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PRIFYSGOL FETROPOLITAN ABERTAWE

Advanced Engine Technology

Lecture 3: Combustion Chamber Design (2)

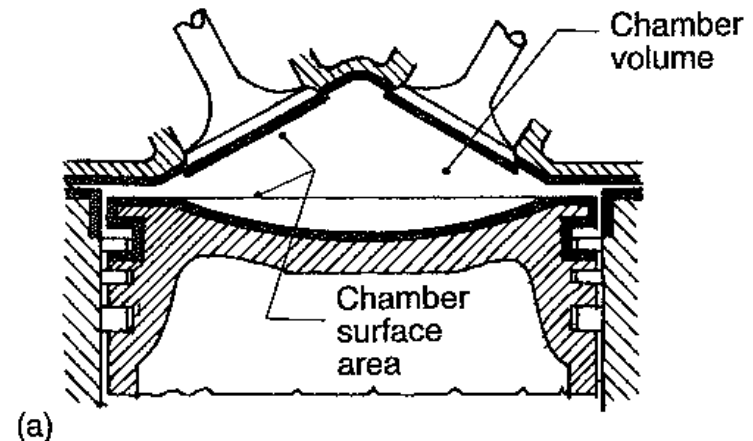
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Surface to Volume Ratio

- To minimise heat losses and hydrocarbon formation within combustion chamber, chamber volume should be maximised relative to surface area
- i.e. Surface area as small as possible compared to chamber volume
- Surface to Volume Ratio



$$\text{Surface to Volume ratio} = \frac{\text{Surface Area of Chamber}}{\text{Volume of Chamber}}$$

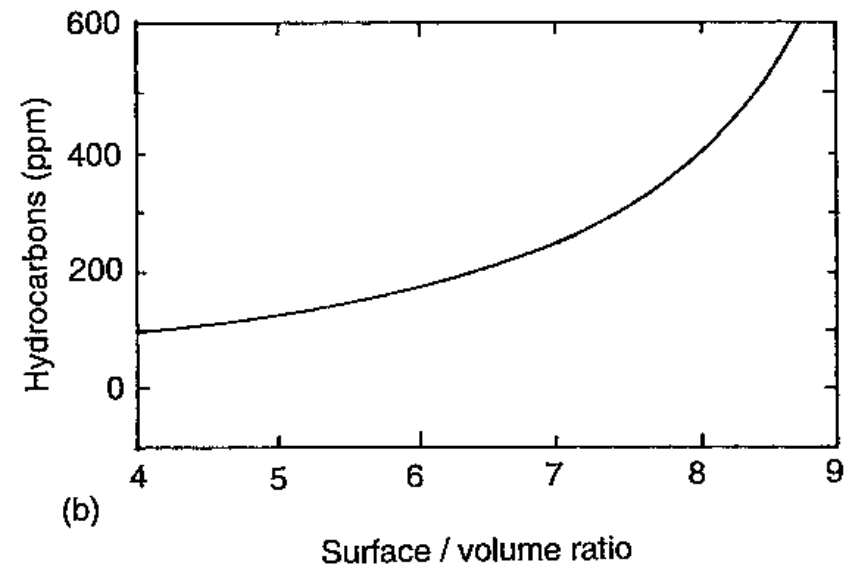
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Surface to Volume Ratio



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- Hydrocarbon formation in exhaust gas is primarily due to:
 - Outer layers of mixture being overcooled near chamber walls
 - Flame cools as it approaches walls until it stops burning
 - Unburnt fuel mixes with combustion products as it passes through exhaust system
 - Large surface to volume gives more wall area for hydrocarbon formation



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Chamber Design Shape

- Generally (for equal bore and compression ratio)
 - Double hemispherical chamber has lowest S/V ratio
 - Bowl in piston chamber design has highest S/V ratio
 - As the quench (squish) area is enlarged, the surface area increases relative to the volume – thus large squish generally promotes higher hydrocarbon formation
- Consider a 100mm diameter cylinder, with 9:1 compression ratio

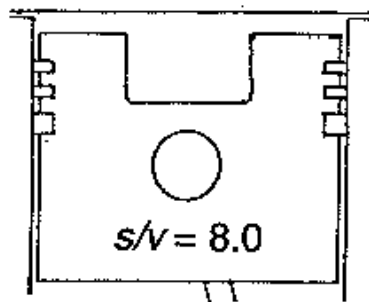
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Chamber Design Shape

