Two Methods for improving Torque of a Diesel Engine in the low Speed Range

Speakers

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Introduction

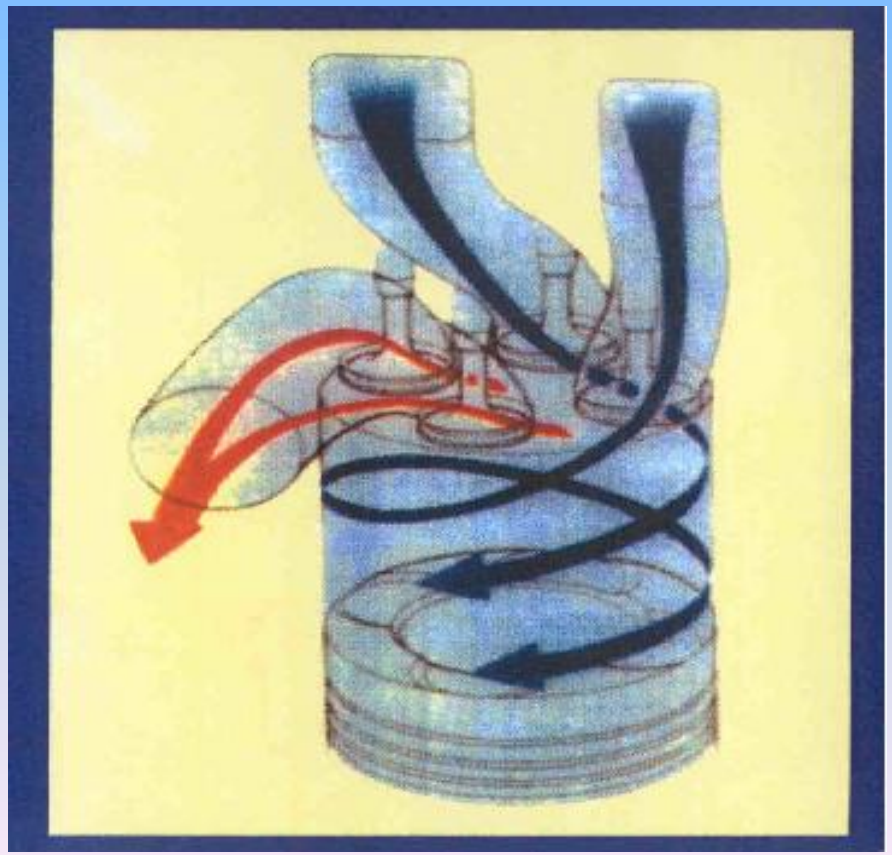
- Engines with high torque in the lower speed range are always desirable for better drivability and traction during acceleration.
- If fueling is increased to achieve high torque,the engine will emit high smoke disproportionately.

Two Methods for Improving Torque at Lower Speeds.

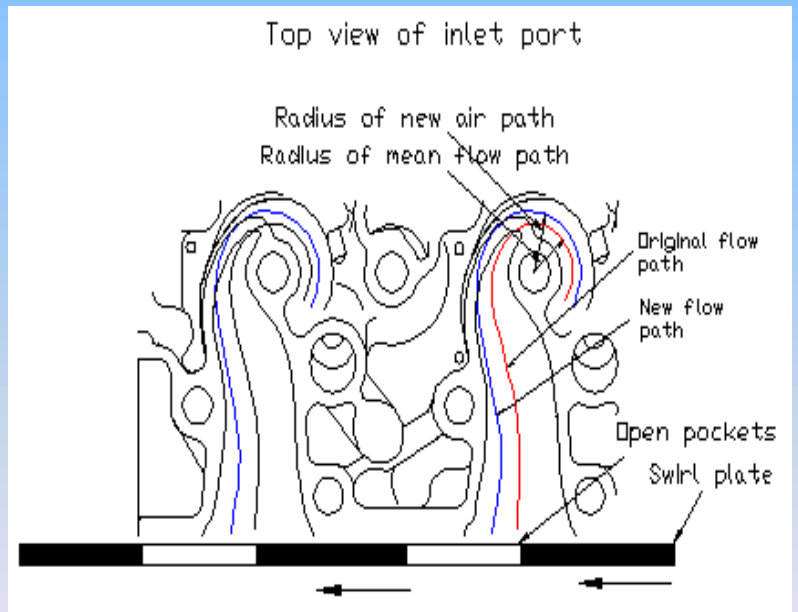
- **Method 1:**
  Improving Smoke In Lower Speed Range By Increasing Swirl Ratio- Variable Swirl Plate

- **Method 2:**
  Improving Air Flow Rate At Lower Speeds By Using Combined Charging System (CCS)

Method –1
Improving Smoke In Lower Speed Range By Increasing Swirl Ratio –Variable Swirl Plate



Change In Swirl By Partially Obstructing Entry To Inlet Port



The system – engine specification

Engine specifications

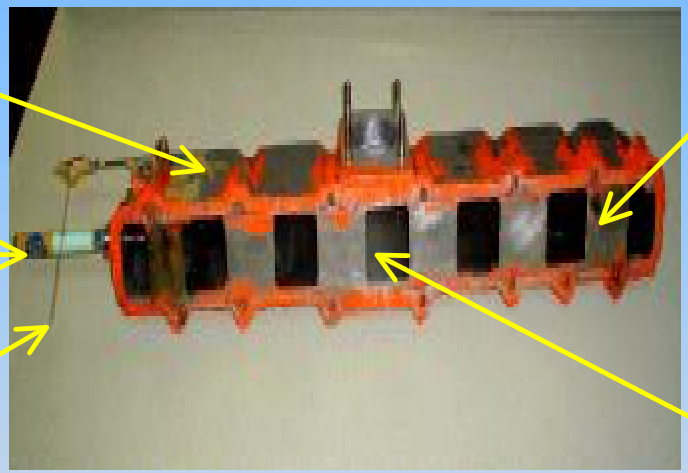
- 5.7 Liters Euro II, 122 kW
- Bore :104 mm
- Stroke :113 mm
- Turbocharged Inter-cooled Direct Injection Diesel Engine
- Helical ports

