



SWANSEA METROPOLITAN UNIVERSITY

PRIFYSGOL FETROPOLITAN ABERTAWE

Advanced Engine Technology

Lecture 2: Combustion Chamber Design

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Contents

- Introduction
- Induction Swirl
- Intensifying Burning Rate

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- Engine Design and Performance
 - Cylinder head / combustion chamber design
 - Valve port geometry
 - Combustion Efficiency
 - Flow Bench Tests
- Engine Intake and Exhaust Systems
 - Induction and Exhaust Manifold Design
 - Influence on air/fuel ratio
 - Practical flow bench tests
- Pressure Charging
 - Turbo and Super Chargers
 - Analysis and selection methods



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- Objective of good combustion chamber design is to
 - optimize filling of cylinder with fresh charge (air/fuel)
 - optimize emptying of exhaust gases from cylinder
 - create conditions in cylinder to produce thoroughly mixed air/fuel
 - to create highly turbulent charge
- **i.e. to achieve complete combustion in the shortest possible time**

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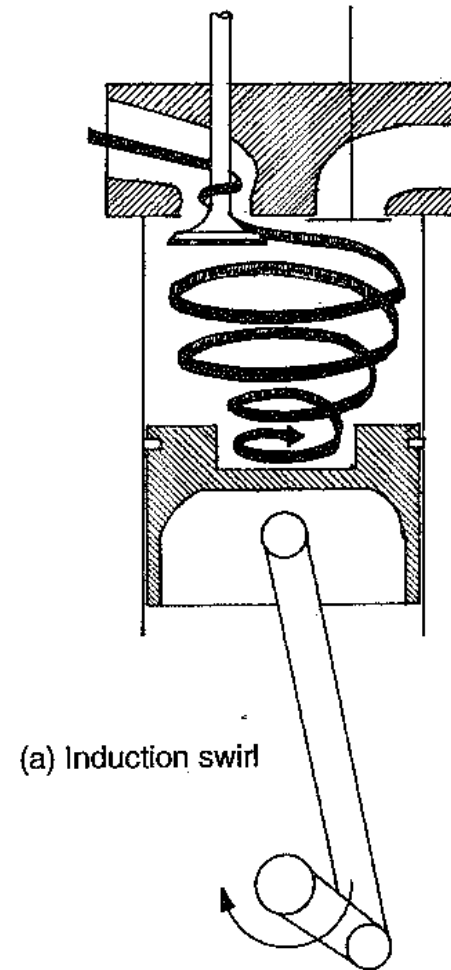
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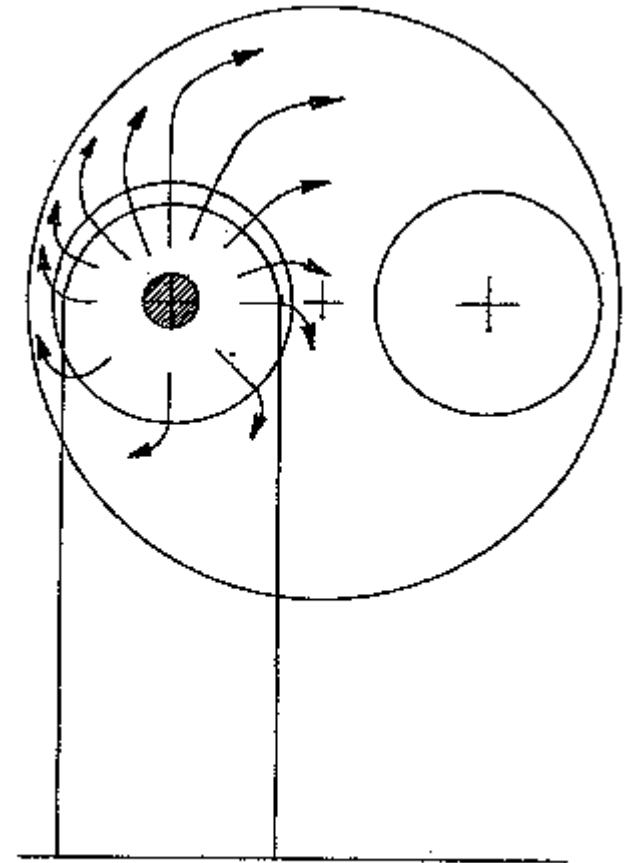
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Induction Swirl

