"Experimental study on effect of spark plug gap on combustible fuel & cbc fluctuation"

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Abstract: Cycle-by-Cycle(CBC) fluctuation is the major phenomenon observed in Spark ignited internal combustion engine, which limits the range of operating condition. The parameters affecting cycle-by-cycle fluctuation have been identified as Mixture Distribution, Mixture Homogeneity, Spark Intensity, Spark Timing, Spark Plug Location, Spark Plug Gap, Number of Spark Plugs, Swirl, Combustion Chamber Geometry, Compression Ratio, Equivalence Ratio, Load & Speed. It has not been possible to clearly pinpoint on each of these parameters & degree to which they effect on cycle-by-cycle fluctuations. The cycle-by-cycle fluctuations in the engine reduces the power out put, increases the engine roughness and emissions. The cycle-by-cycle fluctuation in SI engine has increased the attention to steady one of the parameter like the effect of Spark Gap on CBC fluctuation. The Experimentation is carried out on Four Stroke Single Cylinder Computerized Spark Ignition Engine. The results indicate the best operating spark gap & advanced spark angle, which will results in minimizing the cycle-by-cycle fluctuations and the overall engine performance is improved with better drivability.

Keywords: - CBC fluctuation, Spark plug Gap, Spark Advance Angle, SI engine, etc.,

I. INTRODUCTION

Recent developments in the automotive industry have shown a distinct tendency towards increasing fuel efficiency and reducing dangerous emissions like soot and nitrous oxides (NOx). The main reasons for this are depleting of fuel resources, environmental awareness regarding the ozone depletion and the global warming are becoming more and more stringent in almost all countries that put up higher demands in automotive researchers. [1]

Cycle-by-cycle variation in the pressure development within the cylinder of a spark ignition engine has long been recognized as a phenomenon of considerable importance. Several investigators have considered the overall nature of cyclic variability and its manifestation in the characteristics of spark-ignition engine combustion, with Young providing a good review. Many have considered specific contributors to cyclic dispersion. For example, variations in the spark process or its overall quality have been investigated while others have treated the impact of fluid motion-both bulk gas motion and the random fluctuations due to turbulence-on combustion variability. [2] Some investigators, such as Kantor and Daily have suggested that combustion variations may be largely chaotic in nature.

In a recent study, it was demonstrated that the variation in spark gap significantly leads to cycle-by-cycle variations in IMEP in a single-cylinder engine under conditions of load, and speed. The combustion process in a spark ignition (SI) engine consists of the spark discharge and inflammation, initial flame development, and propagation of the flame in the combustion chamber. However, this combustion process does not repeat identically for each cycle even under steady state operation. This cyclic variation in the combustion process is generally accepted to be caused by variations in the mixture motion, variation in spark gap, in the amounts of air and fuel fed into the cylinder and their mixing, and in mixing with residual gases and exhaust gas recirculation (EGR), especially in the vicinity of the spark plug. Pischinger and Heywood showed that cyclic variations in heat loss to the spark plug electrode also caused the cycle-by-cycle variation of combustion process. [3]

The cyclic combustion variations can be characterized by the pressure related parameters, combustion related parameters, and flame front related parameters. Although the pressure measurement is still one of the most useful tools for analyzing the cyclic combustion variation, the development of advanced techniques for the in-cylinder measurement of the flame initiation and propagation can lead to deeper understanding of the origin and impacts of cycle-by-cycle variation.

Cycle-by-Cycle variations in the combustion process are important for two reasons. They are,

1) Since the optimum spark timing is set to the average cycle, faster than average cycles have effectively over advanced spark timing and slower than average cycles have retarded timing, so losses in power proportional to efficiency results.

2) It is the extremes of the cyclic variations that limit engine operation. The fastest burning cycles with their over advanced spark timing are most likely to knock. Thus the fastest burning cycles determine the engine fuel octane requirement and limits compression ratio. The slowest burning cycles, which are retarded relative to optimum timing, are most likely to burn incompletely. Thus these cycles set the practical lean operating limit of the engine or limit exhaust gas recycle, which the engine will tolerate. [4]

Due to cycle-by-cycle variations, the spark timing and average air fuel ratio must always be compromises, which are not necessarily the optimum for the average cylinder combustion process. The variations in cylinder pressure have seen shown to correlate with variations in brake torque, which directly relate to vehicle drivability.

