Presentation on
Selection of Material, Shape and Manufacturing for an Automotive engine block

Presenters :

- Abhishek Tapkire (19 310 4002)
- Patil Mujahed Alim (19 310 9009)

Outline:

- Introduction to Engine Block
- Problem Formulation
- Selection of Material
- Selection of Shape
- Selection of Manufacturing Processes
- References

Introduction to Automotive Engine Cylinder Block

- **Function of engine Block**

  - Subjected to engine Combustion :

    High temperature and Pressure i.e.

    Cyclic loading hence Fatigue

  - Piston and piston rings reciprocating motion

    i.e. Abrasion resistance hence, Internal surface hardness against: Nicasil Coating/ Hard chrome coating /CI liners on bore of engine Block

  - Absorption of Shock and Vibration
  - Sufficient cooling of engine (Oil Film)

- **Possible failures of the engine Block**
  - Fatigue failure
  - Seizure due to thermal distortion &Improper Cooling
  - Crack in the walls of the combustion chambers
  - Wearing out of an internal surfaces/ Pilling-off Cylinder coating

Formulation of problem

Function	**1. To Sustain High Temp and Pressure of Combustion** **2. Sufficient Cooling of engine** **3. Abrasion resistance against Piston ring reciprocating motion**
Constraints	1. Bore Dia and Length (Engine CC : Mileage to taxation) 2. Engine Weight (Power/wt , Mileage) 3. Creep Rapture Strength
Objective	1. Minimize Mass 2. Maximize Stiffness against engine Pressure and Temperature loading 3. Maximize Fracture Toughness 4. Maximize Fatigue resistance 5. Minimize Thermal distortion 6. Maximize Thermal Conductivity 7. Maximize damping characteristics
Free Variables	1. Material Selection 2. Thickness 3. Manufacturing process

Selection of Material (Material Indices)

Damage Tolerant design : Fracture Toughness : Analogy to Pressure Vessel : Design against bursting under internal pressure were considered. It should have good fracture toughness if struck by abnormal combustion/ Bursting combustion pressure :

Ml = K1C

Yield before break condition :

M2 = K1C/ σf

Strength based design : But it should not result into very thick Wall thickness of Block; hence material with higher yield value and lower weight also to be chosen:

M3 = σy /ρ

Fatigue Strength : **M4 = σe /ρ**

Stiffness based design & Vibration Limited Design (Beam : Maximum Flexural frequencies) : Cylinder with internal pressure Elastic distortion, wall thickness free. It is important as subjected to higher and Interrupted flexural loads over a length of cylinder block and its self weight

M5 = E / ρ

Thermal and Thermo-mechanical design : Creep and thermal distortion :

M6= K/α

We need to **Maximize all the material indexes.**

(Derivation of all above Indices are given in next slide)

Selection of Material (Material Indices derivation)

- **Mass (m) = ρ×A×l**
- **Damage Tolerant design : Fracture Toughness ($\mathrm{M2} = \mathrm{K}_{1c}/\boldsymbol{\sigma}_f$)**

$$\mathrm{K}_{1c} = \boldsymbol{\sigma}_y \times \sqrt{\pi \times \boldsymbol{a}}\, \boldsymbol{f}\left(\frac{\boldsymbol{a}}{\boldsymbol{W}}\right)$$

- **Strength based design ($\mathrm{M3} = \boldsymbol{\sigma}_y/\boldsymbol{\rho}$)**

  Hoop stresses are present and given by

  $\boldsymbol{\sigma} = \frac{\Delta \boldsymbol{p} \times \boldsymbol{r}}{2 \times \boldsymbol{t}}$ substituting for free variable t in **m =** $\boldsymbol{\pi} \times \boldsymbol{d} \times \boldsymbol{t} \times \boldsymbol{\rho} \times \boldsymbol{l}$

- **Fatigue based design: ($M4 = \boldsymbol{\sigma}_e/\boldsymbol{\rho}$)**

  $\boldsymbol{\sigma}_e \geq \frac{\boldsymbol{F}}{\boldsymbol{A}}$ substitute for A in **m = ρ×A×l**