- Rotational flow of charge within cylinder about its own axis
- Produced by positioning the induction port passage to one side of the cylinder axis
- Flow discharges into cylinder tangentially

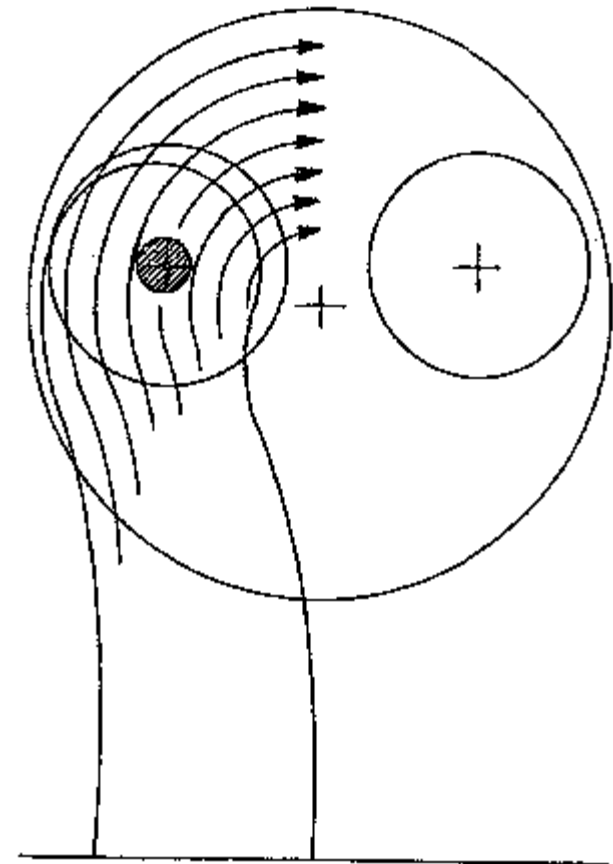


- **Direct straight port**
 - Charge flows through straight and parallel port passage
 - Discharges tangentially via valve
 - Cylinder wall deflects flow sideways and downwards in a spiralling motion



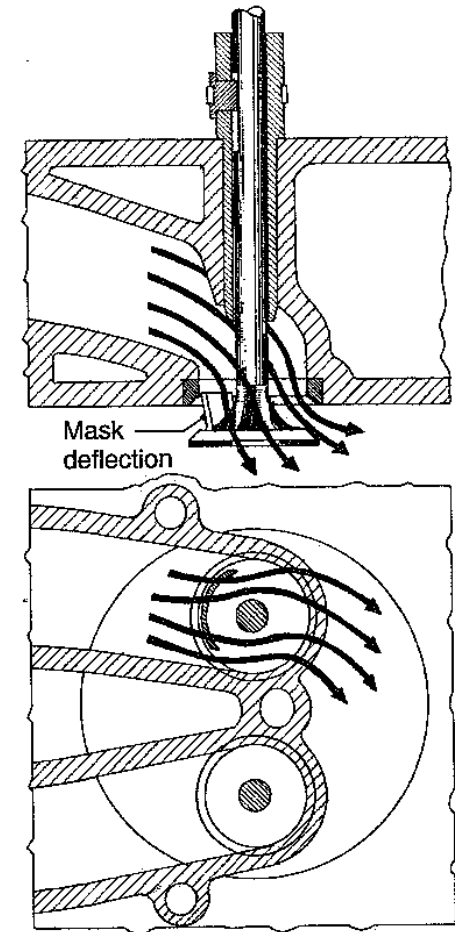
(a) Direct straight port

- **Deflector wall port**
 - Slightly curved and tapered port passage
 - Produces a semi-circular flow path towards valve opening
 - Directional effect produced mainly by outer port wall
 - Less restrictive



(b) Deflector wall port

- **Masked Valve port**
 - Charge flows through straight and parallel port towards valve opening
 - Valve mask forces it to discharge into cylinder with downwards swirling motion
 - Mask closes part of valve area, restricts flow discharge reducing possible volumetric efficiency
 - Benefit is large amount of swirl



