Journal of Advanced Research (2015) **6**, 819–826

Cairo University

Journal of Advanced Research

ORIGINAL ARTICLE

Performance and emission characteristics of the thermal barrier coated SI engine by adding argon inert gas to intake mixture

T. Karthikeya Sharma *

Department of Mechanical Engineering, NIT Warangal, AP, India

A R T I C L E I N F O

Article history:
Received 3 April 2014
Accepted 19 June 2014
Available online 26 June 2014

Keywords:
SI engines
Inert gas
Thermal barrier coating
Argon gas

A B S T R A C T

Dilution of the intake air of the SI engine with the inert gases is one of the emission control techniques like exhaust gas recirculation, water injection into combustion chamber and cyclic variability, without scarifying power output and/or thermal efficiency (TE). This paper investigates the effects of using argon (Ar) gas to mitigate the spark ignition engine intake air to enhance the performance and cut down the emissions mainly nitrogen oxides. The input variables of this study include the compression ratio, stroke length, and engine speed and argon concentration. Output parameters like TE, volumetric efficiency, heat release rates, brake power, exhaust gas temperature and emissions of NO_x, CO_2 and CO were studied in a thermal barrier coated SI engine, under variable argon concentrations. Results of this study showed that the inclusion of Argon to the input air of the thermal barrier coated SI engine has significantly improved the emission characteristics and engine's performance within the range studied.

Introduction

IC Engine has become an indispensible prime mover for use in transportation and agriculture sectors, because of this environmental protection from the toxic emissions of IC gained researchers interest. International emission regulations ratified in recent years have imposed more rigorous limits on engine emissions and fuel consumption.

Several New combustion techniques have been developed to meet the emission regulations, and to improve engine performance. Some of the techniques deal with the recirculation of the exhaust gasses to improve the combustion process, usage of fuel blends, varying stroke length and compression ratio, after treatment devices like catalytic converters to convert NO_x and CO into non-toxic gasses before they released into atmosphere, injecting water into the combustion chamber of the engine [1].

Among SI engines emissions NO_x are the most dangerous pollutants. Main oxides of N_2 are NO and NO_2. High combustion temperatures are responsible to the generation of NO and NO_2. Many other oxides like N_2O_4, N_2O, N_2O_3, N_2O_5 are also formed in low concentration but they decompose spontaneously at ambient conditions of NO_2. The maximum NO_x l evels are observed with A:F ratios of about 10% above

* Mobile: +91 9912194512.
E-mail address: karthikeya.sharma3@gmail.com.

Peer review under responsibility of Cairo University.

ELSEVIER | Production and hosting by Elsevier

2090-1232
http://dx.doi.org/10.1016/j.jare.2014.06.005

stoichiometric. Oxides of nitrogen and other obnoxious substances are produced in very small quantities and, in certain environments, can cause pollution, while prolonged exposure is dangerous to health.

Combustion duration plays a significant role in NO_x formation within cylinder. NO_x highly undesirable, because it reacts to the atmosphere to form ozone and causes photochemical smog. NO_x is mostly created from nitrogen (N_2) of air. Sometimes the fuel contains nitrogen in compound form, for example NH_3, NC, HCN [2].

There are a number of NO_x control technologies that have been developed for SI Engines such as modified combustion to suppress NO_x formation; they are Low excess air operation, off-stoichiometric combustion and exhaust gas recirculation. Several exhaust gas treatment techniques are available, but they are costly.

The power gain and (or) TE have to be castigate with these methods. The promising approach to reduce NO_x emissions form a SI engine is to replace a small percentage of N2 in the intake air with an inert gas.

It was found that the CO_2 of the emissions in the EGR technique has only a small effect on the emissions as it is having low specific heat value [3].

In this study Argon gas having a specific heat ratio (C_p) of 1.6 at ambient temperature is considered to compensate the low C_p of the CO_2. It was considered that the C_p of added Ar and replaced N_2 are equal, why because as the specific heat ratio of the mixture increases the cylinder peak pressure also raises and it occurs at prior crank angles [4].