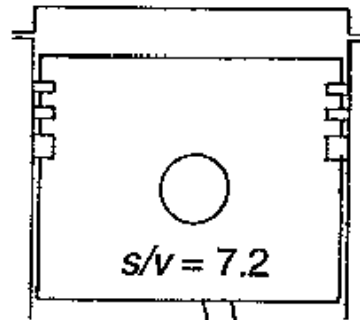


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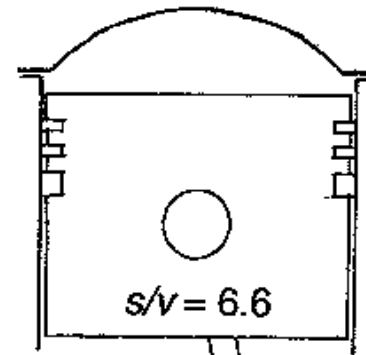
(a) Bowl in piston



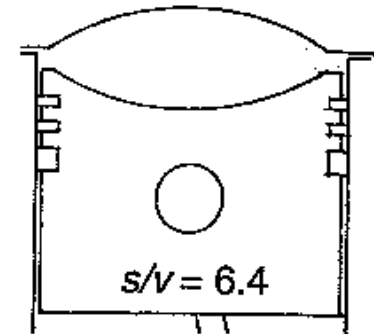
(b) Pancake



(c) Hemisphere



(d) Double hemisphere



- Bowl in piston highest, due to large squish zones
- “Real” chamber designs feature elements of each basic type
- Typical “real” S/V ratios are around those of the pancake chamber

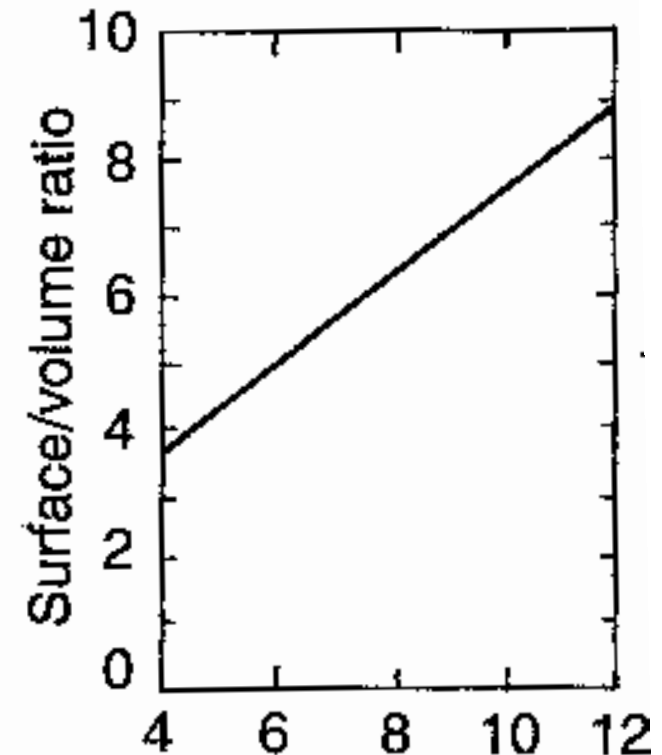
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Compression Ratio



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- For a given cylinder diameter and stroke, raising compression ratio reduces combustion chamber volume
- As clearance volume decreases, surface area becomes relatively larger
- Thus S/V ratio increases with compression ratio



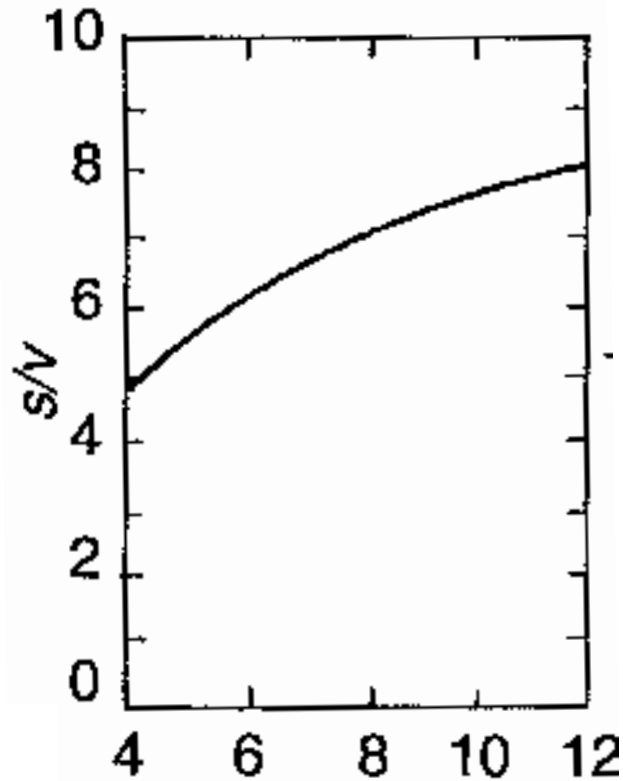
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Cylinder Size & Number

