

# Design and operation of engine testing facility engineering essay



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## **ABSTRACT**

The report covers design and development of an engine testing facility for the operation of diesel and gasoline engines. It consists of two sub-cells for each engine type. It is designed by keeping Euro 5 emission standard in mind.

A study was made to find the power output of the diesel engines of 1.3 lit. Turbo to 6.0 lit. Tdi and gasoline engine of 1.6 lit. With variable vane turbo charger and variable geometry valve timing. The Heat balance sheet for both the engine and the test cell was made on the basis of power output. afterwards, the mass flow rate of the fuel, air, cooling water and oil were calculated to design the test cell. The dynamometer and other equipments were selected based on their types and operation requirements. At the end the bill of material of all the parts purchased was prepared to illustrate that the designed testing facility meets the funds of the project.

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## **CHAPTER 1**

### **INTRODUCTION**

In the present scenario, internal combustion engines have become the most widespread form of energy conversion from chemical to mechanical form. A lot more is going on these days to improve the design of the engine using better materials and techniques in order to achieve more power and fuel economy. Considering the amount of effort that is being put to design an engine from scratch, the art of testing an engine is becoming much harder to master. The work of designing a test cell which should test engines with varied range of power output and size requires not only the skill and technical knowledge of the subject; it also requires the exposure to the new and developing experimental techniques to observe even the minute aspect of the project in order to design the best possible layout. The testing of an engine requires correctly measuring the parameters such as temperatures, air flow, fuel flow, air velocity and several meter readings in the first attempt itself as it's an expensive exercise to conduct an engine test. [2]

### **1. 1 TEST CELL AND FACILITIES**

To build a test cell requires a detailed study of the energy input and output with respect to the engine, size of the engine etc. So the proper plan has to be carried out. The test facility should be well equipped with the modern test <https://assignbuster.com/design-and-operation-of-engine-testing-facility-engineering-essay/>

equipments and instruments like gas analyser, transducers etc. Following topics discussed the facilities.

## **1. 2 A Typical Test Cell Layout**

The following fig. shows a typical cell layout showing the different systems like ventilation for air, conditioning systems, data acquisition, cooling and air conditioning system etc..

### **Fig. 1. 1 A typical Test cell layout**

## **CHAPTER 2**

### **ENERGY BALANCE AND MEASUREMENT**

#### **2. 1 ENERGY BALANCE**

With reference to the table and the figure, an energy balance of the 1. 3 litres turbo engine (manufactured by FIAT), which produces a power of 95bhp @4000 rpm (equivalent to 70 KW) is carried out. The same procedure can be later followed to calculate the energy flows for the 6. 0 litre Tdi V12 Volkswagen engine producing a power of 331 KW @6050 rpm & 560 Nm of torque at 2750 rpm.

#### **2. 2. 1 DIESEL ENGINE ENERGY BALANCE**

Engine: 1. 3 litre turbocharged diesel engine, power output: 95 bhp(70. 87 KW)

Assuming thermal efficiency of the engine = 0. 42,

calorific value of diesel = 44. 8 MJ/kg

So, fuel input power =  $70. 87/0. 42 = 168. 73$  KW

Specific fuel consumption =

Table 2. 2 Energy Balance for the fiat 500 1. 3 litre turbocharged 70. 87 KW  
diesel engine

Item

Energy In

Item

Energy Out

Fuel

168. 73KW

Power

70. 87KW (42%)

Heat to cooling water

33. 746KW(20%)

Heat to oil cooler

5. 0619 KW (3%)

Heat to exhaust

42. 1825KW(25%)

Conv. and Radiation

16. 873KW(10%)

Total

168. 73 KW

168. 73 KW

### **Flow Rate Calculations:**

Mass flow rate of the fuel: =

The density of diesel fuel is  $\rho_f = 0.832 \text{ Kg / lt}$

So, the fuel flow rate is: = 16. 0096 litres / hr.

