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AuE-6080 Vehicle Testing laboratory Assignment-5

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TITLE:

Engine Cylinder Pressure Measurement Laboratory

Executive Summary:

- Calculate the displaced volume of an individual cylinder.
- Report the displacement of an individual cylinder in cubic centimeters.
- Report the combined displacement of all cylinders in total.
- To calculate the clearance volume for each cylinder
- By using crank angle slider equation, plot both cylinder volume (y-axis 1) and cylinder pressure (y-axis 2) vs crank angle degree for one of the cylinders.
- Calculate the Net Indicated Mean Effective Pressure (IMEPn) for each of the 8 cylinders at one engine speed and intake manifold pressure by using any rule.
- Report the IMEPn for each of the 8 cylinders at one engine speed and load, the average IMEPn of all cylinders at that same engine speed and load, and the percent that each cylinder deviates from the average IMEPn at that speed and load.

INTRODUCTION:

Purpose of testing:

- Testing the operating behavior of internal combustion engines is the common purpose of engine test positions.
- Various parameters like fuel consumption or exhaust gas behavior were usually measured as a function of torque and rotary speed and mapped in an engine performance map.
- One of the main emphases in the research work of the IVG, optical measurements in combustion systems, is systematically applied for in-cylinder investigations of the combustion process.
- Due to the application of an asynchronous machine as a brake it is possible to apply different test procedures.
- This allows us to run internal combustion engines under accurate conditions and examine new combustion processes under part and full load conditions and various rotation speeds.
- The engine test stand is used in various research projects that contribute to the further development in the technology of internal combustion engines.
- The back-end of the research programs is moreover related to governmental or industrial funding.

General Information About Topic:

- It is a method to measure and analyze the pressure curve inside the cylinders of reciprocating piston combustion because of high pressures involved.

- The measurement of the internal cylinder pressure is also called as high-pressure indication.

- The Low-pressure indication is a other type of cylinder pressure measurement.

- The process is carried out during the gas exchange phase in order to determine the pressure in intake and exhaust systems. So that the measured pressure can be assigned to a definite working phase of the combustion engine in each case,

- Generally, engine test stand is a facility used to develop, illustrate and test engines. This is often offered as a merchandise of automotive OEMs which allows engine operation in different operating commands and offers measurement of several physical variables associated with the engine operation.

- The Automobile OEMs are usually involved in developing engines that meet the following threefold objectives:

    - To provide high fuel efficiency.
    - To improve the drivability and durability.
    - To achieve reduced emission legislations.
    - Required for engine research, development and tuning.

- The most tests include
    - To determine the efficiency and drivability
    - To determine the torque-speed performance under different conditions.
    - To determine the compliance to relevant emission test cycles.
    - To gain further knowledge or to develop about engine mapping.

- The cylinder pressure measurement used for -
    - Automobile, motorcycle and commercial vehicle engines
    - Large marine engines- 2-stroke and 4-stroke diesel engines.
    - Stationary large engines such as high-power engines for power plants

Materials and methods:

- The materials and methods used for the Engine cylinder pressure measurement lab are

  - RENK Chassis Dynamometer
  - Sensors and Encoder
  - Signal Conditioning and Data Acquisition
  - Data Processing, Quality Checking and Interpretation
  - Cylinder pressure transducer setup
  - Spark plug Transducers

A. RENK Chassis Dynamometer:

- The chassis dynamometer is the mechanical device which is used foe one or more fixed roller assemblies to simulate different load conditions.
- They are used for development purposes and to perform different types of test on the vehicle.
- 4-Wheel Independent Drive (FWD, RWD, AWD)
- Transient and Steady-State
- 125 hp per wheel (AC-Dyno)
- Automated Drive-Cycles
- US06, FTP, SC03, City, Highway etc.

