CHAPTER 5

5.0 ENGINE FLOW DYNAMICS

5.1 INTRODUCTION

To improve engine performance and flow is essential to understand the nature of the internal combustion engine. Characterization of compression in the cylinder IC engine flow, swirl and tumble is done by. The pollutants in the engine combustion process and effective influence on the free shows. Maintain a significant factor in the process of combustion in the cylinder internal combustion engine is a fluid motion. An advance in the cylinder is the standard swirl and tumble. Orientals and in turn generate a swirl flow and combustion engines to detect and inter-wheel inlet port shape results in an intake stroke. Multidimensional modeling is used as an very important tool. Suitable boundary conditions are solved with partial differential equations and govern the physical process or flow and combustion. Recent studies reveals that computational fluid dynamics codes are a part of developing and vision of new engines brought by the car manufactures.

The accuracy of prediction of mixture formation is of great importance concerning the subsequent combustion processes, and thus it influences the ability of numerical simulation to predict e.g. pollutant emission. With the increased attention on the environmental aspects of internal combustion engines, the simulation of spray formation gained increased importance, and became an area of intensive development.

The changing requirements represented by advanced injection systems – e.g. split injection or HCCI engines – resulted in a need for rethinking the conception of spray formation simulation, and providing a new approach to fulfill these requirements. Since measurement technology provides, due to its limitation concerning time and length scales and because of its outstandingly high cost demand, only a limited opportunity to investigate the very small time and length scales characteristic of direct fuel injection, numerical simulation plays an important role in engine-related research as well.
The new approach of using a separate primary breakup model to better simulate the initial phase of liquid breakup represents an answer to the newly arising needs of internal combustion engine research and development. The new model used throughout the simulations of this project is implemented in a commercial CFD code ANSYS FLUENT, and is used for diesel engine injection simulations. The calculations presented here and the new method for predicting child droplet production were realized in the framework of a research project aimed at gaining experience about the combination and interaction of models, identifying areas for improvement and proposing or realizing new ideas aimed at better prediction capability.

5.2 BREAKUP OF FLUID

Fluid columns break up into ligaments or droplets, and these latter breaks up into further droplets according to different, simultaneously acting mechanisms, depending on a number of physical characteristics. The first process is generally referred to as primary breakup and the latter process is called secondary breakup [Faeth et al., 1995]. Based on their characteristic physical processes, these basic breakup regimes can be differentiated, and they are usually treated separately in the literature.

In both basic breakup regimes a number of different breakup types appear. These breakup types can be characterized by various properties of spray. The most important quantity summarizing the influential factors concerning the intensity and type of breakup is the Weber number, calculated with droplet (or nozzle orifice) diameter, and either with ambient gas or injected liquid density, and is referred to as $\text{We}_g$ and $\text{We}_l$, respectively. The type of Weber number to be used depends on the aim of the investigation, but both dimensionless parameters describe the same phenomenon, only from different perspectives.

Another important quantity is the Reynolds number, defined in spray literature in general [Lefebvre G et al., 1989] with density and viscosity values referring to the injected liquid. The third important quantity representing the effect of viscosity and surface tension in the context of spray breakup is the Ohnesorge number.
FLUID BREAK UP MECHANISM:

The relative velocity of the liquid and the surrounding gas, liquid jet break-up of the break-up of properties based on different methods are governed by. The different methods are usually the first nozzle and formation of droplet, size of droplet, break-up length is characterized by the distance between the points. It [Reitz RD, Bracco FV et al., 1986], the practice, the second wind-induced regime, Rayleigh regime are highlighted.

The explanation of experiments and measurements in effect to continuous jet of liquid Weber number are shown. Decomposition process is explained using above process, which shows

\[ We_l = \frac{\mu^2 D \rho_l}{\sigma} \]  

[5.1]

![Ohnesorge diagram: jet break-up regimes](image)

**Fig. 5.1 Ohnesorge diagram: jet break-up regimes**

and the Reynolds number
jet velocity eliminates $u$, Ohnesorge derived the dimensionless Ohnesorge number,

$$R_e = \frac{\mu D \rho_l}{\mu_l} \quad [5.2]$$

$$Z = \frac{\sqrt{We_l}}{R_e} = \frac{\mu_l}{\sqrt{\sigma \rho_l D}} \quad [5.3]$$

All relevant fluid properties (density mL of liquid is: liquid gas interface’s surface tension, $\rho_l$ fluid dynamic viscosity) includes a nozzle hole diameter $d$ that is given in Figure 5.1 mph as the diagram shows where Ohnesorge, again a function. For stable conditions, break up practice of various jet which is between boundaries, is improved by increasing atomization because, although the practice is not enough of a description of the properties of the liquid phase that has turned out to be drawn to the gas density [Hiroyasu H, ARAI M et al., 1990]. Thus, the ratio of gas to liquid density and three-dimensional one shown in Fig Ohnesorge two-dimensional figure explains. 5.2 [Reitz RD, Bracco FV et al., 1986].

