DESIGN, FABRICATION AND ASSEMBLY OF DUAL INPUT HYBRID ELECTRIC POWER TRANSMISSION USING TWO CVTS FOR SMALL VEHICLE

A PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

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ABSTRACT

Project deals with new type of hybrid technology. In this electric power and engine power is used to get a combined output result by both power sources. To combine both outputs together we use a planetary gearbox, where one shaft is powered by engine output and another is powered by motor output. Final output is taken from ring gear of planetary gearbox and is connected to desired output measuring object, here, bike tire. Chain drives and CVTs were also used for transmission of power. Engine power was transferred by chain drive to CVT. CVT and chain drive are connected by shaft. CVT then transfers the power to shaft which is coupled with Sun gear. Hence, making Sun gear rotate. Similarly, motor power is transferred via chain drive to CVT and from CVT to planet gears. The rotary motion of sun and planet gears makes ring gear to rotate. Sprockets connected to ring gear rotate and transfer the output power to the wheels through chain drive. The final power is measured from the wheel. This experimental setup is for small vehicles. It is also a new technology for power transmission for small vehicles. Use of dual CVTs, planetary gearbox and chain drives make it unique from present hybrid system. It is an undemanding technology. Being lucid and penetrable technology, it can be the future of automobile industries. Also, it gives marvelous results.

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LIST OF ABBREVIATIONS

No.	Number
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
EM	Electric Motor
CVT	Continuous Variable Transmission
e-CVT	Electronic Continuous Variable Transmission
PG	Planet Gear
EV	Electric Vehicle
MG 1/2	Motor Generator ½
LPG	Liquid Petroleum Gas
3D	3 Dimension
cc	Cubic centimeter
DC	Direct Current
AC	Alternating Current
BLDC	Brushless Direct Current
INR	Indian Rupees
W	Watt
A	Ampere
V	Volt
MPa	Mega Pascal
Kgf	Kilogram force
HBN	Brinell Hardness Number
HP	Horse Power
EN8	European Norm 8
HRC	Rockwell Hardness
cm	Centimeter
mm	Millimeter
OD	Outer Diameter
Dia.	Diameter

SMAW	Shielded Metal Arc Welding
rpm	Revolutions per minute
Vol.	Volume
pp.	Page to page

LIST OF SYMBOLS

F	Degree of Freedom
l	No. of links
j	No. of binary joints
h	No of higher pair
σ_u	Tensile strength
σ_b	Design bending stress
σ_c	Design contact stress
E	Young's Modulus
m	Module
b	Face width
Z	No of teeth
P_c	Circular pitch
d	Pitch diameter
F_s	Strength of Gear tooth
F_t	Transmitted load
V_m	Mean velocity
N	Speed in rpm
F_d	Dynamic load
C_v	Velocity factor
F_w	Wear load
Q	Ratio factor
k	Load stress factor
τ	Torsional stress factor
T	Torque
ts	No of teeth of sun
tp	No of teeth of planet
tr	No of teeth of ring

CHAPTER 1

INTRODUCTION

Energy is the primary and most universal measure of all kind of work. Everything that happens in the world is an expression of flow of energy in one of its forms. The most basic form of source of energy available to us are coal and petroleum. It's not unknown to the world that these resources are limited in their quantity. Therefore, to save our resources and to prevent our environment from the detrimental gases released in the atmosphere there has been a constant development process in order to optimize and make our machines efficient. In the automobile industry efforts have been made from the past century itself to improve the sustainability. In past developments were made to improve the combustion process by refining fuel and revamping the process.The environmental damage caused by a vehicle can be categorized in four ways car production, fuel production, car use and car disassembly and recovery. In here production of fuel and car usage can only and effectively controlled. Studies have shown that it is always better to use high grade energy than low grade energy to enhance the efficiency.

Hence the preparation of a complete electric vehicle is a pretty viable option yet it is far from being utilized in countries like India. To bridge this gap Hybrid Electric Vehicles (HEV) is the need of the hour. A lot of work and researches has been done in this domain however mostly 4 wheelers were studied. An HEV focuses on running on two power sources, certainly an internal combustion engine (ICE) and electric motor (EM) which may and may not incorporates battery pack.

In this study we have aimed to downscale the technology in order to be used by smaller vehicles, with an aim to demonstrate how power from two shafts can be coupled into a single output shaft simultaneously.

1.1 Ideology

The main ideology behind this project was to obtain better results than already existing technologies. In this project two sources of power are used. One from engine and other from motor. Both these powers are combined together in planetary gear. The final output is to be drawn from the ring gear through chain drive. Engine output is connected to Carrier gears and Motor output to Sun gear. When there is power transferred both gears move respectively and make the ring gear move and hence the output power is generated in a single shaft. A pair of continuous variable drive (CVTs) are also used so that a continuously variable output is achieved as per requirements.

Combining mtotion from both the power sorces is advantageous in all terms.

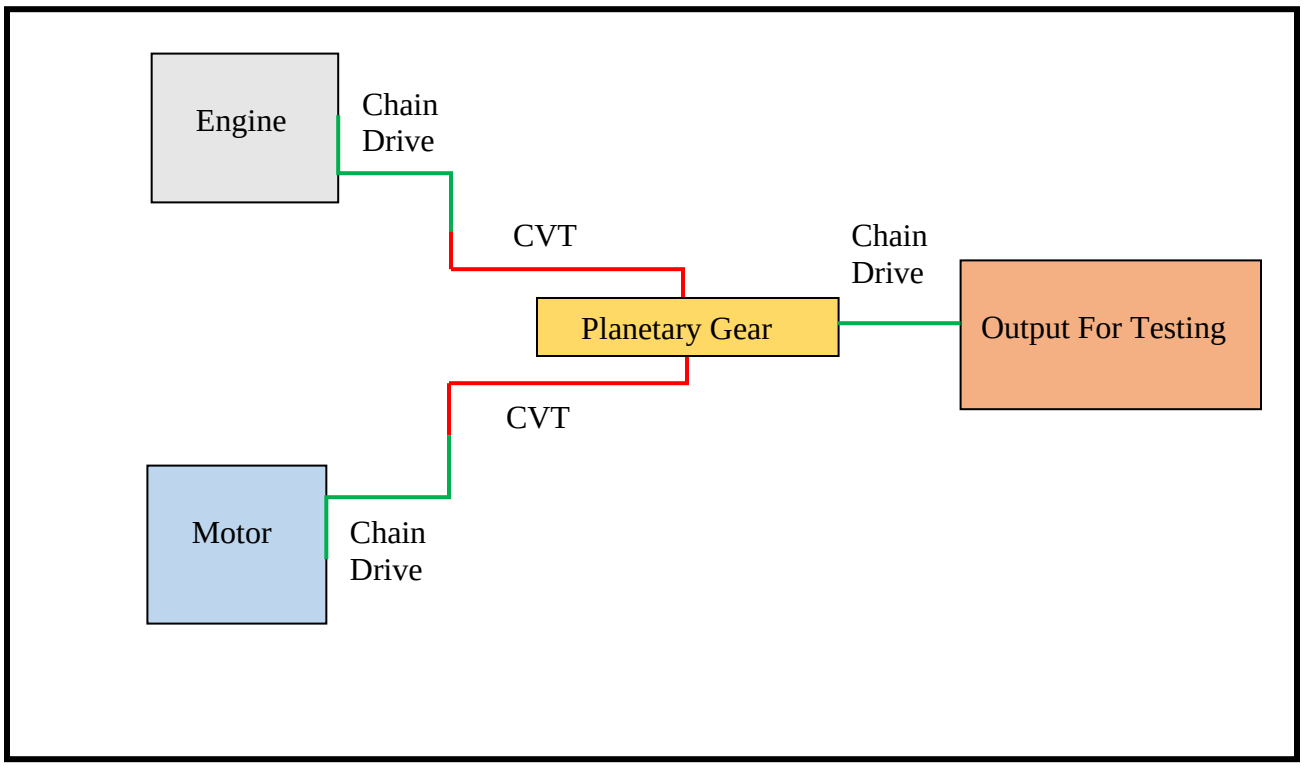

Figure 1.1: Ideology

As we can see in figure 1.7, the basic idea was to use both power source and create new profitable technology. Use of CVT is important here as CVT helps in adapting variable gear ratio. It also eliminates the work of changing gears. Shafts for connecting chain drive and CVT are fabricated according to design.

Sun gear is connected to power output from motor which is transferred first by chain drive then by CVT. Similarly, carrier planet gears are connected to power output from engine which is transferred first by chain drive then by CVT.