B. Sensors and Encoder:

- These are mechanical motion sensor that creates the digital signals from a motion.
- It is an electro-mechanical device that runs with the data on position, velocity and direction.
- They Used to clock the data acquisition system and to measure instantaneous rotational speed.
- Common mounting location options:
  - Nose of crankshaft
  - Flywheel
  - Crank position sensor for ECU

C. Signal Conditioning and Data Acquisition;

- The signal conditioning is the similar process of data acquisition which converts one type of electrical or mechanical signal into another signal where it prepares for next step of processing.

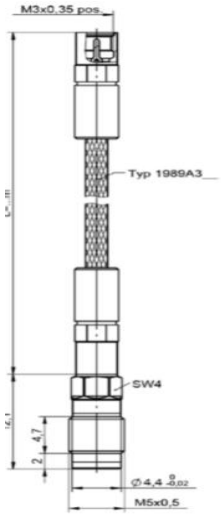
- The data acquisition is the process of sampling signals that measures the real-world physical conditions and adapting the resulting samples into digital numeric values that can be operated by a computer.

- They convert analog waveforms into digital values for processing. The components for the data acquisition systems include:

    - Sensors they convert physical constraints to electrical signals.
    - Signal conditioning circuitry is to convert sensor signals into a form that can be transformed to digital values.
    - Analog-to-digital converters is to transform the conditioned sensor signals to digital values.
    - The Sensors and Encoder, Signal Conditioning and Data Acquisition, Data Processing, Quality Checking and Interpretation is the measurement chain.

D. Cylinder Pressure Transducer Setup:

- Sensor selection and mounting location influence the accuracy of the final results.
- Sparkplug-mounted sensors provide easy in installation, but history have lower accuracy than direct mount.
- Direct mount sensors require cylinder head machining, but generally provide high accuracy.
- Selection of sensor mounting location depends on measurement type (knock?) and thermal conditions.
- Accurate calibration can be difficult to achieve because sensor sensitivity is influenced by operating temperature.



E. Spark plug Transducers:

- The spark plug transducers is the device which delivers the electric current from the ignition system to the combustion chamber to ignite the compressed air by mixture of fuel-air with electric spark. The large passage on the spark plugs can create pressure waves and alters the compression ratio.

Results and discussions:

The data provided contains cylinder pressures measured for all cylinders of a V-8 engine on a crank angle basis. Each data file is recorded at an RPM that is labeled in the filename. Tabs within each spreadsheet represent the intake manifold pressure (in bar) for each point. Points with higher intake manifold pressure create more torque/IMEPn. The data files also provide flywheel encoder 'speed' in units of microseconds per crank angle degree.

Table 1: Engine Specifications

Number of Cylinders	8
Bore	96.01 mm
Stroke	92.00 mm
Connecting Rod Length	155.10 mm
Compression Ratio	10.5
Block V-angle	90 Degrees
Crank Angles between Firing Events	90 Degrees

- From above given data Table-1:

1. Calculate the displaced volume of an individual cylinder. Report the displacement of an individual cylinder in cubic centimeters (cc). Also report the combined displacement of all cylinders in total.

   ➢ The engine displaced volume of an individual cylinder is

   $= \pi/4 * bore^2 * stroke * number\ of\ cylinders$ (cubic. centimeters)

Table-2: Individual displaced volume of each cylinder-

S.NO	Cylinder	Engine displacement (cubic. centimeter)
1.	1	666.06
2.	2	1332.11
3.	3	1998.17
4.	4	2664.23
5.	5	3330.27
6.	6	3996.34
7.	7	4662.43
8.	8	5328.35

- Total displaced volume of 8-cylinders is **5328.46 cu.cm**

2. Calculate the clearance volume for each cylinder. The clearance volume is the minimum cylinder volume achieved as the crankshaft rotates, which occurs when the piston is located at Top Dead Center. Please note that compression ratio is defined at the ratio of maximum volume (when the piston is at Bottom Dead Center) to the minimum volume (when the piston is at Top Dead Center).