Swirl plate arrangement

Inlet manifold

Handle for movement

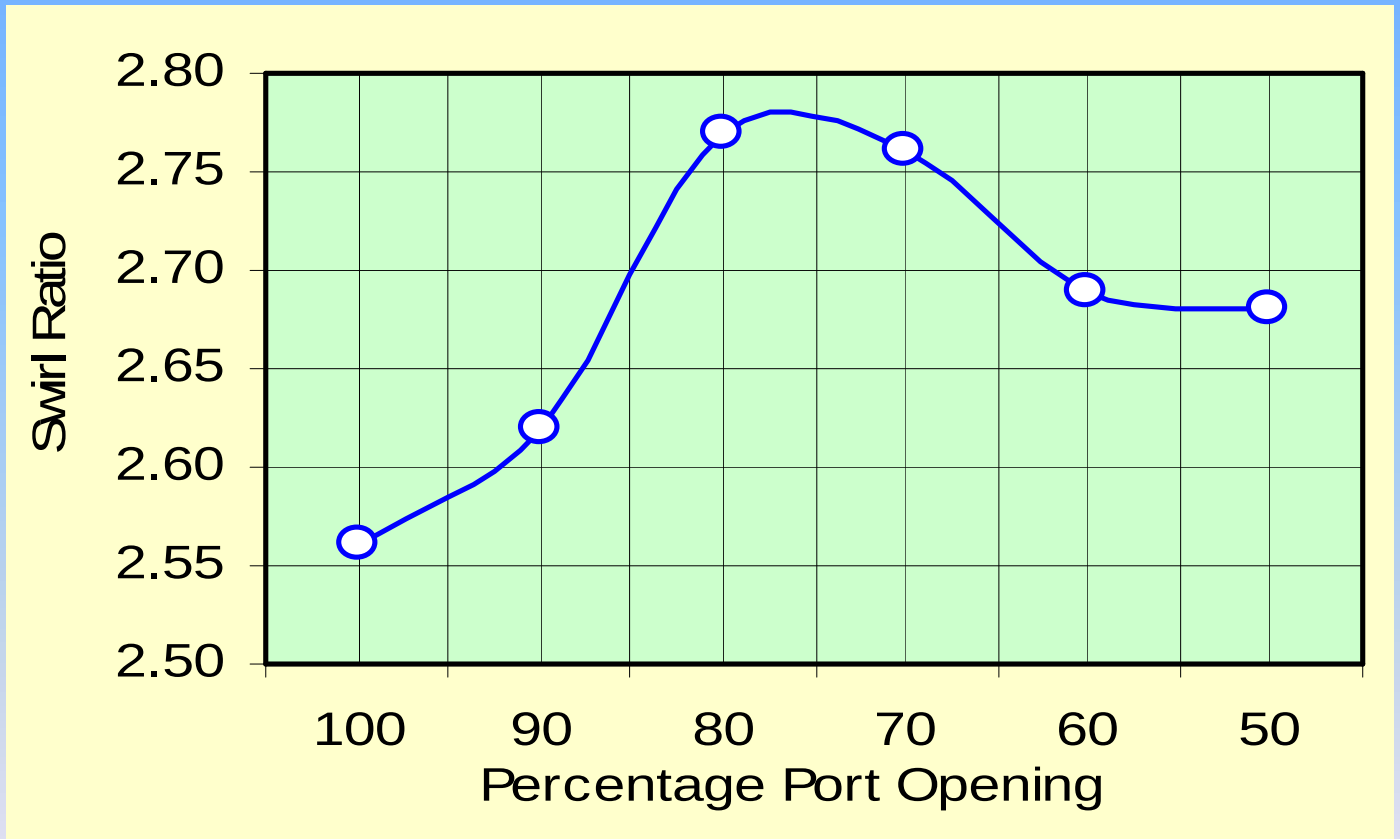
Needle for displacement measurement



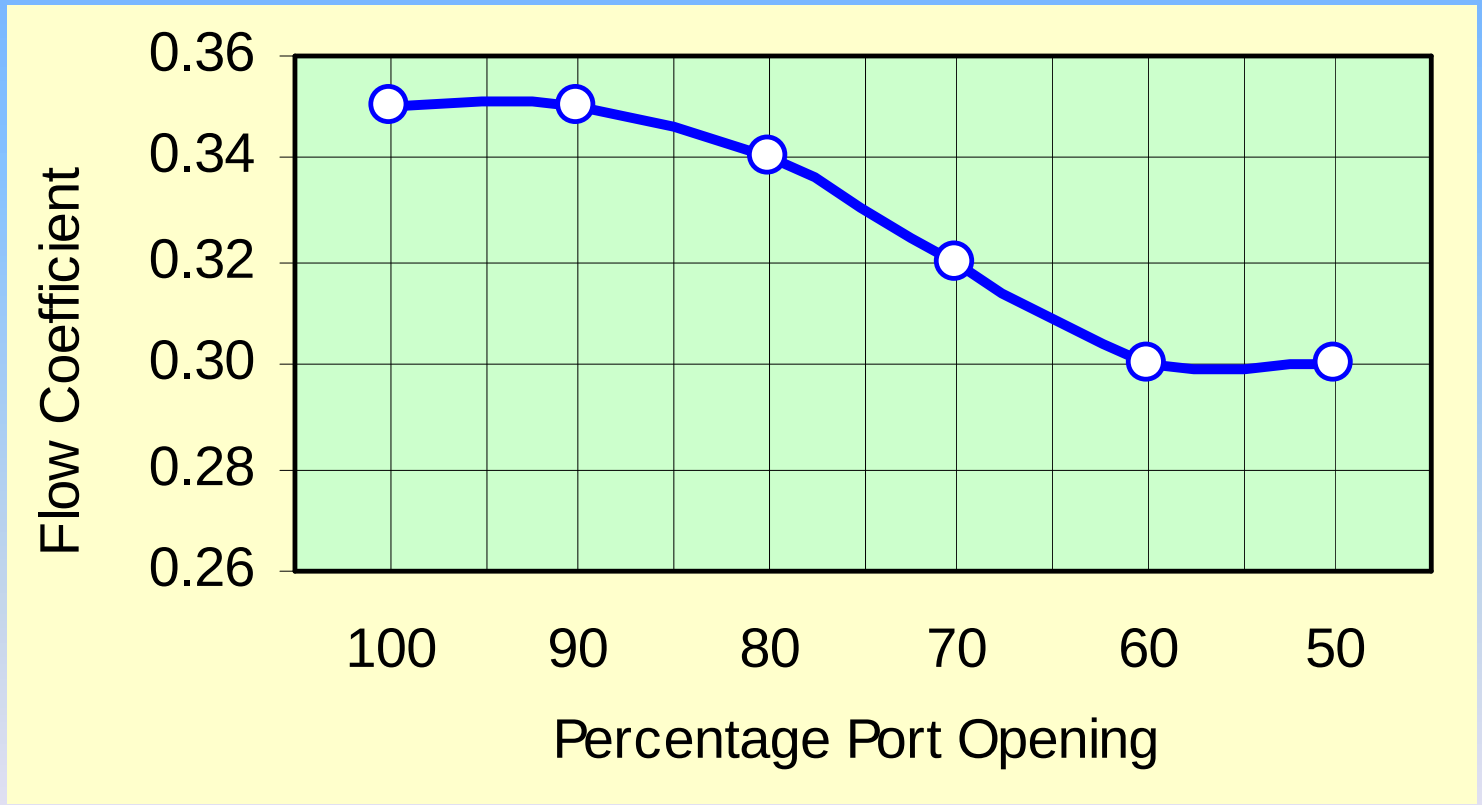
Swirl plate

Openings corresponding to inlet port

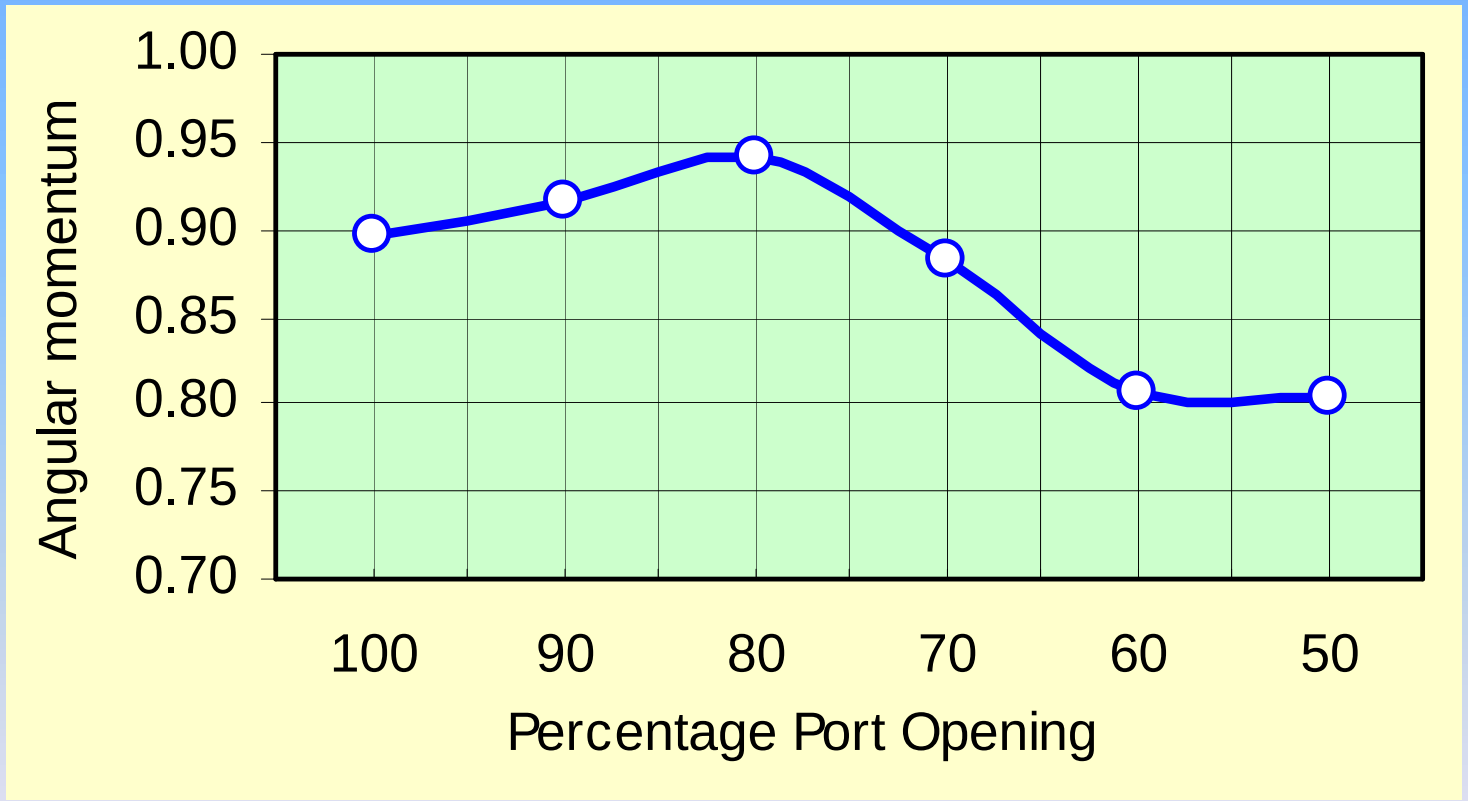
