$\boxed{1}$ * Internal Combustion Engines History *

1. Carnot → stated the heat Engine (steam Engine)
2. Joule → measured the Ratio between Work & Heat.
3. Rankin → stated the absolute Temp. scale.
4. Stiriling → got the external hot air engine.
5. Robert street → patented the reciprocating internal combustion Engine.
6. Lenior → produced the first practical internal combustion Engine.
7. Otto → patented the 4-stroke cycle engine using gaseous fuel.
8. Daimler → produced (Mercedes) : Twin Engine V-shape.
9. Rudolf Diesel → constructed the diesel engine with $\eta = 26\%$

* Important lows *

إذا كانت V_d بوحدة L نضرب ب $\boxed{10^{-3}}$

إذا كانت bmep بوحدة bar نضرب في 10^5

إذا كانت SFc بوحدة kg/kW.h نضرب في $\frac{1}{3600}$

⇒ always : 1) Defult is ~~2-stroke ∴ $n_R = 1$~~ 4-stroke ∴ $n_R = 2$

2) when we use $\boxed{N}$ ∴ $\frac{N}{60}$

3) when we have # of cylinders ∴ multiply V_d by # of cylinders

او A_p

$\Rightarrow$ stroke length $= L = 2a$ (m)

$\Rightarrow \bar{U}_p = 2LN$ (m/s) , $U_p = \frac{ds}{dt}$

$\Rightarrow s = a\cos\theta + \sqrt{L^2 - a^2\sin\theta}$

$\Rightarrow V_d = \frac{\pi B^2 L}{4}$

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

$\Rightarrow r_c = \frac{V_c + V_d}{V_c} = \frac{V_{max}}{V_{min}}$

$\Rightarrow A_p = \frac{\pi B^2}{4}$

$\Rightarrow A = A_{ch} + A_p + \pi B(L + a - s)$

$\Rightarrow \dot{W} = 2\pi T N = VI = T\omega$

$\Rightarrow \dot{W}_b = 2\pi T N$

$\Rightarrow \dot{W}_I = \int P\,dv = \frac{W_i N}{n_R} = \frac{imep * A_p * \bar{U}_p}{2 n_R} = \frac{\dot{W}_b}{\eta_{mech}}$

$\Rightarrow \dot{W}_F = \dot{W}_I - \dot{W}_b$

$\Rightarrow bmep = \frac{\dot{W}_b n_R}{V_d N} = \frac{\dot{W}_b n_R}{V_d N} = \frac{2\pi T n_R}{V_d}$

$\Rightarrow imep = \frac{\dot{W} n_R}{V_d N} = \frac{\dot{W}_i n_R}{V_d N}$

اضرب بعدد cylinders

$\Rightarrow T = F \cdot b = \frac{bmep * V_d}{2\pi n_R} = \frac{\dot{W}}{\omega} = \frac{\dot{W}}{2\pi N}$

$\Rightarrow bsFc = \frac{\dot{m}_f}{\dot{W}_b}$ always Take $\boxed{bsFc * \frac{1}{3600}}$

$\Rightarrow IsFc = \frac{\dot{m}_F}{\dot{W}_I}$

$\Rightarrow \dot{m}_f = bsFc * \dot{W}_b = IsFc * \dot{W}_i = bsFc * bmep * V_d * N$

$\Rightarrow \eta_{mech} = \frac{\dot{W}_b}{\dot{W}_I} = 1 - \frac{\dot{W}_F}{\dot{W}_I}$

$\Rightarrow \eta_c = \frac{Q_{in}}{\dot{m}_f * Q_{HV}}$

$\Rightarrow \eta_{th} = \frac{\dot{W}_b}{\dot{m}_f * Q_{HV}}$

$\Rightarrow \eta_F = \frac{1}{bsFc * Q_{HV}} = \frac{1}{IsFc * Q_{HV}}$

Note that $\eta_{th} = \eta_F$ (take $sFc * \frac{1}{3600}$)

$\Rightarrow \eta_v = \frac{m_a}{\rho_a V_d} = \frac{\dot{m}_a n_R}{\rho_a V_d N}$

$\Rightarrow \dot{m}_a = \frac{\eta_v \rho_a V_d N}{n_R} = Dr * \rho_a * V_d * N$

$\rho_a = 1.17$, $\rho_{atm} = \frac{P}{RT}$

$\Rightarrow AF = \frac{M_a}{M_f} = \frac{\dot{m}_a}{\dot{m}_f}$

$\Rightarrow P_r = (C_R M_v g + \frac{1}{2}\rho_a C_D A_v S_v^2) S_v$

Internal | I | (بسم الله الرحمن الرحيم)

* **Engine**: it's a machine that produces work, including the wind mill, water wheel----.

(1) Carnot ⇒ stated the heat engine (steam engine).
(2) Joule ⇒ measured the ratio between work & heat.
(3) Rankine ⇒ stated the absolute Temp. scale.
(4) Stirling ⇒ got the external hot air engine.

* Hot air Engine Disadvantages:
(1) Poor Sealing.
(2) Hot end Material

* **Types of Combustion Engines:**

[1] Internal Combustion Engines (I.C.E)

⇒ it's an engine in which the chemical energy of the fuel is released inside the engine & used to produce Work.

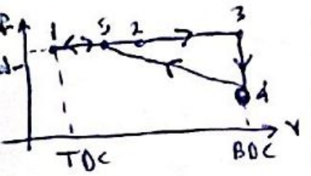
[2] External Combustion Engines (E.C.E)

⇒ it's a seperate combustion to burn the fuel, then the heat is transfered to the cylinder to produce Work.

* Gun Powder ⇒ is usually used as Fuel.

* **Internal Combustion Engines:**

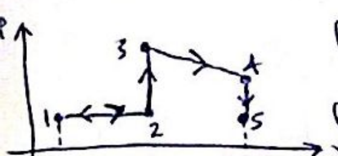
⇒ Atmospheric Engine:



Processes

[1-2] ⇒ Fuel air mixture is introduce into the cylinder
[2-3] ⇒ Combustion at Constant $\underline{P}$ (P_{atm})
[3-4] ⇒ Constant $\underline{V}$ cooling generating Vacum
[4-5] ⇒ isentropic Compression.
[5-1] ⇒ Exhaust process

⇒ First Practical I.C.E by Lenior:



Processes

[1-2] ⇒ Fuel air mixture is introduce into the cylinder.
[2-3] ⇒ Combustion take place at constant $\underline{V}$ and half stroke intake valve closed.
[3-4] ⇒ Work Expansion.
[4-5] ⇒ exhaust valve open.
[5-1] ⇒ exhaust stroke.

(5) Otto ⇒ pattented the $\underline{4}$ stroke cycle engine using gaseous Fuel.
(6) Marcedes ⇒ it's the Twin engine $\underline{V}$ shape produced by Damiler
(7) Rudolf Diesel ⇒ constructed the diesel engine with $\eta = 26\%$
(8) I.C.E is used for Transportation (Trains, airplanes...)
(9) Engine Can deliver from (0.01 to 20000) kW

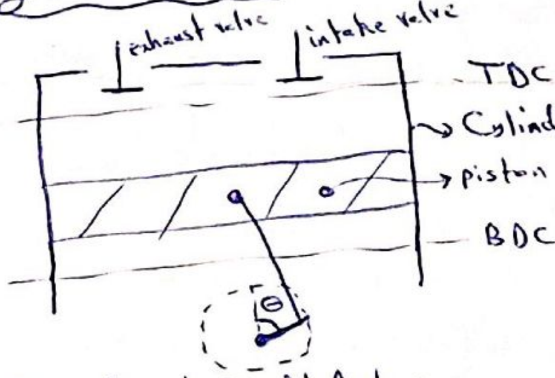
* **Typical Processes of I.C.E:**

Intake Fuel Air > Burning the Fuel ⇒ Expansion & getting Power ⇒ Exhaust Burning Gases.