   ➢ The clearance volume for each cylinder is

   = (bore ÷ 2)2 x 3.1416 x height x 16.3

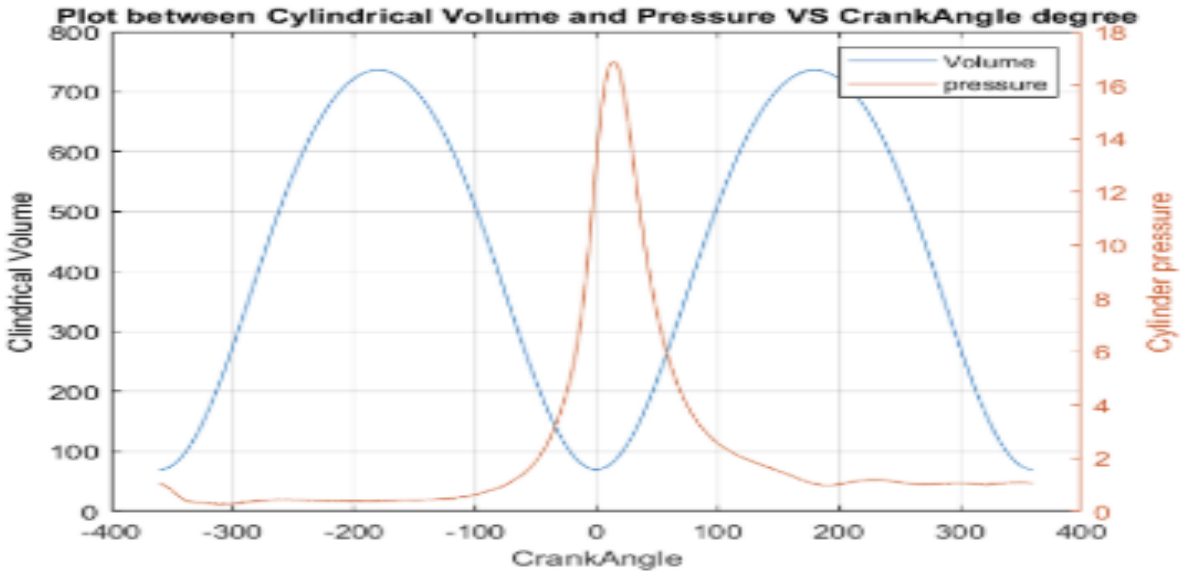
Table-2: Individual clearance volume of each cylinder-

S.NO	Cylinder	Clearance Volume (cubic. centimeter)
1.	1	560.92
2.	2	280.38
3.	3	186.97
4.	4	140.27
5.	5	112.25
6.	6	93.40
7.	7	80.13
8.	8	70.13

- Total clearance volume of 8-cylinders is **70.13 cu.cm**

3. Use the crank-slider equation to calculate cylinder volume as a function of crank angle degree then plot both cylinder volume (y-axis 1) and cylinder pressure (y-axis 2) vs crank angle degree for one of the cylinders.

GRAPH:



4. Calculate the Net Indicated Mean Effective Pressure (IMEPn) for each of the 8 cylinders at one engine speed and intake manifold pressure .To calculate IMEPn you first need to calculate the thermodynamic work for each cylinder over a complete four stroke engine cycle using the equation. Use any numerical method you see fit to integrate the pressure-volume data (e.g. midpoint rule, trapezoid, Simpson's rule, etc.). IMEPnet is then calculated by dividing the work generated by each cylinder by the displaced volume of that cylinder using the IMEPi equation. IMEPi will have units of pressure, and you should report your answers in 'bar'.
   Report the IMEPn for each of the 8 cylinders at one engine speed and load, the average IMEPn of all cylinders at that same engine speed and load, and the percent that each cylinder deviates from the average IMEPn at that speed and load. The IMEPn will depend upon the engine load point that you select, but it should fall within the general range of 0-12bar for all points provided.

