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Shear Force Measured Under Patient's Hip on an Inclined Bed

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Abstract

Shear force is measured under a patient's hip when he is on an inclined bed. To do that, we need to develop an instrument. That means to find a sensor and because it is expected that the shear force is very weak the signal must be amplified so we have to design an amplify, certainly we need a read out unit to indicate the measurement. All these are given in detail in this paper. Through theoretical consideration for a simplified model, a functional relationship between the shear force and the inclined angle of the bed is also obtained. To make it clear the explanation of friction, shear force and shear stress is given in Appendix

Editorial

Patients occasionally required to be on an inclined bed for certain therapy. One easily understandable therapy is to help the blood circulation in the legs and feet. When a patient stays long in a horizontal bed, often will have a muscle clamp in the legs. If the bed can be adjusted to an inclined position the clamp can be stopped. The shear force between his hip and the bed affects strongly how long the patient can stay at that position and is expected to be a function of inclined angle. Shear force is a familiar terminology for mechanical engineers, but it may be not clear to layman outside engineering so a detail explanation is attached in Appendix. Certainly it is good to know exactly the force and the inclined angle how they are correlated. Our project is simply to find that relationship.

There are many different possibilities for the measurement. Search through the literature, we found that the closest paper is done by RHM Goossens, it is entitled "Shear Stress Measured on Three Different Cushioning Materials" [1]. This paper describes the shear stress measured at the patient's hip sitting on an inclined chair for different cushion materials at three different seat angles, 5° forward 5° backward and horizontal. Six sensors were used, but there is no detail about the sensors except the size. The measured results were about 4-7KPa for the shear stress. This is not exactly what we need, however it shows the stress is in very low value and sensors must be thin. Further search we find "Load Cell Assembly" by Kroll et al. [2]. This is a Patient application. It describes the shear stress measured by strain gages. From here we feel that strain gage may be a good candidate for our measurement. Another paper entitled "Plantar Shear Stress Measurements" by Rajalal, Lekkala [3] is a review paper, confirms that strain gage may be used for shear stress measurement.

Our Approach

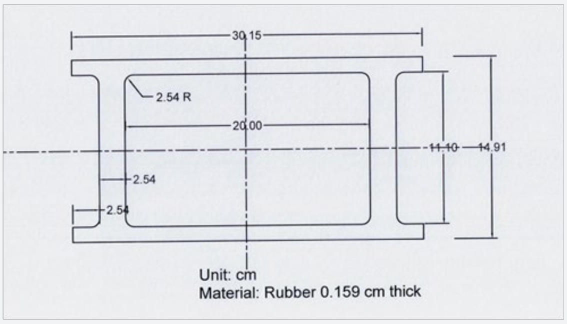

Figure 1: Centre Piece in Sensor Assembly for Mounting Strain Gages.

Since the shear force is based on the friction of patient's hip on an inclined bed, it must be very small or say, it is expected to be a fraction of a kilogram of force. So we choose strain gages to be the sensor, and they are mounted on a piece of rubber with the shape showed in Figure 1. It is known that strain gages are not to be mounted on rubber, it will not stay long. But because other materials will not produce the strain to cause the sensor to react we do not have other choice. The shape is specially designed in this way so that is strain is more in the webs where the strain gages are mounted. Two strain gages are connected in series so it will be more sensitive. This piece of rubber is mounted between two pieces of stainless steel sheet, the top edge is attached to the bottom plate and the bottom edge is attached to the top plate. The stainless steel plates are loosely connected by a screw in the middle so that two plates can be easily moved by the shear force. The whole sensor assembly is 15.24 X 30.48 X 0.476 cm. It is thin enough; it can be buried in the blanket of the bed. The picture of the whole assembly is shown in Figure 2.

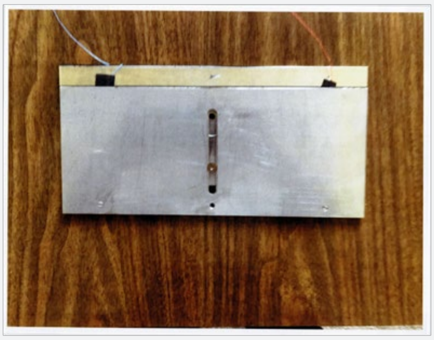

Figure 2: Sensor Assembly.

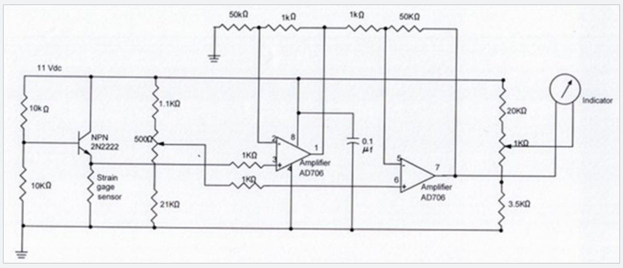

Figure 3: Schematic Diagram for the Amplifier.