- **Stiffness based design & Vibration limited design ($M5 = \boldsymbol{E}/\boldsymbol{\rho}$)**

$$\boldsymbol{\delta} = \frac{\boldsymbol{C} \times \boldsymbol{m} \times \boldsymbol{g} \times \boldsymbol{l}^3}{\boldsymbol{EI}} \text{ use } \boldsymbol{\omega} = \sqrt{{}^{g}/_{\delta}}$$

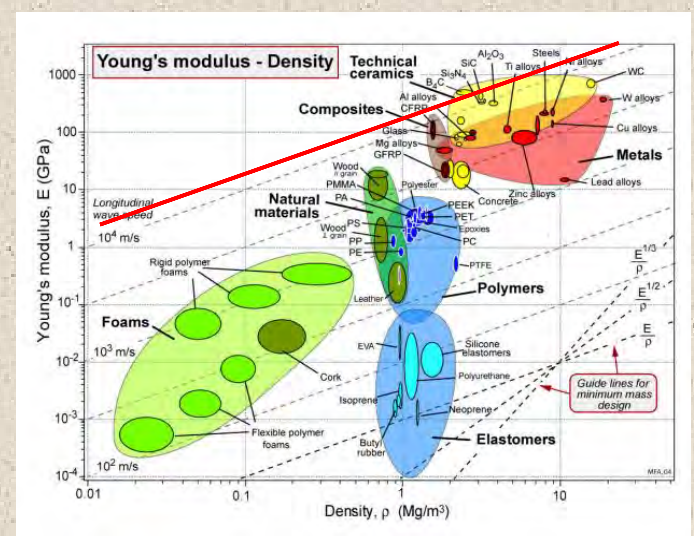
- **Thermo-Mechanical design ($M6 = \boldsymbol{k}/\boldsymbol{\alpha}$)**

  Strain given by $\boldsymbol{\epsilon} = \boldsymbol{\alpha}\Delta\boldsymbol{T}$

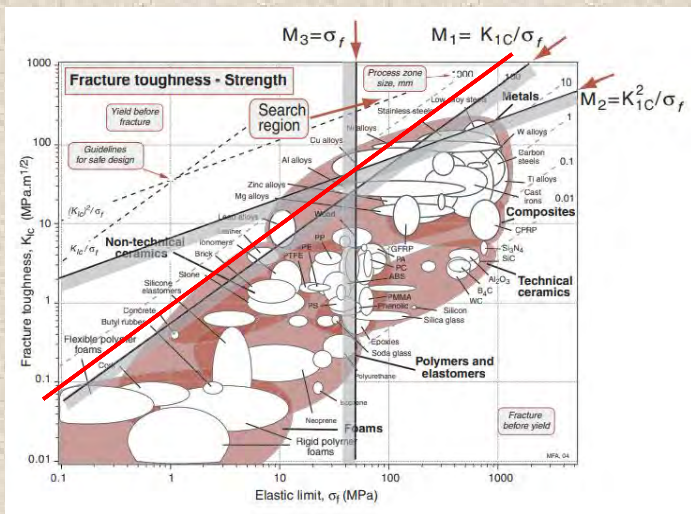
  and $\boldsymbol{Q} = -\boldsymbol{k}\frac{\boldsymbol{dT}}{\boldsymbol{dx}}$