   ➢ **IMEP= 5 bar.**

Conclusions:

- Total displaced volume of 8-cylinders is **5328.46 cu.cm.**
- Total clearance volume of 8-cylinders is **70.13 cu.cm.**
- **IMEP= 5 bar.**

References:

- https://clemson.instructure.com/courses/144709/files/folder/Lab%20-%20ICE%20%20Engine%20Cylinder%20Pressure%20Measurement?preview=11495126
- https://www.thedrive.com/cars-101/40767/what-is-engine-displacement
- https://auto.jepistons.com/blog/how-to-calculate-engine-compression-ratio-and-displacement

Appendix:

3. Use the crank-slider equation to calculate cylinder volume as a function of crank angle degree then plot both cylinder volume (y-axis 1) and cylinder pressure (y-axis 2) vs crank angle degree for one of the cylinders.

MATLAB SCRIPT:

```
load EngineData.mat
crank_angle = EngineData(:,1);
Vc = 70.13;
R = 3.37;
rc=10.5;
p_1 = EngineData(:,5);
Vd = 666.06;


V = (1+(0.5*(rc-1)).*(R+1-(cosd(crank_angle))-(R.^2-(sind(crank_angle)).^2).^0.5))*Vc;


plot (crank_angle,V);
title('Plot between Cylindrical Volume and Pressure VS CrankAngle degree');
ylabel('Clindrical Volume');
xlabel('CrankAngle')
grid on
```

```
hold on
yyaxis right
plot(crank_angle,p_1)
ylabel('Cylinder pressure')
legend ('Volume','pressure')


p_2 = EngineData(:,6);
p_3 = EngineData(:,7);
p_4 = EngineData(:,8);
p_5 = EngineData(:,9);
p_6 = EngineData(:,10);
p_7 = EngineData(:,11);
p_8 = EngineData(:,12);
```

4. Calculate the Net Indicated Mean Effective Pressure (IMEPn) for each of the 8 cylinders at one engine speed and intake manifold pressure .To calculate IMEPn you first need to calculate the thermodynamic work for each cylinder over a complete four stroke engine cycle using the equation. Use any numerical method you see fit to integrate the pressure-volume data (e.g. midpoint rule, trapezoid, Simpson's rule, etc.). IMEPnet is then calculated by dividing the work generated by each cylinder by the displaced volume of that cylinder using the IMEPi equation. MEPn will have units of pressure, and you should report your answers in 'bar'.

Report the IMEPn for each of the 8 cylinders at one engine speed and load, the average IMEPn of all cylinders at that same engine speed and load, and the percent that each cylinder deviates from the average IMEPn at that speed and load. The IMEPn will depend upon the engine load point that you select, but it should fall within the general range of 0-12bar for all points provided.

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p_1 = EngineData(:,5);
Vd = 666.06;


V = (1+(0.5*(rc-1)).*(R+1-(cosd(crank_angle))-(R.^2-(sind(crank_angle)).^2).^0.5))*Vc;


plot (crank_angle,V);
title('Plot between Cylindrical Volume and Pressure VS CrankAngle degree');
ylabel('Clindrical Volume');
xlabel('CrankAngle')
grid on
```

```
hold on
yyaxis right
plot(crank_angle,p_1)
ylabel('Cylinder pressure')
legend ('Volume','pressure')


p_2 = EngineData(:,6);
p_3 = EngineData(:,7);
p_4 = EngineData(:,8);
p_5 = EngineData(:,9);
p_6 = EngineData(:,10);
p_7 = EngineData(:,11);
p_8 = EngineData(:,12);


w1=trapz(p_1);
w2=trapz(p_2);
w3=trapz(p_3);
w4=trapz(p_4);
w5=trapz(p_5);
w6=trapz(p_6);
w7=trapz(p_7);
w8=trapz(p_8);


IMEP_1 = w1/Vd;
IMEP_2 = w2/Vd;
IMEP_3 = w3/Vd;
IMEP_4 = w4/Vd;
IMEP_5 = w5/Vd;
IMEP_6 = w6/Vd;
IMEP_7 = w7/Vd;
IMEP_8 = w8/Vd;
```

```
IMEP=((IMEP_1+IMEP_2+IMEP_3+IMEP_4+IMEP_5+IMEP_6+IMEP_7+IMEP_8)/8)
```