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Heat energy balance of a single cylinder variable compression ratio diesel engine operating on alternative fuels

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ABSTRACT

Nowadays, biodiesel is considered the most promising alternative fuel by the researchers due to its comparable properties with diesel fuel and also other socio-economic and environmental benefits .The investigation was conducted on a single cylinder four stroke variable compression ratio diesel engine fuelled with pure diesel, B10% (5% Methanol+ 5% Rice bran oil + 90% Diesel), 20% (5% Methanol+15% Rice bran oil +80% Diesel) and 30% (5% Methanol+25% Rice bran oil+ 70% Diesel) at different loads, at different compression ratios and at different injection pressures. The water heat loss, exhaust heat loss and unaccounted heat loss decreased with the increase of biodiesel percentage in the blends. The heat balance was in respect of useful work (HBP), heat lost through cylinder jacket water (HJW), heat lost through exhaust gasses (HGas), heat carried away by the lubricating oil and other losses (Hrad). This research work provides an in-depth analysis of the engine heat losses in different subsystems of the engine. Finally, heat energy balancing of the engine has been done by showing all energy flows in and out of the engine.

1.Introduction

Abbreviations:
HBP: Heat energy of brake power.
HJW:Heat lost through cylinder jacket water.
HGas: Heat lost through exhaust gasses.
Hrad: Heat carried away by the lubricating oil and other losses.

It is basically an analysis of the first law of thermodynamics which is also known as energy balance or heat balance. Alcohols have continued to receive worldwide attention as alternative fuels in spite of surpluses in crude oil. Methanol has been targeted as the fuel of the future on the basis of its low cost of production, while support for the use of ethanol has increased in recent years, in the wake of anti-pollution regulations, owing to its anti-knock properties and higher miscibility with gasoline as compared to methanol. In the long term, as the world's crude oil supplies cease to meet global consumption, it is likely that engines running on pure alcohol will become more viable. In the short term, particularly in those countries vulnerable to a shortage in crude oil supplies, contingency plans in the form of alternative liquid fuels to meet the needs of their transport and agricultural sectors are necessary. The extension of diesel fuel supplies is therefore, of particular concern. The use of ethanol in a compression-ignition engine has, therefore, received considerable attention with particular emphasis on adapting the fuel to meet the requirements of the engine. The preliminary steps of measuring engine performance and conducting limited durability tests have been performed by a number of researchers [1-3]. Hansen et al. [4-5] investigated the combustion of ethanol and blends of ethanol with diesel fuel with the aid of a heat release model. They observed that the effects of adding ethanol to diesel fuel were increased ignition delay, increased rates of premixed combustion, increased thermal efficiency and reduced exhaust smoke. Czerwinski [5] used a rapeseed oil, ethanol and diesel fuel blend and compared the heat release curves with diesel fuel. [6]Thermal balancing has been done by using different alternative fuels such as H2-gasoline [7], alcohol-diesel [8]. Biodiesels such as soybean, yellow grease also have been used for thermal balancing [9]. They have reported that all the heat losses except exhaust heat loss were higher while using biodiesels rather than diesel fuel. [10-]T.Lakshman had its research on Pongamia and Neem oil as biodiesel in IC engine and measured its parameters.[11] M.J.Abedin did work on a single cylinder diesel engine and experimentally proved the importance of acetylene, how it reduce the emissions of an IC engine.

2. Materials & Methods

In this research work the fuels used were conventional diesel fuel, rice bran oil biodiesel and methanol. Fuel properties such as density, viscosity, net heating value, flash point and fire point of rice bran oil biodiesel and methanol are determined in the laboratory as shown in the table 1.

Table 1. Properties of diesel, rice bran oil biodiesel and methanol

Property parameters	DDiesel Fuel	Rice Bran Oil Biodiesel	Methanol
Density at 20^0 C (g/cm^3)	00.82	0.96	0.78
Viscosityat 40^0C (mm^2/s)	33.4	4.56	1.35
Flash Point ^{0}C	557	160	21
Fire Point ^{0}C	660	175	25
Calorific value (KJ/kg)	443,500	39,800	28,700

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2.1 Research engine test setup

Experimental set up used for this research work consists of a single cylinder, four strokes, and variable compression ratio diesel engine. The detailed specifications of the engine used as shown in Table 2. Windows based Software Package ''Engine soft'' was taken for on line performance evaluation. Figure: 1 shows the schematic diagram of engine test rig.

Table 2. Specifications of VCR diesel engine.