Finally, the final output is carried by chain drive which is connected to ring gear. Ring gear gets the desried output power by the movement of sun and carrier gears. The tests to be performed will be on this final output power. Likely, a tire will be used where we can observe the final results of the test performed.

CHAPTER 2

LITERATURE REVIEW AND OBJECTIVE

2.1 Literature Review

Ogzu H et al. wrote about power split hybrid electric powertrain design with 2 planetary gear sets. The authors presented a systematic approach to automate and configure the modelling procedure for HEV powertrains. They developed algorithms to analyze the feasibility of different architecture types and transition ability between each mode was detected. The modes are also noted which provides maximum power requirement and broadest range of engine speed.

Bin Wang et al. studied power split strategy for semi active hybrid energy storage in small electric vehicles. The authors used average power method to strategize power splitting in order to accomplish an improvement in the operating current frequencies from batteries for small vehicles. This method also helps to restrain high frequency output current from the batteries.

Emilia Silvas et al. investigated the optimal design strategies of HEV and found that the size, topology technology and control are among the broad parameters where optimization is can help in solving and this can help in the enhancement of target constraints. This technique can help in the hybrid vehicles of different sizes working under different constraints.

Weichao Zhuang et al. studied different combination of planetary gears (PG) and found that PG 3 has slightly better efficiency and also a greater acceleration although they are a little expensive therefore are used particularly.

Florent Querini et al. quantified the amount of harmful gases released in the atmosphere by an ICE and by an HEV and electric vehicle (EV). They concluded that ICE released maximum amount of CO_2 followed by HEV and then followed by EV. These changes seem small but in long run and huge quantity they indeed save our environment.

Fabio Orecchini et al. the authors emphasized to use other fuels such as LPG, methane and biogas etc, than petroleum products. The authors also discussed about the different modes and types of HEVs available in the market by different manufacturers. They discussed about different

technologies and their benefits in their respective categories with examples from different manufacturers.

Jinglai Wu et al. studied energy management strategy for EVs with dual input power split transmission. This strategy focuses on minimizing the consumed power of the two motors which are being used in replacement of a single more powerful motor. Authors also introduced constraints to avoid over loading at any component during transmission.

Chenyu Yi et al. performed modeling, control and performance of a novel architecture of HEV. It is certain that operation of vehicles involves high fluctuation of power and torque and hence to prevent the damage and to make necessary changes according to the need e-CVTs are used. This system lies between a series hybrid and a power split hybrid system.

Cheng-Ta Chung et al. discussed energy management and performance evaluation of full hybrid motorcycle. The authors found that planetary gear set with one way clutch transmission can function easily with low capacity of battery favoring a decrement in production cost.

Yuan-Yong Hsu et al. design and implementation of a HEV management system is studied. A full hybrid motorcycle is designed, manufactured and tested and authors founf that the range has been increased. The authors have used an electronic controller to control the motor based on inputs from various sensors.

Texbooks

2.2 Objective

1. To fabricate a mechanical setup for HEV.
2. Scale down of technology so that it can be implemented in small vehicles.
3. To device a system which can couple inputs from 2 shafts simultaneously.
4. To find proper components which can be incorporated after downscaling.
5. Fabrication and assembly.
6. Simulation (Due to nationwide lockdown)
7. Deducing results if any.

CHAPTER 3

TERMINOLOGY

3.1 Traditional Powertrain

The power train of the traditional vehicles have always been a compound power train where the power is coming from the clutch is transferred to the gearbox, here based on the necessity a gears is selected and driven and drive shafts are parallel to each other following the compound gear train arrangement. In this kind of topology power coming out from one shaft is utilized at a time. No combination of two shafts simultaneously is possible. For variety of use such as high torque and high speed requirement the gearbox size is in fact bigger and heavier than the desired size.

3.2 Concept of Epicyclic Geartrain

Apart from the rotation of the gear if any gear axis is also rotating with respect to some other axis then the train will be known as epi cyclic gear train. It may be simple/compound/reverted. In a planetary gear box the number of links is (l=4), number of binary joint is (j=3), number of higher pair (h=1), thus the degree of freedom is $F = 3(l-1)-2j-h = 2$. Therefore we can infer that 2 different direction of motion along the same axis is possible. The planetary gears are being used in heavy vehicles as they help in high reduction of speeds and thereby generating huge torques. They reduce the size of the gear box because of their ability to have high hybridization also they tend to reduce noise on working.

3.3 Existing HEV Technology

Planetary gear boxes have been used various hybrid automobile. These are mainly used in 4 wheelers. With their usage torque splitting is possible without much losses. Modern hybrid vehicles are divided into few categories based on utility and level of hybridization. They are

1. Micro hybrids
    1.1. Power supply to electrically driven accessories.
    1.2. Start and Stop (putting ICE on standby).
    1.3. Brake energy regeneration
2. Mild hybrids

2.1. Power supply to electrical accessories.

2.2. Start and Stop (like micro hybrids).

2.3. Inactive timing system (valves go to sleep mode and do not absorb any energy, the ICE stops without really switching off.)

2.4. Power supply for traction purpose

2.5. Brake energy regeneration.

3. Full hybrids

3.1. Power supply to electrical accessories.

3.2. Start and Stop (like micro hybrids).

3.3. Inactive timing system (valves go to sleep mode and do not absorb any energy, the ICE stops without really switching off.)

3.4. Power supply for traction purpose

3.5. Brake energy regeneration.

3.6. Opportunity of using ICE and EM individually and simultaneously with any degree of hybridization.

4. Plug in hybrids

They have the ability to work like full hybrids although they also provide the ability to charge the batteries externally via particularly designed sockets.

