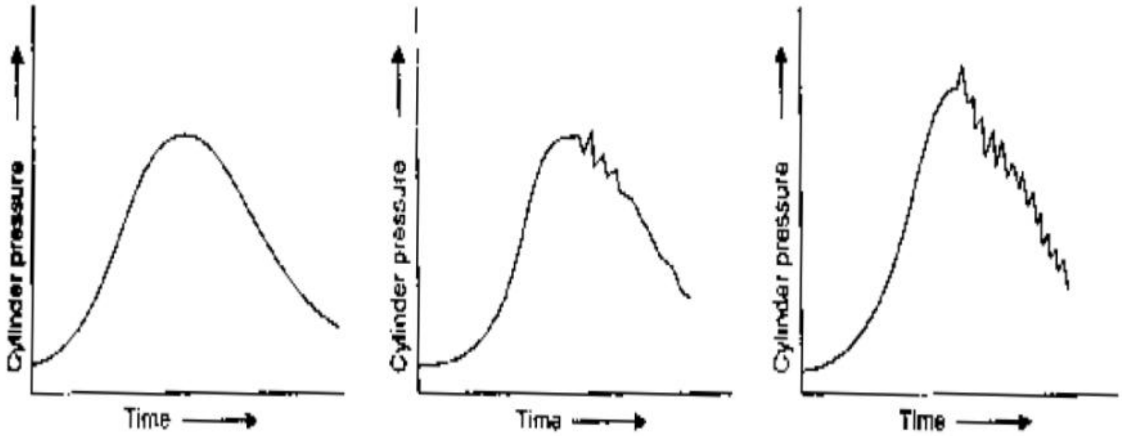
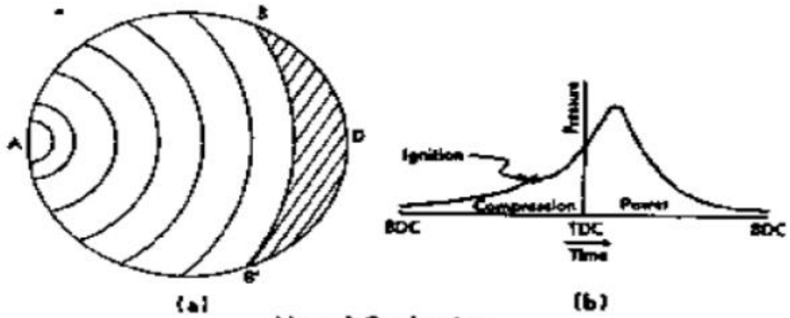
KNOCKING IN SI ENGINE

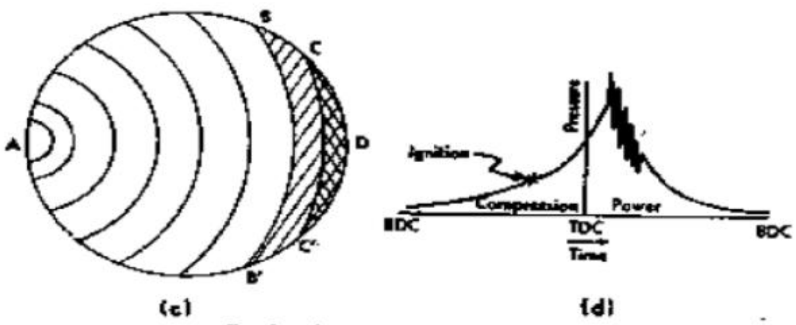
Knocking is due to auto ignition of end portion of unburned charge in combustion chamber. As the normal flame proceeds across the chamber, pressure and temperature of unburned charge increase due to compression by burned portion of charge. This unburned compressed charge may auto ignite under certain temperature condition and release the energy at a very rapid rate compared to normal combustion process in cylinder. This rapid release of energy during auto ignition causes a high-pressure differential in combustion chamber and a high-pressure wave is released from auto ignition region. The motion of high-pressure compression waves inside the cylinder causes vibration of engine parts and pinging noise and it is known as knocking or detonation. This pressure frequency or vibration frequency in SI engine can be up to 5000 Cycles per second.



