Table of Contents

Topic Name *Page No.*

CHAPTER 01

INTRODUCTION

CHAPTER 02

MODIFICATION IN VALVE ACTUATION MECHANISM

CHAPTER 03

EXPERIMENTAL SETUP

CHAPTER 04

INTEGRATION OF SOFTWARE AND HARDWARE

CHAPTER 05

PERFORMANCE AND EVALUATION

CHAPTER 06

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 01

INTRODUCTION

1.1 Overview Of Cam Technology

The cam has been an integral part of the IC engine since its invention. The cam controls the breathing channels of the IC engines, that is, the valves through which the fuel air mixture (in SI engines) or air (in CI engines) is supplied and exhaust driven out. Recently due to demands for better fuel economy, more power, and less pollution, motor engineers around the world are pursuing a radical camless design that promises to deliver liberation from a constraint that has handcuffed performance since the birth of the internal-combustion engine more than a century ago. Camless engine technology is soon to be a reality for commercial vehicles. In the camless valve train, the valve motion is controlled directly by a valve actuator. There's no camshaft or connecting mechanism.

The engines powering today's vehicles, whether these burn gasoline or diesel fuel, rely on a system of valves to admit fuel and air to the cylinders and let exhaust gases escape after combustion. Rotating steel camshafts with precision-machined egg-shaped lobes, or cams, are the hard-tooled brains of the system. They push open the valves at the proper time and guide their closure, typically through an arrangement of pushrods, rocker arms, and other hardware. Stiff springs return the valves to their closed position. In an overhead camshaft engine, a chain or belt driven by the crankshaft turns one or two camshafts located on top of the cylinder head. A single overhead camshaft design uses one camshaft to move rockers that open both inlet and exhaust valves. The double overhead camshaft, or twin-cam, setup devotes one camshaft to the inlet valves and the other to the exhaust valves.

1.2 History of Camless Engine

The first camless engine was built in 1999. Siemens VDO Automotive, in partnership with BMW, built a prototype camless engine. In place of cams it used solenoids, electromagnetically controlled plungers, which were already widely used in cars for things like electronic door locks. The prototype engine was installed in a 3-series BMW sedan. It worked, but had several significant shortcomings. BMW's work proves that it is feasible to control the exhaust valves of an engine using electromagnets.

Push solenoids were selected after considering several alternatives for actuating the engine's valves because they provided simplicity of design which is an important consideration for the project. It allowed an easy way to test the engine and see where future research could go in redesigning the actuators. For the project it was chosen to keep the camshaft timing as a reference to know when the solenoids needed to be actuated.

Originally, camless engine were developed for use as a design aid to automotive engine manufacturers. The use of a camless engine allowed the engineers to experiment with valve timing as a means of designing cam profiles. These early units were not limited by dimensional or power consumption restraints. Instead, these were entirely developed for laboratory use as a design tool.

Aside from laboratory use, history shows that idea of a camless IC engine had its origins as early as 1899, when designs of variable valve timing surfaced. It was suggested that independent control of valve actuation could result in increased engine power. Recently the focus of increased power has broadened to include energy savings, pollution reduction and reliability.

Camless valvetrain have long been investigated by several companies including Renault, BMW, Fiat, Valeo, General motors, Ricardo and Ford. Some systems are commercially available.

1.3 Aim of the Project

To replace mechanically operated valves system by electronic operation in a reciprocating engine.

1.4 Objectives of the Project

This project specifically intends to design an electronically controlled valve mechanism to

- Eliminate gear, pulley and shaft mechanism
- Improve efficiency of the engine
- Reduce fuel consumption

1.5 Working of conventional engine

1.5.1 Push Rod Mechanism

Pushrod engines have been installed in cars since the dawn of the horseless carriage. A pushrod is exactly what its name implies, a rod that goes from the camshaft to the top of the cylinder head which open the valves for the passage of fuel air mixture and exhaust gases. Each cylinder of a pushrod engine has one rocker arm that operates the valves to bring the fuel air mixture and another arm to control the valve that lets exhaust gas escape after the engine fires. There are several valve train arrangements for a pushrod.

1.5.1.1 Crankshaft

Crankshaft is the engine component from which the power is taken. It receives the power from the connecting rods in the designated sequence for onward transmission to the clutch and subsequently to the wheels. The crankshaft assembly includes the crankshaft and bearings, the flywheel, vibration damper, sprocket or gear to drive camshaft .

1.5.1.2 Camshaft

The camshaft provides a means of actuating the opening and controlling the period before closing, both for the inlet as well as the exhaust valves, it also provides a drive for the ignition distributor and the mechanical fuel pump. The camshaft consists of a number of cams at suitable angular positions for operating the valves at approximate timings relative to the piston movement and in the sequence according to the selected firing order. There are two lobes on the camshaft for each cylinder of the engine; one to operate the intake valve and the other to operate the exhaust valve.

1.5.1.3 Working of Engine

When the camshaft turns the cam lobs come under the valve lifter and cause the lifter to move upwards. The upward push is carried by the rocker arm. The rocker arm is pushed by the pushrod, the other end moves down. This pushes down on the valve stem and cause it to move down thus opening the port. When the cam lobe moves out from under the valve lifter, the valve spring pulls the valve back upon its seat. At the same time stem pushes up on the rocker arm, forcing it to rock back. This pushes the push rods and the valve lifter down, thus closing the valve. The figure-1.1 shows cam-valve arrangement in conventional engines, figure 1.2 shows push rod mechanisms.

