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Design and Fabrication of Multipurpose Fitness Equipment

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Abstract: The main objective of this project is to fabricate a fitness equipment which serves to develop various muscle groups of the human body. We are trying to develop a product which is capable enough to replace the traditional fitness equipments with an equipment which serves the purpose of all the individual equipments at a very affordable price. As there is an increase in the energy consumption every year and the existence of energy crisis in today's world, finding an innovative way to use non-conventional energy and to produce electricity is paramount. Many innovative alternate concepts are being worked on to achieve this. One such idea is to recover and use human effort produced in a gymnasium while working out. There are numerous products that generate electricity from machines like elliptical machines, gym cycles, etc., but none for cable and pulley machine. We are trying to generate power as much as possible from such equipments and store it, to run the gymnasium from the power produced from the equipment itself. Power generation can be made possible, as during a typical workout using the equipment, mechanical energy is produced. This mechanical energy is produced by the linear motion of weights. By converting this linear motion into rotary motion and by using a generator, power generation can be made possible and the produced power can be stored for future use.

By incorporating this energy harvesting system into the fitness equipment that we are trying to fabricate, it helps even a common man become fit, healthy and contribute to energy harvesting at a relatively low cost.

Keywords: cable and pulley machine, energy crisis, human effort, linear to rotary motion, non-conventional energy.

I. INTRODUCTION

The field of energy conservation is of surmount importance as energy crisis is on a rise and is at its highest currently. Energy crisis is the depletion of important resources before meeting the demands. Depletion of resources can be reverted by the utilisation of renewable resources, as global warming is also one of the major concerns of recent times. Like the rest of the world such problems are prevalent in India as well, India, a developing country is world's third largest emitter of carbon dioxide and its shown in researches that emissions increase as living standards rise so the problems are going to increase as the country stays on the developing path. Using conventional sources of energy like fossil fuels is only increasing global warming and the aftermath will be heinous. These concerns led to the need to develop a innovative method to conserve energy or harness renewable energy.

As recent studies have suggested physical fitness has a positive impact of health, individuals who are active are at a lower health risk than their sedentary counterparts. Obesity is at a all-time high and is leading to the death of individuals. India being the second most populated country has other issues combined with obesity like the availability of utilizable space. All these led to develop a design which is capable of harnessing the kinetic energy of individuals during exercise, a mechanism capable of generating electricity from cables and pulleys. Our design is a very compact and cost-effective equipment as it combines multiple equipments into one while harvesting energy which would have gone waste otherwise.

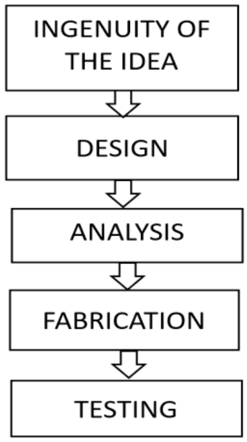
II. OBJECTIVE

1. Our primary objective is to fabricate a multipurpose fitness equipment.
2. To show that power generation is possible using this equipment.
3. The power generated will be stored using batteries and used in daily activities.
4. The multipurpose equipment along with the energy harvesting setup is more economical than a basic traditional fitness equipments.

III. PROBLEM STATEMENT

Fitness is a part of life and is needed to keep the mind active and the body healthy. But fitness equipments in today's market will burn a hole in anyone's pocket. The field of energy conservation has also become eminent and increasingly notable. Engineers and scientists have been working on innovative and unparalleled ways on designing energy harvesting systems. We as engineers decided to tackle the problem of expensive fitness equipments and energy harvesting with a distinguished and solitary solution by designing and fabricating a universal fitness equipment which will utilize human effort to produce electricity.

IV. METHODOLOGY



A. Ingenuity Of The Idea

This idea came into to existence with the thought of harnessing non-conventional energy which was getting wasted in a daily activity such as working out in a gym. We decided to use engineering to construct a cost-effective equipment which would cost less than Rs.50,000. This equipment, on a similar scale will cost more than Rs.2,00,000 in the market.

