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Design and Analysis of LPG Weighing Machine for Household Application

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Abstract

Nowadays in India, everyone have Liquid Petroleum Gas (LPG) cylinders, which are used for cooking, heating, etc. LPG cylinder is made of low cast steel, which has more weight and it is difficult to handle by a person. LPG is filled with high pressure in the cylinder. The user cannot predict how much LPG left inside cylinder so as to order for a new LPG cylinder. This paper is focusing on developing a weighing machine which will be used to carry the cylinder easily. This will enable the user to know the weight of LPG cylinder consequently the amount of LPG is present inside the cylinder. The customer voice data compiled from the survey and plotted in the quality function deployment (QFD) chart to drive the technical voice. The concept were modeled in Catia V5 R21, Solid works 2015 and rendered in Key shot 5 tools. Final concept has been selected by weighted ranking method.

Next step was to create block diagram of product and understand function of each component and make the interface of component with one another. After understanding the interface between components parts were modelled and assembled in Catia V5 R20 and rendered in Key shot 5 to realize actual product how it looks. Further analyzed each components in Abaqus and results were found to be safe, detail drawings of each part were generated. After that fabricated load cell and tested in NI Lab view 2015, calibrated the load cell and took the results of load cell.

Keywords: *LPG, cylinder weight, QFD.*

INTRODUCTION

India is the third largest consumer of LPG in the world after USA and China. According to the ministry of petroleum and natural gas there are total 17.78 crores domestic LPG connections in the country (as survey on 2016 January making it 715 connections for every 1000 households.

LPG is derived from a group of flammable hydrocarbon gases which are liquefied by pressurization; it is commonly used as fuel. Propane, butane and isobutene are other such gases which fall under LPG label. At relatively low pressure LPG gases compressed, LPG requires storage like container which is generally steel vessel like small gas bottle and large gas cylinders, sometimes larger storage tank. Domestic LPG cylinder made of low cast steel which weighs 29.5 kg out of which weight of LPG is 14.2 kg and empty cylinder weighs 15.3 kg.

LITRAURE SURVEY

Pressure sensor in radio frequency identification (RFID) is used for measurement of gas inside the cylinder. The output is given to PIC controller, where the gas weight is stored. The same is displayed in LCD, which is connected to output of controller. A threshold valve is set in the controller. Once the threshold level is reached, the voltage value is given to alarm, which alarms the user and also given to the auto dialer [1].

Load sensor to monitor the gas level and if the level is below the threshold limit the system informs the user by SMS and also by display. So that user has an idea about maximum time the LPG lasts. An automatically booking of the cylinder using GSM module is also used in this proposed system [2].

Weight sensor to monitor the level of LPG inside the cylinder and calibration purpose used weight sensor with load cell. Gas reaches to 0.5kg the sensor sends the signal to controller to provide refilling of cylinder through GSM. The necessities are shown in display such as leakage of gas detection and booking of cylinder [3].

SURVEY OUTCOMES, PROBLEM DEFINATION AND OBJECTIVES

A. Survey outcomes

A survey was conducted across the five homes; following are some of the outcomes of survey conducted.

- Most of the people uses LPG cylinder.
- It was observed during the survey that people are facing difficulty in handling the cylinder.

- It is difficult even to know th e initial weight of LPG present in the cylinder
- Users find a great difficulty in predicting how much LPG left inside the cylinder at any instant of time.
- Those who are using single cylinder, once it gets emptied they have to wait uncooked till another cylinder is delivered.

B. Problem definition

After observing the importance of LPG in household chores, problems associated with are noted. Handling and carrying the cylinder is one of such problem were user needs to carry the heavy cylinder at the time of delivery. The next problem is associated with weight of the cylinder to be checked at the time of delivery to ensure correct weight along with it tracking of the inner LPG volume while cylinder is in use is also the problem faced by the user.

C. Objectives of the paper

Taking into account the problem definition and survey results the objective of this paper is determined. Following are the key essential points defined below.

