Review on Study of Effects of EGR on Performance and Emissions in Gas Turbines

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ABSTRACT

A gas turbine power plant powered by hydrogen as the fuel has high combustion properties because of high reactivity of hydrogen and hence dilution of fuel becomes a necessity for achieving low NOx emissions a high exhaust gas recirculation rate (EGR) rate is applied to the working fluid resulting in lack of oxygen in the fuel and hence the temperature reached during combustion process are reduced resulting in low NOx emissions . Graphs of different EGR rates vs reduction in oxygen and NOx emission are plotted EGR rates beyond the limits i.e higher values are applied so a particular conclusion can be attained for stoichiometric EGR rate values that when applied will give results which will be in equilibrium with surroundings .The conclusion of this analysis is that by using exhaust gas recirculation technique in gas turbines high amount of reduction in NO_x emissions can be attained while some efficiency penalty gets induced because of fuel dilution.

Keywords: ***Exhaust gas recirculation(EGR), Hydrogen gas turbine, NO_x etc.***

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1. INTRODUCTION

The main pollutants in an exhaust gas of a hydrogen fired gas turbine are nitrogen oxides (NO_x).Which have been strongly regulated for many decades now during the combustion of hydrogen the formation of NO_x is mostly controlled by temperature the NO_x formation is strongly sensitive to temperature it means that a very small increase in the range of temperature causes an exponential increase of NO_x[1][2][3].

In modern gas turbines the problem of high temperature region is resolved by mixing fuel and air before sending it to combustion chamber this technology has struggled because fuel premixing leads to many issues related to combustion instability [4].This technology still strives when hydrogen rich fuels are used because hydrogen combustion has wide flammability, very high reaction rates and high flame temperature[5] because of this combustion process occurs too quickly and there is not enough time for premixing of air and fuel which results in high NO_x emissions[6][7].

To lower the NO_x emissions some penalty in efficiency is to be considered the present work suggest a gas turbine cycle that has low NOx emissions for which we need not to dilute fuel nor we do changes in combustion technology it is obtained by recirculating the exhaust gas to the turbine compressor inlet now the air entering the combustion chamber has less amount of oxygen and hence the combustion temperature and NO_x formation is limited because of this concept the burners of the turbine will be simple in construction and cost of manufacturing will be reduced to greater extent[8][9].

2. LITERATURE REVIEW

N.k. Miller jothi studied the effect of Exhaust Gas Recirculation (EGR) on homogeneous charge ignition engine. A stationary four stroke, single cylinder, direct injection (DI) diesel engine capable of developing 3.7 kW at 1500 rpm was modified to operate in Homogeneous Charge Compression Ignition (HCCI) mode.[10]

Amar Pandhare studied the Effect of EGR on the exhaust gas temperature and exhaust opacity in compression ignition engines using Jatropha oil as fuel[11].

Deepak Agarwal et al., investigated the effect of EGR on soot deposits, and wear of vital engine parts, especially piston rings, apart from performance and emissions in a two cylinder, air cooled, constant speed direct injection diesel engine.

Mario Ditaranto studied hydrogen fired gas turbine cycle with exhaust gas recirculation and found the different egr rates for particular amount of NO_x emission[12].

3. WORKING OF HYDROGEN FIRED GAS TURBINE WITH EGR

The exhaust from the hydrogen fired gas turbine has nitrogen as the main content and some amount of steam,oxygen and carbondioxide in it.the EGR rate is defined as the ratio of the volume flow of recirculated exhaust gas to that of exhaust gas.

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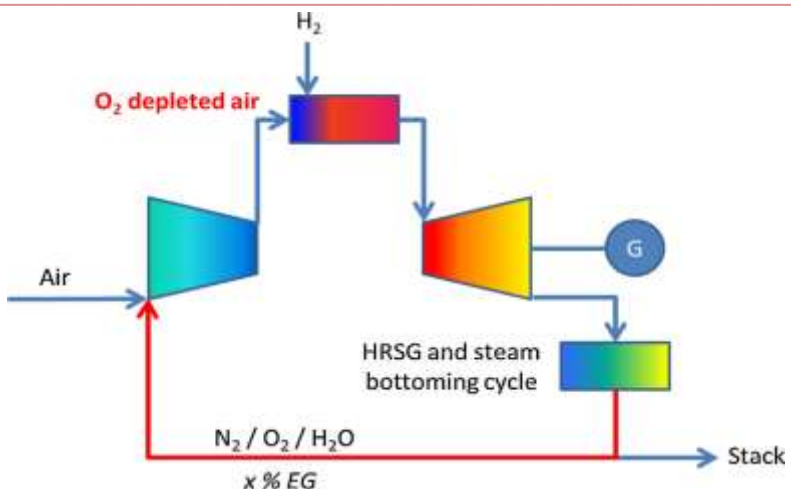