Ref : Ashbey Charts

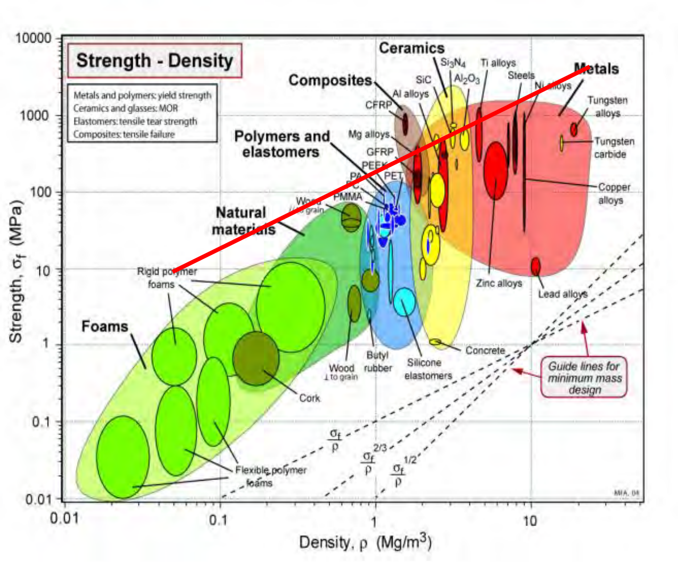
Material Selection



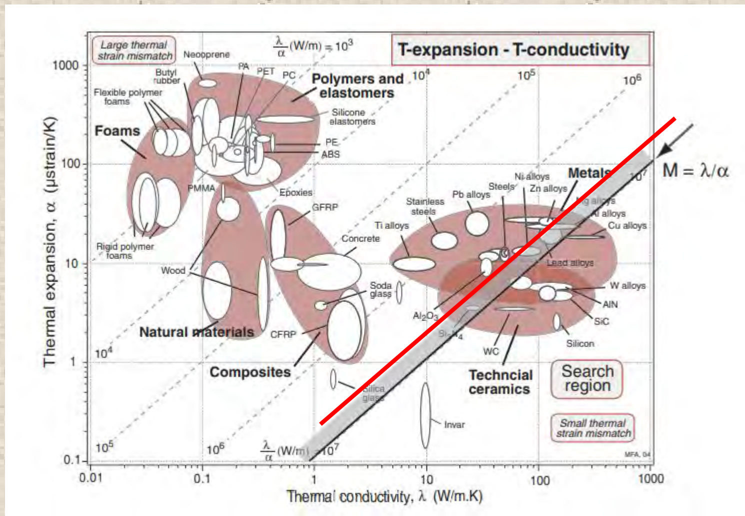
Young's Modulus Vs Density (E/ρ)



Fracture Toughness Vs Strength (KIC/ σf)



Strength Vs Density (σy /ρ)



Thermal Conductivity Vs Thermal Expn Coe (K/α)

Selection of Material (Material Indices derivation)

Material	M1 KIC/ σf	M2 (E/ρ)	M3 (σy /ρ)	M4 (σe /ρ)	M5 (K/α)	W
Cast Iron (Gray Cast iron)	0.25	19.44	110	23.129	$5x10^6$	1.87683271
Aluminum Alloys	1.10	32	200	47.97	$1x10^7$	4.038963774
Titanium Alloys	0.03	20	220	110.81	$1x10^6$	2.418939394
Magnesium Alloys	0.14	25	330	55.55	$6x10^6$	3.009831273

Note : Equal Weightage given to all Indices. Weightage : W= Σ (Mi / Mi(max))

Material Selected (As per Ranking) :

1. Aluminum Alloys
2. Magnesium Alloys
3. Cast iron
4. Titanium

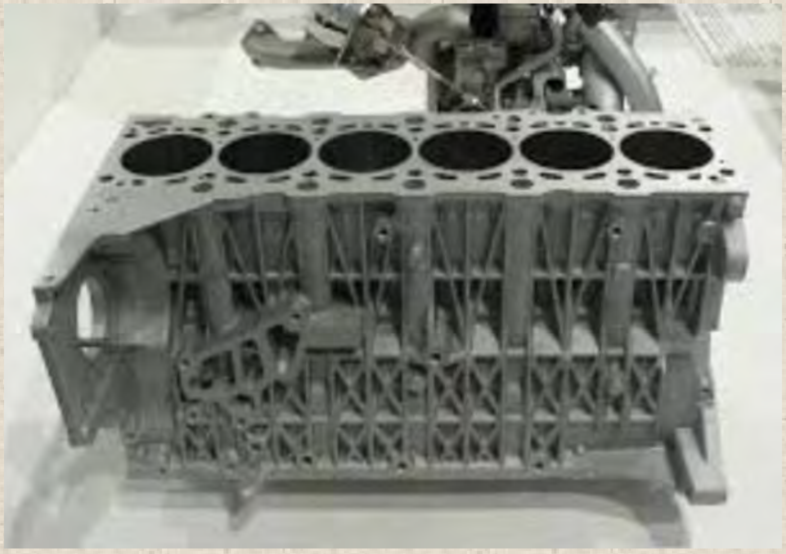
Selection of Shape

Shapes are determined by the application compulsion.