B. Design

The design of the equipment is done in solidworks taking into consideration the standard gymnasium equipment size.

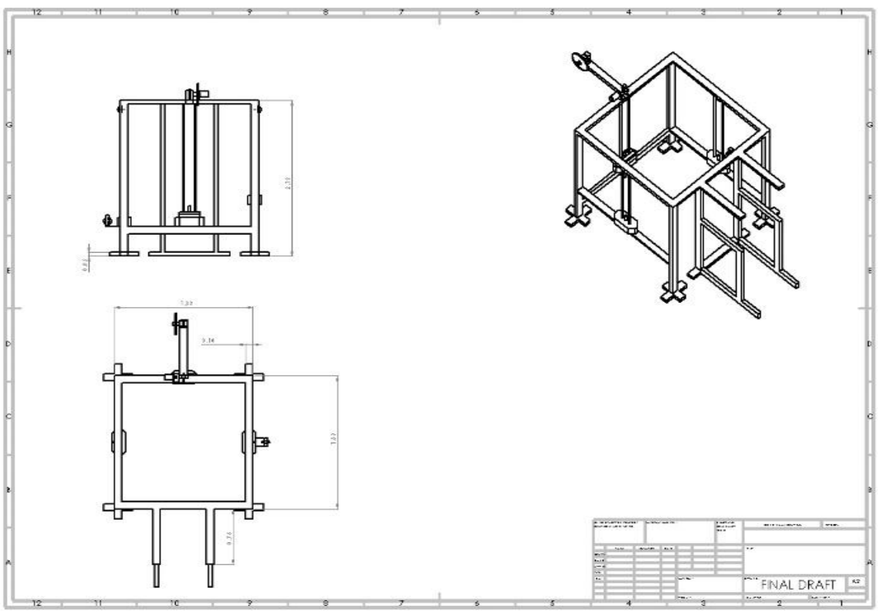


Figure 3.B.1: Final Draft of model

Fig 3.B.2: 3D model of the fabricated equipment done in solidworks.

C. Analysis

The analysis will be carried out to check the feasibly of the equipment and to see if it has load bearing capacity. The software we have used to carry out the analysis process is **Ansys Workbench**.

The analysis is carried out in order to find out the stress, strain and deformation of the structure, when different loads are applied on the structure.

The material we have chosen for the fabrication of the equipment is **Mild Steel**. Mild steel has got the following properties:

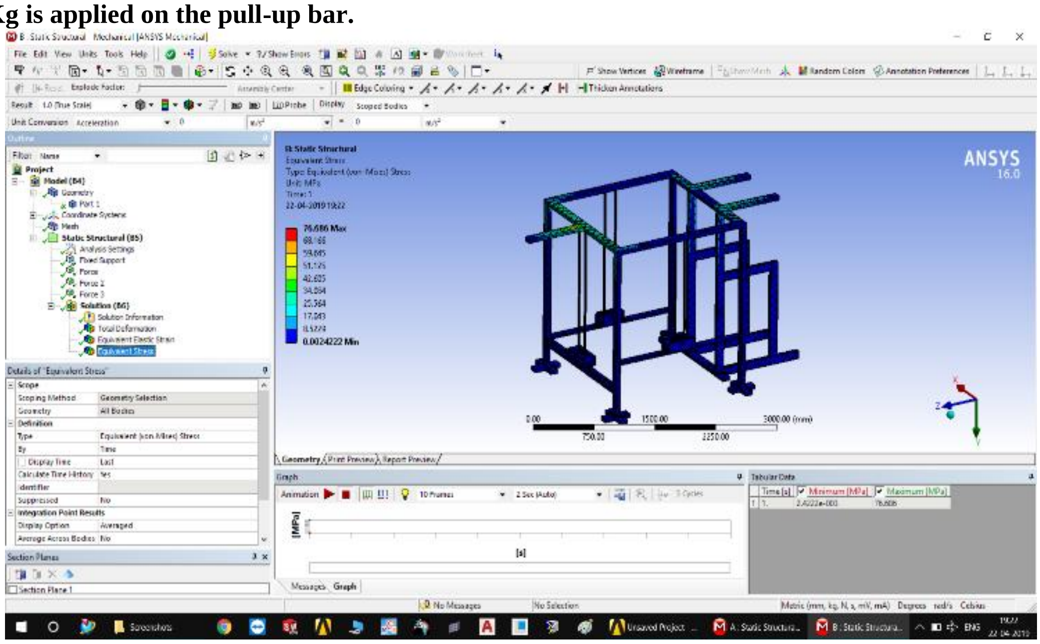
Density: 7850 Kg/m^3

Young’s Modulus: $2x10^{11}$Pa

Poisson’s ratio: 0.3

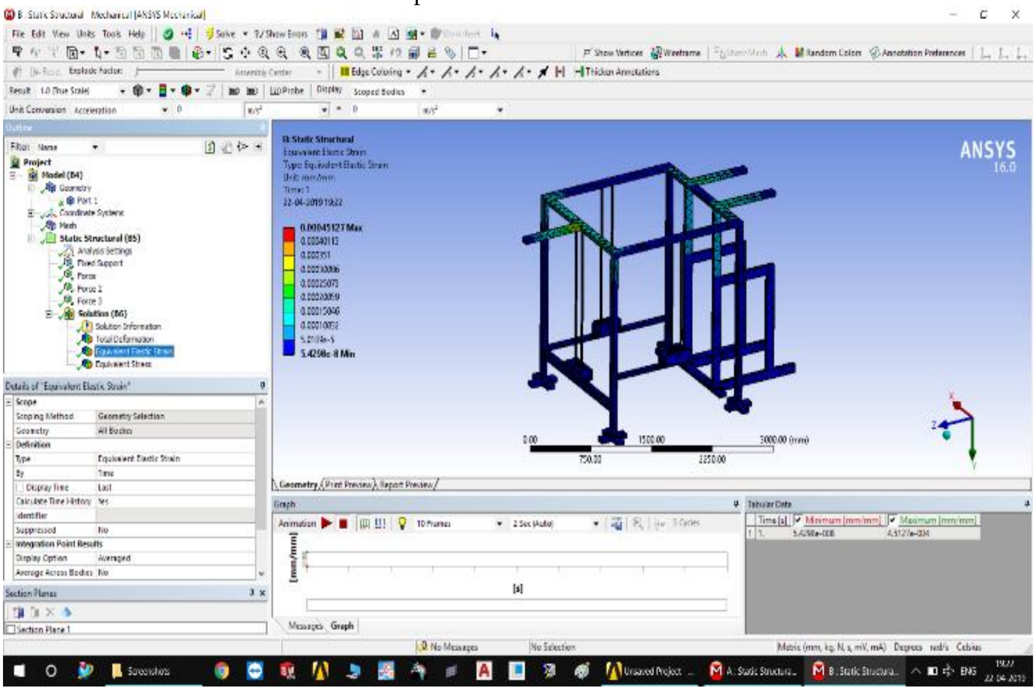
Yield Point of Mild steel: 250MPa

Analysis results of the model when a load of 80Kg is applied at the points and edges where pulling operation of weights is carried out and also at the points where the load is mainly concentrated and a load of 100Kg is applied on the pull-up bar.