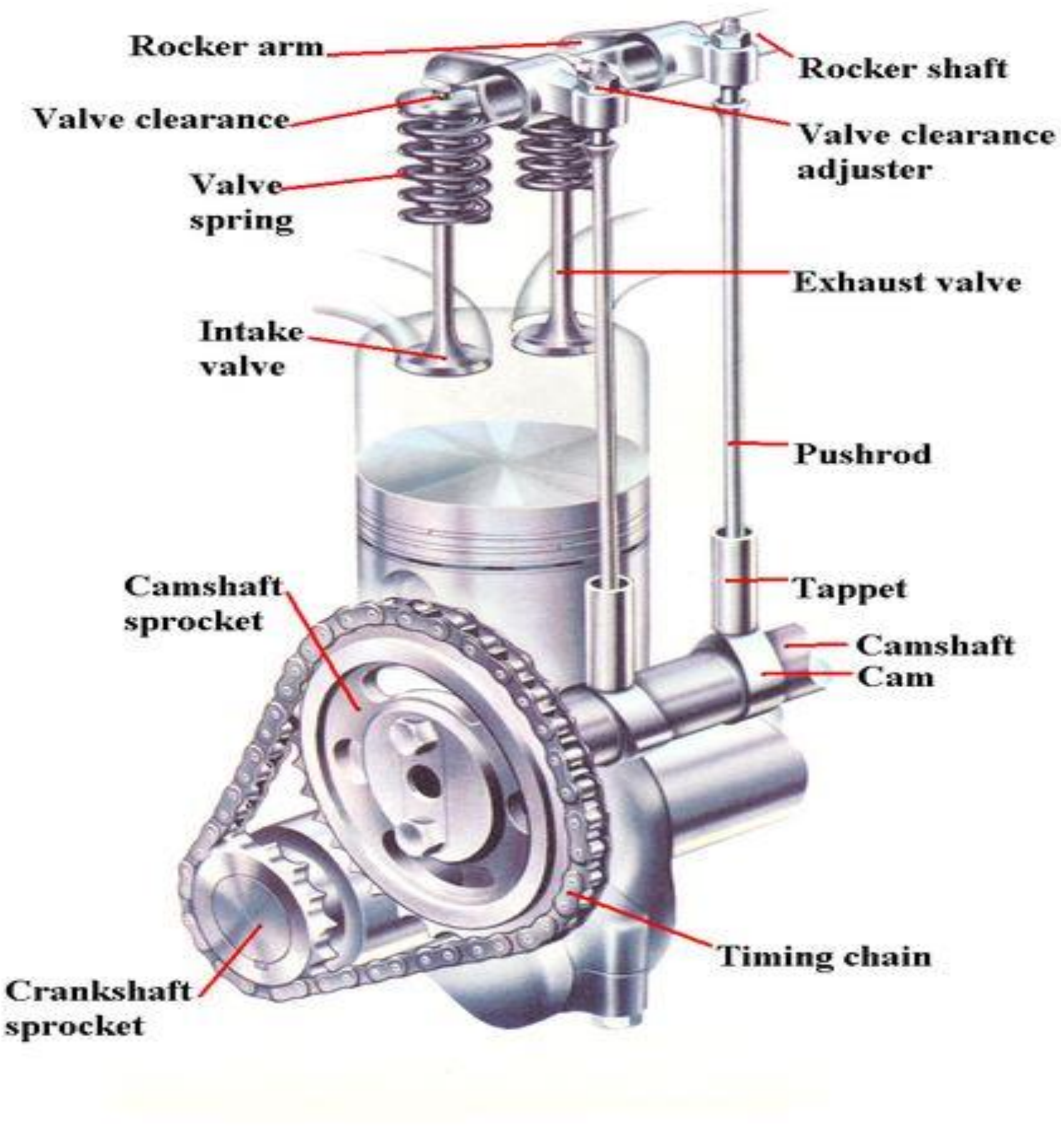


Figure 1.1: Cam Valve Arrangement in Conventional Engine

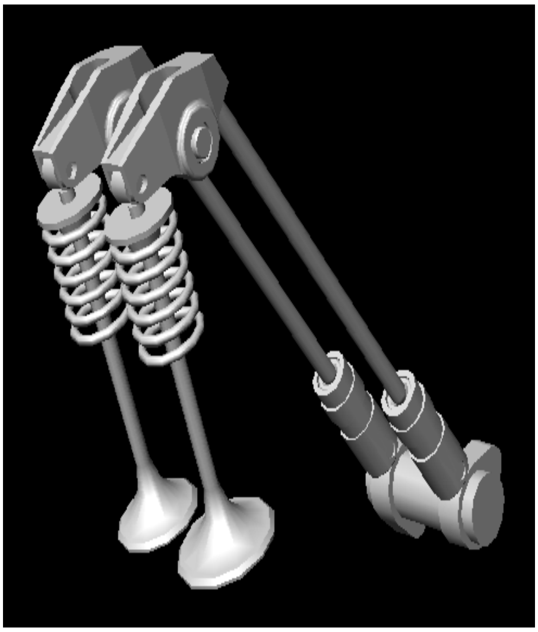


Figure 1.2: Push Rod mechanism

Since the timing of the engine is dependent on the shape of the cam lobes and the rotational velocity of the camshaft, engineers must make decisions early in the automobile development process that affect the engine's performance. The resulting design represents a compromise between fuel efficiency and engine power. Since maximum efficiency and maximum power require unique timing characteristics, the cam design must compromise between the two extremes.

This compromise is a prime consideration when consumers purchase automobiles. Some individuals value power and lean toward the purchase of a high performance vehicle, while others value fuel economy and vehicles that will provide more miles per gallon.

Recognizing this compromise, automobile manufacturers have been attempting to provide vehicles capable o-f cylinder deactivation, VVT, or VCT. These new designs are mostly mechanical in nature. Although they do provide an increased level of sophistication, most are still limited to discrete valve timing changes over a limited range.

1.6 Existing Technology Limitations and its Replacement

Most four-stroke piston engines today employ one or more camshafts to operate poppet valves. The lobes on the camshafts operate cam followers which in turn open the poppet valves. A camless engine uses electromagnetic actuators to open the poppet valves instead. Actuators can be used to both open and close the valves, or an actuator open the valve while spring closes it.

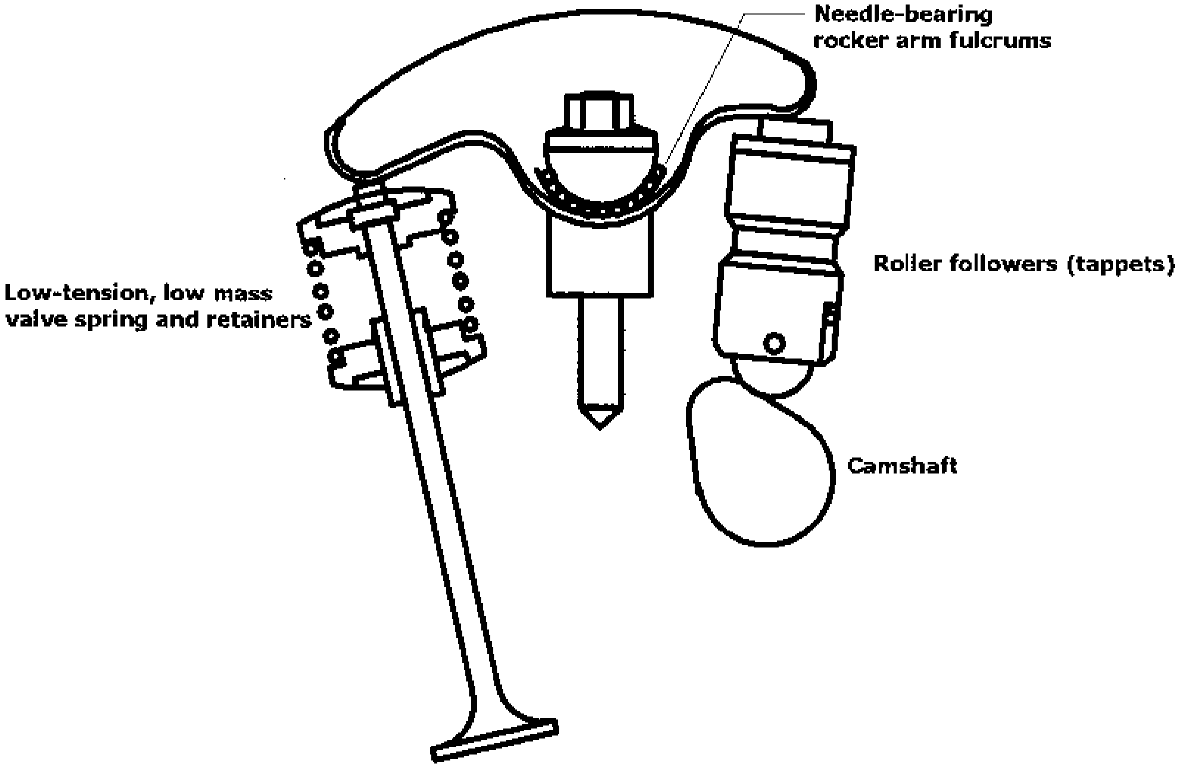


Figure 1 .3: Cam Shaft Operated Valves

As a camshaft normally has only lobe per valve, the valve displacement and lift is fixed. The camshaft runs at half the crank speed. Although many modern engines adjust the lift and valve displacement in a working engine but it is difficult. Some manufacturers use systems with more than one cam lobe, but this is still a compromise as only a few profile can be in operation at once. This is not the case with a camless engine, where lift and valve timing can be adjusted freely from valve to valve and from cycle to cycle switching off the cylinder entirely.

Automobile manufacturers have recognized the compromises associated with engines that are governed by the rotation of a camshaft. This rotation, the speed of which is proportional to the engine's speed, determines the timing of the engine valves. For this reason, engineers must make a decision in the design process that dictates the performance of the automobile. The engine will either have powerful performance or increased fuel economy, but with the existing technology, it is difficult to achieve both, simultaneously.

In response to the needs of improved engines, some manufacturers have designed mechanical devices to achieve some variable valve timing. These devices are essentially camshafts with multiple cam lobes or engines with multiple camshafts. For example, the Honda VTEC uses three lobes, low, mid, and high to create a broader power band. This does represent an increased level of sophistication, but still limits the engine timing to a few discrete changes.

1.7 Disadvantages of Camshaft Technology

Disadvantages of camshaft are as under:

- It consumes power of the engine
- Size of the engine is increased
- Weight of the engine is increased
- With the presence of camshaft engine performance is affected from 5% to 10%
- Friction between the mechanical parts
- Complicated design

CHAPTER 02

MODIFICATION IN VALVE ACTUATION MECHANISM

2.1 Introduction to Camless Valve Actuation Mechanism

Camless Valve Actuation is a new improved technology in which mechanical linkages such as rocker arm, camshaft and gears are removed and replaced by electro-mechanical actuators to actuate the valves. Actuators are coupled with inlet and exhaust valves of the engine, and these inlet and exhaust valves are opened and closed at an appropriate timing using a control system

2.2 Arrangement of electromechanical actuators

The arrangement of the electromechanical valve actuator solenoid is shown in the design below. The design shows the modified cylinder head. Electromechanical valve actuators are placed over the modified head and engine valve is coupled with solenoid.

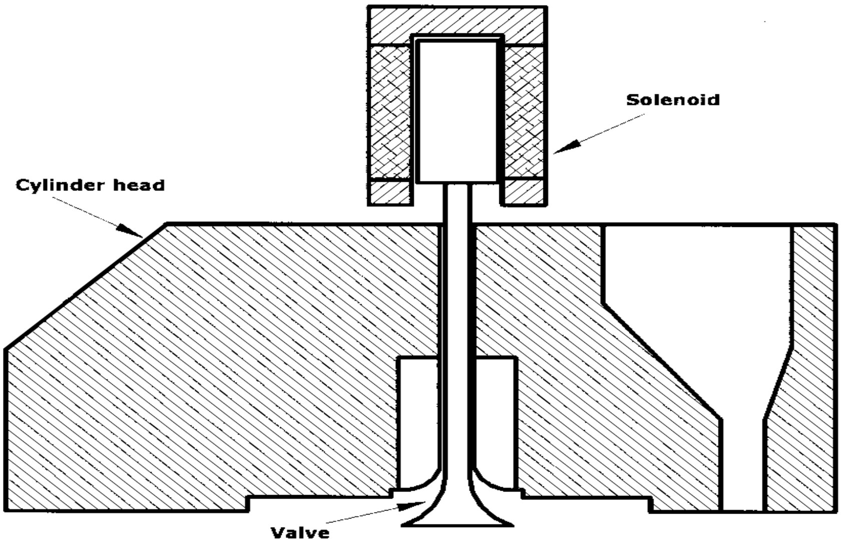


Figure 2.1: Arrangement of electromechanical actuators

2.3 An Overview of Camless Valve Actuation Mechanism

To eliminate the camshaft, rocker arm and other connected mechanisms, the camless engine makes use of three vital components the sensors, the electronic control unit and the actuator

Proximity sensors will send signals to the electronic control unit. The electronic control unit consists of a microprocessor, the microprocessor issues signals which in turn controls the actuator, to function according to the requirements.

