DETERMINATION OF GENERAL EFFICIENCY OF SPARK IGNITION ENGINE WITH STRATIFIED CHARGE WITH DIRECT FUEL INJECTION

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Abstract

Designers of gasoline engines are faced with higher and higher requirements as regards ecological problems and increase in engine efficiency at a simultaneous decrease in fuel consumption. Satisfaction of these requirements is possible due to recognition of the phenomena occurring inside the engine cylinder, choice of suitable optimal parameters of the fuel injection process, and determination of geometrical shapes of the combustion chamber and piston head. The paper presents analysis of increasing in general efficiency of a GDI (Gasoline Direct Injection) engine in dependence on the quality of the stratified mixture and range of loading. For determination of total efficiency of a Gasoline Direct Injection engine test bed investigations were carried out with the aim to determinate the speed and load characteristics of the investigated engine on these basis the total efficiency of a GDI engine can be determined.

1. Introduction

Designers of gasoline engines are faced with higher and higher requirements as regards ecological problems and increase in engine efficiency at a simultaneous decrease in fuel consumption. Satisfaction of these requirements is possible due to recognition of the phenomena occurring inside the engine cylinder, choice of suitable optimal parameters of the fuel injection process, and determination of geometrical shapes of the combustion chamber and piston head.

All these parameters influence significantly improvement of gasoline engine performance and improve their efficiency. Increase of efficiency is connected, first of all, with the change in fuel supply, it means a proper regulation of fuel – air mixture in dependence on the rotational speed and load; hence, combustion of stratified mixtures in a gasoline engines with direct fuel injection is essential for increase in efficiency with a simultaneous decrease in emission of toxic components of exhaust gases and fuel consumption.

Such a kind of supply systems show that, apart from combustion of very lean mixtures a gasoline engine with direct fuel injection possesses many other advantages, i.e.:

- fuel consumption comparable with other engines with self – induced ignition,
- greater power than in other spark ignition engines with multi – point fuel injection.

Engine constructors aim, first of all, at increasing the value of total efficiency, and not only of one of the constituting partial efficiencies; hence a thorough analysis of the above mentioned factors decissive for its real value is justified.

2. Investigation object

A roller chassis test bed equipped with a water, electrically controlled brake, whose maximal moment is 180 [Nm] was adopted for a test bed for determination of speed and load characteristics of a Mitsubishi engine type 4G93GDI of 1834 cm^3 capacity.

The scheme of the measurement test bed for determination of speed and load characteristics of the investigated engine was given in *Fig.1*.