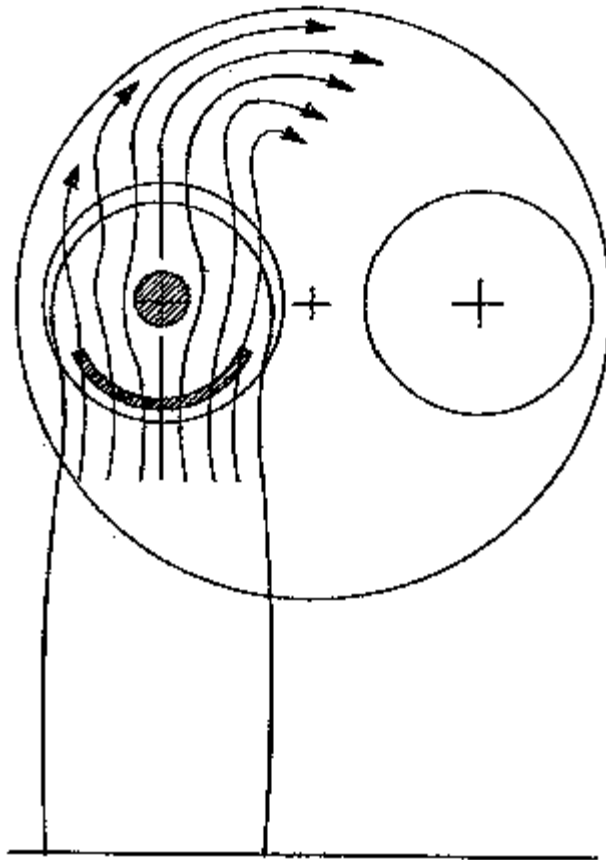
(a) Masked inlet valve directed induction swirl

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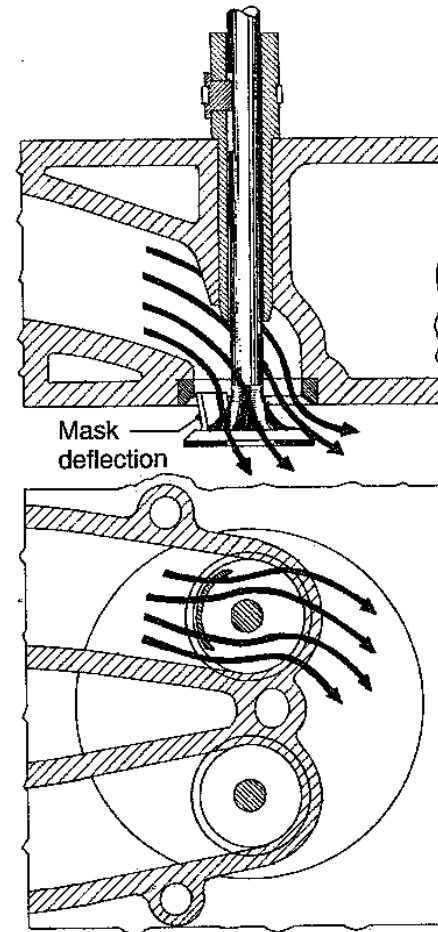
Induction Swirl



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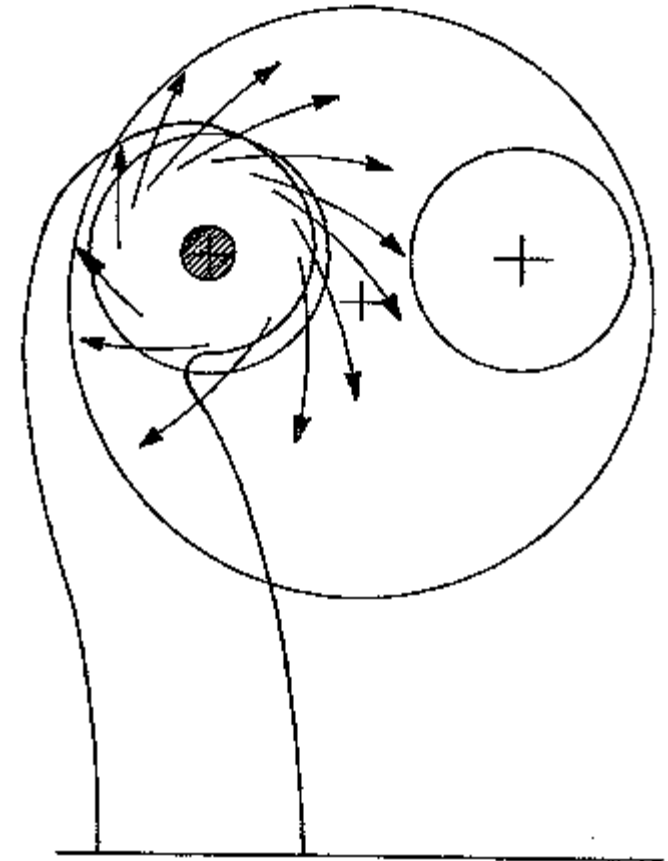
(c) Masked value port