2.4 Selection of Engine

Selection of engine was the first important step to start the project. The following points were considered while selecting an engine:

- As this project is just a prototype so it was decided to use an engine with a single cylinder which was a logical decision
- A 4x stroke engine was selected because it works using valve arrangement.
- It was a cheaper choice as compared to a multi cylinder engine.
- Simplicity in design
- Widely available as per spare parts

So a Honda CD-70 3.5 HP engine was chosen to demonstrate the given project.

2.5 Honda CD-70 Engine's Specifications

Honda CD-70 3.5 HP engine was chosen to demonstrate the given project.

Technical Specifications	
Engine Type	4-stroke single cylinder air cooled engine
Displacement volume	72 cm^3
Bore & Stroke	47 x 41.4 mm
Compression Ratio	8.8 : 1
Maximum RPM	11500
Net Power output	3.5 HP
Net Torque	14 N-m

Table 2.1: Technical Specifications

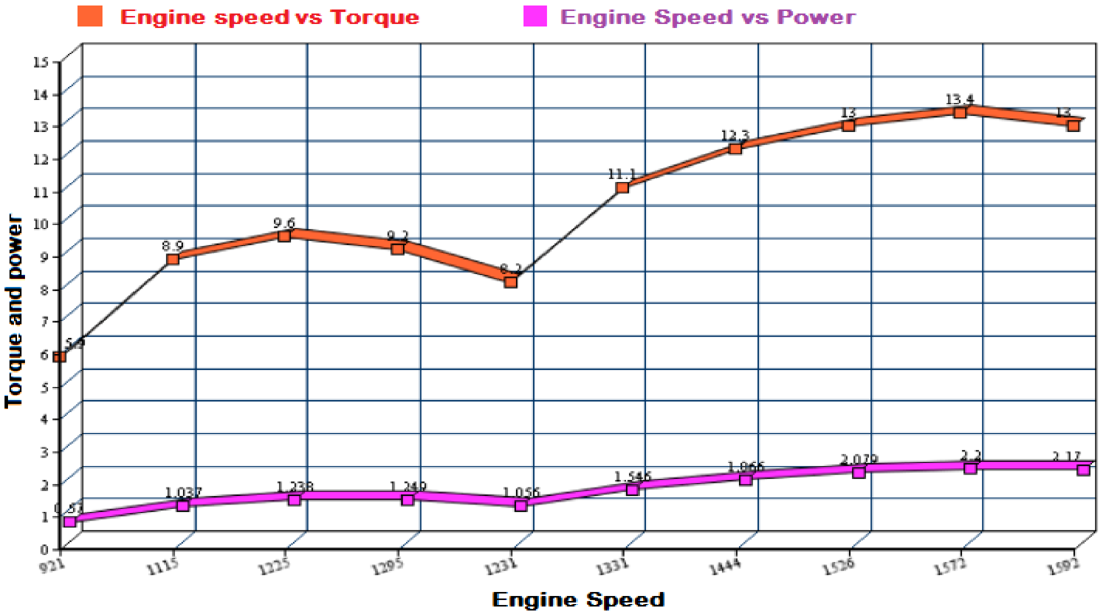
2.6 Analysis of Engine

The following tests were performed in laboratory evaluating the engine on the basis of power produced by the engine, the pressure produced in the combustion chamber during low load, high load and partial load conditions and the fuel consumption of the engine was measured accordingly while taking in to account the surrounding temperature of the lab the results obtained are shown below:

Engine speed, torque and power		
Speed (RPM)	**Torque (N-m)**	**Power (kw)**
921	5.9	0.57
1115	8.9	1.03
1225	9.6	1.23
1295	9.2	1.24
1231	8.2	1.05
1331	11.1	1.54
1444	12.3	1.86
1526	13.0	2.07
1572	13.4	2.20
1592	13.0	2.17

Table 2.2: Engine Speed, Torque and Power

Note: Load is constant, 500 Watt (Electric Load)



Graph 2.1: Speed vs. Torque and Speed vs. Power

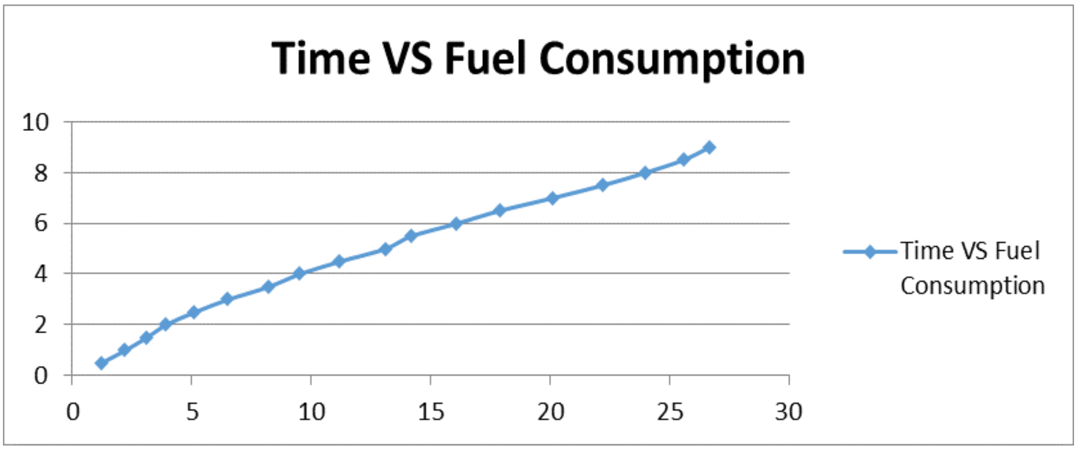
This Graph shows the experimental relationship between the speed, torque and Power. The values of these parameters are taken from the engine test bed with installed cam. The graph shows when the speed increased gradually the torque will also increases. After this applied full load at different speed hence the torque started to decrease.

Readings were taken at 1500 RPM for determining the amount of fuel consumption over a period of 5 minutes and following results were obtained.

Time vs. Fuel Consumption

Time (minute)	Fuel consumption (grams)	Fuel consumption (liters)
0.5	1.2	0.0012
1	2.2	0.0022
1.5	3.1	0.0031
2	3.9	0.0039
2.5	5.1	0.0051
3	6.5	0.0061
3.5	8.2	0.0082
4	9.5	0.0095
4.5	11.2	0.0112
5	13.1	0.0131

Table 2.3: Time vs. Fuel Consumption



Graph 2.2: Time vs. Fuel Consumption

By comparing the relationship between the time and fuel experimentally, these graphs show when the time increases the fuel consumption will also increase at different speeds of engine.

2.7 Calculation for Solenoid Installation

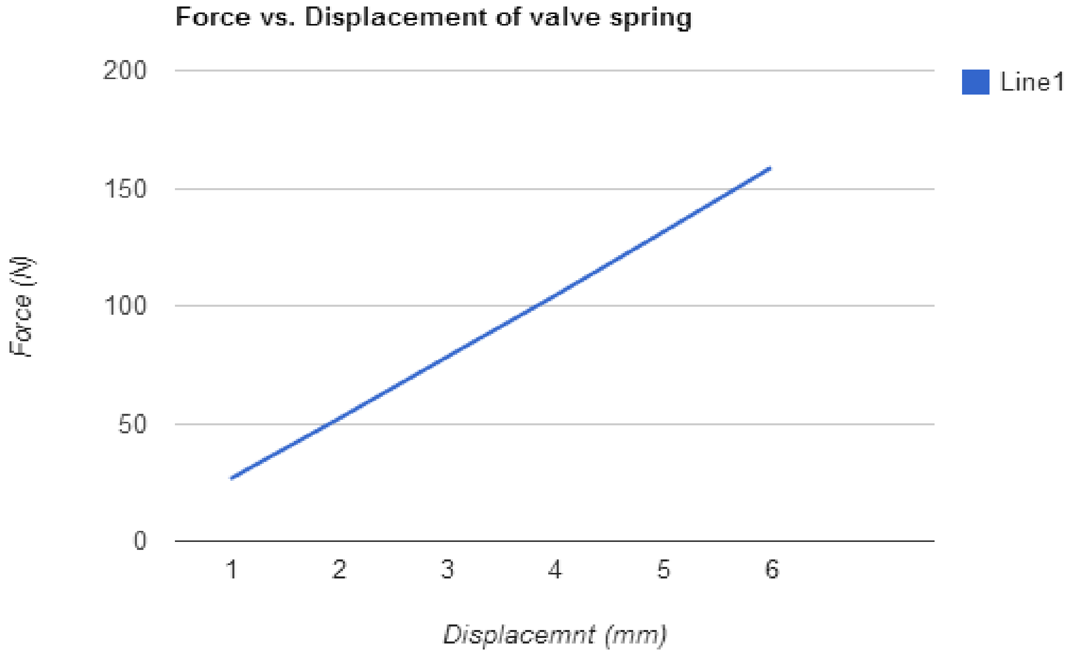
2.7.1 Measuring the spring constant

Spring constant for the solenoid is calculated by measuring the deflection against the forces applied on the spring and then the solenoid was selected against that spring constant.

