MAK 3031- Motorlar

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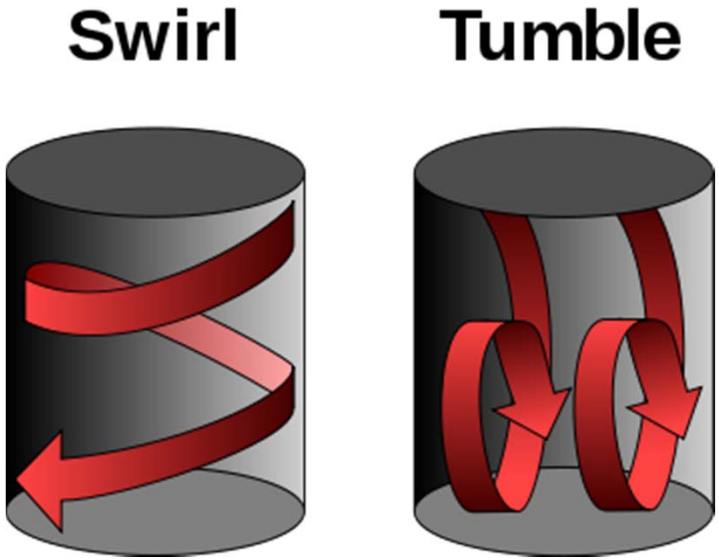
Mixture formation and detonation.

Combustion is a complex physichemical process that occurs in gas phase and duration is about 0.002-0.004 seconds.

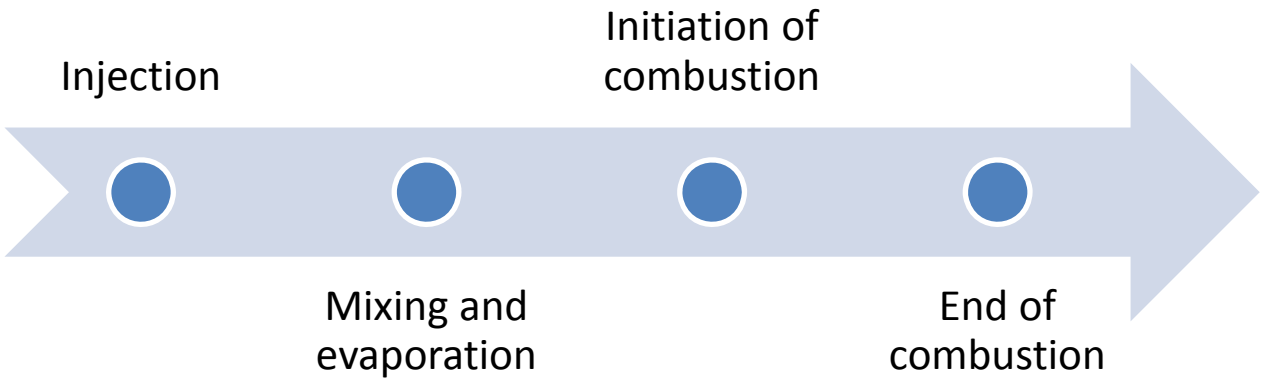
In order to initiate combustion fuel vapour and air have to be homogenised.

If every fuel molecule has enough oxygen at its surroundings that type of mixture can be defined as homogenous mixture.

Molecular diffusion rate can be increased by providing additional air motion within the cylinder. With the help of air motion mixture homogenisation time is reduced.



Mixture formation and detonation.