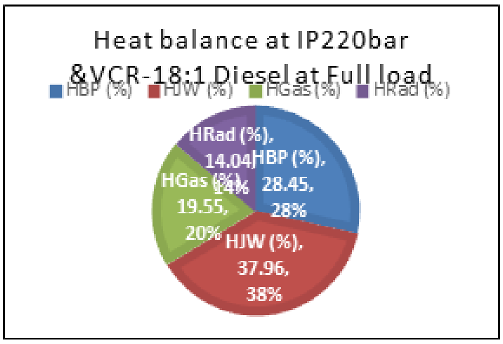
Make	Kirloskar Model AVL
No of strokes per cycle	04
No of Cylinders	01
Combustion chamber position	Vertical
Cooling Method	Water cooled
Starting Method	Cold Start
Ignition Technique	Compression Ignition
Stroke Length (L)	110 mm
Bore Diameter (D)	87.5 mm
Rated Speed	1500 r.p.m.
Rated Power	3.5 KW
Compression ratio	12:1 To18:1

Experimental work was conducted at different loads (20%, 40%, 60%, 80% and 100%) on the engine with the diesel fuel at different variable compression ratios (VCR-18:1, VCR-16:1 & VCR-14:1) and also at different injection pressures (IP 220 bar, IP 200 bar& IP 180 bar). In the same manner the test was conducted with the blend of 90% diesel and B10%(5% biodiesel and 5% methanol), blend of 80%diesel B20% (15%biodiesel and 5% methanol), and 70%diesel B30%(25%biodiesel and 5% methanol). The heat balance was drawn in respect of useful work, heat lost to cooling water, heat lost through exhaust, heat carried away by the lubricating oil and other losses.

Fig 1. Schematic diagram of engine test rig.

3. Results and Discussions

Experimental results obtained from the research work heat utilized to brake power (HBP), heat loss through cylinder jacket water (HJW), heat loss through exhaust gasses (HGas) and heat loss through radiation (HRad) were demonstrated with the help of graphs.



The heat balance chart (HBC) at full load of diesel fuel at 220 bar IP and VCR 18:1 is shown in the figure 2.

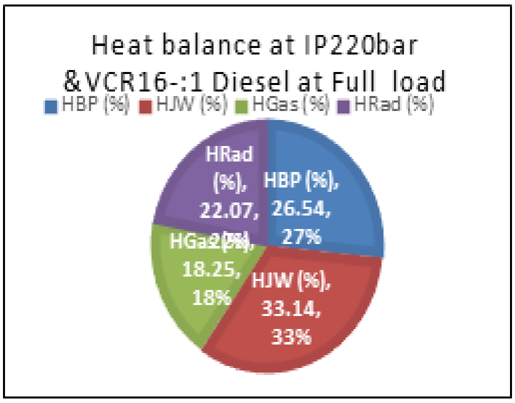


Fig 2. HBC of diesel at 220 bar IP & at VCR18:1.

The HBC at full load of diesel fuel at 220 bar (IP) and VCR 16:1 is shown in the figure 3.

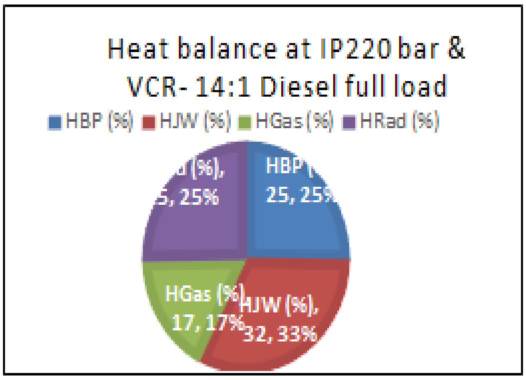


Fig 3. HBC of diesel at 220 bar IP & at VCR16

The heat balance chart at full load of diesel fuel at 220 bar (IP) and VCR 14:1 is shown in the figure 4.

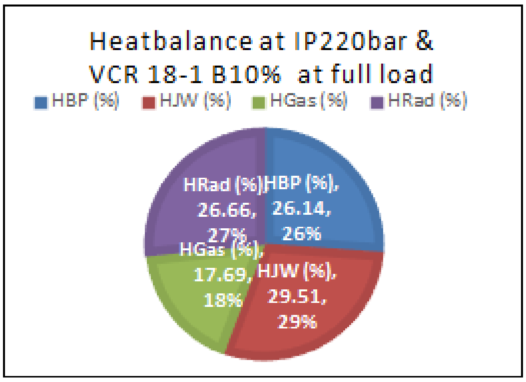


Fig 4. HBC of diesel at 220 bar IP & at VCR14:1

The HBC of 10% blend at full load, at 220 bar (IP) and VCR 18:1 is shown in the figure 5.