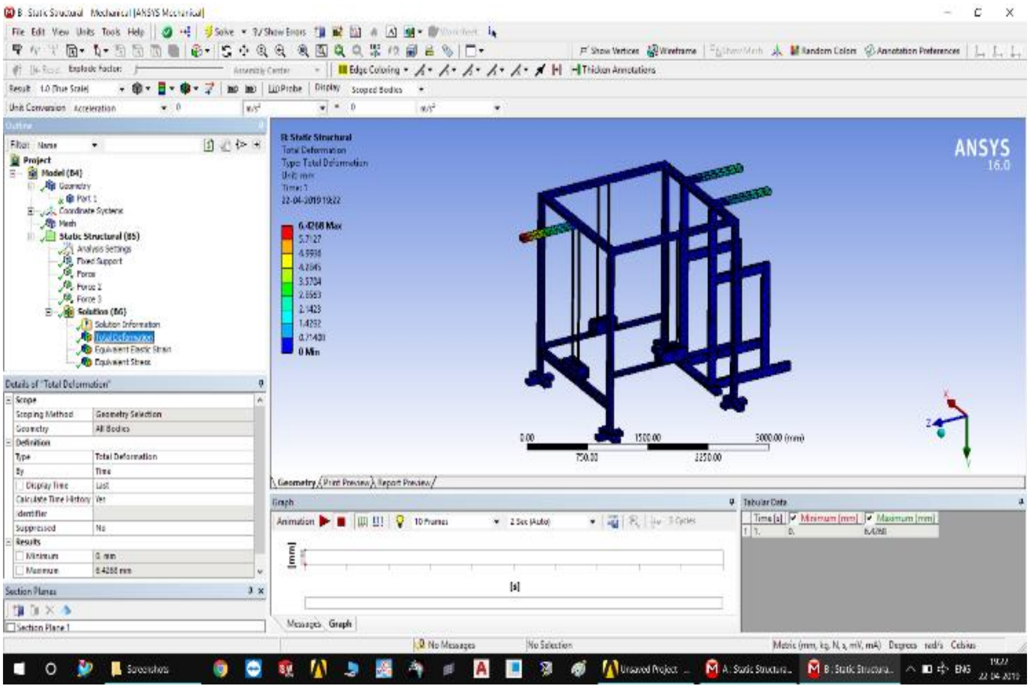
The above picture shows the stress acting at various points of the structure when a load of 80Kg is applied on the bar where pulling operation of weights is carried out. The maximum amount of stress that is produced when a load of 100Kg is applied is 68.166MPa and the minimum amount of stress produced is 0.0024222MPa.

When a load of 100Kg is applied on the pull-up bar, the maximum amount of stress that is produced is 76.686MPaand the minimum amount of stress produced is 0.0024222MPa.



The above picture shows strain acting at various points of the structure when a load of 80Kg is applied on the bar where pulling operation of weights is carried out. The maximum amount of strain that is produced when a load of 80Kg is applied is 0.00040113 and the minimum amount of strain produced is 5.4298×10^{-8}.

When a load of 100Kg is applied on the pull-up bar, the maximum amount of strain that is produced is 0.00045127 and the minimum amount of strain produced is 5.4298×10^{-8}.



The above picture shows deformation when a load of 80Kg is applied on the bar where pulling operation of weights is carried out. The maximum amount of deformation that is produced when a load of 80Kg is applied is 6.4268mm and the minimum amount of deformation produced is 0mm.

When a load of 100Kg is applied on the pull-up bar, the maximum amount of deformation that is produced is 4.2845mm and the minimum amount of deformation produced is 0mm.

Yield Point of Mild Steel is 250MPa and the maximum stress produced is 76.686MPa. Since the maximum stress produced is lesser than the yield point of mild steel, we can conclude that the material is capable of sustaining the load that is applied on it. **Based on these evidences and conclusions, we can therefore say that the design is safe.**

D. Fabrication

The material we have chosen for the fabrication of the equipment is **Mild Steel**.The fabrication of our equipment involves many processes like cutting, welding, brazing and drilling. Firstly, the raw material was cut into the required dimensions as per the design and arranged. Later the parts were welded to obtain perfect joints.

We have used **Arc welding** and **TIG welding** for the fabrication of this project. Arc welding was used in places or joints where not much load is acting and TIG welding is used in joints on which more amount of load is acting.

Drilling was done to create holes of the required size wherever required to obtain perfect fit for the rods with the metal columns.

The **Brazing** process is used to connect the metal chain to the rope which is used to pull the weights

E. Testing

The fabricated equipment was then extensively tested to check the power produced and to make sure the equipment works properly. Calculations, results and discussion are displayed in chapters V and VI.

