Determination of Availability Balance of Ci Engine Fuelled With Biodiesel-A Review

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***Abstract*-Study and analysis of engine cylinder availability is an important scientific objective. This is because energy analysis (first law) gives the information of quantity of energy only while analysis of engine operations according to second law of thermodynamics gives the detail about the quality of energy. Thus along with the first law analysis, availability analysis is necessity of most of the current research's. This paper surveys the publication available in open literature concerning diesel engine engine simulation and availability analysis. Most of the attention is concentrated on the papers that follow the filling and emptying approach. An overviewe is taken covering the details of modelling approaches, engine parameter studied, software used and results of every research. The limitations and future scope from all the research is summarise at the end of this paper.**

***Keywords*- Biodiesel, CI Engine, Simulation, Availability**

I.INTRODUCTION

In the present civilization the use of energy resources has increased tremendously. Fast depleting fossil fuel reserves have inevitably gathered the attention of one and all to think and devise for optimum energy utilization. In order to optimally use energy, the efforts are required for identification and elimination of the sources of inefficiency during its use, which obviously requires in depth study and analysis. A look into the laws of thermodynamics shows that the first law of thermodynamics bases upon the series of experiments done by James Joules, demonstrating the bidirectional numerical equivalence of converting work into heat while second law of thermodynamics exhibits a unidirectional equivalence between work and heat, i.e. for a given amount of heat the equivalent amount of work cannot be obtained whereas vice-a-versa may be there. Thus, the concept of quality of energy came into existence and work is considered as high grade of energy and heat as low grade of energy.

Internal combustion engine simulation modelling has long been established as an effective tool for studying engine performance and contributing to evaluation and new developments. Thermodynamic models of the real engine cycle have served as effective tools for complete analysis of engine performance and sensitivity to various operating parameters On the other hand, it has long been understood that traditional first-law analysis, which is needed for modelling the engine processes, often fails to give the engineer the best insight into the engine's operation. In order to analyze engine performance that is, evaluate the inefficiencies associated with the various processes second-law analysis must be applied. For second-law analysis, the key concept is 'availability' (or exergy). The availability content of a material

represents its potential to do useful work. Unlike energy, availability can be destroyed which is a result of such phenomena as combustion, friction, mixing and throttling. The relationships needed to evaluate availability content. The destruction of availability often termed irreversibility is the source for the defective exploitation of fuel into useful mechanical work in a compression ignition engine. The reduction of irreversibilities can lead to better engine performance through a more efficient exploitation of fuel. To reduce the irreversibilities, we need to quantify them. That is we need to evaluate the availability destructions-we need the second-law analysis.

Objectives of availability analysis of internal combustion engines are:

- To weigh the various processes and devices, calculating the ability of each one of these to produce work.
- To identify those processes in which destruction or loss of availability occurs and to detect the sources for these destructions.
- To quantify the various losses and destructions.
- To analyze the effect of various design and thermodynamic parameters on the exergy destruction and losses.
- To propose measures/techniques for the minimization of destruction and losses, to increase overall efficiency.
- To propose methods for exploitation of losses most notably exhaust gas to ambient and heat transfer to cylinder walls now lost or ignored.

Mathematical modelling is the most suitable and traditional way to perform first law and availability analysis. Mathematical modelling can be defined as process of describing the physical phenomena in a particular system with the help of mathematical equations.

For the process that governs engine performance and emission, two types of models have been developed. These can be categorized as
1)Thermodynamic model 2) fluid dynamic model

This classification is depends on the nature that is whether the equation which gives the model its predominant structure are based on energy conservation or on a full analysis of the fluid motion. So the energy analysis is mainly done with the thermodynamic models. These thermodynamic models are further classified on the basis of dimensional consideration this models are grouped as follows

- Zero dimension models
- Two dimension model
- Multi dimensional models

In the above classification, although the level of detail and proximity to physical reality increases as one precedes downward, so does the complexity of creating and using those models.

Zero dimensional models are the simplest and most suitable to observe the effects of empirical variations in the engine operating parameters on overall heat release rates cylinder pressure schedules. These models are zero dimensional in the sense that they do not involve any consideration of the flow field dimensions.

Zero dimensional models are further sub-divided into:

1. Single zone models
2. Two zone models
3. Multi-zone models

In single zone models, the working fluid in the engine is assumed to be a thermodynamic system, which undergoes energy and/or mass exchange with the surroundings and the energy released during the combustion process is obtained by applying the first law of thermodynamics to the system.

