

## Theoretical Investigation of Influence of Compression Ratio on Performance And Emissions of Spark Ignition Engine.



### Engineering

KEYWORDS : SI engine, compression ratio, emission, VCR engine.

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### ABSTRACT

*Fuel consumption and emissions is one of the major challenges in the automotive industry, so that need to improve the performance characteristics of the engine. For improving the performance of the SI engine, compression ratio below detonating values is a good option. The variation of compression ratio affects engine emissions as well as performance. So compression ratio is the important design variable to deal with effective performance of the engine. To enhance the performance and reduce emissions, optimal compression ratio for SI engine should be selected. The paper is focused on influence of compression ratio on performance of and emissions of SI engine.*

### INTRODUCTION :

Energy is an essential component towards the technological advancement of any country. The primary resources for the development of any country are power generation, industries and transportation. Even the demand of the fossil fuels has increased due to more need of transportation so reserves of these fossil fuels are limited and going to be exhausted in the next coming decades. The vehicles running on gasoline fuel emits gases like unburned HC, CO, CO<sub>2</sub>, NO<sub>x</sub> and that are polluting the environment. So, fuel and emissions are major challenges in the automotive industry. For high engine efficiency and less emissions lot of engineering research has done. The major challenges in the automotive industry are improving engine efficiency by reducing the fuel consumption and reducing the engine emissions and meet the emissions standards. The search for an engine that will produce minimum emissions and maximize fuel efficiency and economy has become the major challenges for the development of the engine. For improving the engine efficiency for SI engine, compression ratio below detonating values is a good option. Even, variation in compression ratio is good option for reducing the engine emissions and improving the engine performance. Increasing compression ratio for SI engine increases the brake power and this due to increase in brake torque at high compression ratio. Increase in compression ratio induces greater turning effect and more push on the piston produce more torque. [24] In the SI engine at high compression ratio produce better mixing and evaporation of the fuel which improve combustion efficiency. High combustion efficiency increases the engine efficiency and reduces emissions.

### LITRATURE SURVEY :

Lattimorea et al [1] 2016, Investigate effects of compression ratio and fuel on combustion and Particular matter emissions for direct ignition spark ignition engine (DISI) For DISI engine increasing compression ratio improved indicated efficiency. Addition of Ethanol to gasoline reduces No<sub>x</sub> and HC emissions and Butanol addition in gasoline reduced PM emissions. The variable compression ratio (VCR) engine improved efficiency, engine performance and reduced emissions and that meets emission standards.

Heywood et al [2] 2014, Investigate influence of compression ratio on SI engine efficiency by stimulation and experimentation. In the experimentation compression ratio varies from 8 to 13.4 and indicated efficiency, brake efficiency and gross indicated efficiency were calculated. The investigation concludes that by increasing compression ratio for SI engine increase the efficiency and for the compression from 10 to 13 relative increases of 5.1% for brake efficiency, 4.6% for gross indicated efficiency and 4.5% for net indicated efficiency. About two-thirds of this increase is

realized by the compression ratio increase from 10 to 11.5.

Hoeltgebaum et al [3] 2016, Investigate the fuel consumption, power output and emissions by changing the compression ratio. The compression ratio of the engine was changed by reconfiguring the mechanisms and increase in compression ratio reduces the engine emissions.

Gupta [4] states that modern engines have to satisfy the customer requirements for a high power output as well as for low fuel consumption and both objectives can be accomplished by a VCR engine.

Yamakawa et al [5] 2012, Study the effects of compression ratio on thermal efficiency of spark ignition engine. Investigation conclude that for SI engine, increase in compression ratio improve the thermal efficiency and power output. In the research work, the authors developed practical technologies to prevent output power loss due to knocking at full load, which is a critical issue for increasing compression ratio. These new technologies allowed increasing the compression ratio significantly and providing an equivalent torque level as a conventional engine. As a result, thermal efficiency has been improved at partial load.

Rajput [6] observes that a fixed compression ratio engine cannot meet the various requirements of high specific output. Hence, the development of variable compression ratio engines seems to be a necessity.

Yin et al [7] 2014, Investigate for SI engine increasing compression ratio and cooled EGR improve the thermal efficiency and anti-knock performance. Investigation also conclude that at high loads operations, thermal efficiency is higher than at low load operation and anti-knock performance at advanced combustion phasing improved. The heat transfer loss with cooled EGR also reduced. GT-Power code is used to calibrate the 1-D thermodynamic model of the engine and a knock prediction correlation considering EGR is developed and validated with the experimental data. In the experiment geometric compression ratio of the engine with EGR is optimized by a strategy combining artificial neural networks (ANNs) with genetic algorithm (GA) with the 1-D engine cycle simulations. Thermal efficiency for the engine also increased without affecting the performance of the engine.

