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EXHAUST ANALYSIS OF GAS TURBINE WITH BIO-DIESEL AS A FUEL

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Abstract : **In this paper we have covered bio diesel as alternative fuels, biogas of mechanization for gas turbine, their properties and composition and their effect on its emission and its combustion performance. There is a good progress for the clean combustion of low calorific value fuel such as biomass and hydrogen enriched fuels by using gasification and lean premixed combustion, which gives low emission particularly NOx. After analyzing these alternative fuels, it has been found that the bio-diesel is the best suited alternative for an existing gas turbine and its performance will be compared on various parameters i.e. thermal efficiency, power output, Emission, Specific fuel consumption etc. The effect of operating conditions such as water or steam injection on emission formation and performance will also be studied with the different combinations of alternating fuels. The wet compression consists of injecting atomized water into the compressor inlet air stream, this water evaporates and cools the inlet air so it reduces compressor work and increases mass flow rate.**

IndexTerms **- gas turbine, bio-fuel, alternative fuels, water injection, and emission.**

1.1 INTRODUCTION

During the analysis of bio-diesel and its blends i.e. BD 20, BD 50 BD 100, the exhaust emission of these blends has been compared with diesel in the existing Rover 1S 60 gas turbine. These tests were conducted at the rated gas turbine rpm of 31500 (which is equivalent of 2050 dynamometer rpm).

The objectives of these tests were to establish the trend of exhaust emission specially NOx value. There is very high ambiguity in the results, shown by different researchers given in the literature review.

The experimental data has been collected for pure bio-diesel, its blends with diesel and pure diesel using in gas turbine at the different loads (from no load condition to the rated power i.e. 30 KW load). These emission data have compared, analyzed and represented in the form of graphs

An effective method of overcoming the problem of NOx, and improving the performance is pre-cooling of the inlet air. The increased density of the cooled air increases the mass flow through the engine, resulting in a significant increase in gas turbine power output, with a slight improvement in efficiency, and the NOx emission is reduced. A further consequence of pre-cooling of the inlet air is that maintenance costs are also reduced, as these depend heavily on the temperature of the hot section.

1.2 EFFECT OF BLENDING ON CO EMISSION

Blending of bio-diesel in the diesel reduces the CO emissions of gas turbine and the maximum reduction in CO emission is with BD 50 blend, which is about 20 - 40% depending on load conditions. As shown in Fig 1.1, the primary reason of reduction of CO emission with higher blending is that, the CO emission decreases due to increase in oxygen content. It is fact that the carbon atom in the fuel molecule can be present in the combustion products as only either CO_2 or CO, as sufficient oxygen is available, CO_2 content increases, so, the CO content will decrease.

It is apparent from the fig 1.1, that CO emission decreases as the turbine load increases, this reduction trend of CO emission with turbine load may be due to increase in combustion temperature leads to more complete combustion at the higher loads. It is also apparent that the CO emission was further slightly increased at higher load condition. The reason for this increase in CO emission may be due to the quantity of air availability decreases at higher loads.

It is also interesting to see that the minimum CO emission level is for BD 50 as compared to pure bio-diesel. It may be due to the higher viscosity and pure spray characteristics of pure bio-diesel which lead to poor mixing and poor combustion. So the CO emission level is higher with pure bio-diesel compared to BD 50 blends.

At no load and part load conditions the reduction in CO emission is more with the blending as compared to the rated load condition, as shown in figure 1.1. It is due to the availability of more air at part load conditions compared to the heavy load conditions.

From the results as shown in fig 1.1, it is clearly visible that CO emission decreases as the blending of bio-diesel in the diesel increases. The minimum CO emission is found with BD50 blend. The reduction of CO emission with BD 50 comparing with the base fuel diesel at no load condition is 22.7%, where as at rated load condition i.e. at 30 kW load , it is 40%.