(a) Masked inlet valve directed induction swirl

- **Helical Port**

- Swirling motion created within port above valve seat
- Charge flows into cylinder with a rotational flow about the valve axis
- Swirl intensity influenced by steepness of port helix and port diameter
- Give higher flow discharges compared to directed ports as whole valve opening area is used
- Poorer volumetric efficiency at high speed due to pressure drop from swirling flow across valve opening



(d) Helical port

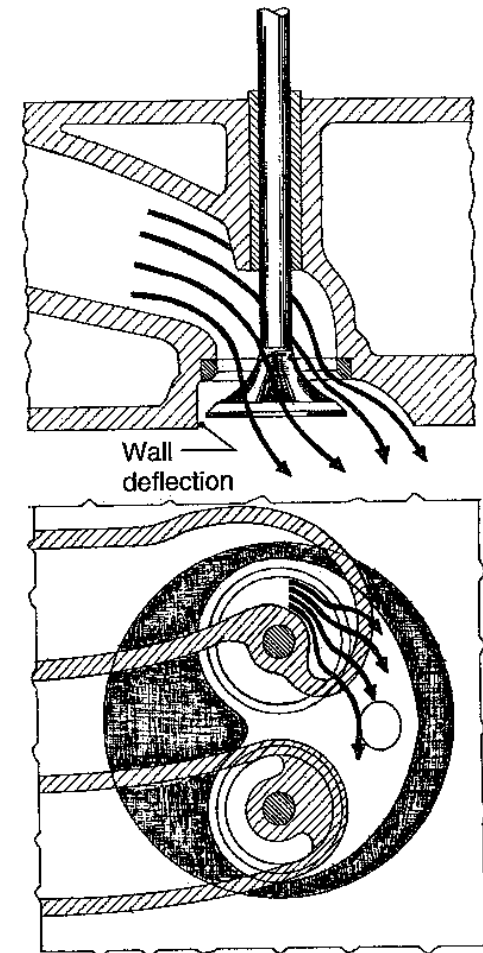
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Induction Swirl



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- Chamber wall deflected swirl
 - Charge flows between steep chamber wall close to one side of the inlet valve and the slanting and widening roof of the chamber on the opposite side
 - The flow partially separates from the steep wall, giving a swirling, spiralling motion within the cylinder



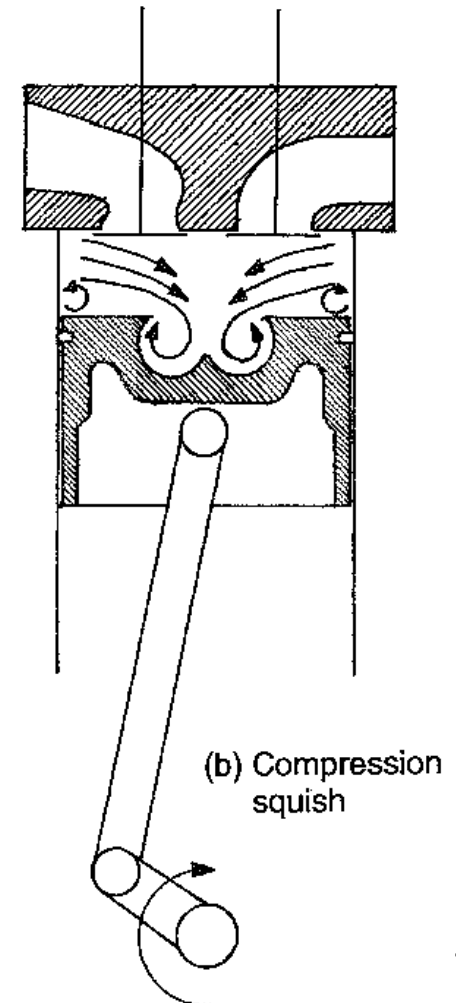
(b) Chamber wall deflected induction swirl