Based on different topology the categorization is as follows

1. Series
2. Parallel
3. Series-parallel or power splitter

CHAPTER 4

WORKING METHODOLOGY OF PROJECT

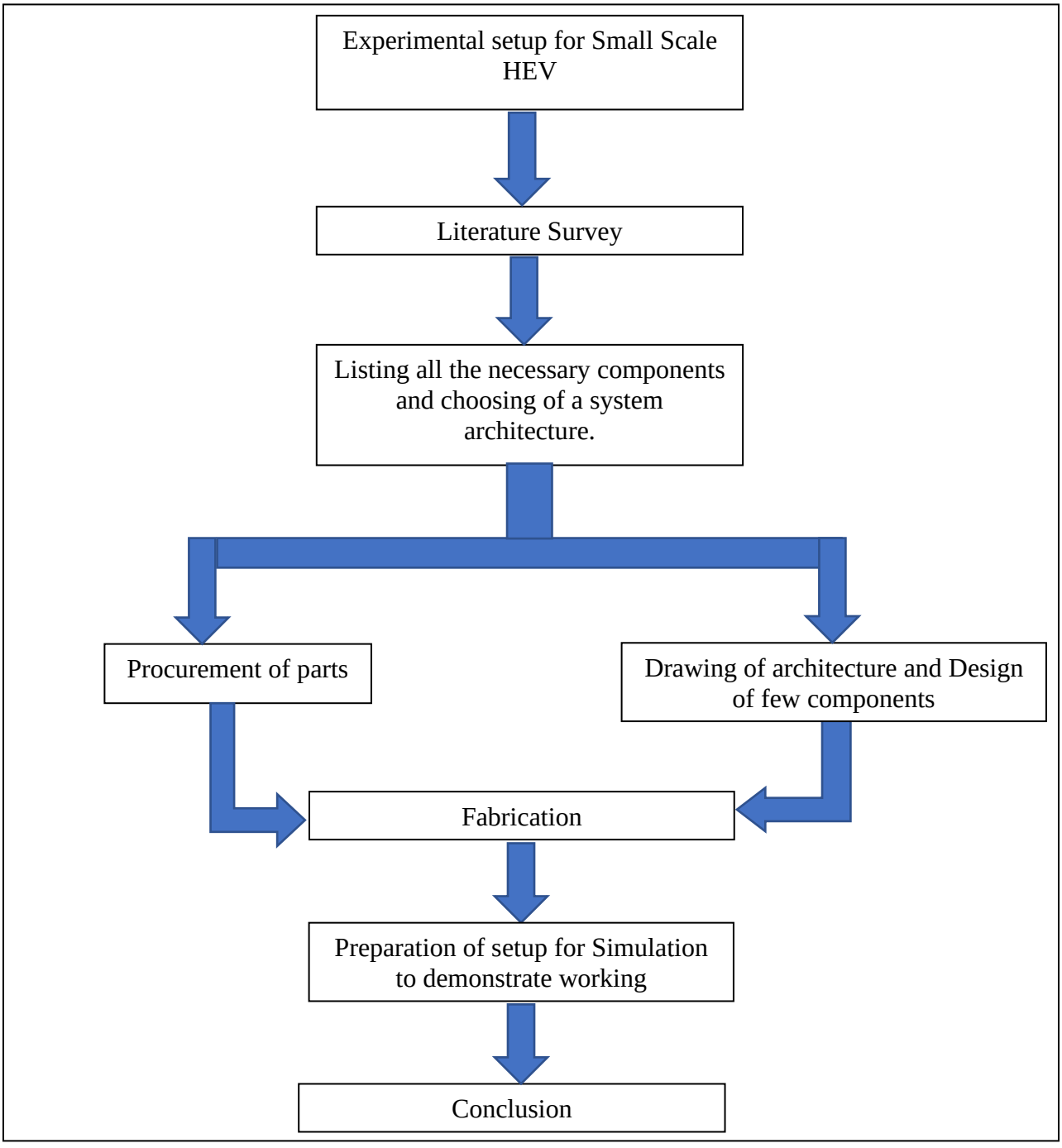

Figure 4.1: Working Methodology

As seen in the above figure 4.1, working methodology can be seen for the steps involved during the project work. Work from begining till the end can be seen. Thinking of an idea or topic to do the project is the begining. After discussing with teammates the topic was choosen to do experimental setup for small scale HEV(Hybrid Electric Vehicle). Next step was on how to do it. So literature survey was done. Papers were read related to the topic and few new innovative and unique ways were found in which the project could be done.

System architecture was proposed. Now all the necessary components had to be listed that would be used in project. Keeping the system architecture in mind components are planned. A system architecture is a simple layout or plan of the project. After choosing system architecture the idea towards the project was clear on how it had to be done.

After knowing what all components were required, search had begun for the components and found. Having enquired few places, collection of required components started with lot of searching in order to get the best component available. Also the components were designed and a proper architecture was drawn using modelling software. Parts or components were collected and fabrication was started.

Fabrication process was carried out. All components or parts were fabricated which were required for the project. Drawings of the parts to be fabricated were made to ease out the operation. Once all the fabrication of parts was done, everything was ready to be assembled on the base. Assembly was done with taking care of fabricated parts, so that they do not get damaged while assemblying them on the base.

Finally the setup was ready after the assembly of all components on the metal base. Now a 3D model is ready to demonstrate a proper functioning and expected results.

CHAPTER 5

SYSTEM ARCHITECTURE AND DRAWING

5.1 System Architecture (Reference)

The system architecture of an existing vehicle with dual input compound planetary gear train is shown in figure 5.1

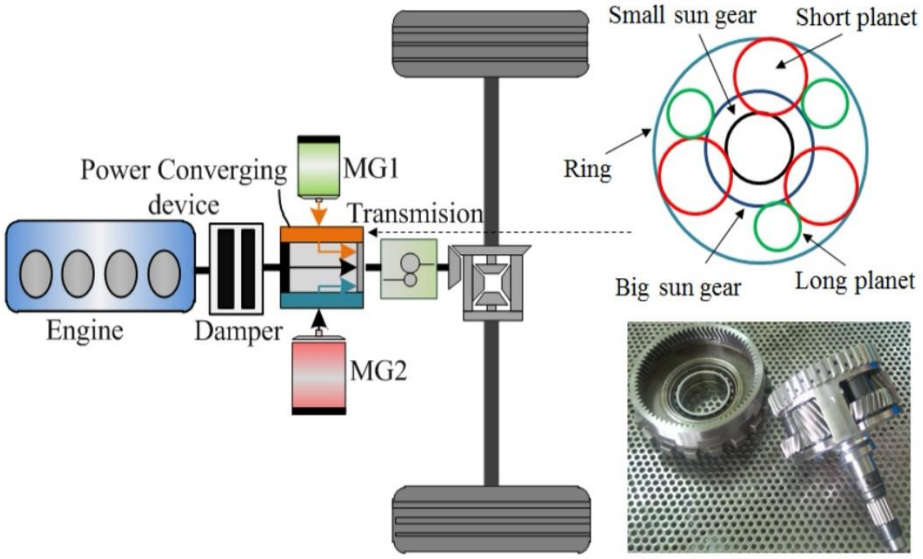

Figure 5.1: System Architecture

The system diagram shown in the figure 5.1 is taken as reference. The above figure highlights all the important details of the layout.Engine can be seen on left top and motor on left bottom.

System taken for reference had a compound planetary gear is used for heavy automobiles in which two motors are used along and single ICE. Motor Generator 1(MG1) works as assisting motor to engine whereas motor generator 2(MG2) works individually. MG2 also charges battery when not in use and the vehicle is moving as it is directly connected to wheels. A switch was used to decide the mode of fuel to be used.

5.2 Drawing

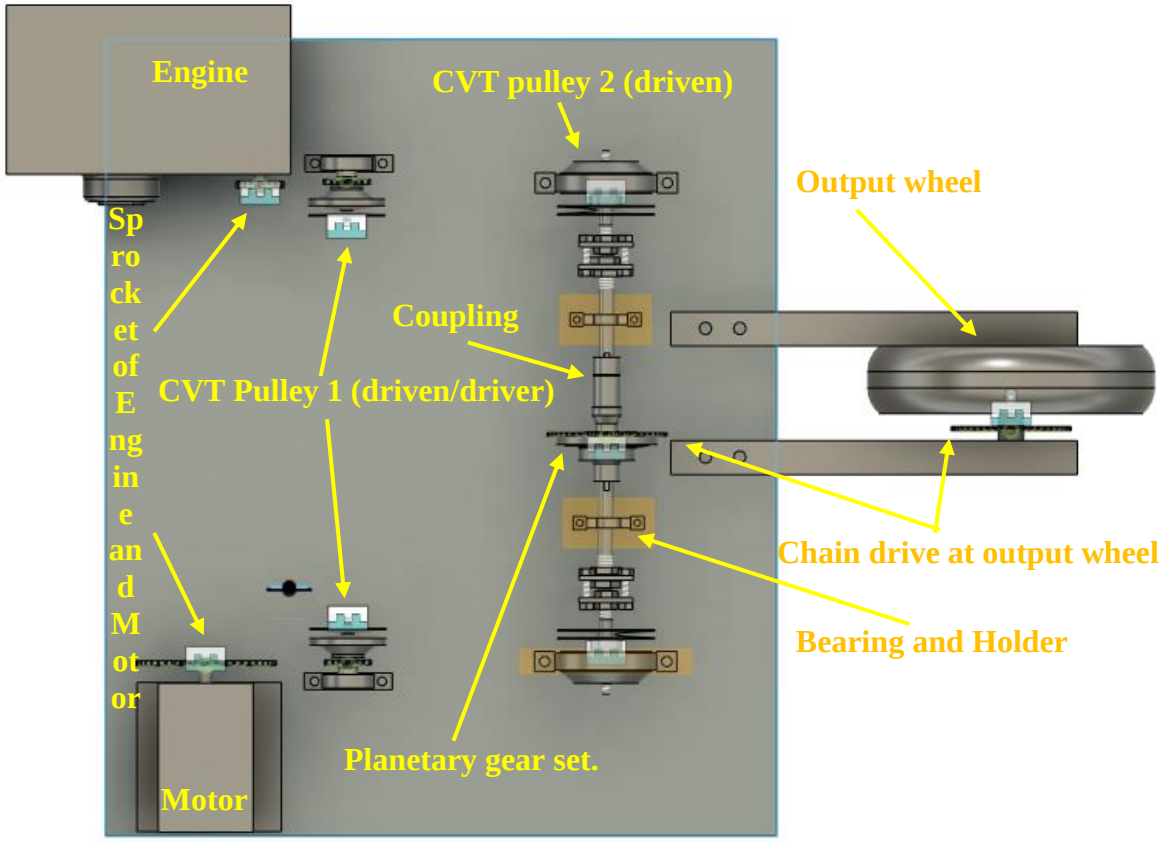

Figure 5.2: Drawing of System

The figure 5.2 clearly demonstrates which drive used in which section to transmit power. Layout for the system was made keeping architecture of system in mind.

The flow of the power as a drawing is shown in the figure 5.3. Flow of power can be understood, originating from two sources engine and motor, power is transmitted by chain drives to CVTs respectively. From CVTs the power is sent to planetary gear via shafts which are coupled to sun and planet gears. Power from engine is sent to planet gears and power from motor is sent to sun gear. The output power is taken from ring gear with the help of chain drive which is connected to wheels.