An example of the cycle-by-cycle variations in the cylinder pressure & crank angle are shown in the figure.

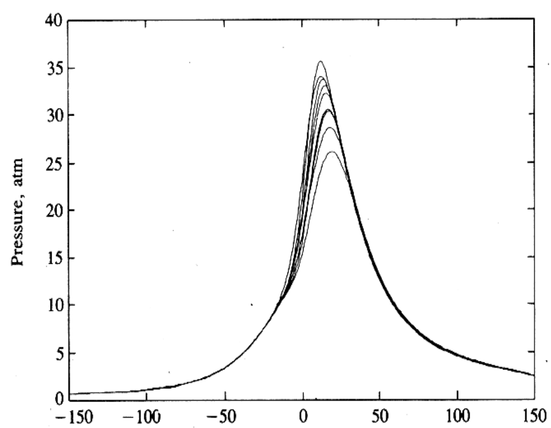
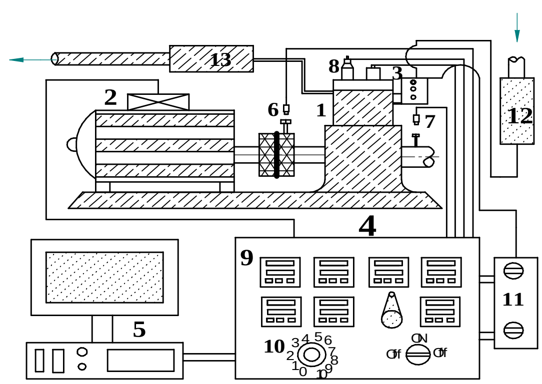


Fig.1, Pressure v/s Crank Angle Measurements for 10 consecutive cycles [4]



Figure, 2 Schematic diagram of experimental apparatus

1. Test engine, 2. Generator / Motor, 3. Pressure-transducer, 4. Controlling unit & data acquisition system, 5. Computer, 6. Speed sensor, 7. Advanced spark angle sensor, 8. Spark Plug, 9.Advanced spark angle controller, 10. Load Controller, 11. Fuel tank, 12. Air inlet analyzer, 13. Exhaust gas analyzer,

II. EXPERIMENTAL SET-UP AND PROCEDURES

The experimental apparatus schematically described in Figure 2, the single cylinder computerized spark ignited petrol engine is an electrically loaded, air-cooled engine, which is directly interfaced with computer. The different parameters like load, speed, Pressure, Temperature, & Spark advanced crank angle etc., are measured in the computer. The pressure variation during each cycle at different crank angle has been measured using piezo-electric pressure transducer, which is fitted at the top of the head by drilling a hole in to combustion chamber. The software supplied by the manufacturer gives the P-θ diagrams. The software also gives the indicated mean effective pressure values for the 25 numbers of cycles. We can also increase the number of cycles as per our requirement, but 25 cycles itself gives the repetitiveness in the readings. Hence the readings are taken only for 25 numbers of cycles.

The experimentation is carried out on the single cylinder spark ignited petrol engine having an off-centered single spark plug located near the intake valve. The advanced spark angle is varied by angle controller and varying the load on the generator, which is electrically loaded type, varies the load. The engine is operated for 20%, 35%, 50% & 70% rated loads with the spark plug gap 0.3 & the readings are tabulated for advanced crank angles of 12^0, 15^0, 18^0 & 20^0.

In the next step, the experimentation is conducted for different spark plug gaps like 0.4, 0.5, 0.6 & 0.64. For each spark plug the engine is operated for 20%, 35%, 50% & 70% rated loads & the readings are tabulated for advanced crank angles of 12^0, 15^0, 18^0 & 20^0. For all the spark plug gaps the experimentation is conducted for different advanced crank angles & for different loads. The readings are tabulated.