(i) Normal combustion with no knock (ii) Combustion with slight knock (iii) Combustion with heavy knock



Normal Combustion



Combustion With Detonation

Knocking is undesirable as it affects the engine performance and life, as it abruptly increases sudden large amount of heat energy. It also put a limit on compression ratio at which engine can be operated which directly affects the engine efficiency and output.

EFFECTS OF DETONATION

The harmful effects of detonation are as follows:

1. **Noise and Roughness:** Knocking produces a loud pulsating noise and pressure waves. These waves which vibrates back and forth across the cylinder. The presence of vibratory motion causes crankshaft vibrations and the engine runs rough.
2. **Mechanical Damage:**

   (a) High pressure waves generated during knocking can increase rate of wear of parts of combustion chamber. Sever erosion of piston crown, cylinder head and pitting of inlet and outlet valves may result in complete wreckage of the engine.

   (b) Detonation is very dangerous in engines having high noise level. In small engines the knocking noise is easily detected and the corrective measures can be taken but in aero-engines it is difficult to detect knocking noise and hence corrective measures cannot be taken. Hence severe detonation may persist for a long time which may ultimately result in complete wreckage of the piston
3. **Carbon deposits:** Detonation results in increased carbon deposits.
4. **Increase in heat transfer:** Knocking is accompanied by an increase in the rate of heat transfer to the combustion chamber walls. The increase in heat transfer is due to two reasons:
   - The minor reason is that the maximum temperature in a detonating engine is about 150°C higher than in a non-detonating engine, due to rapid completion of combustion
   - The major reason for increased heat transfer is the scouring away of protective layer of inactive stagnant gas on the cylinder walls due to pressure waves. The inactive layer of gas normally reduces the heat transfer by protecting the combustion and piston crown from direct contact with flame.
5. Decrease in power output and efficiency is due to increase in the rate of a detonating engine decreases.
6. **Pre-ignition:** The increase in the rate of heat transfer to the walls has yet another effect. It may cause local overheating, especially of the sparking plug, which may reach a temperature high enough to ignite the charge before the passage of spark, thus causing pre-ignition. An engine

detonating for a long period would most probably lead to preignition and this is the real danger of detonation

FACTORS AFFECTING KNOCKING IN SI ENGINE

The various engine variables affecting knocking can be classified as

- Temperature factors
- Density factors
- Time factors
- Composition factors

TEMPERATURE FACTORS

Increasing the temperature of the unburned mixture increase the possibility of knock in the SI engine We shall now discuss the effect of following engine parameters on the temperature of the unburned mixture:

- **RAISING THE COMPRESSION RATIO:** Increasing the compression ratio increases both the temperature and pressure (density of the unburned mixture). Increase in temperature reduces the delay period of the end gas, which in turn increases the tendency to knock.
- **SUPERCHARGING:** It also increases both temperature and density, which increase the knocking tendency of engine.
- **COOLANT TEMPERATURE:** Delay period decreases with increase of coolant temperature decreased delay period increase the tendency to knock.
- **TEMPERATURE OF THE CYLINDER AND COMBUSTION CHAMBER WALLS:** The temperature of the end gas depends on the design of combustion chamber. Sparking plug and exhaust valve are two hottest parts in the combustion chamber and uneven temperature leads to pre-ignition and hence the knocking.

DENSITY FACTORS

Increasing the density of unburnt mixture will increase the possibility of knock in the engine. The engine parameters that affect the density are as follows:

- Increased compression ratio increase the density
- Increasing the load opens the throttle valve more and thus the density.
- Supercharging increase the density of the mixture
- Increasing the inlet pressure increases the overall pressure during the cycle. The high-pressure end gas decreases the delay period, which increase the tendency of knocking.