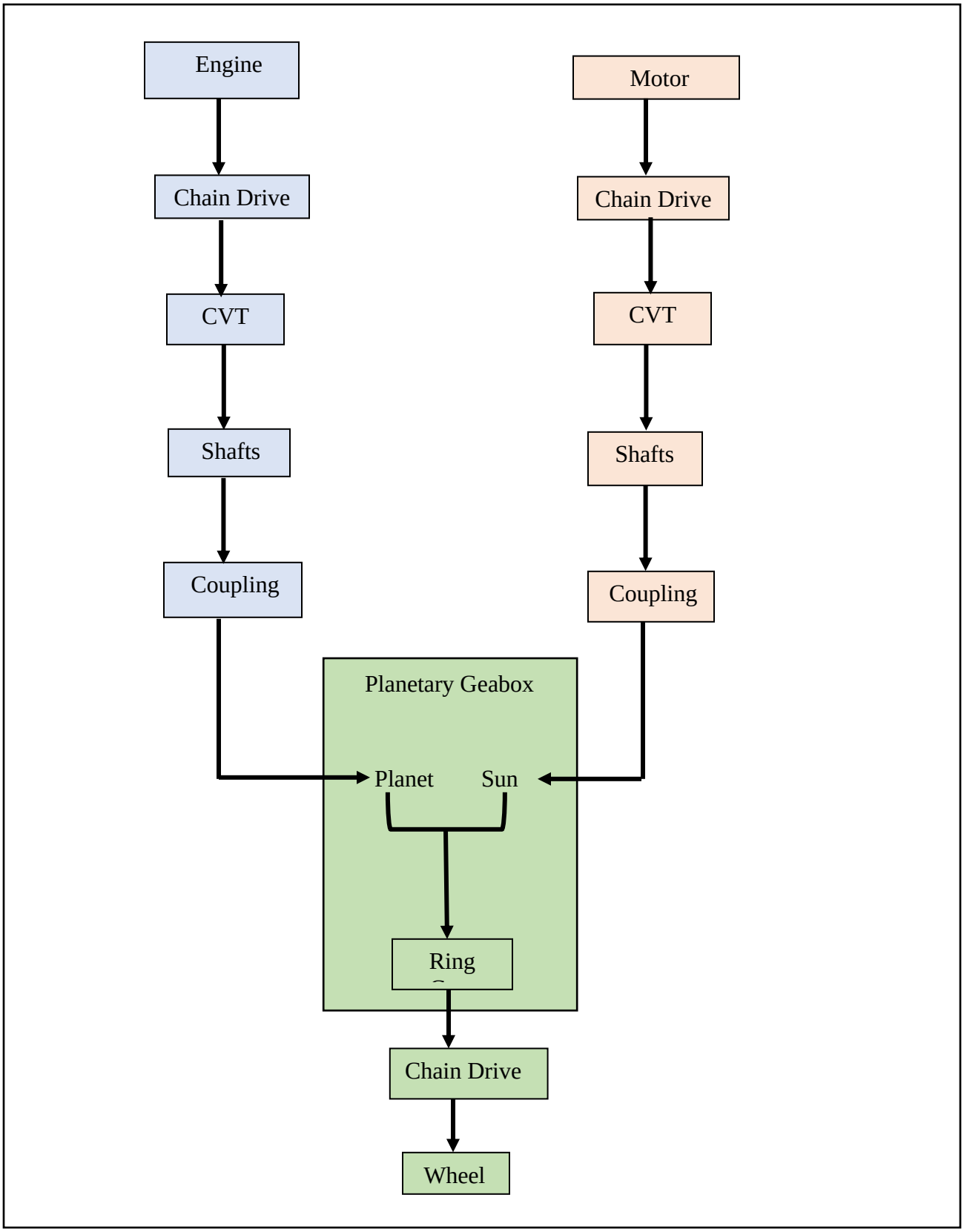

Figure 5.3: Flow of Power

CHAPTER 6

DESIGN AND FABRICATION

6.1 Main Hardware Components

Several components were used in this project, main hardware components are listed below. All these components have their individual importance in the project.

6.1.1 Engine

Engine shown in figure 6.1. It is splendor 2001 model 97 cc 4-stroke petrol engine.

Figure 6.1: Engine

6.1.2 Motor

Figure 6.2: Motor

The figure 6.2 represents a Brushless D.C motor (BLDC) bought online for INR 8000/-. The motor generator is a power DC motor coparable to 4 stroke 150 cc engine. The motor has rated power of 800W, current rating is 15.6 A, voltage rating is 48 V.

6.1.3 Motor Controller

Figure 6.3: Motor Controller

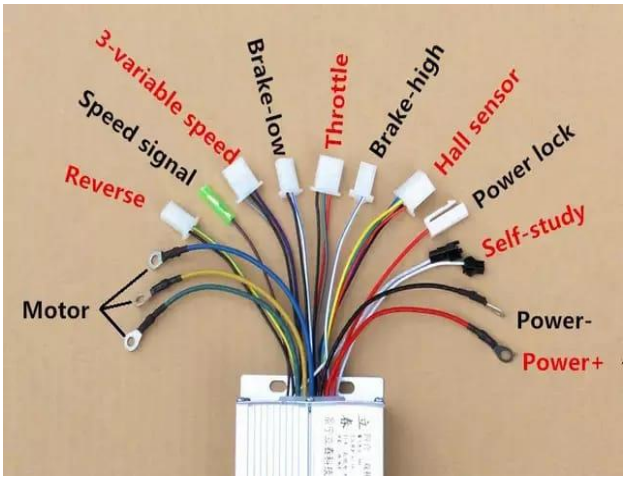

Figure 6.4: Labeling of wires in Controller

Figure 6.5: Motor Controller Specifications

The motor controller as shown in figures 6.3, 6.4 and 6.5 came along with the motor. The motor controller is responsible for the proper functioning of the motor. It converts the given DC supply in 3 phase DC. Also it enables us to control the speed via throttle or it helps us to use 3 preset speeds. Apart from that it has a function to stop the power supply and act as brake to the motor.

Moreover it can start the motor in reverse direction whenever brake is pressed if a shunt signal is provided to it.

6.1.4 Planetary Gear Set (Ring, Planet and Sun Gears)

Figure 6.6: Ring Gear

Figure 6.7: Planet Gears

Figure 6.8: Sun Gear

The figures 6.6, 6.7 and 6.8 shows ring gear, planet gears and sun gear respectively. The sun has 26 teeth, planetary has 18 and ring has 62 teeth. The planetary gear set is bought from the second hand auto parts market and this particular is chosen because its dimension were close to the one calculated and mentioned in the section 6.2.

6.1.5 AC/DC convertor

Due to budget constraints the project nature is slightly switched from a battery pack to charging to using direct ac supply, as in both attempt the aim is to present the stationary working model. The convertor is shown in the figure 6.9 and figure 6.10 represents the specifications of the model.

Figure 6.9: Convertor

Figure 6.10: Specification of Convertor

6.2 Nominal Design

6.2.1 Design of planetary gear set

6.2.1.1Beam Strength of Gear Design from Lewis Equation

The engine produces of 7 HP at 8000rpm.

The material of gear is 40 Ni 3 Alloy Steel

Tensile strength is (σ_u) = 900Mpa, surface hardness is 450 HBN

Design bending stress (σ_b) = (1/3) x (σ_u)

= 300 MPa = 3059.15 Kgf/cm^2

Design contact stress (σ_c) = 2.8 x HBN -70 = 2.8 x 450 – 70 = 1190 MPa

= 12134.43 Kgf/cm^2

The basic information about the gear set is given below,

Young's Modulus (E) = 159 E3 MPa = 1621348.78 Kgf/cm^2

Module (m), is taken as 1.25, (i) is the gear ratio Z_2/Z_1 = 26/18 = 1.44

Face width (b) in (cm), = (3-4) times P_c and P_c is circular pitch in (cm)

Also, P_c in (cm) = (π d)/Z = πm = 0.314 x 1.25 = 0.3925 cm

Lewis form factor (y) can be obtained from data book page number 8.53

So, y = 0.308

Pitch diameter (d), = m Z = 1.25 x 18 = 22.5 mm = 2.25 cm.