Swirl ratio Vs port opening



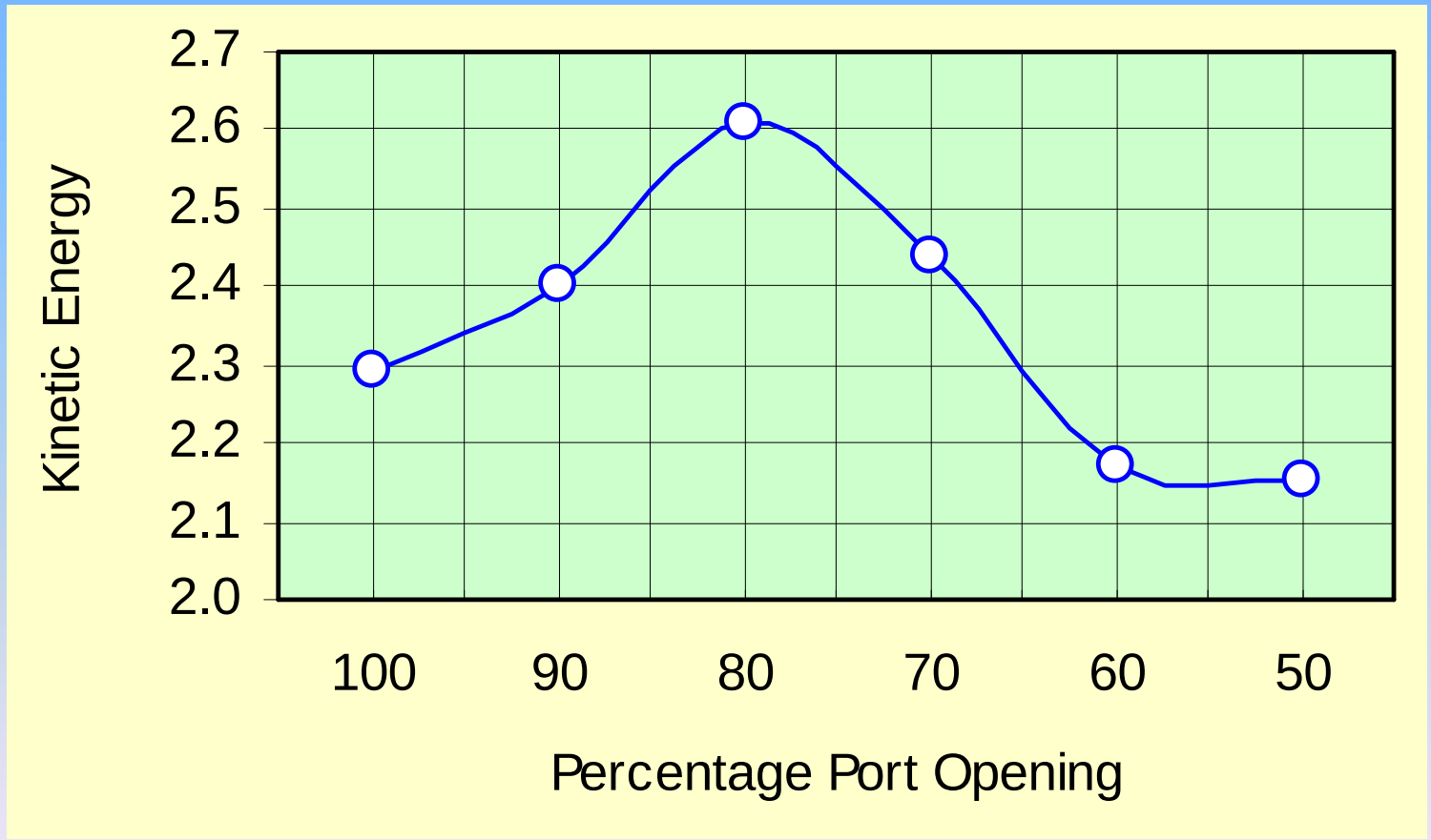
Flow Coeff Vs port opening



Angular momentum Vs Port opening



Kinetic energy Vs Port opening



Full throttle performance test

- Parameters observed
  - Torque in Nm
  - Smoke in HSU
  - SFC (specific fuel consumption) in g/kWh