- The quantity of fuel burnt per cycle before and after TDC, position depends on spark timing. The temperature of charge increases by increasing the spark advance and it increases with rate of burning and does not allow sufficient time to the end mixture to dissipate the heat and increase the knocking tendency.

TIME FACTORS

Increasing the time of exposure of the unburned mixture to auto-ignition conditions increase the possibility of knock in SI engines.

- **Flame travel distance:** If the distance of flame travel is more, then possibility of knocking is also more. This problem can be solved by combustion chamber design, spark plug location and engine size. Compact combustion chamber will have better anti-knock characteristics, since the flame travel and combustion time will be shorter. Further, if the combustion chamber is highly turbulent, the combustion rate is high and consequently combustion time is further reduced; this further reduces the tendency to knock.
- **Location of sparkplug:** A spark plug that is centrally located in the combustion chamber has minimum tendency to knock, as the flame travel is minimum. The flame travel can be reduced by using two or more spark plugs.
- **Location of exhaust valve:** The exhaust valve should be located close to the spark plug so that it is not in the end gas region; otherwise, there will be a tendency to knock.
- **Engine size:** Large engines have a greater knocking tendency because flame requires a longer time to travel across the combustion chamber. In SI engine therefore , generally limited to 100mm
- **Turbulence of mixture:** Decreasing the turbulence of the mixture decreases the flame speed and hence increases the tendency to knock. Turbulence depends on the design of combustion chamber and one engine speed.

COMPOSITION

The properties of fuel and A/F ratio are primary means to control knock:

- **Molecular Structure:** The knocking tendency is markedly affected by the type of the fuel used. Petroleum fuels usually consist of many hydrocarbons of different molecular structure. The structure of the fuel molecule has enormous effect on knocking tendency. Increasing the carbon-chain increases the knocking tendency and centralizing the carbon atoms decreases the knocking tendency. Unsaturated hydrocarbons have less knocking tendency than saturated hydrocarbons.

1. **Paraffins**:
   - Increasing the length of carbon chain increases the knocking tendency.
   - Centralizing the carbon atoms decreases the knocking tendency.
   - Adding methyl group (CH to the side of the carbon chain in the centre position decreases the knocking tendency.
2. **Olefins**
   - Introduction of one double bond has little effect on anti-knock quality but two or three double bond results less knocking tendency except C and C
3. **Napthenes and Aromatics**
   - Napthenes have greater knocking tendency than corresponding aromatics.
   - With increasing double-bonds, the knocking tendency is reduced.
   - Lengthening the side chains increases the knocking tendency whereas branching of the side chain decreases the knocking tendency.

- **Fuel-air ratio:**

The most important effect of fuel-aft ratio is on the reaction time or ignition delay. When the mixture is nearly 10% richer than stoichiomiric (fuel-air ratio = 0.08) ignition lag of the end gas is minimum and the velocity of flame propagation is maximum. By making the mixture leaner or richer (than F/A 0.08) the tendency to knock is decreased. A too rich mixture is especially effective in decreasing or eliminating the knock due to longer delay and lower temperature of compression.

- **Humidity of air:**
  - Increasing atmospheric humidity decreases the tendency to knock by decreasing the reaction time of the fuel

EFFECT OF ENGINE VARIABLES ON KNOCKING IN SI ENGINE

- **Compression ratio:** The pressure and temperature at the end of compression increases with increase in compression ratio. This in turn increases the maximum pressure during the combustion and creates a tendency to knock.
- **Supercharging:** increase the temperature and density of mixture and thus the tendency to knock is increased.
- **Turbulence:** decreasing the turbulence of mixture decreases the flame speed and hence increase the tendency to knock.
- **Octane rating of fuel:** higher the octane number, less the tendency to knock. Paraffin have maximum tendency to knock and aromatic series have minimum tendency to knock.