Fig-1: Simplified layout of the hydrogen fired gas turbine with exhaust gas recirculation concept

A fraction of the exhaust gas is recirculated to the turbines compressor inlet and the gas which comes out of compressor and enters the combustion chamber has less amount of oxygen in it and hence the NOx formed is intrinsically limited because of lower adiabatic temperature reached at the time of combustion [13].A NG gas turbine could operate a gas turbine combuster with up to 35% recirculation of exhaust gas and 17.8% of O_2 concentration[14].

4. RESULTS AND DISCUSSIONS

Older gas turbines were fitted with diffusion type burners in these burners the non premixed fuel and air are injected directly to primary combustion zone these burners have good ignition and flame stability these burners were not so efficient for reducing NO_x as the temperatures reached in these were high thus leading to high NO_x formation .[15]

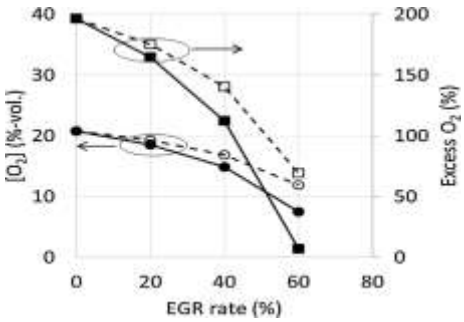

Fig-2: O_2 Vs % of EGR supplied to turbine inlet. Filled symbols:wet EGR; open symbols: dry EGR.

The effects of EGR are depicted in fig2 oxygen concentration decreases rapidly as the EGR rate increases and the decrease in O_2 with EGR is faster when wet EGR is used rather than dry EGR.

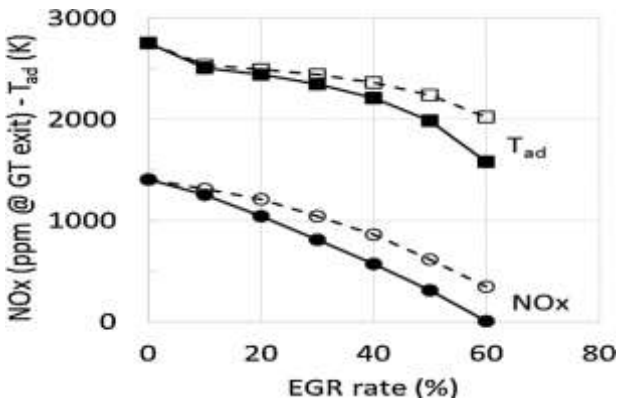

Fig-3:NO_x Vs EGR supplied to turbine inlet. Filled symbols:wet EGR; open symbols: dry EGR.

The fig3 shows decrease in adiabatic temperature and NO_x with increase in EGR rate. The NO_x concentration are reduced to half its value with EGR rate of 30% for wet EGR and 40% for dry EGR.A balanced or moderate rate of recirculation can achieve high reduction in NO_x without nitrogen dilution[16][17][18].

4.1 Premixed combuster mode

In modern gas turbines more air is used in the primary zone of the burner and the results are obtained in this case by considering a perfect premixing is achieved in the primary zone the premixed type of burner are difficult to manufacture when hydrogen is used as afuel.