- To provide ease handling of cylinder.
- To anticipate the amount of LPG within the cylinder.
- To solve the weight related issues.
- To show the accurate weight of LPG

METHODOLOGY

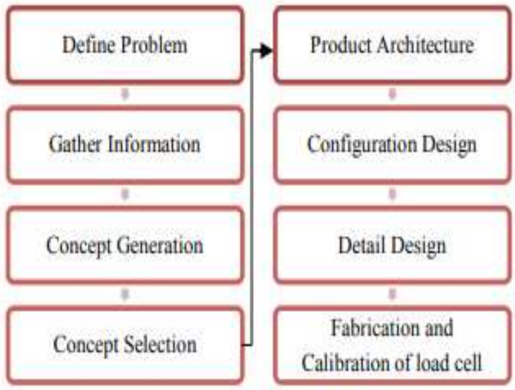

Fig.1. Discrete steps in engineering design process

1) Problem definition

The main aim of this activity is to create a statement that includes what user needs to accomplish to meet the needs of customer.

2) Gather information

Collect the information from the various resources such as internet, literatures and other sources that can be helpful for developing and converting the customer needs into engineering design.

3) Concept generation

Here various concepts are generated by the use of CAD software, and brainstorming.

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The concept can potentially satisfy the problem statement

4) Concept selection to choose potential concept we use Pugh matrix and weighted ranking method.

5) Product architecture to divide the overall design system into subsystem. This helps to physical arrangement of component in order perform their function.

6) Configuration design Modelling and assembly of component and assign the material for the components.

7) Detail design in this stage analysis of component and detail drawings are prepared, and Produce the detailed drawings suitable for manufacturing.

8) Fabrication and testing of the product is carried to check whether it serves the intended function.

QUALITY HOUSE

The customer voice plotted against the technical voice shows that ergonomics, size, and shape are of prime importance in the concept generation.

