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PORTABLE WEIGHT MEASURING DEVICE USING HALL EFFECT

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Abstract – The pavement of new way for the application of Hall Effect sensor to enter into weight measurements. This can be achieved by the usage of Helical Compression Spring which carries the load carrying board. Neodymium magnet is attached to the lower part of the load carrying board. When the load is applied on the load carrying board, the helical compression spring deflects. So, due to deflection of the spring, magnet attached to the load carrying board moves towards the Hall Effect sensor which remains static at the lower part of the setup. So, due to hall effect phenomena, hall voltage will be generated proportional to load applied. Finally, the load applied will be predicted. The output (load applied) can be seen in Mobile or laptop or LCD display.
Keywords – Hall Effect sensor, Hall Effect, Neodymium magnet, load carrying board.

I.INTRODUCTION

In order to calculate the weight of an object or body, devices such as Weighing scale, mechanical balances and Strain gauge load cells are used. Each of the above works in its own principle but the ultimate aim is to measure the weight of the body.Weighing scales or weigh scales are devices to measure weight. Spring balances or spring scales calculate weight that is the product of mass into gravity (9.807 m/s2) on the force on a spring. Some of them can be calibrated to read in units of force (weight) such as Newton (N) instead of units of mass such as kilograms. The conventional weight measuring devices can measure any type of the load with huge parts involvement but measures accurately. Since huge parts are in involvement which makes the device huge in size and cost. This will also make the portability if the weight measuring device to be low. The weight measured will be displayed in the device which cannot be viewed through any other external source or user-friendly source.This paper discusses about a weight measuring device using Hall Effect sensor which makes the weight measuring system at a low cost and high portability than the conventional one. Since there is no application of Hall Effect sensor in weight measurement, it is adaptable to any range of weight just by varying the stiffness of the spring depending upon the desired load applied as the load applied is completely depends on the deflection of the spring. So, helical compression spring plays a very important role in Hall Effect sensor-based Weight measurement.

II.RELATED WORKS

An entirely new system [1] for measuring forces using a gyroscope (called Gyroscopic Weight Measuring Device, or simply “GWMD”) which provides precise direct digital output proportional to the single axis weight applied on it. The action of the GWMD is inherently linear, hysteresis, and drift free.For the direct measurement of the atomic weight of a multi-isotopic sample can be done by a device [2] which has been done by the modification of a magnetic deflection mass spectrometer. Also, for measuring the weight of the vehicle-weight sensor [3] has been used which works by the normal conventional method which deflects the sensor surface and produces an output. The concept deals with the modeling of sensitivity of epitaxial graphene Hall bars, from sub-micrometer to micrometer size, to the stray field generated by a magnetic microbead[4]. Then, a comprehensive numerical analysis is performed to investigate signal detriment caused by sensor material heterogeneities, saturation of bead magnetization at high fields, increment of bead distance from sensor surface, and device width increase. The modern weight measuring instrument named “Portable Weight Measuring Instrument” [5]. The approach towards Portable Weight Measuring Instrument displays the weight of grains as well as price of the selected grain, regardless of this it is made compact and light in weight (portable). These advantages of our system provide time saving and smart work. It is cheaper than other heavy electronic weighing machines. There is compact and lightweight Arduino family board “Arduino pro mini” is used which has capability to store data and to perform the logic operations. The data is of price of different types of grains that can be stored in EEPROM. There is also a design and development of an instrument for non-destructive fabric grams per square metre (GSM) measurement [6]. This uses the capacitance principle to obtain the fabric GSM. The relative permittivity of the sample fabrics changes the capacitance value. A relationship between capacitance and GSM that best fits the look-up table is obtained. Also, the developed system is applicable for all kind of fabrics both knitted and woven fabrics.

III.PROPOSED WORK AND PARTS DESCRIPTION

The figure-1 explains about the fabrication work of Portable weight measuring device using Hall effect comprises of all parts involved in the device such as Helical Compression Springs, Hall Effect sensor, Load carrying Board,Cover walls.