A diplomatic explanation of the jet break up practice is shown in figure 5.3. the fixed nozzle geometry and properties of the fluid are not variant, the fluid velocity is one of the variable in Jet velocity (fig 5.4) as a function of the intact jet length that describes the corresponding break-up curve, shown as follows

Fig. 5.2 Schematic diagram - effect of gas density on jet break-up
Fig. 5.3 Schematic description of jet break-up regimes

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Fig. 5.4: Jet velocity $U$ as a function of the surface to break up. ABC: drip flow, CD: Raleigh breaks up EF: The first wind-induced break-up, FG (F): the second wind-induced breakup, out of G (H): atomization regime.

Drops at a very low velocity flow and a jet is formed. Increases with increasing velocity, the intact jet length, results in the formation of an increase in the U.S.. This condition states Rayleigh break-up. This shows fluid inertia and surface tension forces launched a full jet Volume axis - symmetric oscillations, the growth is due. The droplets of jet are removed and description of flow size nozzle hole diameter $d$ [Raleigh Lord FRS et al., 1878] is over. More advanced analysis have been published [Rutland DF GJ Jameson et al., 1970] for example. Jet break-up
length and velocity results in a further increases, depicts nozzle diameter. The size of the droplet lessen and diameter of a nozzle is considered. As the first phase begins Rayleigh regime relevant forces, wind-induced regime are charged up using aerodynamic forces. Parameters which are relevant in Weber number \( W_e = \frac{u^2 \rho g}{\sigma} \), explains the gas phase influence on surroundings. The flow of nozzle is turbulent in the next process. Weather causes short-wave length surface waves by aerodynamic forces is a resultant of Jet break-up in the jet. The nozzle diameter is smaller than droplets and break up the length of Reynolds number, decreases with the FG line in Fig. 5.4. Detailed theoretical analysis of the re [Reitz RD, Bracco FV et al., 1986] is given. The jet is no longer breaks as a whole. Jet surface from small droplets on the surface of the decomposition process starts and until it is completely broken down jet slowly erodes. The length of the break up, break up the surface (intact to the surface) and the jet break-up (core length) describing the length of the length of the end should be responsible for. The whole surface of the jet velocity goes down comparing increasing length resulting in rise of core length.

The increase in both the length scale at Reynolds numbers is difficult, and for this reason, several authors of the experimental results may be different from the rule that it must be pointed out. If it reaches zero, the whole surface of the atomization regime is reached. Spray cone progresses, and the jet nozzle, spray nozzle inside the cone to the apex of the bend is located immediately after the spraying begins. One of the core intact or fragments comprising at least liquid nozzle diameters downstream of the nozzle of a dense core still may be present. Spray the engine is related to the rule. The diameter of nozzle is so small for the droplets.. The decomposition process strongly usually unknown and chaotic nature of the nozzle hole, depending on the flow conditions, because the theoretical description of jet atomization in the break-up, more complex than any other system of governance. Experiments extremely high velocity, small size, and very dense spray is critical because of the validity of the models, it is difficult.
5.3 LIQUID DROPS - BREAK-UP REGIMES

Drops break-up which has spray droplet and the surrounding gas, the relative velocity between the fuel inspired by the aerodynamic forces (friction and pressure) is done. Aerodynamic forces, resulting in a volatile gas / liquid interface or the last decomposition and resulting in small droplets of the growing waves. The drop of more induced break up, relating to aerodynamics.