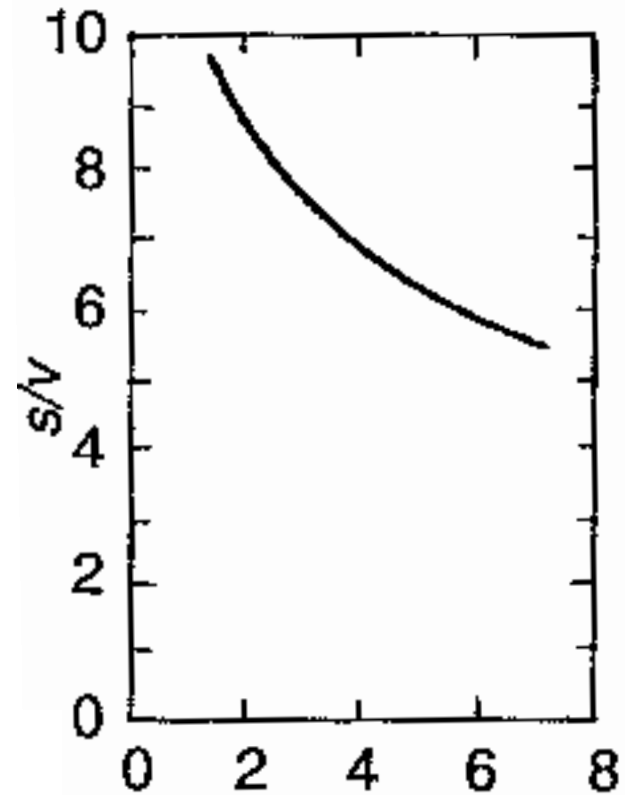
- For a given engine capacity, fewer, bigger cylinders gives the lowest surface/volume ratio
- Cylinder volume increases with the cube of diameter, whereas area increases with square of diameter, so s/v ratio falls for larger cylinders
- Increasing the number of cylinders decreases the size of each cylinder, giving a higher s/v ratio

