computation of Net Heat Release Rate analysis is the combustion pressure – crank angle history in the combustion chamber.

CHAPTER - III

COMBUSTION HEAT RELEASE RATE CALCULATIONS
CHAPTER-III

HEAT RELEASE RATE CALCULATIONS

Pressure crank angle history is obtained from the engine data logger for the defined engine load. After obtaining data from the combustion cycle, net heat release rate is calculated based on the first law of thermodynamics. Heat transfer from the gases to cylinder is computed, and deducted from the gross heat release rate to arrive at net heat release rate and presented in the form of graph. The computed Heat Release Rate (NHRR and CHRR) profiles are shown in figures 3.2 and 3.3, for the recorded pressure data of the engine cylinder in figures 3.1.

When analyzing internal combustion engine, the in-cylinder pressure has always been an important experimental diagnostic due to its direct relation to the combustion and work producing processes. The in-cylinder pressure reflects the combustion process involving piston work produced by the gas (due to changes in cylinder volume), heat transfer to the combustion chamber walls as well as mass flow in and out of crevice regions between the piston, piston rings and cylinder liner. Thus, for accurate results it is required to know how the combustion process propagates through combustion chamber and each of these processes must be related to cylinder pressure Richard stone [1999], Heywood [1988], so the combustion process can be distinguished. Reduction of an effective change in volume, heat transfer and mass loss at the cylinder pressure is called heat release analysis and is done within the framework of the first law of thermodynamics, when the intake and exhaust valves are closed, i.e. during the closed part of engine cycle. The simplest approach is to consider cylinder contents as a single zone, whose thermodynamic state and properties are modeled, being uniform throughout the cylinder and represented by the average values. As no spatial variations are considered, so the model is said to be zero-dimensional. Models for the heat transfer and crevice effects can be easily included to analyze. Krieger R. B., Borman have contributed a lot to develop the Heat release rate models for the I C engines.

3.1 Heat release based on 1st Law of thermodynamics

On the basis of first law of thermodynamics the heat release model is:
\[
\frac{dQ_n}{d\theta} = \gamma p \frac{dV}{d\theta} + \frac{1}{\gamma - 1} V \frac{dp}{d\theta}, \quad \text{where} \quad \frac{C_p}{C_v} = \gamma, R = C_p - C_v
\]

The gas temperature can be found from the equation of state \((pV = mRT)\), since the pressure and volume are known, and it has been assumed mass is constant. The gas properties vary with temperature, but the variation is modest, it is acceptable in most cases to evaluate the properties at the gas temperature computed in the previous increment. Equations below can be used to evaluate the properties \(u\) and \(R\), from which \(\gamma\) can be evaluated. Once the gas temperature has been evaluated, it is possible to estimate the rate of heat transfer, by assuming wall temperature and employing a heat transfer correlation.

An approach adopted by Krieger and Borman [1966] is used in this work. They provided polynomial coefficients from the curve fit to combustion problem calculations for weak mixtures \((\phi \leq 1)\) of \(C_nH_{2n}\) with air.

\[
u = K_1(T) - K_2(T)\phi k J/kg\text{ of original air}, \quad \text{Where}
\]

\[
K_1 = 0.692T + 39.17 \times 10^{-6} T^2 + 52.9 \times 10^{-9} T^3 - 228.62 \times 10^{-13} T^4 + 277.58 \times 10^{-17} T^5
\]

\[
K_2 = 3049.33 - 5.7 \times 10^{-2} T - 9.5 \times 10^{-5} T^2 + 21.53 \times 10^{-9} T^3 - 200.26 \times 10^{-14} T^4
\]

With gas constant given by: \(R = 0.287 + 0.020\phi k J/kg\text{ of original air}/K\)

### 3.2 In cylinder heat transfer

This model incorporates all the processes taking place in the cylinder for heat transfer calculations, i.e. in-cylinder air motion, fuel spray development and mixing, sprays impingement on the walls, turbulence, droplets evaporation, fuel ignition delay and combustion process.

\(T =\text{insananeous bulk gas temperature (K)}, T_s =\text{mean surface temperature (K)}\)

\(A_s =\text{insananeous surface area (m}^2)\), \(Q_s =\text{Insananeous heat flow rate (W)}\)

Annand and Ma [1971] have developed the following equation for heat transfer:

\[
\frac{Q_s}{A_s} = c\left(\frac{k}{B}\right)^{b} (T - T_s) + d(T^4 - T_s^4)
\]

\(k = \text{thermal conductivity, } B = \text{Bore diameter, } k \alpha T^{0.75}\)
And for a compression ignition engine Watson and Janota 1982 suggested that

\[ b = 0.7, \quad 0.25 < c < 0.8, \quad d = 0.576\sigma \], where \( \sigma = \text{Stefan-Boltzmann constant} \)

The obtained graphs for the net heat release and cumulative heat release rates have been envisaged in figures 3.2 and 3.3. The values have been calculated from the real time combustion pressures logged by Pressure - crank angle data logger using excel chart.

![Graph](image1)

**Fig.3.1** Input pressure data signatures drawn at different loads in limited range of 0° to 720° crank angle with 90% BD(COME) + 10% Triacetin blend fuel run
3.3 Summary

The computed Heat Release Rates (NHRR and CHRR) profiles are drawn for the recorded pressure data of the engine cylinder with respect to crank angle. The other graphs drawn are shown in results and appendix for the experiments conducted with diesel, biodiesel and triacetin additive -COME blends as fuel.

The following chapter (Chapter-IV) deals with experimental set up and experimentation. A laboratory based direct injection diesel engine is used to test triacetin additive - COME biodiesel blends at various percentages by volume.