Kramer et al [8] 2000, Study effect of compression ratio the combustion of pressure charged gasoline direct injection engine. The effects at full load by varying the compression ratio, knocking sensitivity, fuel consumption, emissions, stability of combustion and exhaust gas temperature at  $\lambda=1$  as well as for stratified

charge are investigated. For the S.I. engine with gasoline direct injection volumetric efficiency is reduced so stratified charge may be enhanced. The investigation concludes that higher compression ratio is advantageous for stable combustion for the engine. At full load, reduction in compression ratio leads to slightly higher full load torque and lower emissions, but results in deteriorated fuel consumption at part load and full load.

Muranaka et al [9] 1987, An analysis of the factors that limit the improvement in thermal efficiency at higher compression ratios was performed with both thermodynamic calculation and experiment. The results showed that the major factors were cooling loss and unburned fuel. Both of these factors increase with smaller swept volume, larger S/V ratio combustion chamber, and lower engine speed and load. These effects explain the observation that thermal efficiency peaks at relatively low compression ratio.

Gumbleton et al [10] 1976, Study the effects of compression ratio and influence of energy losses for higher octane fuels on engine efficiency was studied. A catalytic converter-EGR system and a manifold reactor-EGR emission control systems were evaluated on six vehicles. CID engines were tested at compression ratios of 7.4, 8.3 and 9.2:1. The catalytic converter-EGR system appears to provide equal to or improved energy utilization compared to the reactor-EGR control system.

De Souza et al [11] 1998, Evaluate the effects of compression ratio with EGR for 4 cylinder one liter capacity engine. The engine performance was evaluated on two compression ratio 8.9 and 9.6. The compression ratio is increased by reduction of the volume of combustion chamber and which improve overall engine performance. The emissions of ( $\text{NO}_x$ ) and carbon monoxide ( $\text{CO}_2$ ) reduced. There is a loss of torque and power and emission of unburned hydrocarbons (HC) increased and it depends on engine speed.

Porpatham et al [12] 2012, Investigate the performance, emission and combustion characteristics with different compression ratios. The investigation concludes that thermal efficiency for the engine is high at high compression ratio and compression ratio above 13:1 increased  $\text{NO}_x$ , HC and CO emissions. The reduction in the ignition delay and higher heat release rate with increase in compression ratio. Power and thermal efficiency reached their highest values with the compression ratio between 13:1 and 15:1 and the equivalence ratio between 1.08 and 0.95.

Iyer et al [13], 2008 Study the influence of ignition voltage, compression ratio and piston crown geometry on the performance of CNG gas engines.

By increasing the ignition voltage and compression ratio improve torque and power output for the CNG engine and 100 % reduction in HC emissions and 20% reduction in CO is seen in CNG compared to gasoline.

Siewert et al [14] 1993, Investigate the environment effects for 2.8 Liter CNG fuelled car with premixed charge of natural gas and with a base compression ratio 8.9:1. In the investigation engine emissions were evaluated at two compression ratio 11.5: 1 and 14:1. The results conclude that by increasing compression ratio with  $\text{CH}_4$  fuel, reduces the  $\text{NO}_x$  emissions and and increases the HC emissions

Crookes et al [15,16] Concluded that for biogas engine, increased in the compression ratio and reduction of  $\text{CO}_2$  from biogas engine can leads to high power and thermal efficiency.

Jiang and Yao [17], Study for biogas engine increasing compression ratio increased the energy for ignition which increased the

burning rate for biogas fuel and solved the problem of low velocity of burning. For biogas combustion velocity is slow, and that is why the whole combustion period is long, and the efficiency is low, and the reliability and economy is bad.

W.F Wardzinski et al [18], 1991, Designed a single cylinder research engine equipped with mechanism which will make it possible to adjust the compression ratio continuously during the engine operation. The variable engine ( V R/L E ) had a base engine of 650 cu.cm displacement in volume and for research purpose, only one of the cylinders was used. The change of compression ratio brings about the simultaneous changes of the lengths of all the piston strokes. The engine displacement volume becomes therefore smaller at higher compression ratios. The investigation concludes that the application of variable compression engine concept makes it feasible to adjust the compression ratio continuously during the engine operation. The expected tendency of efficiency improvement along with increasing the compression ratio is not significantly altered by the simultaneous changes of the engine cycle.

Motoyama et al [19], 1993 study the effects of higher compression ratio on fuel consumption and power output for 2 stroke motorcycle engine. The investigation concludes that for the compression ratio in the range from 6.6 to 13.6, fuel consumption can improve up to 1 to 3 % and power output can also improve by increasing the compression ratio. The maximum compression ratio for the engine is limited due to knocking tendency of the engine at high loads and that can be reduced by retarding ignition timing at full load.