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Cylinder Size & Number



Number of Cylinders



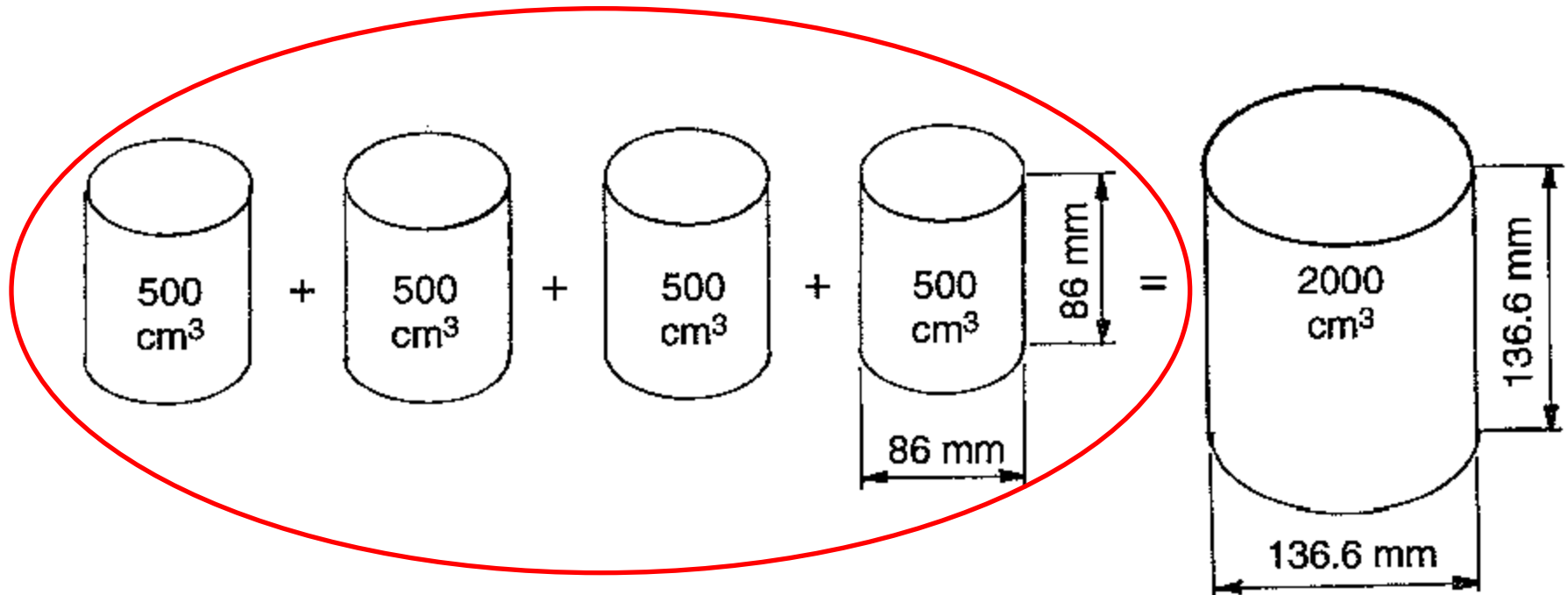
Cylinder Volume

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Cylinder Size & Number



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$$S = 4 \left[2 \left(\frac{\pi D^2}{4} \right) + \pi D L \right] = 4 \left[2 \left(\frac{\pi \times 86^2}{4} \right) + \pi \times 86 \times 86 \right]$$

