Internal Combustion Engines

ENGINE CHARACTERISTICS

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Engine Performance Parameters

Engine performance parameters are power, torque and specific fuel consumption.

Brake torque is normally measured with a dynamometer – engine is mounted on a test bed and the shaft is connected to the dynamometer rotor. The rotor is coupled electromagnetically, hydraulically or by mechanical friction to a stator, which is supported in low friction bearings. Torque exerted on the stator with the rotor turning is measured by balancing the stator with weights, springs or pneumatic means.

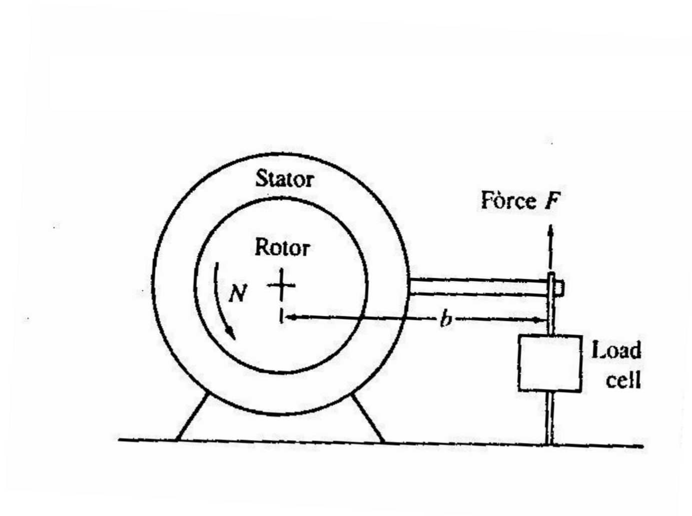
The torque exerted by the engine is, $T = Fb$

The power delivered by engine is, product of torque and angular speed,

$$P = 2\pi NT$$

Brake power is P_b

Engine Performance Parameters



Engine Performance Parameters

Indicated work per cycle

Cylinder pressure data is used to calculate the work transfer from the gas to the piston – cylinder pressure vs cylinder volume throughout the cycle gives p~V diagram.

Indicated work per cycle $W_{c,i}$ is obtained by integrating around the curve to obtain the area enclosed on the diagram

$$W_{c,i} = \oint p \, dV$$

Pumping work during gas exchange is substracted to obtain net indicated work per cycle.

Engine Performance Parameters

Mechanical efficiency

Part of the gross indicated work per cycle or power is used to expel exhaust gases and to induct fresh charge. An additional portion is used to overcome the friction of bearings, pistons, and other mechanical components of the engine and to drive engine accessories. All these power req are called friction power, P_f

$$P_{ig} = P_b + P_f$$

Mechanical efficiency,

$$\eta_m = \frac{P_b}{P_{ig}} = 1 - \frac{P_f}{P_{ig}}$$

Engine Performance Parameters

Road load power

$$P_r = \left[C_R M_v g + \frac{1}{2} \rho_a C_D A_v S_v^2 \right] S_v$$

C_R	Coefficient of rolling resistance, (0.012 – 0.015)[3]
M_v	Mass of vehicle
g	Accn due to gravity
C_D	Drag coefficient (0.3 – 0.5)[3]
A_v	Frontal area of vehicle
S_v	Vehicle speed

Engine Performance Parameters

Mean effective pressure

$$\text{work per cycle} = \frac{P \ n_R}{N}$$

Where n_R is the number of crank rev for each power stroke per cylinder
Mean eff pressure is,

$$p_{me} = \frac{P \ n_R}{V_d N}$$

For naturally aspirated SI-engines, 850 – 1050 kPa at engine speed for max torque (around 3000 rpm), turbocharged SI engines, 1250 – 1700 kPa.

For CI-engines, 700 – 900 kPa

Engine Performance Parameters

	Operating cycle	Compression ratio	Bore, m	Stroke/bore	Rated maximum: Speed, rev/min	Rated maximum: bmep, atm	Rated maximum: Power per unit volume kW/dm³	Weight/power ratio, kg/kW	Approx. best bsfc, g/kW·h
Spark-ignition engines:									
Small (e.g., motorcycles)	2S,4S	6–11	0.05–0.085	1.2–0.9	4500–7500	4–10	20–60	5.5–2.5	350
Passenger cars	4S	8–10	0.07–0.1	1.1–0.9	4500–6500	7–10	20–50	4–2	270
Trucks	4S	7–9	0.09–0.13	1.2–0.7	3600–5000	6.5–7	25–30	6.5–2.5	300
Large gas engines	2S,4S	8–12	0.22–0.45	1.1–1.4	300–900	6.8–12	3–7	23–35	200
Wankel engines	4S	≈ 9	0.57 dm^3 per chamber		6000–8000	9.5–10.5	35–45	1.6–0.9	300
Diesel engines:									
Passenger cars	4S	17–23	0.075–0.1	1.2–0.9	4000–5000	5–7.5	18–22	5–2.5	250
Trucks (NA)	4S	16–22	0.1–0.15	1.3–0.8	2100–4000	6–9	15–22	7–4	210
Trucks (TC)	4S	14–20	0.1–0.15	1.3–0.8	2100–4000	12–18	18–26	7–3.5	200
Locomotive, industrial, marine	4S,2S	12–18	0.15–0.4	1.1–1.3	425–1800	7–23	5–20	6–18	190
Large engines, marine and stationary	2S	10–12	0.4–1	1.2–3	110–400	9–17	2–8	12–50	180

