

Internal Combustion Engines - MMM4066

Coursework 2025-26

The performance and emission characteristics of a modern three-cylinder 1l turbocharged direct injection engine are currently under investigation in the research laboratory of the Powertrain research Centre at the University of Nottingham. The engine is operated at 2000rpm and delivers a 40Nm torque. The in-cylinder gas pressure, recorded from a pressure transducer installed in the combustion chamber, is measured with a ½ crank angle degree resolution; the pressure recordings are provided in an excel file (CW_Case 2000rpm_40Nm.xlsx) and uploaded on the MMME4066 Moodle page. The engine specification and operating conditions are summarised in the table below.

	value	Units			value	Units
IVC	140	BTDC		Intake Air Temp at IVC	31.6	degC
EVO	162	ATDC				
Intake Duration	240	CA		Bore	71.9	mm
Exhaust Duration	248	CA		Stroke	82	mm
				Crank radius (a)	41	mm
Speed	2000	rpm		Connecting rod length (l)	137	mm
Load	40	Nm		Compression ratio	10.5	-

Answer the following points:

- Plot the engine cycle on a pressure-volume (pV) diagram. Calculate gamma, the “isentropic” index, from the experimental pressure-volume data
- Calculate the gross indicated work transfer and IMEPg
- Write the equation for brake mean effective pressure (BMEP) and calculate the BMEP at 2000rpm
- Calculate the in-cylinder temperature from IVC to EVO and plot the results as function of the crank angle

Additional information:

This is a self-study activity designed to be completed in the two hours allocated to the lecture scheduled for the 28th October 2025. Calculations can be performed using Excel or Matlab. Given that you would need a PC/Laptop and lecture notes, it might be appropriate for you to complete the activity either in your room or in the library. However, on Tuesday 28th October I will be available on Teams to answer queries and provide support. You are encouraged to work in groups.

Results and solutions will be discussed before in one of the following lectures. Please take calculations and solutions to the lecture.

Solutions

Plot the engine cycle on a pressure-volume (pV) diagram. Calculate gamma, the “isentropic” index, from the experimental pressure-volume data. TOTAL

The volume is calculated using equation 2.7 in Heywood. Or using equation in lecture notes

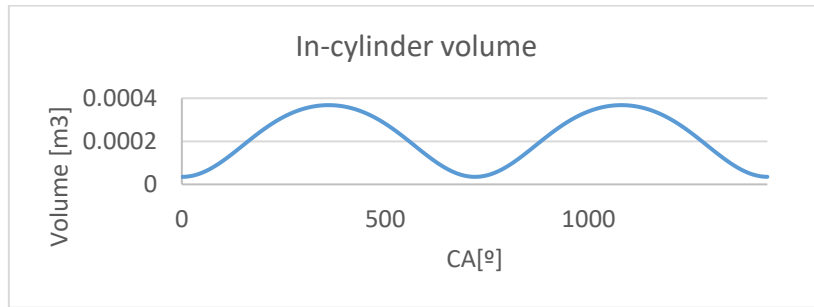
Piston position, at any crank positions, is:

$$s = a \cos \theta + \left(l^2 - a^2 \sin^2 \theta \right)^{1/2}$$

Cylinder volume at any crank positions J, V

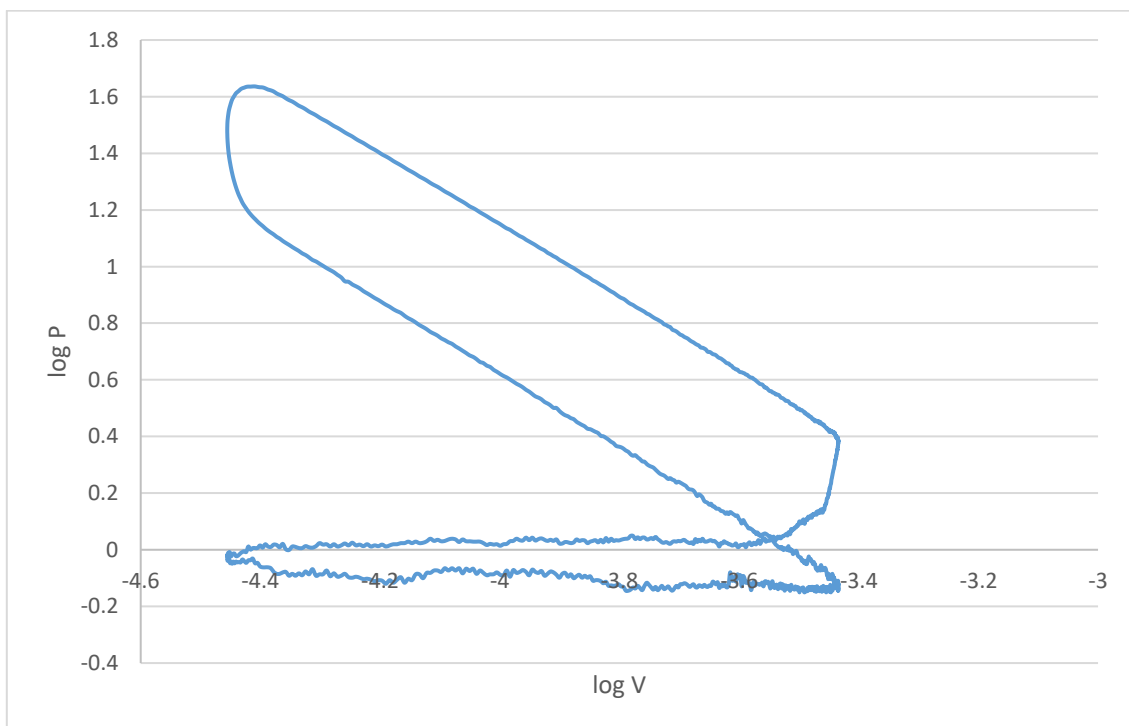
$$V = V_c + \frac{\pi B^2}{4} (l + a - s)$$

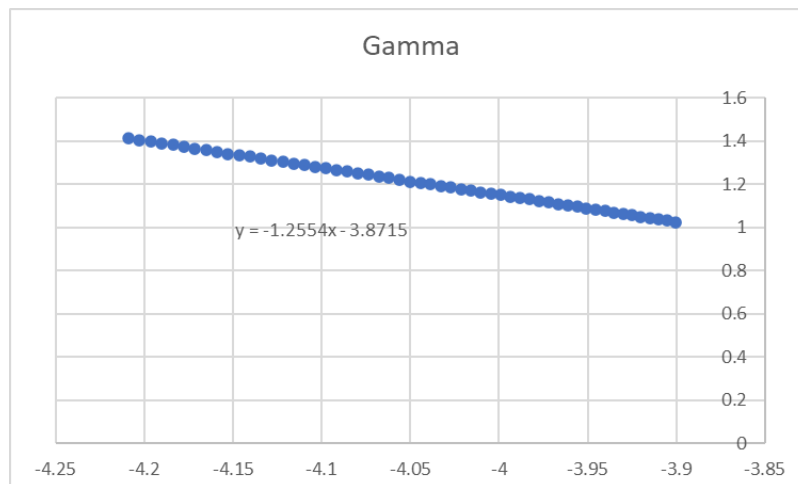
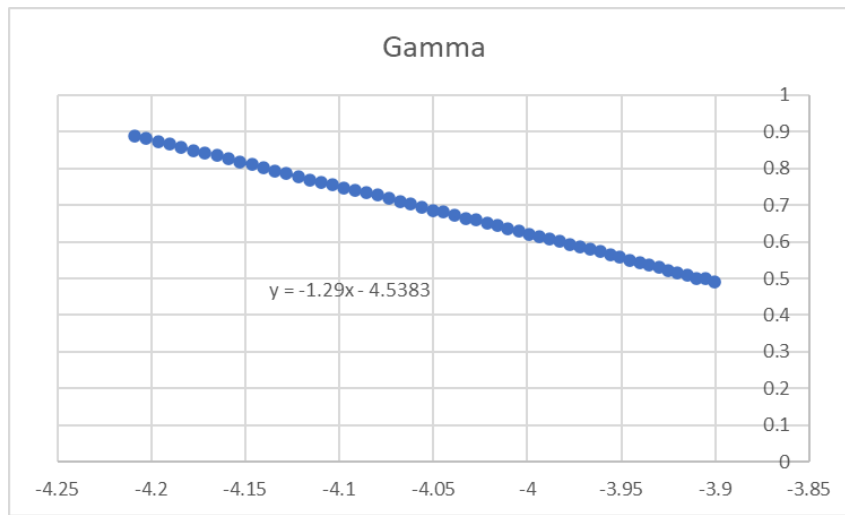
The volume is then:



swept volume		0.000332937	m3
clearance volume		3.5046E-05	m3

Plot of log p and log V is





Gamma is calculated from the p-v diagram in logarithm scale: 1.272 as an average value between the compression and expansion strokes.