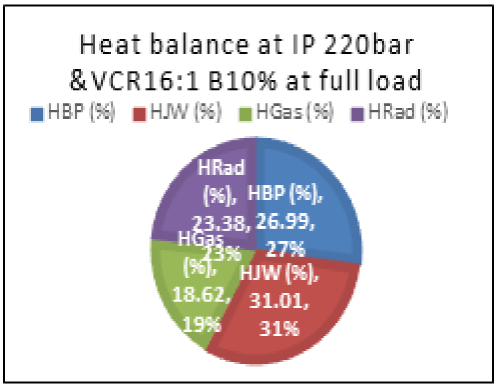


Fig 5. HBC of B10% at 220 bar IP & at VCR18:1

The HBC of 10% blend at full load, at 220 bar (IP) and VCR 16:1 is shown in the figure 6.

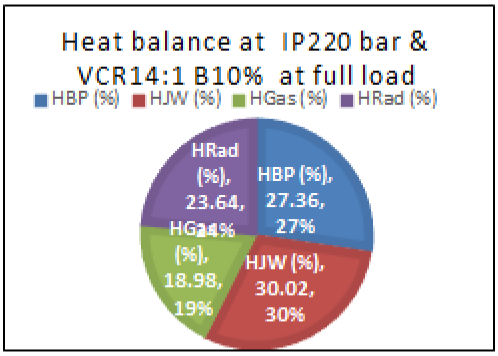


Fig.6 HBC of B10% at 220 bar IP & at VCR16:1

The HBC at full load for 10% blend at 220 bar (IP) and VCR 14:1 is shown in the figure 7.

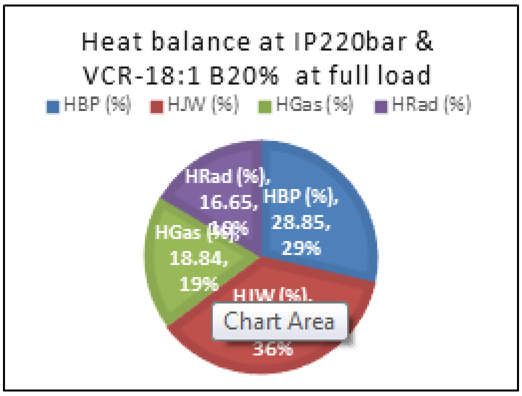


Fig7. HBC of B10% at 220 bar IP & at VCR14:1

The HBC at full load of 20% blend at 220 bar (IP) and VCR 18:1 is shown in the figure 8.

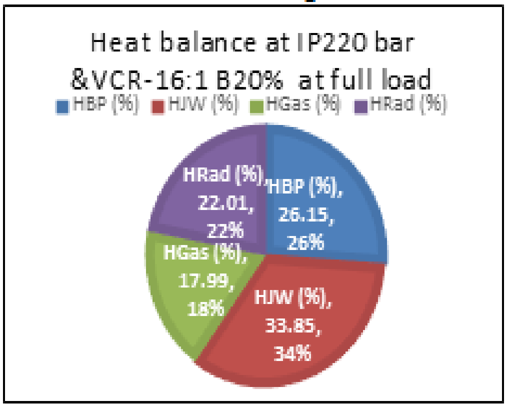


Fig 8. HBC of B 20% at 220 bar IP & at VCR18:1

The HBC at full load of 20% blend at 220 bar (IP) and VCR 16:1 is shown in the figure 9.

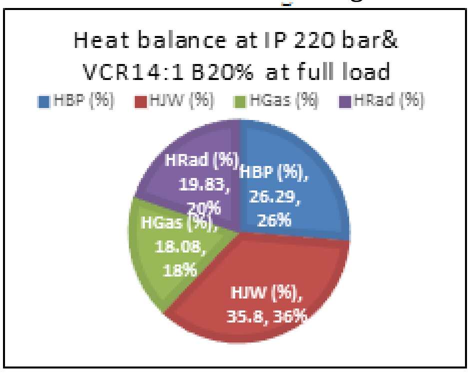


Fig 9. HBC of B 20% at 220 bar IP & at VCR16:1

The HBC at full load for 20% blend at 220 bar (IP) and VCR 14:1 is shown in the figure 10.

