Unit - 3

Air standard cycle -

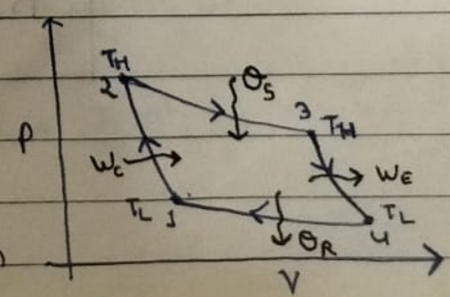
• Defination - the efficiency of engine using air as the working medium is known as air standard efficiency & the cycle is known as air standard cycle.

• Assumptions -

i, The working medium is air (perfect gas)
ii, There is no change in mass of air during cycle
iii, working medium has constent specific heat C_p & C_v
iv, The working medium homogenous & no chemical rxn takes place
v, Physical constents of working medium are same as that of Air. at standard atmospheric pressure.
$C_p = 1.005$, $C_v = 0.718$ kj/kg , $\gamma = \frac{C_p}{C_v} = 1.4$
vi, K.E & P.E of working fluid are neglected.
vii, Operation of engine is frictionless.
viii, Heat is supplied / rejected in a reversible manner instant
ix, source of heat supply & sink for heat rejection are external to air (working medium)
x, compression & Expansion process are reversible adiabatic i.e no loss or gain of entropy.

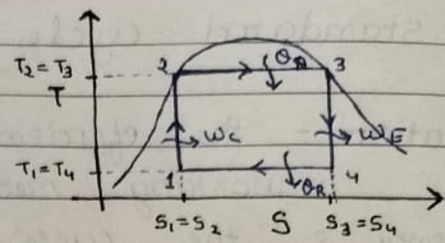
Carnot cycle :~

contains four Process.



i, 1→2 Reversible adiabatic compression
ii, 2→3 Reversible isothermal heat addition
iii, 3→4 Reversible adiabatic / isoentropic expansion
iv, 4→1 Reversible isothermal heat rejection

We know, that



$$\int ds = \int \frac{dQ}{T}$$

now, $$\int_2^3 ds = \int_2^3 \frac{dQ}{T_H}$$

$$Q_S = m \cdot T_H (S_3 - S_2)$$

and $$\int_4^1 ds = \int_4^1 \frac{dQ}{T_L}$$

$$Q_R = m \cdot T_L (S_4 - S_1)$$

$$\therefore \quad \eta = \frac{\text{output}}{\text{input}} = \frac{W_{net}}{Q_S}$$

acc to 1st law, $W_{net} = Q_{net}$

$$W_{net} = Q_S - Q_R$$

$$\therefore \quad \eta = \frac{Q_S - Q_R}{Q_S}$$

$$= \frac{m \cdot T_H (S_3 - S_2) - m \cdot T_L (S_4 - S_1)}{m \cdot T_H (S_4 - S_1)}$$

in carnot cycle, $S_1 = S_2$ & $S_3 = S_4$, then

$$= \frac{m \cdot T_H (S_4 - S_1) - m T_L (S_4 - S_1)}{m \cdot T_H (S_4 - S_1)}$$

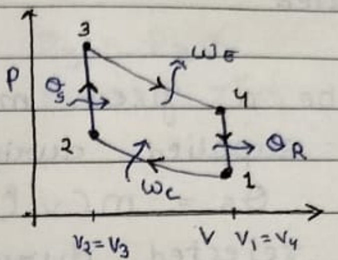
$$= \frac{T_H - T_L}{T_H}$$

$$\boxed{\eta = 1 - \frac{T_L}{T_H}}$$

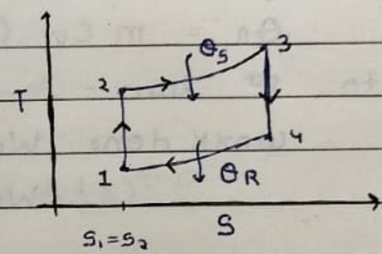
Air standard otto cycle :~

- Also known as const. volume cycle, by using these cycle petrol, gas or any spark ignited engines are designed.

i, $1 \to 2$ reversible adibatic compresion
ii, $2 \to 3$ const. volume heat addition
iii, $3 \to 4$ reversible adibatic Expansion
iv, $4 \to 1$ ischoric heat rejection.

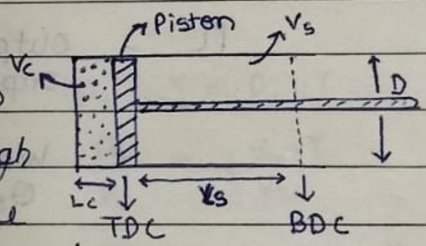


- $1 \to 2$ Air compressed adibatically from V_1 to V_2, then compression ratio $\gamma = \frac{V_1}{V_2} = \frac{V_T}{V_C}$



$\gamma = \frac{V_S + 1}{V_C}$

- $2 \to 3$ Piston momentarily at rest, at TDC and heat is added to working fluid at const. volume from an external heat source which is brough into contact with cylinder head, Due to heat addition Pressure increases via an explosion ratio $\alpha = \frac{P_3}{P_2}$



$V_T = V_C + V_S$

V_C = clearance volume

V_S = stroke volume

L_C = clearance length

L_S = stroke length

Area $= \frac{\pi D^2}{4}$

Volume $= \pi/4 \cdot D^2 \cdot L$

$V_C = \frac{\pi}{4} D^2 \cdot L_C$

$V_S = \frac{\pi}{4} D^2 \cdot L_S$

- $3 \to 4$ due to increased high pressure great force is exerted to pistion Hence it expands from TDC to BDC Expansion of W.F take place & adibatically work is done by system., then

Expansion ratio $= \frac{V_4}{V_3}$

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- 4-1 Piston is momentarily at rest at BDC. Heat is rejected to External Sink by bringing this in contact with cylinder head. The process come to initial state and cycle is completed.

Let m be a fixed mass of a working fluid (Air), then
Heat supplied during process 2-3

$$Q_S = mC_V(T_3-T_2)$$

Heat rejected during process 4-1

$$Q_R = mC_V(T_4-T_1)$$

Acc. to 1st law -
work done $W_{net} = Q_{net}$

$$W_{net} = Q_S - Q_R$$

$$\eta = \frac{\text{output}}{\text{input}}$$

$$= \frac{W_{out}}{Q_S} = \frac{Q_S - Q_R}{Q_S}$$

$$= \frac{mC_V(T_3-T_2) - mC_V(T_4-T_1)}{mC_V(T_3-T_2)}$$

$$= \frac{T_3 - T_2 - T_4 + T_1}{T_3 - T_2}$$

$$= 1 - \frac{(T_4-T_1)}{(T_3-T_2)}$$

for Ideal gas $PV = nRT$

$PV^\gamma = \text{const}$ (adiabatic)

at point 1 : $V_1 = V_2 r$

b/w 1-2 process :- (adiabatic compresion) $P_1V_1^\gamma = P_2V_2^\gamma$

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

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

at point 3 : $V_3 = V_2 = \frac{V_1}{\gamma}$

Explosion ratio : $\alpha = \frac{P_3}{P_2} \Rightarrow P_3 = P_2 \alpha$

$P_3 = P_1 \gamma^{\gamma} \alpha$

constant volume process : $\frac{P_2}{T_2} = \frac{P_3}{T_3}$

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

$\Rightarrow T_3 = T_2 \alpha$

$\Rightarrow T_3 = T_1 \alpha (\gamma)^{\gamma-1}$

at point 4 : $V_4 = V_1$

adiabatic expansion : $P_3 V_3^{\gamma} = P_4 V_4^{\gamma}$

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

$P_4 = P_3 \left(\frac{V_2}{V_1}\right)^{\gamma}$

$P_4 = P_1 \cancel{\gamma^{\gamma}} \alpha \frac{1}{\cancel{\gamma^{\gamma}}}$

$P_4 = P_1 \alpha$

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

$T_4 = T_3 \left(\frac{V_3}{V_4}\right)^{\gamma-1} = T_3 \left(\frac{V_2}{V_1}\right)^{\gamma-1}$

$T_4 = T_3 \left(\frac{1}{\gamma}\right)^{\gamma-1} \Rightarrow \frac{T_1 \alpha \cancel{(\gamma)^{\gamma-1}}}{\cancel{\gamma^{\gamma-1}}}$

$T_4 = T_1 \alpha$.