Since the shear force is low, the signal in the strain gages is weak; in order to have readable output we must have a good amplifier. A differential amplifier with IC AD706 is chosen for our circuit. The constant current to the strain gages is supplied through an NPN transistor 2N2222. If the whole signal of the strain gage is sent directly to the amplifier, the output will be very high even the amplifier with the limited gain. To solve this problem we build a compensation circuit to balance the dc voltage output from the strain gages. In this way only the increased voltage in the strain gages will be amplified. High gain of 50 is chosen for the amplifier. Because this instrument will not be used constantly, the part for dc voltage measurement in a multi meter is used for the readout unit. The advantage of using a multi meter is that its' sensitivity is automatically built in, the most sensitive position is 0.6 v, next is 3.0v and then 12v. We can easily ship the sensitivity when the output changes. To make the reading stable near the zero, another compensation circuit is built for the zero point adjustment. The whole circuit is shown in Figure 3. The power is supplied from an adjustable voltage AC power supply and rectified by a full wave bridge circuit with a complete filter. The voltage at the input is 11 volts.

The instrument is tested to make it certain that the performance is sensitive and stable. Then we calibrate the instrument. A spring scale is used for the indication of the input force. The calibration results are given in Figure 4.

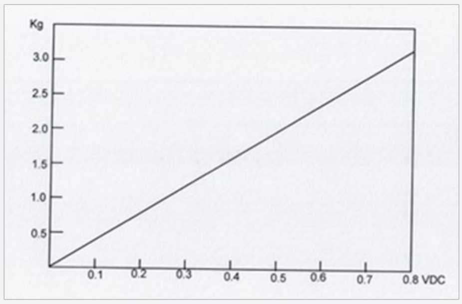

Figure 4: Calibration Line.

Analysis

The analysis done in the following is much simplified from the actual situation. The sensor is placed under the hip of the patient but the patient lying down on an inclined bed, actually is supported by upper body, hip and legs. The model considered here assumes no connection between hip and other parts of the body. Because the forces between hip and other parts are unknown and complicated. This analysis certainly is overly simplified. However if we use three sensors and all three parts of the patient's body are supported by sensors and the results are added together. This analysis may be close to that case.

Consider that the weight of the block is W, the tangential component of the weight is $Wt = W \sin\theta$ and the normal component of the weight is $Wn = \mu W \cos\theta$ acting on the block in tangential direction is

$$F_T = W \sin\theta - \mu W \cos\theta$$

If, $F_T < 0$, the block will not move, if $F_T > 0$ then the block will move down the slope.

$$F_T = \frac{W}{g} a$$

The tangential force acting on the inclined plane (shear force measurement sensor) is

$$F_{shear} = F_f = \mu W \cos\theta$$

To verify the above analysis, we did one measurement with the setup as in Figure 5. A piece of plywood is used for the inclined plane with $\theta = 17^0$, W = 2.73 kg. The shear force sensor is placed directly on the wood then another piece of wood is placed on the sensor and books used as the load, we had reading on the sensor of 0.25 V, from calibration Figure 4, it is found the shear is 0.90 kg. Because $W_t = 0.8kg$ and

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$F_{shear} = 0.9kg$. Hence the block is not moving. Consequently we find the friction coefficient between wood and stainless steel is 0.345.This is a reasonable number.

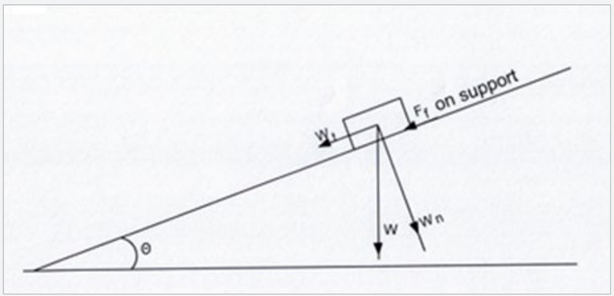

Figure 5: Simplified Model.

Conclusion

Because we have not done actual measurement on patient so this report can be only considered as a progress report. Further research work should be done to make the work complete. However we did one measurement. That means the sensor is working. And from the analysis we find that the functional relation for the shear force on the support is.

$$F_{shear} = F_f = \mu \cos\theta$$

This relationship should be fairly accurate. Further experiment can only prove it will not change it. This is our conclusion.

Appendix

Friction, Shear Force, and Shear Stress

Friction is the resistance that is encountered when two solid surfaces slide or tend to slide over each other. The friction force is known equals the normal force between the surfaces times the friction coefficient. When the surfaces are sliding the friction is smaller than that at stationary, because moving friction coefficient is smaller than static friction coefficient.

Shear force is a force that acts parallel or tangential to the surface. So friction is the shear force. When the shear force is divided by the area the force applied, it is called shear stress.

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