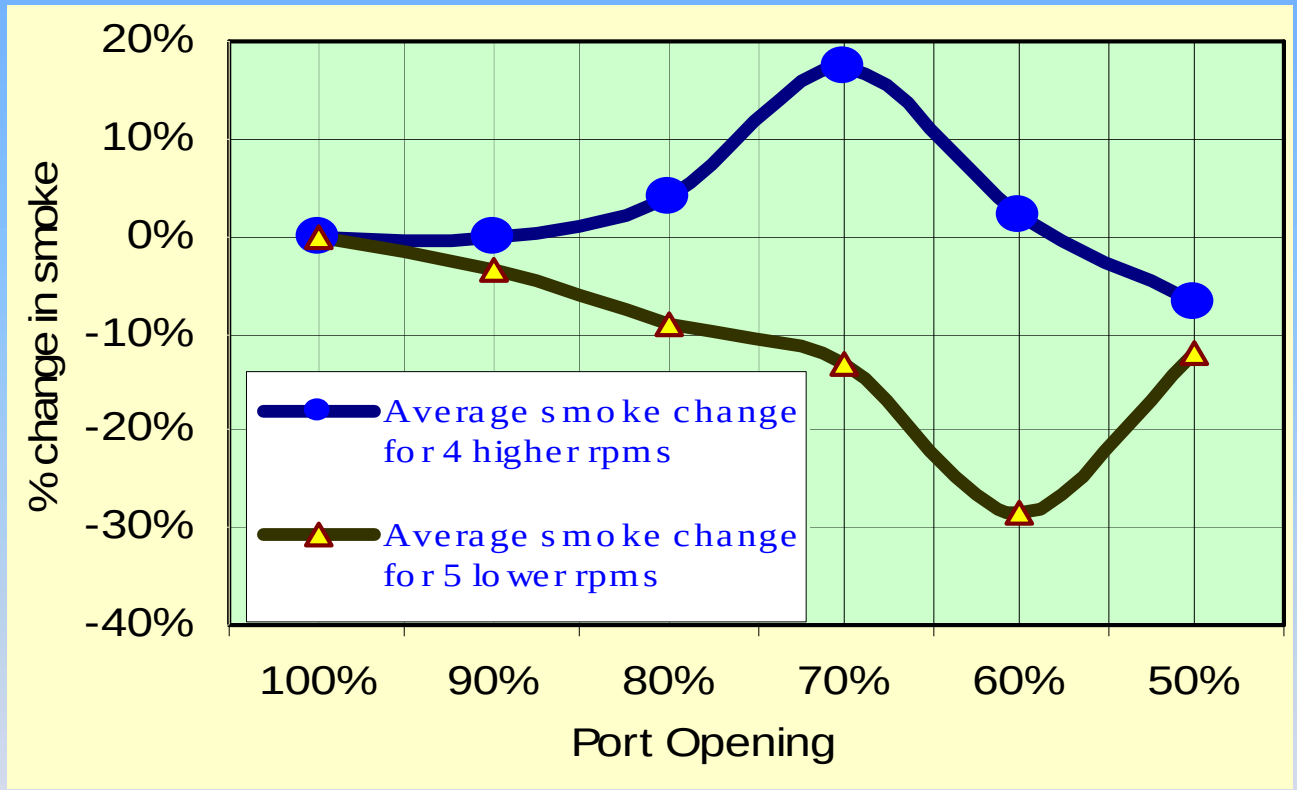
% change in smoke at various speeds with different port openings compared to 100% port opening

speed	Port opening 100%	90%	80%	70%	60%	50%
2400	0.0	0.0	25.0	20.0	2.5	-3.8
2200	0.0	0.0	-28.6	4.3	-24.3	-25.7
1800	0.0	0.0	0.0	0.0	16.0	-4.0
1600	0.0	0.0	20.0	46.0	14.0	6.0
1500	0.0	-11.1	-11.1	-11.1	-6.7	-14.4
1400	0.0	-9.1	-9.1	-18.2	-11.8	-12.7
1350	0.0	0.0	-7.7	-23.1	-66.9	-11.5
1200	0.0	0.0	-8.7	-9.6	-47.8	-15.2
1080	0.0	2.9	-8.6	-4.0	-8.6	-5.7
All speeds	0.0	-1.9	-3.2	0.5	-14.8	-9.7
4 upper speeds	0.0	0.0	4.1	17.6	2.1	-6.9
5 lower speeds	0.0	-3.5	-9.0	-13.2	-28.4	-11.9

4 upper speeds

5 lower speeds

% change in smoke Vs Port opening

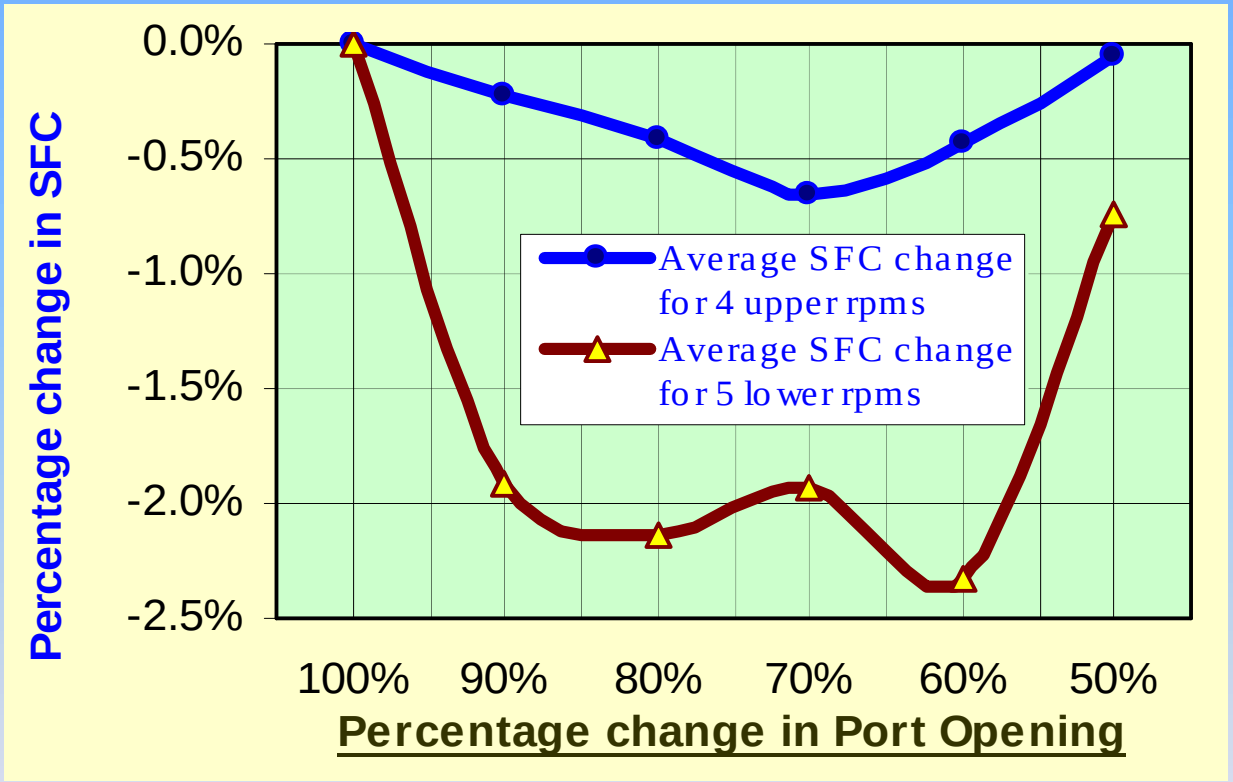


- Decrease in % value of smoke at lower speeds.