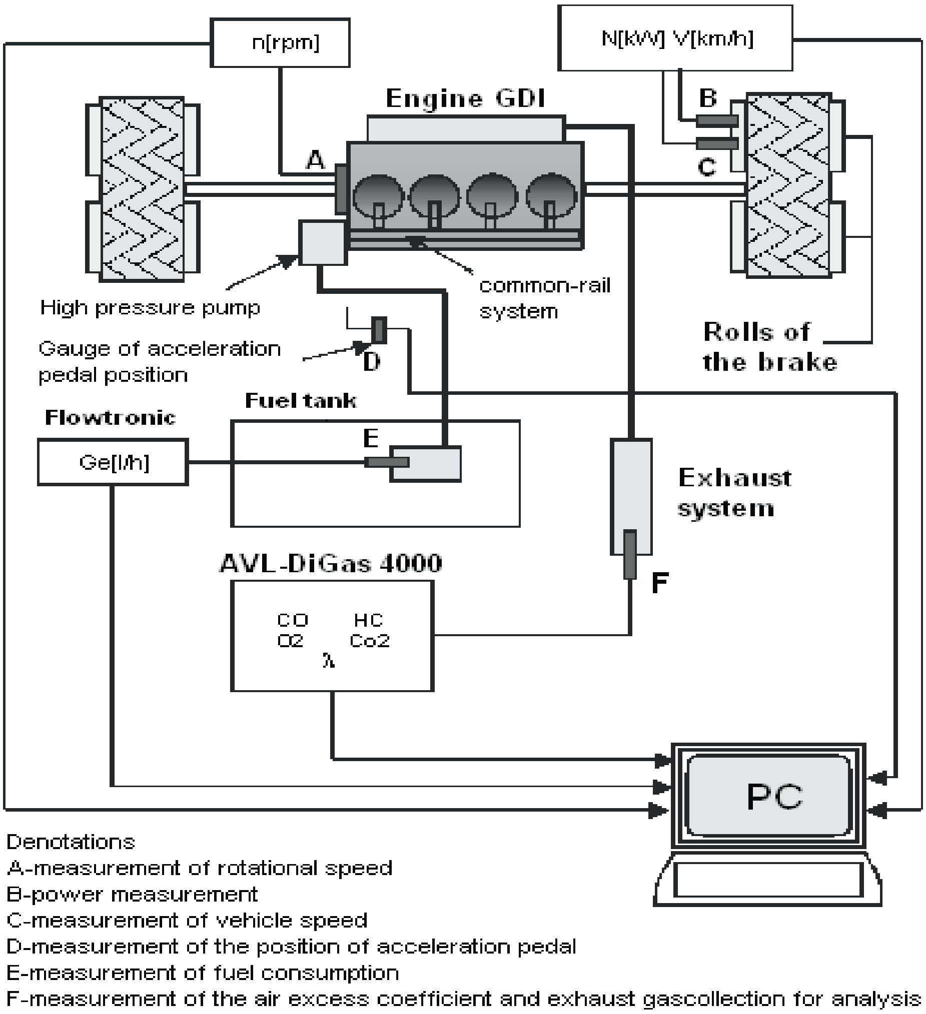

Fig. 1. The scheme of the measurement test bed

The system was equipped with a vehicle speed meter V [km/h] and power on wheels [kW].

The system for fuel consumption measurement was equipped with apparatus of the type Flowtronic, measuring fuel consumption per hour Ge [l/h], connected to the fuel pump located in the fuel tank.

All measurement systems were integrated with the central measurement computer mounted on the test bed for precise determination of all possible data for a given rotational speed and load of the investigated engine.

3. Determination of total efficiency on the basis of test bed investigation results

With regard to considerable decrease in fuel consumption per hour and per unit within the rotational speed from 750 - 2700 [rpm] caused by engine work in the mode of stratified fuel-air mixture ($\lambda \cong$ 1.5-2.1 in dependence on engine rotational speed an load) the diagrams were to be complemented by an additional characteristics of fuel consumption per unit. With this aim in mind diagrams of fuel consumption per unit in the same range of rotational speed 750 – 2700[obr/min] were drawn in such a way as for an engine working on homogeneous mixture (($\lambda \cong 1$). In consequence of it the value of fuel consumption per unit does not show the characteristic jump from one mode of work to the other.
Fig. 2-7 show traces of changes of fuel consumption per unit and total efficiency of GDI engine in function of rotational speed.

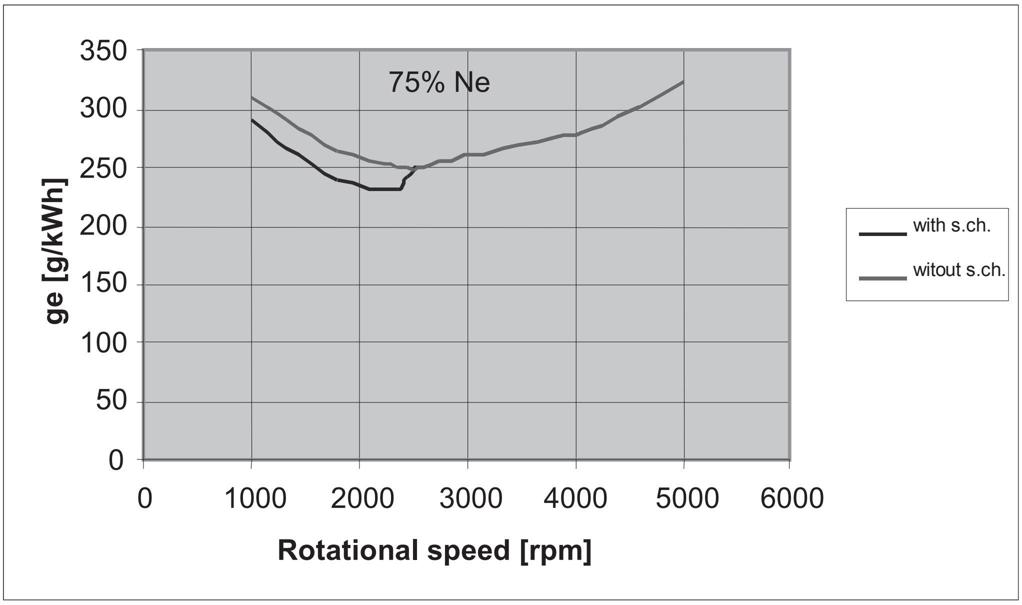

Fig. 2. Relation of fuel consumption per unit in function of engine rotational speed for 3/4 rated power