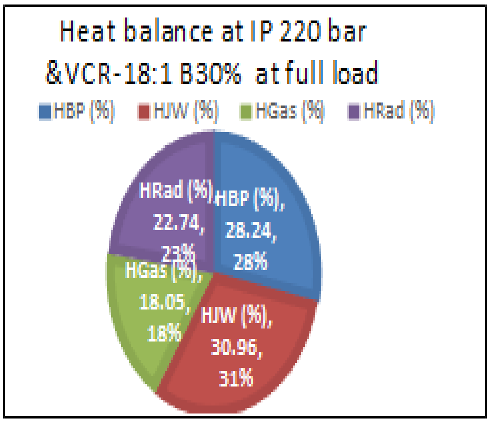


Fig 10. HBC of B 20% at 220 bar IP & at VCR14:1

The HBC at full load of 30% b lend at 220 bar (IP) and VCR 18:1 is shown in the figure 11.

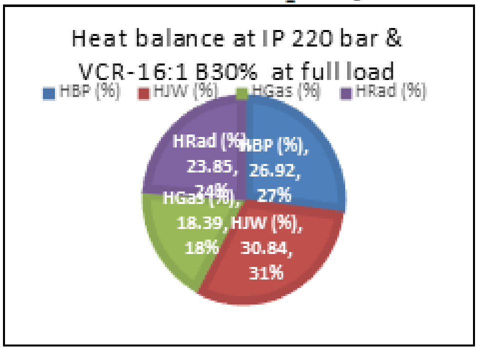


Fig 11. HBC of B 30% at 220 bar IP & at VCR18:1

The HBC at full load of 30% blend at 220 bar (IP) and VCR 16:1 is shown in the figure 12.

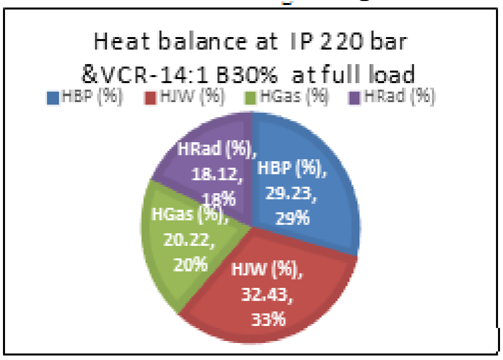


Fig 12. HBC of B 30% at 220 bar IP & at VCR16:1

The HBC of 30% blend at full load, at 220 bar (IP) and VCR 14:1 is shown in the figure 13.

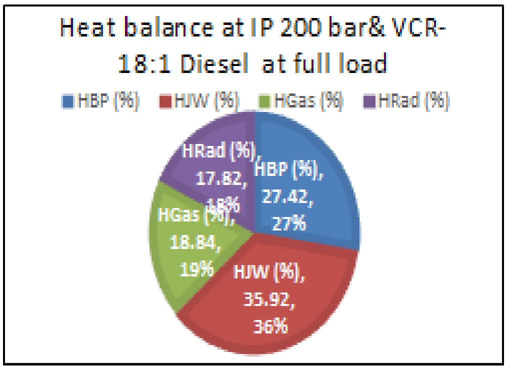


Fig.13 HBC of B 30% at 220 bar IP & at VCR14:1.

The HBC of diesel at full load, at 200 bar (IP) and VCR 18:1 is shown in the figure 14.

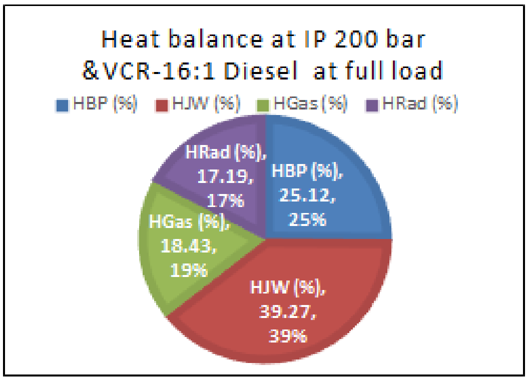


Fig14. HBC of diesel at 200 bar IP & at VCR18:1.

The HBC of diesel at full load, at 200 bar (IP) and VCR 16:1 is shown in the figure 15.

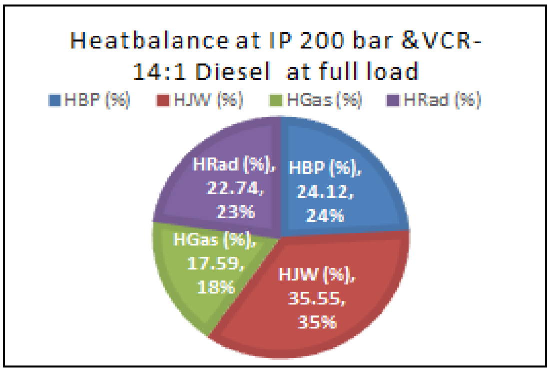


Fig15. HBC of diesel at 200 bar IP & at VCR16:1.