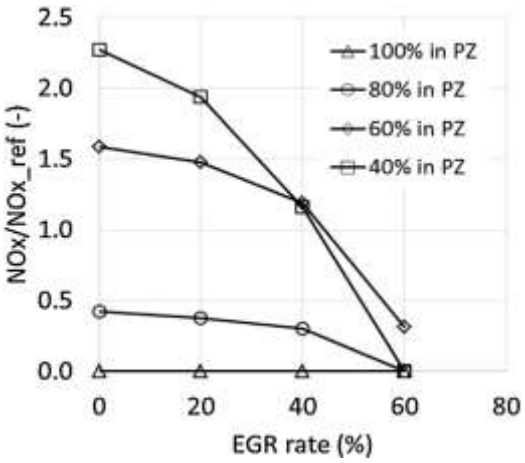

Fig-4: Calculated equilibrium NOx emissions with dry EGR at different working fluid distribution ratios in the primary flame zone (PZ) of the combustor.

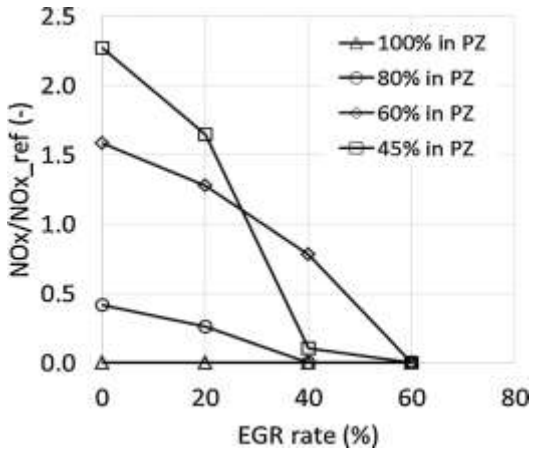

Fig-5: Calculated equilibrium NOx emissions with wet EGR at different working fluid distribution ratios in the primary flame zone (PZ) of the combuster.

More the working fluid is present in primary zone lower will be the NOx emissions results show that when 45% of the fuel is in primary zone the condition near to stoichiometry is obtained i.e we get lower NO_x emissions and the EGR rate to be supplied is also within limits nearly to 40% as seen from fig4 &fig5.

5. CONCLUSION

To avoid the efficiency penalty which occurs because of dilution of hydrogen rich fuel an EGR system is used which generates an oxygen depleted working fluid for reducing NO_x emissions

1) At high EGR rates the fluid entering combuster is highly oxygen depleted thus temperature reached are minimum and hence the NO_x emissions.
2) Application of EGR in wet mode is more effective in reducing the NO_x emissions as compared to dry mode.
3) Both diffusion type and premixed type combuster can be used but at higher EGR rates use of lean premixed combuster becomes feasible because of decrease in reactivity of hydrogen.

6. RECENT MODIFICATIONS AND FUTURE SCOPE IN EGR

Gas turbine cycle technologies will play a major role in future power generation, and several well-justified concepts have been developed or are the subject of major feasibility studies. Currently the, gas turbine cycles are modified with steam injection between the combustion chamber exit and the gas turbine inlet.

Heat recovery steam generators, utilizing the exhaust gases, provide these cycles with the injected steam at saturated vapor. The thermodynamic characteristics of the various cycles are considered in order to establish their relative importance to future power generation markets. The irreversibility of the different composing units of the cycles and the variation of gas properties due to steam injection as well as changes in the interrelation of component performance parameters are taken into account.

The present modified cycles with steam injected cycles have higherl power output as well as higher efficiencies, resulting in a lower specific cost. At the chosen values of the operating parameters, the enhancement achieved in the overall efficiency for the simple, reheat (with steam injection at high and low pressures) and partial oxidation (with steam injection at high and low pressures) gas turbine cycles are of about 20–30%, 120–200%, 10–12%, 120–260% and 20%, respectively. The present modified cycles technique can be considered among the possible ways to improve the performance of gas turbine cycles-based power plants at feasible costs. This concept can be used for similar core engines[19].

Cleaning the exhaust gas with scrubber , the EcoSilencer has been introduced in the EGR system to clean the exhaust gas and, if possible, also to reduce some of the emission components. The performance of the EGR scrubber has proved so efficient that a test of evaluating the potential of this scrubber as after-treatment scrubber for two-stroke and four-stroke engines has been started. And some auto check systems have been installed in the plants with EGR system that automatically checks the leakages from the system this makes the working safe and efficient.[20].

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