Strength of gear tooth (F_s) = (σ_b) b^3 y P_c Kgf/cm^2

= 3059.15 x (1.1)^3 x .308 x .3925

= 492.23 Kgf

Transmitted load (F_t) = HP x (75/ V_m); (V_m) is mean velocity in (m/s),

V_m = π d N/60 = (3.14 x 22.5 x 8000)/ (60 x 1000) = 9.42 m/s

Therefore, (F_t) = (7 x 75/ 9.42) = 55.732 Kgf

Now, Dynamic load (F_d) = (F_t) x (C_v) and,

(C_v) is velocity factor and from data book, (C_v) = (6+ V_m)/6 = (6+9.42)/6 = 2.57

Hence, (F_d) = 55.732 x = 143.23 Kgf

Finally, we can see that **(F_s) > (F_d)** hence the **design is safe**.

OR, the chosen planetary gear is fit for usage.

6.2.1.2 Wear strength of gear design

Wear load (F_w) = (d Q k b) and,

(Q) is the ratio factor, (Q) = 2i/ (i+1) = 2 x 1.44/ (1.44+1) = 1.18

Load stress factor (k) = $[(\sigma_c^2)$ x (sin α) x {(1/E) + (1/E)}]/1.4

= $(12134.43)^2$ x (sin 20º) x (2/1621348.78)/1.4

= 44.37 Kgf/cm^2

Now, (F_w) = 2.25 x 1.18 x 44.37 x 1.1 = 129.582 Kgf/cm^2

In case of **severe service**, **Buckingham's dynamic load is given as (F_d)**

$$(F_d) = (F_t) + [\{0.164 \times V_m \times (cb + (F_t))\}/ \{0.164 \times V_m + 1.485(cb + (F_t))^{0.5}\}]$$

The value of cb is obtained from data book page no. 8.53 (cb = 163.075)

= 55.732 + [{0.164 x 9.42 x (163.075 + 55.732)}/{0.164 x 9.42 + 1.485(163.075 + 55.732)$^{0.5}$}]

= 55.732 + 14.37 = 70.10 Kgf

Therefore in case of severe service also we find, **(F_s) > (F_d) also (F_w) > (F_d)**

Hence the design of the planetary gear set chosen for the project is safe.

6.2.2 Design of Shafts

6.2.2.1 Physical properties

Physical properties of material of shafts

1. Usually the shafts are made of steel of grade EN8.
2. The Rockwell hardness of the steel used is 50-55 HRC.
3. The tensile strength (σ_u) of the material used is 700-850 MPa.
4. The machine used to perform all the operations was Horizontal Lathe.

6.2.2.2 Drawing of Shafts

The drawing finalized for the shafts are shown in the following figures 6.11, 6.12 and 6.13. These are drawing keeping into the consideration of dimensions and

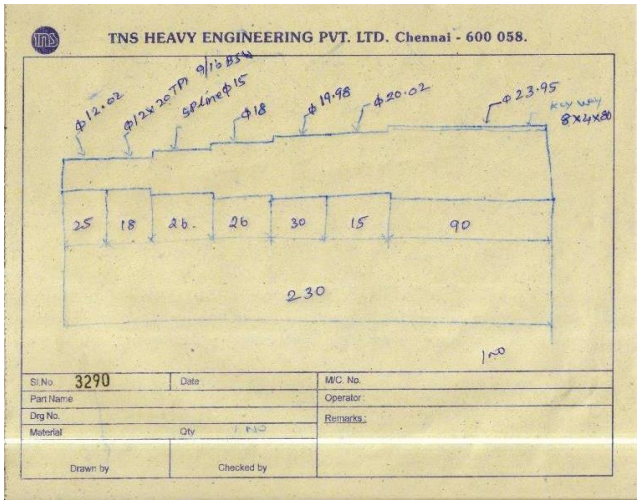

Figure 6.11: Drawing of shaft connected to Sun gear

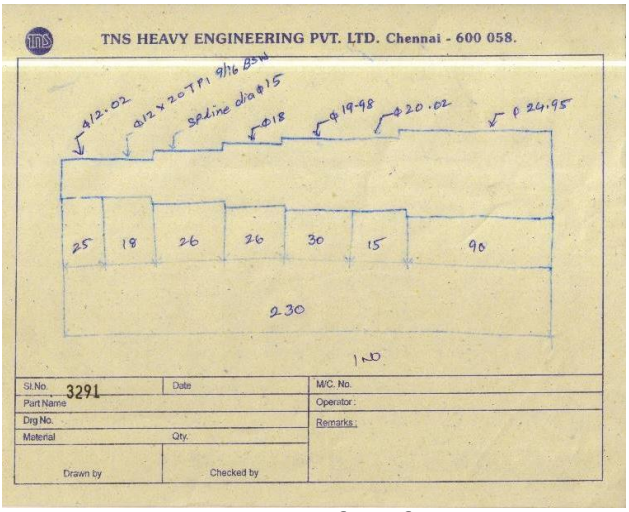

Figure 6.12: Drawing of shaft connected to Planet Gears

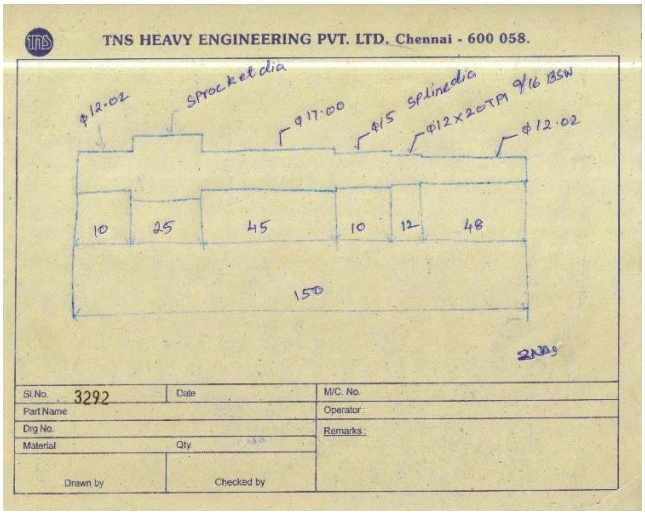

Figure 6.13: Drawing of shafts of CVT

6.2.2.3 Design based on Shear Stress

The torsional shear stress (τ) the shaft can handle is $0.6*\sigma_u = 0.6*800$ MPa

So, $\tau = 480$ MPa.

Maximum engine torque (T) is 8.05 N-m @ 5000rpm.

We know that $T= \pi/16 * \tau d^3$ here, d = (min. shaft diameter)

Therefore d = cube root ($T*16/ \pi/ \tau$)

Cube root (8.05*16/3.14/ 480 E6)

Cube root (8.545 E-8)

d min= 4 mm

It is clearly visible in the diagram that the minimum shaft diameter used is 12.02 mm.

The design of shaft is safe.

6.2.2.4 Operation Performed on Shafts

To bring the dimension according to the drawing the operations performed on the shaft are

1. Operations performed on the lathe were
   1.1. Facing – to reduce the length.
   1.2. Turning – to reduce the diameter.
   1.3. Step turning – to make steps on the shaft
2. A spline cutter was used to cut threads over the shaft. These threads are used to grip the shafts and to drive the component by transmitting power.
3. A shaper machine is used to make keyway.

6.3 Coupling

Coupling is used for couple two shafts together with an aim to transmit motion. It can be done by joint to components permanently or temporarily. Few types of coupling are.

1. Flange coupling
2. Pin bush coupling
3. Gear coupling

4. Key way coupling
5. Fluid coupling

In the project key way coupling has been used to transmit power from one shaft to the planetary gear set. The figures 6.14 and 6.15 show the diagram of a coupling.