The HBC of diesel at full load, at 200 bar (IP) and VCR 14:1 is shown in the figure 16.

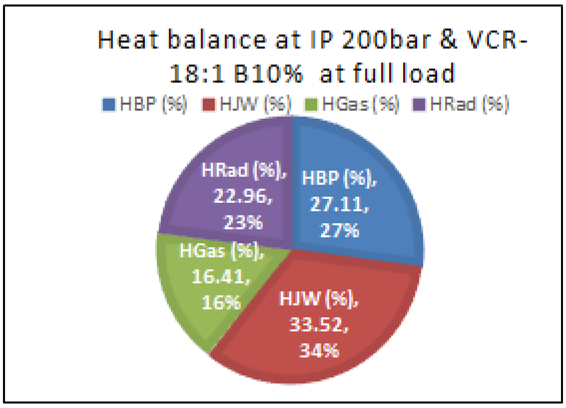


Fig 16. HBC of diesel at 200 bar IP & at VCR14:1.

The HBC of 10% blend at full load, at 200 bar (IP) and VCR 18:1 is shown in the figure 17.

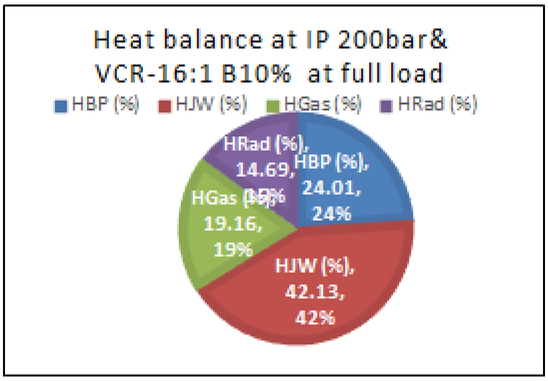


Fig 17. HBC of B10% at 200 bar IP & at VCR18:1.

The HBC of 10% blend at full load, at 200 bar (IP) and VCR 16:1 is shown in the figure 18.

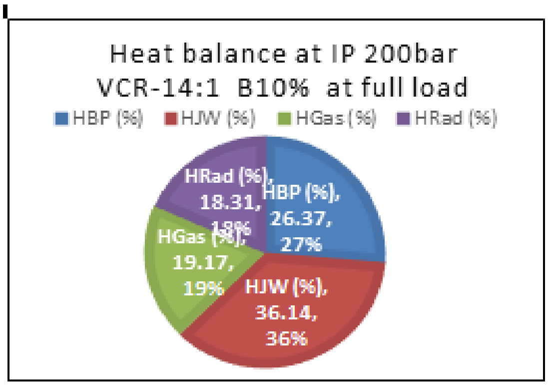


Fig.18 HBC of B10% at 200 bar IP & at VCR16:1.

The HBC of 10% blend at full load, at 200 bar (IP) and VCR 14:1 is shown in the figure 19.

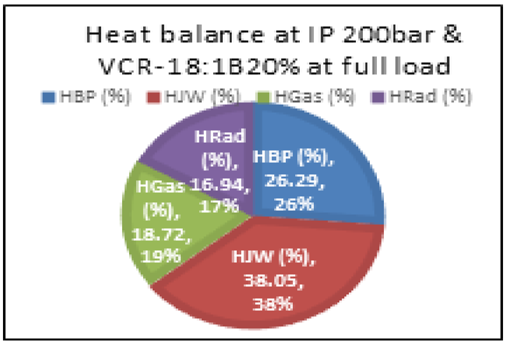


Fig 19. HBC of B10% at 200 bar IP & at VCR14:1.

The HBC of 20% blend at full load, at 200 bar (IP) and VCR 18:1 is shown in the figure 20.

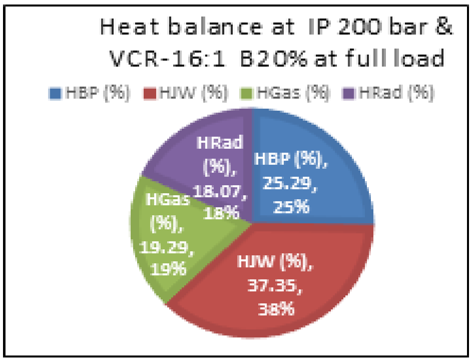


Fig 20. HBC of B20% at 200 bar IP & at VCR18:1.

The HBC of 20% blend at full load, at 200 bar (IP) and VCR 16:1 is shown in the figure 21.