. On the other hand, tries to keep a spherical droplet surface tension force of the reaction force and deformation. The surface tension force in turn depends on the surface: a small droplet, the surface tension force and volatile droplet deformation and break-up leads to a large complex of relative velocity, is greater. The behavior of the gas phase by the Weber number,

\[ We_g = \left( \frac{\rho_g u_{rel}^2 d}{\sigma} \right) \quad [5.4] \]

1. vibrational break-up

2. bag break-up

3. bag / streamer break-up

4. stripping break-up

5. catastrophic break-up

Fig. 5.5. Drop break-up regimes

From the experimental investigation of the different droplet Weber number, depending on the break-up modes exist, which is also known. Figure 5.5 summarizes the break-up of the
system to drop. The published literature is that Weber numbers must be pointed out that the transitions are not compatible. Covering a range of 100 to 1000 for the Weber number Table 5.1 sub-regimes where additional high Weber numbers on the break-up methods is especially true, and the messy break-up is out Weg = 1000, the vibration mode of the droplet deformation does not lead to a break up $\approx 12$, Weg near the critical value Weber number is very low. Deformation due to drop a bag of a decomposition results in the bag to break up. There is a large drop in their loose, the rest of the bag, leading to distribution of bimodal size, breaks into small droplets. An additional jet bag-streamer regime appears. Boundary layer removes minute droplets are due to the constant pressure forces the stripping rule, the drop diameter decreases gradually. Distribution of size of bimodal droplet is the final result. The above break up has two phases at the same time because of the short-wavelength surface waves and stripped off to form small droplets are produced, a strong decline, large amplitude, and a large drop in production with a decomposition lead to the wavelength of the frequency of droplet.

Engine spray, all the break-up of the system is. Further downstream of the Weber number and the break-up due to the evaporation of the droplet diameter is significantly smaller, and because of a decrease in the relative velocity, the decomposition occurs close to nozzle at increased Weber numbers.

**Table 5.1. Transition Weber numbers - drop break-up regimes**

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<td>1. Vibrational</td>
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<td>2. Bag</td>
<td>$&lt; 20$</td>
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<td>$&lt; 18$</td>
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<td>3. Bag-jet (Bag-streamer)</td>
<td>$&lt; 50$</td>
<td>3. Bag-jet (Bag-streamer)</td>
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<td>4. Stripping</td>
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<td>5. Catastrophic</td>
<td>$&gt; 100$</td>
<td>5. Sheet stripping</td>
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5.4 MODELLING SPRAY FORMATION

To appropriately model spray formation, a number of physical processes must be taken into consideration. Separate sub-model accounts for most of these processes. Besides breakup such processes are evaporation, droplet drag and collision and coalescence of droplets. All these processes need a detail calculations for generally accepted models, hence a detail description is not given, only brief description on primary and secondary breakup is given.

Modeling of liquid breakup has undergone significant development in the past two decades, however most of these models utilize those approaches generally used in simulations. A good example for this is that droplets are generally tracked in a Lagrangian way in a gas flow field, which latter is treated by conservation equations forms, momentum and energy as well as turbulence in an Eulerian frame of reference.

Another general framework is represented by the Discrete Droplet Model (DDM). Since the typical number of droplets arising during a high pressure diesel injection is in the order of magnitude of 106–108, the registration and tracking of each and every individual droplet is not practical and not even necessary. Therefore, in the DDM approach the droplets are collected into parcels, and they have uniform properties (diameter, velocity, temperature etc.) within one parcel. A parcel behaves like one drop with the additional information on the number of identical droplets represented.
Hence, the calculation does not need to be performed for every single droplet; however, the diversity of droplets is still well represented by choosing an appropriate number of parcels (typically in the order of $10^4$).

The calculation of the parcel movement is done with a sub cycling procedure between the gas phase time steps taking into account the forces exerted on droplets in the parcels by the gas phase as well as the related heat and mass transfer. In an analogous way, the gas phase receives the forces resulting from spray movement as source terms in the subsequent gas time step.

A further approach that is used by most of the prevalent models is the rate approach [H. Zhau, J. Li, T. Ma, N. Ladommatos et al., 2002]. As it is described by equation 5.70, it describes the phenomenon of breakup through the velocity of loss of droplet radius, providing a widely used approach of breakup.

$$\frac{dr}{dt} = -\frac{r-a}{r}$$  \hspace{1cm} [5.5]
The sub models for breakup used in most CFD codes all aim at determining the value of stable radius $a$ and characteristic breakup time $\Gamma$ determining the breakup rate, and they mostly use all the above approaches as a framework for operation. The advancement is thus usually achieved through creating new models for determining the stable radius $a$ and characteristic breakup time $\Gamma$.