% change in SFC Vs Port opening

Speed	Port Opening					
	100%	90%	80%	70%	60%	50%
2400	0.0	-0.6	-0.5	-0.8	-0.8	0.1
2200	0.0	-0.7	0.5	-0.8	0.2	0.0
1800	0.0	0.1	-0.1	-0.6	-0.5	-0.3
1600	0.0	0.4	-1.6	-0.4	-0.8	-0.1
1500	0.0	0.0	-0.8	-0.4	-0.6	0.0
1400	0.0	-3.4	-3.6	-2.4	-4.3	0.9
1350	0.0	0.6	0.0	-0.4	-0.2	0.4
1200	0.0	-5.6	-5.4	-5.3	-5.3	-5.0
1080	0.0	-1.2	-1.0	-1.1	-1.3	0.0
All speeds	0.0	-1.2	-1.4	-1.4	-1.5	-0.4
4 upper speeds	0.0	-0.2	-0.4	-0.7	-0.4	-0.1
5 lower speeds	0.0	-1.9	-2.1	-1.9	-2.3	-0.7

% change in SFC Vs Port opening

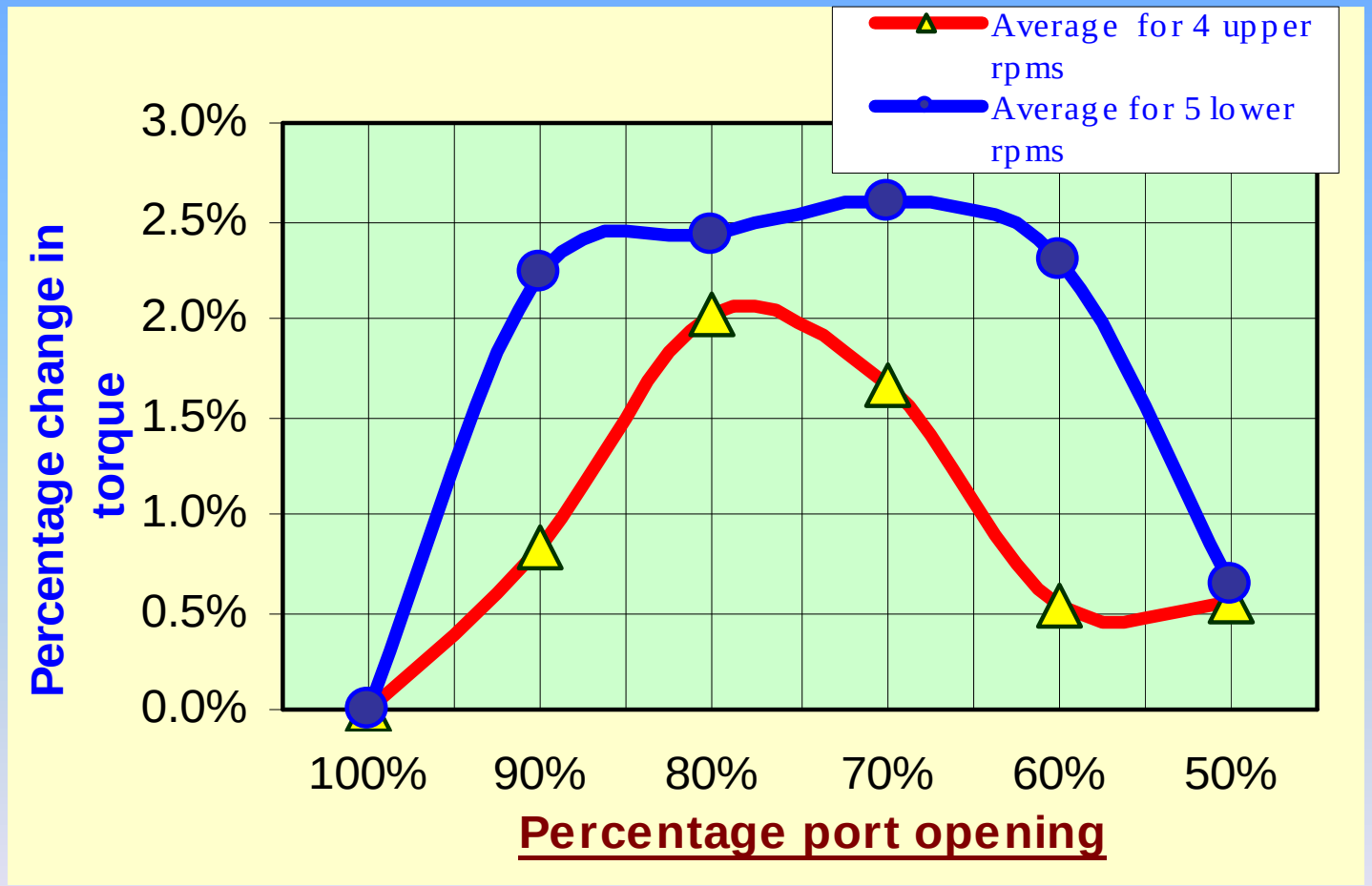


- Decrease in average values of % changes in SFC

% change in Torque Vs Port opening

Speed	Port Opening					
	100%	90%	80%	70%	60%	50%
2400	0.0	0.6	1.2	1.4	-0.2	-0.1
2200	0.0	1.0	1.5	1.7	-0.1	0.5
1800	0.0	0.8	2.0	1.8	1.3	0.9
1600	0.0	0.9	3.4	1.7	1.2	1.0
1500	0.0	1.8	3.4	2.3	1.8	1.2
1400	0.0	2.4	3.7	2.4	3.8	-0.7
1350	0.0	2.6	2.5	4.0	2.2	1.3
1200	0.0	2.7	2.2	2.7	2.0	1.4
1080	0.0	1.7	0.3	1.5	1.6	0.0
All speeds	0.0	1.6	2.2	2.2	1.5	0.6
4 upper speeds	0.0	0.8	2.0	1.7	0.5	0.6
5 lower speeds	0.0	2.2	2.4	2.6	2.3	0.6