Force vs. Displacement of valve spring

Load	Displacement	Force	Spring Constant
2.7Kg	1 mm	26.46 N	26.46 N/mm
5.3 Kg	2 mm	51.94 N	25.97 N/mm
7.98 Kg	3 mm	78.20 N	26.06 N/mm
10.64 Kg	4 mm	104.27 N	26.06 N/mm
13.4 Kg	5 mm	131.32 N	26.26 N/mm
16.2 Kg	6 mm	158.76 N	26.46 N/mm

Table 2.4: Force vs. Displacement of valve spring



Graph 2.3 Force vs. Displacement of Valve Spring

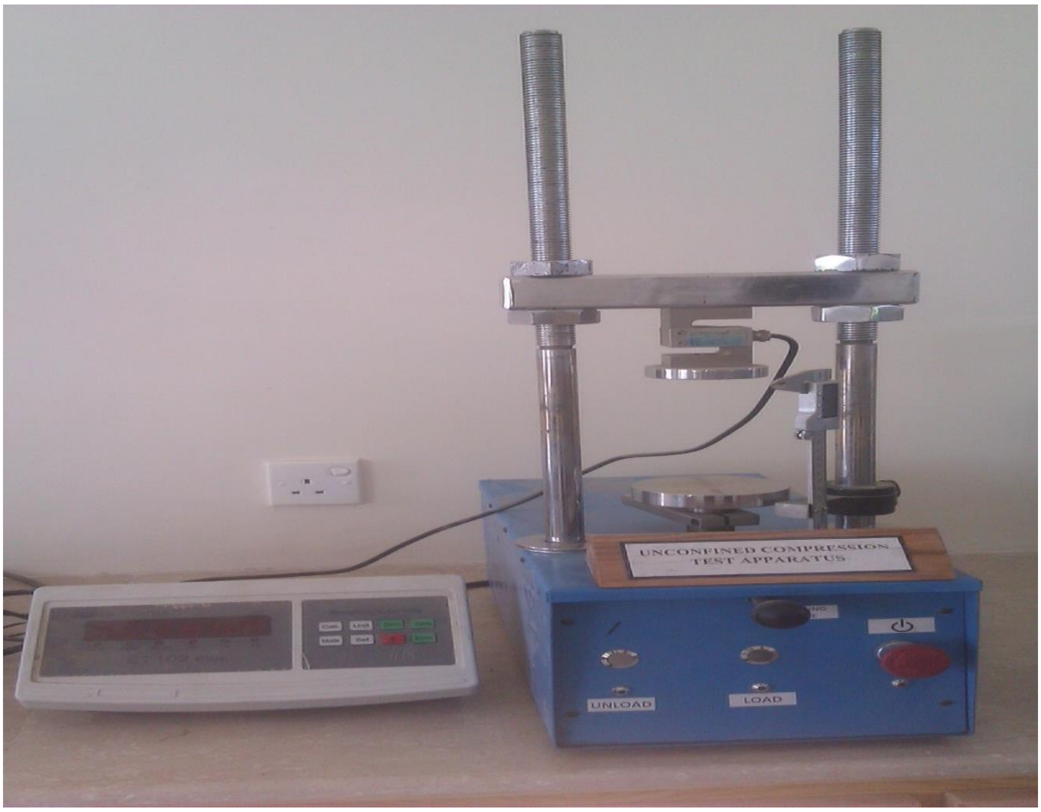


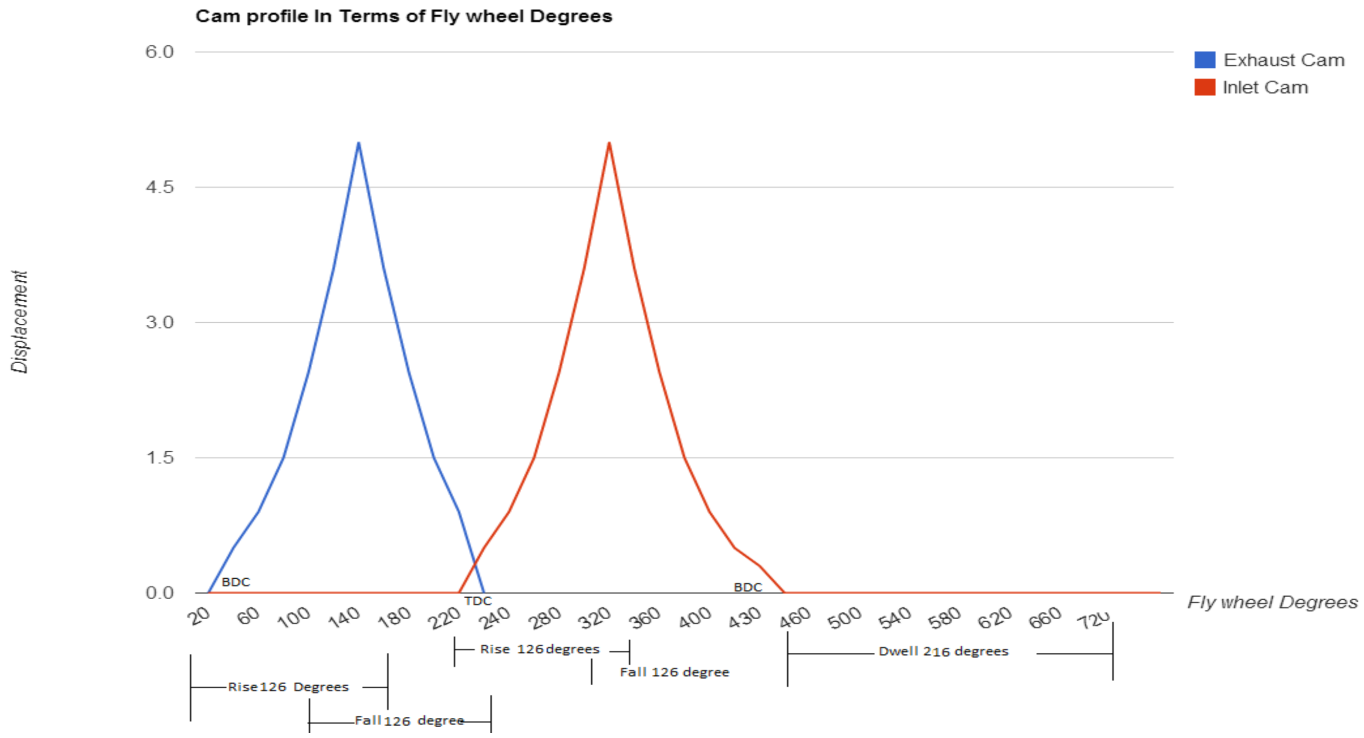
Figure 2.2 Spring Compression Measuring Apparatus

2.8 Cam Profile

Inlet valve displacement (mm)	Camshaft angles (degree)	Exhaust valve displacement (mm)	Camshaft angles (degree)
0	105	0	0
0.5	115.5	0.5	10.5
0.9	126	0.9	21
1.5	136.5	1.5	31.5
2.45	147	2.45	42
3.6	157.5	3.6	52.5
5	168	5	63
3.6	178.5	3.6	73.5
2.45	189	2.45	84
1.5	199.5	1.5	94.5
0.9	210	0.9	105
0.5	220.5	0.5	115.5
0	231	0	126

Table 2.5: Cam Shaft Rotation With Valve Displacement

Took the cam of engine and drew the cam profile by using the dial gauges with protector. This profile shows the different angles of the cams which are used for opening and closing the valve.



4.7 Method Used For Cam Profiling

- First took off the head casing of the engine in order to expose the cam assembly.
- Adjusted the top dead center marking on the fly wheel with the top dead center marking on the engine body and patched the degree wheel on the fly wheel
- Confirmed the top dead center ,bottom dead center and the engine valve timing given by the manufacturer by rotating the fly wheel
- Prepared a fastening assembly in order to attach the dial gauge firmly in the desired position so the tip of the dial gauge rests on the cam surface
- Set the pointer on the dial gauge to its zero position after placing the tip on the cam where it provides no lift to the valve
- Rotated the fly wheel in the counter clockwise direction and took reading of the valve lift provided by the cam profile after equal intervals and drew the cam profile using graphing techniques in Microsoft excel
- Repeat the same procedure for both the inlet and the exhaust cams and take at least 10 reading to make an acceptable cam profile that clearly shows the rise and fall angles.