V. SYSTEM USED AND CALCULATIONS

Figure 5.1: Pinion gear and dynamo gear coupled by chain drive

Figure 5.2: Shaft connecting geared pulley and pinion

The main concept used in our designed energy harvesting system is the conversion of linear movement of the cable which is used during a workout, into rotational movement which is transferred from the geared pulley into the shaftand finally to the pinion. The pinion which we have used has 95 teeth (T1=95). The pinion is directly coupled to the dynamo gear (T2=24) using chain drive.

We know that, angular velocity is given by,

$omega = 2\pi * (rps)\ rad/sec$……………...…….…... ..(1)

Linear velocity is given by

V=omega ×radius

$V = r * 2\pi * (rps) m/s$………………………...……...(2)

Linear velocity is also equal toDistance/Time…….…….(3)

From (3) and (2).

$\frac{Distance}{Time} = 2\pi * (rps) * r$…..…………………..………(4)

Here linear distance is the distance moved by the workout bar in order to rotate the geared pulley.

Case 1: For first person

Linear distance is equal to 0.66m.

Time taken to move the workout bar (10cycles) = 13.6s

Time taken to move the workout bar.(1cycle) = 1.36s

Radius of the geared pulley= 0.05m

Substituting the above values in (4), we get, rps of geared pulley=1.54

Since the geared pulley and the pinion are mechanically coupled,

rps of geared pulley=rps of pinion=1.54

The radius of pinion= 0.145m

The radius of dynamo gear=0.025m

The ratio of radius of pinion to dynamo gear= 0.145/0.025= 5.8

Therefore, the rps of dynamo gear= 5.8×rps of pinion= 5.8×1.54=8.93

N1=rpm of pinion=1.54×60 = 92.4rpm

N2=rpm of dynamo gear = 8.93×60 = 535.8rpm

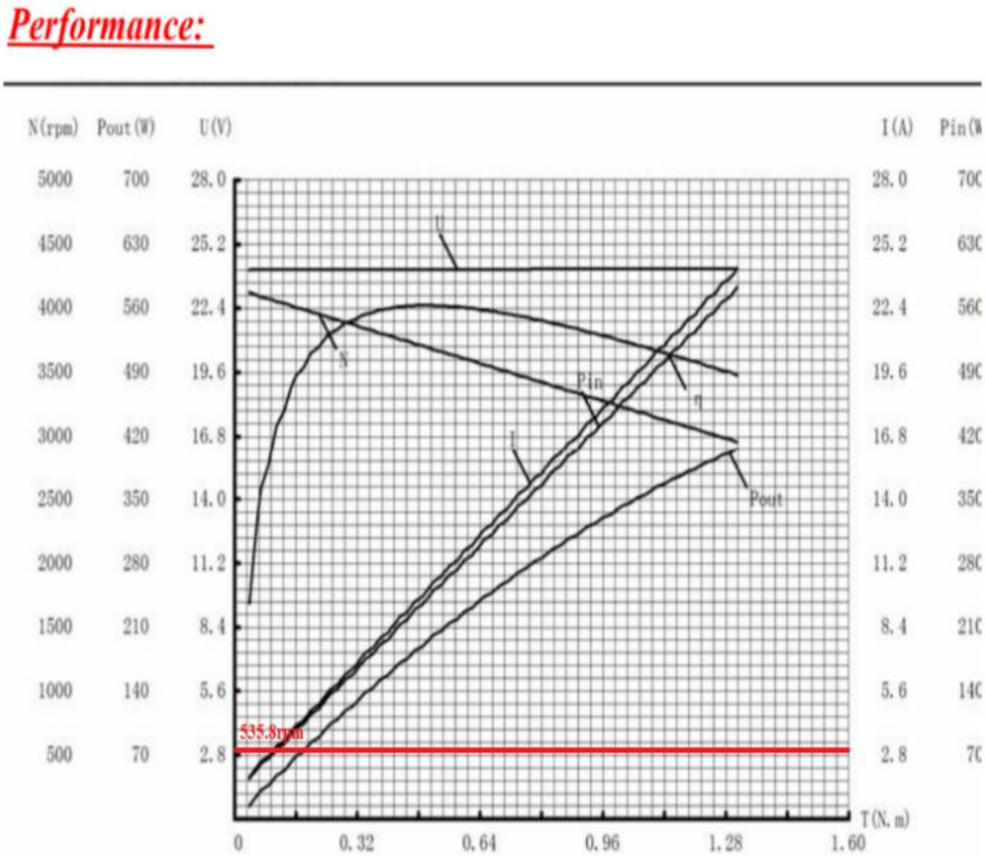


Figure 5.3: Performance curve of dynamo12V-36V
case 1 [6]

According to this curve, for 535.8 rpm we get,
Current (I) = 2.98A; Power output (Pout) = 74.66W

Case 2: For second person
Linear distance is equal to 0.58m.
Time taken to move the workout bar (15cycles) = 18.06s
Time taken to move the workout bar.(1cycle) = 1.204s
Radius of the geared pulley= 0.05m
Substituting the above values in (4), we get, rps of geared pulley=1.534
Since the geared pulley and the pinion are mechanically coupled,
rps of geared pulley=rps of pinion=1.534
The radius of pinion= 0.145m
The radius of dynamo gear=0.025m
The ratio of radius of pinion to dynamo gear= 0.145/0.025= 5.8
Therefore, the rps of dynamo gear= 5.8×rps of pinion= 5.8×1.534=8.89
N1=rpm of pinion=1.534×60 = 92.04rpm
N2=rpm of dynamo gear = 8.89×60 = 533.4rpm