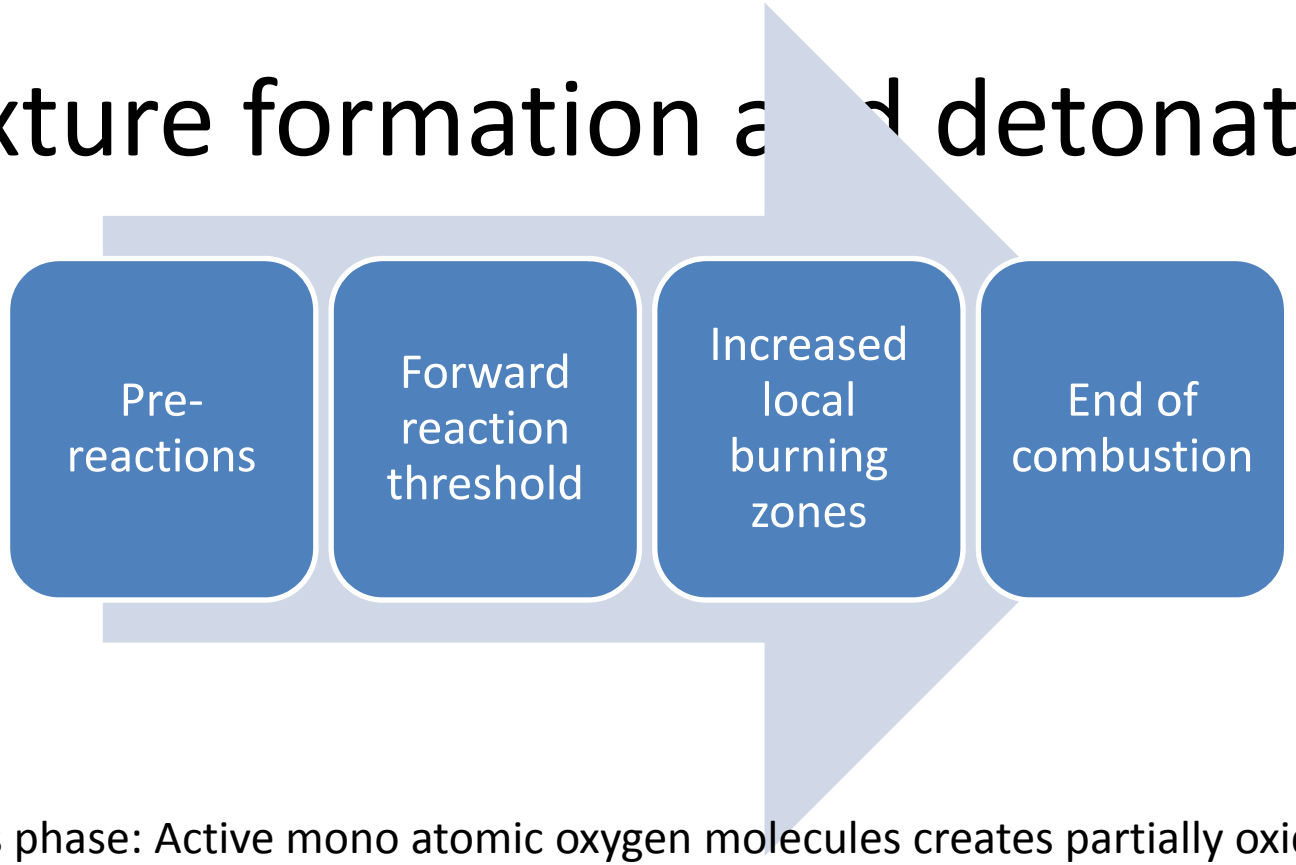


In diesel engines charge is self-ignited at high temperatures but to achive a complete combustion evaporation and mixing is to be completed. In contrast to spark ignition engines, diesel combustion takes place while mixing process is continuing where the mixture can not be assumed as homogenous. Homogenisation is provided by quicker droplet heating and evaporation. In diesel engine combustion rate is a direct function of evaporation and mixing with air.

Burn rate or combustion speed is higher in homogenous mixtures.

Combustion in ICE is comprised of several chain reactions product of each of this reaction will be reactant of the next and so on. This contiunes process creates different gas compounds, monoatomic gases and hydrocarbons.

Mixture formation and detonation



Pre-reactions phase: Active mono atomic oxygen molecules creates partially oxidized hydrocarbons.

