Hydrogen Fuel Engine - A Review

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Abstract **-Internal combustion engines continue to dominate in many fields like transportation, agriculture and power generation. Among the various alternative fuels, hydrogen is a long-term renewable and less polluting fuel (Produced from renewable energy sources). In the present experimental investigation, the performance and emission characteristics were studied on a direct injection diesel engine in dual fuel mode with hydrogen inducted along with air adopting carburetion, timed port and manifold injection techniques. Results showed that in timed port injection, the specific energy consumption reduces by 15% and smoke level by 18%. The unburnt hydrocarbons and carbon monoxide emissions are lesser in port injection. The oxides of nitrogen are higher in hydrogen operation (both port and manifold injection) compared to diesel engine. In order to reduce the NOX emissions, a selective catalytic converter was used in hydrogen port fuel injection. The NOX emission reduced upto a maximum of 74% for ANR (ratio of flow rate of ammonia to the flow rate of NO) of 1.1 with a marginal reduction in efficiency. Selective catalytic reduction technique has been found to be effective in reducing the NOX emission from hydrogen fueled diesel engines.**

Keywords: Hydrogen; Manifold Injection Technique; Catalytic Converter; Diesel Engine.

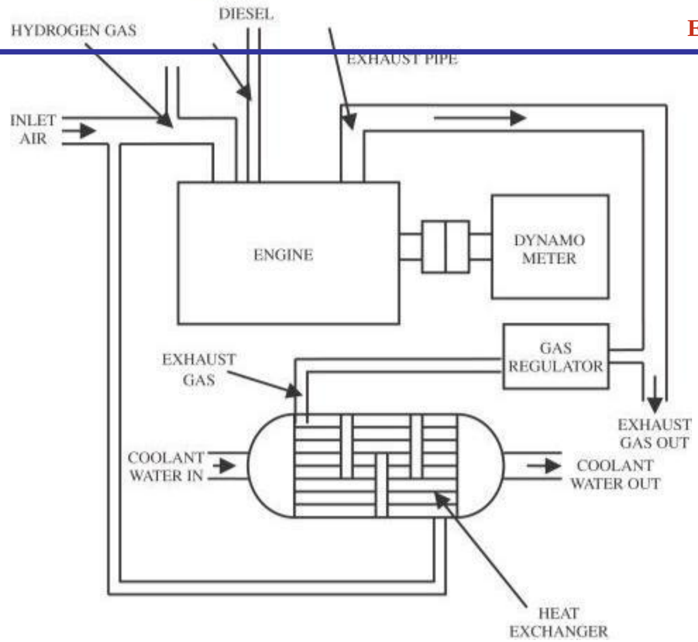
INTRODUCTION

One alternative fuel to carbon-based fuels is hydrogen[1]. In the near term, the use of hydrogen in internal combustion engine may be feasible as a low cost technology to reduce emissions[2]. The in-cylinder gas flow characteristics have major influence on combustion process, fuel consumption, emission production and engine performance[3,4]. A single cylinder compression ignition engine was operated throughout its load range inducting small proportions of hydrogen in intake air [5-10]. It has the advantage of the durability of exhaust gas valves and turbochargers due to the low exhaust gas temperatures that result from a lean combustion[11-14]. At the wide-open throttle (WOT) condition, it can also provide thermal efficiency levels similar to those achieved by a conventional diesel engine since the onset of knocking phenomena is depressed and the compression ratio can be higher than for a conventional gasoline engine[15-19].Engine dynamometer testing was conducted on a production automotive engine. Untreated exhaust emissions were measured over a range of hydrogen/natural gas fuel mixtures and equivalence ratios ({Phi})[20]. The most important finding was that, with retarded ignition, extremely low raw NO{sub x} emissions can be attained at the same time as high brake thermal efficiency[21-23].

EXPERIMENTAL SET UP

Design of Experiment

There are various ways in which the emissions from the exhaust of an engine can be reduced. The fuel that is being handled is hydrogen, which does not have components like carbon and nitrogen [1,24].



Experimental Procedure

The engine used for the investigation is a four stroke, water cooled, single cylinder, direct-injection (DI), vertical diesel engine running at a rated power of 3.78 kW and at a rated speed of 1500 rpm. The specifications of the test engine are shown in Table 1. Hydrogen is supplied from a high pressure cylinder (150 bars) to an outlet pressure of 1 bar using hydrogen pressure regulator. Hydrogen is then passed through a fine control valve to adjust the flow rate of hydrogen. Then it passes through the digital mass flow meter, which meters the flow of hydrogen in terms of l/min. Then hydrogen is passed through an NRV, which prevents the reverse flow of hydrogen into the system. Such a possibility of reverse flow can occur sometimes in a hydrogen injected engine, particularly in the latter part of injection. Hydrogen is then passed through a flame arrestor, used to suppress the explosion inside the hydrogen containing system. The flame arrestors operate on the basic principle that the flame gets quenched if sufficient heat can be removed from the gas by the arrestor[1,25].