Air flow: : Assuming that the air-fuel ratio at full load is 25: 1 and

air density is 1. 2 Kg /,

= 333 Kg / hr. =  $333.5 / 1.2 = 277.5 \text{ m}^3/\text{hr}$ .

Cooling water flow : : Heat loss to the cooling water is assumed to be 20%

Therefore, Heat loss =

Assuming 10 degrees rise in the water temperature

= 48. 4392 kg/min

Exhaust flow : = 346. 32 Kg/hr

Engine: Volkswagen 331 KW, 450 BHP engine

The energy balance and mass flow rates for this engine was calculated by similar fashion as shown in the above case.

Table 2. 3 Energy Balance for the Volkswagen 331 KW, 450 bhp engine:

Item

Energy In

Item

Energy Out

Fuel

788. 09KW

Power

331 KW (42%)

Heat to cooling water

157. 6KW(20%)

Heat to oil cooler

23. 64 KW (3%)

Heat to exhaust



197. 02 KW (25%)

Conv. and Radiation

78. 809KW(10%)

Total

788. 09 KW

788. 09 KW

Table 2. 4 Flow rates for the Volkswagen 331 KW engine:

## **Particulars**

### **Mass flow rate**

Fuel

63. 3286 kg/hr

Air

1583. 21 /hr

Cooling Water

226. 22 kg/min or lts/min

Exhaust

1583 kg/hr

## **2. 2. 2 DIESEL CELL ENERGY BALANCE**

The energy balance for the diesel cell has been shown the table 2. 5. Some of these calculations are being done in the ventilation system section.

Table 2. 5 Energy balance for the diesel test cell for 450 BHP diesel engine

### **Item**

### **Energy In**

### **Item**

### **Energy Out**

Fuel 788. 09 KW

Exhaust Gas 150 KW

Ventilation Fan Power 10 KW

Dynamometer Power 373 KW

Electrical Cell Services 25 KW

Engine Cooling Water 157. 6 KW

Ventilation Air 150. 868 KW

Cell Wall Losses 5 KW

**Total 823.09 KW**

**Total 823.09 KW**

### **2.3.1 GASOLINE ENGINE ENERGY BALANCE**

This cell is required to test the engines from 1.6 litre variable vane turbocharger with variable valve timing to 3 litres 400 BHP engine.

Engine: Toyota corolla 1.6 litre VVT, 110 bhp@6000 rpm, 150 Nm@3800 rpm

The energy balance and flow rate calculations are same as that of the previous. Assuming 30-30-10 thumb rule. The calorific value of petrol is = 48000 KJ/kg.

Table 2.6 Energy Balance for the Toyota corolla 1.6 litre 80 KW petrol engine

Item

Energy In

Item

Energy Out

Fuel

267KW

Power

80 KW (30%)

Heat to cooling water

80 KW (30%)

Heat to exhaust

80 KW (30%)

Conv. and Radiation

27 KW (10%)

Total

267 KW

267 KW

The 30-30-30-10 rule is used for the assumption that means assuming 30% thermal efficiency of the engine and the fuel power input has been calculated on this basis. Later, 30% heat loss is carried away by the engine cooling water and the exhaust of the engine. The 10% heat is lost to the surrounding air by convection and radiation.

Following table represents the various flow rates for the engine assuming the air - fuel ratio at full load to be 15: 1 for the gasoline engines.

Table 2. 7 Flow rates for the Renault 1. 6 litres VVT 80 KW engine

## Particulars

### Mass flow rate

Fuel

20 kg/hr

Air (A: F = 15: 1)

250 /hr

Cooling Water

115 kg/min or lts/min

Exhaust

320 kg/hr

Engine: A 3. 0 litre 400 BHP (294 KW) gasoline engine

Energy balance and flow rates have been calculated similarly as previous cases.