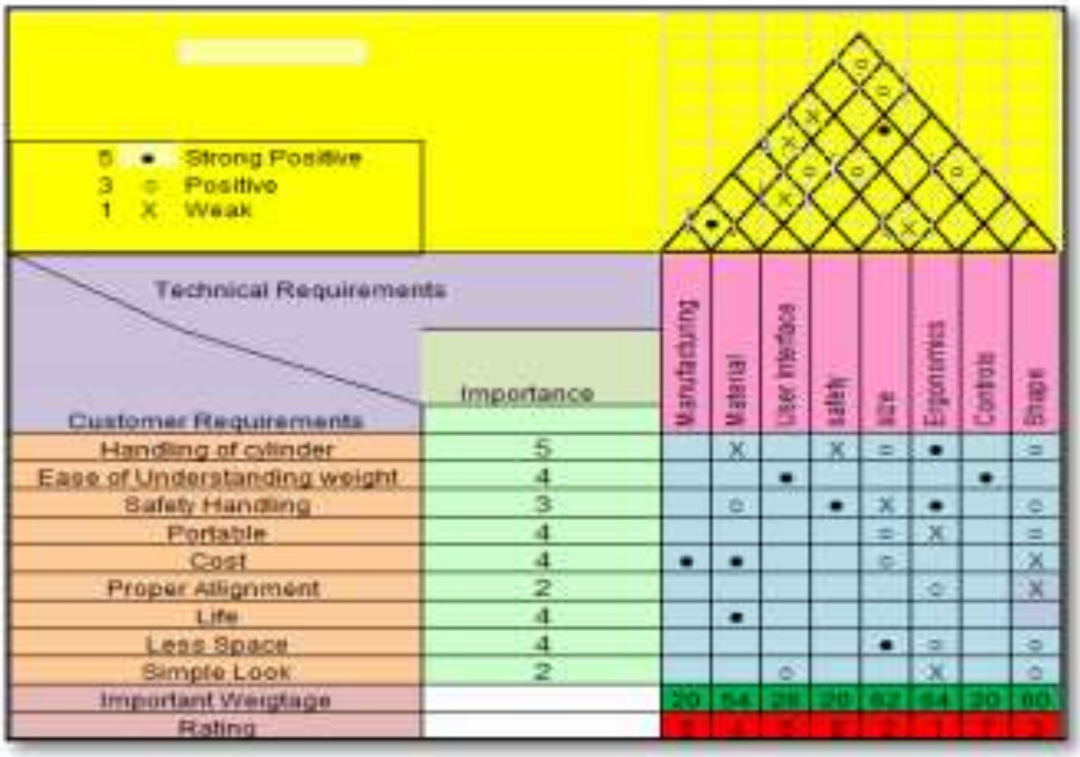

Fig.2. Quality house

CONCEPT GENERATION

Product concept is a brief description of the technology, working method and shape of the product. It is brief information of how the product will satisfy the customer needs. Concept is usually described as a sketch or as a rough three-dimensional model.

1) Lead screw operating system

It consist of two plates, one is fixed in which load cells, wheels are attached to carry out their functions and another plate is movable in which carries the LPG cylinder. Movable plate can be operated by lead screw mechanism. In order to check the weight of cylinder user uses the handle which is connected to the lead screw which rotates and plate linearly move downwards until it is placed over the load cell and show the weight of cylinder. After that it can be moved up using same mechanism.

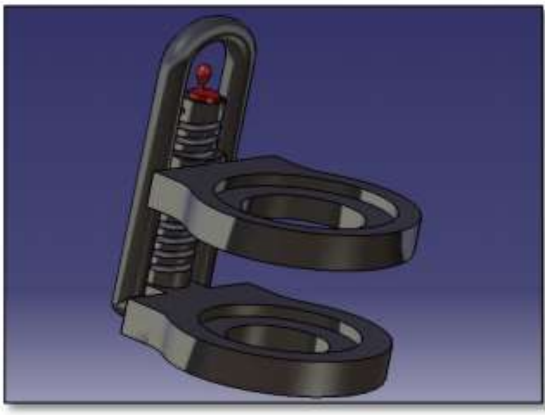

Fig.3. Lead screw operating system

2) Nut and Bolt operating system

This concept is similar to concept 1 but here weighing machine plate is movable, which is operated by the handle as shown in figure. The main reason behind this concept is to reduce the man-effort to operate the system over the concept 1

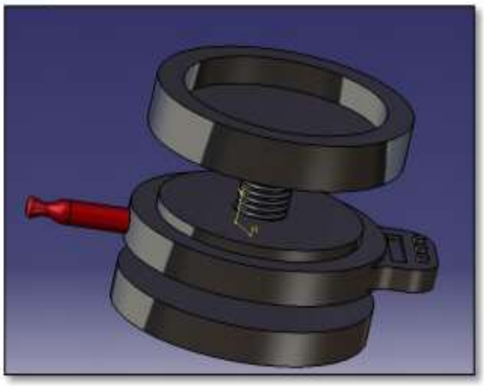

Fig. 4. Nut and Bolt operating system

3) Hydraulic jack Operating system

In this concept operating mechanism is hydraulic system. Cylinder is kept on top plate which is movable and it is supported by hydraulic jack ram as shown in figure 5. Load cell mounted on middle plate. In order to check the weight of the cylinder, release the pressure valve of hydraulic jack ram moves downwards and it placed over load cell which deforms and shows the weight of cylinder after that close the pressure valve and cylinder can be lifted through hydraulic pedal operating system.