* **Classification of I.C.E:**

[1] Ignition Type → SI → Benzine Engine; → CI → Diesel Engine
[2] Engine Cycle → 2-stroke; → 4-stroke
[3] Valve location → in head; → in block.
[4] Basic Design → Respocating; → Rotary.
[5] Air Intake → Turbo Charged; → Super Charged
[6] Fuel used → Petrol; → Gas; → Diesel.
[7] Method of Fuel input.
[8] Piston Number.
[9] Applications.
[10] Cooling Type.

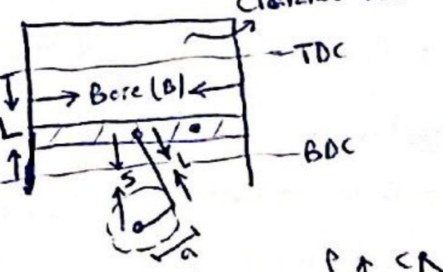
* **Engine Components:**



⇒ θ = Cranck Shaft Angle.

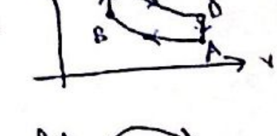
* **Chapter 2: Engine Operating Parameters**

⇒ Otto Engine Operating Cycle (S.I.E) ⇐



B = Bore
L = stroke length
l = connecting Rod length
a = crankshaft offset
N = Turning speed

⇒ Ideal Cycle:

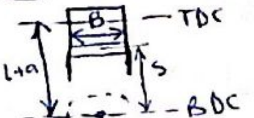


⇒ Actual Cycle:

[2] (بسم الله الرحمن الرحيم)

* Analysis:

[1] length $= L = 2a$ (m)



[2] Speed

=> Rotational speed = Average piston speed $= \bar{U}_p = 2LN$

→ $\bar{U}_p$ ∴ 5 to 15 m/s (5: Diesel, 15: Automobile)

→ N (rev/sec) => always Take $\boxed{\frac{N}{60}}$

=> instantaneous speed $= U_p = \frac{ds}{dt}$

[3] Distance between cranck shaft axis & piston pin $= s$

=> $s = a\cos\theta + \sqrt{L^2 - a^2\sin\theta}$

[4] Volume

=> Clearance volume $= V_c$ = the volume of the cylinder when the piston @ TDC

=> displaced volume = Swept volume = Max. volume $= V_d = \frac{\pi B^2 L}{4}$

=> Cylinder volume (at any cranck shaft angle) $= V(\theta)$

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

=> Compression Ratio $= r_c = \frac{V_c + V_d}{V_c} = \frac{V_{max}}{V_{min}}$

[5] Area

=> Piston Top surface Area $= A_p = \frac{\pi B^2}{4}$ => (نضرب بعدد cylinders).

=> Combustion chamber surface Area $= A = A_{ch} + A_p + \pi B(L+a-s)$

[6] Torque $= T = F \cdot b$ (N.m) $= \dot{W}/\omega = \dot{W}/2\pi N = \frac{b\,mep \times V_d}{2\pi n_R}$

[7] Power = the rate at which the work is done

=> Power delevered by an engine rotating at speed N =

Power $= \dot{W} = 2\pi N T = VI = T\omega$

هو اللي بنستفيد منه

=> Brake power = usable power delevered by the engine

$= \dot{W}_b = 2\pi T N$

→ it's less than gass power due to (friction, AC, pump)

=> Indicated power = power produced in the cylinder

$= \dot{W}_I = \int P\,dV = \frac{W_i N}{n_R} = \frac{\dot{W}_b}{\eta_{mech}} = \frac{imep\,A_p \bar{U}_p}{2n_R}$

→ also: it's the Area under P-V diagram.

→ n_R = number of rev/cycle → 1 --- 2-stroke; 2 --- 4-stroke

* Power Increasing by:

1) Engine size.
2) Compression Ratio.
3) Engine Speed.
4) Super charger & Turbo charger devices

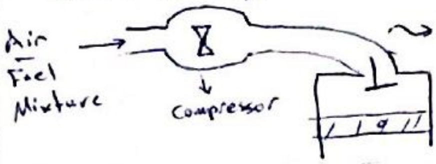
* Power Increasing by Super Charger & Turbo Charger:

=> This done by increasing the intake pressure.

[1] Super Charger Device:

=> it's a compressor that driven by the engine.

=> it increases the amount of the Air fuel Mixture that enters the cylinder.



[2] Turbo Charger Device:

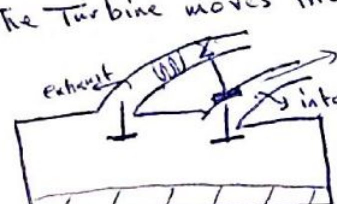
=> it's a couple of turbines with compressor driven by the engine.

=> the Turbine is located between (Exhaust & Intake).

=> when the gases (high Temp. & pressure) are go outside

=> when the gases (high Temp. & pressure) are go outside

∴ The Turbine moves the Compressor.



=> after cooler is used to cool the air Fuel Mix.

∴ the density will increase.

* Mechanical Effeciency:

=> Some of the power generated in the engine is used to overcome friction pumping & gas induction.

=> Friction Power = it's a term used to count for all the losses.

→ $\dot{W}_F = \dot{W}_{Ig} - \dot{W}_b$

=> Mechanical Effeciency $= \eta_{mech} = \frac{\dot{W}_b}{\dot{W}_{Ig}} = 1 - \frac{\dot{W}_F}{\dot{W}_{Ig}}$

=> Mechanical Effeciency depends on:

[1] Throttling which → increase pumping work. → decrease brake power.

[2] Engine speed

[3] Engine design.

(بسم الله الرحمن الرحيم)

⇒ **Mean Effective Pressure (mep):** $mep = \frac{\dot{W} n_R}{V_d N}$ (Pa)

[1] **Indicated mean Effective Pressure (imep):**

⇒ it's an imaginary constant pressure that produced the same work per cycle if acted on the piston during the power stroke.

$\therefore imep = \frac{\dot{W}_i n_R}{V_d N}$ → عند تعلم نضرب بعدد الـ cylinder $= \frac{\dot{W}_i n_R}{V_d * N * \#c}$

$\therefore$ Indicated power $= \dot{W}_I = \int P_i dv = \frac{W_i N}{n_R} = \frac{imep * A_p * \bar{U}_p}{2 n_R}$

[2] **Brake mean Effective Pressure (bmep):**

$\therefore bmep = \frac{\dot{W}_b}{V_d * N} = \frac{2\pi T n_R}{V_d}$ ... V_d لازم نضرب بعدد cylinders

$\therefore$ Torque $= T = F \cdot b = \frac{bmep * V_d}{2\pi n_R}$

⇒ bmep Values:

- 2-stroke ⇒ SI : 500 - 1600 kpa
- 4-stroke ⇒ SI : 800 - 1600 kPa
  - CI : 500 - 900 kPa

⇒ **Specific Fuel Consumption (SFC):** $SFC = \frac{\dot{m}_f}{\dot{W}}$

[1] **Brake Specific Fuel Consumption (bsFc):**

⇒ it's a measure of how effecient fuel is converted into power.

