Engines course

Exercise IV: idle regulation of a S.I Engine

Data:

Consider the following 4 cylinders spark ignition 2L engine:

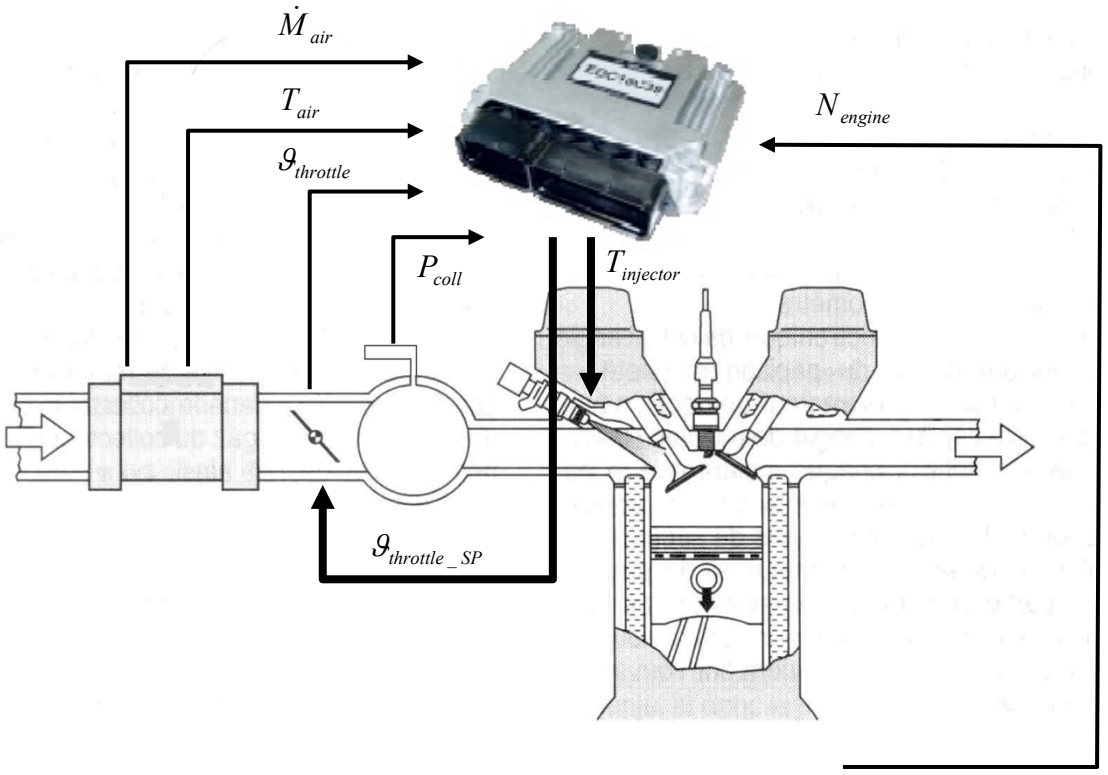

Fig 1: Scheme of an ECU regulation in a S.I engine

Type of engine:	In-line 4 cylinders
Cylinder engine displacement:	500 cm^3
Compression ratio:	ε = 10:1
Exhaust manifold pressure:	P_{exh} = 1013 mbar
Specific gas constant:	r =287 J/kgK
Intake manifold temperature:	T_{coll} = 40°C
Target lambda:	λ = 1.00
Air / Fuel ratio of the fuel:	$R_{A/F}$ = 14.2
Lower heating value of the fuel:	Δh_i^0 = 42'600 kJ/kg

Hypothesis:

- ⇨ The engine is operating at idle speed (which means: $E_e^- = 0kW$, except for Q5)
- ⇨ The engine is equipped with a direct injection system
- ⇨ The scavenging phenomenon are neglected, it means that the exhaust valve closing concur with the intake valve opening. Both occurs at TDC
- ⇨ The residual gas mixing process with fresh air will be approximate by an isothermal expansion
- ⇨ Approximation by ideal gas law

Questions:

1. Determine the air mass introduced into the cylinder during the intake stroke as a function of P_{coll} (intake manifold pressure)

   a) Show that M_{air} can be written as: $M_{air} = A \cdot P_{coll} + B$

   b) Find *A* and *B*

   c) Explain why these parameters in a real engine depend on the engine speed

2. Estimate the manifold pressure as a function of the friction torque. Use the fundamental equation of dynamic and separate the mean indicate torque in the two following terms:

   Low pressure torque ($C_{i,LP}$): C_i^-

   High pressure torques ($C_{i,HP}$): C_i^+

   Fundamental equation of dynamic: $C_i^- + C_i^+ - C_{friction} = J_{mot} \cdot \frac{d\omega}{dt}$

   Numerical Application: C_f = 20 Nm (per cylinder), η_i = 0.84

3. Determine the engine speed assuming that the air flow mass through the throttle $\dot{M}_{th} = 0.003\ kg/s$

4. Knowing that the fuel injectors flow rate are given by the following relation:

$$t_{inj}(ms) = 0.358 \cdot M_{fuel}(mg) + 0.97$$

   Calculate the lower / higher injector opening time at idle speed that the Electronic Control Unit (ECU) has to maintain to guarantee the 3 ways catalyst regulation. λ_{low} = 0.98, λ_{high} = 1.02

5. How many crank angle degree (c.a°) will take the injector opening period at full load operation meaning the following conditions:

   N = 6'800 rpm, P_{coll} = 980 mbar, λ_{FL} = 0.82

6. At idle speed, the driver switches on the Air Conditioning system (AC). Calculate the manifold pressure knowing that the compressor needs 40 Nm to be driven. How big is the engine speed drop without any action of the ECU over the throttle?

7. Estimate the air flow mass quantity through the throttle that the ECU has to increase in order to maintain a minimum engine speed of 700 rpm.