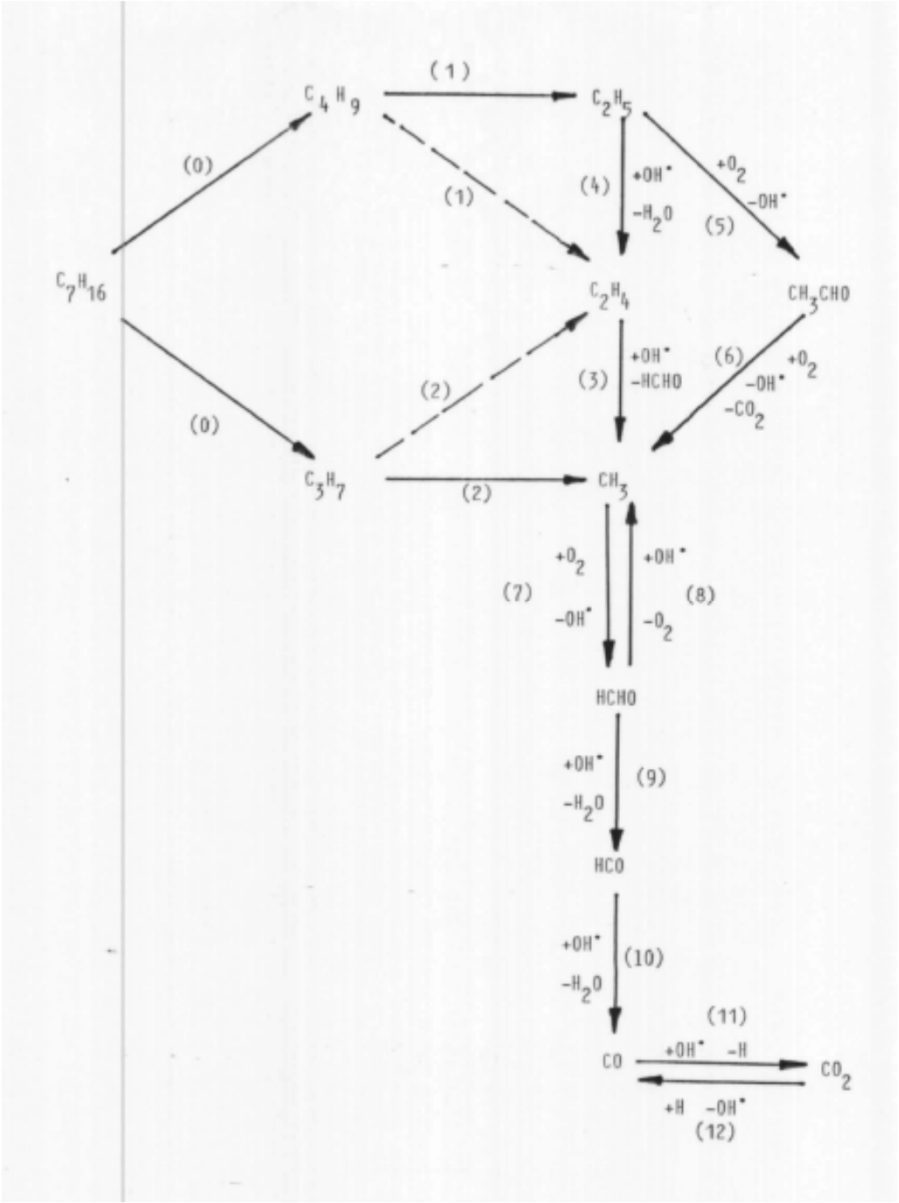
Forward reaction treshold: After sustaining enough heat with pre-reactions, hydrocarbons will create active radicals.

Increaase of local burning zones: When the local zone temperature reach high enough to ignite the mixture, visual combustion initiates and develops.