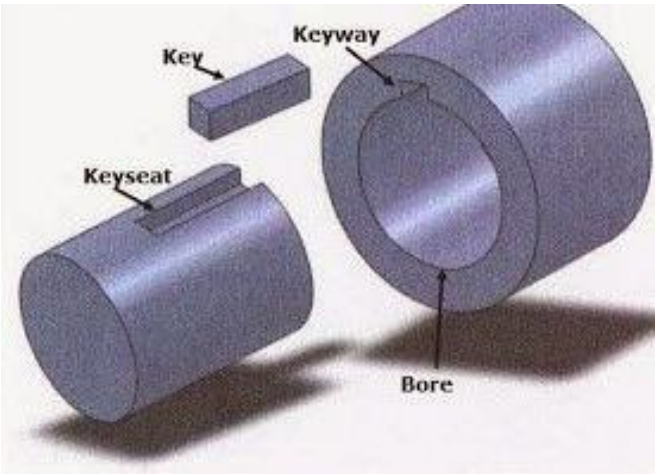

Figure 6.14: Isometric view of coupling

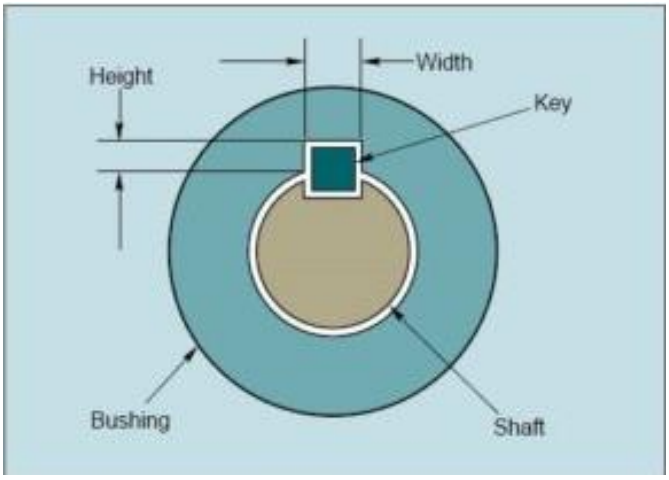

Figure 6.15: Front view of coupling

The dimension of the key way in (mm) is 8x7x80 (b x h x l). The standardized dimension of parallel key and kay ways are taken from PSG design data book page number 5.16.

6.4 Bearing

The bearing used in the project is shown in figure 6.16. are ball bearings. In this type of bearing balls of steel are present to maintain the separation of the races of the bearing. Their main impetus is to reduce rotational friction and to support the shafts radially and axially.

The specification of the bearing used for the project are given below.

6000-2Z Radial Ball Bearing Double Shielded Bore Dia. 10mm OD 26mm Width 8mm

The given figure illustrates a ball bearing.

Figure 6.16: Bearing

6.5 Bearing Holder

The bearing holder is shown in the figure 6.17 are mild steel bars. The bearing and the bearing holder have a tight fit. The bearing is forced by hammer into the holder. The space in the holder is made by milling operation by milling machine and is exact size to that of bearing.

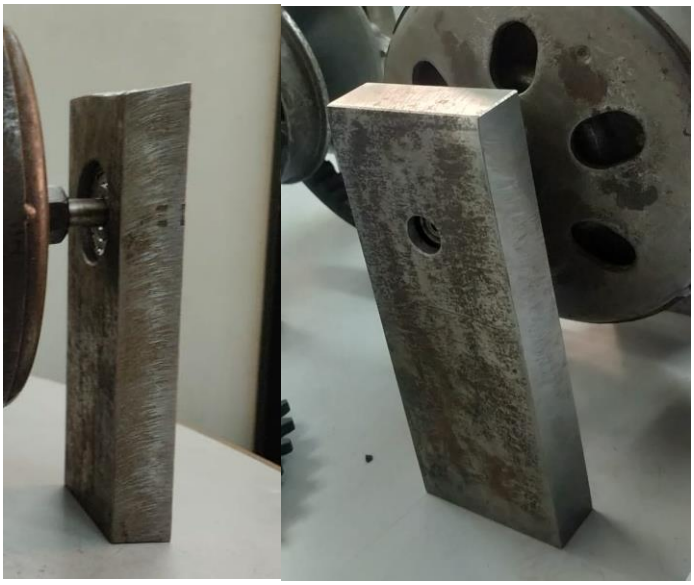

Figure 6.17: Bearing Holders

6.6 Assembly of Components

The components are prepared according to desired dimensions in the drawing. All the necessary steps are taken in order to fulfill the need of components according to proposed layout. The figure 6.18 shows the idea of the proposed assembly.

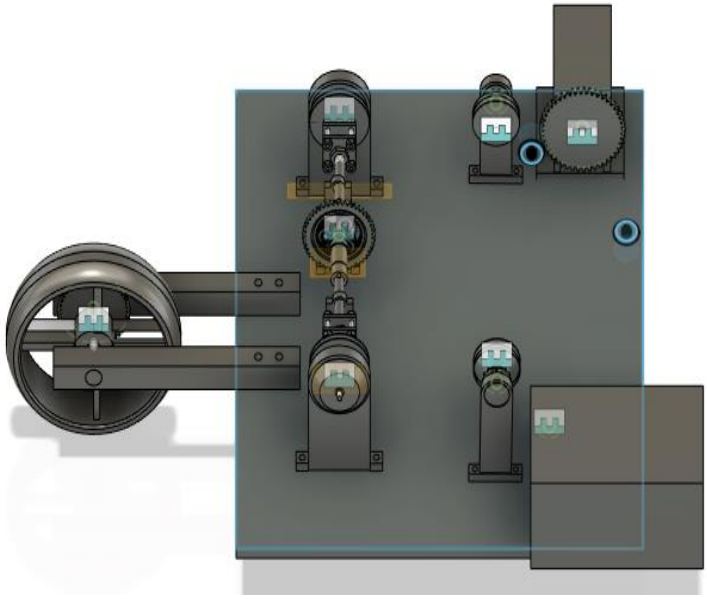

Figure 6.18: Proposed Assembly

Each component is first of all arranged on a board and is then assembled in segments.

1.The power from the engine and motor is given to the driver pulley of CVT via chain drive.

2.Both the driver CVTs are placed in between Holder and is supported by Bearing fitted in them.

3.The driven CVTs are also placed in between the Holders and is also supported by the bearings fitted in them.

4.The driven CVTs are also coupled with the sun and carrier of the planetary gear set via key way coupling.

5.The CVT and chain drive combination which is driven by the EM, delivers power to the sun, whereas the other combination which is driven by the ICE, delivers power to the carrier of the gear set.

6.A sprocket is bolted over the ring gear.

7.All these components are assembled together and placed on a board and checked for errors in the proper functioning.

An error is identified in this process. It was found that the ring gear is slipping axially slightly over the planetary gears. To rectify this error a bearing is placed tightly over the carrier and its housing is placed over the bearing which is then welded to the ring gear. In this way the ring gear is now rotating freely over the planetary gear with a constant distance from one end.

A platform of dimension is (165 x 75 x 0.75) in (cm) is selected to place every component on a platform. The ICE and EM are bolted over this steel platform and all the other components are supported by holders. These holders are placed properly over the platform following the schematic layout and are fixed to it by using shielded metal arc welding (SMAW) welding.

The CVTs are assembled and coupled with carrier as shown in figure 6.19 and the other is coupled with the sun gear as shown in figure 6.20. Figure 6.21 shows the mounting of sprocket over the ring gear with bolts and figure 6.22 shows the complete assembly of CVTs and planetary gear set along with the sprocket bolted for the output at the ring.

Figure 6.19:Assembly of Planet gears with CVT

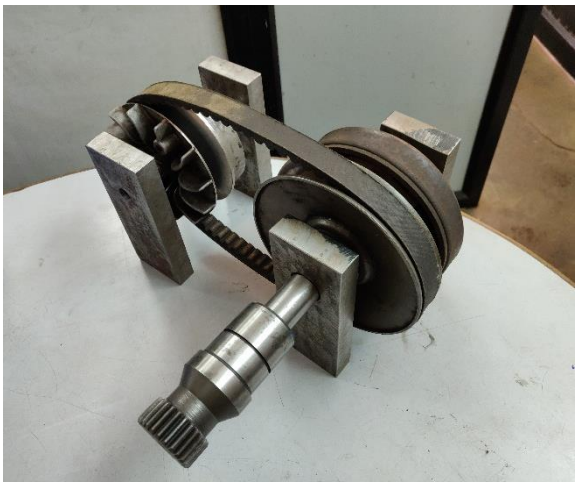

Figure 6.20:Assembly of Sun Gear with CVT

Figure 6.21:Assembly of Ring & sprocket with Planet Gears

Figure 6.22:Assembly of Planetary Gearbox with CVTs

6.7 Welding

Welding was required to permanently fix the fabricated parts and components to the metal base. SMAW welding was used to weld the parts. Parts like all bearing holders were welded to the base metal for rigid support. Also wheel holders were welded to the base to give it strength against the vibration and movement. It was done carefully as any one mistake would risk or damage the part which could create error. The images of the welding process is shown in the figure 6.23, 6.24, 6.25, 6.26.

Engine and motor were not welded to the base. They were mounted tightly using bolts to base. They have however been steady and less vibrant.