Fig. 5.7 The Wave model relates breakup to Kelvin-Helmholtz instability and product droplet size is proportional to surface wave length [6]

The early efforts of an oscillating and distorting droplet and a spring - mass system is based on the analogy between the Taylor analogy break up (TAB) to model. External force acting on the droplet is presented by aerodynamic forces, the spring force is related to the surface tension, and viscosity of the fluid damping force is getting force. Hence, as a reaction to the aerodynamic forces, the droplet starts to oscillate. As soon as the amplitude of this oscillation reaches a predefined level, the droplet disintegrates, i.e. breakup occurs.

A similar idea, based also on the elliptic deformation of the droplet, is reflected in the Dynamic Droplet Breakup (DDB) model, which tracks the motion of the mass centers of the half droplets. It is essentially a nonlinear formulation of the TAB model equations, and the time-consuming numerical integration seems not to have been offset by the increase in accuracy, since the model has not found wide acceptance.
The most commonly used single secondary breakup model was developed [H. Zhau, J. Li, T. Ma, N. Ladommatos et al., 2002] and is called Wave. This model is used for simulating the secondary breakup in the calculations presented in this paper; therefore its working principles are described here in more detail.

This model relates breakup to the Kelvin-Helmholtz instability.

The growth of an initial perturbation of a liquid surface is linked to the liquid Reynolds number as well as the gas Weber number and other physical and dynamic parameters (e.g. viscosity) related to the domain fluid and the injected fuel. The stable radius. Simulation of spray evolution in internal combustion engines is linked to the wavelength of the fastest growing surface wave according to equation [H. Zhau, J. Li, T. Ma, N. Ladommatos et al., 2002].

\[ a = C_1^\lambda \quad [5.6] \]

Where \( \lambda \) represents the wavelength of the fastest growing surface wave, and is defined in equation 5.72.

\[ \lambda = 9.02r \frac{(1+0.45Oh^{0.5})(1+0.4T^{0.7})}{(1+0.87We_g^{1.67})^{0.6}} \quad [5.7] \]

\[ T = Oh\sqrt{We_g} \quad [5.8] \]

The breakup time is calculated with a number of factors as defined in equation 5.9

\[ \tau = C_2 \frac{3.726}{\Omega} \quad [5.9] \]

where \( \Omega \) represents the growth rate of the fastest growing surface wave, and is defined in equation 5.10,

\[ \Omega = \left( \frac{\rho_l}{\sigma} \right)^{-0.5} \frac{0.34+0.38We_g^{1.5}}{(1+Oh)(1+1.4T^{0.6})} \quad [5.10] \]

and \( C_1 \) and \( C_2 \) are model constants.

When exposed to certain conditions (e.g. high relative ambient gas velocities), and the actual radius is larger than the stable radius under the circumstances considered, the droplets of a parcel
start ‘losing’ diameter as prescribed by equation 5.10. In the basic case, the mass shed from these droplets in each sub cycle is used to update the diameter of drops. This is done by calculating the new drop diameter from the rate of equation 5.10, according to the local conditions for stable diameter \( a \) and breakup time \( \Gamma \). Based on the updated radius, the total mass is converted into an increased number of droplets of identical diameter (within the same parcel). Hence, the mass in a parcel is always conserved (not considering evaporation, or child droplet productions described later), only the number of droplets contained changes according to droplet diameter.

Since the droplets lose diameter always only in proportion to the time passed since the last spray time step, the model does not deliver enough small droplets near the nozzle. Therefore, a so-called child production mechanism was inserted into Wave [H. Zha, J. Li, T. Ma, N. Ladommatos et al., 2002]. The basic idea of the child production mechanism is that a certain proportion of the shed mass immediately reaches a size (the stable diameter), i.e. does not ‘approach’ it incrementally according to the rate approach of equation 5.10. Since the basic idea of the DDM method is that a parcel contains droplets of identical properties, the droplets created in the framework of the child droplet mechanism, referred to as child droplets, are placed in a newly created parcel. The diameter of these child droplets is in most cases much smaller than the value reached by the parent droplets (the droplets from which the child droplets were created) in the same timeframe, which provides the necessary additional droplet surface for evaporation already in the vicinity of the injection nozzle.