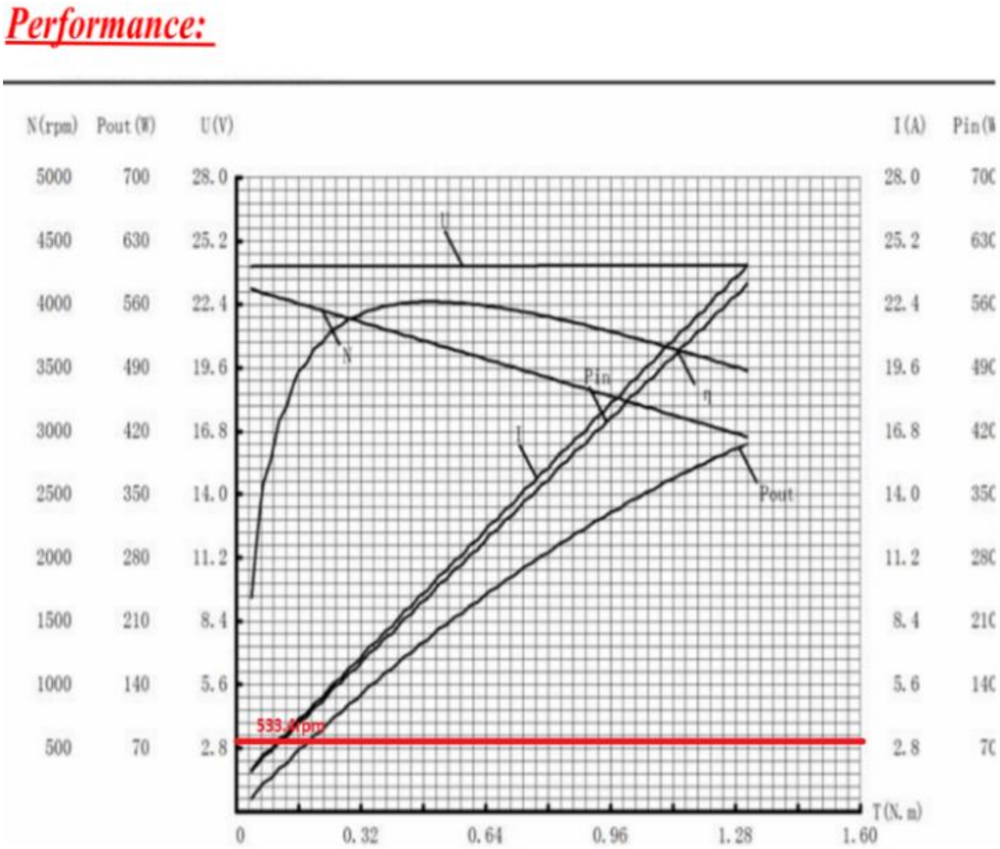


Figure 5.4: Performance curve of dynamo12V-36V
case 2 [6]

According to this curve, for 533.4 rpm we get,
Current (I) = 2.95A; Power output (Pout) = 74.24W

Case 3: For third person

Linear distance is equal to 0.63m.
Time taken to move the workout bar (15cycles) = 22.06s
Time taken to move the workout bar.(1cycle) = 1.47s
Radius of the geared pulley= 0.05m
Substituting the above values in (4), we get, rps of geared pulley=1.36