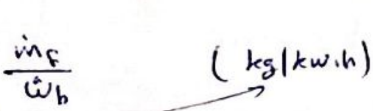
$\therefore bsFc = \frac{\dot{m}_f}{\dot{W}_b}$ (kg/kw.h) $* \frac{1}{3600}$

⇒ $\dot{m}_f$ = mass flow rate of the fuel $= \frac{V}{t}\gamma$ (kg/h) $= \dot{W}_b * bsFc$

[2] **Indicated specific fuel Consumption (isFc):**

$\therefore isFc = \frac{\dot{m}_f}{\dot{W}_I}$ (kg/kW.h)

* Note that: a lower value for SFC is desirable



* **Road load Power** = The power required to drive a vehicle @ steady speed on a level road.

$\therefore P_r = (C_R M_v g + \frac{1}{2}\rho_a C_D A_v S_v^2) S_v$

- C_R = cooling coeffecient = (0.012 - 0.015)
- M_v = mass of vehicle.
- g = gravitational acceleration.
- ρ_a = density of air = 1.17
- C_D = Drag Coeffecient (0.3 - 0.5)

A_v = Frontal Area
S_v = Speed

* **Note: Fuel Heating Values (MJ/kg)**

⇒ Methane 50
⇒ LPG 46
⇒ Gasoline 44.5
⇒ Diesel 43
⇒ Methanol 20

* **Types of Effeciency:**

[1] Mechanical Effeciency $= \eta_{mech} = \frac{\dot{W}_b}{\dot{W}_{Ig}} = 1 - \frac{\dot{W}_F}{\dot{W}_{Ig}}$

[2] Consumption Effeciency $= \eta_c = \frac{\text{actual Heat in}}{\text{Theoritical Heat in}} = \frac{Q_{in}}{\dot{m}_f * Q_{HV}}$

[3] Thermal Effeciency $= \eta_{th} = \frac{W}{Q_{in}} = \frac{W}{\eta_c \dot{m}_f Q_{HV}} = \eta_F$

[4] Fuel Conversion Effeciency $= \eta_F = \frac{W}{\dot{m}_f Q_{HV}} = \frac{1}{SFC * Q_{HV}}$ $* \frac{1}{3600}$

[5] Volumetric Effeciency $= \eta_v = \frac{\text{actual air indicated}}{\text{theoritical air}}$

⇒ $\eta_v = \frac{M_a}{\rho_a V_d} = \frac{\dot{m}_a n_R}{\rho_a V_d N}$

⇒ $\dot{m}_a$ = air mass flow Rate $= \frac{\eta_v \rho_a V_d N}{n_R}$

$\rho_{atm} = \frac{P}{RT}$, $\rho_a = 1.17$

* Note that:

[1] Q_{HV} = Heating Value.

[2] Air-Fuel Ratio $= AF = \frac{\dot{m}_a}{\dot{m}_f} = \frac{m_a}{m_f}$
- ideal AF ≈ 15

[3] for indicated : $\eta \approx$ 50 - 60 %
for Brake : $\eta \approx$ 30 %

[4] Possible Combustion for air ≈ 6 - 19

[5] Engines Comparison by:
1) mep
2) bsFc
3) η
4) η_v
5) Energy Balance.

* Dr = Delivery Ratio = same as the volumetric effeciency but uses the ambient air density instead of the intake air density.

⇒ $\dot{m}_a = \frac{\eta_v \rho_a V_d N}{n_R} = Dr * \rho_a * V_d * N$ (ρ_a = 1.17)

(بسم الله الرحمن الرحيم)

* 2-Stroke Engines:

=> Properties:

1. No seperate intake & exhaust strokes.
2. Two strokes per cycle.
3. One power stroke per revolution.

=> states:

state (1) => Fuel air mixture is introduce into the cylinder then it compressed.

state (2) => combustion products expands doing work and then exhaust.

=> usage:

1. For model engines and small size engines.
2. scooters, chains.
3. for large size engines may be used in Marine & Power generation.

=> Advantages:

1. Compact.
2. light.
3. simple.
4. Cheap.

=> Disadvantages:

1. poor scarevenging.
2. Short circuiting fuel.
3. High Thermal stresses.

* Chapter 3: Thermodynamics & Engine Cycles:

=> V = volume ∴ v = specific volume $= \frac{V}{m}$

=> R = gas constant ∴ R_u = universal gas constant $= \frac{R}{M}$

$= 0.287$ KJ/kg.k (air) $= 8.314$ KJ/Kmol.K

=> N = number of Moles ∴ M = molecular weight.

$m = N.M$

∴ Ideal Gas law

=> $$\boxed{\begin{aligned} PV &= mRT \\ Pv &= RT \\ PV &= N R_u T \\ PV &= N \frac{R}{M} T \end{aligned}}$$

* Processes on Ideal Gas:

1. Constant Pressure ∴ $W = \int P.dV = P(V_2 - V_1)$
2. Constant Temp. ∴ $W = RT \ln\left(\frac{V_2}{V_1}\right)$
3. Constant Volume. ∴ $W = \int P.dV = 0$
4. Polytropic Process ∴ $PV^n = \text{constant}$ → $n=0 \dots P=c$, $n=1 \dots T=c$, $n=\infty \dots V=c$
5. Adiabatic Process ∴ $n = \frac{C_P}{C_V}$

* Note: Specific Heat Ratio $= K = C_P/C_V$

* Thermodynamics Processes:

1. steady state steady flow process (SSSF).
2. steady state Uniform flow process (SSUF).
3. Transient Process.

* Types of Systems:

1. Closed system => Mass = constant (can not pass through boundary.)

∴ $\boxed{Q - W = \Delta U}$

2. Open System => Mass, Work, energy = can pass through boundary.

for SSSF: $\dot{Q} - \dot{W} = \sum \dot{m}_e h_e - \sum \dot{m}_i h_i$ as $\sum \dot{m}_e = \sum \dot{m}_i$

for SSUF: $Q - W + \sum \dot{m}_i \left(h_i + \frac{V_i^2}{2} + gZ_i\right) - \sum \dot{m}_e \left(h_e + \frac{V_e^2}{2} + gZ_e\right) = (m_2 u_2 - m_1 u_1)_{CV}$

~~* Gas Mixtures:~~

~~1) $\bar{u} = \sum y_i \bar{u}_i$~~
~~2) $\bar{h} = \sum y_i \bar{h}_i$~~
~~3) $\bar{M} = \sum y_i \bar{M}_i$~~
~~4) $\bar{C}_P = \sum y_i \bar{C}_{P_i}$~~
~~5) $\bar{C}_V = \sum y_i \bar{C}_{V_i}$~~

~~y_i = Mole fraction~~

~~* Mass Basis:~~

~~1) $u = \sum mf_i u_i$~~
~~2) $h = \sum mf_i h_i$~~
~~3) $C_P = \sum mf_i C_{P_i}$~~
~~4) $C_V = \sum mf_i C_{V_i}$~~

~~mf = mass fraction~~

(بسم الله الرحمن الرحيم)

* Ideal Cycles & Real Cycles:

	Ideal Cycles	Real Cycles
Working fluid.	Air	Air-Fuel Mixture
) Combustion Process.	Not considered	Full combustion Process
) Intake & exhaust Processes.	Not considered	There are intake & exhaust processes
4) Friction & Heat loss	No friction & Heat loss	friction & Heat loss are considered.