To reduce bsfc in cylinder heat rejection and to improve TE adopting higher compression ratios are a usual practice in IC engines. Increase in thermal and mechanical stresses is the result of both the cases. According to the second law of thermodynamics TE of an IC engines increases by insulating the Combustion chamber of the engine. Insulation of the engine combustion chamber enhances the durability of the engine at elevated temperatures [5].

Literature reviews reveal insulation of the engine combustion chamber reduces heat rejection, improves TE and increases energy availability in the exhaust. But some researchers reported that they observed no considerable improvement in TE [6,7]. Different composites like SiCa, silicon nitride, Al, $MgSiO_2$ and other ceramic materials were used in Low hear rejection engine concept [8].

Because of this, it is the main destine of the present study to probe in detail the effects of argon gas as an intake air diluting gas of the engine to analyze the performance and emissions. The present study was performed on a single cylinder, port fueled, 4 stroke SI engine whose pistons were coated with $MgZrO_3$ (with a thickness of a 320 μm) and NiCrAl (over a thickness of 160 μm) bond coat. $CaZrO_3$ was used to coat cylinder head and valves. The aim of the present work is to investigate the thermodynamics properties of the intake gas mixture with added Ar, the effects of inclusion of argon on the output parameters of the engine and on the emissions, and heat release rate.

Experimental

A four stroke engine with modified intake to admit the preset concentrations of argon and air ($O_2 + N_2$) was used. This section deals with the apparatus used for the experiments and its procedure.

Engine experimental apparatus

A mono cylinder port fuel, 4 stroke and water cooled SI engine coated with $MgZrO_3$ and NiCrAl was used in the present study. $CaZrO_3$ was coated for the cylinder head and valves of the engine in the present work. An engine having the facility to add Ar gas up to 15% of the intake air was used in the present work. The test rig built has the capability to vary the argon concentration by keeping the oxygen concentration in the intake air as constant (i.e. 21% by volume), this was achieved by adding one oxygen cylinder to the system. The nitrogen gas is replaced by the argon gas in the intake air.

SmartTrak 100 digital flow meter was used to measure Ar flow rate in terms of volume. XFM Stainless steel Multi-drop capability RS-232/RS-485, profibus DP digital thermal mass flow meter was used to measure the air rate of flow. WITT MM-2 K pressure fluctuation free gas mixture has been used to mix the argon and oxygen in required concentrations. Silicon chip fuel mixture display system has been used to control the air fuel ratio, and it consists of Exhaust Gas Oxygen (EGO) sensor which is kept in the exhaust system and reads the exhaust gas continuously. Based on the results it monitors the air–fuel ratio by generations corresponding to output voltages. Engine Management system continuously reads this information and adjust the air–fuel mixture to provide maximum power and low emissions. Brief technical data are shown in Table 1.

Gasoline with 95 octane number, carburetor under full throttle opening and an ignition timing of 22° BTDC was used for the experiments. A Kistler model 6005 Quartz high pressure engine combustion sensor was used to measure the engine cylinders combustion pressure.

A PicoScope 4423 oscilloscope, 2000 A current clamp, 60 A current clamp 4 channel digital oscilloscope was used to measure and record various signals. Oscilloscope is fed with the amplified signals from the pressure sensor and degree marker. PicoScope is fast and accurate enough in the measurement, storing and analysis of high-speed phenomena. The input signal could be stored at the rate of up to 1500 MHz. Five sets of wave forms can be saved and fed to personal computer for computational analysis.

Table 1 Engine specifications.

Engine specifications	
Number of cylinders	1
Bore	95.12 mm
Stroke	71.5 mm
Displacement volume	1297 cc
Maximum speed	3500 rpm
Max. Cylinder pressure	130 bars
Compression ratio	8 Constant
Ignition timing, deg. BTDC	22
Cooling system	Water cooled
Valve arrangement	Two vertical over head valves
Max power	6.76 kW @ 3500 rpm
Max torque	18.7 N m @ 2600 rpm