Above modelling technique have been traditionally used in two different directions.

1)In these models have been used to predict the in-cylinder pressure as a function of crank angle from an assumed energy release or mass burned profile (as a function of crank angle).

2) Another use of these models lies in determining the energy release/mass burning rate as a function of crank angle from experimentally obtained in-cylinder pressure data**.**

2.LITERATURE REVIEW

Numerous scholars have done the work for engine modelling and availability analysis. Here is the overview of some them.

2.1 C.D. Rakopoulos, E.G. Giakoumis(2006): presented a detailed study for the second law analysis on the internal combustion engine operation. Zero dimensional single zone models had been used for this study. Equations like equation for state properties and conservation of energy were used for energy analysis with data obtained from the first law analysis the exergy balance was carried out. For exergy balance general availability balance equation was applied to engine cylinder and it was explained in reference with crank angle. Along with the engine cylinder the availability of engine subsystems like turbocharger, intercooler, aftercooler, inlet manifold and outlet manifold was calculated.

They also reviewed research of various authors who had studied the effect of engine parameter on the availability balance such as crank angle, injection timing, combustion duration, fuel air ratio, engine speed, engine load, compression ratio etc.

It was observed that all the parameter which increase the level of pressure and temperature in the cylinder i.e. fuel air equivalent ratio, compression ratio, cylinder wall insulation, increased turbocharging leads to reduction in combustion irreversibilities, but the reduction in availability destruction cannot always be realized as an increase in brake power. On the contrary, it is unfortunately transformed into an increase in the heat transfer to the cylinder walls or increase in the exhaust gas availability.[1]

2.2 B.Rajendra Prasath, P.Tamilporai, and Mohd.F.Shabir (2010): Simulation of the combustion and performance characteristics of biodiesel fuel indirect injection (D.I) low heat rejection (LHR) diesel engine was carried out. Comprehensive analysis of combustion characteristics such as cylinder pressure, cylinder peak pressure, ignition delay, heat release rate and performance characteristics such as specific fuel consumption, brake thermal efficiency is carried out. The engine simulation was develop and modified for both diesel and biodiesel. On the basis of first law of thermodynamics the properties at each degree crank angle was calculated. Method for preparation of biodiesel and the important correlation for the thermodynamic property measurement was presented. Preparation and reaction rate model was used to calculate the instantaneous heat release rate. To calculate preparation rate Whitehouse-Way model was used. A gas-wall heat transfer calculations are based on the ANNAND's combined heat transfer model with instantaneous wall temperature to analyze the effect of coating on heat transfer. The simulated results are validated by conducting the experiments on the test engine under identical operating condition on a turbocharged D.I diesel engine. In this analysis 20% of biodiesel (derived from Jatropha oil) blended with diesel and used in both conventional and LHR engine. The simulated combustion and performance characteristics results are found satisfactory with the experimental value. [2]

2.3 C.N.Michos, E.G.Giakoumis, C.D.Rokopolus (2008): exetended their previously developed validated zero-dimensional, multi-zone, thermodynamic combustion model for the prediction engine performance and nitric oxide (NO) emissions to include second-law analysis. The main characteristic of the model is the division of the burned gas into several distinct zones, in order to account for the temperature and chemical species stratification developed in the burned gas during combustion. Within the framework of the multi-zone model, the various availability components constituting the total availability of each of the multiple zones of the simulation were identified and calculated separately. The model was applied to a multicylinder, four-stroke, turbocharged and aftercooled, natural gas (NG) SI gas engine running on synthesis gas (syngas) fuel. The major part of the unburned mixture availability consists of the chemical contribution, ranging from 98% at the inlet valve closing (IVC) event to 83% at the ignition timing of the total availability for the 100% load case, which is due to the presence of the combustible fuel. [3]

2.4 M.A. Scott, D.C. Kyritsis, E.G. Giakoumis, C.D. Rakopoulos(2008): studied computational investigation pursued for the case of mixtures of hydrogen and natural gas combusting in a diesel engine cylinder. The terms of the availability balance during engine operation were studied as a function of hydrogen content of the fuel and the operating parameters of the engine. Of particular importance was the confirmation of results provided in earlier work by the authors that combustion irreversibilites during hydrogen combustion could be drastically reduced. A single-zone computational model of the engine operation was used and the hypothesis of chemical equilibrium was invoked for combustion calculations. For the description of engine processes, such as fuel preparation and heat transfer, computational models established for hydrocarbon fuels were used so that a comparison was performed under the assumption that hydrogen combustion would be feasible in conditions that do not depart exceedingly from engine configurations.[4]