* For Thermodynamic Analysis:

هذه الحالة سوف نأخذها فقط حتى لا نستخدم الجداول

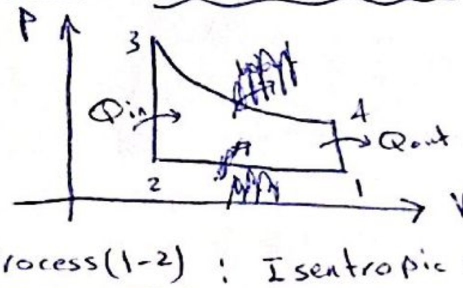
1. Constant specific heat at Room Temp $\Rightarrow C_p, C_v =$ constant
2. Variable specific heat $\Rightarrow C_p, C_v = F(T)$

* Ideal Cycles:

1. Ideal SI Engines Cycle ∴ Ex: Otto Cycle.
2. Ideal CI Engines Cycle ∴ Ex: 1) Diesel Cycle. 2) Dual Cycle.

* First Cycle: Ideal Otto Cycle:

all we assume Constant C_p, C_v



$\Rightarrow$ Process (1-2) : Isentropic Compression.

Specific Heat Ratio $= k = \frac{C_p}{C_v}$, C_p & C_v = constants

r_c = compo Ratio $= V_{max}/V_{min}$

for (air): $C_p = 1.006$, $C_v = 0.718$ ∴ $\boxed{k = 1.4}$

$$\left(\frac{T_2}{T_1}\right) = \left(\frac{V_1}{V_2}\right)^{k-1}$$

$$\left(\frac{P_2}{P_1}\right) = \left(\frac{V_1}{V_2}\right)^{k}$$

$\Rightarrow$ Process (2-3) : Constant Volume Heat addition

$V_2 = V_3$

$$\frac{P_3}{P_2} = \frac{T_3}{T_2}$$

$$Q_{in} = mC_v(T_3 - T_2)$$

*if Q_{in} is given $\Rightarrow$ 1) find $m = \frac{PV}{RT}$ $\rightarrow V = 884 \times 10^{-6}$, $R = 0.287$

2) find $q_{in} = \frac{Q_{in}}{m}$

3) use q_{in} to find $\boxed{T}$

$\Rightarrow$ Process (3-4) : Isentropic Expansion

$$\left(\frac{T_4}{T_3}\right) = \left(\frac{V_3}{V_4}\right)^{k-1}$$

$$\left(\frac{P_4}{P_3}\right) = \left(\frac{V_3}{V_4}\right)^{k}$$

$V_4 = V_1 = V_{max}$ or $\frac{V_3}{V_4} = \frac{V_{min}}{V_{max}} = \frac{1}{r_c}$

$\Rightarrow$ Process (4-1) : Constant Volume Heat Rejection

$$Q_{out} = mC_v(T_4 - T_1)$$

$\Rightarrow$ Work $= Q_{in} - Q_{out} = W_{net}$

$\Rightarrow$ Thermal Effeciency $= \eta_{th,otto} = \frac{W_{net}}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$

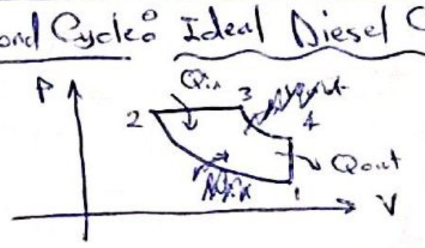
$\Rightarrow$ Mean Effective pressure $= MEP = \frac{W_{net}}{V_d} = \frac{W_{net}}{V_{max} - V_{min}}$

$\Rightarrow$ Compression Ratio $= r_c = \frac{V_{max}}{V_{min}}$

$\Rightarrow$ displaced (swept) Volume $= V_d = \frac{\pi D^2 L}{4}$

$\Rightarrow$ Mass → if it's not given ∴ assume $\boxed{m = 1}$
→ for givens ∴ $m = \frac{PV}{RT}$ for state # 1

* Second Cycle: Ideal Diesel Cycle:



$\Rightarrow$ Process (1-2) : Isentropic Compression

$k = \frac{C_p}{C_v}$, C_p & C_v = constants

$$\left(\frac{T_2}{T_1}\right) = \left(\frac{V_1}{V_2}\right)^{k-1}$$

$$\left(\frac{P_2}{P_1}\right) = \left(\frac{V_1}{V_2}\right)^{k}$$

$\Rightarrow$ Process (2-3) : Constant Pressure Heat addition

$P_2 = P_3$

$V_3 = 2V_2$

$$\frac{T_3}{T_2} = \frac{V_3}{V_2}$$

$$Q_{in} = mC_p(T_3 - T_2)$$

$\Rightarrow$ Process (3-4) : Isentropic Expansion

$V_4 = V_1$
$V_3 = 2V_2$

$$\left(\frac{T_4}{T_3}\right) = \left(\frac{V_3}{V_4}\right)^{k-1}$$

$$\left(\frac{P_4}{P_3}\right) = \left(\frac{V_3}{V_4}\right)^{k}$$

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⇒ Process (4-1): Constant Volume Heat Rejection

$$Q_{out} = m c_v (T_4 - T_1)$$

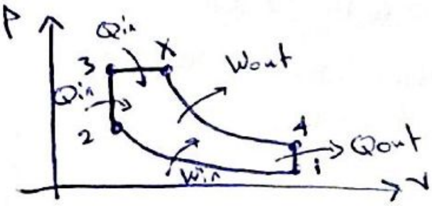
⇒ Mass = $m = \frac{PV}{RT}$ for state #(1)

⇒ Work = W_{net} = $Q_{in} - Q_{out}$

⇒ $\eta_{th,Diesel} = \frac{W_{net}}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$

⇒ $MEP = \boxed{\frac{W_{net}}{\underbrace{V_{max}}_{V_1} - \underbrace{V_{min}}_{V_2}}} = \boxed{\frac{W_{net}}{V_d}}$

* Third Cycle: Ideal Dual Cycle:



⇒ Process (1-2): Isentropic Compression.

⇒ Process (2-3): Constant volume Heat addition.

⇒ Process (3-X): Constant Pressure Heat addition.

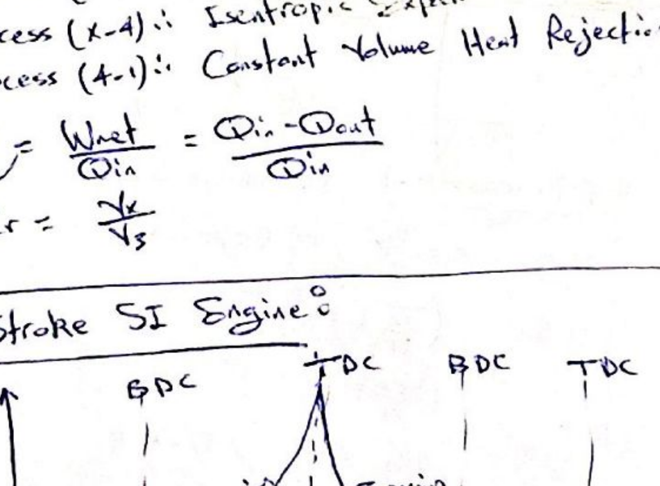
⇒ Process (X-4): Isentropic Expansion.

⇒ Process (4-1): Constant Volume Heat Rejection.

⇒ $\eta = \frac{W_{net}}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$

⇒ $C_r = \frac{V_x}{V_3}$

* 4-Stroke SI Engine:



* Heat Release Model:

⇒ Otto & Diesel Cycles assume {→ constant volume, → constant Pressure} release.

⇒ Actual Temp. & Pressure dont match.

* Typical Heat Release:

⇒ Weibe function for Heat Release = $X_b(\Theta)$

$$\therefore X_b(\Theta) = 1 - \exp\left[-a\left(\frac{\Theta - \Theta_s}{\Theta_d}\right)^n\right]$$

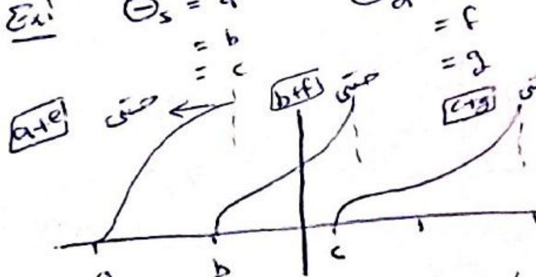
- X_b = burned fraction
- Θ = crank angle
- Θ_s = start of Heat Release
- Θ_d = duration of Heat Release
- a = weibe effeciency factor
- n = weibe form factor.