The above models have been used – and are still widely used – to predict the entire spray breakup process. However, a disadvantage of all these models if used alone is that certain initial properties of the spray have to be provided by the user, or have to be assumed by the model based on practical or theoretical considerations. Such initial circumstances include the spray angle and droplet diameter at the nozzle orifice and the transition from a continuum liquid column to droplets that can subsequently be handled by secondary breakup models discussed above. The use of an appropriate separate primary breakup model facilitates the prediction of these initial quantities. The basic prerequisite necessary for this is to have information about the injector flow properties, which are regarded to play a key role in early spray properties, such as spray angle. The Diesel Breakup model, the primary breakup model used throughout this research uses a so-called nozzle file for this purpose.
The nozzle file is created in advance in a separate, 3 dimensional, time dependent multi-phase simulation of the flow in the injector nozzle, so at the beginning of the spray calculation all relevant data on the nozzle flow is available time and spatially resolved in the nozzle file. The subsequent, separate spray calculation uses this data source as an input for the breakup mechanism. Hence, all droplets initialized by the primary breakup model display the properties of the injected liquid, as calculated in the previous simulation. The use of an independent simulation and a separate nozzle file enables e.g. various combustion chamber geometries to be simulated using the same nozzle file without the need for repeating the injector nozzle calculation for each case. According to this approach the injected liquid is already tracked in the injector nozzle (this information is contained in the nozzle file). After leaving the injector nozzle it is treated by the primary breakup model, and after reaching certain predefined conditions (e.g. a predefined Weber number) the droplets are handed over to the secondary breakup model. All these droplets are treated by the secondary breakup model until a final stable diameter is reached, and no more breakups occur.

In the vicinity of the nozzle – where primary breakup occurs and hence the primary breakup model should be used – two different mechanisms result in breakup. One of them is a consequence of the turbulence of the flow of the liquid, while the other one is related to the aerodynamic forces acting on the droplet, as in case of secondary breakup. There is no general agreement in the literature as to which of these mechanisms dominates primary breakup, and it also depends on the topical circumstances of spray formation considered. Therefore, a basic idea of the Diesel Breakup model is to let these mechanisms compete in case of every breakup. Hence, for each parcel equation 5.10 is calculated by means of both mechanisms and the mechanism giving a higher breakup rate will govern breakup.

The aerodynamic mechanism is accounted for by the Wave model, just as in case of secondary breakup throughout this research. Turbulent breakup is calculated from the turbulence values of injected liquid (contained in the nozzle file), according to equations 5.11 and 5.12.

\[ a = C_3 C_\mu^{0.75} \frac{k^{1.5}}{\varepsilon} \quad [5.11] \]

\[ \tau = C_4 C_\mu \frac{k}{\varepsilon} \quad [5.12] \]
The formation of soot is suppressed during combustion as there is no fuel-rich zone which in turn results in non-luminous flame. Fig 5.8 shows the formation of thermal nitric oxides and suppressing of local temperatures are the results of high air excess ratio. Apart from diesel fuel and gasoline, alternate fuels can be used. For example, fuels like methanol, hydrogen and natural gas etc.

![Figure 5.8 Combustion of HCCI – reduction of NOx and soot](image)

### 5.5 HCCI CHEMISTRY

The final products of combustion are reaction of intermediates, the heat release, and auto ignition timing are determined by HCCI oxidation chemistry. Two–stage heat release is shown in diesel engines. these deviations are shown in Fig 5.9, combustion of Single stage and two-stage is performed by high octane number gasoline fuels.
NTC REGION:

Temperatures approx. 800 K and 1000 K, the fuel radicals shows two reactions

\[ R^* + O_2 \rightarrow alkene + HO_2^* \]  [5.13]

\[ HO_2^* + HO_2^* \rightarrow H_2O_2 + O_2 \]  [5.14]

an accumulation of \( \text{H}_2\text{O}_2 \), which is relatively inert as the temperature is below 1000 K.

Temperature increases due to compression, and above 900-1000 K the chain branching reaction

\[ HO_2 + M \rightarrow OH^* + OH^* + M \]  [5.15]
Fig. 5.10  Hydrogen ignition – Negative temperature coefficient a,b

Rapidly produce a large number of OH • radicals, and thus begins the second phase of the heat release process. The temperature of the fuel is free. The decomposition of H2O2 in the cylinder charge temperature (eg, higher compression ratio, the first phase of the ignition temperature of the intake exceeds the increased heat release) to reach out to make any engine parameter which will be at the beginning of combustion.