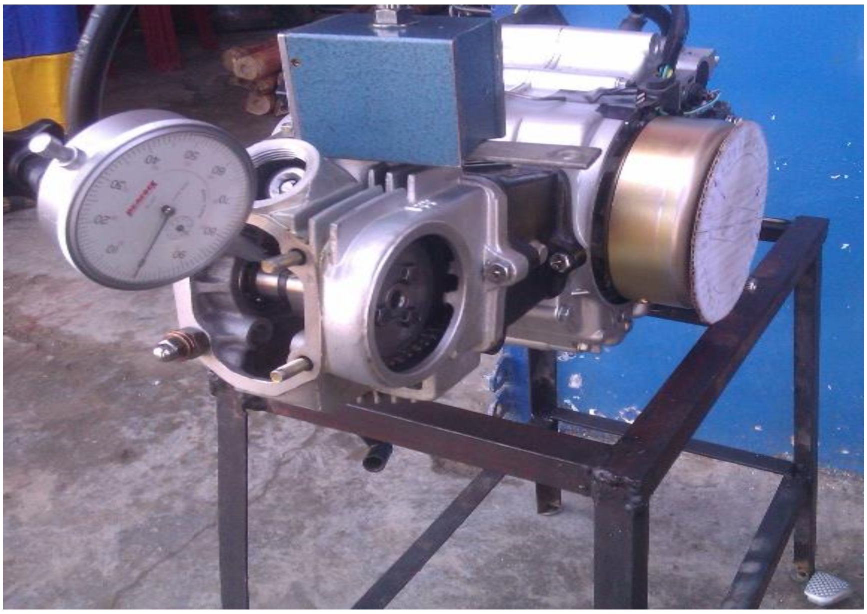


Figure 2.3: Cam Profiling Measuring

CHAPTER 03

EXPERIMENTAL SETUP

3.1 **Modification**

Following tasks were needed to be performed before taking the readings for the experiment.

- Removal of cam
- Installation of solenoid
- Adjustment of intake and exhaust valves
- Making of Teflon weightless flywheel
- Measuring and installation of metal strips on flywheel
- Installation of sensors
- Programming
- Installation of micro-processors and electrical circuit

3.1.1 Removal of Cam

Head of the engine was removed from the engine so that cam could be eliminated from it and solenoid could be installed.

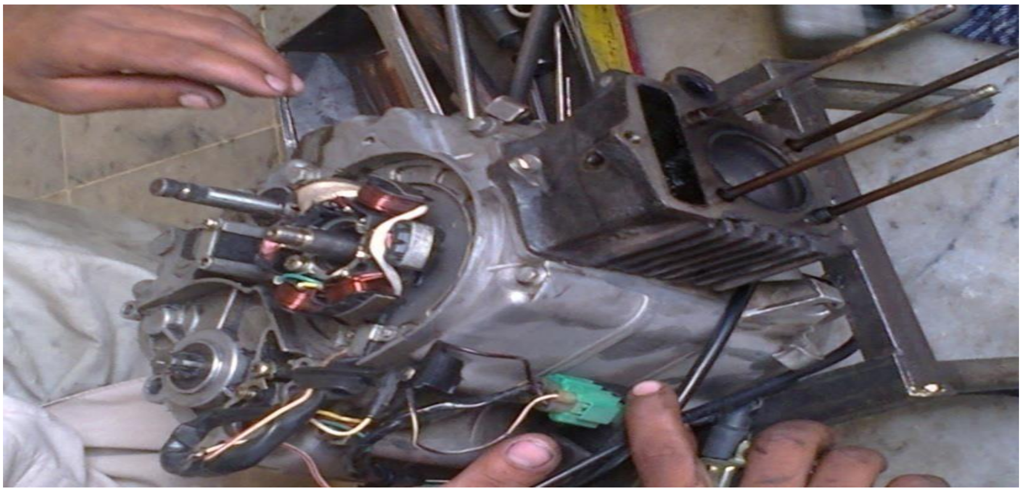


Figure. 3.1: Removal of Head Engine

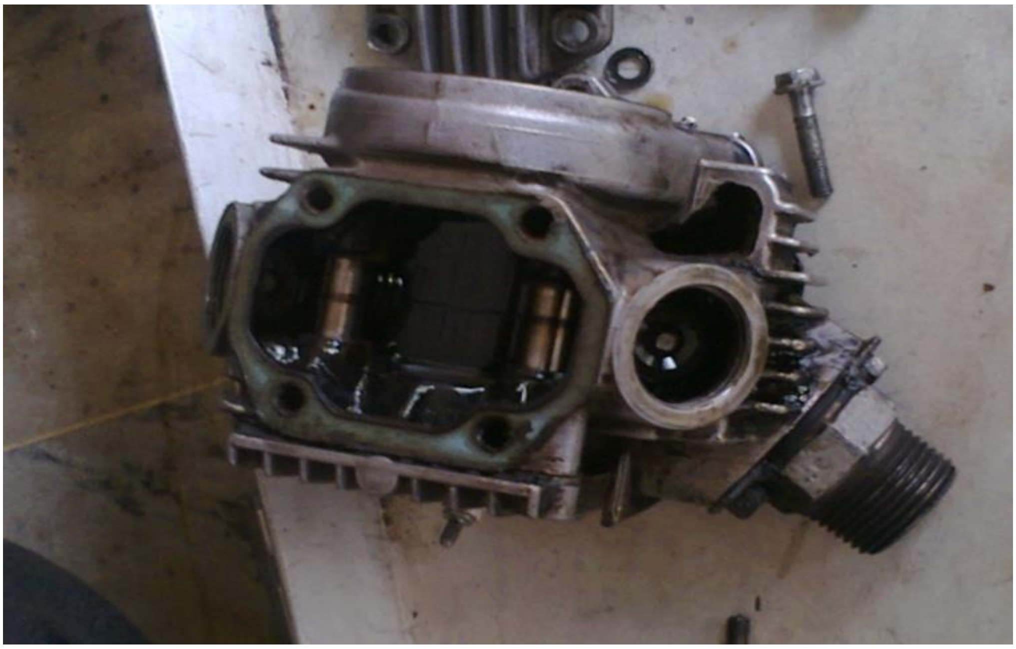


Figure 3.2: Removal of Camshaft from Head of the Engine

3.1.2 Installation of Solenoid

Solenoid actuators with required force in DC-type solenoid were not available in Pakistan so selection of an AC-type solenoid was made to implement the proposed system. Also a disc assembly was designed in accordance with the threads available on the valve's passage so that the actuators sit firmly and at the right angle to provide optimum lift to the respective valve.

The solenoids used are capable of the following:

- Generating enough force to open the valve
- Providing enough force to hold the valve open

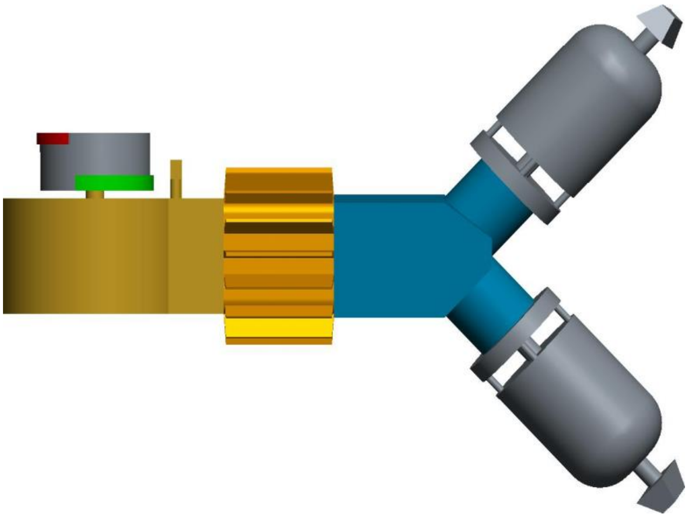


Fig. 3.3: Installation of Solenoids

3.1.3 Adjustment of Intake and Exhaust Valves

Intake and exhaust valves are adjusted in such a way that they open and close by the help of solenoid. The adjustment of solenoid actuators on valve sleeves was also compulsory so that no wear and tear occurred during engine operation.

Figure 3.4 Installation of Solenoids

3.1.4 Making of Teflon Weightless Flywheel

The use of Teflon for making the fly wheel attachment was made keeping in view the ease of machining and light weight of the material as compared to actual flywheel.

A flywheel of same radius was designed so that the exact valve timing could be implemented on it, keeping in mind the limitations of sensors operating frequency and simplicity of programming.

3.1.5 Measuring and Installation of Metal Strips On Flywheel

The metal strips were placed in accordance with the intake and exhaust valves operation duration measured by experimental procedures. The opening and closing angles were found by experiments performed on the cam profile.

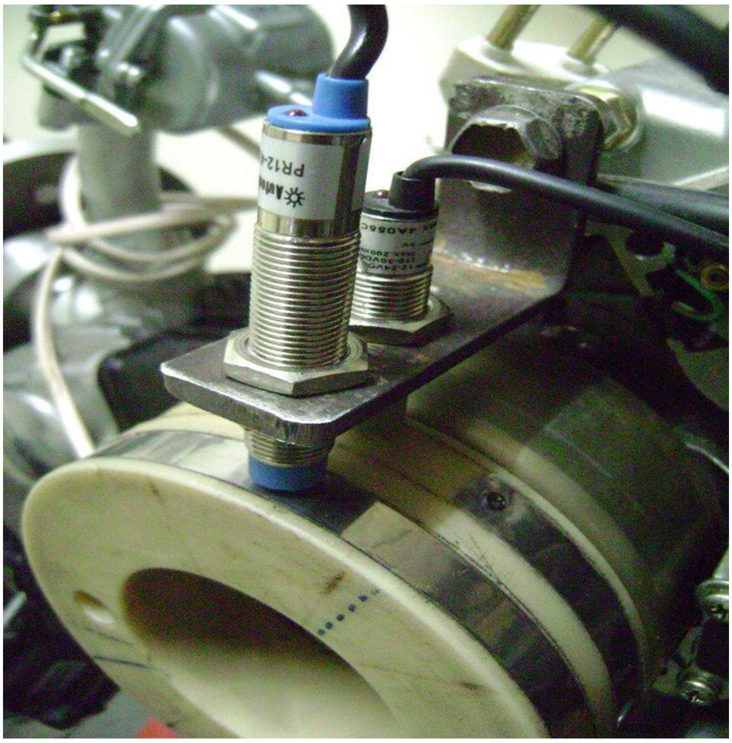


Figure 3.5 Installation of Sensors

3.1.6 Installation of Sensors

Figure 3.6: Laser/Proximity Sensor

Sensors are proximity sensors used to sense the metal strip for opening and closing of valves used as a solenoid valves via the program.