Since the geared pulley and the pinion are mechanically coupled,
rps of geared pulley=rps of pinion=1.36
The radius of pinion= 0.145m
The radius of dynamo gear=0.025m
The ratio of radius of pinion to dynamo gear= 0.145/0.025= 5.8
Therefore, the rps of dynamo gear= 5.8×rps of pinion= 5.8×1.36=7.88
N1=rpm of pinion=1.36×60 = 81.6rpm
N2=rpm of dynamo gear = 7.88×60 = 473.28rpm

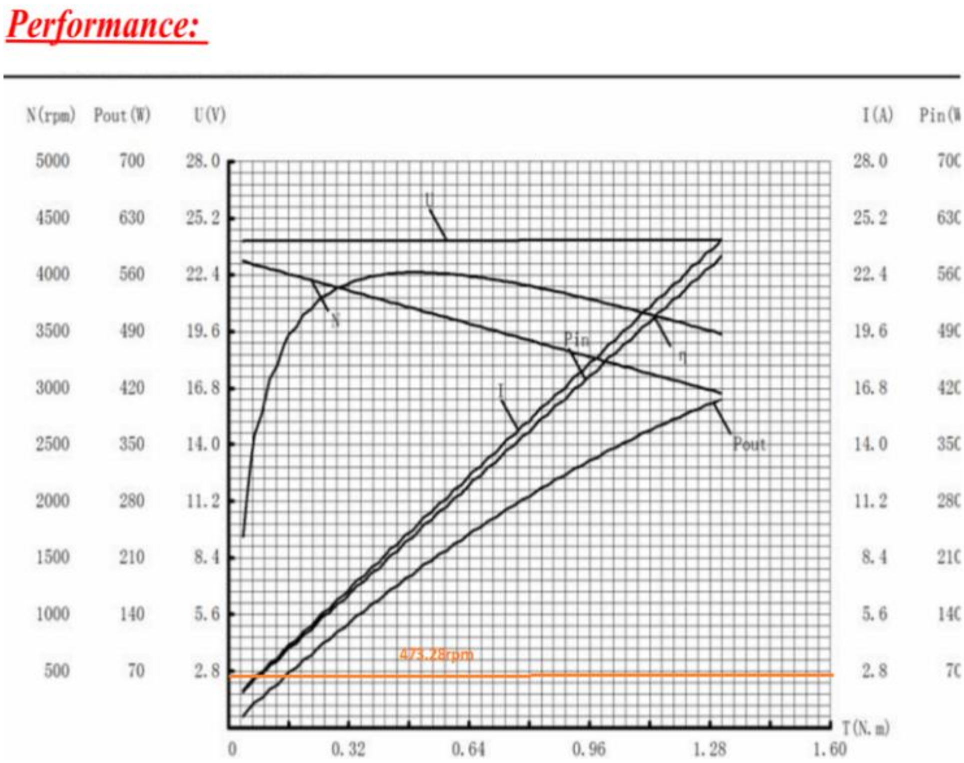


Figure 5.5: Performance curve of dynamo12V-36Vcase 3 [6]