Figure 6.23:Welding

Figure 6.24:Welding of bearing holder

Figure 6.25: Welding to metal base

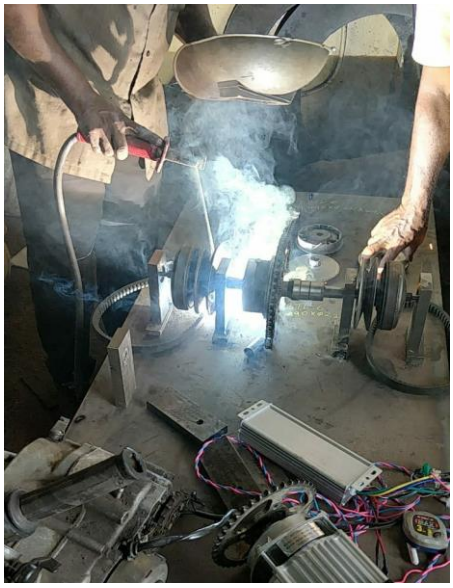

Figure 6.26: Welding different parts

Similarly, rest of the parts were welded and mounted. The image shown in figure 6.27 shows the test run. The complete arrangement and assembly is shown in the figures 6.28, 6.29, 6.30, 6.31, 6.32. These images are taken at different angles to show different components, their assembly and their connection to the next very next component.

Figure 6.27: Complete Assembly test run with motor

As seen in Figure 6.27, a trial run was held by running only motor with the system. As result to it, it was noted that the working is totally functional and valid. After this engine was mounted to the base metal and Figure 6.28 was taken.

Figure 6.28: Complete Assembly-I

Figure 6.29: Complete Assembly-II

As seen, engine is mounted on left side and motor is mounted on right side when viewed from bottom figure 6.31. Chain drives carry the power to shafts connecting CVT, which are connected to shafts coupled with Sun and Planet gears respecrively. The output drive is taken from ring gear through chain drive connecting the wheels.

Figure 6.30: Complete Assembly-III

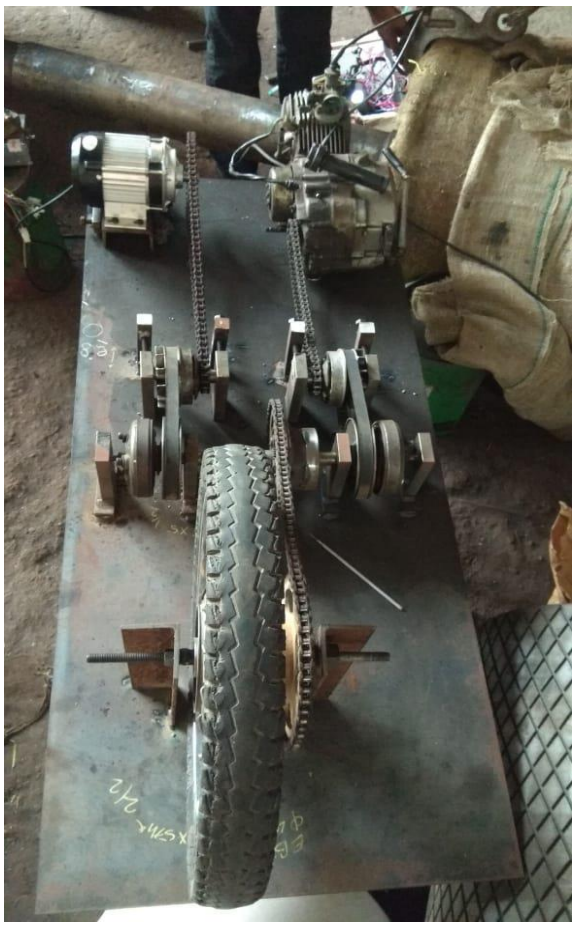

Figure 6.31: Complete Assembly-IV

Figure 6.32: Complete Assembly

During testing it was found that there was slight problem in the engine wires and relays as there is irregularity in the generation of the spark. Although the assembly of all components is complete and the testing has been postponed due to the lockdown .

CHAPTER 7

SIMULATION

The animation is prepared using fusion 360 software. All the components were created with accuracy and their dimension is as close as possible although silght difference is there in the planetary gear set, with the same standard module of 1.25 as used in the fabrication. Sun gear - 24 teeth, 23.3base dia, 30 outer diameter, Planetary gear - outer diameter 33.5, Base dia 25.5, 24 teeth
Ring gears - 60 teeth, base diameter - 92

The animation prepared represents the dual CVT transmission for hybrid vehicles under running conditions. This complete system is used to couple 2 different power sources simultaneously into single shaft. CVTs are used here in this project and they are of great importance this combination of dual CVT helps the power sources delivery high torque and/or rpm as per requirements by the planetary gear set. This shift in delivering of torque and speed of CVT vary according to the speed of the source and requirement by the gears at output. The animation has additional component which is an actuator that can be either hydraulic or solenoid which can be used to set the ratio of CVT instead of depending on centrifugal force of driver shaft this precise setting of the CVT helps to drive and specific gear ratios if required.

The animation is repeated at following speed of CVT1 3000- 7000 rpm and CVT2 2000-5000rpm. For the current hybrid model CVT 1 transfer power between motor and planetary carrier CVT 2 between engine and sun gear and output is obtained by ring gears which is connected to a sprocket of 52 teeth. In a test run when engine is giving an output of 5000 rpm and motor is running at 5000 rpm then the output which was obtained was 3000 rpm from the ring gear. Such system can help in the use of power sources with less torque or rpm to be used to assist in a hybrid system.

Some pictures of the simulation is shown in the figure 7.1,7.2,7.3,7.4.

In the table 1 ts, tp, tr are number of teeth of Sun, Planet and Ring which are 24, 24, 60 respectively. X and y are respective speeds given to sun and carrier respectively and ths table explains how the velocity of each component varies with the involvement of new input X and y.

Table 7.1 shows the tabulation method used to calculate the velocities of different components of Planetary Gear Set.

Operation	Spider/ Carrier "L"	Sun (S) ts	Planet (P) tp	Ring (R) tr
Arm L is locked and Sun 'S' is given +1	0	+1	-ts/tp	(-ts/tp)(tp/tr)
Multiply by "X"	0	X	(-ts/tp)X	(-ts/tr)X
Add "y" to all columns	y	y+X	y-(ts/tp)X	y-(ts/tr)X

Table 7.1: Method to find velocity ratios

Table 7.2 shows the final resulting linear equation which can be solved using different input values of X and y.

Carrier	Sun	Planet	Ring
	X	-X	-0.4X
y	y+X	y-X	y-0.4X

Table 7.2: Linear equation for velocity ratio

These calculations are done for the simulation.

Now, lets take Engine Speed to be 1000 rpm and motor speed to be 1500 rpm.

The CVT used in the simulation has a range of 0.268 to 3.727 to change the speed intput given.

Thus, engine output at the end of CVT is a minimum of 268.29 rpm and maximum of 3727.27 rpm

Similarly, Motor output at the end of CVT is a minimum of 402.439 rpm and Maximum of 5590.90 rpm.

Therefore, for planetary gear set the input values are obtained.

In the simulation engine is powering the carrier (y) and motor is powering sun (X).

Hence taking the maximum speeds as input of gearset we have,

$$\text{The velocity of ring} = y - 0.4 \times X$$
$$= 3727.27 - 0.4 \times 5590.90$$
$$= 1490.91 \text{ rpm.}$$

Thus with a set of engine speed and motor speed four output speeds are possible if CVTs were set to work at extreme speeds.

The figures 7.1, 7.2, 7.3 and 7.4 represent the simulation layout from different angles.

Figure 7.1 depicts sprocket in green colour, clutch in black colour also the driven pullies are shown here connected and powering the shafts.