Krishna [51] has also shown almost about 40% reduction in CO emission by using bio-diesel. Pier [31] has shown about 26% reduction in CO emission by using 20% rapeseed ethyl ester bio-diesel. The several other investigators also have shown the same trends [28, 50, 53, 60, 61, 63, 64]

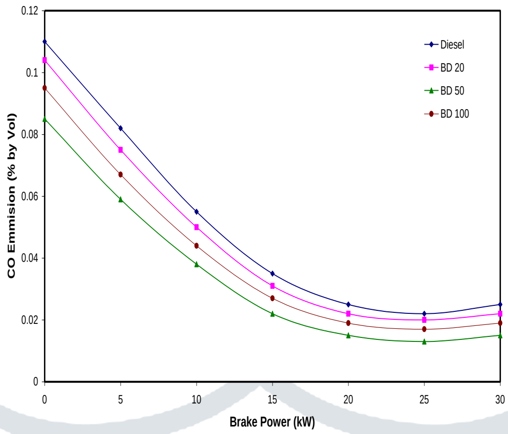

Fig 1.1: Effect of blending on CO Emission

1.2 EFFECT OF BLENDING ON NOX EMISSION

Blending of bio-diesel in the diesel increases the NOx emissions of gas turbine as shown in fig 1.2. The maximum increment in NOx emission was observed for B100, which is about 15% -17%. This increment in NOx emission is the result of 12% oxygen content of the B100 blend and higher gas temperature in the central zone of the combustion chamber due to better combustion. Though, the average temperature of turbine inlet temperature is slightly less for B100 blend compared to diesel.

NOx formation increases as load increases, which is the result of higher combustion temperature due to higher turbine load. This NOx concentration varies almost linearly with load. As load increases the overall fuel air ratio increases which results in an increase in the average gas temperature in the combustion chamber and hence NOx formation which is sensitive to temperature increases.

However NOx emission increased with the increased load up to middle loads. At the higher loads the rate of increment of NOx emission diminishes slightly. It may be due to the increase in turbulence inside the combustion chamber, which may be contribute to a faster combustion and to lower residence time of the species in the higher temperature zones

The NOx emission increment of pure bio-diesel at no load condition is about 17% where as at higher load condition it is about 15%. It shows that the NOx emission increment is about constant throughout the load scale, when comparing it in terms of percentage with the NOx emission of base line fuel i.e. diesel as shown in fig 1.2.

From the experiment it has been found that the NO_x increases as blending of bio-diesel increases. The maximum increment in No_x emission using pure bio-diesel at rated load is about 15% as compared to baseline fuel diesel.

Nascimento et al [48] have shown increment in No_x by using soya & rapeseed bio-diesel in the gas turbine. Ellis et al [52], Bolszo et al [57, 58], Altaher et al [60], Li et al [61] also have shown increase of No_x by using bio-diesel in gas turbine.

Some researchers [49, 50, 51, 63, 67].also have shown reverse trend which is nicely explained by Glaude et al [62]. They have mentioned that flame temperature can be considered as the major determinant of NO_x emission in the gas turbine. Flame temperatures of Diesel fuel & FAME are close even though diesel tends to have higher values. The composition of fuels is very sensitive to the flame temperature. The Diesel rich in alkanes and naphtenes could have a lower flame temperature than a much unsaturated bio-diesel. Reversely, an increasing proportion of aromatic species in the diesel fuel will dramatically increase the flame temperature.

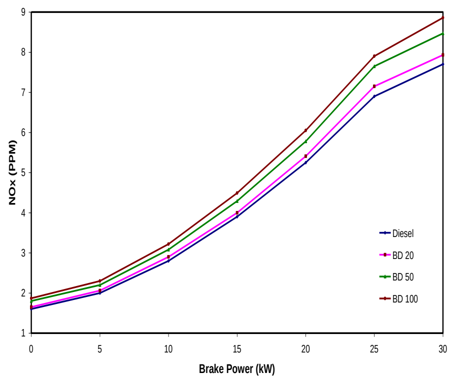

Fig 1.2: Effect of blending on NOx Emission

1.3 EFFECT OF BLENDING ON UNBURNT HYDROCARBON EMISSION

Blending of bio-diesel in the diesel reduces the Un-burnt Hydrocarbon (UHC) emission of gas turbine up to 60%. As shown in Fig 1.3 the UHC emission decreases with increasing bio-diesel percentage in the blend. The reduction in UHC was linear with the addition of bio-diesel for the blends. The reduction in UHC emission of pure bio-diesel with that of diesel at higher load condition was also about 60%.

Bio-diesel involves higher oxygen content, which leads to more complete combustion. Additionally, the decrease in UHC emissions was caused not only by the oxygen content but also by the cetane number. Higher cetane number of bio-diesel could reduce the burning delay and provides better combustion, which results in the UHC emissions reduction.