Table 2. 8 Energy Balance for the 3. 0 litre 400 BHP petrol engine

Item

Energy In

Item

Energy Out

Fuel

980KW

Power

294 KW (30%)

Heat to cooling water

294 KW (30%)

Heat to exhaust

294 KW (30%)

Conv. and Radiation

98 KW (10%)

Total

980 KW

980 KW

The values shown in the above table have been calculated assuming the 30-30-30-10 rule as discussed in the previous section and the table below shows the various flow rates for the gasoline engine.

Table 2. 9 Flow rates for the Renault 1. 6 litres VVT 80 KW engine

## Particulars

### Mass flow rate

Fuel

73.5 kg/hr

Air (A: F = 15: 1)

920 /hr

Cooling Water

422 kg/min or lts/min

Exhaust

1178 kg/hr

### 2. 3. 2 GASOLINE CELL ENERGY BALANCE:

The table below represents the energy flows in and out of the cell when operating on full capacity of 400 BHP gasoline engine

Table 2. 10 Energy balance for the gasoline test cell for 400 BHP engine

#### Item

#### Energy In

#### Item

#### Energy Out

Fuel 980 KW

Exhaust Gas 274 KW

Ventilation Fan Power 5 KW

Dynamometer Power 250 KW

Electrical Cell Services 25 KW

Engine Cooling Water 294 KW

Ventilation Air 187 KW

Cell Wall Losses 5 KW

**Total 1010 KW**

**Total 1010 KW**

The energy balance sheets for the diesel and gasoline engines lay a firm foundation for the design of the in-cell services and selection of the equipments that have been carried out in the later chapters.

## **CHAPTER 3**

### **3. 2 TEST CELL DESIGN**

The test cells must be provided with the following services:

Water supply and drainage system

Fuel supply system

Ventilation system

Taking engine exhaust to exterior



Fire and safety regulations

Portable test stand for the engine and dynamometer

Control room or console etc...

We have to keep the temperature maintained at the ambient, so we have to give importance to ventilation system also.

General purpose engine test cell has been shown in fig. 3. 1. A typical test cell layout that has been used for these types of engines has also been shown in the fig. 3. 2. Such type of cells is usually built side – by – side with common control room. The engines are imported in the cell from the rear – door whereas the operator could enter from the front door. A thick glass is mounted between the control room and the engine cells so the operator could have a look at the cells while sitting inside the control room. [1]

Fig. 3. 1 General arrangement inside an engine cell aligned against a wall and the control room on the other side of the engine.

Fig. 3. 2 A layout of the test facility with two cells having a common control room ..

Fig. 3. 1 and 3. 2 shows the typical layout of a facility incorporated with two separate cells and a common control room with a thick glass window separating the cell and the control room. The cells are aligned with a wall which leads the exhaust outlet to the atmosphere.

### **3. 3 CELL SERVICES**

#### **3. 3. 1 VENTILATION SYSTEM**

Ventilation system plays a very important role in any engine testing laboratory or testing cell. Inside the cell due to running of heavy engine a high temperature is developed also at the surface of the engine. So it is necessary to carry away this heat ventilation system should be strong enough, also it is necessary to keep the surrounding temperature at ambient conditions.

The convection and radiation losses are assumed as below (based on diesel engine):

Engine

78. 809 KW (10% as mentioned in heat balance)

Exhaust Manifold

10 KW

Exhaust tailpipe and silencer

10 KW

Dynamometer

40 KW

Electrical equipments

15 KW

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Forced draught fan

5 KW

Subtotal

158. 809 KW

Total (assuming 95% efficiency of the ventilation system)

150. 868KW

Table 3. 2 Heat losses to be considered for the ventilation system design

For the total heat loss from engine by convection and radiation  $H = 150. 868$  KW, the volume flow rate of air can be calculated as:

Taking  $H = 150. 868$  KW,  $C = 1. 01$  KJ/Kg-K,  $\rho = 1. 2$  kg/m<sup>3</sup>, and temp rise of 10, the mass flow rate is: 12. 447 m<sup>3</sup>/sec. or 746. 87 m<sup>3</sup>/min.

the air flow velocity in the duct could be taken in between 15-20 m/sec. For this value, the cross-sectional area could be 0. 37-0. 49 m<sup>2</sup>. So, from a range of standard duct area, it could be taken as 600mm X 600mm ( square duct) as it results into the air flow velocity of 19. 5m/sec (satisfies the range of 15-20 m/sec) and velocity pressure or dynamic pressure of 228 Pa. [3] from the above data centrifugal and axial fans were selected for the inlet and outlet respectively . typical ventilation system is as shown in the fig.