Engine Performance Parameters

Indicated power

Forces acting on the piston, $$P = p_{mi} \frac{\pi D^2}{4}$$

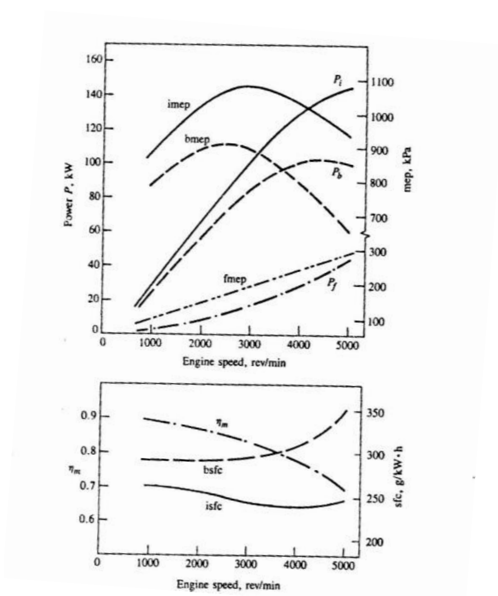
Work done is $$W = p_{mi} \frac{\pi D^2}{4} . S$$

Indicated power, for n [rpm] and 4-stroke engine

$$\text{Power}_i = z \frac{\pi \; D^2}{4} S \; p_{mi} \frac{\text{n}}{2 \text{ x } 60}$$

$$\text{Power}_i = z V_h \; p_{mi} \frac{\text{n}}{2 \text{ x } 60}$$

Engine Performance Parameters



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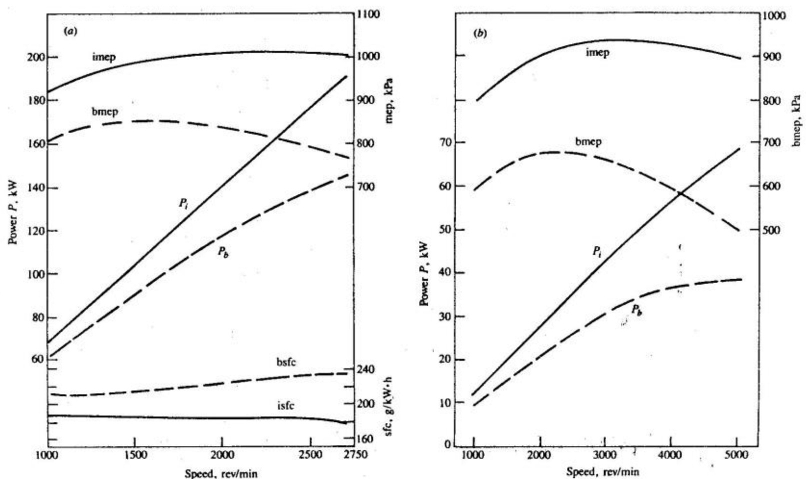


Engine Performance Parameters

Effective power

$$P = p_{me} V_H \, n \frac{1}{2 \text{ x } 60}$$

Power can be increased by incresing stroke volume (increasing cylinder diameter or stroke, number of cylinders), engine speed or mean effective pressure.

Stroke volume

increasing the stroke, inc mean piston speed, inc wear and reduces volumetric efficiency

inc bore, inc cylinder temperatures

inc number of cylinders, easy start up, better balacing, inc weight, inc engine length and vibrations

Engine Performance Parameters

Engine speed

reduces volumetric efficiency, inc inertia forces – valves, inc cylinder temperatures, reduces time available for combustion (Diesel engines)

Mean effective pressure

advance technology required, inc of compression ratio
requires wider wall thickness
turbocharging

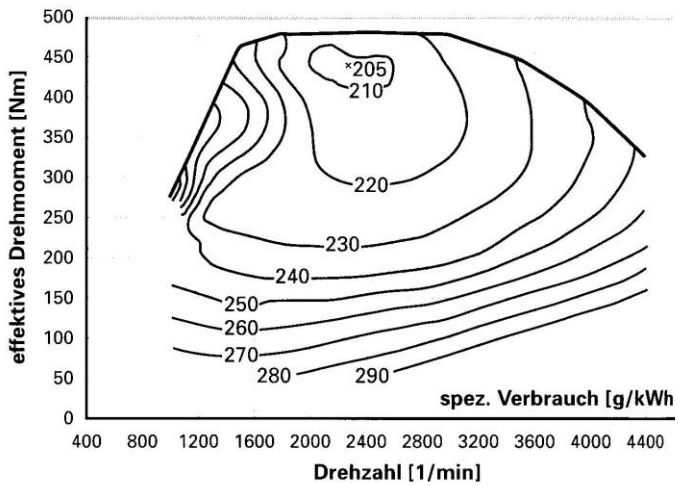
Engine Performance Parameters

Specific fuel consumption

$$sfc = \frac{\dot{m}_f}{P}$$

Low values of sfc are desirable, for SI-engines 250 – 270 g/kW.h and for CI-engines, 200 g/kW.h

Engine Performance Parameters



Engine Performance Parameters