)

$\mathbf{C = h/2}$ -- (3)

M = Pl--- **(4)**

(Where p = load and l = length of the beam)

n = b/h Ratio--------------------------------------- (5)

So, By Rearranging equation (1), (2), (3), (4) and (5), we get

h = (6Pl / ns) $^{1/3}$ ----------------- (6)

The **b/h** ratio means **n** should be at least 7 in order to keep the crosstalk between the horizontal and vertical signals to a minimum level.

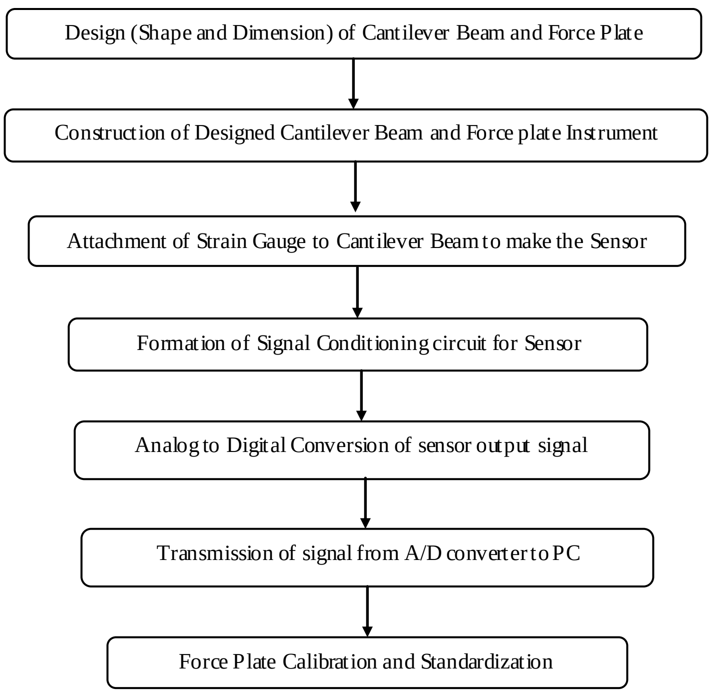


Fig 1: Steps in Force plate Construction

So by using equation (6), we get

h = 3.8 mm,

Where

P_{max} = 980 N (assuming both Subject and suspended plate weight)

l = 5 cm = 0.05 m

n = 10

S = 502 MPa

So

b = nh = 10*3.5 = 35mm = 3.8 cm

So width and height of cantilever is 3.8 cm and 3.8 mm. But we have chosen width and height of 3.5 cm and 3.5 mm according to the availability of stainless steel material **[Fig 2]**.

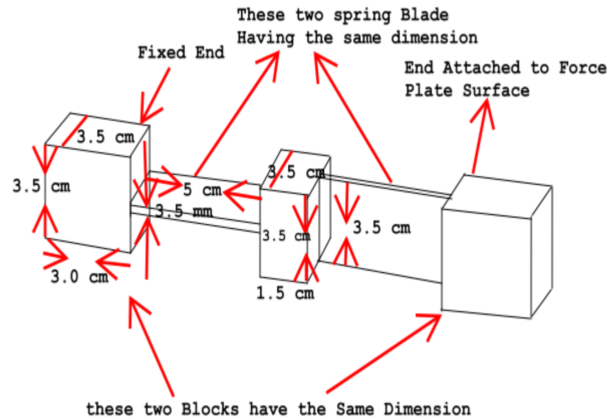


Fig 2: **Cantilever Design and Dimension**

2.3 Cantilever Construction

Steps involved in cantilever construction:

1. Stainless Steel rod and blade was cut into 3.5 cm*3.0 cm, 3.5 cm*1.5 cm and 5 cm*3.5 mm size blocks respectively using power saw machine.

2. Then both were drillerd using drilling machine in workshop.

2.4 Force Plate Design

This design is consisted of a rigid plate surface suspended at 4 points (4 corners) by a transducer element (Fig 3). The transducer element is composed of two strain-gauge instrumented spring blades orientated at 90° to each other; the horizontal blade is sensitive to the vertical force, and the vertical blade is sensitive to the horizontal force. Each spring blade is modeled as if it were two identical cantilevered beams joined at their distal ends.

