Department of Mechanical Engineering

Applied Thermodynamics (ME 321) – 3:0:0:6

Assignment **Due Date: 11 April 2022**

(To be submitted ONLY in the form of Hard Copy)

Internal Combustion Engines

1. A three-litre V6 spark ignition square-engine operates on a four-stroke cycle at 3300 rpm. At this speed, the combustion ends at 20°aTDC. The compression ratio of the engine is 9.6 and the length of connecting rod is 16 mm. Calculate, (a) bore and stroke length of the cylinder; (b) average piston speed; (c) clearance volume of one cylinder; (d) piston speed at the end of combustion; (d) distance the piston has travelled from TDC at the end of combustion; (e) volume of the combustion chamber at the end of combustion
2. A three-litre V6 spark ignition square-engine operates on a four-stroke cycle at 3300 rpm. It is connected to a dynamometer that gives brake torque of 205 N.m. The air enters the cylinder at 80 kPa and 57°C. The mechanical efficiency of the engine is 82%. Calculate, (a) brake power; (b) indicated power; (c) brake mean effective pressure; (d) indicated mean effective pressure; (e) friction mean effective pressure; (f) power lost to friction; (g) brake power per unit mass of the gas in the cylinder; (h) brake specific power; (i) brake output per displacement; (j) engine specific volume.
3. A three-litre V6 spark ignition square-engine operates on a four-stroke cycle at 3300 rpm. The engine is running at air-fuel ratio of 15 with combustion efficiency of 97%. Calculate, (a) rate of fuel flow into the engine; (b) brake thermal efficiency; (c) indicated thermal efficiency; (d) volumetric efficiency; (e) brake specific fuel consumption.
4. A four-cylinder petrol engine has a bore of 55 mm and stroke of 90 mm. The engine is tested at rated speed of 3000 rpm against a brake torque arm of 360 mm at atmospheric condition. The net brake load is 155 N with fuel consumption of 6.75 litres/hr. A Morse test is carried out and the cylinders are cut out in the order 1, 2, 3 and 4 with corresponding brake loads of 111 N, 106.5 N, 104.2 N and 111 N, respectively. Calculate, (a) engine torque; (b) brake mean effective pressure; (c) brake thermal efficiency; (d) specific fuel consumption; (e) mechanical efficiency; (f) indicated mean effective pressure; (g) volumetric efficiency.

5. A four-cylinder 2.5 litre, SI engine operates at WOT on a four-stroke Otto cycle at 3000 rpm. The engine has a compression ratio 8.6 with mechanical efficiency of 85% and stroke to bore ratio of 1.03. The air-fuel ratio is 15 and the combustion efficiency is 98%. At the start of compression stroke, the conditions in the cylinder of combustion chamber are, 100 kPa and 60°C. (a) Perform a complete thermodynamic analysis for the engine; (b) If the exhaust pressure is 100 kPa, calculate, exhaust temperature, pressure and residual; (c) If the engine runs at part throttle with intake pressure of 50 kPa, calculate the temperature in the cylinder at the start of compression stroke
6. A truck engine operates on an air-standard diesel cycle with heavy diesel fuel and has combustion efficiency of 98%. The engine has a compression ratio of 16 and the maximum cycle temperature is 2400°C. The temperature and pressure in the cylinder at the start of compression stroke are, 55°C and 100 kPa, respectively. Calculate, (a) the temperature, pressure and specific volume at each state of the cycle; (b) air-fuel ratio in the cylinder; (c) cylinder temperature when the exhaust valve opens; (d) indicated thermal efficiency.
7. A small truck has four-cylinder CI engine that operates on dual cycle with light diesel and air-fuel ratio of 18. The compression ratio is 17 and the bore diameter is 120mm. At the beginning of compression stroke, the conditions of the cylinder are, 60°C and 100 kPa with 2% residual gas. Assume that half of the heat input from combustion is added at constant volume followed by constant pressure. Calculate, (a) temperature and pressure at each state of the cycle; (b) indicated thermal efficiency; (c) exhaust temperature; (d) air temperature in intake manifold; (e) volumetric efficiency
8. Isoctane is burnt with 110% theoretical air in a three-cylinder automobile engine. Calculate, (a) air-fuel ratio; (b) fuel-air ratio; (c) equivalence ratio
9. A gasoline fuel is designed by blending of 18% butane, 72% triptane and rest with isodecane. Determine the anti-knock index and sensitivity of the blended fuel.
10. In a CI engine running at 1700rpm, the combustion starts at 14°bTDC. The ignition delay for the fuel is 5.2°CA. Calculate the start of fuel injection and ignition delay time.
11. The spark plug is fired at 18°bTDC in an engine running at 1750rpm. It takes 8°of engine rotation to start combustion and get into fuel propagation mode. Flame termination

occurs at 12°aTDC. The bore diameter is 86 mm and the spark plug is offset 8 mm from the centerline of the cylinder. (a) Calculate the effective flame speed; (b) The engine speed is increased to 3000 rpm and flame termination has to occur 12°aTDC. The flame front speed is directly proportional to the 0.85N. Calculate the advancement of ignition timing.