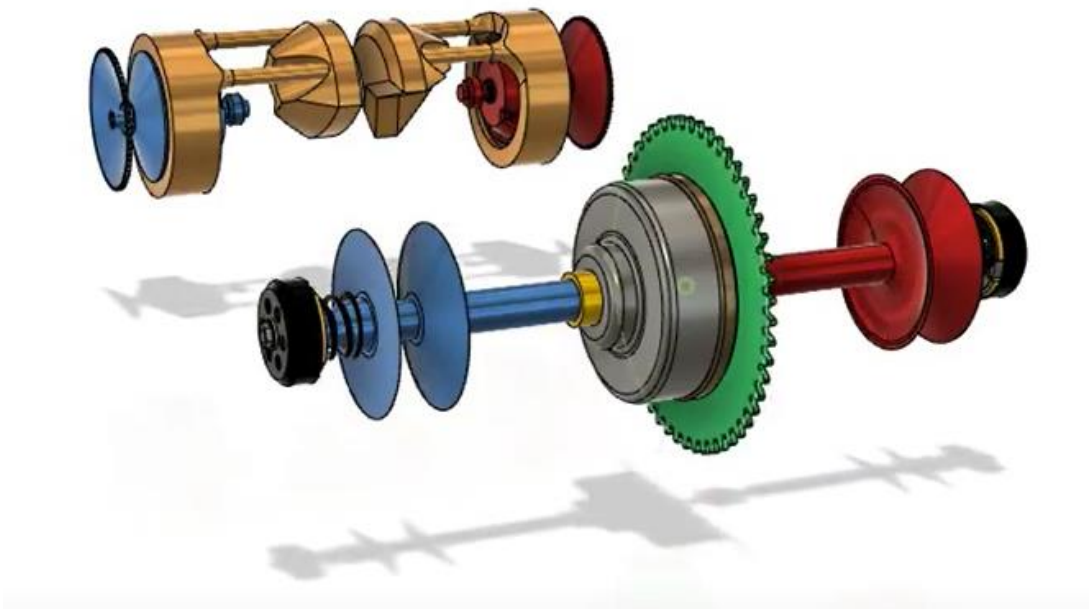

Figure 7.1: Simulation Presentation-I

The figure 7.2 depicts the meshing of sun, planetary and ring gear in dark grey colour.

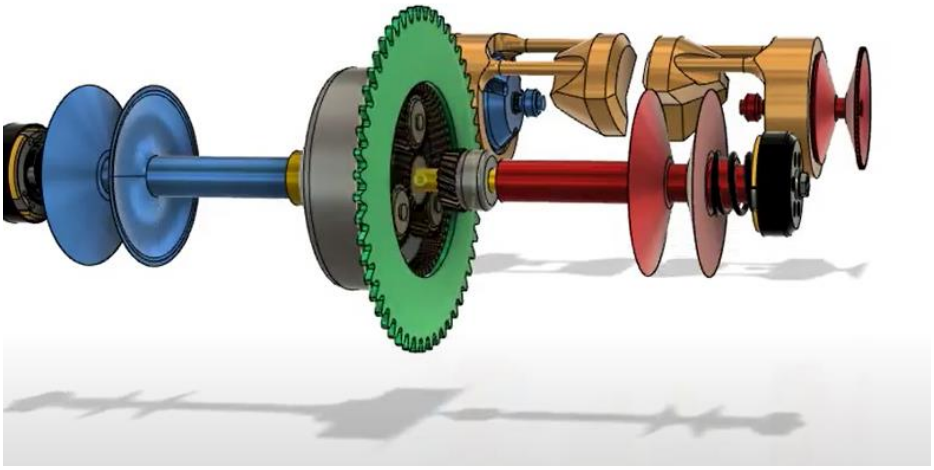

Figure 7.2: Simulation Presentation-II

The figure 7.3 displays the bearing housing, also it is clearly visible that the blue coloured shaft is connected to the golden coloured planet carrier via a hidden keyway coupling. Also the the blue coloured pullies are a part of CVTs powered by EM and similarly red ones are powered by ICE.

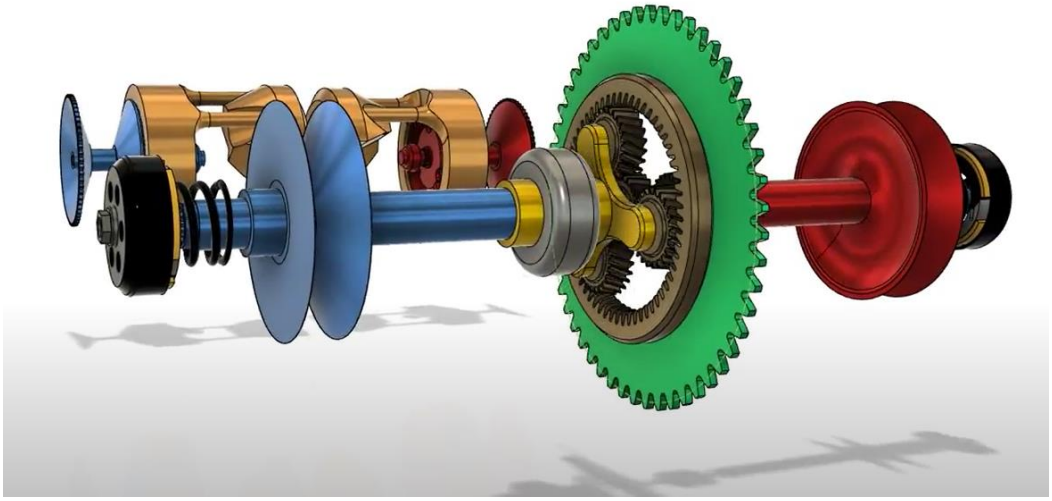

Figure 7.3: Simulation Presentation-III

In the figure 7.4 the brown part is the actuator which is usually hydraulic. These are responsible for controlling the diameter of the driving pullies of the CVTs hence controlling the speed and torque of the engine.

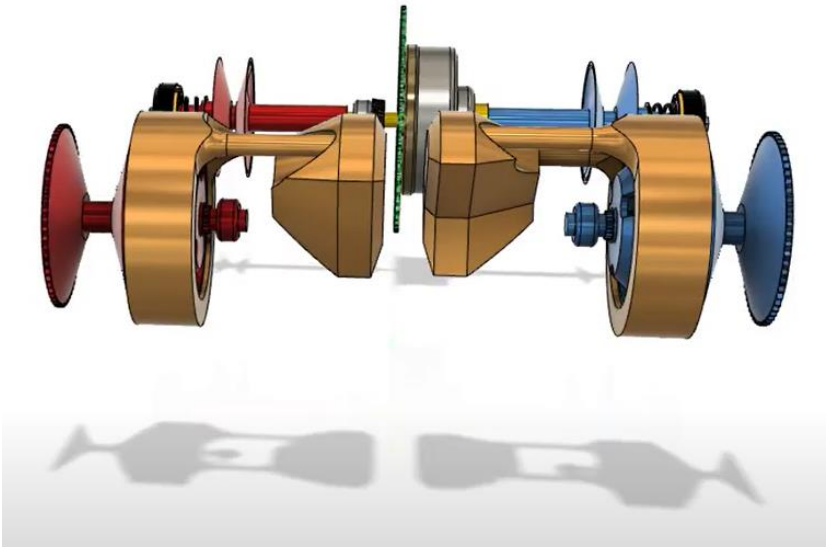

Figure 7.4: Simulation Presentation-IV

CHAPTER 8

FUTURE WORK

Future work of this project can be related to many aspects. Firstly, main aspect would be more and more existing automobile industries trying to adapt this technology. Existing automobile industries trying to think this as an innovative and excelling technology which can be highly utilized in fulfilling many aspects of modern technologies. Use of both engine and motor makes it a unique type of hybrid system.

Many hybrid system do exist but this one is unique as here the concept of using planetary gearbox is used to combine both the power sources and a final combined output is achieved. The drive also involves the usuage of CVTs which is used to attain infinite gear ratios depending on the speed and troque. It involves using a simple concept to attain an environmental friendly solution, as it uses less fuel then already existing technologies. Mileage to the vehicle can increase by using this technology. Few modifications can be made later in the setup as required. Automobiles can jump on to new technology dealing with current situation. It is economical, ecologial and modern solution to the problems arising.

With increased budget and resources a proper schematic tunning between the usuage of power from ICE and EM is possible based on speed and driving condition. This can be done using sensors and electronics.

It can also be used to create many more new technologies using similar or somewhat similar design and idea of this technology or project. Innovative ideas can lead to better future. This technology can be studied by juniors and also they can contribute by modifying it or adding certain valuable components to make this technology expand in automobile sector.

CHAPTER 9

CONCLUSION

The purpose of the project is to demonstrate a working model of a dual input hybrid electric power train using dual CVTs and the model has been sucessfully fabricated, due to lockdown the testing of the project let alone remain. The project is expected to couple shafts into a single shaft and give the desired output. The CVT put to use vary the torque and speed accordingly as required by the driving conditions. Fusion 360 software has been used to simulate the working of the project. Based on simulated model below mentioned expected results are obtained. The expected results as calculated above in the simulation section with the input speed of engine at 1000 rpm and input speed of motor at 1500 rpm the output at the ring gear as calculated is 1490.91 rpm.

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