Mixture formation and detonation

No	REAKSİYONLAR (40)
0	$C_7H_{16} \xrightarrow{K_0} n\,C_3H_7 + n\,C_4H_9$
1	$C_4H_9 \xrightarrow{K_1} C_2H_4 + C_2H_5$
2	$C_3H_7 \xrightarrow{K_2} C_2H_4 + CH_3$
3	$C_2H_4 + OH \xrightarrow{K_3} CH_3 + HCHO$
4	$C_2H_5 + OH \xrightarrow{K_4} C_2H_4 + H_2O$
5	$C_2H_5 + O_2 \xrightarrow{K_5} CH_3CHO + OH$
6	$CH_3CHO\ O_2 \xrightarrow{K_6} CH_3 + CO_2 + OH$
7	$CH_3 + O_2 \xrightarrow{K_7} HCHO + OH$
8	$HCHO + OH \xrightarrow{K_8} CH_3 + O_2$
9	$HCHO + OH \xrightarrow{K_9} HCO + H_2O$
10	$HCO + OH \xrightarrow{K_{10}} CO + H$
11	$CO + OH \xrightarrow{K_{11}} CO_2 + H$
12	$CO_2 + H \xrightarrow{K_{12}} CO + OH$

Mixture formation and detonation



Mixture formation and detonation

Arrhenius Equation

$$k = \frac{dc}{dt} = Ae^{\frac{-E_a}{RT}}$$

$A = Constant\ for\ each\ reaction\ type$

$E_a = activation\ energy$

$R = Ideal\ gas\ constant$

$T = Temperature$

$k \Rightarrow Reaction\ rate\ constant$

Ignition delay

- Ignition delay is the time between the start of injection and visual initiation of combustion.
- Determination of visual combution start is relatively hard to measure in that case a treshold quantity of ROHR is assumed as an indicator of start of combustion.
- ID can be divided into two main phases one of which is the physical ID phase. Main parameters affecting are injection pressure, injection physical parameters such as spray cone angle, in-cylinder temperature and air motion.
- Second and realtively low ID phase is called as chemical ID. Which is defined as the time between the chain reactions.