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- Caused by compression of trapped charge between parallel sections of the cylinder head and piston crown as piston approaches TDC
- Charge is squeezed at high velocity into the combustion chamber
- The charge suddenly expands as it enters the chamber, giving increased charge turbulence
- This promotes better fuel mixing and increased rates of heat transfer during combustion



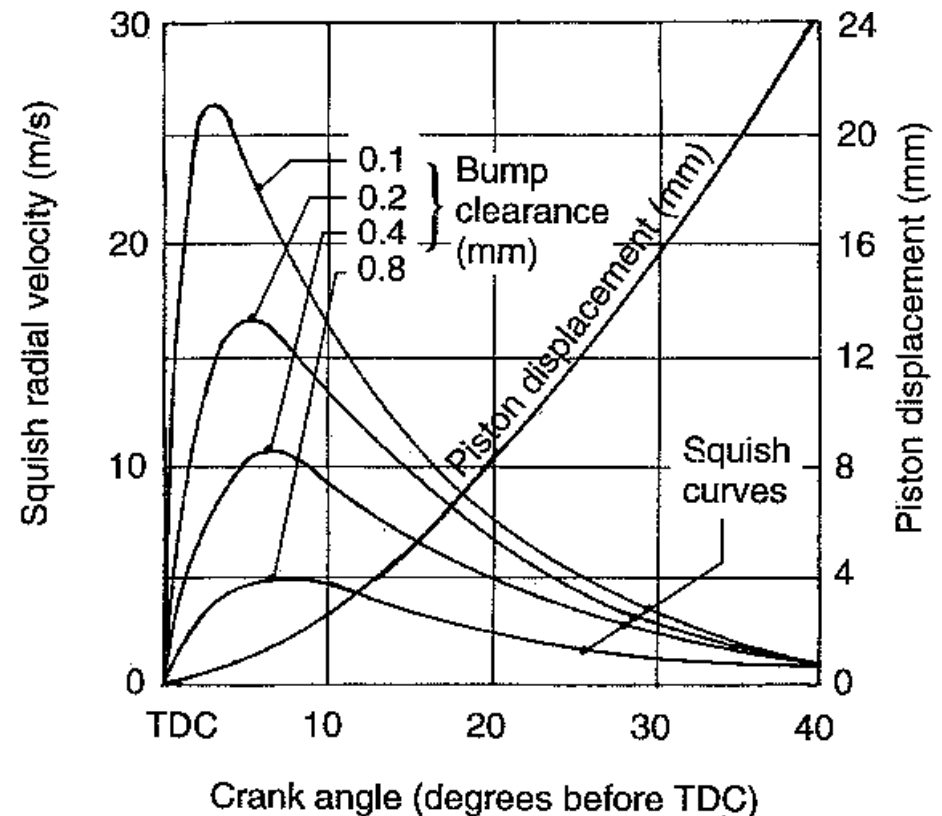
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Squish



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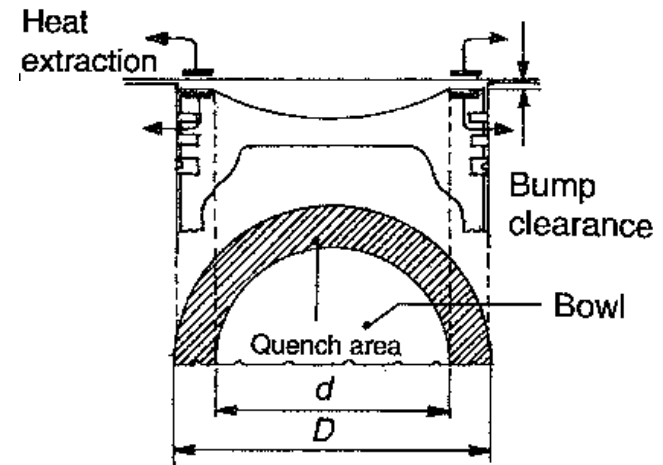
- Flow velocity depends on the distance between the parallel opposing portions of piston crown and cylinder head at TDC