Oxidation of alkynes-High temperatures

Temperature above 900k, leads to break up molecules with long chains into short C1- and C2-hydrocarbons. First, alkyl radicals release due to H-atoms abstraction.

\[
RH + X^* \rightarrow R^* + HX \quad [5.16]
\]

X• represents radicals like H•, O•, OH• and HO2• [Flowers, D., Aceves, S., Martinez, R., Hessel, R. and Dibble, R. W et al., 2003]. The most important chain branching reaction responsible for the production of radicals during HTO (> 1100 K) is

\[
H^* + O_2 \rightarrow O^* + OH^* \quad [5.17]
\]

Thermal break-up is a resultant of abstraction of H-atom and high temperature.
\[ R^* \rightarrow R^{1\circ} + alkene \]  

[5.18a]

There is a break-up of alkyl radical R, O•, OH•, HO2•. splits alkenes. CnH2n.later decomposition may lead to radicles of CH3 and CH5, forming formaldehyde (CH2O).

Resulting in burning of C2 hydrocarbons. (C2H6, C2H5, C2H4, C2H3, C2H2).

The important reaction is

\[ CO + OH^* \rightarrow CO_2H^* \]  

[5.18b]

The temperature at which the reaction rate is significantly below 1100 or above, which is significantly lower than that of the conventional diesel HCCI - a process for increasing CO emissions, combustion temperature, partial oxidation Co. illustrates the process.

Diesel or diesel fuel is used as a two-stage ignition, like methane, gasoline, natural gas when there is absence of LTO, in which ignition time by direct compression of the critical temperature is reached depends on.

5.6 EXTENDED CHEMICAL MODELS:

There was a complexity in auto-ignition and combustion chemical kinetics. In the year 1970 the first decrease in auto-ignition delay time in one engine speed models were developed to predict. In 1980 there was a rapid growth in field of chemical kinetic models. However, hundreds of species of simple hydrocarbons such as butane is used, even if the reaction is to be modeled. Such as N-heptanes with high molecular weight in the case of fuel, there is more complexity in modeling. Overcoming this defect, detail, using chemical methods, several methods reported. Few authors explained the zones relating to CFD models, other multi-use zone ones. At the time of ignition and combustion of the fuel or EGR models originally designed for the analysis of the effect is very useful. However, the relevant chemistry, three-dimensional turbulence in homogeneities within a certain consideration and a detailed description of the combustion chamber, the HCCI combustion process is a fundamental importance. However, CFD is time consuming, expensive and cannot be applied practically results in a mixture of chemistry. From this point of view, the best solution is CFD with reduced chemical models.
Reduced models of chemical ignition time, fuel consumption, temperature, pressure and heat release as the main features of the calculations necessary to conduct reactions which are crucial. [Li H, Miller DL, Cernansky NP et al., 1996] a kinetic model is developed for primary reference fuel (PRF) has been minimized ... The model includes 29 reactions and 20 active species. Auto Ignition [Zhang et al., 2005] clamping simulations of ignition heat release, ignition timing and pressure of the first phase of the experimental data agree with. The HCCI combustion process, he successfully expanded the model. The new model consists of reactions numbered 69 and active species numbered 45, the low, intermediate of Chemistry, and is associated with high temperature areas. CFD modeling of the engine behind the background is explained in the next chapter.

5.7 VALVES

Poppet valve is used commonly. This has a mushroom shape and also a direct cylinder rod. The uses of this valve are easy lubricant, good seat, cheaper, good flow properties, and the cylinder head is a good heat transfer. And a rotary disc valve is sometimes used, but the poppet valve is the opposite, the heat transfer, lubrication, and clearance is a problem. Another one is valve sleeve. It is a poppet valve has some advantages, but the disadvantages of using it. Use the sleeve valve best suited for gas turbine engines, aerospace engines were first introduced. Sleeve valve poppet valve associated with the benefits of the hot spot was removed.

5.8 ENGINE PERFORMANCE AND EMISSIONS – VALVE EVENTS

INTAKE VALVE OPENING TIMING-IVO AND ITS EFFECTS:

The outlet present in the intake valve permits fuel/air mixture to get into the cylinder through the intake manifold. Intake valve allows only air into the cylinder in direct injection engines. The second parameter is the timing of IVO which defines the overlapping of valves and also considers the dormant factor, along with timings of given engine. Intake valve opening before TDC may lead to exhaustion of gases into intake main fold instead of exhaust valve. The exhaust recirculation at full load will be determined and goes up space, or else the engine can take up a fresh charge. So, depending on part load conditions an addition of EGR will be
beneficial from improvisation of efficiency and reduction in exhaust pollutants. In the next phase intake valve opening can stop the inlet of air/fuel towards the manifold leading to in-cylinder pressure to decrease as the piston starts letting after TDC, resulting in EGR. The opening of exhaust valve leads to drawing back gases into cylinder, as the same process explained above. The closure of exhaust valve the delaying of IVO may not be significant, because it is not directly influenced by the amount of fresh charge present in the cylinder. The timing of typical IVO is near about 0-10 degrees before TDC which leads in overlapping of valve which is fairly symmetrical. to avoid internal EGR the timing is obviously set by full load optimization.