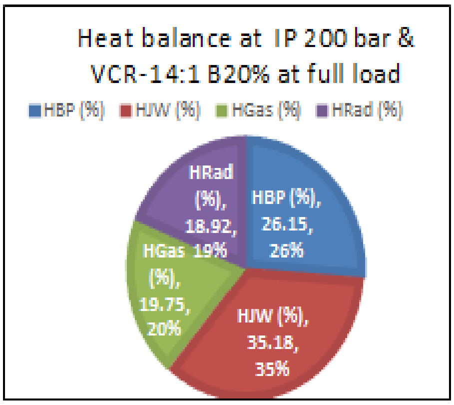


Fig 21. HBC of B20% at 200 bar IP & at VCR16:1.

The HBC of B20% at full load, at 200 bar (IP) and VCR 14:1 is shown in the figure 22.

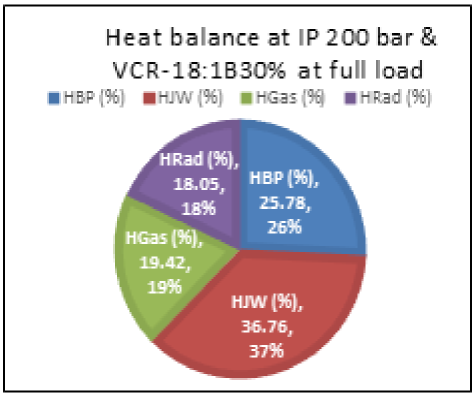


Fig 22. HBC of B 20% at 200 bar IP & at VCR14:1.

The HBC of B30% at full load, at 200 bar (IP) and VCR 18:1 is shown in the figure 23.

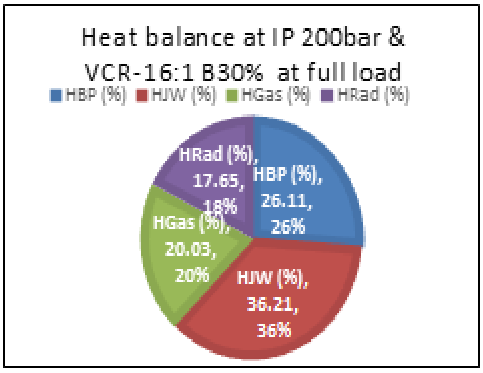


Fig 23. HBC of B 30% at 200 bar IP & at VCR18:1.

The HBC of B30% blend at full load, at 200 bar (IP) and VCR 16:1 is shown in the figure 24.

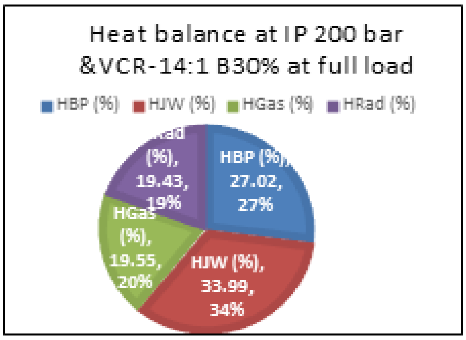


Fig 24. HBC of B30% at 200 bar IP & at VCR16:1.

The HBC of B30% at full load, at 200 bar (IP) and VCR 14:1 is shown in the figure 25.

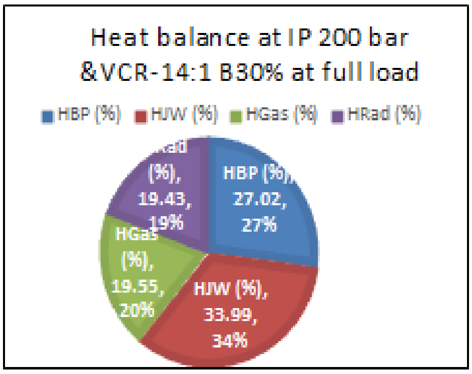


Fig25. HBC of B30% at 200 bar IP & at VCR14:1.

The HBC of diesel at full load, at 180 bar (IP) and VCR 18:1 is shown in the figure 26.

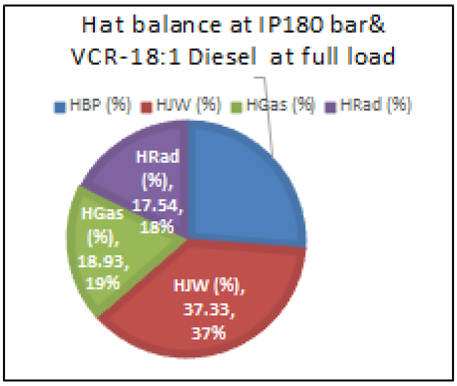


Fig 26. HBC of diesel at 180 bar IP & at VCR18:1.