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Quench Area

- Parallel area between cylinder head and piston crown
- At TDC, these surfaces areas have a large area compared to the volume of charge trapped between them
- This leads to rapid cooling of the trapped charge – hence the “quench” area



$$\begin{aligned}\% \text{ quench area} &= \frac{\text{piston area} - \text{bowl area}}{\text{piston area}} \times 100 \\ &= \frac{\frac{\pi}{4} D^2 - \frac{\pi}{4} (D^2 - d^2)}{\frac{\pi}{4} D^2} \times 100 \\ &= \frac{D^2 - (D^2 - d^2)}{D^2} \times 100 \\ \% A_q &= \frac{d^2}{D^2} \times 100\end{aligned}$$

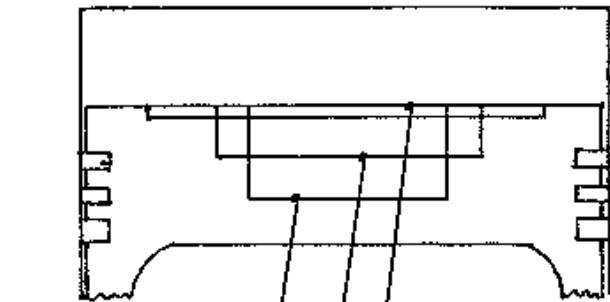
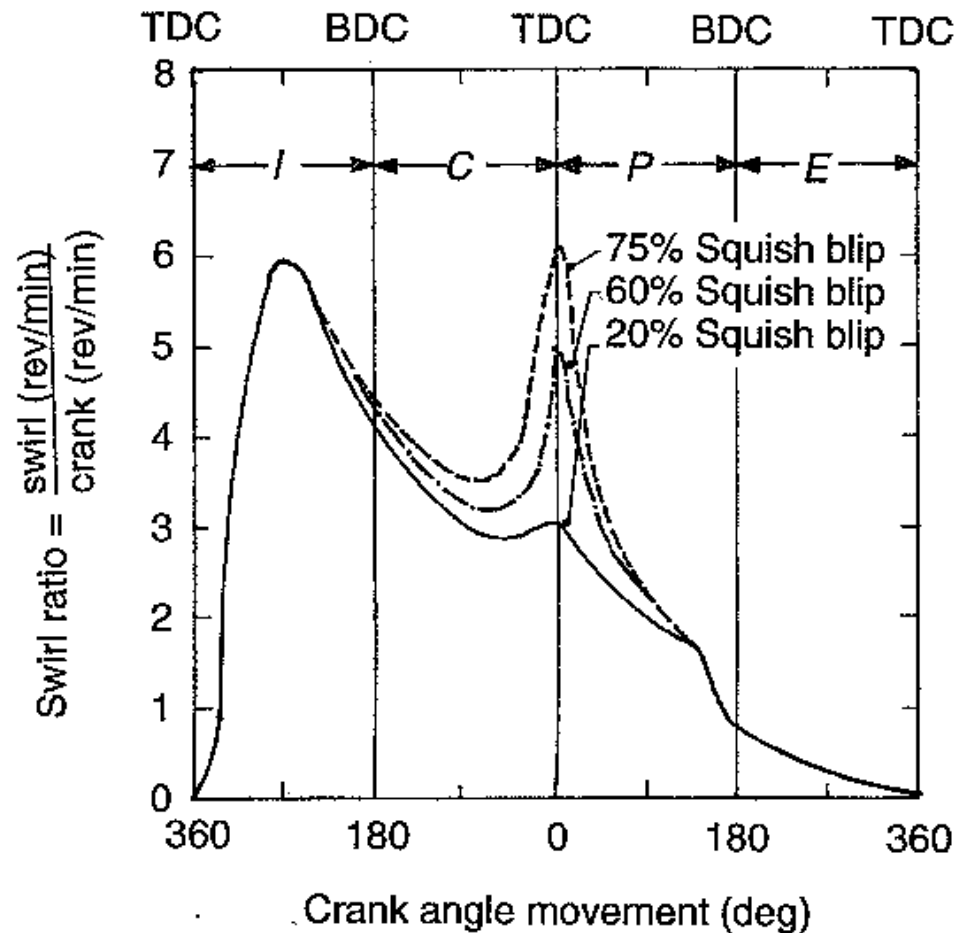
- Swirl is a rotational flow of charge about cylinder axis.
- This can be related to engine RPM – the ratio of swirl rotations to crankshaft rotations is known as the Swirl Ratio
- Helical ports can give ratios of 3 to 5 at TDC with a flat piston crown
- A bowl in the piston crown can give much higher swirl ratios – up to 15
- Deep bowls can give large rises in swirl as piston approaches TDC on compression stroke just before ignition