A. Hall Effect Sensor

Hall Effect sensor [7] is fixed at a certain distance (within the range) from the load carrying board which is carried by the helical compression springs. The sensor [8] should be fixed in such a manner that the centre axis of the sensor should coincides with centre axis of the magnet

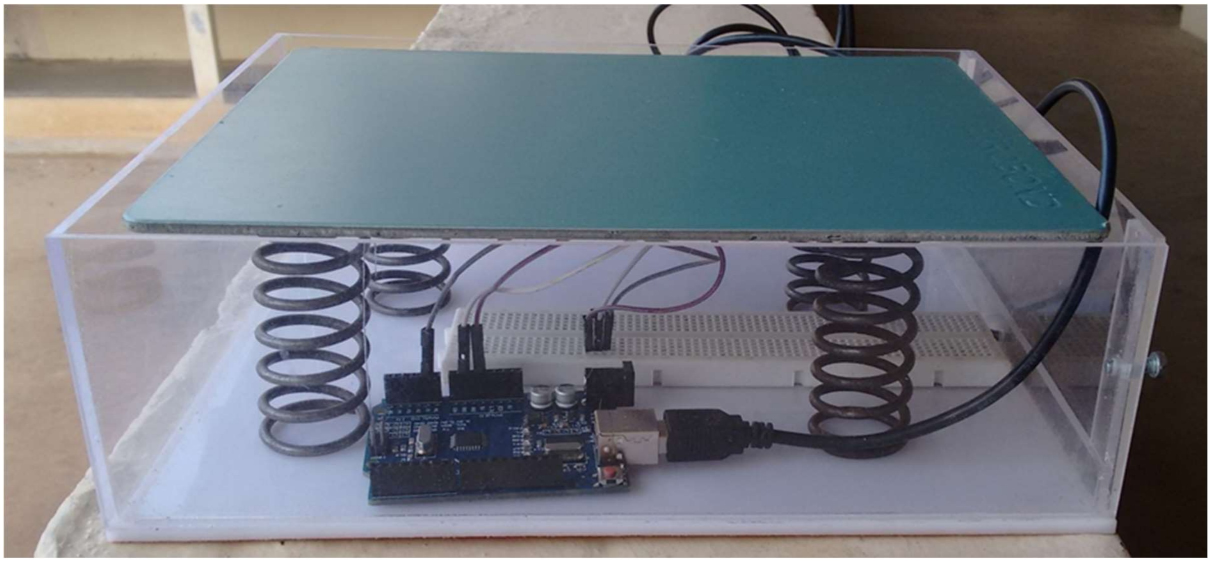

Fig. 1 Fabrication of Portable Weight measuring Device using Hall Effect

(neodymium magnet) which is placed below the load carrying board. As the deflection of spring occurs, magnet attached with load carrying board moves,so its effect should be caught by the sensor. Hall effect sensor should be designed in rectangular shape and various analysis for geometries[9] has been made.

B.Neodymium Magnet

Neodymium magnet is chosen for the reason that the magnetic field strength will be more as compared to other magnets and it is readily available in the market. The effect needed to produce the output signal from the sensor is higher enough when this magnet is used. This magnet will be placed on the bottom side of the load carrying board. Also, this magnet is of circular cross section as shown in figure 2.

Fig. 2 Load carrying Board with Neodymium magnet

C.Load Carrying Board

Fig.3 Load carrying Board

Load carrying Board as shown in figure 3 plays a vital role in this device. As the name implies the load which is to be estimated will acts only on this board and is made of Aluminium alloy to withstand the enough load. The load applied on the board will be directly acting on the helical compression springs since springs are employed here to carry the load and to make the deflection action. The centre axis of the load carrying board consists of Neodymium magnet.

D.Helical Compression Springs

Helical Compression springs are used to withstand the load and show the proportional deflection to the load applied on the load carrying board. There will be four helical compression springs which will be placed at the exact corners of the load carrying board as shown in figure 4. As the load is applied, the load carrying board distributes the load to the helical compression springs so that the spring deflects so the board which carries magnet moves towards the hall effect sensor probe and produces a corresponding output signal.

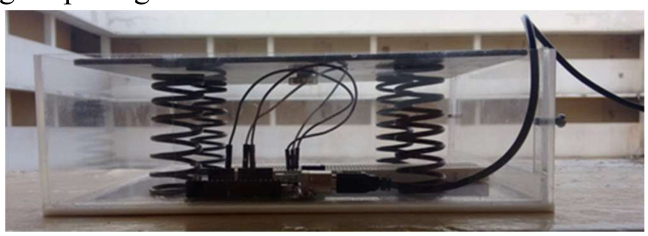

Fig.4 Helical Compression springs carries load carrying board

E.DC Supply Battery

DC Supply battery should be used because variation in the current or voltage will proportionally affects the output, hence input (current or voltage) supply should be maintained constant. So, DC supply battery which is readily available in the market can be used

F.Arduino

In this device, Arduino [5] acts as a processor or processing system. This will helps to display the output signal of the sensor by the processing of the data obtained from the sensor. This can be done by fed a desired Arduino program using the software. This also helps to display the output in variable forms depending upon the user criteria. The output can be seen in laptop, LCD display (special program is to be fed) or in mobile by connecting Bluetooth of the mobile to (attached) Bluetooth module.