The HBC of diesel at full load, at 180 bar (IP) and VCR 16:1 is shown in the figure 27.

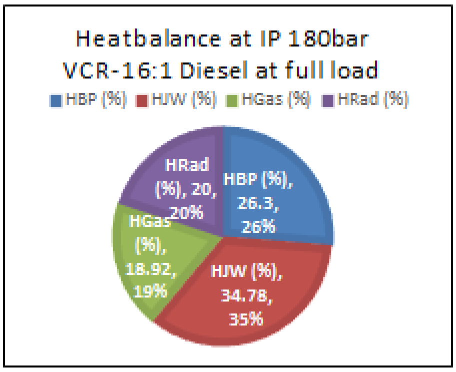


Fig 27. HBC of diesel at 180 bar IP & at VCR16:1.

The HBC of diesel at full load, at 180 bar (IP) and VCR 14:1 is shown in the figure 28.

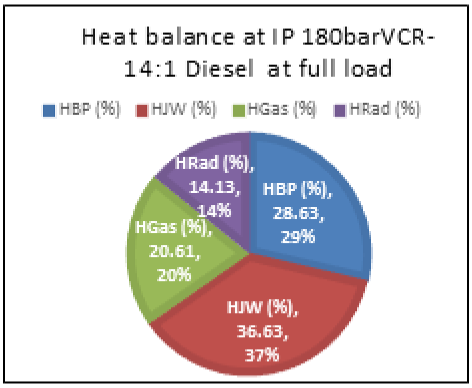


Fig 28. HBC of diesel at 180 bar IP & at VCR14:1.

The HBC of B10% at full load, at 180 bar (IP) and VCR 18:1 is shown in the figure 29.

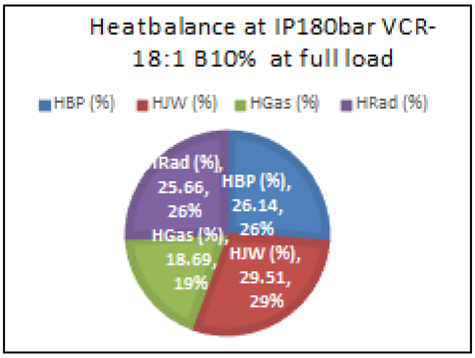


Fig 29. HBC of B10% at 180 bar IP & at VCR18:1.

The HBC of B10% at full load, at 180 bar (IP) and VCR 16:1 is shown in the figure 30.

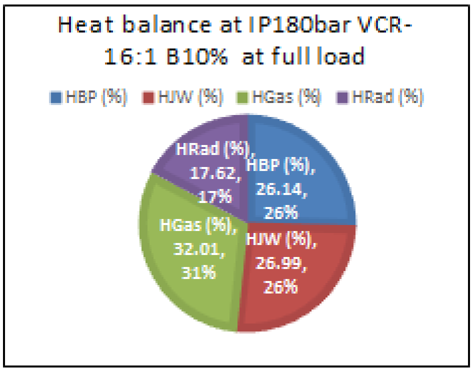


Fig.30 HBC of B10% at 180 bar IP & at VCR16:1.

The HBC of B10% blend at full load, at 180 bar (IP) and VCR 14:1 is shown in the figure 31.

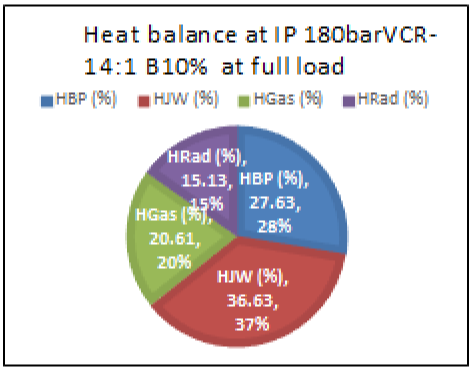


Fig 31. HBC of B10% at 180 bar IP & at VCR14:1.

The HBC of B 20% at full load, at 180 bar (IP) and VCR 18:1 is shown in the figure 32.

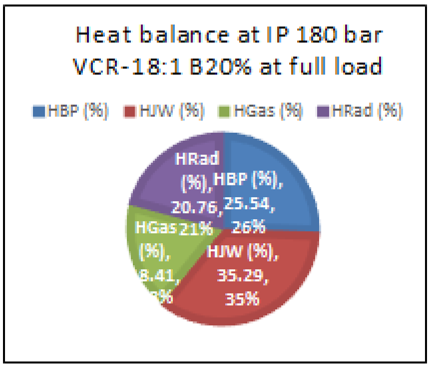


Fig 32. HBC of B20% at 180 bar IP & at VCR18:1.