Fig 3: **Force Plate Design**

2.5 Circuit for Force Plate

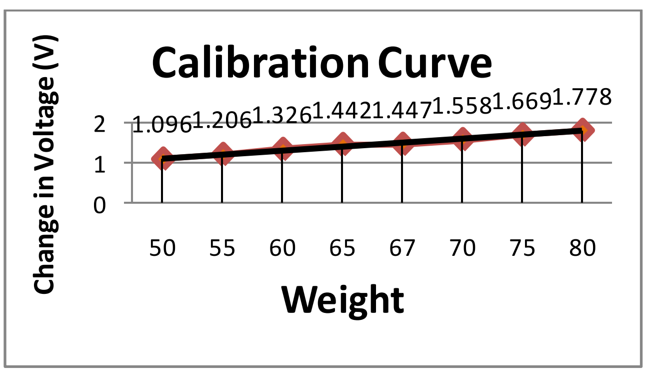
Wheatstone bridge is used for measuring the change in resistance of strain gauge. Four Wheatstone bridge circuit is used for four cantilevers each. Output of each Wheatstone bridge is transferred to separate Instrumentation Amplifier (AD620). Now we have four output signals so we have added these four signals with the help of adder. Output of the adder is the final output.

3. RESULTS

3.1 Calibration Data Table

Subject	Weight	Change in Output (Voltage)	Change in Output per Kg (Vol / Kg)
1	50	1.096	0.022
2	55	1.206	0.022
3	60	1.326	0.022
4	65	1.442	0.022
5	67	1.447	0.022
6	70	1.558	0.022
7	75	1.669	0.022
8	80	1.778	0.022

Table 1: **Output for Different Normal subjects**



$$\text{Slope of the Line} = \frac{(1.778-1.096)}{(80-50)}$$

$$= 0.022733 \text{ V/ Kg}$$

So output voltage per kilogram will be 0.022 and weight required to give an output of change of 1 voltage required 44 kg.

3.2 Output Curve

Force plate output for a 65 kg person (Subject 4 (table 1)) was obtained as below [Fig 4].

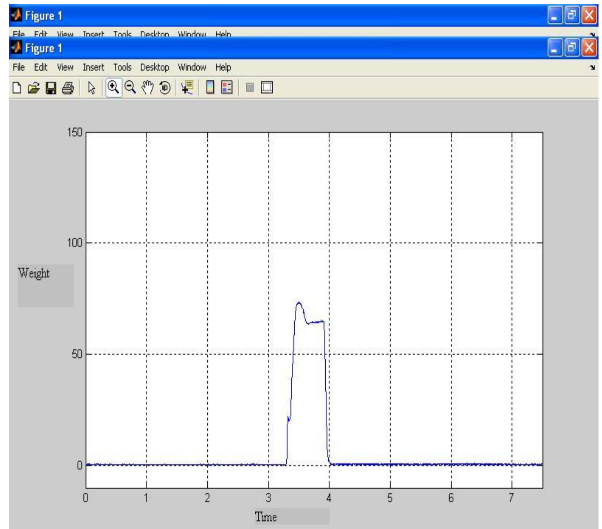


Fig.4

Maximum peak comes at loading of the foot just before mid-stance with a value approximately of 73.5 kg and at toe-off the value is approximately 65 kg, Close to the weight of subject. Our output containing the three peaks which present in the typical force plate output according to literature [29]. where first, referred to as the impact force peak is associated with heel strike. The second, referred to as the loading force peak and corresponds to loading of the foot just before mid-stance and third, referred to as the propulsion force peak, is associated with the Toe-off (push-off).

4. CONCLUSION

The main aim of the present study was to construct a low cost strain gauge based force plate. This study was started because of high cost of the force plates which are available in India. Cantilever were prepared using stainless steel and dimensions are chosen such that it can bear a weight up to 1000 N or 100 kg. After construction of force plate Design we have attached the strain gauge to cantilever and output were measured. we further propose that after some more calibration and addition of strain gauge to horizontal cantilever force sensors the system will be ready for work.

5. REFERENCES

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