UHC emission decreases as the load increases. The UHC emission has a grater decrease at low load conditions as compared to higher load conditions. This is a uniform trend with all the blends and diesel fuel.

The UHC emission reduction due to use of pure bio-diesel at no load condition is about 56.47% where as at higher load condition it is about 55%. It shows that the UHC emission reduction is almost constant throughout the load scale, when comparing it in terms of percentage with the UHC emission of base line fuel i.e. diesel as shown in fig 1.3.

The UHC emission reduction due to use of pure bio-diesel at no load condition is about 56.47% where as at higher load condition it is about 55%. It shows that the UHC emission reduction is almost constant throughout the load scale, when comparing it in terms of percentage with the UHC emission of base line fuel i.e. diesel as shown in fig 1.3.

The reduction in UHC emission by using pure bio-diesel compared to baseline fuel diesel at the rated load is about 56.6%. This reduction is due to higher oxygen content in the bio-diesel, which leads to better combustion & higher content No of the bio-diesel.

Ellis et al [52] also have shown low UHC emission and explained that, it may be due to lower aromatics in the bio-diesel.

Altaher et al [60], Li [61], Hashimoto et al [63] have also shown the reduction in UHC emission with the blending of bio-diesel in the diesel.

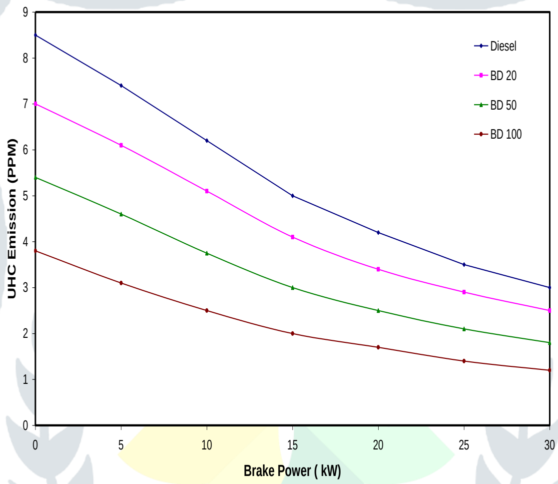

Fig 1.3: Effect of blending on Un-burnt Hydrocarbon Emission

1.4 EFFECT OF WATER INJECTION ON EXHAUST EMISSIONS OF THE GAS TURBINE:

1.4.1 Effect of water injection on CO Emission:

The water injection at the compressor air inlet increases the CO emission of the gas turbine by about 10-20% as shown in fig 1.4 – 1.7. It is due to the fall in the temperature of combustion chamber which results higher CO emission.

1.4.2Effect of water injection on CO Emission:

The water injection at the compressor air inlet increases the CO emission of the gas turbine by about 10-20% as shown in fig 1.4 – 1.7. It is due to the fall in the temperature of combustion chamber which results higher CO emission.

1.1.2Effect of water injection on NOx Emission

The water injection at the compressor air inlet reduces the NOx emissions of the gas turbine. This reduction is varying in the range of 18-42%. *Higher reduction is with 50% blending of bio diesel* about 42% as shown in fig 4.8–4.11. So in this case also 50 % blending seems optimum between emission reduction and power output.

1.4.3Effect of water injection on Un-burnt Hydrocarbon Emission

The water injection at the compressor air inlet increases the un-burnt Hydrocarbon emission of the gas turbine. The average increment was about 25%. The maximum increment in the UHC emission was with pure bio-diesel and it was 31% as shown in fig 4.12–4.15. The reason is due to the fall in the combustion chamber temperature which will increase the un-burnt hydrocarbon emission.