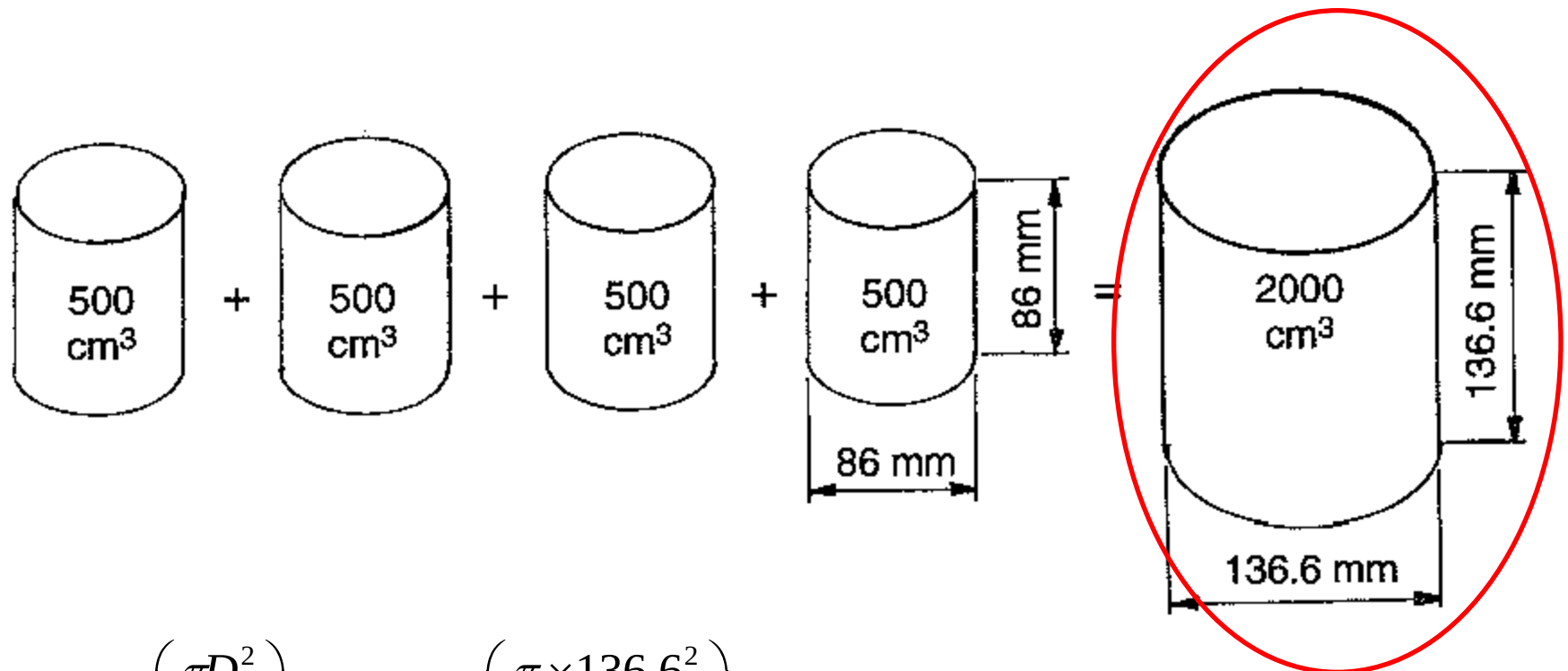
$$S = 139411.3 \text{ mm}^2$$

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Cylinder Size & Number



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$$S = 2\left(\frac{\pi D^2}{4}\right) + \pi DL = 2\left(\frac{\pi \times 136.6^2}{4}\right) + (\pi \times 136.6 \times 136.6)$$

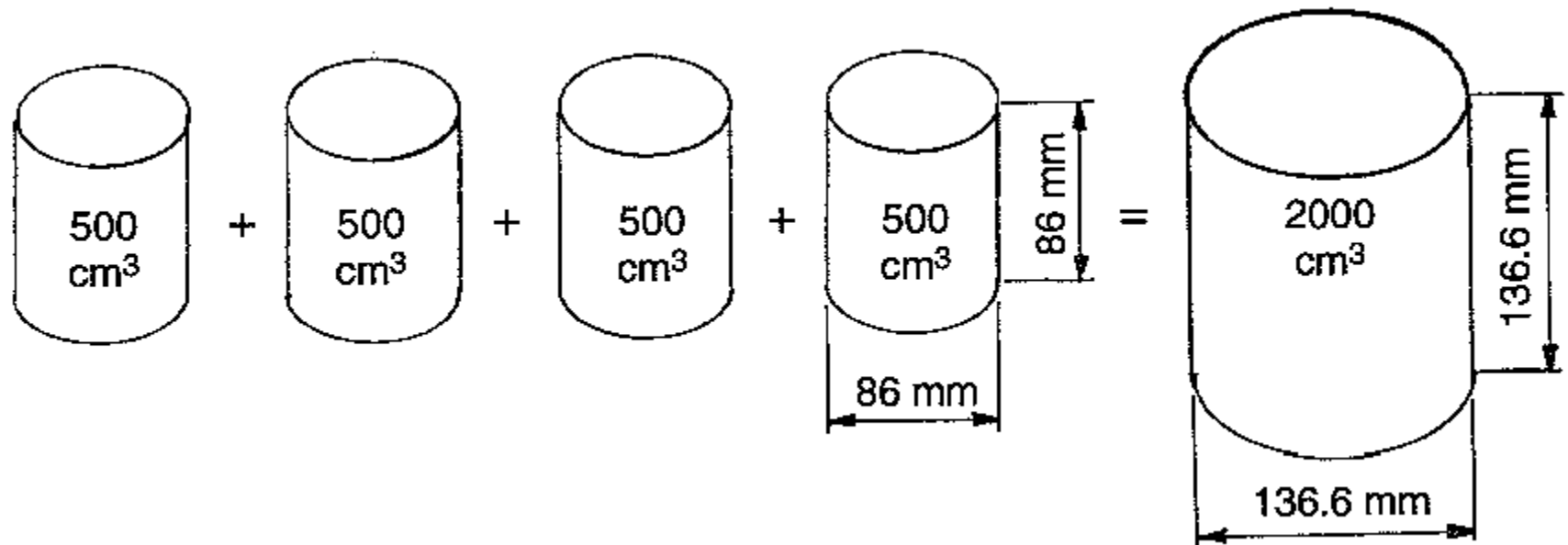
$$S = 87931.1 \text{ mm}^2$$

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Cylinder Size & Number



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$$\frac{139411}{87931} = 1.585 \approx 1.5$$

