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TECHNIQUE FOR PLANTAR PRESSURE MEASUREMENT USING PIEZO CRYSTAL SENSOR

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Abstract

In this paper, the method and the application of plantar pressure measurement technique is investigated. This project came from the objective of designing a suitable foot wear for people who suffer from deformities of foot as well as insensitive foot due to loss of sensation of pain. The various diseases causing abnormal pressure are Rheumatoid Arthritis, Diabetes Mellitus, Halux Valgus, Claw Toes and Leprosy.etc

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Introduction

Deformities which are mainly anatomical as well as that arises due to abnormal pressure distribution in the sole can be satisfactory dealt with by designing the proper foot wear so as to compensate for the deformity. Our motivation is to make foot wear for insensitive foot so that they do not develop deformities due to high pressure. In order to design a proper foot wear we should know a good deal about the pressure distribution beneath the foot.

II. PHYSIOLOGICAL BACKGROUND

Anatomy of Foot

Fig.1.shows foot structure with different bones. The bones of foot consist of Tarsus, Metatarsus and Phalanges. The tarsus (ankle) is the proximal region of the foot and consists of seven tarsal bones. They include:-

(1) Talus-It is the 2nd largest tarsal bone located at the posterior part of the foot. It has a head, a neck and a body with no muscular attachment.

(2) Calcaneus- It is the largest tarsal bone located at the posterior part of the foot. It forms the prominence of the heel.

(3) Cuboid-It is the lateral bone of the distal row of the tarsus.

(4) Navicular-It is boat-shaped, situated on the medial side of the foot.

(5)Cuneiforms-There are three cuneiform bones, medial, intermediate and lateral.

The foot also have arches which help in the transmission of weight. The different types of arches shown in fig are:-

a) Medial Longitudinal Arch

b) Lateral Longitudinal Arch

The structure provides the maintenance of the arch as follows:-

1. Shape of the segments
2. Inter-segment ties
3. Presence of number of segments
4. Suspension of arch from below

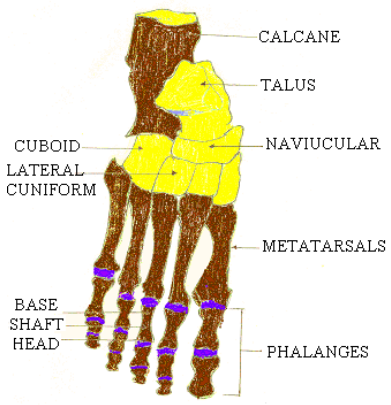

Fig. [1] Bones of Foot

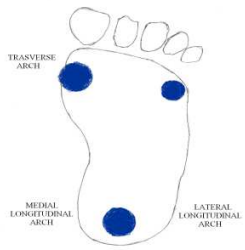

Fig.[2] Medial & Lateral Longitudinal Arches

Standing Foot

The body is supported on two feet whicher together makes dome shaped resilent structure.The muscle are slightly relaxe due to the form of tarsal bone and strength of the ligaments minimizes the call on the muscular activity.The shape of thestanding foot is not suitable for walking and if it is immobilize in this position then needs the help of the artificial rocker.

Walking Foot

During walking the sole is transformed in to a rockre(sole) and a pusher (toes) since the step is completed in less than a second the actual acts can only be observed by high-speed cinematography.The walking pressures pass rapidly acros the sole.After the body has rolled acress the rocker the toes combine for the push off and stable toes prevent the slipping of the footforwards as the body rises on the metatarsal heads at the end of the stride.

The toes perform no function during standing.All principle of the care of limbs with nerve damage apply to leprosy.

Gait Evaluation & Body Weight Transmission

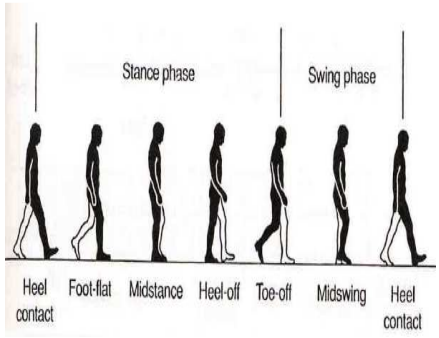

Fig.[3] Gait Analysis

a) Normal Static Pressure

In normal foot the major part of the weight that comes on sole is taken by heel side. During standing the weight of the body is balanced by medial process of tubes calcane, lateral side of the foot and finally by the heads of the metatarsal bones. One study suggested that the loading is equal at forefoot and heel whereas some other found that ratio to be 5:3.

The 1st metatarsal bone bears about 1/3rd of the weight that is transmitted towards the metatarsal while the lateral 4-metatarsal

head bears the remainder of the weight. So the 1st metatarsal bone is heavily built.

B) Normal Dynamic Pressure

Walking is a complex process which is learned the hard way by child between the ages of 1-2 years.