2.1 Co-efficient of variation in indicated mean effective pressure:

One important measure of cyclic variability derived from measured pressure data is the co-efficient of variation in indicated mean effective pressure. It defines the cyclic variability in indicated work per cycle. It has been found that the vehicles drivability problems usually results when COV_{imep} exceeds about 10%. It is given by

$$COV_{imep} = \frac{\sigma_{imep}}{Avg_{imep}} \times 100$$

Where, COVimep = Co-efficient of variation in IMEP, σ_{Imep} = standard deviation of IMEP for 'n' number of cycles, σ Avg_{imep} = Average of IMEP for 'n' number of cycles.

Table No. 1. **Engine Specifications.**

Sl.No.	Particulars	Details
1	Make	Greaves HSPPMK25
2	Type	4-Stroke, side valve, single cylinder, air cooled and horizontal shaft.
3	Bore mm	70.5
4	Stroke mm	66.7
5	Displacement	256 CC
6	Engine output	2.2 KW
7	Maximum Torque (Nm)	7 @ 3000rpm, 12.36 @ 1700rpm.
8	Cooling	Forced Air Cooling
9	C R	4.67
10	Dry Weight	26 Kg
11	Starting	Recoil Starter
12	Lubrication system	Splash type

13	Spark Plug & gap	MICO M45 Z8, 0.5 mm
14	Carburetor	Greaves 1320 up draught type float system
15	Muffler	Pepper pot type
16	Cylinder	Cast iron BS: 1452/17
17	Crank case	Cast Aluminum with separate oil reservoir
18	Connecting rod	Aluminum Alloy
19	Crank shaft	SG Iron
20	Ignition system	Electronic
21	Bearings on both sides	6305/C3 25x62x17 mm
22	Valve tappet clearance mm	Inlet: 0.15-0.2 Exhaust: 0.2-0.25

III. RESULTS AND DISCUSSION

3.1 Variation of COV_{imep} under the condition of Spark gaps of 0.3, 0.4, 0.5, 0.6, & 0.64 for 12^0, 15^0, 18^0 & 20^0 Advanced Spark angles at 20%, 35%, 50% & 70% Rated loads.

Advanced Spark angle	**Spark Gap**	**Rated Loads**			
		20%	**35%**	**50%**	**70%**
12^0	0.3	22.26	20.45	17.35	13.66
	0.4	21.76	19.48	15.45	12.65
	0.5	20.53	18.87	13.78	11.78
	0.6	19.37	17.22	12.34	8.57
	0.64	21.46	21.81	16.45	13.32
15^0	0.3	22.46	19.58	16.84	11.95
	0.4	20.89	18.49	14.95	10.52
	0.5	19.67	17.48	13.38	9.96
	0.6	15.12	14.57	11.14	6.55
	0.64	21.38	20.2	15.57	10.93
18^0	0.3	20.09	16.34	14.59	12.56
	0.4	19.02	15.53	13.34	10.23
	0.5	17.9	14.43	11.76	9.5
	0.6	11.78	11.45	9.45	5.78
	0.64	19.49	17.56	13.76	10.75
20^0	0.3	23.69	19.37	17.47	14.37
	0.4	21.67	18.47	14.57	11.34
	0.5	20.55	16.37	12.56	11.38
	0.6	19.57	14.67	11.38	9.56
	0.64	22.34	22.13	15.59	13.34

The above chart shows the percentage of COVimp for different spark gap at different spark advanced angle and at different loads.

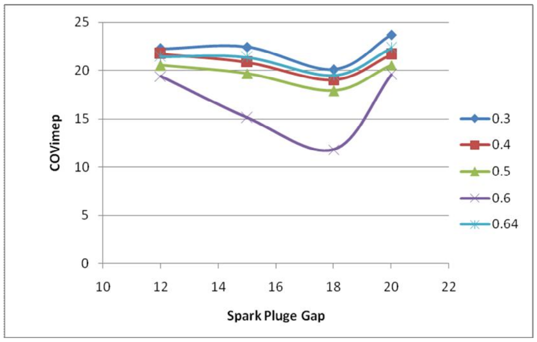


Fig.3 Variation of COVimep at Constant Load of 20% for 0.3, 0.4, 0.5, 0.6, & 0.64 Spark Gaps

From the above chart we can see that at 18 degree Spark Advance angle for load of 20% COV_{imep} decreased from 21.5% to 12.18% when we changed the Spark gap from 0.3 to 0.6mm. When the gap was increased to 0.64mm COV_{imep} again increased to 18.7%.