⇒ Note: 1) $\boxed{a = 5, n = 3}$ ∴ Best fit for experimental data

2) Rate of Heat Release as Function of Θ

$$\therefore \frac{dQ}{d\Theta} = Q_{in} \frac{dX_b}{d\Theta}$$

Ex: $\Theta_s = a$, $= b$, $= c$ $\Theta_d = e$, $= f$, $= g$



Best الوسط هو

chapter 4 : (7) (بسم الله الرحمن الرحيم)

* Engine Fuels :

=> To use the engines for automobiles ∴ a liquid fuel was needed.

- - - - - -

* **Knock** : it's an auto ignition phenomenon that limits the pre compression of fuels.

∴ if Comp. Ratio increase => P, T of the fuel increase too.

=> P, T will increase eventually reaching the self ignition point.

=> knock is result in uncontrolled combustion yield in a poor performance & engine damage.

[redacted]

* Liquied Fuel History :

=> The engines were built as stationary power plants with solid fuels.

=> Liquid Fuels :

[1] start by using animal fats => large amount of heat was needed to vaporize the fats

[2] 1880 => first of distilling the crude oil into (asphalt, kerosine & Gasoline).

[3] 1890 => Diesel was used the powdered coal adding to it lubricating oil.

∴ he results that using 100% meduem oil ignited more uniformly.

=> he end up using Diesel fuel in the Engine.

∴ Diesel fuel → Heavier than kerosine. → lighter than lubricating oils.

∴ Origional Gasoline has a very low anti knock limits (r_c 4:1 of SI)

[4] 1926 => pure iso-octane was isolated octane

∴ Octane # is the iso octane fraction.

ex :

n - heptane	0
iso - octane	100

* Types of Oil :

[1] Crude oils => it's formed due to fossilization of organic matters underground from (C, H, O_2, Hg & others).

[2] Light oils => includes :

a) ~~Standard~~ saturated Hydro Carbons (C_nH_{2n+2}) ex : Paraffines & Normal Alkanes.

=> Note : if n = 1-4 -- gas
= 5-15 -- liquid
> 15 -- Solid.

b) Unsaturated Hydro Carbons. ex : Benzene (C_6H_6)

c) Resin & Asphalt => which are heavier Hydro Carbons => rich in : N_2, O_2

* light oil products :

1) Refinary gas.
2) LPG
3) Gasoline
4) Diesel & lubricating oils.

* Refining → Distilation.
→ Catalytic cracking (Heating)
→ Reforming (with steam or H)

* Types of Fuel :

[1] Indolene : it's well refined gasoline with low level of (sulfur, phospherus & vapor pressure) used for SI - Engine.

[2] Diesel : [redacted] → average molecular weight.
→ greater boiling point than gasoline
→ used for CI - Engine.

[3] Compressed Natural Gas : primary methane (CH_4) used for Vehicles, generates less emissions than gasoline.

[4] Methanol (CH_3OH) : → lower emissions than gasoline
→ good alternative fuel
→ usually → 85% methanol → 15% unleaded gasoline

[5] Ethanol (C_2H_5OH) : automotive fuel (22% Ethanol) with gasoline produced from (corn, ...

(بسم الله الرحمن الرحيم)

* Residual Gas:

=> it's the remained exhaust gas in the engine which mixed with the fresh fuel air mixture.

=> Temp. of Residual Gas = Remained exhaust gas Temp

$$\therefore \boxed{T_{exhaust} = \left(\frac{P_e}{P_4}\right)^{\frac{k-1}{k}} * T_4}$$

↳ P_e = exhaust pressure.

=> $\boxed{\text{Residual fraction} = f = \frac{1}{r_c}\left(\frac{P_e}{P_4}\right)^{\frac{1}{k}}}$

* Intake Process => $\boxed{m_6 = m_1 f}$

=> $\boxed{m_i = m_1 - m_6 = m_1(1-f)}$

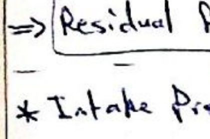
↳ m_1 = mass of BDC
↳ m_6 = mass of TDC
↳ m_i = The fresh entered mass.

* Energy Analysis => $\boxed{T_1 = (1-f)T_i + f\,T_e\left[1-\left(1-\frac{P_i}{P_e}\right)^{\frac{k-1}{k}}\right]}$

* Fuel Properties:

[1] Volatility => it's the tending of liquid to evaporate

[2] Distilation Curve => it's a repesentation of the percentage evaporated at different Temps



=> it has a great effect on the engine performance.

Case(1): volume of the evaported fuel at 70 °C => should be enough to ensure good start.

Case(2): Volume of the evaported fuel at 100°C => should be high enough to reduce mixing with engine lubricating oil.

Case(3): Volume of the evaporated fuel at 180°C => determines the normal operation.

[3] Vapor Pressure => it depands on the composition of fuel.

[4] Driveability Index => it predicts the Engine Performance

$$\therefore \boxed{DI = 1.5\,T_{10} + 3\,T_{50} + T_{90}}$$

↳ T_{10} = Temp. of liquid evaporated at 10%.

Note: DI for Gasoline = 1000-1200

[5] Octane - Cetane Rating =>

↳ Octane Rating: The quality of gasoline ignition
↳ Cetane Rating: The quality of diesel ignition.

if octane # (Rating) increase
if Cetane # (Rating) decrease] : Resistance to knock will increase.

[6] Calorific Value => it's the Energy Contents in the fuel.

* Fuel Composition (Hydro Carbons):

[1] Paraffines & Alkanes => straight chained hydrocarbon

(Form): C_nH_{2n+2}
→ n = 1-4 ... gas
→ n = 5-15 ... liquid
→ n ≥ 15 ... solid

Ex:
n=1 : CH_4 ... methane
n=2 : C_2H_6 ... ethane
n=3 : C_3H_8 ... propane
n=4 : C_4H_{10} ... butane
] are Gases.

[2] Aromatics => highly octane blended hydrocarbons

Ex: Benzene (C_6H_6)

[3] Olefines => gasoline hydro carbons resulting from several refining process.

(Form): C_nH_{2n}

Ex: Ethylene, Propylene.

[4] Acetylenes

(Form): C_nH_{2n-2}

[5] Alcohols => OH replaces on H

Ex: 1) Methane (CH_4) => Methyl alcohol = Methanol (CH_3OH)
2) Ethane (C_2H_6) => Ethanol (C_2H_5OH)

[6] Oxygenates => octane contains (C, H, O) in their molecular structure to improve combustion.

[7] Additives => chemicals added to gasoline, to:
1) improve combustion.
2) reduce wear.
3) limit deposite formation.

Ex: Antioxidants, corrosion inhibitors, detergents

9 (بسم الله الرحمن الرحيم)

* Uncontrolled Combustion :

(1) ⇒ Abnormal (uncotrolled) Combustion : it's the bearning of fuel before it's reached by the flame.
↳ it causes → 1) Engine damage.
→ 2) Noise.

(2) ⇒ knock : it's an auto ignition phenomenon that limits the precompression of fuels.
(or)
it's the sound resulted from the pressure waves as a result of early ignition of F/A mixture.

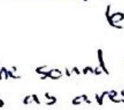
(3) ⇒ Surface ignition : it's the ignition of F/A mixture by any hot surface other than spark.