Specification of the fan used in the ventilation system is as follows:

**Fan****Air vol. (m<sup>3</sup>/hr)****Speed (rpm)****Power (KW)**

Centrifugal

920

2250

0. 29

Axial

958

1680

0. 21

Table 3. 4 represents the specification of fans selected for ventilation

**3. 3. 3 COOLING WATER SYSTEM**

Water is an almost ideal cooling fluid as it has a high specific heat value, low viscosity, relatively low corrosivity and is freely available (Martyr and Plint, 2007). The required flow rates can be calculated similarly to that of air if the heat to be transferred and the change in temperature is known. Additives such as ethylene glycol (antifreeze) can be added to the water to improve the operating temperature range of the cooling system and inhibit corrosion, although the specific heat value will be reduced.

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There are various types of cooling water circuits that can be considered like:

Open water circuit, where the water is supplied directly from the mains and is therefore not circulated back.

Closed water cooling circuits, where the water is supplied from a sump or tank and can be circulated back. This has an advantage that the coolant could be mixed in water sump to improve the cooling effect.

Closed pump circuit

### **3. 4 DIESEL TEST CELL LAYOUT**

C: UsersrohitDesktopdiesel cell layout. png

Fig. 3. 4 The diesel cell layout based on all the calculations done

## **CHAPTER 4**

### **DYNAMOMETERS**

Dynamometers are used inside the test cell to measure the torque which is developed on the engine output shaft. It also measures the power output of the engine.

#### **4. 1 WORKING OF DYNAMOMETER**

Fig. 4. 1 typical setup of dynamometer

The dynamometer resists the rotation of the engine shaft to measure its torque. The rotor rotates inside the stator which, as the name indicates, is stationary. The rotor exerts torque on the stator and this is balanced by the load cell. The torque is given by:

$$T = F \times B$$

And so the power developed by the engine could be known as:

$$P = 2\pi n T \text{ KW}$$

If the engine speed (in rpm) is measured using tachometer, the power could be easily calculated using the above equation.

## **4. 2 TYPES OF DYNAMOMETER :**

The dynamometer types which are in practice include:

Hydraulic Dynamometer

DC Dynamometer

AC Dynamometer

Eddy current Dynamometer

Each one of the above mentioned dynamometers has different set of working principle. There are four quadrants in which a dynamometer can operate: rotating clockwise producing or absorbing torque and rotating counter clockwise producing or absorbing torque. Figure gives a diagrammatical layout of these four quadrants. Most water brakes can only operate in the first quadrant. Eddy current dynamometers can operate in the first two quadrants, while AC/DC dynamometers can be used in all four quadrants.

### **Figure 3-13: Dynamometer operating quadrants (Martyr and Plint, 2007)**

#### **4. 3 DYNAMOMETER SELECTION:**

Different types of dynamometer has been studied by considering the advantage and disadvantage of each type of dynamometer the AC dynamometer has been chosen as it can perform in all the four quadrants and has lower inertia than the DC dynamometers, which makes it less vulnerable to vibrations due to rotation of the shaft.

#### **Diesel Cell:**

As the cell has been designed to fit in the engine ranging from 75-500 BHP.

The dynamometer selected for this cell is AC – 500 – 1811. 373 kw

manufactured by Mustang dynamometer . The specifications are listed in table 4. 2:

Horsepower

Cooling Type

Constant torque range(ft-lb)

Max Torque (ft-lb)

500

Blower

2455

2455

Table 4. 2 AC dynamometer selected for diesel cell

### **Gasoline Cell:**

The gasoline cell has been designed in such a way that it will test the engine with a maximum of 400 BHP.