Subsituting all value, then.

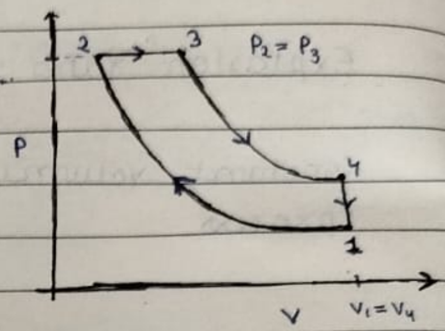
$$\eta = 1 - \frac{(T_1\alpha - T_1)}{(T_1\alpha(\gamma)^{\gamma-1} - T_1(\gamma)^{\gamma-1})} = 1 - \frac{\cancel{T_1}\cancel{(\alpha-1)}}{\cancel{T_1}\gamma^{\gamma-1}\cancel{(\alpha-1)}}$$

$$\boxed{\eta_{ASE} = 1 - \frac{1}{\gamma^{\gamma-1}}}$$

- Air Standard Diesel Cycle

Also known as const. pressure heat addition cycle

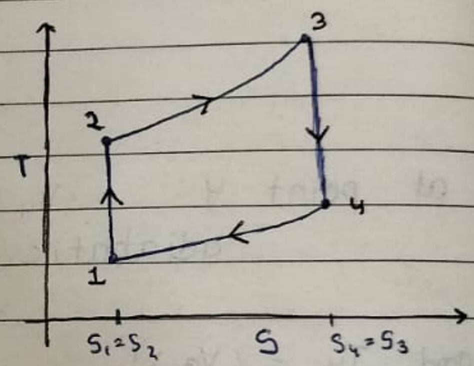
Process 1→2 Reversible adiabatic or isentropic compression process.



Working fluid (air) is compress adiabatical from state point 1 to 2 via compression ratio $r = \frac{V_1}{V_2}$

$P\uparrow$, $V\downarrow$, $T\uparrow$

Process 2→3 Constant pressure heat addition.



During these process heat is added to w.f (air) at const. pressure due to these volume & temp. increases.

Point 3 is called "cutt-off point" with a cutt-off ratio $r_c = \frac{V_3}{V_2}$

$Q_S = m C_p (T_3 - T_2)$

Process 3→4 Reversible adiabatic Expansion process

~~Due to~~ these increased high pressure Exerts a greater amount of force on the piston toward BDC. Expansion of Air take place isentropically & work is done by the system via Expansion ratio $r_e = \frac{V_4}{V_3} = \frac{r}{r_c}$

Process 4→1 Constant volume heat Rejection

The piston is momentarily addressed at BDC heat is n cycle. rejected at const. volume to external sink & air comes to intial state 1 & cycle is completed.

$P\downarrow$, $T\downarrow$ $\qquad Q_R = m\,C_v\,(T_4 - T_1)$.

Let m be the fixed mass of working fluid (Air), then

$$Q_S = m\,C_p\,(T_3 - T_2)$$
$$Q_R = m\,C_v\,(T_4 - T_1)$$
$$W_{net} = Q_S - Q_R$$

now,

$$\eta = \frac{\text{output}}{\text{Input}} = \frac{W_{net}}{Q_S} = \frac{Q_S - Q_R}{Q_S}$$

$$= \frac{m\,C_p\,(T_3 - T_2) - m\,C_v\,(T_4 - T_1)}{m\,C_p\,(T_3 - T_2)}$$

$$= 1 - \frac{C_v\,(T_4 - T_1)}{C_p\,(T_3 - T_2)} \qquad \left[\gamma = \frac{C_p}{C_v}\right]$$

$$= 1 - \frac{1\,(T_4 - T_1)}{\gamma\,(T_3 - T_2)}$$

Efficiency in terms of r, r_c & γ, then.

Process 1→2 adiabatic compression, then

$$P_1 V_1^{\gamma} = P_2 V_2^{\gamma} \qquad\qquad \frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma - 1}$$

$$P_2 = P_1 \left(\frac{V_1}{V_2}\right)^{\gamma} \qquad\qquad T_2 = T_1\,(r)^{\gamma - 1}$$

$$P_2 = P_1\,r^{\gamma}$$

process 2-3 constant pressure, then $(V \propto T)$

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

$$T_3 = T_2\,r_c \Rightarrow T_3 = T_1 . r^{\gamma - 1} . r_c$$

Process 3→4 adiabatic Expansion, then (PV^{γ} = const)

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

$$T_4 = T_3\left(\frac{V_3/V_2}{V_4/V_2}\right)^{\gamma-1} = T_3\left(\frac{r_c}{r}\right)^{\gamma-1} \quad [\because V_4 = V_1]$$

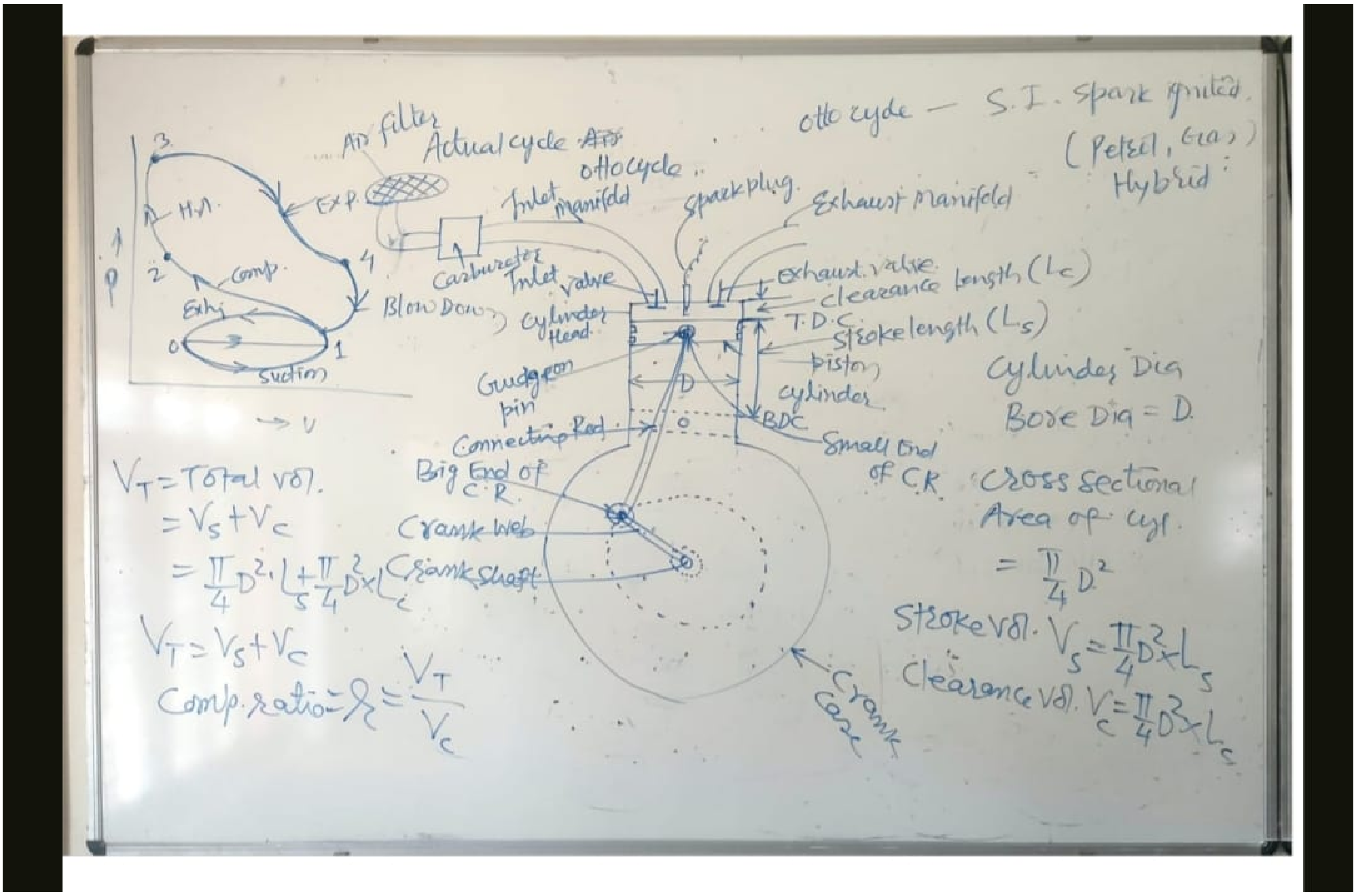
$$T_4 = T_1 \cdot \cancel{r^{\gamma-1}} \cdot r_c \cdot \frac{r_c^{\gamma-1}}{\cancel{r^{\gamma-1}}}$$

$$T_4 = T_1 \cdot r_c^{\gamma}$$

put the value of T_2, T_3 & T_4 in eq 1,

$$\eta = 1 - \frac{1}{\gamma}\frac{(T_1 \cdot r_c^{\gamma} - T_1)}{(T_1 \cdot r^{\gamma-1} \cdot r_c - T_1 \cdot r^{\gamma-1})}$$

$$\boxed{\eta_{Diesel} = 1 - \frac{1}{\gamma \cdot r^{\gamma-1}}\left(\frac{r_c^{\gamma}-1}{r_c-1}\right)}$$