3.1.7 Programming

Programing was an essential part of the project. The programming had to be simple enough to allow for customization and yet on the other hand had to be efficient enough for high frequency operation of the actuated valves.

3.1.8 Installation of Micro-Processors and Electrical Circuit

The microprocessor was selected on two basic criteria:

- It had to be readily available and cheap in order to be experimented on by using different experimental logics in the initial stages of the project.
- It had to provide sufficient processing power to run the program without any delay.

CHAPTER 04

INTEGRATION OF SOFTWARE AND HARDWARE

4.1 Control System

This chapter includes a brief introduction and design of the control system developed for camless engine. It also describes the features of the components of control system. Program, which is burned into the microcontroller and simulation of that program in Proteus software, has been discussed as well.

4.2 Block Diagram of Control System

Sensors act as an input in control system of the electronic valve arrangement; it sends the input signal to the ECU that includes microcontroller which after processing the signal sends a pulse to the actuating mechanism.

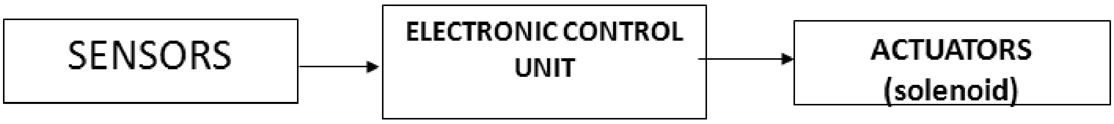


Figure 4.1: Overview of Control System

4.3 Components of Control System

Components of the control system that play an important role in controlling the timing of the engine are:

- Microcontroller
- Solenoid Actuator
- Laser / proximity sensors

4.4 Design of Control System

Control system designed for the electronic valve arrangement consists of laser/proximity sensors, microcontroller and solenoid actuators, designed in a closed loop control system for the project in which no feedback is involved.

Laser/ proximity sensors acts as an input which receives the signal from the second flywheel and send it to the microcontroller which actuates the electronic actuators when they need to be actuated.

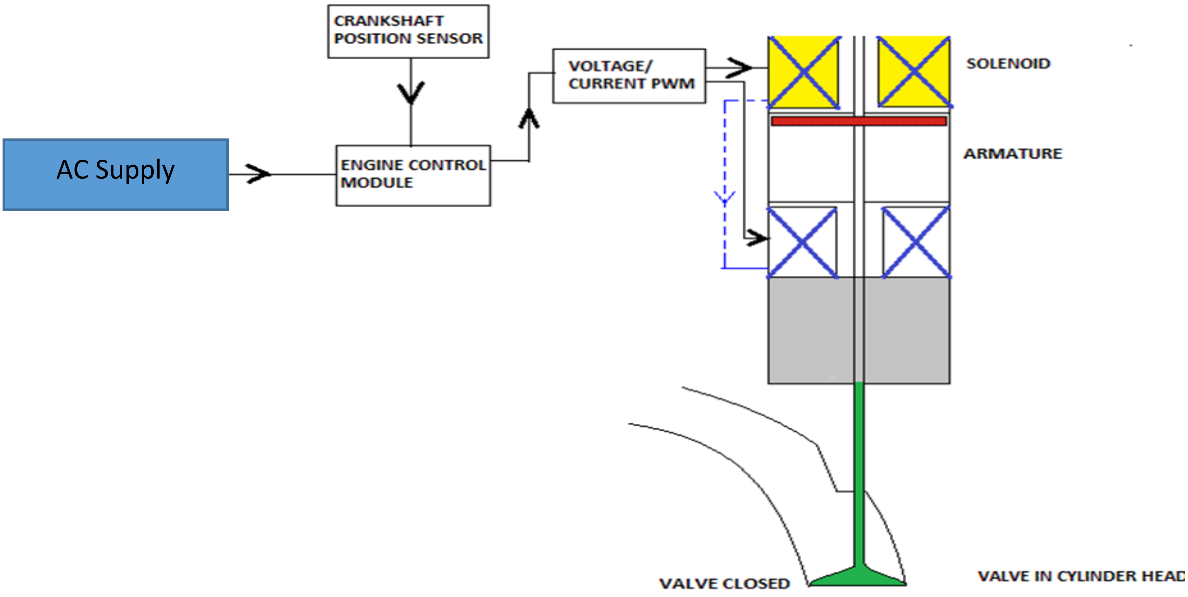


Figure 4.5: Design of Control System

4.5 Simulation in Proteus Software

After making the design of the electronic valve arrangement control system, Simulation was done on PROTEUS software as shown in figure 4.6.