% change in Torque Vs Port opening



- Increase in %change in torque in all the speeds

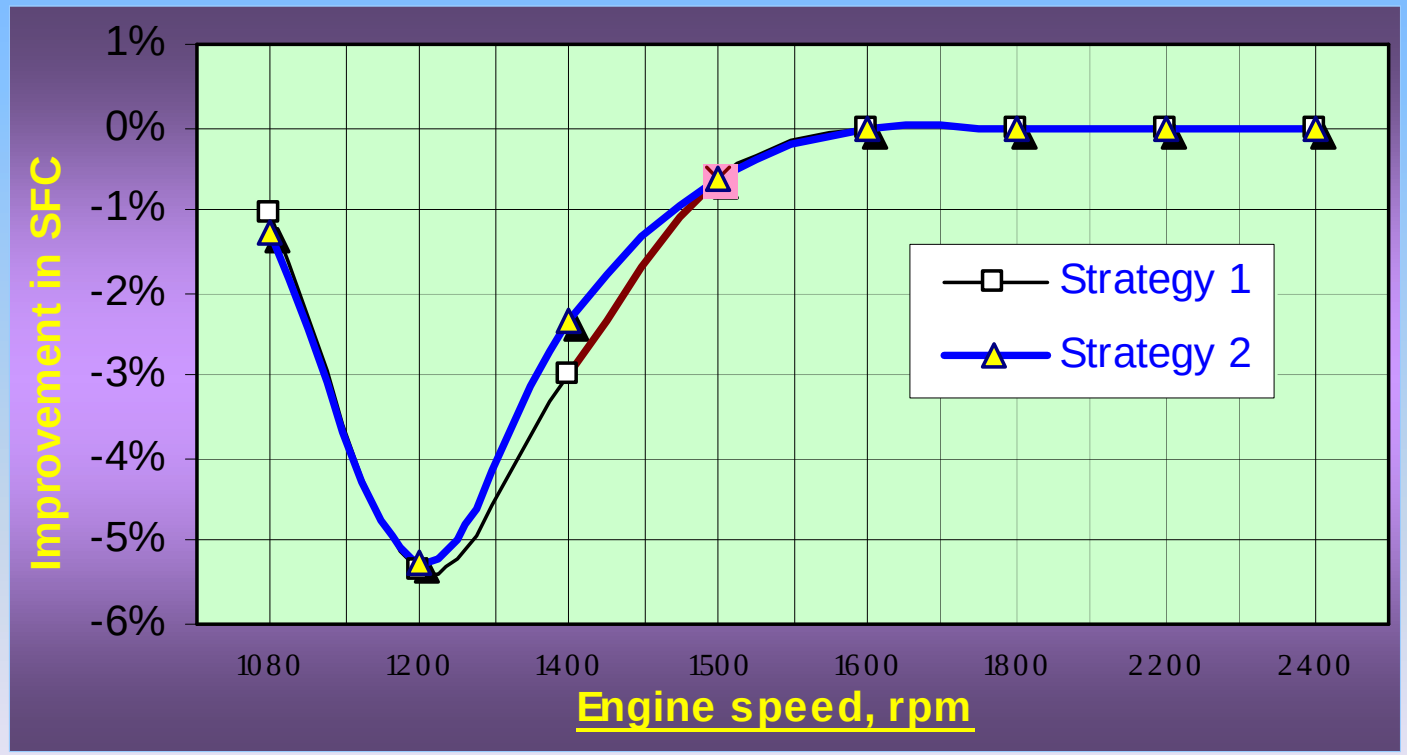
Proposed strategies

- Strategy 1: Ports 100% open at speeds above 1500 rpm and 75% open at speeds less than 1500 rpm.
  - A balanced favorable change for all 3 parameters.

- Strategy 2: Ports 100% open for all speeds above 1500 rpm and at lower speeds, those port openings are adopted at which the smoke is minimized at the corresponding speeds.
  - More focus on smoke reduction