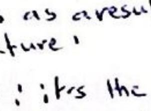
* Knocking :

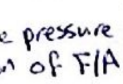
Firstly; Definition :

⇒ knock : it's an auto ignition phenomenon that limits the precompression of fuels.
(or)
it's the sound resulted from the pressure waves as a result of early ignition of F/A mixture.

Secondly: Types :

1) Light knock ⇒ 

2) heavy knock ⇒ 

Normal Combustion ⇒ 

Thirdly: Effect :

1) limits the Compression Ratio.
2) causes Engine damage.
3) causes poor Engine performance
4) Noise

Spark Time (long)
Burning Time (long)

Fourthly: variables in knock occurance :

1) if The Burning time is long ⇒ time avaliable before the arrived of the flame.

2) The end gas Temp.

Fifthly: Variable affected knock :

1) Compression Ratio ⇒ high r_c ∴ high T, P
∴ This promotes the knock occurance
(9-10.5) ~~حد~~

2) Engine Speed ⇒ low speed ∴ flame velocity is slow
∴ The Burning time is long
∴ more time for auto ignition.
Autoignition الوقت عند بدء Temp الاحتراق زاد

3) Spark Time ⇒ advance spark Time ∴ P, Tmax @ TDC
∴ enhance knock occurance.
ازاي تزود

⇒ spark Time is set 1% before MBT = max. Brake. Torque

Sixthly: knock depends on :

1) Engine
2) fuel.
3) Vehicle
4) Ambient conditions.

Seventhly: To avoid knocking

1) r_c is 9 - 10.5
2) decrease inlet air Temp.
3) retarding the spark timing.
4) increase the anti knock quality of fuel octane #

* Measurement of Octane # :

* Measurement of Octane # for Single Cylinder

⇒ Conditions to measure octane # for Single Cylinder

1) Bore = B = 3.25"
2) Strokelength = L = 4.5"
3) Comp. Ratio = r_c = 3-30

⇒ The Minimum octane # should be specify for the Engine

Standard Conditions	Research Method	Motor Method
Inlet Temp (°C)	52	149
Speed (rpm)	600	900
Spark advance	13	19-26
Coolant Temp (°C)	100	
inlet pressure	1	
Humidity (kg H₂O/kg air)	0.0036 - 0.0072	

⇒ $\boxed{\text{Anti knock Index} = AKI = \frac{RON + MON}{2}}$

↳ RON = Research octane Number.
↳ MON = Motor Octane Number.

⇒ Octane # for chemicals with anti knock quality better than 100 :

∴ $ON = 100 + 28.28T \div [1 + 0.736T + (1 + 1.472T - 0.035216T$

↳ T = millitiler of tetraethyl lead per US galon

⇒ Additives : (Lead alkyls) is the most additive effect on anti knock.

	RON	MON
⇒ Methan (r_c = 12.6)	120	120
Propane (r_c = 12.2)	112	97
Methanol	106	92
Ethanol	107	89
iso octane	100	100
gasoline	91	83

(بسم الله الرحمن الرحيم)

* Gas Mixtures:

- ⇒ m = mass = NM (kg)
- ⇒ M = molecular weight (kg/kmol) - from Tables
- ⇒ N = number of moles (kmol)
- ⇒ R = gas constant = 0.287 kJ/kg.k for air = $\frac{R_u}{M}$
- ⇒ R_u = universal gas constant = 8.314 kJ/kmol.k

* Important laws:

⇒ Here → m means Total
→ i means One Element
→ f means fraction

1. Total Mass = $m_m = \sum m_i$ = كتلة العناصر (kg)
2. Mass fraction = $m_f = \frac{m_i}{m_m}$ = كتلة العنصر / الكتلة الكلية للعناصر = $y_i \frac{M_i}{M_m}$
3. Number of mole = $N_i = \frac{m_i}{M_i}$ = كتلة العنصر / الوزن الذري للعنصر (من الجدول) (kmol)
4. Total Number of moles = $N_m = \sum N_i$ (kmol)
5. Mole fraction = $y_i = \frac{N_i}{N_m}$ = عدد مولات العنصر / مجموع عدد مولات العناصر
6. Total Molecular weight = $M_m = \sum y_i M_i = \frac{m_m}{N_m}$ (kg/kmol)
7. Gas Constant = $R = \frac{R_u}{M_m} = \frac{8.314}{M_m}$ (kJ/kg.k)
8. Specific Heats → $C_{pm} = \sum m_{fi} C_{pi}$ (kJ/kg.k)
→ $C_{vm} = \sum m_{fi} C_{vi}$
9. Internal Energy → $U_m = \sum U_i = \sum m_i u_i$
→ $\bar{U} = \sum y_i \bar{u}_i$

* Notes:

1. if givens are mass in kg
   - find $m_m = \sum m_i$
   - find m_f
2. if givens are percentages on mass basis
   - m_m = 100 kg (assumly or given)
   - $m_f = y_i$ = percentage.
   - $N_i = \frac{m_i}{M_i}$ = قيمة المعطى / M_i
3. if givens are percentages on Volume
   - y_i = percentage
   - $M_m = \sum y_i M_i$
   - $m_f = y_i \times \frac{M_i}{M_m}$
4. M ⇒ O = 16, N = 14, C = 12, H = 1

* SI-Engine Fuel:

1 Crude oil

⇒ it contains a large number of Hydrocarbons (25000)
⇒ Refining process is to seperate crude oil into various fractions.
⇒ still is to heat a sample boiling off lighter compounds which are then condensed & recovered.

2 Fractions

⇒ The group of compounds that boil between two Temps.
⇒ Fractions are with no chemical processing.
⇒ Types of fractions → 1) Light, 2) Heavy
⇒ fractions order resulting from refining:

Napha distillate gas oil residual oil	straight run or virgin compounds

* Note: 1) Straight run Napha can be used as Gasoline
2) Gasoline Temp. ⇒ (25-225) °C
3) Diesel Temp. ⇒ (180-360) °C
] distillate Temp

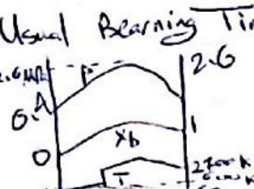
* Chemical Processing for fractions, is used to:
1) produce gasoline from other fraction.
2) upgrade a given fraction, Ex: producing iso-octane from → butane → iso-butane

⇒ to reduce CO, HC emissions ∴ Oxygen contents in gasoline is increased 3% by weight in winter

* Flame creating by the heating of the flow of charge (The Oxygen & The fuel)
* Flame spreads away from the spark.

* Bearning Time = $t_{90\%} = \frac{\Delta\theta_{90\%}}{\frac{N\,rpm}{60} \times 360°}$

* Usual Bearning Time ⇒



	N	t (ms)
idle car	500	16.7
Car@Max power	4000	2.1
formula cars	19000	0.4

⇒ formula Cars have high speed because they have a very short stroke & wide bore.

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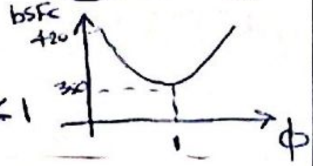
* Optimum Equivalence Ratio:



$\Rightarrow$ Maximum Power @ $\phi = 1.1$

$\Rightarrow$ Best Fuel Economy @ $\phi < 1$

* Spark Timing:

$\Rightarrow$ Best Time to ignite is before Top center (Burning is centered about Top center)

$\Rightarrow$ Optimum spark Timing is that gives the Max. brake torque

$\Rightarrow$ Start of Combustion → early : work is done against the piston
→ too late : peak pressure is reduced

* Chapter $\boxed{6}$: Combustion

$\Rightarrow$ Combustion : it's the process of oxidization of fuel with energy release.