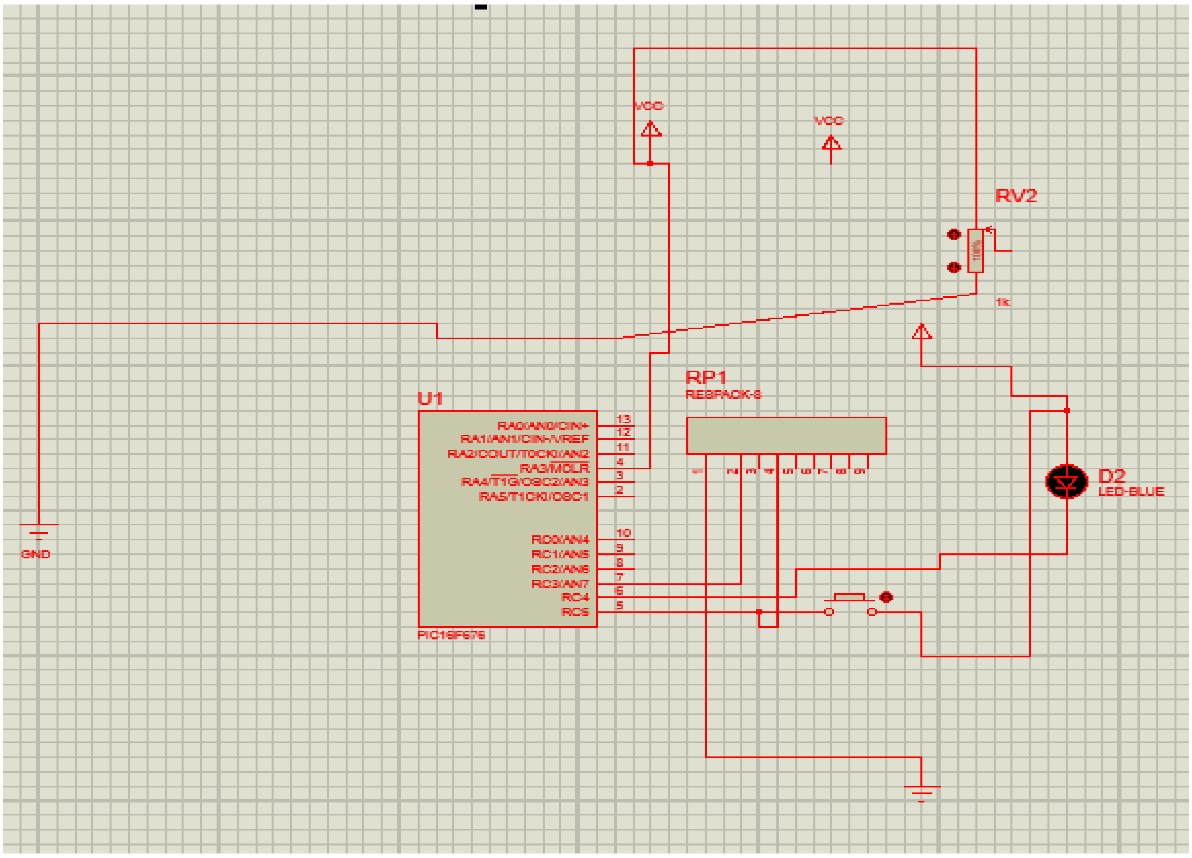


Figure 4.6: Simulation of Control system on Proteus

4.6 Program Burned In Microcontroller

Program burned in the microcontroller is given below:

```
#define  rly1 PORTC.F4

#define  sw1 PORTC.F5

//            65535

int x;

unsigned int j;

// batt1,2,3== 9v

unsigned int r_adc;

unsigned int test;

//int    tlong;

long     tlong;

long Answer,highset,lowset,involt,temp;

void    mux();

void    chk1();

void    chk2();

void    chk3();

void    chk4();

void   get_ad();

void   get_ad1();

void   get_ad2();

void   get_ad3();

void   getmath();

void    paus();

void    bcd4();

unsigned char i;
```

```
void main()
{
        ansel = 4;
        adcon1 = 0x20;
        TRISA = 0x4;
        TRISc = 0x00;
        portc = 0xff;
        porta = 0x00;
        //  ansel = 4;
        //    adcon1 = 0x20;
        //    TRISA = 0x4;
        //    TRISc = 0x00;
        //    portc = 0xff;
        //    porta = 0x00;
        //   ANSEL   = 255;              // Configure AN pins as digital
        //  CMCON  = 7;           // Turn off the comparators
        // TRISA =255;
        //
        //  ADCON0.VCFG = 0;      ///5V REF INT
        // PORTC=0B11111111;
        //  unsigned int x;
         //    int J;
        //TRISC=0x00;
        trisc.f1=0;
        trisc.f2=0;
        trisc.f3=1;
```

```
trisc.f4=0;

trisc.f5=1;

rly1=1;///off

//  one pulse missing inlet stays close first ic

//   one pulse missing exhaust stays close second ic

DELAY_MS(500);

while(1)

 {

        if(sw1==1) {

        DELAY_us(50);

        while(sw1==1);

        DELAY_us(50);

        while(sw1==0);

        rly1=0;

        DELAY_us(50);

        while(sw1==1);

        rly1=1;

        DELAY_us(50);

        while(sw1==0);

        DELAY_us(50);}}}
```

CHAPTER 05

PERFORMANCE AND EVALUATION

5.1 Mechanical Design

The proposed mechanical design has reduced the required parts of the mechanical system. Camshaft, rocker arm, timing chain, tappet rod and other mechanical components were removed by the use of solenoid as direct actuator of the valves. The force for the solenoids to drive the valve easily and safely is calculated by measuring the spring constant for the existing spring in the Cylinder head of the engine. The cap for the intake and exhaust sides were removed and a mounting was designed to firmly attach the solenoid to the engine head while keeping in mind that the plunger of the solenoid is parallel to the stem of the valve and centers of both are perfectly joined. The solenoid thus drives the valve of the engine directly.

5.2 Software Performance

As the system has been totally integrated together with the software. The components have been tested individually. There are working code modules for the Solenoid driver Circuit, reading the position encoder and altering the Solenoid driver Circuit. It is anticipated that these software modules will be fully working together and in a position to allow someone to easily adapt them to fit a more complicated model of the system.

5.3 Overall System

With the use of Solenoid Driver Circuitry, the overall system designed to demonstrate the principles of electronic valve actuation should provide a good functional model which can be readily built on for use in real world situations.

5.4 ECVA Advantages and Possibilities

ECVA have the advantages that could be seen

- The engine is mechanically simple. There are no timing gears. There is no camshaft. There are no cams or push rods.
- The electronics that replace these mechanical parts are lighter, smaller and lower in cost.
- The mechanical losses are reduced because there are fewer moving parts.

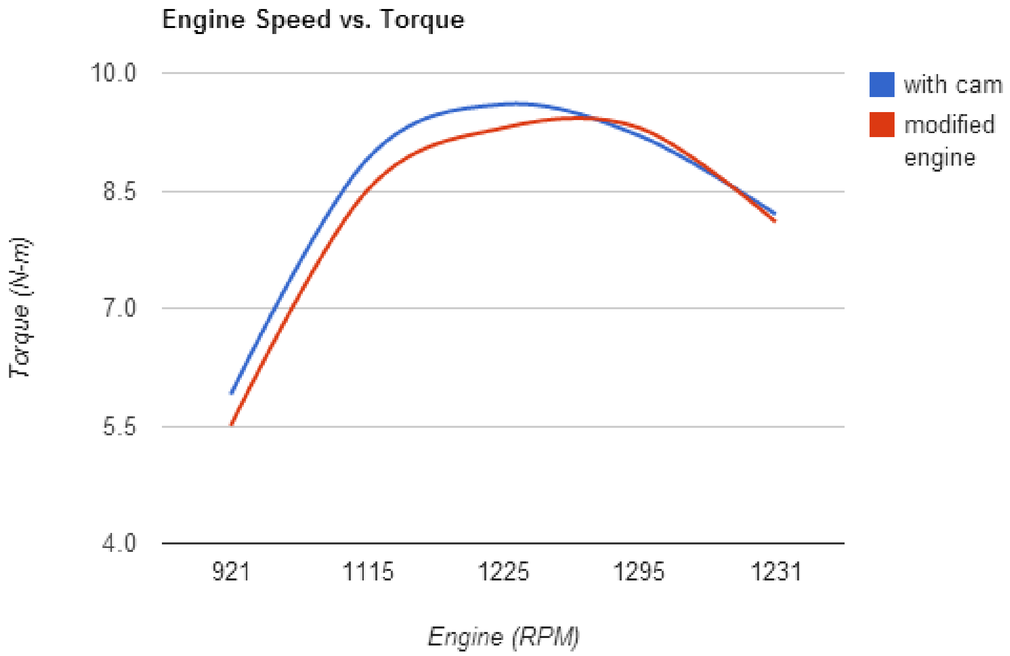
- The electrical energy required to operate the valves can be generated when other demands on the engine are low. When engine loads are high the energy to operate the valves can be taken from the system battery. This time shifting of the engine load can be of tremendous advantage.
- An ECVA engine can be throttled by changing the valve timing. An "Electronic Throttle" that reduces the intake charge by valve timing has lower pumping losses than does an engine throttled by the traditional method of a restriction in the intake manifold.
- High speed power and efficiency can be achieved without creating an engine that refuses to idle.
- The valve timing can be dynamically varied to improve fuel economy, reduce engine emissions and/or increase power output.
- An ECVA engine can be used in a hybrid application to achieve even greater fuel economy

5.5 Comparison Between Conventional Engine And Modified Engine

5.5.1 Engine Speed vs. Torque

Speed (RPM)	Torque(N-m) with cam	Torque (N-m) with camless
921	5.9	5.5
1115	8.9	8.5
1225	9.6	9.3
1295	9.2	9.3
1231	8.2	8.1

Table 5.1: Speed vs. torque (Conventional and Modified Engine)



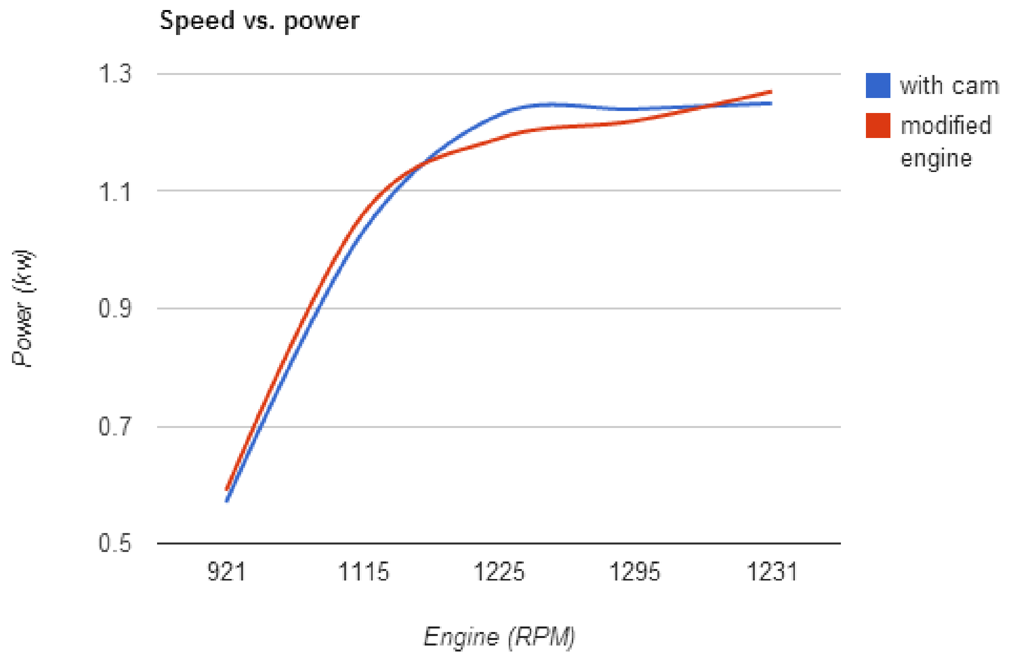
Graph 5.1: Speed vs. torque (conventional and modified engine)

The graph shows the final results of torque at different speed. These graph values taken from the engine test bed during practical. The comparison shows that the torque is decreased by increasing the speed of the engine.