According to this curve, for 473.28 rpm we get,
Current (I) = 2.66A; Power output (Pout) = 66.5W

CASE	CYCLES	POWER PER CYCLE	CURRENT PER CYCLE
1	10	74.66W	2.98A
2	15	74.24W	2.95A
3	15	66.5W	2.66A

Table 5.6: Aggregation of total trials

The average output power = 72.78W
The average output current = 2.86A
The output as measured in multi-meter is,
Current (I) = 2-3A

The theoretical and experimental values of the current are aligned.

VI. RESULTS AND DISCUSSION

Units used:

A watt (W) is a unit of power, and power is the rate at which energy is produced or consumed.
A watt-hour (Wh) is a unit of energy; it's a way to measure the amount of work performed or generated.
Hence if the designed model is used continuously for an hour, the energy produced by the model on an average is 72.78Whr.
A gymnasium will be open from 5:00 to 23:00 hrs, which is a total of 18hrs. Considering that the equipment will be only used for half that time, that is 9hrs, the total energy produced by the equipment in a day = 72.78*9 Whr = 655.02 Whr
In a month considering 30 days, the total energy produced = 655.02*30 = 19650.6 Whrs = 19.6506 kWhrs
1-unit of electricity = 1KWhrs
In village areas it will be 4–5Rs per unit. In city/metro areas it will be 7–10 Rs Per unit.

Therefore, our model will save, 19.6506 *10 = 196.506 Rs in the monthly bill.

Our model is effectively contributing to energy harvesting from non-conventional sources and is saving money on the monthly electricity bill.

VII. CONCLUSION

Energy efficiency is a way of the future. The world is moving towards energy sustainability as major resources of energy are at the brink of depletion. A good first step towards energy sustainability is generating your own energy. The world is also plagued with poor fitness as the population is finding it increasingly hard to put enough effort and time into fitness.

This design answers these challenges of the world, green power generation and poor fitness. This design and fabrication is an implementation to solve these issues in the form of an innovative exercise equipment to generate power for day to day purposes.

The equipment is a combination of various fitness equipment carefully combined to work on all muscle groups of users. It is also an energy harvesting and generation system that converts mechanical human energy dissipated by the fitness setup to electrical energy.

It has four different workout stations out of which three concentrate on weighted exercises while the fourth and final one provides the structure needed for self-weight exercises.

As per reports the equipment is economically feasible to implement as a replacement for standard equipment and would be sustainable as energy harvesting and fitness equipment. This fabricated power generation equipment is designed for the day to day fitness purpose of a common man and can also be modified and coupled with the available equipment in the market.

The results and data analysis report present several remarkable points on the use and importance of energy harvesting from ambient energy sources like human power.

The goal was to fabricate cost effective multipurpose fitness equipment which also contributes in energy harvesting and generation. We have achieved our goal and taken a first step towards the direction of renewable energy and sustainable living.

VIII. SCOPE FOR FUTURE WORK

The world is being led in a direction of energy conservation and generating systems. One of the innovative ways is generation through gym equipment. Existing gym equipment is just used for the basic purpose or exercising and fitness. Our equipment can be implemented instead, which helps in a small amount of energy harvesting per system. The problem of overpopulation can be used in our favour by utilizing the human power spent while exercising in a small amount of green energy generation per system. If every gym in our city changes to power generation equipment's the major amount of non-renewable energy can be saved and it would a major impact on the environment taking this as an example the entire nation or the world can learn how each individual can make his contribution towards green energy.

There are pre-existing equipment which generate energy through only the cardio machines, hence contributing to only 21 percent of the overall machines .Our equipment setup can be implemented leading to almost 90 percent of the machinery to contribute in energy harvesting.

As todays population is more health conscious and are spending their time in gym exercising. The energy generation will be large; they can be used for commercial purposes aswell. In future this mechanism might lead to similar large generation processes as it would be model for the world.

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