12. A diesel engine has a compression ratio 18 and operates on a Dual cycle at 2500 rpm. The combustion starts 7.2°bTDC and lasts for 42° of engine rotation. The ratio of connecting rod length to crank offset is 4. Calculate ignition delay and fuel cutoff ratio.
13. It is desired to have combustion in a CI engine operating on Diesel cycle starting at 1.5°aTDC with ignition delay of 4°CA. The engine has 6-cylinder operating at 980 rpm with total displacement of 15 litres. The stoke of the engine is twice the bore size and the compression ratio is 16. Calculate, the average piston speed, start of fuel injection and ignition time delay.
14. A 3-litre, 5-cylinder 4-stroke SI engine has volumetric efficiency of 82% while operating at 2800 rpm. The stroke of the engine 1.1 times the bore size. At certain point of the engine cycle, the gas temperature is 2300°C and cylinder wall temperature is 195°C. Calculate convective heat transfer wall to the cylinder wall.
15. A twelve-cylinder, two-stroke CI engine operates at 550rpm to produce brake power 2450kW by using stoichiometric light diesel fuel. The engine has a bore of 240mm and stroke of 320mm with volumetric and combustion efficiency of 98%. Calculate, (i) mass flow rate fuel into the engine; (ii) specific emission of hydrocarbons due to unburnt fuel; (iii) emission index of hydrocarbons due to unburnt fuel.
16. The cylinder of an IC engine contains gaseous combustion products at 7 bar and 847°C just before the opening of exhaust valve. Determine the specific exergy of the gas.

Gas Turbines

17. In a Brayton cycle, air is drawn from atmosphere at 1 bar and 30°C into the compressor. The maximum pressure and temperature of the cycle is limited as 8 bar and 900°C, respectively. If the heat supply to the cycle is 100 MW, calculate, (a) thermal efficiency of the cycle; (b) work ratio; (c) power output; (d) exergy flow rate of gas leaving the turbine.
18. A gas turbine plant operating on Brayton cycle has maximum and minimum temperature as 25°C and 1000°C, respectively. Calculate, (a) maximum specific work done by the gas; (b) optimum pressure ratio; (c) cycle efficiency; (d) ratio of cycle efficiency to Carnot efficiency.
19. A gas turbine unit produces 5MW power while operating at pressure ratio of 9.5 by involving two compressors with intercooling between stages. A HP turbine is used to drive the compressor and the LP turbine drives the generator. The temperature of the gas at the entry to the HP turbine is 750°C and the gases are further reheated to same temperature. The exhaust gases leaving the LP turbine are passed through a heat exchanger to heat the air leaving HP compressor. The compressors have equal pressure ratio and the intercooling is complete between the stages. The air inlet temperature is 15°C. The isentropic efficiency of each compressor stage is 0.82 and that of turbine is 0.88. The heat exchanger has thermal ratio of 0.72. Calculate, (a) cycle efficiency; (b) work ratio; (c) mass flow rate.
20. Determine the specific work output, fuel consumption and cycle efficiency for a simple gas turbine unit with a free turbine for the following data: compressor pressure ratio: 12.5, turbine inlet temperature: 1450 K, Isentropic efficiency: compressor (0.82) & turbine (0.88), mechanical and combustion efficiency: 0.98, combustion chamber pressure loss: 6% of compressor delivery pressure, exhaust pressure loss: 0.03 bar, ambient condition: 1 bar, 288K
21. Determine the specific thrust, fuel consumption for a simple turbojet engine with following specification: compressor pressure ratio: 9.2, turbine inlet temperature: 1350 K, Isentropic efficiency: intake (0.93), compressor (0.85), turbine (0.9), propelling nozzle (0.95), mechanical and combustion efficiency: 0.98, combustion chamber pressure loss:

4% of compressor delivery pressure, exhaust pressure loss: 0.03 bar, ambient condition: 0.22 bar, 220 K; Mach number: 0.8

22. An aircraft driven by turbojet engine is flying at 230 m/s at an altitude where ambient conditions are 0.22 bar and -47°C. The compressor pressure ratio is 10.5 and the maximum cycle temperature is 900°C. Calculate, the thrust developed by the engine and specific fuel consumption by using the following data: Isentropic efficiency: intake (0.9), compressor (0.9), turbine (0.92), propelling nozzle (0.92), mechanical and combustion efficiency: 0.98, combustion chamber pressure loss: 0.15 bar, nozzle outlet area: 0.07 m^2.

<u>Reciprocating air compressor</u>

23. A single-stage reciprocating compressor receives 1.15m^3 air per minute at atmospheric condition. The pressure ratio is 8.5 and index of compression is 1.3. (a) Calculate the indicated power; (b) If the compressor is to be driven at 400 rev/min, find the cylinder bore for a stroke to bore ratio of 1.35; (c) Calculate the power required by the motor to drive the compressor for a mechanical efficiency of 82% and transmission efficiency of 90%; (d) Calculate the isothermal efficiency of the compressor
24. Atmospheric air is compressed in a single-acting, two-stage reciprocating air compressor at a rate 6 kg/min and pressure ratio of 10.5. Both stages have same pressure ratio with the index of compression 1.3 and intercooling is complete between the stages. The clearance volumes of both stages are 5% of the respective swept volume and the compressor runs at 300 rev/min. (a) Calculate the indicated power and swept volume of the cylinder; (b) Determine the rate of heat loss to the cylinder jacket cooling water and rate of heat loss to the intercooler circulating water.