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Swirl Ratio



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Deep bowl
75% squish blip
Shallow bowl
60% squish blip
Disc recess
20% squish blip

$$\% \text{ quench blip} = \frac{\text{piston area} - \text{bowl area}}{\text{piston area}} \times 100$$

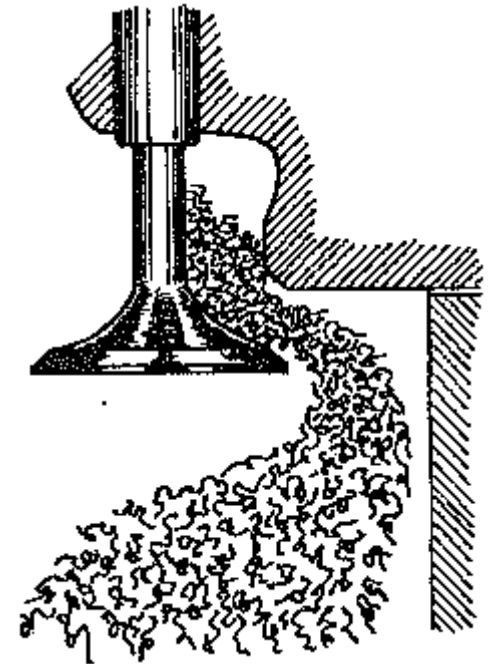
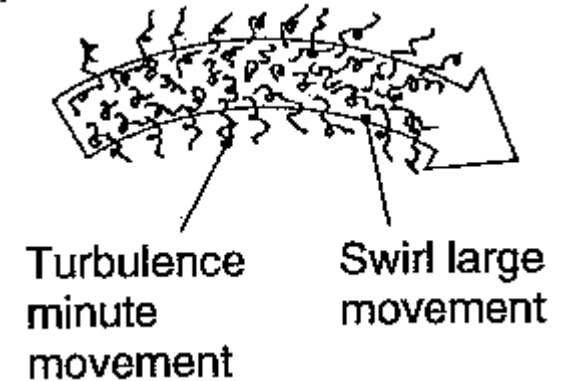
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Turbulence



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- Randomly dispersed vortices superimposed on the flow stream
- Interaction between these vortices promotes fuel mixing and improves heat transfer rates



- If cylinder charge moves with a steady (laminar, smooth) motion, then:
 - Spark ignites fuel molecules
 - Heat transfers (radiation and conduction) to adjacent molecules, raising their temperature until they ignite
 - Temperature rise increases movement of gas molecules – more collisions between themselves and with adjacent unburnt fuel molecules
 - Pressure increase causes expansion of burning molecules – propagation of ignition