Air filter
Actual cycle
otto cycle
Otto cycle — S.I. - Spark ignited
(Petrol, Gas)
Hybrid
3
H.A.
EXP.
2
4
comp.
Exh
Blow Down
0
1
suction
P
V
Carburetor
Inlet manifold
Spark plug
Exhaust manifold
Inlet valve
Exhaust valve
clearance length (L_c)
Cylinder Head
T.D.C
Stroke length (L_s)
Piston
Cylinder
Gudgeon pin
D
Connecting Rod
BDC
Small End of C.R.
Big End of C.R.
Crank web
Crank shaft
Crank case
V_T = Total vol.
$= V_s + V_c$
$= \frac{\pi}{4} D^2 \cdot L_s + \frac{\pi}{4} D^2 \times L_c$
$V_T = V_s + V_c$
Comp. ratio $= r = \frac{V_T}{V_c}$
Cylinder Dia
Bore Dia = D.
Cross sectional Area of cyl
$= \frac{\pi}{4} D^2$
Stroke vol. $V_s = \frac{\pi}{4} D^2 \times L_s$
Clearance vol. $V_c = \frac{\pi}{4} D^2 \times L_c$

Fuel air cycle

→ specific heat varies with Temp - $C_p - C_v = R$

for monoatomic gases.

$C_v = \frac{3R}{2}$, $C_p = \frac{5R}{2}$, $MC_v = \frac{3MR}{2}$, $MC_p = \frac{5MR}{2}$

for diatomic gas

$C_v = \frac{5R}{2}$, $C_p = \frac{7R}{2}$, $MC_v = \frac{5MR}{2}$, $MC_p = \frac{7MR}{2}$

for polyatomic gas.

$C_v = 3R$, $C_p = 4R.$, $MC_v = 3MR$, $MC_v = 4MR.$

where, R is character gas constanat

MR = mole weight x character gas constant

= universal gas constant

= 8.314 KJ

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- Effect of variable specific heat on efficiency of air standard cycle

$=V_1]$ (a) Otto cycle

we know that

$$\eta = 1 - \frac{1}{r^{\gamma-1}} = 1 - r^{-(\gamma-1)}$$

$$\boxed{\eta = 1 - r^{1-\gamma}}$$

and $C_p - C_v = R$

or $\frac{C_p - C_v}{C_v} = \frac{R}{C_v} \Rightarrow \frac{C_p}{C_v} - 1 = \frac{R}{C_v} \Rightarrow \gamma - 1 = \frac{R}{C_v}$

then,

$$\eta = 1 - r^{-R/C_v}$$

$$1 - \eta = r^{-R/C_v}$$

taking log on both side

$$\log(1-\eta) = -\frac{R}{C_v} \log r$$

Differentiating

$$\frac{1}{(1-\eta)} \cdot -d\eta = -R \log_e r \left[-\frac{1}{C_v^2} dC_v \right]$$

or $d\eta = -\frac{(1-\eta) \cdot R \log_e r \cdot dC_v}{C_v^2}$

Dividing by η

$$\frac{d\eta}{\eta} = -\frac{(1-\eta)}{\eta} \cdot \frac{R}{C_v} \cdot \log_e r \cdot \frac{dC_v}{C_v}$$

$$\underbrace{\frac{d\eta}{\eta}}_{\text{variation in eff.}} = -\frac{(1-\eta)}{\eta} \cdot (\gamma-1) \cdot \log_e r \cdot \underbrace{\frac{dC_v}{C_v}}_{\text{variation in specific heat at constant volume}}$$

(b) Diesel cycle

Efficiency of Air standard Diesel cycle is

$$n = 1 - \frac{1}{\gamma \cdot r^{\gamma-1}} \cdot \left(\frac{r_c^{\gamma}-1}{r_c-1}\right)$$

$$1-n = \frac{1}{\gamma \cdot r^{\gamma-1}} \cdot \left(\frac{r_c^{\gamma}-1}{r_c-1}\right)$$

taking log both side.

$$\log(1-n) = \log\left(\frac{1}{\gamma \cdot r^{\gamma-1}} \cdot \left(\frac{r_c^{\gamma}-1}{r_c-1}\right)\right)$$

$$= \log\left(\frac{1}{\gamma \cdot r^{\gamma-1}}\right) + \log\left(\frac{r_c^{\gamma}-1}{r_c-1}\right)$$

$$= -\log(\gamma \cdot r^{\gamma-1}) + \log(r_c^{\gamma}-1) - \log(r_c-1)$$

$$= -(\log\gamma + \log(r^{\gamma-1})) + \log(r_c^{\gamma}-1) - \log(r_c-1)$$

$$\log(1-n) = \log_e(r_c^{\gamma}-1) - \log_e(r_c-1) - \log_e\gamma - (\gamma-1)\log_e r$$

Differentiating

$$\frac{1}{(1-n)} \cdot -dn = \frac{1}{r_c^{\gamma}-1} \cdot r_c^{\gamma} \ln r_c \cdot d\gamma - \frac{1}{\gamma} \cdot d\gamma - \ln r\,(d\gamma)$$

or $$dn = -(1-n) \cdot \left[\frac{r_c^{\gamma}\ln r_c}{r_c^{\gamma}-1} - \frac{1}{\gamma} - \ln r\right] d\gamma$$

Dividing both side by n

$$\frac{dn}{n} = +\frac{(1-n)}{n} \cdot \left[\ln r + \frac{1}{\gamma} - \left(\frac{r_c^{\gamma}}{r_c^{\gamma}-1}\right)\ln r_c\right] d\gamma.$$

$\because$ $C_p - C_v = R \Rightarrow \frac{C_p - C_v}{C_v} = R \Rightarrow \gamma - 1 = \frac{R}{C_v}$

Diff., then $\Rightarrow d\gamma = -\frac{R}{C_v^2} \cdot dC_v \Rightarrow d\gamma = -(\gamma-1) \cdot \frac{dC_v}{C_v}$

$$\boxed{\frac{dn}{n} = -\frac{(1-n)}{n} \cdot (\gamma-1) \cdot \left[\ln r + \frac{1}{\gamma} - \left(\frac{r_c^{\gamma}}{r_c^{\gamma}-1}\right)\ln r_c\right] \cdot \frac{dC_v}{C_v}}$$

Q what is the effect of % change in efficiency of otto cycle having compression ratio 7, if specific heat at cons vol. increase by 1% ?