Wither V-Shaped or Inline Engine Block,

Ribs, Gussets are given on the casting itself, mostly having rectangular / Semi circular Cross section.

- Which gives good Bending Strength (Flexural rigidity) &
- Reduced weight
- Ribs and Coolant, Oil Galleries are combined

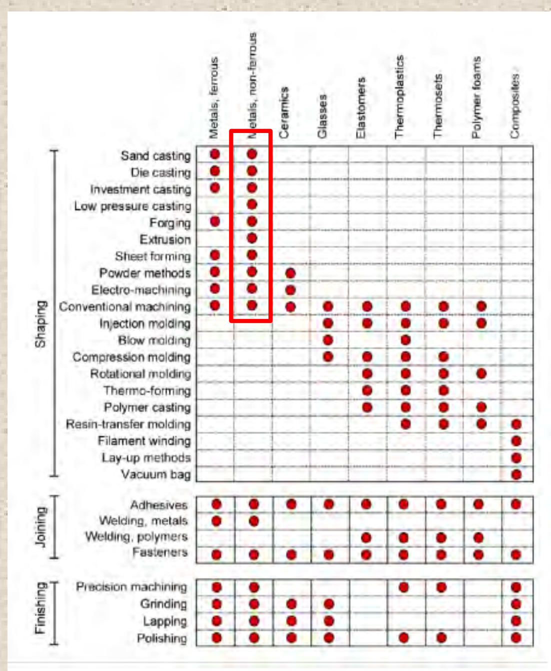


Manufacturing of an Engine Block

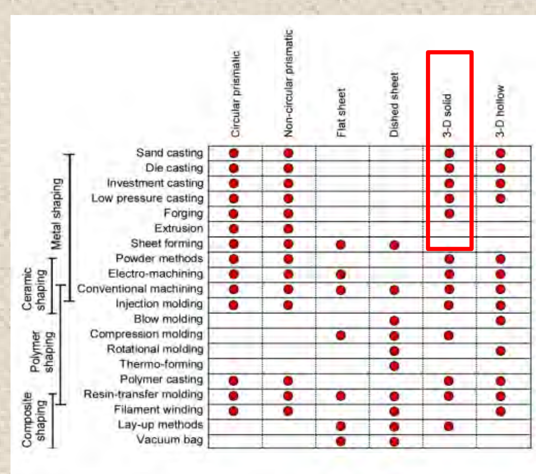
Function	To Shape an Automotive engine Block
Constraints	1. Material Class : Metallic Non ferrous 2. Shape Class : 3D Solid 3. Mass : 30-50 kg (4 cylinder engine Block for Sedan/SUV) 4. Minimum Section thickness : 5 mm (Intricate shaped cooling Jackets/ Cylinder bore Gaps Vs strength) 5. Tolerances : 1 mm (All other surfaces) +/- 10 Micron (For Cylinder Bore) +/- 50 Micron (For Cylinder Head Matching) 6. Surface Roughness : +/- 0.5 Micron (For Cylinder Bore) +/- 1.6 Micron (For Cylinder Head Assy/ Bearing Surface) +/- 20 micron (All other surfaces) 7. Batch size : Automotive application 1000 to 10000
Objective	1. Minimize Weight 2. Requisite Quality Level; (eg : Radiography Level …)
Free Variables	1. Choice of Process 2. Process chain Option

Selection of Manufacturing Process (Compatibility Matrix)