G.Arduino Program Concept

Arduino program is framed in such a way that certain experimentations have been made and electromotive force generated for the standard weight applied on the load carrying board is noted down. After the results of various trails, the average of the outputs obtained from the various experimentations or trials needed to be take down into account and programme frame is to be done. For example, when one kg standard weight is applied on the board, the proportional electromotive force (emf) will be generated, but the output obtained for various trials for this one kg will not be same, so all the outputs are noted and lower limit and upper limit are obtained and fed into a program. Similarly, same process is to be done for all standard weights depending upon the range of the device.

H.Cover Walls

Cover walls are just outer surfaces of the device which acts as a boundary layer just by separating the device from the surrounding. The material used for Cover walls is made of Plastic sheets except the bottom side of the device because the bottom side material is of acrylics to withstand the entire load acting on the device. One side of the cover wall is not permanently fixed but it is temporarily fixed by the incorporation of screw.

I. Clearance Spaces

Clearance spaces will be present between the cover wall and load carrying board. These spaces are set for the reason that before the application of the load, air will be present entirely below the board and bottom surface of the device. When the load is suddenly applied, air below the board gets compressed as there is no way to escape from the device since it is completely rigid. As compression takes place, pressure of the air gets increased, at the same time, temperature of the air which is in contact with the magnetic field transmission gets increased, finally affected. Ultimately, the rise in temperature of the air will affect the Hall Effect sensor output signal which results the incorrect output of the load applied.

IV. DETAILED DESCRIPTION

Hall Effect sensor is attached to breadboard, the input and output connections to the sensor are given by the Arduino for which bread board acts as an intermediator between them. They consume only 6 pins of the breadboard. The power input to the Hall Effect sensor is given by Arduino which consumes power from the laptop as it is connected via USB port to laptop. This act as a lower part of the system. There will be four helical compression springs to carry the load and makes the deflection action. For carrying the load, Load carrying board will be there. This board will be placed on the four helical compression springs. The neodymium magnet is placed at the lower part of the board. The magnet should be placed in such a way that the central axis of Hall Effect sensor and magnet should coincide with each other. When the load is applied on the load carrying board, the board which is carried by the springs deflect and magnet moves toward the Hall Effect sensor. As the result of Hall Effect, the electrons flowing through the current carrying conductor deflects which result in generation of hall voltage. The hall voltage will be generated as an output of Hall Effect sensor. This will be displayed in the laptop. The generated hall voltage will be proportional to the load applied on the load carrying board. To convert the hall voltage to Load applied, calibrations are made depending upon the various iterations.There will be also clearance spaces present around the load carrying board. These clearances are mainly meant for removal of the air which is present below the load carrying board. Normally, there will be presence of air in the device. When the load is applied, the air gets compressed which tends to increase in pressure which makes the temperature to increase. So, increase in temperature, changes the magnetic field which results in the fault load applied data. In order to remove this error, clearance spaces are made on the device which helps to escape of air from the system when the load is applied. The clearance space will be more in vertical region than in horizontal region because of the fact that when this device is used for application say in hospitals to predict the weight of the patient. When he/she applies the load and if there is presence if clearance space in the horizontal region same as vertical region, there is a chance of leg finger to be exposed into that clearance space. So, considering the safety factors, we have made the horizontal space region smaller than the vertical region which is sufficient enough to remove air from the system.Also, there will be removal of one part of the support wall in order to correct the alignment of sensor and magnet if there is any misalignment. This is the important feature because as springs and load carrying board are permanently fixed, there is no chance of correct the misalignment occurred below the load carrying region say Breadboard, Hall Effect sensor and Arduino. The support wall can be removed by removing four screws and can be attached by tightening four screws.The output of the Hall Effect sensor can be viewed by either in LCD display or in mobile or in Laptop. The LCD display based output can be done by inserting the corresponding program into the Arduino. The mobile or laptop based output can be attained by connecting the USB port of Arduino through the cable to their mobile or laptop. Also, wireless mode also possible by connecting the Wi-Fi module and inserting the corresponding program to the UNO Arduino, this is also possible.

V. CALCULATIONS

The calculations were made for the spring with an assumption that load acting on the centre of the load carrying board using PSG Design Data Book.