Walking cycle consist of two phases, namely stance phase and swing phase. In Stance phase both feet are on the ground. This occupies about 3/5th of the cycle while in swing phase one foot is off the ground and lasts about 2/5th of the cycle.

On an average a healthy individual takes 50 steps/min. average speed 1m/s for minimum energy expenditure.

When diseases which affects foot is present then this can be revealed only by the abnormal foot pressure distribution during gait.

The heel and mid foot region are in contact with ground for approximately 60% of stance period of the gait while the metatarsal head are in contact with the ground for some 80%pf of the time and the toes for 50% to 55% of time.

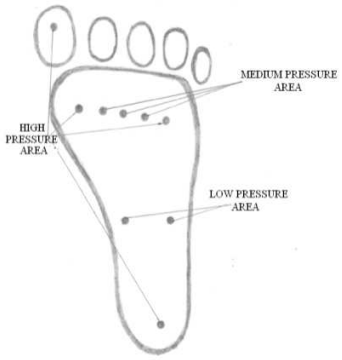

Fig [4] Pressure patterns of foot pressure a various location

III. System Details

A. TransducerDesign

The piezo- crystal transducer is thin, rugged and low cost. It operates with simple and power efficient electronics. The transducer has good linearity since the sensor is insulated with Mayer film it is free from moisture and dust**.**

- Transducer thickness:-0.5cm
- Pressure Sensitivity Range:-500gm to 10Kg
- Device rise time:-1 to 2 msec(mechanical)
- Life time:-10000 actuations
- Pressure Repeatability:-2% to 5% of full scale

Fig.[5] Transducer placement &design

Although pressure are measured in normal range of zero to 800Kpa, transducers are required that can withstand the occasionally high-pressure caused by jumping or stepping on a small object. Hence the only best option was to use a piezo crystal.

Heel :-Center point on heel

Arch1:-First transducer on first arch of foot

Arch2:-Second transducer on second arch of foot

MTH1:-Below first metatarsal head

MTH3:-Below third metatarsal head

MTH5:-Below fifth metatarsal head

FING:- In the center of the head of middle toe

TOE:-In the center of head of great toe

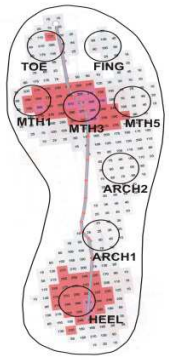

Fig. [6] Transducer Placement

B. System Block Diagram

Fig shows entire block diagram of the system .The first important part is to design appropriate sensors, which can be fixed in shoe sole and which can also sense the pressure applied on it. Here piezo crystal transducer is used for pressure sensing purpose which converts the pressure applied on it in voltage.

The output from transducer is very small, hence it needs to be passed through a stage of buffer amplifier LM 324 which is high impedance quad op-amp.

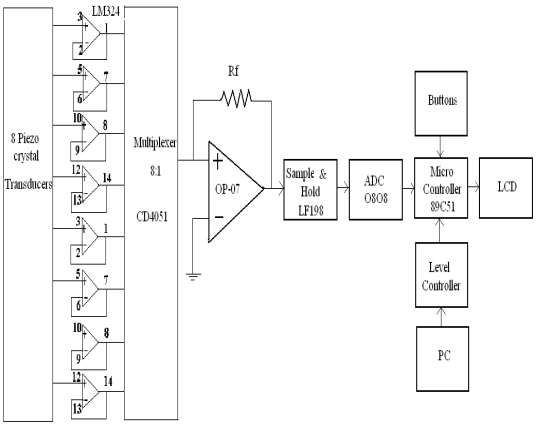

Fig.[7]Block Diagram

The output of buffer is given to eight inputs of the MUX namely 4051,so that one of the input can be selected to measure pressure .The 4051 is a low power CMOS 8:1 multiplexer. It has eight bi-directional analog switches, each with one side connected to an independent Input/Output(X0---X7) and the other side connected to a common Output/Input(X).

With the Enable input (INH) low one of the switches is selected (low impedance, ON states) by the address inputs A,B,C.The output of the multiplexer is given to input of the differential amplifier based on op07 IC the gain is set such that the full span of the A/D converter is used on full load. The output of diffential amplifier is given to sample and hold circuit LF 198 which samples the maximum peak of corresponding output voltage and holds it.

The output from sample and hold circuit is given to ADC 0808 which converts the analog input into digital output to drive microcontroller. The output from ADC 0808 is then applied to eight bit microcontroller 89C51 for further processing. Software program is assembly language is feeded to microcontroller for achieving different tasks.

Testing Procedure

Criteria for Subject Selection

- Criteria for normal control subject selection were no history of diabetes mellitus, ability to walk independently without pain or an assistive device and no history of mental, neurological, or orthopedic problems.

- The inclusion criterion for diabetic patients was diagnosis of diabetes mellitus through regular blood sugar testing and detected diabetic types 1 or 2 under stable metabolic control.