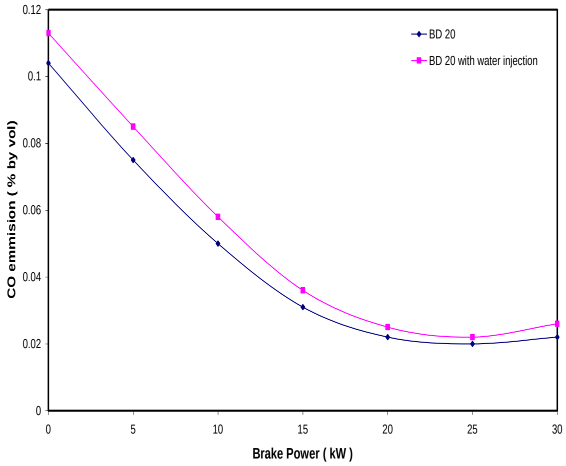

Fig 1.5: Effect of water injection on CO Emission with 20% bio-diesel

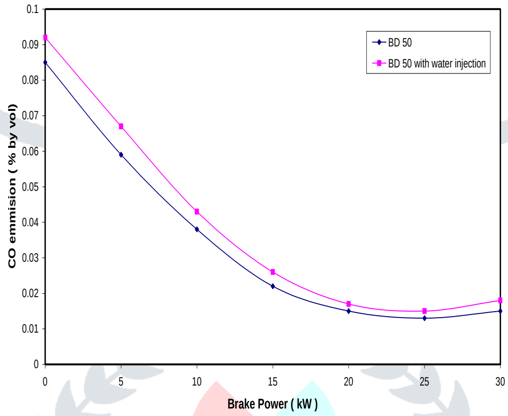

Fig 1.4: Effect of water injection on CO Emission with 50% bio-diesel

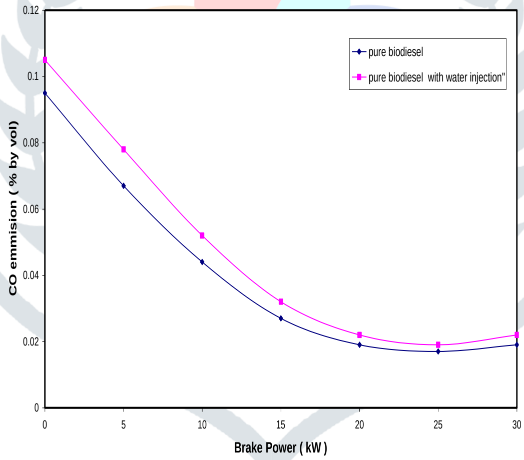

Fig 1.6: Effect of water injection on CO Emission with pure bio-diesel

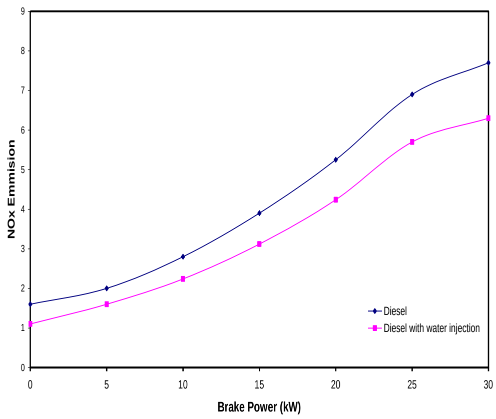

Fig 4.8 : Effect of water injection on NOx Emission with Diesel

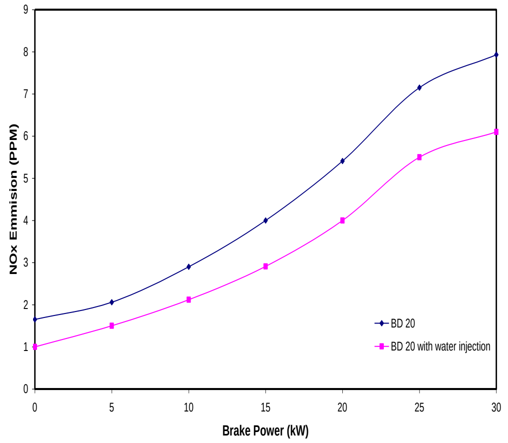

Fig 4.9: Effect of water injection on NOx Emission with 20 % bio-diesel

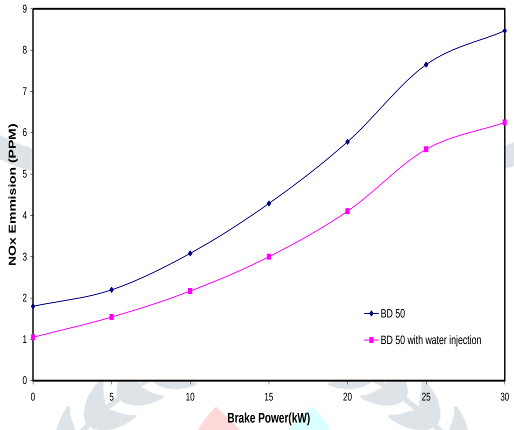

Fig 4.10: Effect of water injection on NOx Emission with 50 % bio-diesel

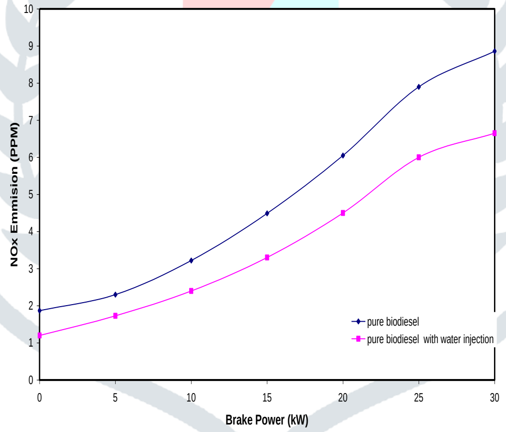

Fig 4.11: Effect of water injection on NOx Emission with pure bio-diesel

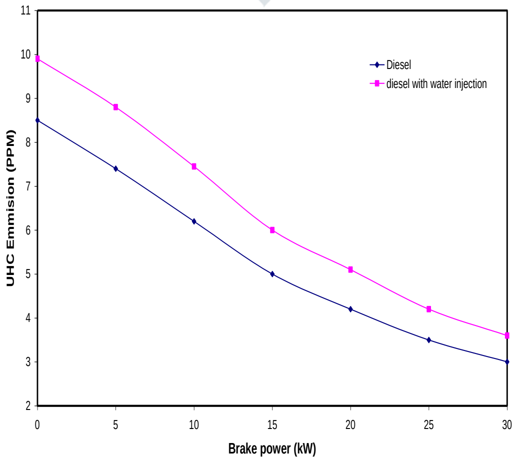

Fig 4.12: Effect of water injection on Un-burnt Hydrocarbon Emission with diesel

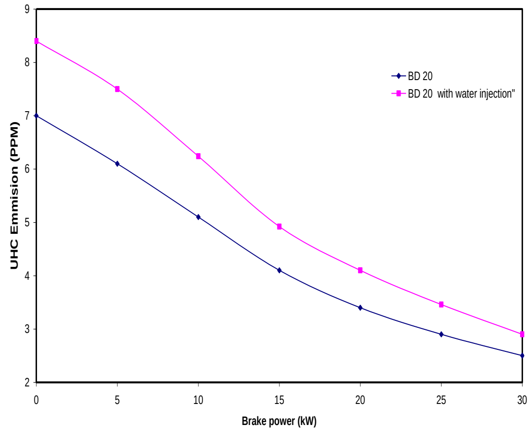