$$ID = ID_{\text{physical}} + ID_{chemical}$$

Ignition delay

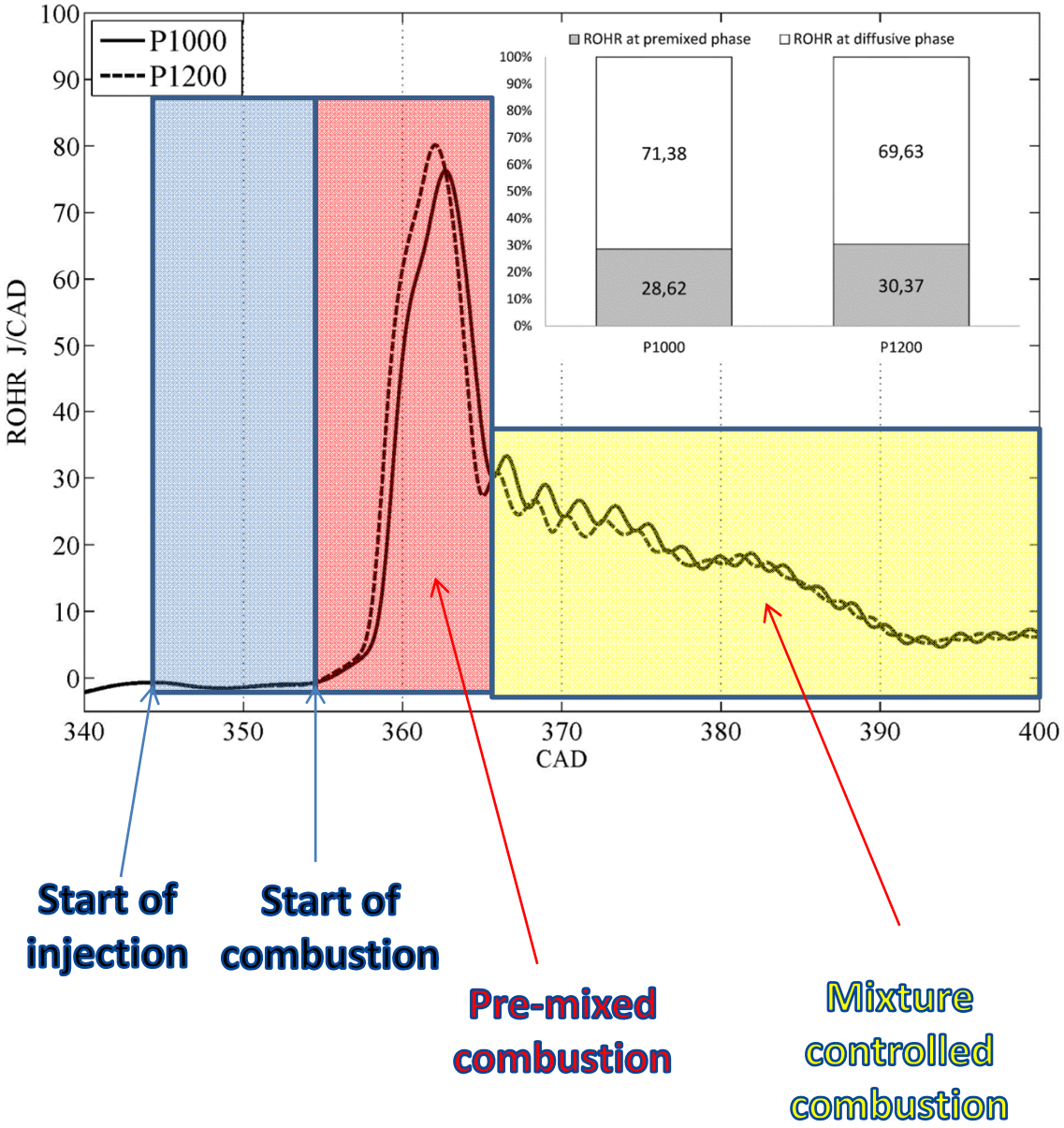
- To shorten the physical ignition delay period, air-fuel mixing rate is to be increased. Most common methods are:
  - Increasing injection pressure (10-30 micrometer droplet size can achived)
  - Multiple injection holes in nozzle
  - Increasing charge pressure (Supercharging)
  - Increasing swirl and tumble rate

Ignition delay

- Chemical period of ID primarly depends on fuel chemistry and hydrocarbon type. Such as parrafines have the shortest delay while the aromatics have the longest.