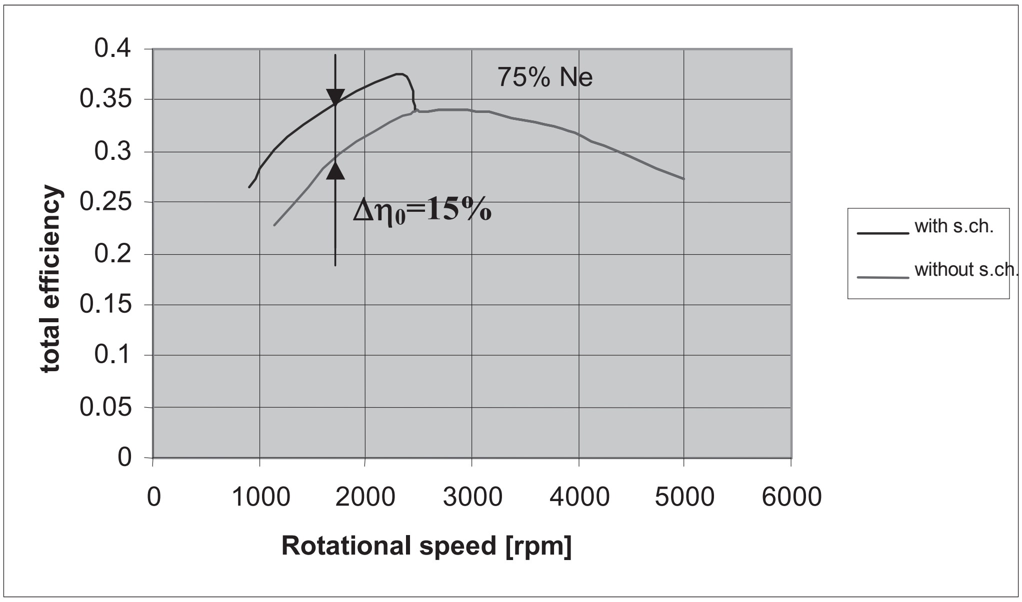

Fig . 3. Relation of totall efficiency of the engine η_0 i function of engine rotational speed for 3/4 rated power