5.5.2 Engine Speed vs. Power

Engine speed (RPM)	Power (kw) with cam	Power (kw) with modified engine
921	0.57	0.59
1115	1.03	1.06
1225	1.23	1.19
1295	1.24	1.22
1231	1.25	1.27

Table 5.2: Speed vs. power (Conventional and Modified Engine)



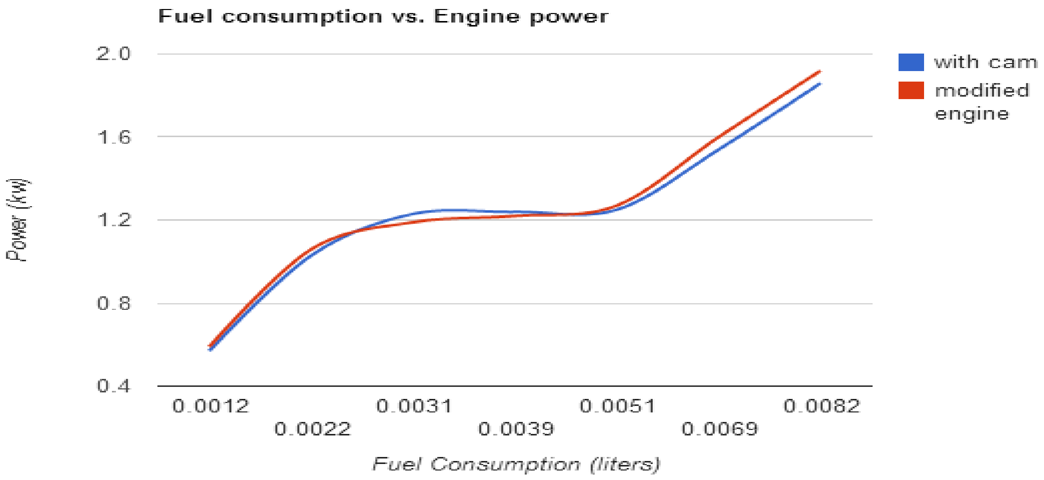
Graph 5.2: Speed vs. power (Conventional and Modified Engine)

The graph shows the final results of power with cam and without cam. These graph values taken from the engine test bed during practical. The power output is also improved by increasing speed.

5.5.3 Fuel consumption vs. Engine power

Fuel consumption (liters)	Engine power (kw) with cam	Engine power (kw) with modified engine
0.0012	0.57	0.59
0.0022	1.03	1.06
0.0031	1.23	1.19
0.0039	1.24	1.22
0.0051	1.25	1.27
0.0069	1.54	1.6
0.0082	1.86	1.92

Table 5.3: Fuel Consumption vs. Engine Power (Conventional and Modified Engine)



Graph 5.3: Fuel Consumption vs. Engine Power (Conventional Engine and Modified Engine)

The final result of fuel consumption of conventional and modified engine are plotted in the graph .

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

The project met its goals of providing a mechanical design for electronic valve actuation. It looked at the feasibility of electronic valve actuation and infinitely Variable Valve Timing.

6.1 What is Really Holding Back This Technology

- Cost and reliability are the two most common answers to this question.
- Concluded that the single acting ECVA solenoid system even with lever arm valve solenoid assemblies would cost less than a camshaft system, considerably less. The engine becomes mechanically much simpler. Solenoids are easy to make and are not expensive when manufactured in volume.
- The electronics to control them are inexpensive and constantly dropping in price.
- There is no doubt in mind that the automotive industry can make the required parts highly reliable, just as they have done with camshaft systems.

As an opinion, the hold-back lies somewhere else, suggested the following:

- The valve position with respect to crankshaft position will vary with engine operating conditions.
- Always soft landing the valve on the valve seat is challenging even with a valve position sensor.
- Solenoid operated valves create audible and objectionable noise.

6.2 Outcomes of This Project

Solenoid operated valves is capable of providing very flexible variable valve timing rather infinitely variable valve timing. With the proper control hardware and software the engine designer should be able to implement optimum valve timing for any desired set of engine operating conditions.

With solenoids it is possible to change the valve timing and duration. The software can determine the crankshaft position and apply voltage to the solenoid to open the valve at the desired time. The voltage can be removed from the solenoid such that it closes at the desired time.

6.3 Benefits of Camless Engine

The benefits of electronic valve arrangement actuator systems are in terms of infinitely variable valve timing. More torque is made available throughout the rpm range due to the valve timing changes enabling optimal volumetric efficiency. This increases engine performance, increasing durability and engine life, and allowing compensation for different types of fuel and varying altitudes.

Siemens claims that even today, fuel savings of at least ten percent can be obtained in the European test cycle by using a camless valve train.Further fuel consumption reductions could be obtained by combining camless valve technology with a high-pressure direct fuel injection system.

The amount of engine oil required would also be dramatically reduced because no lubrication would be required for the traditional complex camshaft valve system. Cold start wear would also be minimal to the valve train hardware. There electromechanical valve actuation will increase overall valvetrain efficiency by eliminating the frictional losses of the camshaft mechanism, the weight of the mechanism and the cam mechanism's drain of power from the crankshaft.

6.4 Benefits Of This Project To The Students Involved

The key skills that were learned during the completion of project are:

- A basic knowledge of internal combustion engines
- System design skills to calculate forces, select solenoids and define the control system
- Mechanical design skills to modify the head and design the parts to mount the solenoids
- Machine shop skills to do the modifications and make the necessary parts
- Electrical hardware skills to design and assemble the micro computer controls

6.5 Recommendation

"The future of engine is camless engine" as said by Koenigsegg company owner Christian von Koenigsegg who gave engineers a new hope for camless engines.

- Apply this prototype on cars for optimum performance in terms of parameter's discussed in this study.
- This prototype can be further refined by utilizing compact and efficient actuators which also decreases vibrations in the engine as well as increases fuel efficiency.
- Designing of special engine heads for actuators, can be done which reduces the need of designing a special assembly for mounting electronic actuators on the engine head.
- The size of the fly wheel attachment can be reduced by designing a control system that would directly relate the size of fly wheel with the valve events required for the engine.
- Variation in terms of variable valve lift would also be achievable.
- Vibration analysis should be incorporated in the design process.

6.5.1 Safety Recommendation

- By designing the control process in such a way that it is integrated with an inbuilt test which would most efficiently avoid a valve event being missed.
- A control system is proposed which would be able to disconnect the crank circuit if there is a fault in our valve actuation mechanism
- The use of a more reliable sensing system is proposed as done in the project the use of metal strips that define the valve opening and closing durations in an effective way.
- RPM sensor can be integrated in the control system that would act as a secondary measure and would actuate the valve by predicting valve events preprogrammed in the logic design.

ACADEMIC RESEARCH

The help we got from different text books was very useful. Some of them are as follows:

- A Textbook of Machine Design by R. S. Khurmi and J. K. Gupta
- Applied Thermodynamics for Engineering Technologists by T. D. Eastop and A. McConkey
- Electronic Devices by Floyd
- Internal Combustion Engines (Applied Thermoscience) by Colin R. Ferguson and Allan T. Kirkpatrick
- ME Engines – The New Generation of Diesel Engines article
- Robots and Manufacturing Automation by C. Ray Asfahl
- Modeling and Sensorless Control of an Electromagnetic Valve Actuator by Peter Eyabi and Gregory Washington
- Development of Camless Engine Valve Actuator System for Robust Engine Vave Timing Control by Kanghyun Nam and Seibum B. Choi
- John Lumley in the book Engines an Introduction (ISBN 0-521-64489-5)

REFERENCES

- General Motors – GM and the Environment. May 21, 2001.
- General Motors. June 13, 2001
- Mori, Kaz. Honda's High-Output LEV Engine Home Page. Honda June 13,2001
- Lexus – Variable Valve Timing a First in an SUV. Auto world. June 18, 2001
- Gould, L; Richeson, W; and Erickson, F., 1991, "Performance Evaluation of a Camless Engine Using Valve Actuation with Programmable Timing," SAE Paper No. 910450.
- Schechter, M.; and Levin, M., 1998, "Camless Engine," SAE Paper No. 960581
- Anderson, M; Tsao, T-C; and Levin, M., 1998, "Adaptive Lift Control for a Camless Electrohydraulic Valvetrain," SAE Paper No. 981029
- Anonymous, "First Camless Truck Reaches the Summit of Pikes Peak!" Power Stroke Registry, spring 2001
- Dobson and Muddel, G., 1993, "Active Valvetrain System Promises to Eliminate Camshafts," Automotive Engineer February/March 1993.
- Ladd; Camless Engine is Gaining Momentum .September13, 1999.
- "Valeo". Web.archive.org. 2007-11-20. Retrieved 2011-06-30.
- Richman "A Computer-Controlled Poppet-Valve Actuation System for Application on Research Engines."
- Schechter and Levin 1998,"CamlessEngine" SAE Paper No. 960581

- Gould, Richeson; and Erickson. 1991, "Performance Evaluation of a Camless Engine using Valve Actuation with Programmable Timing SAE Paper No.910450.
- Murray; Electronic Controls to Replace Camshafts in Engines. April 14, 2000
- Murray, C; Electronic Controls to Replace Camshafts in Diesel Engines. April 14, 2000 to July 7, 2000
- Anderson, Tsao and Levin, 1998, "Adaptive Lift Control for a Camless Electromechanial Valve train" SAE Paper No. 981029
- www.siemensauto.com
- www.sturmanindustries.com
- www.internationaldelivers.com
- www.datasheetcatalog.com
- www.wikipedia.com
- www.google.com
- www.scribd.com

APPENDIX