Ignition delay-Diesel engines

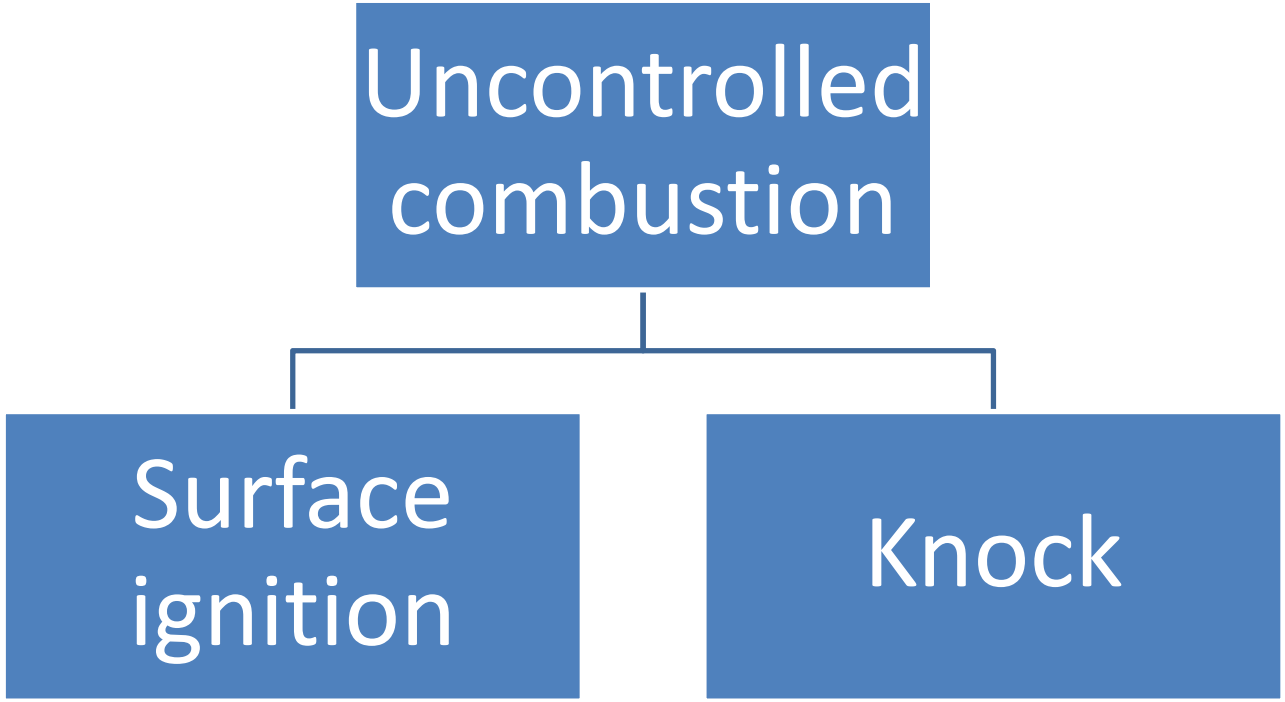
- Ignition delay is defined as the time between the start of fuel injection and the start of apparent combustion.
- Ignition delay is important because, if it is too long, the bulk of the charge in the cylinder tends to fire simultaneously, causing violent combustion.
- If it is too short, combustion procees becomes fully mixture controlled this will create higher smoke emission.



SI engine ignition

- In SI engines, mixture is ignited by a spark which has tiny amount of energy. After spark discharge small volume near the plug reaches 10000 degree Celcius. This high temperature core heats the rest of the charge and initiates combustion. Flame extends from the spark through the cylinder walls.

Detonation



Detonation

Knock: Can be described as self iginition of fuel-air out of the falme front zone. A bell tone is audible as a characteristic indicator of knock in SI engines which can easily be distiguished from the normal operating condition. Intense knock causes hammer hit like noise which actually starts as bell noise than increase gradually.

Surface ignition: Random ignition of charge due to hot spots in cylinder such as a hot piston surface or spark plugs

When knocking or surface ignition occus chemical energy of the charge releases way faster than normal combustion and it creates pressure waves that move so fast.