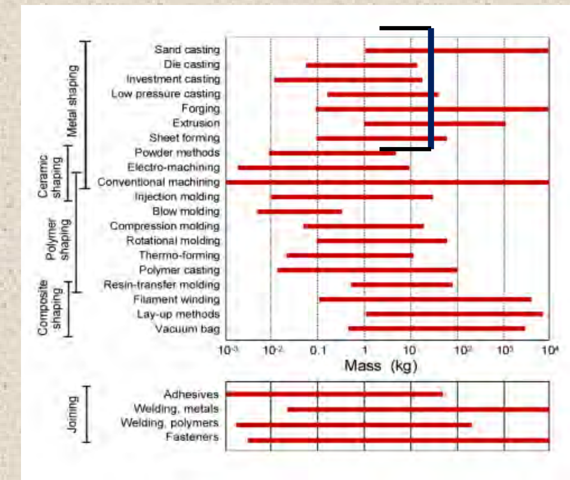
Ref : Ashbey Charts



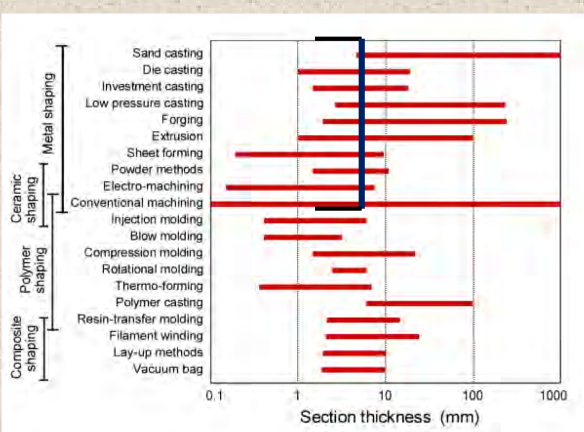
Material – Process



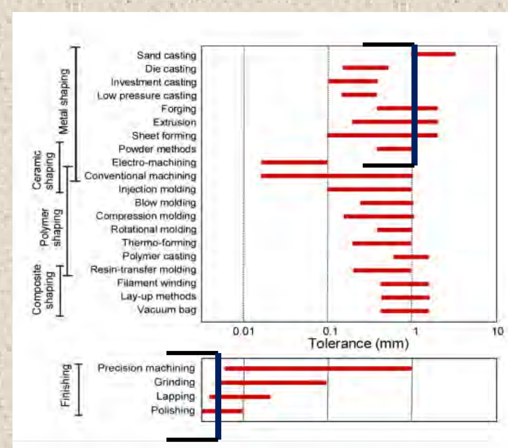
Process – Shape



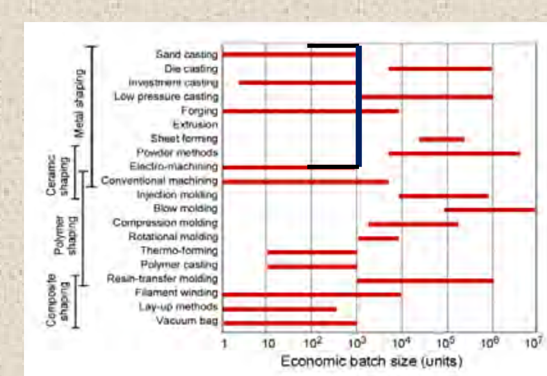
Process-Mass



Process-Section thickness



Process- tolerance & Surface Roughness



Process-Economic batch size

Manufacturing of Cylinder Block

Sand Casting is usually adopted for the Automotive application.
However, if there is a need of high quality castings (depending upon the Radiography level requirement, Size of component, Min sectional thickness, Size of Batch) die casting is also adopted. LPDC/ Gravity Die casting is generally preferred choice.

Aluminum alloy (LM-9/LM-13) is used as a material

Casted engine block bore is machined by Jig Boring, Coated with Hard Chrome Coating followed by Honing/ Jig Grinding to obtain desired surface finish and tolerance.

Cylinder head matching Portion is machined by means of Surface grinding.

Other areas are machined by VMC get correct dimensions and smooth surfaces of the engine block.

Inside portion of block is Coated with hard chrome plating/ Nicasil Coating/ Liners (Thermal Expansion matching of Aluminum and coating)

Manufacturing of Cylinder Block

Patterns

Core box

Cores

Mould

Casted block

Machining

References

1. M.F Ashbey: Material Selection in Mechanical Engineering (2005) for engineering data and process charts
2. Wikipedia (https://en.wikipedia.org/wiki/Engine_block)

Image Courtesy :

1. http://newengineeringpractice.blogspot.com/2011/08/engine-block-manufacturing-
2. https://link.springer.com/chapter/10.1007/3-211-37762-X_7

Thank You