*2.5 Perihan Sekmen, Zeki Yılbasi(2011):*presented the paper on application of exergy and energy analysis using biodiesel as fuel. In the study, the first and second Laws of thermodynamics were employed to analyze the quantity and quality of energy in a four-cylinder, direct injection diesel engine using petroleum diesel fuel and biodiesel fuel. The experimental data were collected using steady-state tests which enable accurate measurements of air, fuel and cooling water flow rates, engine load, and all the relevant temperatures. Balances of energy and exergy rates for the engine were determined and then various performance parameters and energy and exergy efficiencies were calculated for each fuel operation and compared with each other. The results of tested biodiesel offer similar energetic performance as petroleum diesel fuel. In addition to this, the exergetic performance parameters usually follow similar trends according to the energetic performance parameters.[5]

2.6 Lukas Lansky(2008.**):**did the modelling and the control processes in the cylinder of the diesel engine In the first part the detailed description of a Matlab-Simulink model of a cylinder was given. That includes the description of cylinders thermodynamics, geometry and mass flows, Combustion process and engine performance. The second part was focused on a design of a controller for the control of engines output torque. Several appropriate PI controllers and H controller are suggested. The behaviour of the closes-loop is then compared. This model allows to simulate the cylinder pressure and temperature development in crank-angle domain. The observation and control of engine performance parameters is also possible. The validation was done through the output torque (maximum error is less than 4%) and the air/fuel ratio (maximum error is less than 15%). Although there were many simplifications in the modelling of the diesel engine processes the model gives satisfactory results. The torque control problem was defined and several controllers were suggested and designed. The performance of PI and H∞ controllers was compared with non-linear Simulink model.[6]

2.7 Vivek Kumar Gaba, Prerana Nashine and Shubhankar Bhowmick(2012): developed a combustion model for a diesel compression ignition (CI) engine for constant pressure combustion process. The work analytically examines the performance of a CI engine with the minimum use of diesel fuel as pilot fuel, and bio-diesel as secondary fuel. The combustion model has been developed for an ideal diesel engine using blends of biodiesel ranging from 20% to 100%. Using the first law of thermodynamics and equation of state in each process, the cycle was critically analyzed. The specification of a standard CI engine was used for numerical calculations. The variation of temperature with different equivalence ratio were studied and reported. The thermal efficiency of a pure diesel engine was observed to decrease exponentially from 67% to 47% as the equivalence ratio increases from 0.7 to 1.3. It was also observed that B-20 and B-40 formed a good mixture among all other blends and the efficiency of pure bio-diesel was comparatively less than diesel as well as for other blends.

A sharp increase in work output was observed as the equivalence ratio increases due to more fuel injection. It was also observed that efficiency of pure bio-diesel is comparatively lesser than all other blends, but the maximum cycle temperature for this blend is least. This indicates that NOx emission was not present in case of pure diesel; hence pure biodiesel can be used resulting in less pollution despite of less efficiency & work output.[7]

*2.8 Slobodan J. Popovic, Miroljub V. Tomic ():*presented novel method for obtaining information about combustion process in individual cylinders of a multi-cylinder Spark Ignition Engine based on instantaneous crankshaft angular velocity was presented. The method was based on robust box constrained Levenberg-Marquardt minimization of nonlinear Least Squares given for measured and simulated instantaneous crankshaft angular speed which was determined from the solution of the engine dynamics torque balance equation. Combination of in-house developed comprehensive Zero-Dimensional Two-Zone SI engine combustion model and analytical friction loss model in angular domain was applied to provide sensitivity and error analysis regarding Wiebe combustion model parameters, heat transfer coefficient and compression ratio. The analysis was employed to evaluate the basic starting assumption[8].