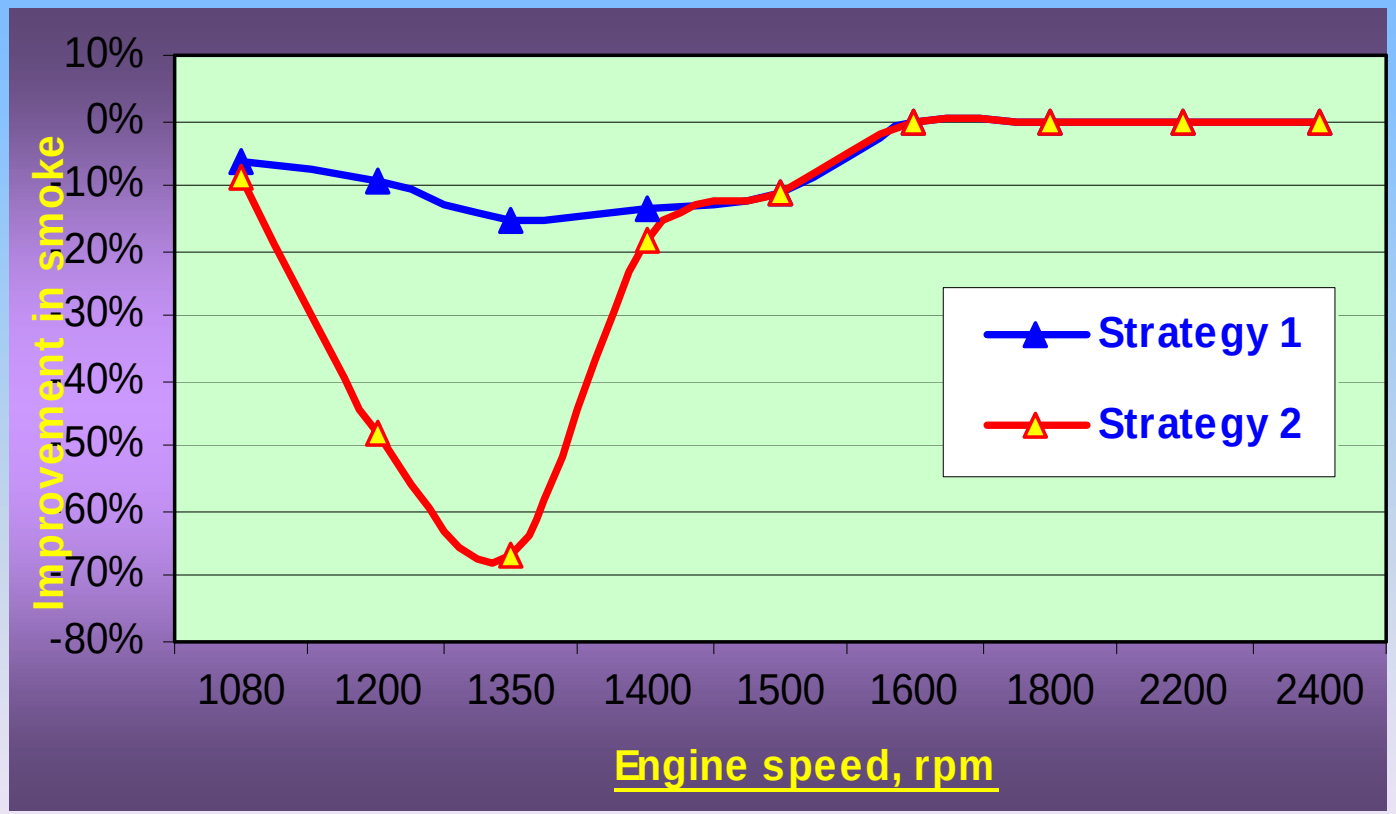
Comparison of the 2 strategies-SFC

% change in SFC with two strategies with respect to original



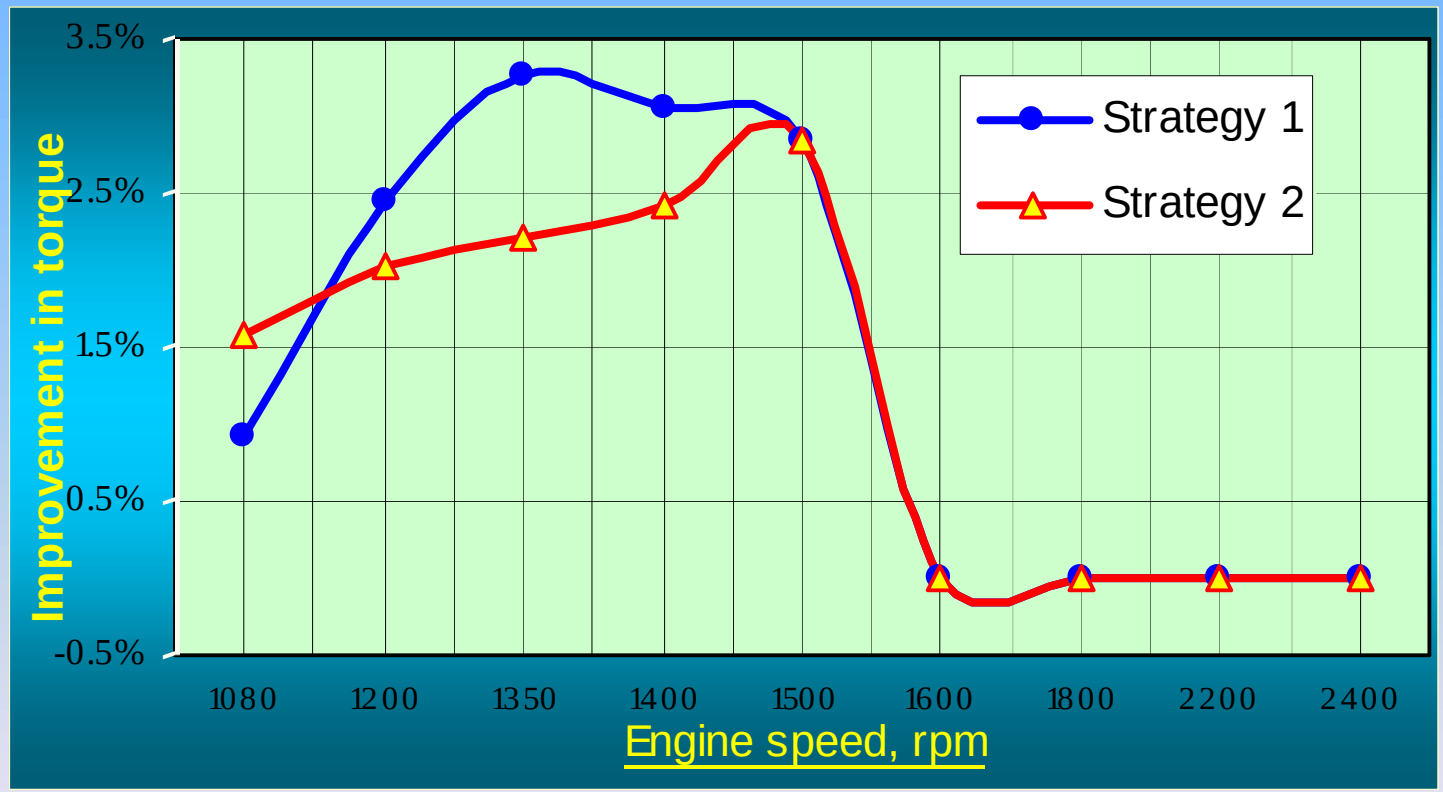
Comparison of the 2 strategies-Smoke

% change in smoke with two strategies with respect to original



Comparison of the 2 strategies-Torque

% change in torque with two strategies with respect to original



Further thought

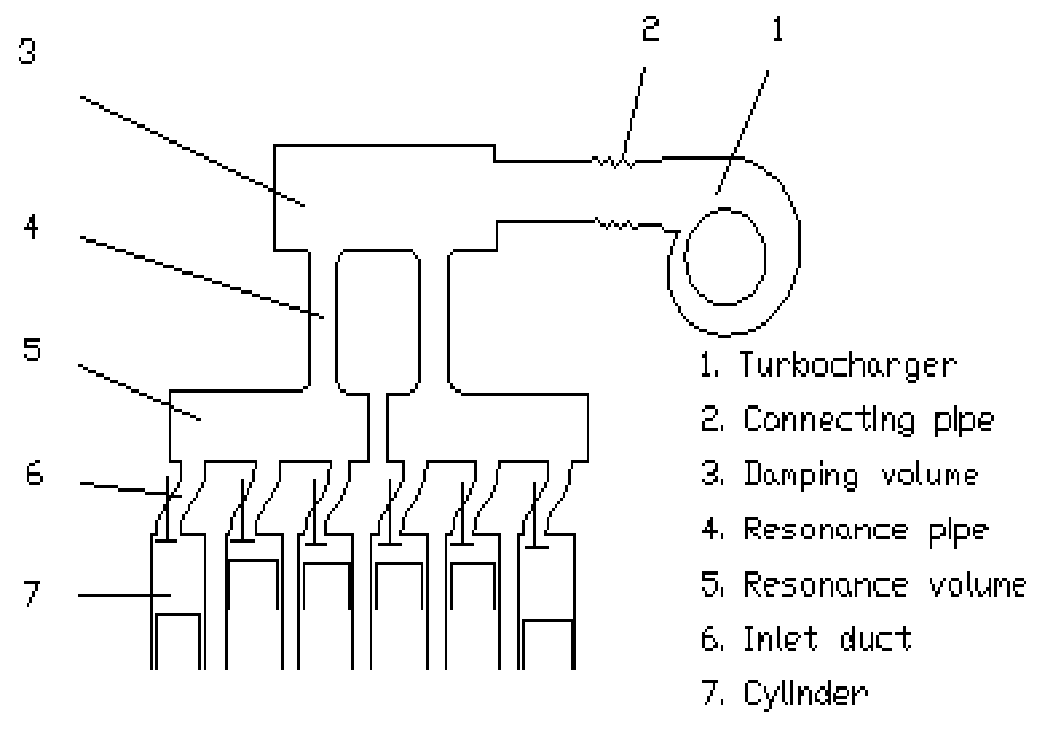
- **Experimenting with openings of different shapes and sizes in swirl plate can further refine the method of increasing swirl at lower speeds.**

Method-2
Combined charging system (CCS)

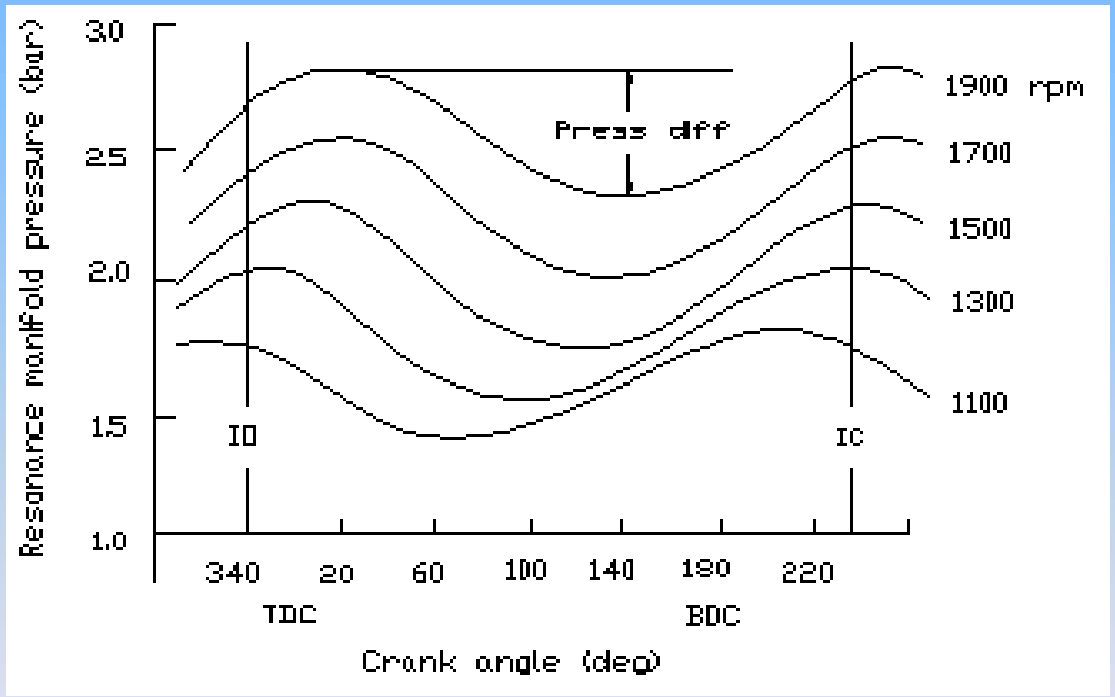
- CCS improves air flow at lower speeds
- Reduces smoke, SFC and improves Torque at lower speeds
- Leads to better Combustion
- Better Turbocharger matching