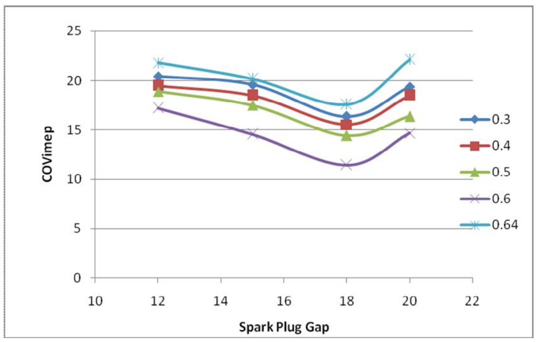


Fig.4 Variation of COVimep at Constant Load of 35% for 0.3, 0.4, 0.5, 0.6, & 0.64 spark gaps

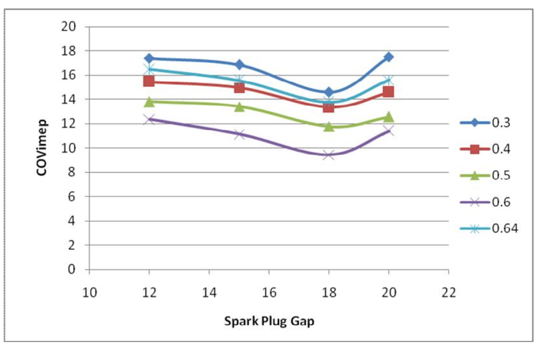


Fig.5 Variation of COVimep at Constant Load of 50% for 0.3, 0.4, 0.5, 0.6, & 0.64 Spark Gaps

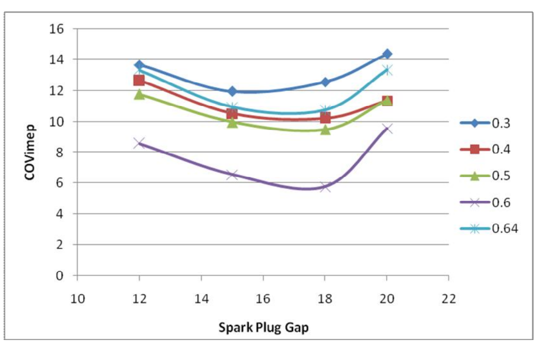


Fig.6 Variation of COVimep at Constant Load of 70% for 0.3, 0.4, 0.5, 0.6, & 0.64 Spark Gaps

At 18 degree Spark Advance angle for load of 35% COV_{imep} decreased from 18.5% to 12.26% when we changed the Spark gap from 0.3 to 0.6mm. When the gap was increased to 0.64mm COV_{imep} again increased to 16%.

At 18 degree Spark Advance angle for load of 50% COV_{imep} decreased from 14.73% to 12.1% when we changed the Spark gap from 0.3 to 0.6mm. When the gap was increased to 0.64mm COV_{imep} again increased to 13.56%.

At 18 degree Spark Advance angle for load of 70% COV_{imep} increased from 8.99% to 11.37% when we changed the Spark gap from 0.3 to 0.6mm. When the gap was to increased 0.64mm COV_{imep} again decreased to 9.49%. For this reason, the spark advance angle as to be increased by 1 or 2 degree to get minimum COVimep.

3.2 Variation of COVimep at Rated Loads of 20%, 35%, 50% and 70% for 0.3, 0.4, 0.5, 0.6, & 0.64 mm Spark Gaps at 12^0, 15^0, 18^0 & 20^0 advanced spark angles.

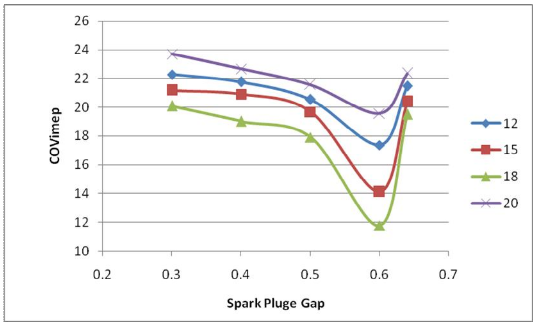


Fig. 7 Variation of COVimep at Constant Load of 20% for 0.3, 0.4, 0.5, 0.6, & 0.64 mm Spark Gaps at 12^0, 15^0, 18^0 & 20^0 advanced spark angles.