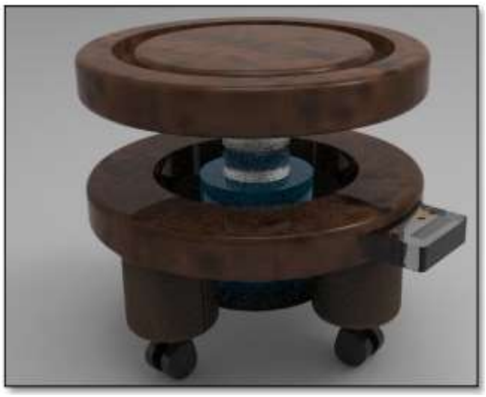

Fig.5. Hydraulic jack Operating system

4) Rack and pinion operating system

In this concept, which consists of two plates which are mounted horizontally, the plates move over one another by the use of rack and pinion mechanism, motor is attached to pinion when motor is turned on which converts rotary motion of pinion to linear motion of rack. Cylinder is placed on middle of the plates in order check weight of cylinder it comes over the load cell and displays the weight of cylinder.

Fig.6. Rack and pinion operating system

CONCEPT SELECTION

Concept selection is process of assessing concepts with respect to customer requirements and other criteria, equate the relative strengths and weakness of the concept, and selection for forthcoming stages. Concept selection method followed by weighted ranking method. A. Weighted ranking method Concept selection has been carried out by weighted ranking method to identify the best concept; in this method selection matrix is prepared which consists of criteria i.e. ease of use, less space, efficiency, accuracy, and etc. These criteria are rated by evaluating against 100%. In each concept there are column provided for giving score against each criteria.

Concepts		Load Screw Operated		Nut Operated		Hydraulic Operated		Rack & pinion Operated	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Ease of Use	9	8	72	8	72	8	72	8	72
Less Space	10	8	80	8	80	8	80	5	50
Cost	12	6	72	6	72	6	72	8	96
Life	15	5	75	7	105	8	120	6	90
Feasibility	5	8	40	6	30	8	40	6	30
Maintainability	6	4	24	6	36	7	42	8	48
Safety	4	7	28	7	28	9	36	6	24
Simple Look	4	7	28	7	28	7	28	5	20
Alignment	4	8	32	8	32	9	36	5	20
Efficiency	15	5	75	6	90	9	135	6	90
Accuracy	12	8	96	4	48	8	96	6	72
Assembly	4	7	28	7	28	9	36	7	28
Total Score		650		645		793		640	
Rank		2		3		1		4	

Figure: 7

From the weighted ranking method as shown in fig.7 concept 3 has been selected which got highest score of 793

BASIC BLOCK DIAGRAM OF LPG WEIGHING MACHINE

Figure 8 shows schematic representation of LPG weighing machine which represents the arrangement of chunks in order, this helps to proceed further with actual design as this building block shows the interface among the component. As shown in figure the bottom plate is moved by the caster wheel assembly, the bottom plate comprises supporting column and bottle jack assembly within itself. Above that the middle plate which carries load cell assembly to measure the force and this plate is supported by supporting column. Carrying plate which holds the LPG cylinder and it is supported by hydraulic jack

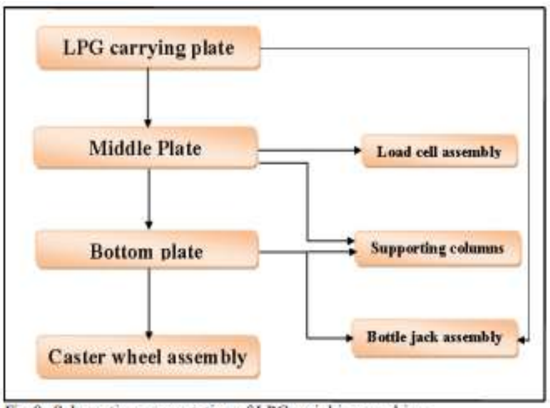

Fig 8. Schematic representation of LPG weighing machine

DETAIL DESIGN

In this stage analysis of components and detail drawings are prepared, and Produce the detailed drawings suitable for manufacturing.