The HBC of B20% at full load, at 180 bar (IP) and VCR 16:1 is shown in the figure 33.

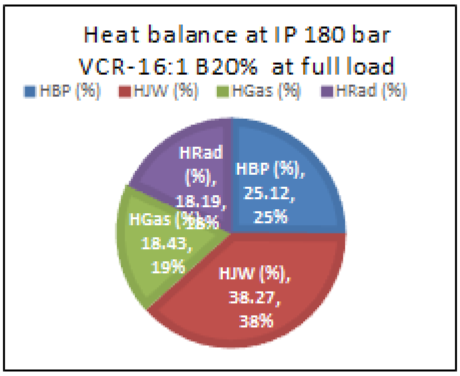


Fig 33. HBC of B 20% at 180 bar IP & at VCR16:1.

The HBC of B 20% at full load, at 180 bar (IP) and VCR 14:1 is shown in the figure 34.

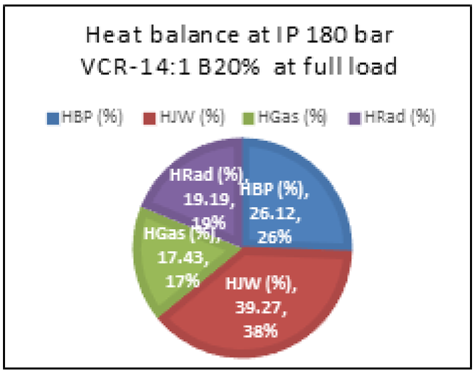


Fig 34. HBC of B 20% at 180 bar IP & at VCR14:1.

The HBC of B 30% at full load, at 180 bar (IP) and VCR 18:1 is shown in the figure 35.

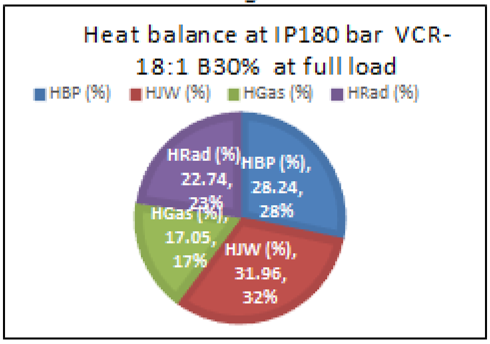


Fig35. HBC of B30% at 180 bar IP & at VCR18:1.

The HBC of B 30% at full load, at 180 bar (IP) and VCR 16:1 is shown in the figure 36.

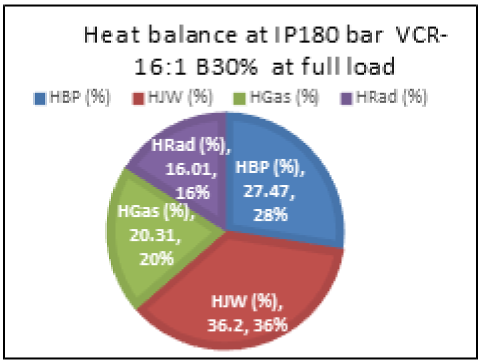


Fig 36 HBC of B 30% at 180 bar IP & at VCR18:1.

The HBC of B 30% at full load, at 180 bar (IP) and VCR 14:1 is shown in the figure 36.

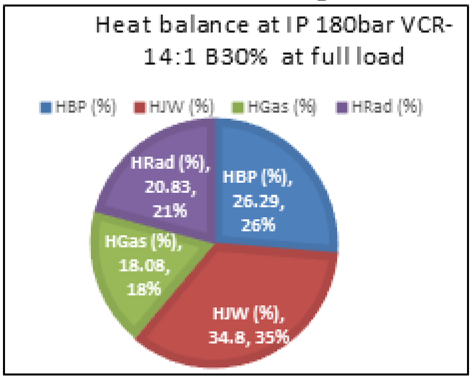


Fig 37. HBC of B 30% at 180 bar IP & at VCR14:1.

4. Conclusion

- The heat lost through exhaust gasses was minimum at 200 bar injection pressure and at 18:1 variable compression ratio and at B10% approximately 16%.

- The utilization heat was maximum at 220 bar injection pressure, at 18:1 compression ratio and at B20% approximately 29%.
- The heat lost through cooling system was minimum at 220 bar injection pressure and at 18:1 variable compression ratio and at B10% approximately 29%.
- The other heat losses were minimum at 220 bar injection pressure and at 18:1 variable compression ratio for diesel approximately 14%.

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