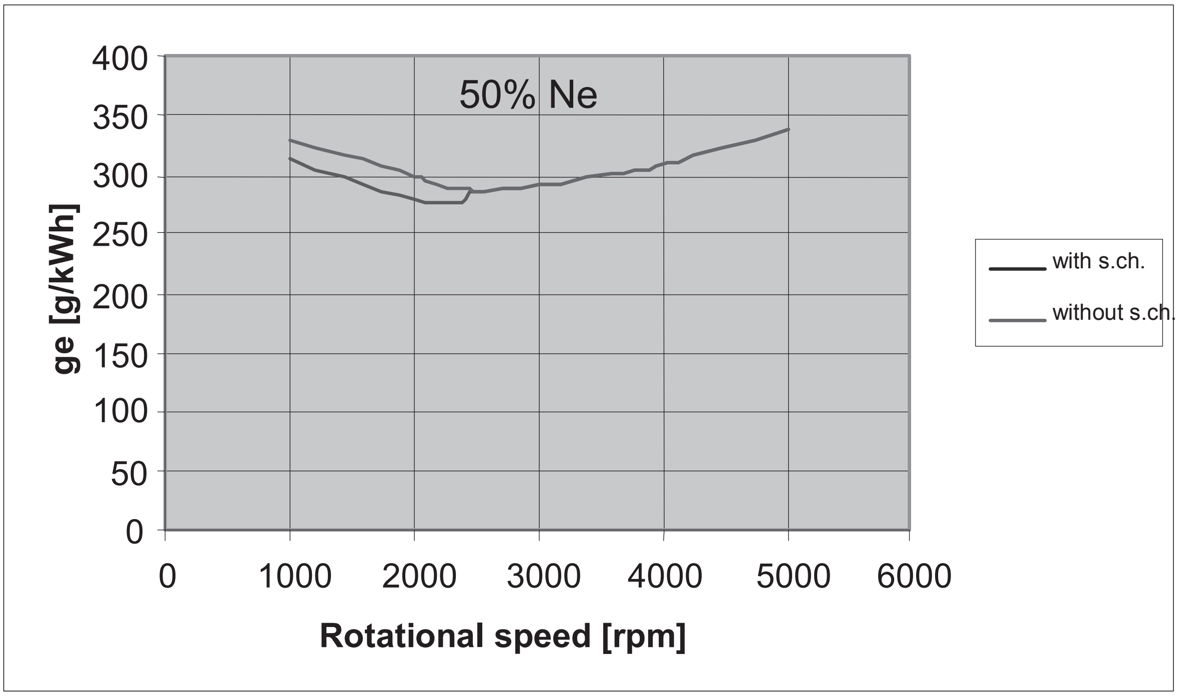

Fig. 4. Relation of fuel consumption per unit in function of engine rotational speed for 1/2 rated power

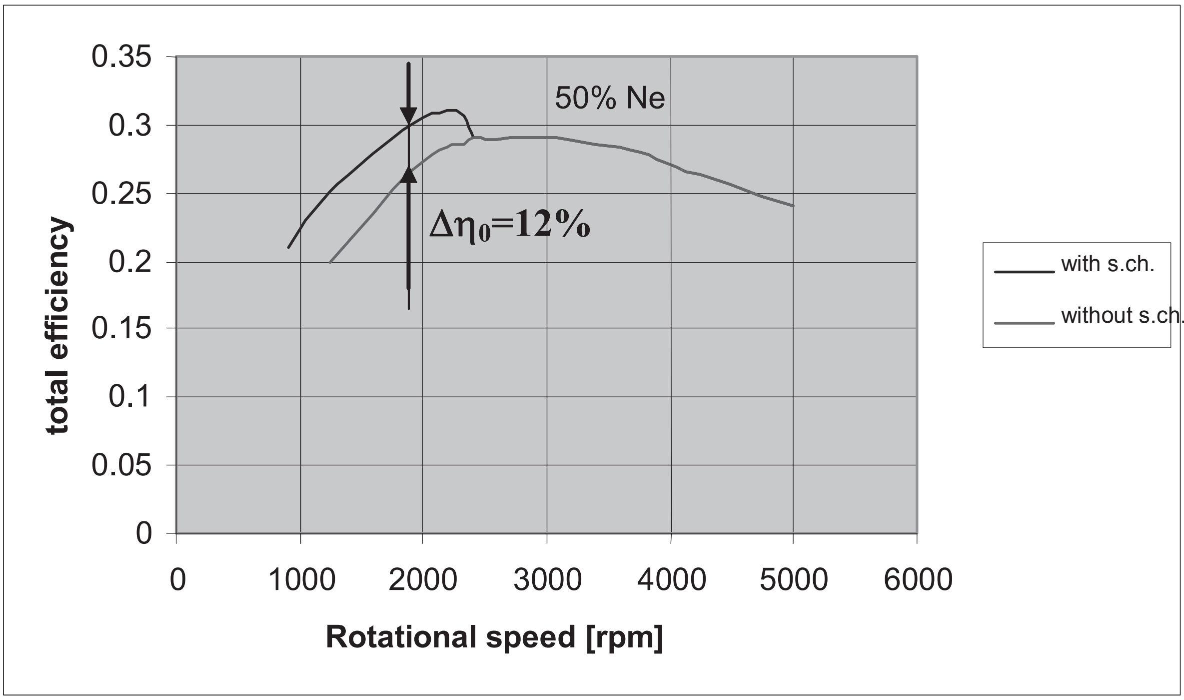

Fig. 5. Relation of totall efficiency of the engine η_0 i function of engine rotational speed for 1/2 rated power