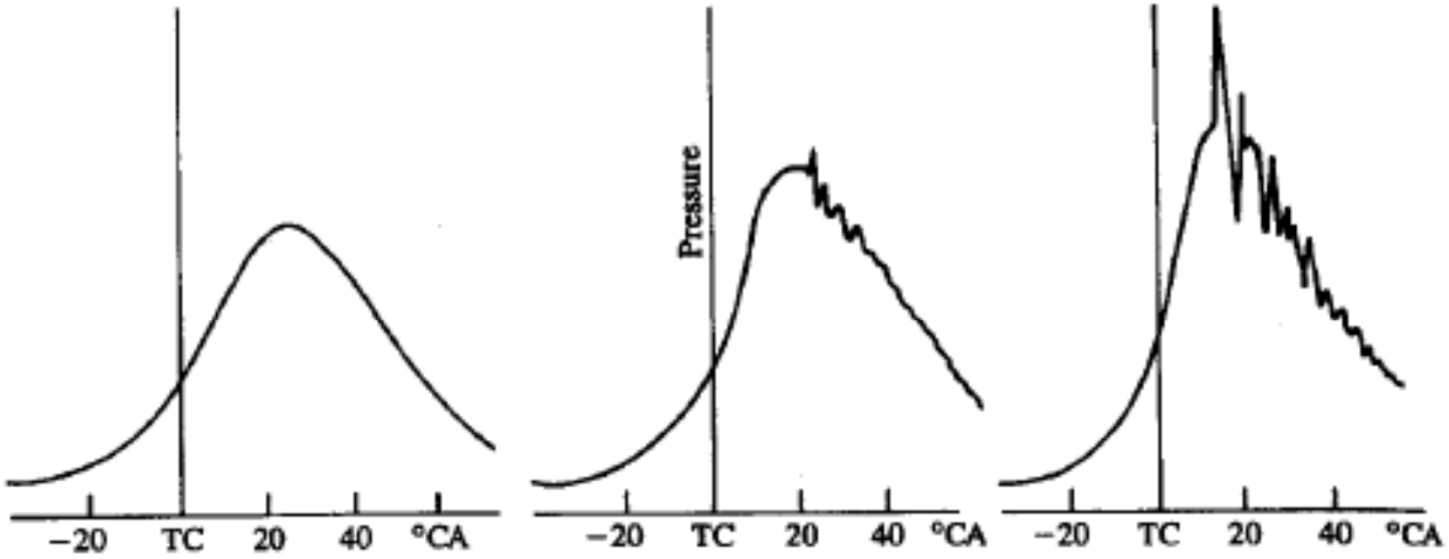
Detonation

Harmfull effect of konocking phenomenon

Combustion rate of an intense knocking case is very high there we can assume that the combustion occurs at constant volume. Such a case creates superior thermal load on components such as piston, ring and cylinder head. That rapidly moving pressure waves also increase the mechanical load on such components and cause premature engine failure.
High thermal load is caused by the high heat transfer which also causes increased specific fuel consumption and thermal efficiency.

Knocking combustion related high heat transfer rate also rises the boundary temperatures and it increases during consecutive cycles. Therefore if knocking starts in a certain scenario it is going to increase the density unless external interference/modification is made.

Detonation



(*a*) Normal combustion, spark 28°BTC

(*b*) Slight knock, spark 28°BTC

(*c*) Intense knock, spark 32°BTC

Detonation

Factors effecting detonation

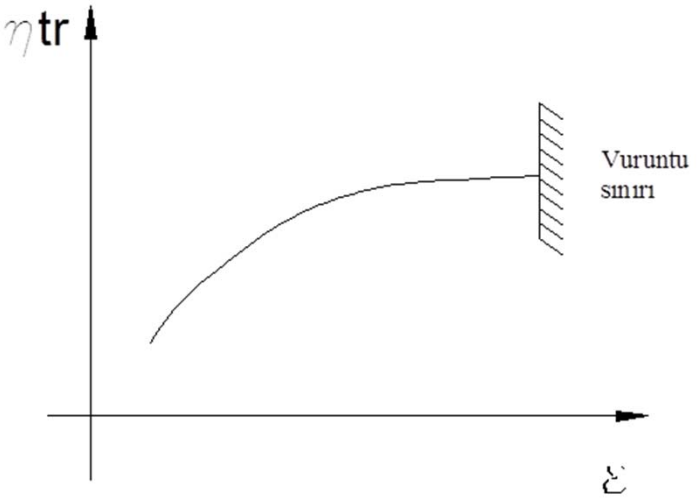
1- Constructional factors
2- Operating factors
3- Fuel factor