- The DN subjects were included in the study if they were found to be at risk of developing a plantar ulcer due to a loss of protective sensation.
- The presence of diabetic peripheral neuropathy was confirmed using Neuropathy Disability Score (NDS), and if it was greater than 5/10.
- The exclusion criteria for all subjects: muscular/orthopedic problems, inability to ambulate independently, inability to walk without pain and without an assistive device; amputation of the lower-extremity.
- These tests were performed by the medical staff at hospitals and after confirmation of neuropathy; the subjects were accepted for evaluation as diabetic with neuropathy case.

Table1..Piezocrystal response in volts for different pressures

Voltage (Volts)	Pressure (KPa)
0	50
0.34	100
0.43	200
0.64	300
0.76	400
0.886	500
1.23	600
1.36	700
1.44	800
1.71	900
1.92	1000

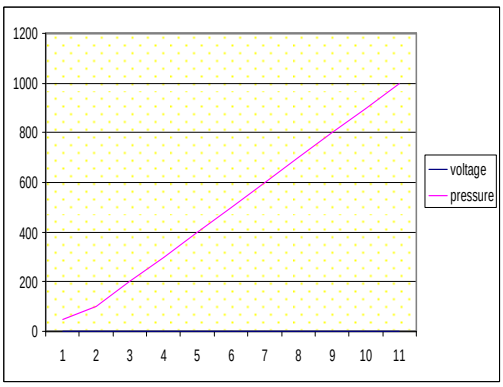

Fig.9 .Piezocrystal response in volts for different pressures

Preamplifier Stage

The purpose of pre amplifier is to set up the power level of the electrical signal given by the transducer prior to subsequent signal manipulation. Here the gain of the

preamplifier I kept at 2. The bandwidth is not very crucial, as the signal measurement is DC .

The slew rate has to be excellent for maximum linearity in measurement. Also the CMRR has to be very high about 90db to reject all the common mode signal Transducer, which produces an output voltage proportional to the measurement variables, require a high impedance amplifier configuration.

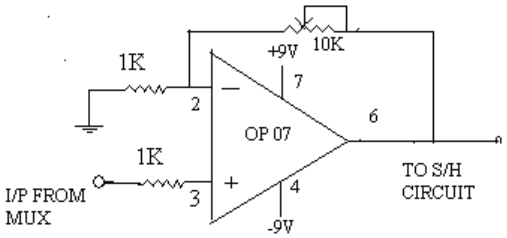

Fig [8] OPAMP design

A BIFET op-amp OP-07 may be used for the above purpose. It has very low input offset voltage 75µV maxi. It has input bias current ±4nA and high open loop gain. It also has a CMRR of 86db and draws about 1.4MA current on no load. It has an input impedance of 10MΩ.

IV. Recording Techniques

As shown in photo picture object is told to wear the shoes in which sensors are placed and related reading were taken.

Fig[9.1] Instrument set up

Fig[9.1] Instrument set up

Results

Table 2.Observations

Press.	Pressure on various heads (kPa/N)		
Heads	N Gp.	D Gp.	RA Gp.
Heel	19.5	22.7	24.3
Arch1	-----	11.9	11.4
Arch2	-----	10.4	11.3
MTH1	17.5	20.1	19.8
MTH3	16.2	17.9	18.2
MTH5	5.5	7.2	6.4

Fing	------	11.1	10.5
Toe	10.9	13.9	14.2
Press. Heads	19.5	22.7	24.3

V. Clinical Application

- Halux valgus is one of the most common deformities of the foot. The maximum loading on the medial four toes are significantly les in patients with a halux valgus. Triple arthrodesis and disease state of venile chronic arthritis, both have same effect on the foot pressure pattern.

The load is shifted towards the heel, without reduced loading particularly under the medical metatarsal region. Using this system it is possible to design proper foot wear which can smoothen out the abnormal pressures arising in the foot.

- Similar to that of the fingers. Toes plays no part in standing and infact are out of contact with the ground in many normal feet. In claw toes the toe power fails and hence the body weight slips forward on metatarsal heads at maximum pressure and they fail to give momentum during the push off.

A slow gait is still possible by a sequence of stumbles over the metatarsal pads. We can design a proper foot wear in case of, claw toes and Leprosy by measuring the pressure distribution under the foot.

- Using this system the development of force plates, accurate measurements of the foot force during walking have become possible.

Using this system it is possible to measure the magnitude of the peak pressures of the people suffering from flatness of foot leprosy.

VI. Conclusion

- The result shows that pressure applied is higher at heel in DN group than N and D groups.
- The pressure applied on mid foot generally MTH1 and MTH5 is higher in case of DN group than N and D groups.
- This indicates that diabetic patients suffering of neuropathy have uncontrolled footfall and hence higher pressure on heel.
- They also spent more time in stance phase to maintain the balance hence applying more pressure on mid-foot and fore-foot.

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