Sol. $\eta = 1 - \frac{1}{r^{\gamma-1}} = 1 - \frac{1}{7^{1.4-1}} = 1 - \frac{1}{7^{0.4}} = 1 - 0.46 = 0.54.$

$\eta = 54\%$

now, $\frac{d\eta}{\eta} = -\frac{(1-\eta)}{\eta} \cdot (\gamma-1) \ln r \cdot \frac{dC_v}{C_v}$

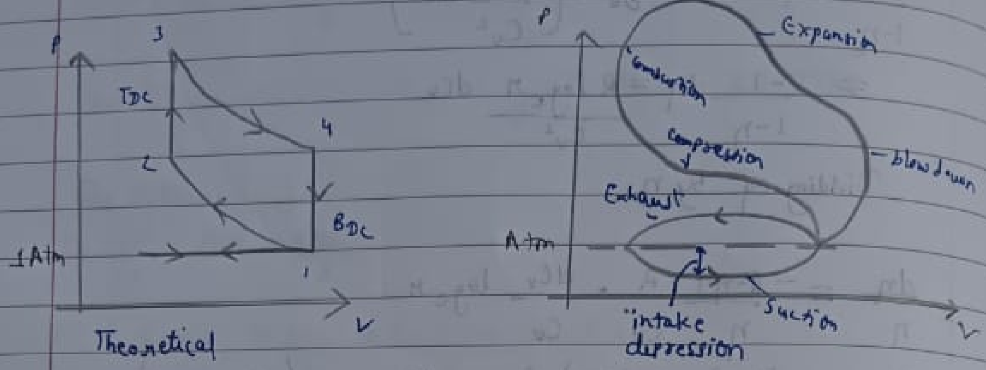
$= -\frac{(1-0.54)}{0.54} \cdot (1.4-1) \ln 7 \cdot 0.01$

$= -6.63 \times 10^{-3}$

$= \frac{-6.63 \times 10^{-1}}{\cancel{100}} \times \cancel{100}$

$= -0.663\%$

- Theoretical & Actual P-V Diagrams for engines



For efficient suction, the pressure inside the cylinder at suction is less than atmospheric pressure. This pressure diff. is called intake depression. This is needed to overcome resistance of the flow of the charge through the restricted area of the inlet passage.
For proper exhaust of the burnt gases, there has to be net positive pressure from inside of the cylinder to outside. That is why exhaust line does not coincide with the atmospheric pressure line but it is slightly above it.
Compression & expansion are not isentropic and there is interchange of heat between the charge (fuel) & the cylinder walls. There is always time lag between the ignition of the charge & its actual combustion and also combustion does not take place at constant volume and pressure rise is not along straight line.
Opening & closing of the valve are not instantaneous. It takes some time. That's why PVT will change & this is reflected by rounding of the corners on PV diagram.
Ignition of charge & opening of the walls is never at dead centre. This occurs at some degree on either side of the dead centre to get better charging better ignition & pushing of burnt gases.
At high pressures and temperatures, there are chances of dissociation of products of combustion

Dissociation or Chemical Equilibrium Loss:-

This is the disintegration of burnt gases at high temperatures. This is a endothermic, reversible process & increases with temperature. During dissociation, a considerable amount of heat is absorbed. This heat will be liberated when the elements recombine as the temperature falls. So general effect of dissociation is ~~suppres~~ suppression of a part of heat during combustion period & liberation of heat during expansion process. So effect of dissociation is much lesser than that of change in specific heats.

This causes power & efficiency loss

The dissociation is mainly of CO_2

$$2CO + O_2 \rightleftharpoons CO_2 + \Delta$$

at 1000°C → dissociation starts

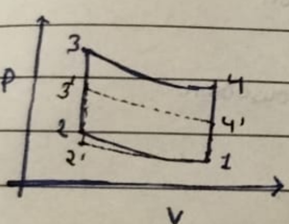
at 1500°C ⇒ 1% dissociation

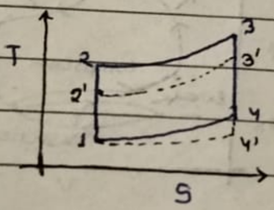
Temp in diesel engine during combustion ≈ 1500 – 1800°C

$$2H_2 + O_2 \rightleftharpoons 2H_2O + \Delta$$

Dissociation is very severe in case of chemically correct mixture.

Effect of variable specific Heat & dissociation on P-V & T-S digram of otto cycle.

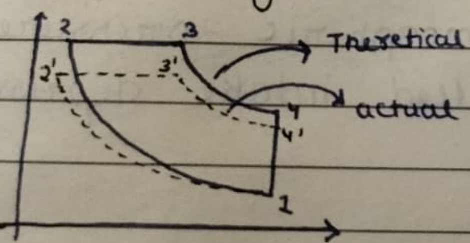




→ Loss in actual engine

- Loss is due to variation of sp. heat with temp
- Chemical equilibrium loss or dissociation loss
- Time loss
- Direct heat losses (from cylinder walls)
- Exhaust blow down loss
- Pumping loses
- Loss due to incomplete combustion.

Diesel cycle



Q. Engine working in otto cycle the air is at 37°C at 1 bar the press. at the end is 30 ~~bar~~ and press. at the end of combustion is 80 bar. Calc. Compression ratio %, high temp of cycle and ASE.

Q. A otto cycle operate under suction cond^n at 1 bar at 326 °C and C.R is 8 Calc. P & T at the end of compress. and ASE

Q. An engine working on deisel cycle operate suction 1 bar 37 °C at the end of comp the press. is 3.5 bar the cutoff is take place at 6% of the stroke Calc C.R. the % clearance heat supplied, heat rejected, thermal efficiency

Q. In an engine cylinder bore 13.7 cm stroke length 13 cm clearance volume is 280 cm^3 express the clearance as p % of ~~clearance~~ swept volume also calc. ASE

Q. An engine working on otto cycle energy generated per cycle is twice higher than the rejected heat Calc. ASE and C.R.

Q. In otto cycle air at 1 bar 15 °C the compr. ratio is 8 200 kJ is ~~releas~~ released to a each cycle. Calc. C.R so that net work done inc. by 20 %

Q. In an air stand. otto cycle max. cycle p & T 5 mpa and 2250 °K min. p & T of cycle 0.1 mpa and 300 K Calc. net work output and thermal efficiency.

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Q-1 What are different pattern materials.

OR

Explain different pattern materials. explain the factors on which selection of patterns depends.

pattern

Q3. What are different pattern materials? Explain
Ans. The different pattern materials are:-

(a) Wood :- Wood is the most common material for pattern, as it satisfies many properties. It is easy to work, can be made in many shapes by glueing, bending and curving and can be preserved by shellac. But it has disadvantage that is readily affected by moisture and wears out quickly. The most commonly used wood is teak wood.

(b) Metal: When conditions are too severe for wood, metals are used. Metals don't change their shape when subjected to moist conditions. Metal patterns are very useful in machine moulding because of their accuracy, durability and strength. When metal patterns are to be cast from master patterns, double shrinkage must be allowed. Various metals used for casting are:

(i) Cast iron: It is used for some highly specially types of pattern. It is strong, gives a good smooth mould surface.

(ii) Brass: It is used when patterns are small. It is strong, does not rust, takes a better finish than cast iron.

(iii) Aluminium: It is probably the best all round metal because it melts at relatively low temperature, is soft & easy to work.

(iv) White metal: It is not much used but is the best material for making intricate & fine shapes.

(c) Plastics : Plastics are now finding their place as a modern pattern material. They do not absorb moisture, are strong & dimensionally stable, resistant to wear and have very smooth surface. Plastic material have very low solid shrinkage. Mainly two types of plastics are used - Thermosetting and Thermoplastic.

(d) Rubber : Certain types of rubbers, such as silicon rubber are favoured for a very intricate type of casting. The material like epoxy resin is available in two parts - binder and hardener.

(e) Plasters : Gypsum cement, known as plaster of paris is also used for making patterns and core boxes. It has high compressive strength upto 300 kg/cm^2 & it can be readily worked with wooden tools

... selection of patterns depends.

Q-2 List various types of patterns. explain cope and drag pattern and matchplate pattern.