A. Load Cell Calculation

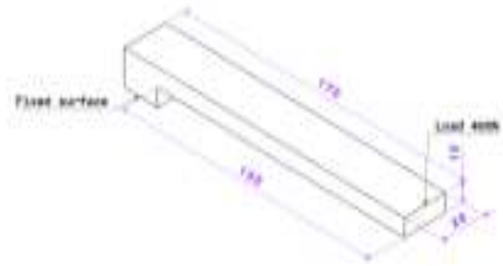

Fig.9. Cantilever beam load cell

Design Specification:

Material: Stainless steel, Young's modulus E: 200 GPA, Length of beam L: 150mm Distance between gauge position & point of load application. Lg = 140 mm, Width of bar B: 25 mm Thickness of bar D: 10mm, Yield strength: 215MPA, Load W: 400N

Moment of Inertia I: bd3 /12

I = 25×103/12

I = 2083.34 mm4

Deflectionδ: WL3/3EI

δ= 392.3×1503/ 3×2×105×2083.34

δ=1.06 mm

S = 60000/416.66

S = 144 N/mm2

At the gauges,

Stress s= S × Lg/L

s = 144 × 140/150

s = 134 N/mm2

Strain ϵ = s/E

Strain ϵ = 0.00067

Stress value is less than yield strength value, hence design is safe. It measures the force up to 0N to 400N.

B. Finite Element Analysis

The design for the components made considering the parameters of LPG cylinder, the unknown parameters are generated after analysis done using Abaqus tool with some trial and error for failure.

a. Load Cell

Boundary condition:

U1=U2=U3=RU1=RU2=RU3=0

Load on surface = 400 N

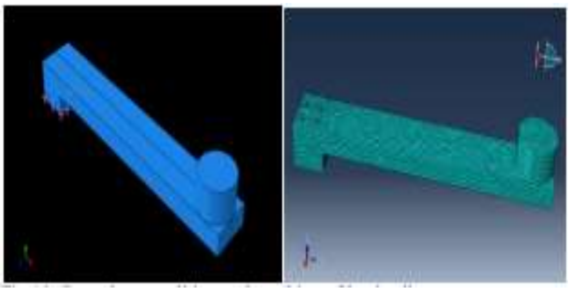

Fig.10. Boundary condition and meshing of load cell

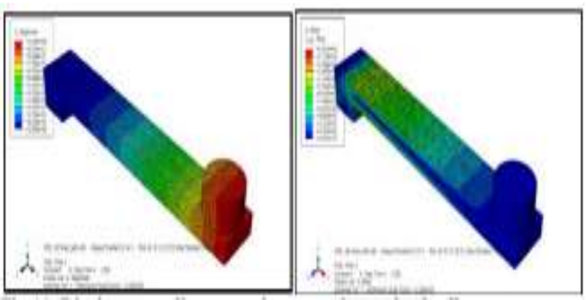

Fig.11. Displacement diagram and stress acting on load cell

RESULT:

Maximum Von Misses stress found in top plate is 187 N/mm2 which is less than yield stress of the material which is 215N/mm2 .So design is considered to be safe with very less deformation of 1.04mm.

b. Top Plate Boundary condition: U1=U2=U3=RU1=RU2=RU3=0 Load = 400 N applied on the top plate surface

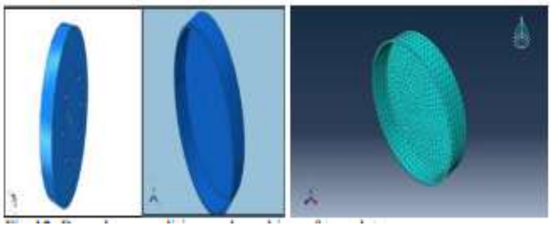

Fig.12. Boundary condition and meshing of top plate

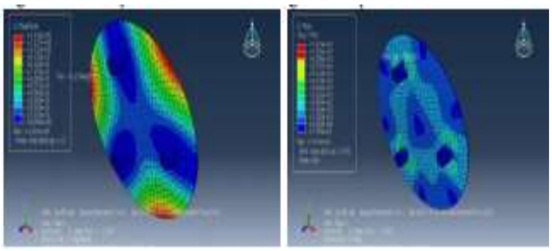

Fig.13. Displacement diagram and stress acting on top plate

RESULT:

Maximum Von Misses stress found in top plate is 84 N/mm2 which is considerably less than yield stress of the material which is 270N/mm2 , so design is considered to be safe with very less deformation of 0.1327mm.

c. Base Plate Boundary condition:

U1=U2=U3=RU1=RU2=RU3=0 Load on surface = 500 N

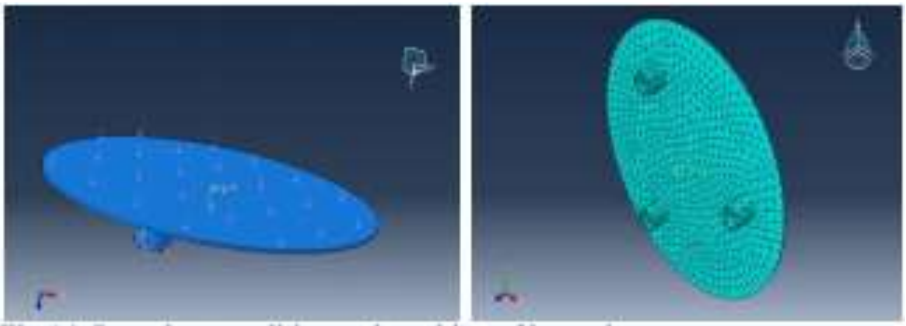

Figure:-14 Boundary condition and meshing of base plate

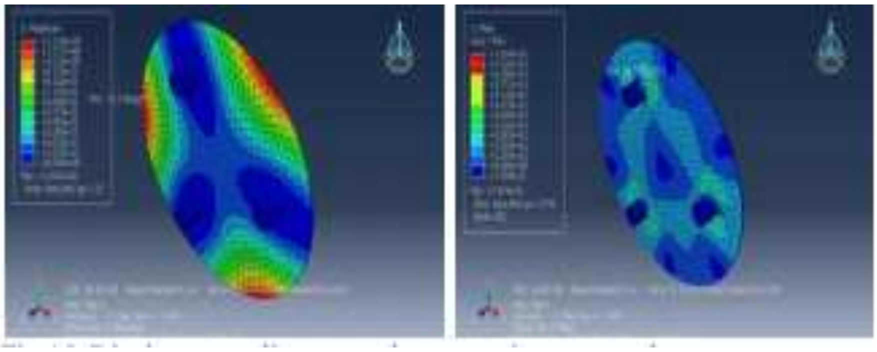

Fig.15. Displacement diagram and stress acting on top plate

RESULT:

Maximum Von Misses stress found in top plate is 76 N/mm2 which is considerably less than yield stress of the material which is 270N/mm2 .So design is considered to be safe with very less deformation of 1.218 mm.

Fig.16. Assembly of LPG weighing machine

C. Final Assembly of LPG Weighing Machine

Figure 6.10 shows assembly of LPG weighing machine which was assembled in Catia V5 R20 and rendered in Key shot 5.

FABRICATION AND CALIBRATION OF LOAD CELL

A. Load Cell Preparation

Load cell is the important part of the assembly. It begins with search for the scrap material to make the load cell, aluminium material being one of the scrap material is used for testing. Firstly marking is made on the plate as per dimension (170×25×3mm). Plate is cut by using grinding wheel and four holes are made on one side plate in order to fasten plate and make it as cantilever beam. Before installing of strain gauge on plate, it requires fine surface finish. Sand papers are used to get the fine surface finish. After polishing of plate, cotton cloth is wiped on the bonding site using water or solvent. Making the marked on strain gauge bonding site, (100mm from the free end) further a drop of adhesive is applied on the gauge and immediately put on the marked area of plate. Gauge is covered with plastic sheet and pressed strongly over the sheet for a minute. After a few minutes connection between strain gauge lead and electric cable is made by the use of soldering gun. Figure 17 shows load cell is connected with cable now it is ready for testing.