A.Maximum Load Capacity (W_{max}):

Maximum load = 80 kg = 80 x 9.81 = 784.8 N
4 springs can withstand maximum load = 80 kg
1 spring can withstand maximum load = 80/4 = 20kg
= 20 x 9.81= 196.2 N
Maximum load bearing capacity (W_{max}) = 196.2 N

B. Free length of the spring (L_f):

Since, Sensing distance of Hall Effect sensor = 9.5 cm
Considering factor of safety = 7 cm
So, Free length of the spring (L_f) = 7 cm = 70 mm

C.Mean Diameter of the spring(D):

$$Lf/D < 3$$
$$Lf/3 < D$$
$$70/3 > D$$
$$D = 23.33 \text{ mm}$$

Considering Factor of safety , D = 28 mm
Mean Diameter of the spring (D) = 28mm

D. Diameter of the wire (d):

For MS, ι = 400-800 MPa
ι_{avg} = 600 MPa = 600 N/mm^2
Assuming Wahl Stress factor lies between 1.1 to 1.6,therefore, Wahl Stress Factor = 1.3

$$\iota = \frac{Wah\ \ stress\,factor\,x\,8PD}{\pi d^3}$$

$$600 = \frac{1.3\,x\,8\,x\,196.2\,x\,28}{\pi d^3}$$

$$d^3 = \frac{57133.44}{600\pi}$$

$$d = 3.12 \text{ mm}$$

Mean diameter of the wire , d = 3 mm

E. Spring Index (c):

We know that, $c = \frac{D}{d}$

$$c = \frac{28}{3}$$

Spring index, $c = 9.33$

F. Deflection of the spring (y):

$$y = \frac{8PD^3n}{Gd^4}$$

For MS, G = 78 GPa = 78 x 10^3 N/mm^2

$$y = \frac{8 \text{ x } 196.2 \text{ x } 28^3 \text{x } 8}{78 \text{ x } 10^3 \text{ x } 3^4}$$

$$= \frac{275646873.6}{6318000} = 4.629$$

$$y = 4.629 \text{ mm}$$

G. Spring rate or Stiffness (q):

$$q = \frac{Gd^4}{8D^3n}$$

$$= \frac{78 \ x \ 10^3 \ x \ 3^4}{8 \ x \ 28^3 x \ 8}$$

$$= \frac{6318 \ x \ 10^3}{1404928}$$

$$q = 4.497 \text{ N/mm}^2$$

H. Pitch (p):

Assume n = 8, $L_f = n \ p$

$$70 = 8 \ p$$

$$p = \frac{70}{8}$$

$$p = 8.75 \text{ mm}$$

I. Resilience (R):

$$U = \frac{Py}{2}$$

$$U = \frac{196.2 \text{ x } 43.629}{2}$$

$$= \frac{8560.0098}{2}$$

$$= 4280 \text{ N-mm.}$$

$$U = 43.629 \text{ kgf -cm}$$

J. Solid length (L_s):

$$L_s = n \ d$$

$$= 8 \text{ x } 3$$

$$= 24 \text{ mm}$$

Solid length, $L_s = 24$ mm

VI.MATHEMATICAL MODEL

$$\frac{dx}{dt} = \frac{d\emptyset}{dt} = e$$

where, $\frac{dx}{dt}$ = rate of change of displacement in helical spring.

$\frac{d\emptyset}{dt}$ = rate of change of magnetic flux generated form magnet.

e = Hall voltage generated in millivolts.

The emf generated will be directly proportional to the weight of the component or load applied.

$$e \propto W$$
$$W = a.e$$

where, e = Hall voltage generated by Hall effect sensor.

W= Weight of the component

a = constant of proportionality.

VII.OUTPUT VARIATIONS

Output variations will be there due to current supply, change in temperature and sensitivity of the Hall Effect sensor[10]. As said before, constant current supply should be given with voltage regulator.The sensitivity of conventional Hall Effect sensors is strongly limited by the well-known short-circuit effect [11]. To reduce offset and noise, a new shape of integrated horizontal Hall Effect device is presented. The reduction of "length to width ratio" is the new shape proposed and also results in reduction of sensor's average resistance. By doing so, error occurrence can be reduced which ultimately results to closeness to the accurate value. The sensors are made in such a way that it should not change the output signal due to temperature difference, the magnetism is being affected [12] so high temperature withstanding sensor is to be made [13].

VIII. RESULTS AND DISCUSSION

Thus, outputs obtained from sensor output signal reveals that the portable weight measuring device will practically works on and cost efficient and portable behaviour is achieved.

IX. CONCLUSION

Thus, Portable weight measuring device paved the way for new application of Hall Effect sensor and output display method of this device can be in any form which increases the user friendliness of the device. Highly flexible, cost efficient and less weight. Also, Power consumption of the device is very low say 5V only which is sufficient to do all the required process or operation and do not need any external source to support the system. As the entire device is made of plastic sheets and acrylics which paved the characteristic called Portability-Highly portable. Easy instalment and no need of any special Knowledge except Arduino programming.Load bearing capacity and sensitiveness of the device can be increased by changing the stiffness of the Helical Compression Spring.

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