Magnesium		Upto
		Over 1200
Brass	16.0	
Bronze	10.5-21	depends on composition
Malleable iron	11.8	6 mm section thickness
	10.5	9 mm section thickness
	9.2	12 mm section thickness
	7.9	15 mm section thickness
	6.6	18 mm section thickness
	4.0	22 mm section thickness
	2.6	25 mm section thickness

11.4 TYPES OF PATTERNS

The type of pattern selected for a particular casting will depend upon several conditions. Among these, one is the anticipated ease or difficulty of the moulding operation to come. Others are whether a small or large number of castings is wanted, the type of moulding process and other factors which may enter the situation because of characteristics peculiar to

the casting. Several of the more commonly used types of pattern are list
and described below :

1. Single-piece pattern
2. Split pattern
3. Match plate pattern
4. Cope and drag pattern
5. Gated pattern
6. Loose-piece pattern
7. Sweep pattern
8. Skeleton pattern
9. Segmental pattern
10. Shell pattern
11. Built-up pattern
12. Boxed-up pattern
13. Lagged-up pattern
14. Left- and right-hand pattern

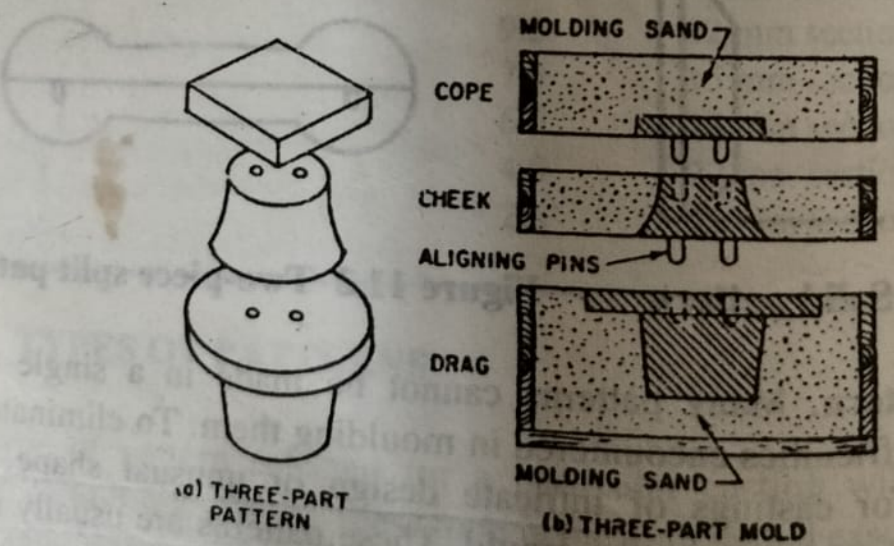
Single-piece or solid pattern. A pattern that is made without joi partings, or any loose pieces in its construction is called a single-piec solid pattern. A single-piece pattern is not attached to a frame or plate is, therefore, sometimes known as a *loose pattern*. These patterns cheaper. When using such patterns, the moulder has to cut his own run and feeding gates and risers. This operation takes more time, and they not recommended except for limited production. Single-piece patterns usually used for large castings of simple shapes.

The simplest type of pattern classified under this heading is the back as shown in Fig. 11.1. It may have few or no irregularities, ma have a core print, but very seldom does it have loose pieces. completed ... in the drag or entir positions by means of dowel-pins fasten[illegible] holes bored in the other. The surface formed at the line of separation of the two parts, usually at the centreline of the pattern, is called the *parting surface* or *parting line*. It will also be the parting surface of the mould.

It is sometimes necessary to construct a pattern for a complicating casting that requires three or more parts instead of two to make the completed pattern (Fig. 11.3). This type of pattern is known as *multi-piece pattern*. A three-part pattern may necessitate the use of a flask having three parts, although it is possible to mould some types of three-part patterns in a two-part flask.

Spindles, cylinders, steam valve bodies, water stop cocks and taps, bearings, small pulleys and wheels are few examples of castings that require the use of split patterns.

Match plate pattern. When split patterns are mounted with one half on one side of a plate and the other half directly opposite on the other side of the plate, the pattern is called a match plate pattern. A single pattern or a number of patterns may be mounted on a match plate. The pattern is made of metal, and the plate which makes the parting line may be either wood or metal. Aluminium is commonly used for metal match plates. Patterns for gates and runners are fastened to the drag side of the plate in their correct positions to from the complete match plate. When the match plate is lifted off the mould all patterns are drawn, and the cope or upper half of the mould matches perfectly with the drag or lower half of the mould. The gates and runners are also completed in one operation.



Fugure 11.3 Three-piece split pattern

Fig. 11.4 shows such a plate, upon which are mounted the patterns for two small dumbbells. Match plate patterns are used for producing small castings in large quantities in moulding machines which give accurate and rapid production. They are expensive to construct, but the initial cost is justified when quantity production is desired.

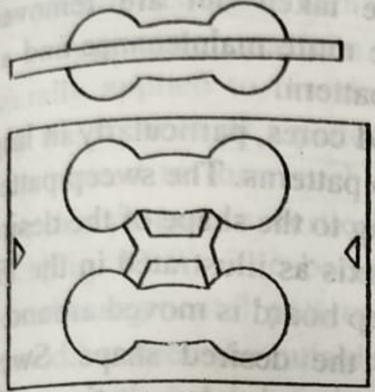


Figure 11.4 **Match plate pattern**

Cope and drag pattern. In the production of large castings, the complete moulds are too heavy to be handled by a single operator. Therefore, cope and drag patterns are used to ease this problem to efficient operation. The patterns are made in halves, split on a convenient joint line, and separate cope and drag patterns are built and mounted on individual plates or boards. This arrangement permits one operator or group of operators to prepare the cope half of the mould while another operator or group worked on the drag half. This planned distribution of labour increases production appreciably.

Gated pattern. To produce good casting, it is necessary to ensure that full supply of molten metal flows into every part of the mould. Provision for easy passage of the flowing metal into the mould is called gating which cannot be made by hand operations for volume high production particularly because of the time involved. In mass production, a number of castings are produced in a single multicavity mould by joining a group of patterns, and the gates or runners for the molten metal are formed by the connecting parts between the individual patterns. The time ordinarily is spent by the moulder in cutting gates and drawing patterns is eliminated by this arrangement. Such groups of patterns with gate formers attached to the pattern proper are called gated patterns as shown in Fig. 11.5.

Gated patterns may be made of wood or metal and are used for mass production of small castings.

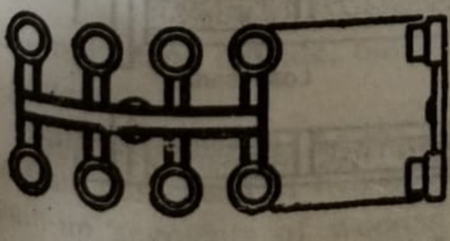


Figure 11.5 **Gated pattern**

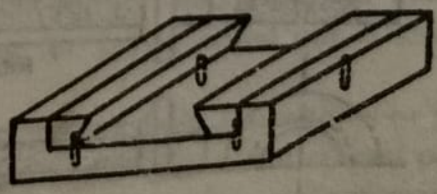


Figure 11.6 **Loose-piece pattern**

Q.3 Explain different types of pattern marking allowances why allowance are added to a pattern?

11.5 PATTERN MAKING ALLOWANCES

Patterns are not made the exact same size as the desired casting for several reasons. Such a pattern would produce castings which are undersize. Allowance must therefore be allowed for shrinkage, draft, finish, distortion, and rapping.

Shrinkage allowance. As metal solidifies and cools, it shrinks and contracts in size. To compensate for this, a pattern is made larger than the finished casting by means of a shrinkage or contraction allowance. In laying measurements for the pattern the patternmaker allows for this by using shrink or contraction rule which is slightly longer than the ordinary rule of the same length. For example, when constructing a pattern for cast lion, the pattern maker uses a shrink rule measuring about 10 mm longer per metre than the conventional rule since cast iron shrinks 10 mm per metre. Different metals have different shrinkages, therefore, there is a shrink rule for each type of metal used in a casting. Typical shrinkage allowances are shown in Table 11.2. 'A master pattern from which metal patterns are cast may have double shrinkage allowance.

Draft allowance. When a pattern is drawn from a mould, there is always some possibility of injuring the edges of the mould. This danger is greatly decreased if the vertical surfaces of a pattern are tapered inward slightly. This slight taper inward on the vertical surfaces of a pattern is known as the draft. Draft may be expressed in millimeter per metre on a side, or in degrees, and the amount needed in each case depends upon (1) length of the vertical side, (2) intricacy of the pattern, and (3) the method of moulding. Under normal conditions the draft is about 10 to 20 mm per metre on exterior surfaces and 40 to 60 mm per metre on interior surfaces. Fig. 11.13 shows how a draft is provided in a pattern.