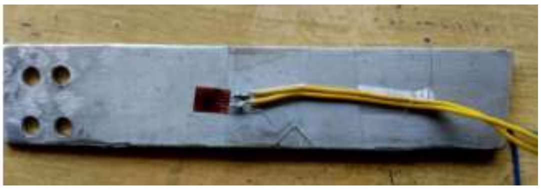

Fig.17. Load cell connected with cables

B. Load Cell Testing

A load cell was tested by using Lab view 2015 in NIE college DST lab. Following are the components which were used for testing the strain gauge based load cell

C. NI cDAQ-9178

Figure 18 shows the NI cDAQ-9178 which consists of 8 slots and USB chassis designed for connect to computer and test the modules. It combines with up to eight input modules and gets the output through the NI lab view 2015. Various modules are available for measurement of thermocouples, RTDs, strain gages, load and pressure transducers, torque cells, etc.

Fig.18. NI cDAQ-9178

D. NI 9219

Figure 19 shows the NI 9219 which consists of 4 channels designed to check in any NI DAQ. With this module can measure various signals such as strain gauge, load cell, thermo couples, RTD, and other powered sensor. This module is plugged into DAQ port in order to check the result of module

Fig.19. NI 9219

E. Calibration of load cell

Before applying load on load cell it have some strain present on the plate and note that strain value and minus that value with after application of load and get the exact strain of an object.

Strain present in load cell before application of load ε0 = 0.000001

Length L: 150mm, Width b: 25 mm, Height h: 3mm Young's modulus E: 68900 N/mm2 ε0 = 6WL/Ebh2s

Fig.20. load cell experimental setup

Table 1.Calibration Results

SL. NO	ε_0	W_i	ε_a	W_o	$W = W_o - W_i$
1	0.000001	0.001 kg	0.00015	0.261 Kg	0.25 Kg
2	0.000001	0.001 kg	0.0003	0.51 kg	0.5 kg
3	0.000001	0.001 kg	0.0009	0.76 kg	0.75 kg

Where,

ε0 = Strain present in load cell before application of load.

W_i = Weight of load cell before application of load.

εa = Strain present in load cell after application of load.

Wo = Weight of load cell after application of load.

Figure 21 shows on the left side, graph indicates the strain value with respect to time of a load member which is applied on the load cell. On the right side of figure shows the configuration diagram, in which graph and strain value is connected to DAQ in order to show the results on display graphically and indicate strain values.

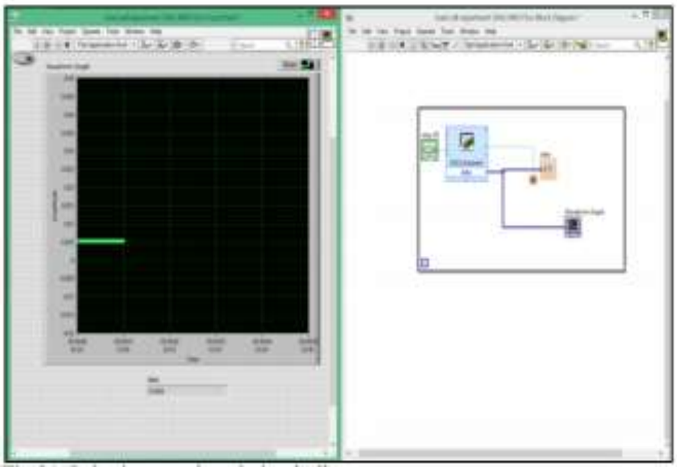

Fig.21. Lab view graph and circuit diagram

CONCLUSION

This paper attempts to address the above problem by making use of load cell and hydraulic jack arrangement. Load cell was designed, analysed and tested in the Lab view 2015. Following conclusion are made on project work as noted as follows.

1) The design was made in such a way that the cylinder could be easily moved and as the LPG within the cylinder goes down it indicate accurate amount of LPG within the cylinder.

2) Design a 200kg capacity of bottle jack, which is sufficient to lift the LPG cylinder and reduce the height of the system.

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