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Stroke to Bore Ratio

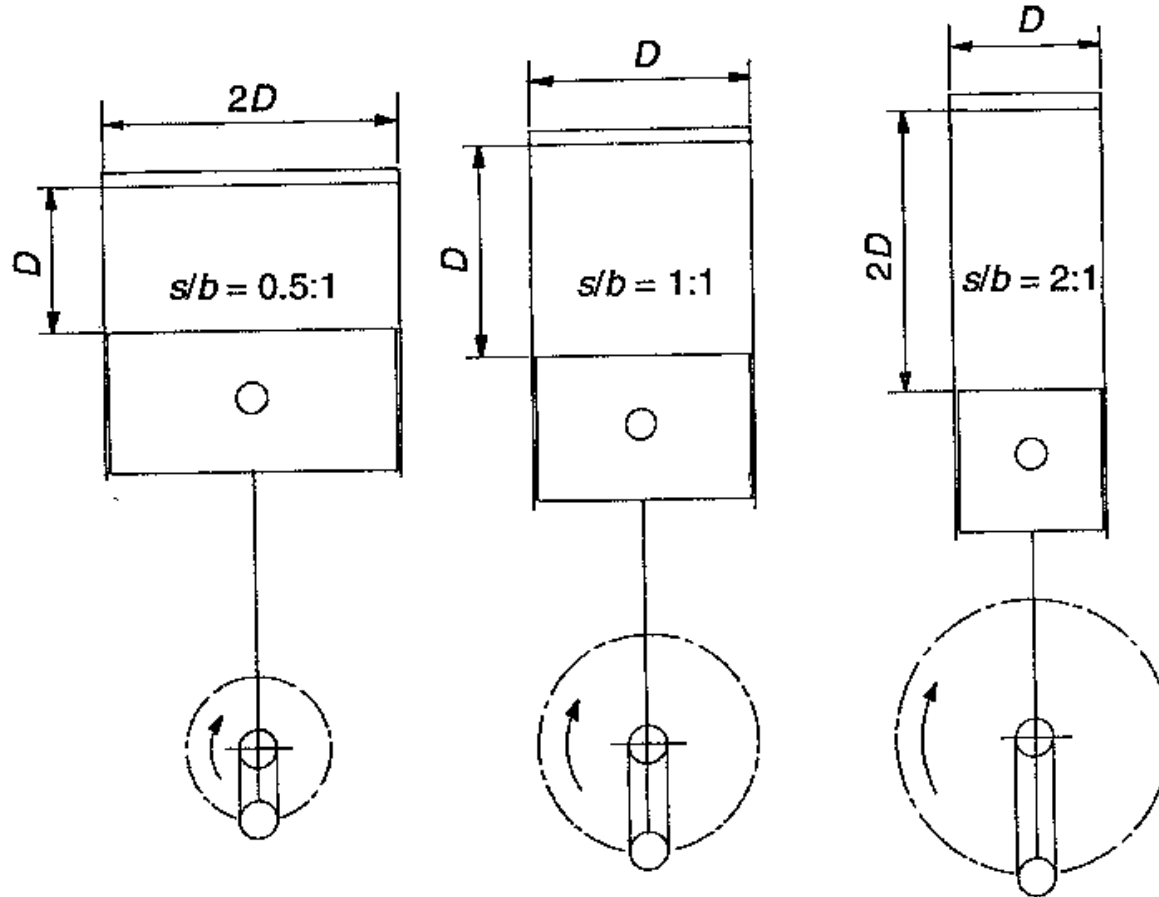
- Square engine $\rightarrow$ stroke and bore equal
 - E.g. Bugatti Veyron W16 engine (86mm bore and stroke)
- Over-square engine $\rightarrow$ stroke $<$ bore
 - Allows more and larger valves
 - Lower friction (less distance travelled by piston rings)
 - Favours high revving engines
 - Extreme example – F1 engine, bore = 2.5 x stroke
- Under-square engine $\rightarrow$ stroke $>$ bore
 - Lower speeds
 - Useful for transverse front wheel drive applications
- Stroke to bore (s/b) generally ranges from 0.6:1 to 1.4:1

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Stroke to Bore Ratio



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(a) Over square engine (b) Square engine (c) Under square engine

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Stroke to Bore Ratio



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- Long stroke, small diameter is nearer to minimum surface area of a sphere than the short stroke, large bore cylinder of same displacement
- Thus, long stroke engine is preferred to minimise heat losses and hydrocarbon formation
- This advantage diminishes with *very* long stroke engines