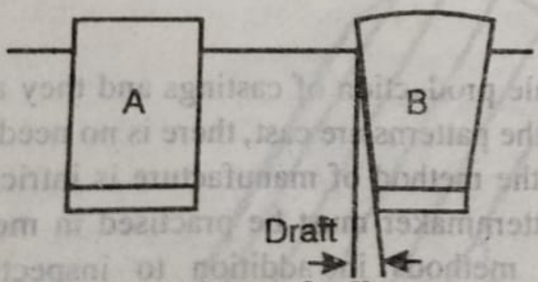
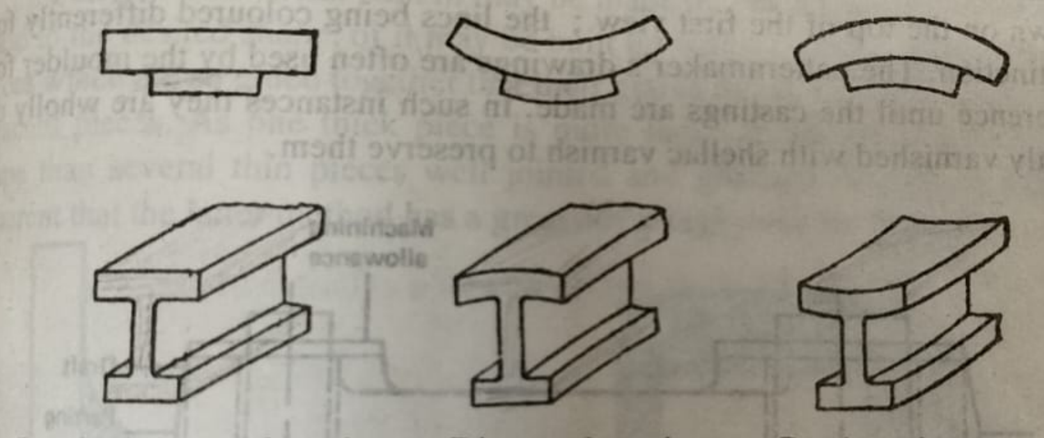


Figure 11.13 Draft allowance

Machining allowance. Rough surfaces of castings that have to be machined are made to dimensions somewhat over those indicated on the finished working drawings. The extra amount of metal to be provided on the surfaces to be machined is called machine finish allowance and the edges of these surfaces are indicated by a finish mark *V*, or *F*. The amount that is to be added to the ;pattern depends upon (1) the kind of metal to be used, (2) the size and shape of the casting and (3)method of moulding. The standard finish (machining) allowance for different cast metals in mm for hand moulding is given in Table 11.3

Distortion or camber allowance. Some castings, because of their size, shape and type of metal, tend to warp or distort during the cooling period. This is a result of uneven shrinkage and is due to uneven metal thickness or to one surface being more exposed than another, causing it to cool more rapidly. The shape of the pattern is thus bent in the opposite direction to overcome this distortion. This feature is called *distortion* or *camber allowance*. As an example, a casting shaped like the letter *U* will be distorted with the legs diverging, instead of parallel (Fig. 11.14). To compensate for this condition, the pattern is made in such a manner that the legs converge but as the casting cools after its removal from the mould, the legs straighten and remain parallel. Although no distortion data in published form is available, the distortion allowance ranges from the standard finish allowance upto 20 mm when large castings are considered.



Required shape of casting   Distorted casting   Cambered pattern

Figure 11.14 Distortion in casting

TABLE. 11.3 STANDARD MACHINING ALLOWANCE

Diameter of hole / distance from locating point	*Cast iron* Bore	*Cast iron* Surfaces	*Cast steel* Bore	*Cast steel* Surfaces	*Nonferrous* Bore	*Nonferrous* Surfaces
200	3	3	4	4	1.5–2.0	1.5
200—400	4.5	4	5.5	5	2.0	1.5
400—700	6	5	7	6	3.0	2.0
700—1100	7	6	9	7	3.5	2.5
1100—1600	9	7	11	9	4.0	3.0
1600—2200	10	8	13	11	—	—
2200—3000	12	9	15	13	—	—

Rapping allowance. When a pattern is rapped in the mould before it is withdrawn, the cavity in the mould is slightly increased. In every cases where castings must be uniform and true to pattern, rapping or shake allowance is provided for by making the pattern slightly smaller than the actual size to compensate for the rapping of the mould.

11.6 METHODS OF CONSTRUCTING PATTERNS

After the moulding procedure and the form of the pattern have been decided upon, a layout of the pattern is made.

PREPARATION OF PATTERN LAY OUT

Layouts are, in general, reproductions of the blue prints laid out to full-size scale on a flat smooth wooden board. The boards for laying out large work ...es blackened on the face, and the drawings set down in the ... more than one view is required, the additional views are set ...op of the first view ; the lines being coloured differently for ... The patternmaker's drawings are often used by the moulder for ... until the castings are made. In such instances they are wholly or ... shellac varnish to preserve them.

Q.4 Explain compsints.

following whi... as *skewer* as shown in Fig. 11.25.

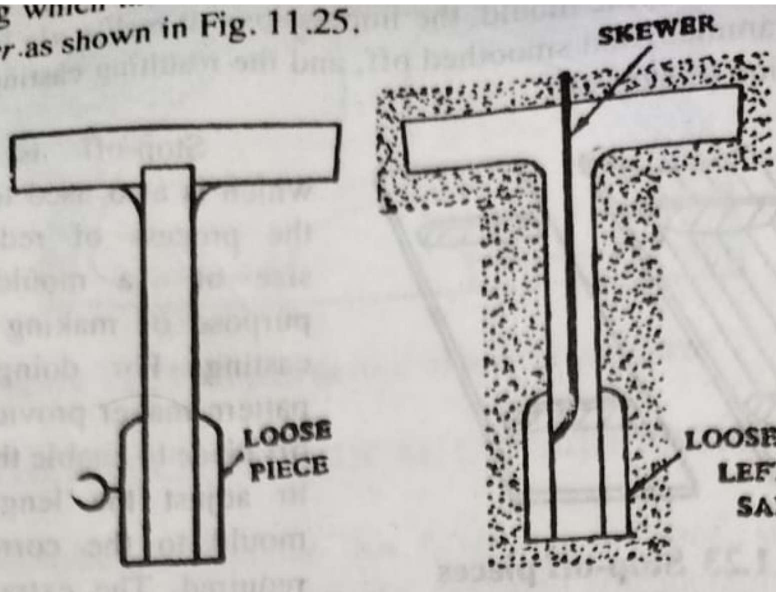


Figure 11.25 Pattern showing loose-pieces

11.8 COREPRINTS

Castings are often required to have holes, recesses, etc. of various sizes and shapes. These impressions are obtained by using sand cores which are separately made in boxes known as coreboxes. For supporting the cores in the mould cavity an impression in the form of a recess is made in the mould with the help of a projection suitably placed on the pattern. This projection on the pattern is known as the coreprint. A coreprint

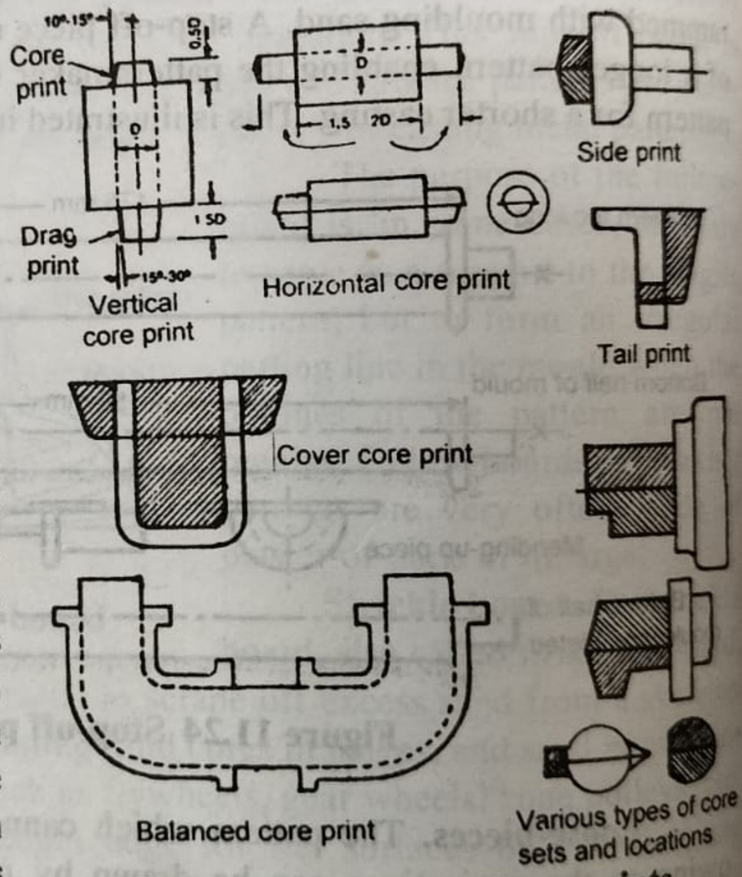


Figure 11.26 Types of coreprints

is, therefore, an added projection on a pattern, and it forms a seat which is used to support and locate the core in the mould. There are several types of coreprints, viz., horizontal or parting line coreprint, vertical or cope and drag coreprint, balancing coreprint, cover or hanging core-print, wing or drop core-print. (Fig. 11.26).