The selected dynamometer was AC – 400 HP dynamometer manufacture by Dyne systems and its specifications are listed in the table 4. 3

Horsepower

Constant Torque range (ft-lb)

Constant HP range

Max Torque (ft-lb)

400

1175

3525

1787. 91

Table 4. 3 AC dynamometer selected for the gasoline cell



## **CHAPTER 5**

### **SELECTION OF INSTRUMENTS**

#### **5. 1 SHAFT SPEED MEASUREMENT**

Tachometer is used for the engine speed measurement the non contacting digital tachometer is used so that it will not affect on the speed of the shaft . following tachometer is selected

Make: Check-line ltd, Model: ctd-1000hd, Non-contact type, Measuring rang :

1. 00-99999 Rpm, Prize:

#### **5. 2 TEMPERATURE MEASUREMENT**

The inlet air, coolant inlet and outlet, exhaust and oil temperatures can be measured with thermocouples. Depending on the temperature to be measured, K and J type Thermocouples are the most common thermocouples available. J types operate in a smaller range, approximately to 150°C while K types operate up to 1500°C

#### **5. 3 FLOW RATE MEASUREMENTS**

a) Turbine-flow meter: Omega, model: FTB790 Series. It has an output range of 0-5V DC

b) Fuel-flow meter: Fischer-Porter Digital fuel flow meter is selected

c) Air-flow meter: Mass-air flow meter manufactured by Shijiazhuang Fortune Industrial & Trading Co., Ltd. and FHC Ind, model: FHC-CMF I-DNXX Limited has been selected. temp range of -40 to 200.

## 5. 4 PRESSURE TRANSDUCERS

**Omega high accuracy pressure transducer has been selected  
Model: PX01C1 -100G5T 5. Range: 0-400 bar, with 0 to 5  
Vdc Output accuracy .**

## 5 EMISSION EQUIPMENT

The equipments used should be of euro 5 standards following chart shows the emission norms for euro 5 and euro 6 standards:

**EURO 5**

**EURO 6**

**PETROL**

**DIESEL**

**PETROL**

**DIESEL**

**CO**

1

0.5

1

0.5

**THC**

0.1

—

0.1

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–

## **NMHC**

0.068

–

0.068

–

## **NOX**

0.06

0.18

0.06

0.08

## **HC+NOX**

–

0.23

–

0.17

## **PM**

0.005

0.005

0.005

0. 005

Fig. 5. 2 EURO 5 and EURO 6 emission standards

Exhaust gas analyser:

XM2000 5 -gas analyser Exhaust Measurement System provides a portable, low cost tool for continuous analysis of engine exhaust gas components (HC, CO, CO<sub>2</sub>, NO, O<sub>2</sub>) system. XM2000 -gas analyser manufactured by Dyne Systems Inc.

## **5. 6 PRICE-LIST**

**Items**

**Price (**

**Reason for purchase**

Dynamometers

1, 20, 000

Power and Torque measurement

Centrifugal Fans

500

Forced Draught

Axial Fans

1800

Ventilation Exit

Feet levelling for beds

700

Absorb vibrations

6 thermocouples

100

Temp. measurement

2 Infrared thermometers

280

Non-invasive temp.

2 Digital Tachometers

125

Engine Speed measurement

2 Data-Acquisition System

1, 10, 000

Record and transfer data to control room

2 Pressure Transducers

700

Cylinder Pressures

All types of flow meters

10, 000

Measure mass flow rates

Gas Leak Detectors

400

To detect leaks

Smoke Detectors

50

To detect fire

5-Gas Analyzers (2nos)

4, 50, 000

To check emission

TOTAL COST

**6, 67, 780 £**

**CHAPTER 6**

**CONCLUSION**