Alternatively calculate gamma as function of in-cylinder temperature. This leads to a more robust calculation of the index during compression and expansion and ultimately allows more a thorough calculation of the heat release calculations.

- Calculate the gross indicated work transfer and IMEPg TOTAL

Output of any heat engine and in ICE, is generated by in-cylinder working fluid (gasses)

Result of force due to gas pressure acting through the distance in which the piston moves

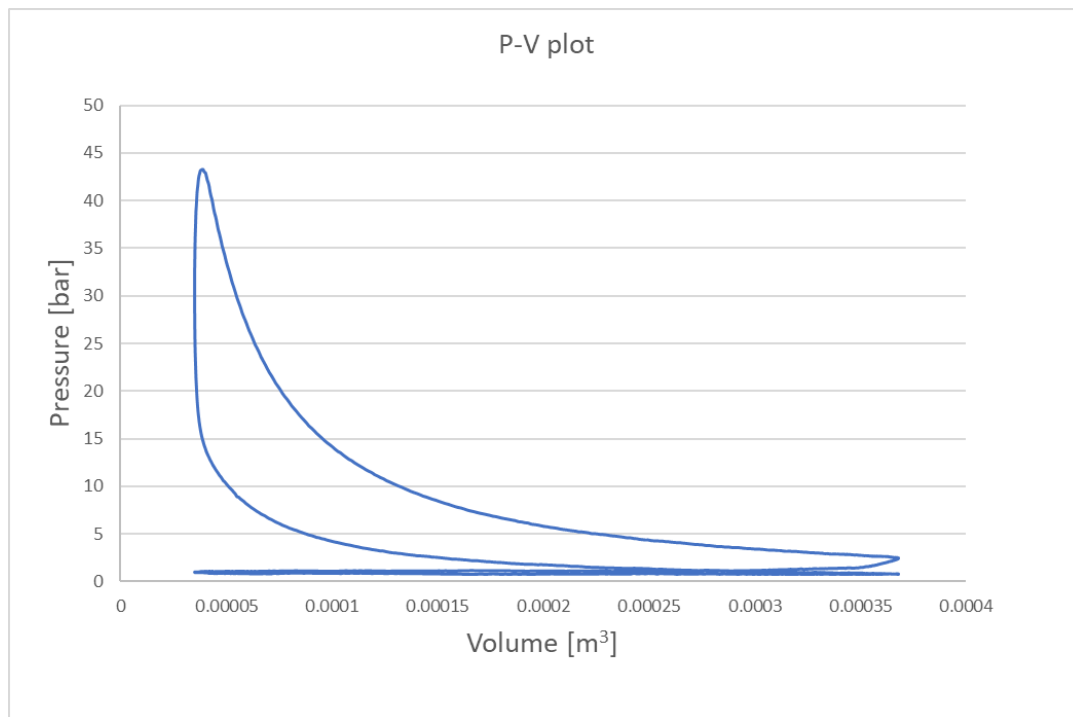
Can be obtained through an engine cycle plotted on a $p - V$ coordinates (indicator diagram) – indicated work

$$W_i = -\oint p dV$$

Gross indicated work per cycle (per cylinder) $W_{c,ig}$ work delivered to piston over compression and expansion strokes only

Gross indicated work calculated from integral of $-pdv$, from pressure trace plotted versus V. the integral is then calculated from 180°C_A to 540°C_A.