Horizontal coreprint. This is laid horizontally in the mould and is located at the parting line of the mould. The coreprint is often found on the split or two-piece pattern. When it is important that certain core be located at a desired angular relationship with respect to the central axis, a flat portion at one end is made to coincide with a flat portion of the coreprint.

Vertical coreprint. This stands vertically in the mould. This is why this type of core is referred to as a vertical coreprint. The coreprint is located on the cope and drag sides of a pattern and is constructed with considerable taper specially on the cope side (about 10-15°)so that they are easily moulded. The taper on drag print is only 1.5–3°.

Balancing coreprint. This is used when a horizontal core does not extend entirely through the casting, and the core is supported at one end only. An important feature of this coreprint is that the print of the core in the mould cavity should balance the part which rests in the core seat.

Hanging or cover coreprint. This is used when the entire pattern is rammed in the drag and the core is required to be suspended from top of the mould. In this case, the core serves as a cover for the mould, and also as a support for hanging the main body of a core.

Wing or drop coreprint. This is used when the cavity to be cored is above or below the parting line in the mould. Wing coreprints are also known as "chair", and "tail" coreprints.

11.9 CORE BOXES

A core box is essentially a type of pattern made of wood or metal into which sand is rammed or packed to form a core. The types of core boxes, in common use, in foundry work, are described below.

• **Half box.** A half box, as shown in Fig. 11.27, is used to form two identical halves of a symmetrical core. After they are shaped to form and ...ther to form a completed core.

Q.5 What are different ingrediants of moulding sand ?

Santhal Pargana (Bihar), Batala (Gurdaspur, Punjab), Bhavnagar (Saurashtra), Londha (Maharashtra), Avadi and Veeriyambakam (Madras), Kanpur, Jabalpur, Rajkot, Guntur, in Ganges and many other places.

Principal ingredients. The principal ingredients of moulding sands are : (1) silica sand grains, (2) clay, (3) moisture, and (4) miscellaneous materials.

Silica in the form of granular quartz, itself a sand, is the chief constituent of moulding sand. Silica sand contains from 80 to 90 per cent silicon dioxide and is characterized by a high softening temperature and thermal stability. It is a product of the breaking up of quartz rocks or the decomposition of granite, which is composed of quartz and feldspar. The feldspar, when decomposed, becomes clay (hydrous aluminium silicate). However, silica sand grains impart refractoriness, chemical resistivity, and permeability to the sand. They are specified according to their average size and shape.

Clay is defined as those particles of sand (under 20 microns in diameter) that fail to settle at a rate of 25 mm per minute, when suspended in water. Clay consists of two ingredients : fine silt and true clay. Fine silt is a sort of foreign matter or mineral deposit and has no bonding power. It is the true clay which imparts the necessary bonding strength to the mould sand, so that the mould does not lose its shape after ramming. True clay is found to be made up of extremely minute aggregates of crystalline, usually flake-shaped, particles called clay minerals. Most moulding sands for different grades of work contain 5 to 20 per cent clay.

Moisture, in requisite amount, furnishes the bonding action of clay. When water is added to clay, it penetrates the mixture and forms a microfilm which coats the surface of flake-shaped clay particles. The bonding quality of clay depends on the maximum thickness of water film it can maintain. The bonding action is considered best if the water added is the exact quantity required to form the film. On the other hand, the bonding action is reduced and the mould gets weakened if the water is in excess. The water should be between 2 and 8 per cent.

Miscellaneous materials that are found, in addition to silica and clay, in moulding sand are oxide of iron, limestone, magnesia, soda, and potash. The impurities should be below 2 per cent.

Classification. Moulding sands may be classified generally into

Q.6. Explain properties of moulding sand.

sand from drying rapidly.

11.16 PROPERTIES OF MOULDING SAND

Proper moulding sand must possess six properties. It must have porosity, flowability, collapsibility, adhesiveness, cohesiveness or strength, and refractoriness. The properties are determined, not only by the chemical composition, but by the amount of clayey matter in the sand, by its moisture content, and lastly by the shape and size of the silica sand grains.

Porosity. Molten metal always contains a certain amount of dissolved gases, which are evolved when the metal freezes, Also, the molten metal, coming in contact with the moist sand, generates steam or water vapor. If these gases and water vapor evolved by the moulding sand do not find opportunity to escape completely through the mould they will form gas holes and pores in the casting.

The sand must, therefore, be sufficiently porous to allow the gases or moisture present or generated within the moulds to be removed freely when the moulds are poured. This property of sand is called porosity or *permeability*.

Flowability. Flowability of moulding sand refers to its ability to behave like a fluid so that, when rammed, it will flow to all portions of a mould and pack all-round the pattern and take up the required shape. The sand should respond to different moulding processes. High flowability is required of a moulding sand to get compacted to a uniform density and to obtain good impression of the pattern in the mould. Good flowability is very essential where energy for compaction during ramming is transmitted through the sand mass as in machine moulding. Flowability increases as clay and water content increase.

Collapsibility. After the molten metal in the mould gets solidified, the sand mould must be collapsible so that free contraction of the metal occurs, and this would naturally avoid the tearing or cracking of the contracting metal.

Adhesiveness. The sand particles must be capable of adhering to another body, i.e., they should cling to the sides of the moulding boxes. It is due to this property that the sand mass can be successfully held in a moulding box and it does not fall out of the box when it is removed.

Cohesiveness or strength. This is the ability of sand particles to stick together. Insufficient strength may lead to a collapse in the mould or its partial destruction during conveying, turning over or closing. The mould may also be damaged during pouring by washing of the walls and core by

Q.7 Explain moulding ~~so~~ process.

is indicated on the ... hardness can also be read on another scale ...

11.19 MOULDING PROCESSES

Moulding processes in common use may be classified according to different forms. They may broadly be classified as : (1) hand moulding, and (2) machine moulding. In piece and, small-lot production foundry practice, sand moulds are made by hand ; moulding machines are employed in large-lot and mass production.

Moulding processes are often classified according to (1) the type of material of which the mould is made or (2) the methods used in making the mould. Under the first heading the following items are included : (1) green sand moulds, (2) dry sand moulds, (3) skin-dried moulds, (4) loam moulds. Moulds classified as to the methods commonly used are : (1) bench moulding, (2) floor moulding, (3) pit moulding, (4) sweep moulding, and (5) plate moulding.

11.20 MOULDING PROCESSES BASED ON SAND USED

metal.

TABLE 11.9

Material
Floor sand
New sand
Coal dust
Carbon blackin
Talc (french ch

It is c refractory mat

Q.8 Explain permanent mould casting.

2. Decreasing hardness of compacted sand from inside to the outside.
3. High surface quality.
4. Dimensionally stable casting
5. Reduced cleaning.

Disadvantages of the process are :

1. High cost of manufacturing.
2. Change-over time high.

11.27 PERMANENT MOULD CASTING

While in the sand castings the moulds are destroyed after solidification of castings, the moulds are reused repeatedly in the permanent mould castings. This requires a mould material that has a sufficiently high melting point to withstand erosion by the liquid metal at pouring temperature, a high enough strength not to deform in repeated use, and high thermal fatigue resistance to resist premature crazing (the formation of thermal fatigue cracks) that would leave objectionable marks on the finished castings. Finally, and ideally, it should also have low adhesion.

The material used for making moulds (dies) may be cast iron, although alloy steels are the most widely used. For higher-melting alloys such a brasses and ferrous alloys, the mould steel must contain large proportion of stable carbides. More recently refractory metal alloys, particularly molybdenum alloys, have found increasing application. Graphite moulds can also be used for steel although only for relatively simple shapes. The resistance of the mould to the melt can be increased with refractory coatings (mould washes) and adhesion can be reduced by graphite, silicon, or other parting compounds.