*2.9 C.D. Rakopoulos, E.G. Giakoumis():*has developed the analysis to study the energy and availability performance of a turbocharged diesel engine, operating under transient load condition. The model was incorporated with many features for simulation of transient operation, such as detailed analysis of mechanical friction, separate consideration for the processes of each cylinder during a cycle and mathematical modelling of pump. The model had been validated against experimental data taken from diesel engine. The author used the models (equation) of various authors for separate process such as rate of burning, heat loss to the cylinder walls, Friction inside the cylinder etc. In this work the dynamic analysis of engine and its subsystem was also carried out. The availability terms for the diesel engine and its subsystems were analyzed, i.e. cylinder for both the open and closed parts of the cycle, inlet and exhaust manifolds, turbocharger and aftercooler. In particular the irreversibilities term, which was absent from any analysis based solely on the first-law of thermodynamics, was given in detail as regards transient response as well as the rate and cumulative terms during a cycle, revealing the magnitude of contribution of all the subsystems to the total availability destruction.[9]

2.10 C. Sayin, M. Hosoz, M. Canakci and I. Kilicaslan(): presented comparative energy and exergy analyses of a four-cylinder, four-stroke spark-ignition engine using gasoline fuels of three different research octane numbers (RONs), namely 91, 93 and 95.3. Each fuel test was performed by varying the engine speed between 1200 and 2400 rpm while keeping the engine torque at 20 and 40 Nm. Then, using the steady-state data along with energy and exergy rate balance equations, various performance parameters of the engine were evaluated for each fuel case. It was found that the gasoline of 91-RON, the design octane rating of the test engine, yielded better energetic and exergetic performance, while the exergetic performance parameters were slightly lower than the corresponding energetic ones. Furthermore, this study revealed that the combustion was the most important contributor to the system inefficiency, and almost all performance parameters increased with increasing engine speed.[10]

2.11 A.K. Amjad, R. Khoshbakhi Saray, S.M.S. Mahmoudi, A. Rahimi. ():The aim of research was to investigate the exergy analysis of HCCI combustion when a blended fuel, which consists of n-heptane and natural gas. In order to accomplish this task, a single-zone combustion model had been developed, which performs combustion computations using a complete chemical kinetics mechanism. The study was carried out with different percentages of natural gas in blended fuels and EGR (exhaust gas recirculation) ranging from about 45 to 85 percent and 0 to 40 percent, respectively. The results reveal that, when mass percentage of natural gas increases, exergy destruction is decreased increasing the second-law efficiency. Introducing EGR into the intake charge of dual fuel HCCI engine up to some stage (optimum value) enhances the second-law performance of the engine in spite of a reduction in work.[11]

*2.12 Saleel Ismail, Pramod S. Mehta():*presented the estimation of irreversibilities associated with various sub-processes occurring during combustion in a hydrogen fueled spark ignition engine. A quasi-three zone phenomenological combustion model was used for predicting the pressure and temperature histories of a single cylinder, four stroke spark ignition engine operating at equivalence ratios of 0.3- 0.75 in the speed range 1500-3500 rpm. For each sub-process, the history of availability destruction during combustion and the effects of operating conditions were discussed. Measures were proposed for improving the exergetic efficiency by mitigating availability destruction. It was observed that chemical reaction is the major contributor to irreversibility generation, followed by pressure equilibration and heat loss to walls. While more than 94% of the fuel supplied undergoes combustion, nearly 20-30% of the reactant availability was destroyed. Charge preheating, product mixing and piston motion were observed to have negligible effects on irreversibility generation. [12]

3. THE FUTURE SCOPE

In concern with the availability analysis all the above researchers considered the term mechanical availability only the chemical availability was not considered so there is lot scope in future to do the analysis with consideration of chemical availability.

Simulation and modelling for exhaust gas analysis that is analysis of soot formation and NO_x
And particulate matter Can be the area for more research.

4. THE CONCLUSION

The modelling results shows that, with increase in speed the peak pressure, peak temperature and brake thermal efficiency increases and decreases the specific fuel consumption. engine operated with diesel shows better performance than biodiesel operation but not up to the extent of lower level.

From most of the availability analysis it is concluded that unfortunately the decrease is availability destruction cannot be the increase in the brake power On the contrary, it is usually transformed into an increase in the heat transfer to the cylinder walls and/or increase in the exhaust gases availability. The recovery of these energy streams that are now usually ignored (e.g. through the use of heat recovery devices or bottoming cycles), is an important subject whose exploitation needs to be established and implemented. At the moment, the heat transfer from the hot cylinder walls to the cooling water, being at a very low temperature, destroys the greatest part of this available energy.

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