$\Rightarrow$ Oxidizer is (O_2 in Air)

$\Rightarrow$ Fuel : it's any material that store energy in their chemical bonds.

$\Rightarrow$ Fuel used is (Hydro Carbon)

$\Rightarrow$ Air : 1) consist of → 20.9% O_2, → 78.1% N_2, → 1% others ∴ → 21% O_2, → 79% N_2 abouttly.

2) one mole of O_2 is accompained with 3.76 mole of N_2 at high Temp.

3) N_2 reacts to form NO_x = pollutant.

* Combustion Eqns:

* Combustion of HydroCarbon with O_2 :

$\boxed{1}$ Combustion of HydroCarbon with O_2

$$\Rightarrow C_nH_m + \left(n+\frac{m}{4}\right) O_2 \rightarrow n\,CO_2 + \frac{m}{2} H_2O$$

Ex: a Complete Combustion for propane (C_3H_8):

$$\Rightarrow C_3H_8 + 5\,O_2 \rightarrow 3\,CO_2 + 4\,H_2O$$

$\boxed{2}$ Complete Combustion of Hydro Carbon with Air : (or) Stoichiometric Combustion

$$\Rightarrow C_nH_m + \left(n+\frac{m}{4}\right)(O_2 + 3.76 N_2) \rightarrow n\,CO_2 + \frac{m}{2} H_2O + 3.76\left(n+\frac{m}{4}\right) N_2$$

$$\Rightarrow A/F = \frac{1}{F/A} = \frac{\left(n+\frac{m}{4}\right) M_{O_2} + 3.76\left(n+\frac{m}{4}\right) M_{N_2}}{n\,M_C + m\,M_H}$$

$\boxed{3}$ Incomplete Combustion of Hydro Carbon with Air :

$$\Rightarrow C_nH_m + \left(n+\frac{m}{4}\right)(O_2 + 3.76 N_2) \rightarrow (n-\alpha) CO_2 + \left(\frac{m}{2} - \beta\right) H_2O + 3.76\left(n+\frac{m}{4} - \frac{\gamma}{2}\right) N_2 + (\alpha CO_2 + \beta H_2 + \gamma\, NO + \text{some } O_2)$$

* Notes on the Incomplete Combustion:

1) The Term : $(\alpha CO_2 + \beta H_2 + \gamma\, NO + \text{some } O_2)$ is Called $\Rightarrow$ Dissociation products.

2) Fuel lean mixture $\Rightarrow$ excess Air $\gamma > 1$

$$\therefore C_nH_m + \gamma\left(n+\frac{m}{4}\right)(O_2 + 3.76 N_2) \rightarrow n\,CO_2 + \frac{m}{2} H_2O + d\,N_2 + CO_2$$

3) Fuel rich mixture $\Rightarrow$ excess Air $\gamma < 1$

$$\therefore C_nH_m + \gamma\left(n+\frac{m}{4}\right)(O_2 + 3.76 N_2) \rightarrow a\,CO_2 + b\,H_2O + d\,N_2 + e\,CO + f\,H_2$$

4) Equivalence Ratio :

$$\Rightarrow \phi = \frac{(F/A)_{act}}{(F/A)_s} = \frac{(A/F)_s}{(A/F)_{act}}$$

→ $\phi < 1$ --- Rich
→ $\phi = 1$ --- stoichiometric
→ $\phi > 1$ --- Lean

* The amount of CO, NO_x, CH products depends on:

1) Fuel
2) Combustion Conditions.
3) How fast the products are cooled

* Enthalpy of Combustion (formation):

* Change in Energy of a system during a chemical reaction

$\Rightarrow$ Change in Energy of a system during a chemical reaction

$$\Delta E_{sys} = \Delta E_{state} + \Delta E_{chem}$$

$\Rightarrow$ if state inlet = state exit

$$\Delta E_{sys} = \Delta E_{chem}$$

$\Rightarrow$ for : 1 kmol C, 1 kmol O_2, 25°C, 1 atm $\therefore \Delta E = 393520\,J$

* Enthalpy of Reaction :

$\Rightarrow$ it's the difference between the enthalpy of products at a state & the enthalpy of reactants at the same state for complete Combustion.

$\Rightarrow$ for combustion Process : Enthalpy of Reaction is called Enthalpy of Combustion

$$h_R = h_c = H_{prod} - H_{react}$$

* Definitions :

$\boxed{1}$ Exothermic Reaction : during which chemical energy is released in the form of heat.

$\boxed{2}$ Endothermic Reaction : reactions that need energy to be done.

(بسم الله الرحمن الرحيم)

* Heating Value:

⇒ it's the amount of heat released when the fuel is burned completely in steady state, and the products produced are returned to the same state of reactants.

* Types of Heating Value:

[1] Higher heating value (HHV)

⇒ it's the value of enthalpy when H_2O is in liquid state.

[2] Lower heating value (LHV)

⇒ it's the value of enthalpy when H_2O is in vapor form.

$$\therefore HHV = LHV + m_{H_2O} h_{fg}$$

* First law Analysis:

[1] steady flow System

$$\Rightarrow \dot{Q}_{in} + \dot{W}_{in} + \sum \dot{n}_R (\bar{h}_f^\circ + \bar{h} - \bar{h}^\circ)_R = \dot{Q}_{out} + \dot{W}_{out} + \sum \dot{n}_P (\bar{h}_f^\circ + \bar{h} - \bar{h}^\circ)_P$$

[2] Closed system

$$\Rightarrow Q_{in} - Q_{out} + (W_{in} - W_{out}) = U_P - U_R$$

$$\Rightarrow Q - W = \sum N_P (\bar{h}_f^\circ + \bar{h} - \bar{h}^\circ - P\bar{v})_P - \sum N_R (\bar{h}_f^\circ + \bar{h} - \bar{h}^\circ - P\bar{v})_R$$

[3] Adiabatic flame Temp

$$\Rightarrow Q = 0 \quad \therefore H_P = H_R$$

(Products reach the Maximum Temp.)

* N_2 effect in the products ⇒ is absorbs a large amount of heat release.

* H_2O effect in the products ⇒ 1) is absorbs some heat release
2) increase the dew point Temp.

* Reasons for Incomplete Combustion:

[1] insuffecient burning time.
[2] insuffecient O_2.
[3] Bad Mixing.
[4] Dissociation.

* Enthalpy of Combustion is due → to the burning of fuel.
* Enthalpy of Formation is due → to the composition of the substance.
* In Combustion process ($h_c = h_f$) → if in the result is a single substance

* To find:

$$\Rightarrow A/F = \frac{m_a}{m_F} = \frac{1}{F/A}$$

1) نقوم بموازنة المعادلة لإيجاد المجاهيل مثل (a_{th})
2) نجد m_a مجموع الـ O_2 و N_2 في المتفاعلات =

Ex: $2(O_2 + 3.76 N_2) \Rightarrow m_a = 2 * 4.76 * 29$

3) نجد m_f مجموع الـ C و H في المتفاعلات =

Ex: $C_3H_8 \Rightarrow m_f = 3 * 12 + 8 \times 1$

Note: always
- fuel is C & H & أي شي ثاني
- Air is O_2 & N_2

] = في المتفاعلات

* Emission & Air Pollution:

[1] Carbon Monoxide (CO)

(a) it's the most dangerous to human health
(b) Colourless
(c) Odourless
(d) highly poisonous gas.
(e) Reduce O_2 carrying capacity in blood.
(f) it's effect at 100 ppm → 600-700 ppm causes headache
→ over 4000 ppm fatal in less than 1 hour.
(g) CO is produced in fuel rich mixtures.
(h) diesel engines produce less CO than gasoline engines.