Toshiyuki Suga et. al [20], 2000, Study the effects of compression ratio for natural gas fuelled 4 cylinder 1.6 liter Honda Civic GX. The engine was tested for the compression ratio in the range of 9.4 to 12.5 to take the advantage of high octane number of NG. Sequential MPI system should be adopted to control the A / F ratio within a narrow stoichiometry. Improved oxygen sensors to be developed with better electronic EGR system to reduce  $\text{NO}_x$ .

The engine is equipped with a Variable Valve Timing and Lift Electronic Control Technology ( VTEC ) to minimize the power loss and also to promote stable combustion for the gaseous fuel injection. A sequential multi-point manifold gaseous injection system is adopted to manage fuel control in the engine.

Results conclude for the optimum spark timing dedicated natural gas engine produce same power (3.7 kW) as the gasoline engine under 2000 rpm and maximum torque is lower than that of the base gasoline engine also NG powered Civic GX achieves vehicle emission of only 1/10th of Ultra-low emission vehicle (ULEV) levels for all three criteria pollutants.

Changup Kim et. al [21] in 1999. Study the emissions characteristics for two compression ratios ( 8.6 : 1 and 10.6 : 1 ) and various EGR ratios. The results conclude that at high compression ratio and lean burn method lead to the increase in the engine efficiency and decrease in  $\text{NO}_x$  &  $\text{CO}_2$  emissions. Increasing CR, which makes more stable combustion by higher combustion pressure, temperature and turbulence intensity, extended engine lean operation limit. At the same A/F, increasing the EGR (%) resulted in less  $\text{NO}_x$  emissions. However HC emission, engine efficiency and the production of ozone were not greatly affected by the change of EGR (%).

Kichrio Kato et.al [22], 1999, developed a dedicated engine to run on CNG. Toyota Camry, a 2.2 liter gasoline engine was modified to run on CNG. The results conclude that for CNG engine had a higher compression ratio than the base engine.

Takagaki et. al [23] ,1997 Study the effects of compression ratio on NOx and HC emissions on a single cylinder SI engine fuelled with natural gas. The engine was tested at different equivalence ratio, spark timing and for the compression ratio of 8 and 15 at constant throttle. Investigation concludes at wide open throttle increase in NO concentration with increasing CR when compared at constant spark timings. The relative effect of CR on NO emissions decreased as CR was increased. For part throttle at MBT timing, the measurements showed that as CR was increased, the NO emissions initially increased but then decreased. Increasing CR resulted in an increase in HC emissions when compared at constant spark timing.

The results were similar for both lean and stoichiometric conditions. For part throttle operation at MTB timing, HC generally increased with CR but reduced at the highest CR tested. At very advanced spark timing, HC emissions were found to decrease with established trends over the normal spark timing range. This result is possibly due to increasing exhaust temperatures which were measured with the advanced timing used.

#### CONCLUSION:

- For DISI engine increasing compression ratio improved indicated efficiency. The VCR engine improved efficiency, engine performance and reduced emissions and that meets emission standards.
- The variable compression engine concept makes it feasible to adjust the compression ratio continuously during the engine operation. Modern VCR engines produced high power output as well as for low fuel consumption.
- For SI engine, increase in compression ratio improves the thermal efficiency and power output. Engine knocking is also increased at full load and that can be prevented by developing the practical technologies.
- The compression ratio for the SI engine was changed by reconfiguring the mechanisms and increase in compression ratio reduces the engine emissions.
- For SI engine, increasing compression ratio and cooled EGR improve the thermal efficiency and anti-knock performance. At high loads operations, thermal efficiency is higher than at low load operation and anti-knock performance at advanced combustion phasing improved.
- For the S.I. engine with gasoline direct injection volumetric efficiency is reduced so stratified charge may be enhanced and higher compression ratio is advantageous for stable combustion for the engine.
- For the biogas fuelled SI engine thermal efficiency for the engine is high at high compression ratio and compression ratio above 13:1 increased NOx, HC and CO emissions.
- By increasing the ignition voltage and compression ratio for the CNG fuelled gasoline engine improve torque and power output. The 100 % reduction in HC emissions and 20% reduction in CO is seen in CNG compared to gasoline.
- For the biogas fuelled SI engine, increase in the compression ratio and reduction of CO2 can lead to high power and thermal efficiency.
- Increasing compression ratio and lean burn method for the SI engine improve thermal efficiency and reduces the engine emissions of NOx & CO2.

- For the two stroke motor cycle engine, increasing compression ratio improves power output and fuel consumption. The maximum compression ratio for the engine is limited due to knocking tendency of the engine at high loads and that can be reduced by retarding ignition timing at full load.

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