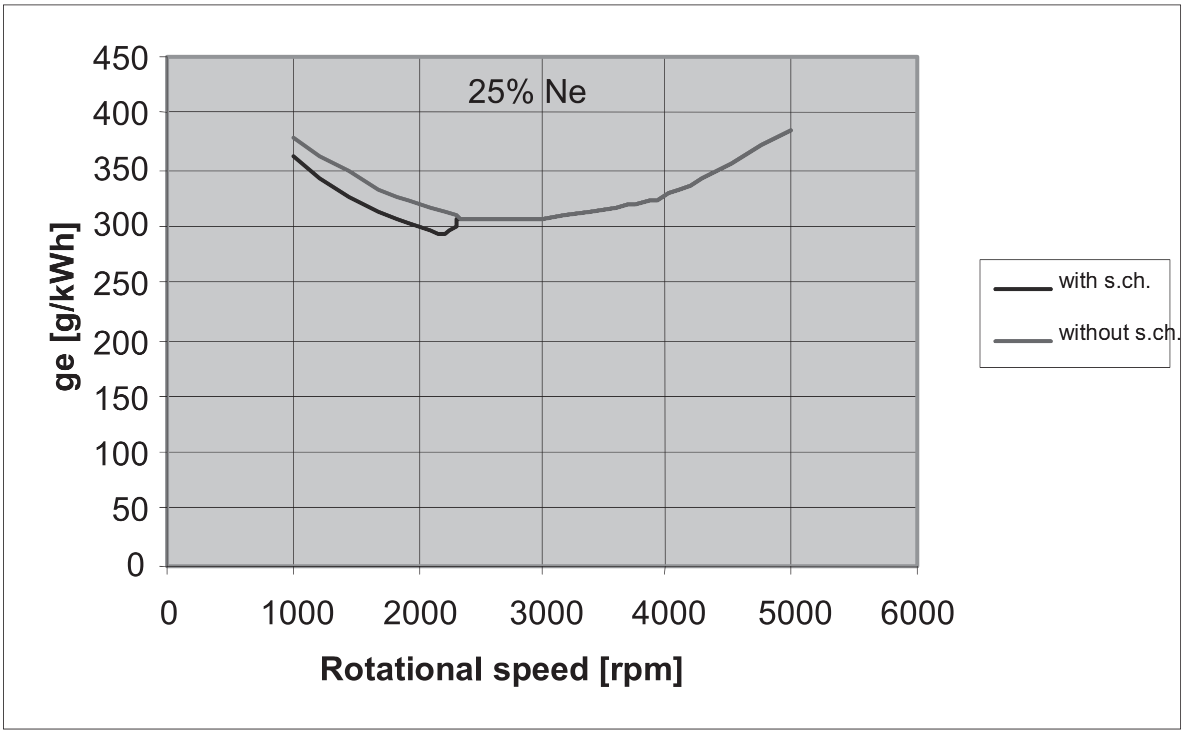

Fig. 6. Relation of fuel consumption per unit in function of engine rotational speed for 1/4 rated power