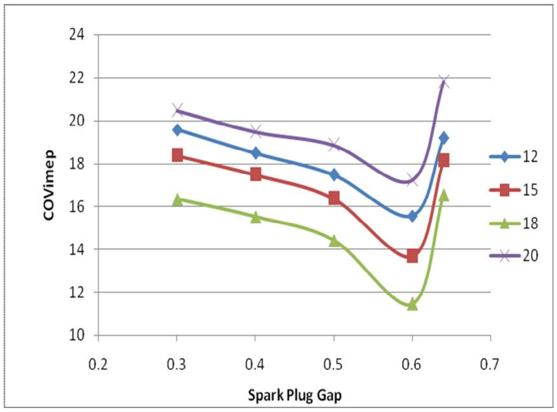


Fig. 8 Variation of COVimep at Constant Load of 35% for 0.3, 0.4, 0.5, 0.6, & 0.64 mm Spark Gaps at 12^0, 15^0, 18^0 & 20^0 advanced spark angles

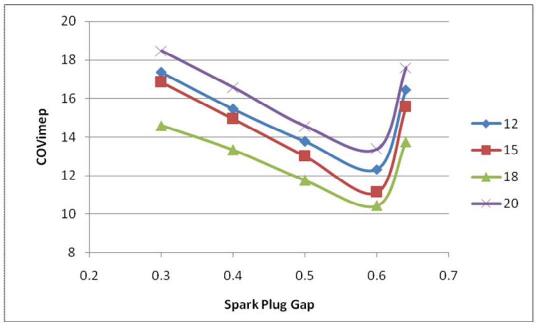


Fig. 9 Variation of COVimep at Constant Load of 50% for 0.3, 0.4, 0.5, 0.6, & 0.64 mm Spark Gaps 12^0, 15^0, 18^0 & 20^0 advanced spark angles

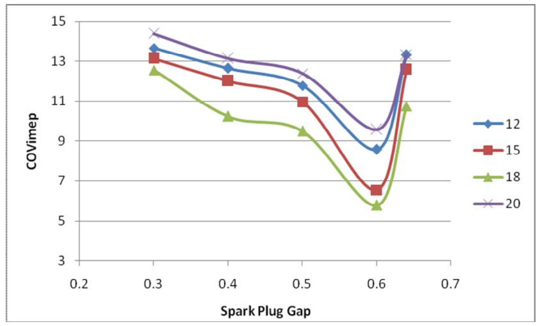


Fig. 10 Variation of COVimep at Constant Load of 70% for 0.3, 0.4, 0.5, 0.6, & 0.64 mm Spark Gaps at 12^0, 15^0, 18^0 & 20^0 advanced spark angles

From charts it can be found that minimum cyclic variation is between 2% and 4% has been observed at the Spark Advanced angle of 12^0, 15^0, 18^0 & 20^0, for all the loads at 0.6 mm spark gap compared to normal spark gap of 0.5 mm. The coefficient of variation of Indicated mean effective pressure is found to be with in the limit at spark gap of 0.6 mm for all the advanced spark angles compared other spark gaps, thus the spark gap of 0.6 mm is suitable to minimize the cycle by cycle fluctuation, this shows the increased combustion process.

IV. CONCLUSIONS

The coefficient of variation of Indicated mean effective pressure is minimum at spark gap of 0.6 mm at advanced spark angle of 18 deg and the same spark gap & advanced spark angle is suitable for reduce the CBC fluctuations.

The cyclic variation is between 2% and 4% has been observed at the Spark Advanced angle of 12^0, 15^0, 18^0 & 20^0 for all the loads at 0.6 mm spark gap compared to normal spark gap of 0.5 mm. The coefficient of variation of Indicated mean effective pressure is found to be with in the limit for spark gap of 0.6 mm 18^0at advanced spark angle to minimize the cycle-by-cycle fluctuation. This shows the increased combustion process and the drivability of the engine is found to be smoother.

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