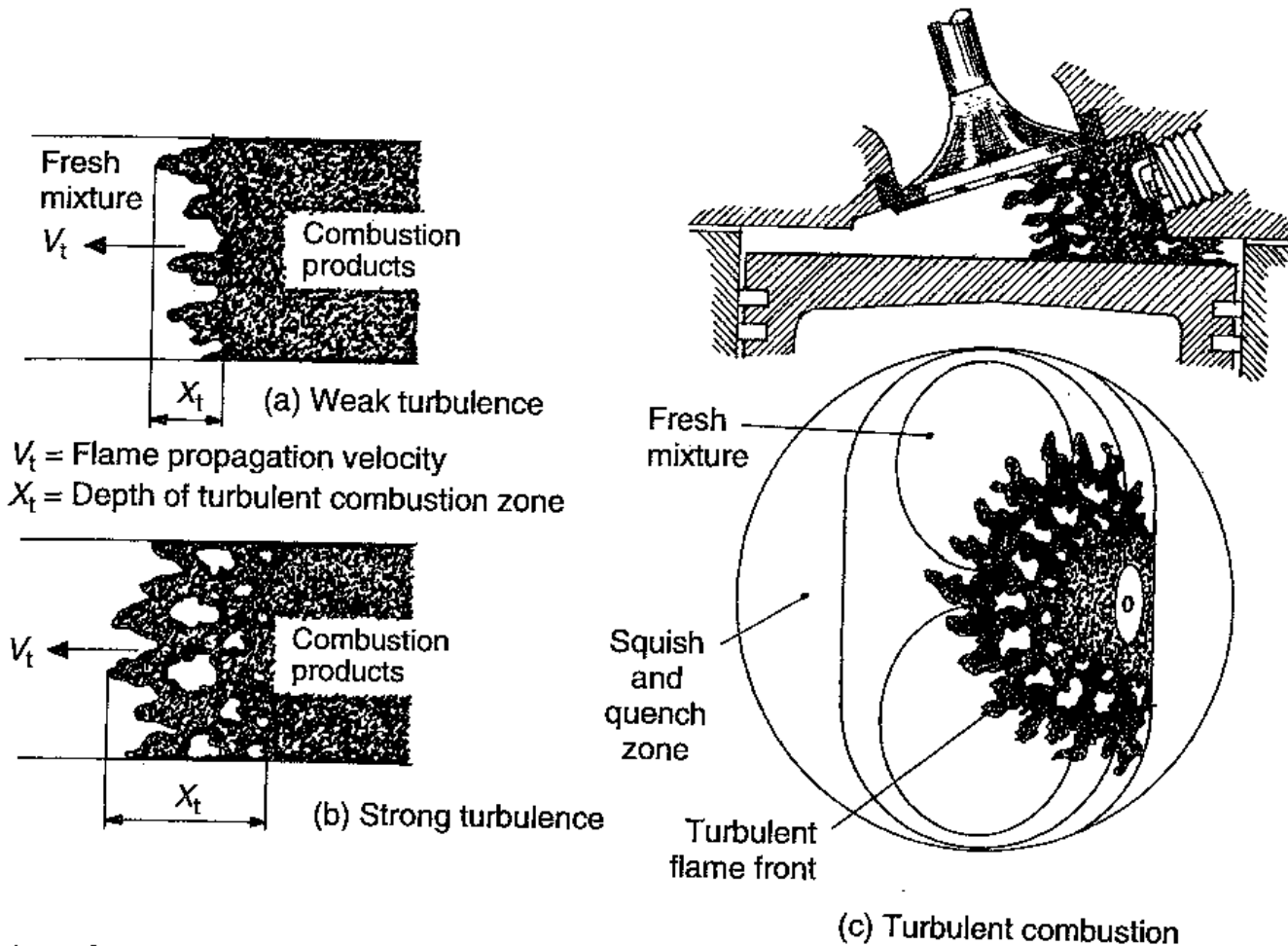
- But this is too slow for complete combustion and effective power generation during ignition stroke
- However, charge is in a turbulent, swirling state
 - Vortices distort the flame front, breaking it into separately burning focal points
 - This enlarges the flame front surface area significantly, giving increased heat transfer
 - “agitation” from turbulent vortices intensifies heat transfer and diffusion across the flame front
 - Irregular flame front leads to local currents, speeding up heat transfer

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Flame Propagation



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retrogression of turbulent flame front

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Flame Propagation

- Typical flame front propagation speeds
 - 15 m/s at idle speed (say 1000 rpm)
 - 70 m/s at full throttle (say 6000 rpm)
- Without turbulence, the petrol engine would be unable to operate over this speed range