Fig 4.13: Effect of water injection on Un-burnt Hydrocarbon Emission with 20% Bio-diesel

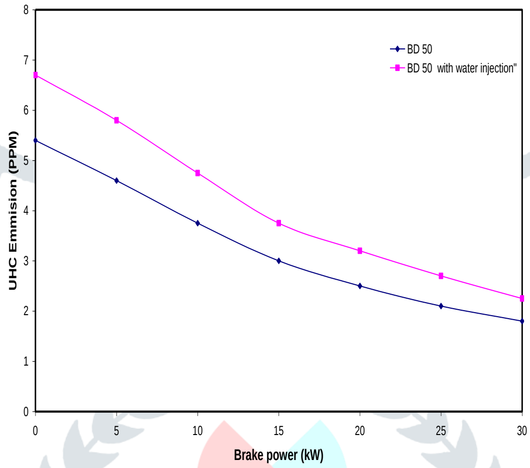

Fig 4.14: Effect of water injection on Un-burnt Hydrocarbon Emission with 50% Bio-diesel

4.6 CONCLUSION:

Water injection shifts the characteristics to higher mass flow ratio. A marginal thermal efficiency increase along with a substantial power boost has been found. From the above results it is clearly indicate that the effect of water injection at compressor inlet is same irrespective to the type of fuel used. The problems due to the wet compression technology and fogging are compressor blade erosion and turbine load-bearing structure distortion. In order to reduce these disadvantages, water droplets injected into the air flow should be very small and the droplets should have to evaporate in a short time. The spray nozzles should be placed correctly with suitable pressure and drain systems which will assure small droplet diameters.

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