[2] Unburned HydroCarbon

(a) 35% of Hydrocarbon in Atmosphere is due Transportation
(b) Causes Risk to health & Leukaemia.
(c) Produced in Lean fuel Mixtures

[3] Nitrogen Oxides (NO, NO_2)

(a) 50% of NO_x is due Transportation.
(b) NO: Colourless, odourless, not toxic.
(c) NO_2: reddish-brown, causes lung damage at high concentrations.
(d) NO_x: → reacts with HC → to form Ozone.
→ reacts in Atmosphere → to form Nitric Acid (acid Rain)
(e) produced in lean fuel Mixtures.

[4] CO_2

(a) Not Toxic or pollutant.
(b) responsible about 80% of global warming.
(c) Diesel Engines produce (20-30)% CO_2 less than Gasoline

[5] Sulphur Dioxide (SO_2)

(a) Colourless acidic gas.
(b) Causes eye irritation & lung problems

بسم الله الرحمن الرحيم

* Enmission Control :

[1] Fuel Modification

=> The oxygenated fuel can significantly reduce HC.

[2] Engine Technology

(a) EGR = Exhaust Gas Recirculation.

=> Reducing NO_x by reducing P&T.

(b) Turbocharging.

=> Reducing CO

(c) Combustion chamber design.

=> better mixing ∴ more complete combustion.

[3] Treatment of Exhaust Gases

=> Catalytic Converter ∴ it accelerates the chemical reaction while it remains unaffected by the reaction.

=> Platinum, Palladium, Rohodium ∴ are promote oxidation of (CO, HC, NO)

=> Particulate filter is used in Diesel Engines.

* Friction => it occurs due to the contact between surfaces when they move relative to each other.

* Lubrication => it used to seperate surfaces by adding a layer of oil between them.

* Oil layer => it's order in μm.

* Types of Friction :

[1] Mechanical friction Losses.
[2] Pumping losses.
[3] accessory losses.

* Notes on friction :

[1] To reduce friction => light short pistons are used.
[2] friction ends up by heat dissipation.
[3] Maximum friction occurs @ TDC & BDC
=> due to extremely low piston speed resulting in boundary lubrication.
[4] Frictional Work → is measured using Motor with Dynamometer

* Frictional Power: it's the power used to motor the engine at a given engine speed & conditions.

* Motor Friction Test => it's performed to have similar operation of engine conditions
=> it's performed directly after the normal

* Oil & Lubrication :

=> Modern cars use oil pump to lubricate all parts of car engine.

=> Old cars used splashing method to:
1) Lubrication.
2) Cooling.
3) Slow corrision.
4) Removing contaminants

* Notes:
1) Lubricating oils are heavy HC
2) The name of the oil is given according to it's viscosity
=> The higher number of oil → The higher it's viscosity

Ex: SAE 20 W - 50
↓ cold oil ↓ winter ↓ hot oil

* Engine Heat Transfer :

=> Heat is Transfer from hot gases of the engine to the different parts of the engine.

$$\therefore q = q_{conv} + q_{rad}$$

q_{conv} ⇓ Higher value; q_{rad} ⇓ lower value

* Heat Transfer Models :

1) Nusselt => The first Equ. used for Heat Transfer

$$\therefore h = h_c + h_r$$

$$h_c = 5.41E-3\,(1+1.24\,V_p)\,(P^2 T)^{1/3}$$] Higest value

$$h_r = \frac{4.21E-4\left(\left(\frac{T}{100}\right)^4 - \left(\frac{T_w}{100}\right)^4\right)}{\left(\frac{1}{\varepsilon_j} + \frac{1}{\varepsilon_w} - 1\right)(T - T_w)}$$

2) Eichelberg

$$\therefore h = (7.67E-3)(V_p)^{1/3}(PT)^{1/3}$$] lower value

3) Anound Model

=> Instantanous heat flux $= q'' = a\frac{k}{D} Re^{0.7}(T - T_w) + b(T^4 - T_w^4)$

- $a = 0.35 - 0.8$
- $b = 3.31 \times 10^{-1} - 4.3 \times 10^{-12}$
- Re based on $\bar{U}_p$ & B

4) Wochni Mode

$$h = \frac{W}{nATk} = 3.2\,B^{-0.2} * (P_{in\,kPa})^{0.8} * (T)^{-0.55} * (\bar{U}_p)^{0.8}$$

$$\therefore q'' = h\,\Delta T = h(T_g - T_{wall})$$

$\boxed{14}$ (بسم الله الرحمن الرحيم)

Problems:

$\boxed{1}$ 4-stroke Deisel Engine:

$\Rightarrow r_c, \gamma = k, T_i, P_i, \frac{P_i}{P_e}, M, q_{in}$: are givens

$\Rightarrow$ We assume: $T_e = 1000\ k$, $f = 0.05$, $P_e = 1\ bar$] unkowns

1) state (1)

$\Rightarrow$ find $\boxed{T_1}$ $\therefore T_1 = (1-f)T_i + f\,T_e\left[1-\left(1-\frac{P_i}{P_e}\right)^{\frac{k-f}{k}}\right]$

$\boxed{P_1} = P_i$

2) state (2)

$\Rightarrow$ find $\boxed{P_2}$ $\frac{P_2}{P_1} = (r_c)^k$

$\boxed{T_2}$ $\frac{T_2}{T_1} = (r_c)^{k-1}$

3) state (3)

$\Rightarrow$ find $\boxed{P_3} = P_2$

$\boxed{T_3}$ $(1-f)\,q_{in} = m\,C_P(T_3 - T_2)$

4) state (4)

$\Rightarrow$ find $\boxed{P_4}$ $\frac{P_4}{P_3} = \left(\frac{V_3}{V_4}\right)^k = \left(\underbrace{\frac{V_3}{V_2}}_{\frac{T_3}{T_2}} \times \underbrace{\frac{V_2}{V_4}}_{\frac{1}{r_c}}\right)^k$

$\boxed{T_4}$ $\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^k = \left(\underbrace{\frac{V_3}{V_2}}_{\frac{T_3}{T_2}} \times \underbrace{\frac{V_2}{V_4}}_{\frac{1}{r_c}}\right)^k$

5) state (5)

$\boxed{T_5}$ $\frac{T_5}{T_4} = \left(\frac{P_5}{P_4}\right)^{\frac{k-1}{k}} \Rightarrow T_5 = T_e$

* check: $f = \frac{1}{r}\left(\frac{T_4}{T_e}\right)\left(\frac{P_e}{P_4}\right)$

$\boxed{2}$ Fraction of Condensed Water

1) Balance the Equ.

2) N_w for H_2O in products $= \underbrace{N_{H_2O}}_{\text{عدد مولات } H_2O \text{ المتكون}}\ N_w$

3) P_v @ $T = 20°C$

4) $\frac{N_v}{N_P} = \frac{P_v}{P_P}$
- $\to N_v \Rightarrow N_{H_2O} - N_w$
- $\to N_P \Rightarrow N_{products} - N_w$
- $\to P_v$ ✓✓
- $\to P_P = 101.325$

5) find $N_w \Rightarrow \frac{N_w}{N_{H_2O}} = \square$

$\boxed{3}$ Enthalpy of Combustion $= h_C$

$h_c = H_P - H_R = \sum N_P \bar{h}^o_{fP} - \sum N_R \bar{h}^o_{fR}$ ← جاهز في الجداول

$0 = \bar{h}$ لأي مادة في صورتها الطبيعية

$\Rightarrow \boxed{h_{fN_2} = h_{fO_2} = 0}$