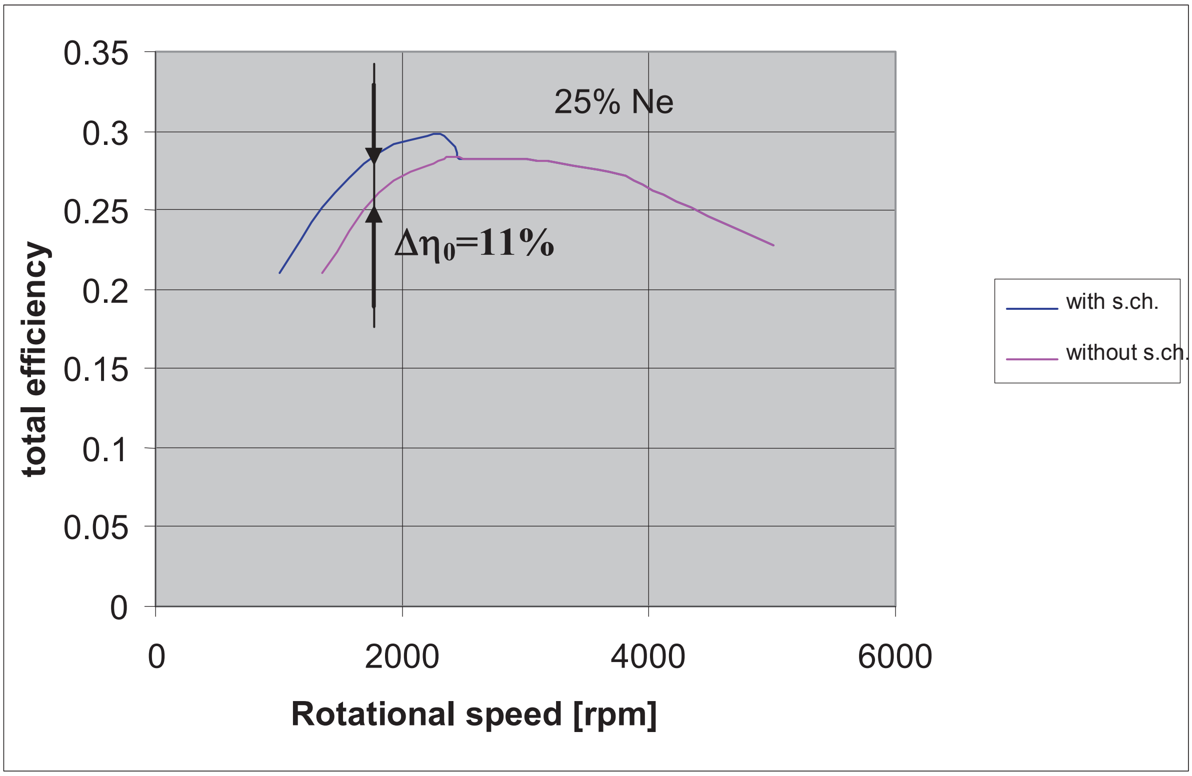

Fig. 7. Relation of totall efficiency of the engine η_0 i function of engine rotational speed for 1/4 rated power

4. Discussion

1. A considerable increase in total efficiency of the investigated direct gasoline injection engine about 17% in determined rotational speed during work on stratified mixtures (injection during compression stroke) in effect a fuel consumption decrease per unit and per hour by obout 17%.
2. The value of the coefficient of aie excess during work on heterogeneous mixture increases to the value $\lambda \cong 2.2$.
3. Stratifications of the charge depends, first of all, on the rotational of the engine and its load and remains on this level up to about 2700 [rpm].
4. Characteristics moment of transition from the engine work on heterogeneous mixture to work on homogeneous mixture is noticeable in form of a rapid jump of fuel consumption per unit by about 60 [g/kWh] on all characteristics of partial powers respectively for full power, 3/4, 1/2 and 1/4 of the rated power.
5. During work on idle gear a decrease in the rotational speed to about 600 [rpm] is nociceable, in effect a fuel consumption decrease on idle gear.
6. The range of rotational speeds where the total efficiency increase is within the range 600-2700 [rpm] in dependence on engine work conditions.

5. References

[1] Sendyka B., Cygnar M., Analysis of behaviour of the fuel stream in a gasoline direct injection engine, KONMOT-Materiały konferencyjne, Silniki spalinowe, t.2, KONMOT, Pasym, maj 2002.

[2] Han Z. Reitz R.D., Effects on Injection Timing on Air Fuel Mixing in a Direct Injection Spark Ignition Engine, Gasoline Direct Injection Engine SAE International Congress, Detroit, 2000.

[3] Gasoline Direct Injection Engine, Mitsubishi Engine, Technical Information, Japan, 1996.
Gasoline Direct Injection Engine SAE International Congress, , Detroit, 2000.

[4] Heywood J.B., Internal Combustion Engine Fundamentals, McGraw-Hill Book, New York, 1988.

[5] Karl G., Analysis of a Direct Injected Gasoline Engine', SAE 970624 International Congress &Exposition, USA, Feb 1997.

[6] Tomoda T., ‚Development of Direct Injection Gasoline Engine – Study of Stratified Mixture Formation, SAE 970625 International Congress &Exposition, USA, Feb 1997.

[7] Kume T., Combustion Control Technologies for Direct Injection SI Engine, SAE 960600 International Congress &Exposition, USA, Feb 1997.

[8] Ohsuga M., Mixture Preparation for Direct – Injection SI Engine SAE 970542 International Congress &Exposition, USA Feb 1997.

[9] Harada J.,Development of Direct Injection Gasoline Engine SAE 970540 International Congress &Exposition, USA, Feb 1996.

[10] Y. Iwamoto Y., Development of Gasoline Direct Injection Engine, SAE 970541 International Congress &Exposition, USA, Feb 1997.