All cast metals can be cast by permanent mould method. Zinc, copper, aluminium, lead, magnesium and tin alloys are most often cast by this process. Grey iron castings can also be produced by this method though a thin refractory coating or lining of sodium silicate or phosphoric acid is given so as to withstand high temperature of the molten metal.

In general, castings to be produced by permanent mould methods should be relatively simple in design with fairly uniform wall thickness and without undercuts or complicated coring. Undercuts on the exterior of castings complicate the mould design, resulting in additional mould parts and increased costs. Cores, if required, are made in sand.

Permanent mould castings have some distinct advantages over the casting.

Q.9 Explain gating and risering of pattern.

11.28 GATING AND RISERING OF CASTINGS

The term gate is defined as one of the channels which actually leads into the mould cavity, and the term gating or gating system refers to all channels by means of which molten metal is delivered to the mould cavity. The functions of a gating system are :

1. To provide continuous, uniform feed of molten metal, with as little turbulence as possible to the mould cavity. Excessive turbulence results in the aspiration of air and the formation of dross.
2. To supply the casting with liquid metal at best location to achieve proper directional solidification and optimum feeding of shrinkage cavities.
3. To fill the mould cavity with molten metal in the shortest possible time to avoid temperature gradient.
4. To provide with a minimum of excess metal in the gates and risers. Inadequate rate of metal entry, on the other hand, will result many defects in the casting.
5. To prevent erosion of the mould walls.

6. To prevent slag, sand and other foreign particles from entering the mould.

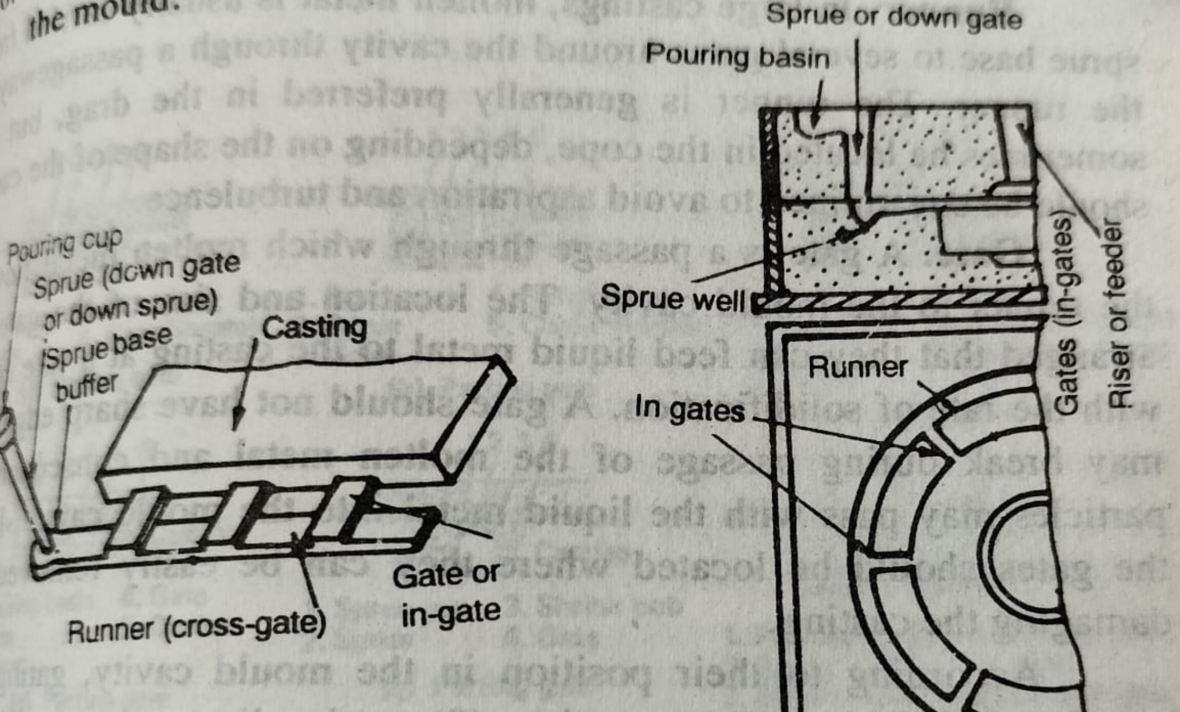


Figure 11.85 Parts of gating system

Q.11 Explain defects in casting.

removed. Sand-bla machines are employed for cleaning surface of ligh tings. In these machines dry sand or cast iron shot is ompressed air against the surfaces of the casting. The or shot , moving at a high velocity on the surface removes the and. In hydro-blasting, a high velocity stream of water and sand is blasted on the castings. This action results in more efficient cleaning and polishing. The hydro-blast method is better adapted to nonferrous castings since ferrous ones tend to get corroded by the action of water.

Sometimes *pickling* in a suitable acid (sulphuric acid, hydro- fluoric acid or nitric acid) helps in removing any adhering sand from the casting. After pickling in acid, the casting is pickled in alkaline solutions and, finally, hot water to neutralise the acid remaining on the casting. Pickling is used principally for preparing the surfaces of casting for plating, although it is occasionally used for cleaning fragile castings.

Defects such as blow holes, gas holes, cracks, warping, deformation, etc. may often occur in castings. Such defective castings cannot be rejected outright for reasons of economy and they are therefore repaired by suitable means which include various types of welding, soldering, resin impregnation, epoxy filling metal spraying etc. Derormed or warped castings can be straightened in a press by applying pressure.

11.36 DEFECTS IN CASTINGS

Sand casting , particularly, are subject to certain defects which in a well designed casting, are controllable by proper foundry technique, but are not wholly preventable. However , the common types of defects found in castings, their causes and remedies are explained hereunder.

1. *Shifts*. This is an external defect in a casting caused due to core misplacement or mismatching of top and bottom parts of the casting usually at a parting line. Mis-alignment of flasks is another likely cause of shift.

   The defect can be prevented by ensuring proper alignment of the pattern or die part, moulding boxes, correct mounting of patterns on pattern plates, and checking of flasks, locating pins, etc. before use.

2. *Warpage*. Warpage is unintentional and undesirable deformation in a casting that occurs during or after solidification. Due to different rates of solidification different sections of a casting, stresses are set up in adjoining walls resulting in warpage in these areas. Large and flat sections or intersecting sections such as ribs are particularly prone to

warpage.

The remedy is to produce large areas with wavy, corrugated construction, or add sufficient ribs or rib-like shapes, to provide equal cooling rates in all areas. A proper casting design can go a long way in reducing the warpage of the casting.

3. *Fin*. A thin projection of metal, not intended as a part of the casting, is called the fin. Fins usually occur at the parting of the mould or core sections. Moulds and cores incorrectly assembled will cause fins. Insufficient weighting of the moulds, or improper clamping of flasks may again produce the fin.

The remedy lies on the use of sufficient weight on top part of the mould so that the two parts fit tightly together, and correct assembly of the moulds and cores used for the casting.

4. *Swell*. A swell is an enlargement of the mould cavity by metal pressure, resulting in localised or overall enlargement of the casting. This is caused by improper or defective ramming of the mould.

To avoid swells, the sand should be rammed properly and evenly.

5. *Blowholes*. Blow holes are smooth, round holes appearing in the form of a cluster of a large number of small holes below the surface of a casting. These are entrapped bubbles of gases with smooth walls. Blow holes are caused by excessive moisture in the sand, or when permeability of sand is low, sand grains are too fine, sand is rammed too hard, or when venting is insufficient.

To prevent blowholes, the moisture content in sand must be well adjusted, sand of proper grain size should be used, ramming should not be too hard, and venting should be adequate.

6. *Drop*. A drop occurs when the upper surface of the mould cracks, and pieces of sand fall into the molten metal. This is caused by low strength and soft ramming of the sand, insufficient fluxing of molten metal and insufficient reinforcement of sand projections in the cope.

The above factors are eliminated to avoid drop.

7 *Dirt*. In some cases , particles of dirt and sand are embedded in the casting surface. This is caused by crushing of the mould due to improper handling, sand wash and presence of slag particles in the molten metal.

Dirt may be prevented from entering the mould cavity by proper fluxing and the use of dirt traps.

8. *Honeycombing* or *sponginess*. This is an external defect consisting of a number of small cavities in close proximity. Honey-combing is caused by dirt or "scurf" held mechanically in suspension in the molten metal, and is due to imperfect skimming in the ladle.