Table 1.
Specifications of the test engine

General details	Single cylinder, four stroke, compression ignition, constant speed, vertical, water cooled, direct injection
Bore	80 mm
Stroke	110 mm
Swept volume	553 cm^3
Clearance volume	36.87 cm^3
Compression ratio	16.5:1
Rated output	3.7 kW at 1500 rpm
Rated speed	1500 rpm
Injection pressure	240 bar

Fig. 1 Photographic view of the engine setup

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MATHEMATICAL MODELLING

On the basis of the ideal process, the premixed engine combustion is described by the constant volume process[26]:

$$\eta_{cv} = 1 - CR^{1-\gamma}$$

Cylinder wall heat losses, Q_{wh}: The computation of the wall heat losses was also performed by WEG using a Woschni correlation for the heat transfer coefficient α_w:

$$\alpha_w \approx s_p^{0.8} \cdot p_{cyl}^{0.8} \cdot B^{-0.2} \cdot T_{cyl}^{-0.53}$$

Subtracting all the above-described losses to the energy introduced by the fuel Q_b multiplied by $(1-\eta_{cv})$ results in an amount slightly lower than the indicated work:

$$\eta_{cv} \cdot Q_b - (Q_{ic} + Q_{rc} + Q_{wh} + W_{gx}) > p_{mi} \cdot V_D = \oint p_{cyl} \cdot \quad V$$

RESULTS AND DISCUSSION

In this investigation, the performance and emission characteristics of a DI diesel engine are studied by using hydrogen enrichment. Without EGR, with 15% EGR and with 25% EGR the flow rate of hydrogen is set at 20 l/min[26-30].

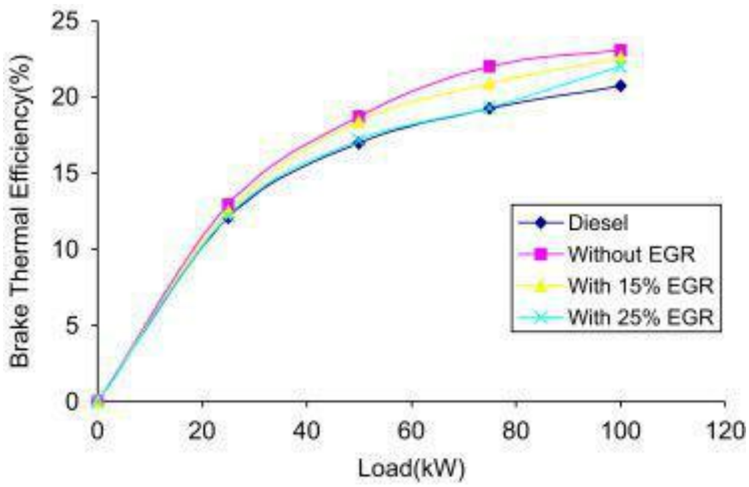

Table 2 : Brake thermal efficiency

The reduction in SEC is due to the operation of hydrogen-fueled engine at leaner equivalence ratio.

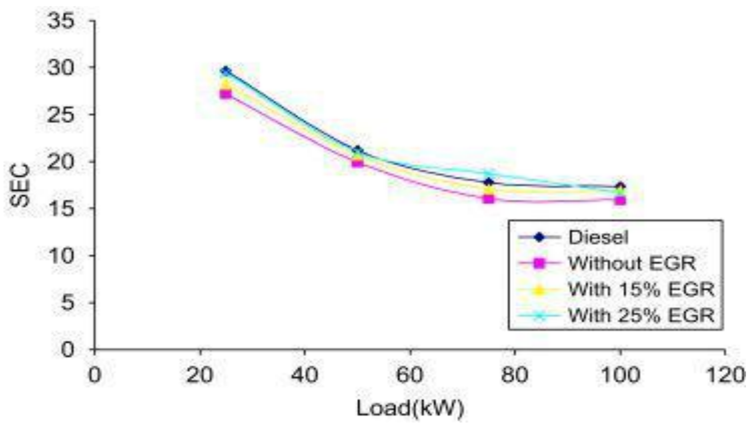

Table 3 : Specific Energy Consumption

NO*x* emissions in this study were very high compared to the levels expected in future emissions regulations. In future work, we will investigate the effect of exhaust gas recirculation (EGR) on the combustion and emissions of the supercharged producer gas–diesel dual-fuel engine, concentrating on NO*x*. We conclude with some remarks regarding the overall benefit of H2ICEs and possible future work[28-30].

CONCLUSIONS

There are excellent prospects to achieve very satisfactory S.I. engine operation with hydrogen as the fuel.The question of whether hydrogen can be obtained abundantly and economically remains yet to be answered satisfactorily..There is a need to give a greater attention to heat transfer. Also, hotter water jacket temperatures than normally employed for gasoline operation are needed for lean operation. Cooler temperatures need to be employed, however, for high loads with hydrogen and to avoid uncontrolled preignition.Resort to catalytic methods to reduce exhaust NOx emissions and any unconsumed hydrogen. Both of these components of the exhaust gas tend to be very low in concentration, especially for lean mixture operation. There are also excellent prospects to enhance the combustion process within the engine cylinder through the suitable provision of catalytic surfaces.In general it is concluded that hydrogen operated dual fuel engine shows an improvement in performance and reduction in emissions except NOX which can be controlled effectively with selective catalytic reduction technique which is well suited for hydrogen–dual fueled engines.

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