**INTAKE VALVE CLOSING TIME –IVC-EFFECTS:**

The engines volumetric efficiency is mostly based on the timing of IVC in the given speed. The engine performance and economy driven by IVC is trapped in the cylinder is affected by the amount of fresh charge. Intake valve fresh fuel-air mixture consisting in cylinder for a large group together to achieve maximum torque is must stop at a certain time. Airflow into the cylinder by pressure waves in the intake system. This process is executed after BDC. This leads to change in the optimum IVC timings with speed of engine. To attain maximum gain from the intake pressure waves, the timings of IVC are moved further after BDC. The torque results are obtained by closure of intake valve either before or after optimal timing. The air in the cylinder is flown back into the intake main fold when there is a late intake closing, whereas early intake closing works in opposite way. In either case the efficiency of the load can be advanced. The IVC’s typical timing ranges from 50-60 degrees after BDC, resulting high and low speed requirements.

**EXHAUST VALVE OPENING TIMING –EVO-EFFECTS :**

The opening of exhaust valve causes the pressure in the cylinder due combustion which leads to escape of gas into that particular exhaust system. The exhaust valve should not be opened till the piston reaches Bottom Dead Centre (BDO) because the extraction of maximum amount of work from the gas cylinder cannot be executed. There is even a chance of dropping of
pressure levels in the cylinder to the lowest possible value that is back pressure exhaustion even before there is a raise in piston. Thus there is a reduction in the working capability of a piston, even before taking in the fresh charge. The two requirements needed are,

1. EVO requirement after BDC
2. EVO requirement before BDC.

The timings of EVO is an adjustment between the work essential to piston raise and the works lost by letting the combusted gas to release before it is completely expanded, while the pressure in the cylinder is higher than the exhaust back-pressure, the lifting of valve is slowly done from its seat using conventional valve train leading to a powerful flow restriction .In this process EVO timing ranges from 50-60 degrees before BDC in a production engine. The gases pressure inside the cylinder and engine speed and load get optimized by the ideal timings of EVO. As the movement of EVO and BDC comes closer the pressure in the cylinder comes more closer to that of exhaust back pressure, which in turn takes less time to move from the valve. An earlier EVO requirement is needed why because the time taken by the cylinder pressure tends to decrease to the exhaust back pressure.

**EXHAUST VALVE CLOSING TIME –EVO-EFFECTS:**

The amount of exhaust gas left in the cylinder at the beginning of intake stroke of an engine is very crucial for the timing of EVC. Along with above considerations EVC also defines the valve overlap, which shows effect cylinder contents occurring in the intake stroke. The less quantity relating to exhaust gas is needed to allow maximum volumes of fuel and fresh air entering during the intake stroke. The above process is applicable for full load operation. There will be the requirement of EVC after TDC. The EVC timings influence the conditions like exhaustion of the pressure waves to bring out gas in the cylinder or driving gas back to the cylinder. This is applicable when exhaust system is in a active mode. The pressure wave timings changes along with the speed of engine, so setting of constant EVC timings is essential for one speed and liable to others. Some of the exhaust gas in the cylinder to maintain the load operation as a part of the fresh fuel and air intake will reduce the capacity of the cylinder. The need to prevent the intake throttle plate, the cylinder is retained in the exhaust gases are reduced by reducing the pumping capacity. The EVC timing can be further moved after the increase in TDC
of internal EGR which reduces exhaust emissions. EGR tolerance of a cylinder has a limit before combustion, but lowers due to engine load to reduce charge density.

There is no stability in the process as the EGR levels increases leading to slow rate of combustion. When there is a constant ratio of oxygen to fuel, the proportion of cylinder contents is reduced by EGR. Combustion in stability is caused by reduction of inert cylinder contents. The range of EVC timings are from 5-15 degrees after TDC. The elimination of internal EGR is affected by these timings which in turn affect full load performance.