Detonation

a- Compression ratio

End of compression temperature

$T_2 = T_1 \varepsilon^{k-1}$



b- Engine capacity

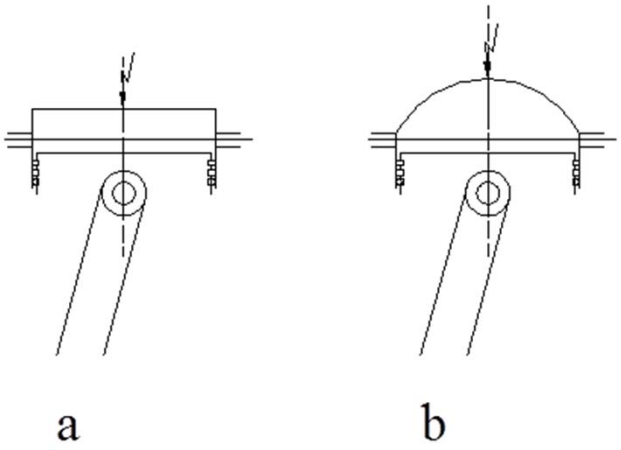
Heat transfer area per cubic volume is getting smaller when the capacity rises. Hence the risc of detonation increases.

c- Valve superposition

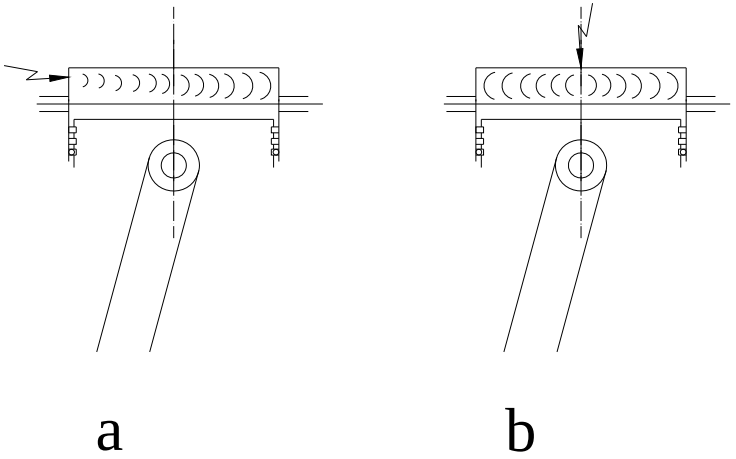
Valve superposition can be described as the duration for both of the valves are open. Valve superposition enhances the scavenging of the residual gases which are hot. And therefore the Valve superposition reduces the probablity of detonation.

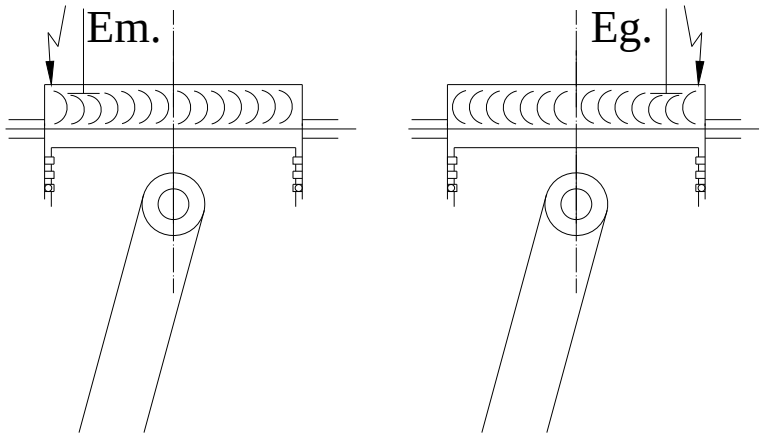
Karışım teşkili, vuruntu ve detonasyon

Combustion chamber shape



Spark plug loaction





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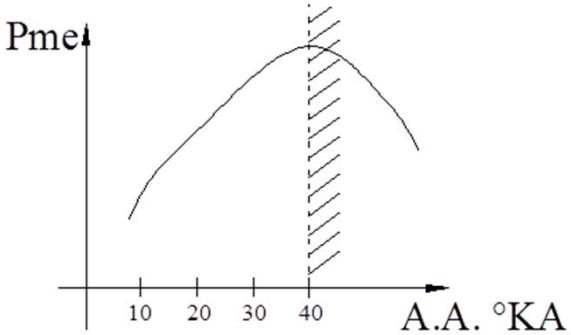

Ignition advance CAD

Compression ratio