If we calculate the integral from 0-720 °C_A we obtain the net work



The trapezoidal rule of numerical integration simply approximates the area by the sum of several equally spaced trapezoids under the curve between the limits

1 Cyl	W _{gi}	222.2
1 Cyl	W _{ni}	209

Mean Effective Pressure is work divided by swept volume (nV_s)

$$imep_{gross} = \frac{W_{c,ig}}{(nV_s)}$$

swept volume	0.000332937	m ³
clearance volume	3.5046E-05	m ³
nV _s	0.00099881	m ³

1 Cyl	IMEP _n	2.09

1 Cyl	IMEPg	2.21
3 Cyl	IMEPg	6.64

Write the equation for brake mean effective pressure (BMEP) and calculate the BMEP at 2000rpm

Brake power: Power transferred from engine to the output shaft

$$\dot{W}_b = 2\pi NT$$

Brake power is = $2 * 3.14 * 2000 / 60 * 40 =$

brake power = (2 pi N T)			8377.6	W
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$$bmep = \frac{\dot{W}_b}{(nV_s)N/2} = \frac{W_b}{(nV_s)}$$

BMEP = 5.03 bar

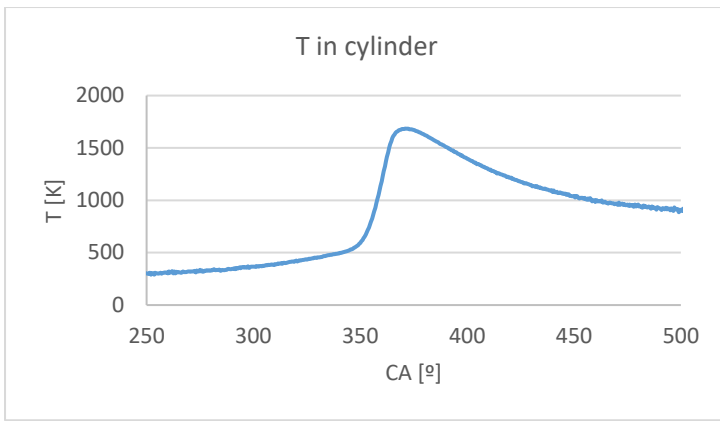
Calculate the in-cylinder temperature from IVC to EVO and plot the results as function of the crank angle

Intake air temperature at intake valve closing is 31.6°C.

Then assuming working fluid to be a perfect gas in a closed system during IVC and EVO:

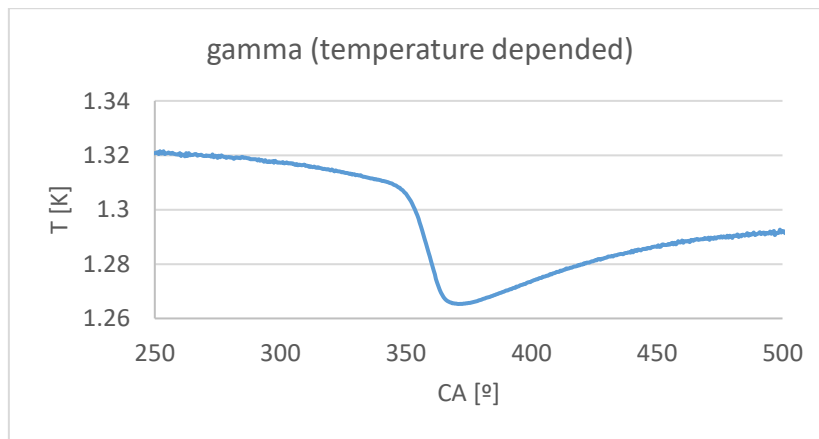
perfect gas equation

$$T_{cyl(i)} = T_{cyl(i-1)} * (p(i) * V(i)) / (p(i-1) * V(i-1))$$



Using the following temperature depended equation:

$$\gamma = 1.338 - 6 \cdot 10^{-5} \cdot T_{cyl} + 1 \cdot 10^{-8} \cdot T_{cyl}^2$$



Useful consideration for heat release calculations:

Issues associated with the accurate determination of gross heat release energy.

- If Gamma is assumed constabt. Varying gamma, γ , (ratio of specific heats) for the case of the First Law model with constant gamma and no heat transfer. Gamma has a very large effect on both the magnitude of the heat release and the shape of the cumulative heat release curves. A low value of gamma produces both a heat release value which is too high and a heat release rate which is negative after the completion of combustion.
- If a Temperature depended gamma is used. gamma reduces significantly with advancing crank angle due mainly to the increasing charge temperature and to a lesser extent the changing charge composition. So the correlation used is important. Typically a second order correlation between gamma and temperature is used as it gives a reasonable fit to all of the data
- Errors in the measured cylinder pressure will always be present and will have an effect on the accuracy of the calculated heat release data. Typical measurement errors include incorrect absolute pressure referencing, thermal shock, calibration and crank angle phasing and cylinder volume errors due to incorrectly assumed compression ratio.