Second order resonance system

PHYSICAL PROCESS



Pressure variation in the intake manifold with the resonance system



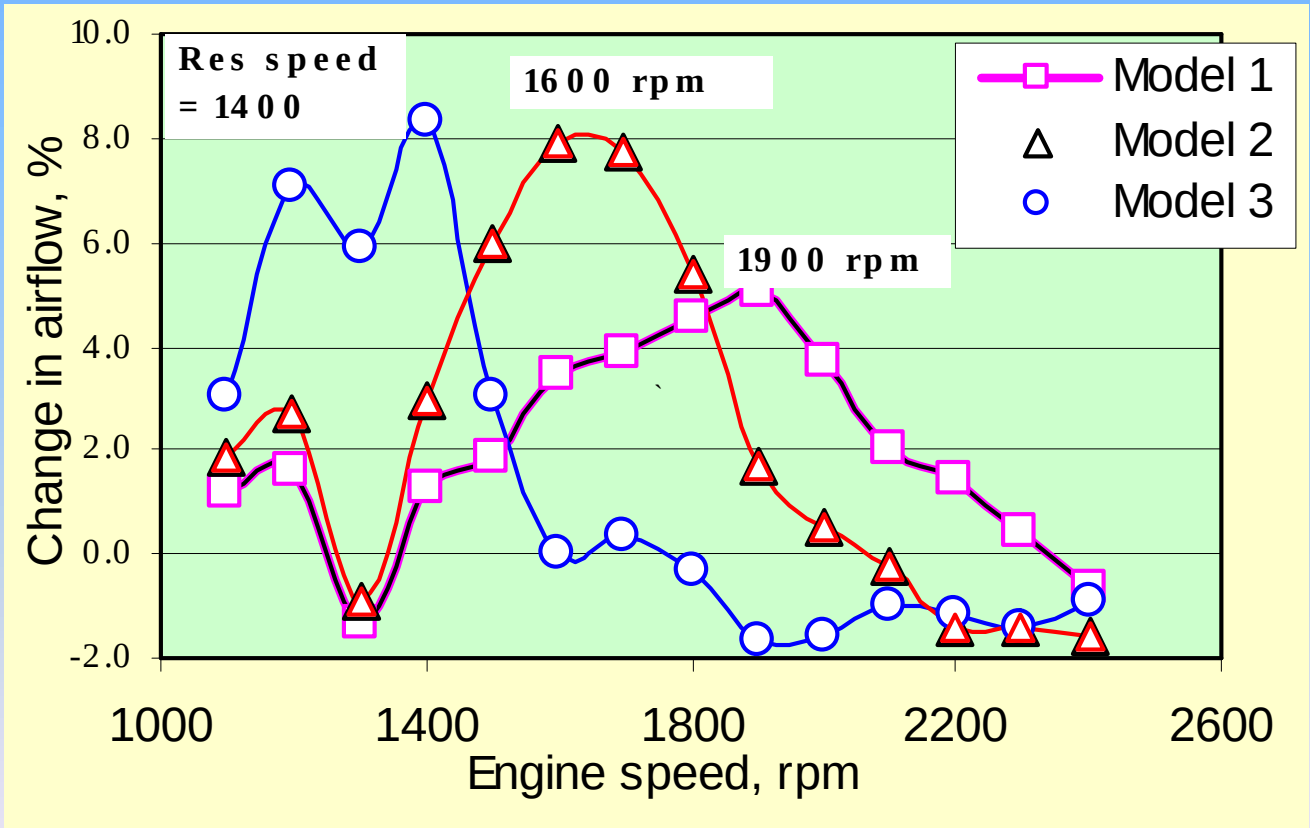
Experimental setup

- Model - 6.5 Liter Light Turbocharged Direct Injection (DI) diesel engine
- Bore - 107.25mm
- Stroke - 120.8mm
- Rated power – 98 kW developed 2400rpm
- Max torque – 450 Nm at 1600 rpm
- Mechanically governed A-type fuel pump

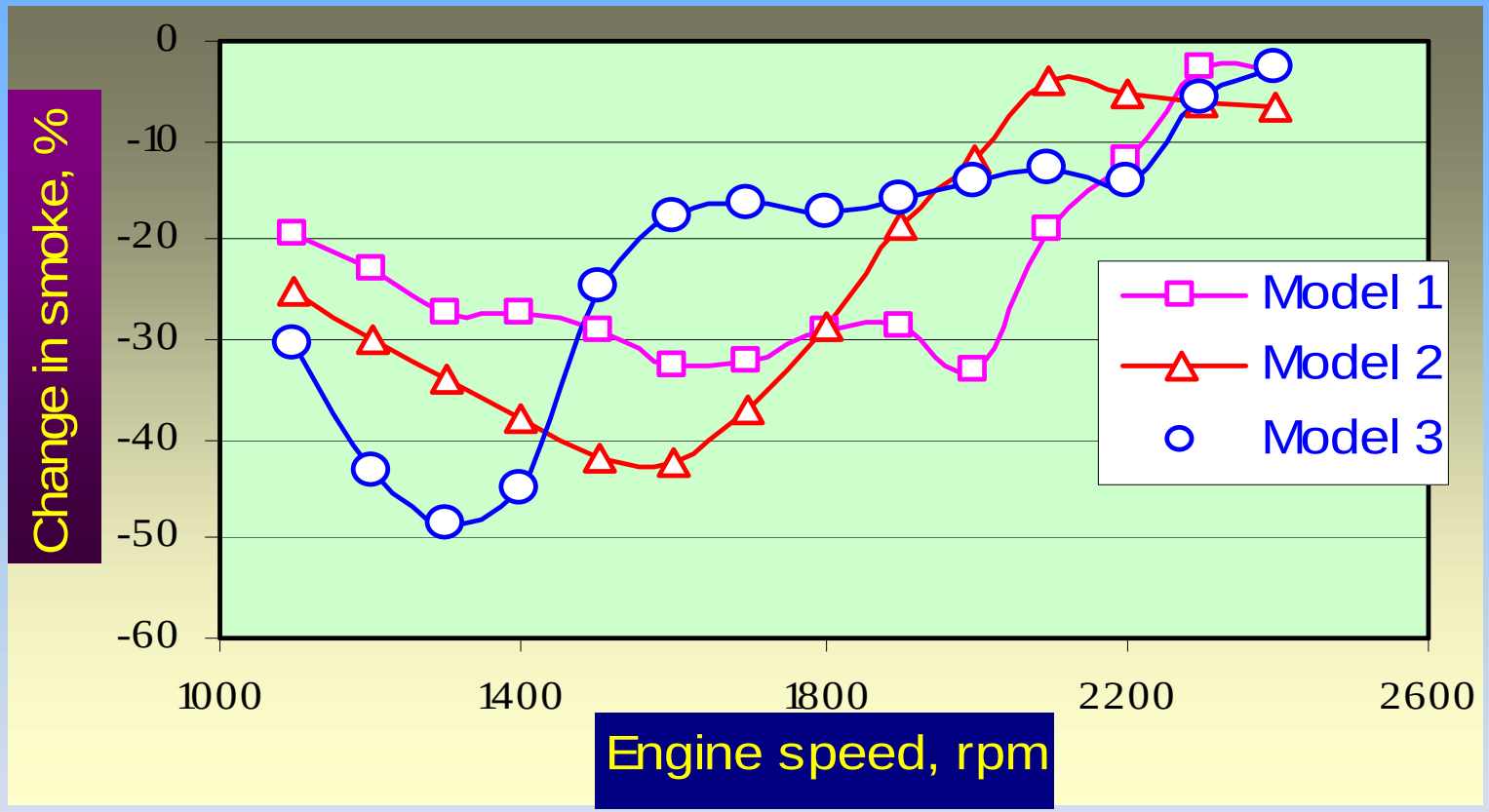
Geometrical details of three different CCS models tried

• Model	1	2	3
• Resonance volume, lit	3.0	2.3	2.3
• Resonance pipe length, mm	500	800	1000
• Resonance pipe diameter, mm	55	60	60
• Frequency, Hz	76.2	75.0	66.9
• Resonance speed (N_{res}) Calculated	1742	1499	1337
• Resonance speed (N_{res}) Experimental	1900	1600	1400

The change in airflow for the three models over the conventional manifold

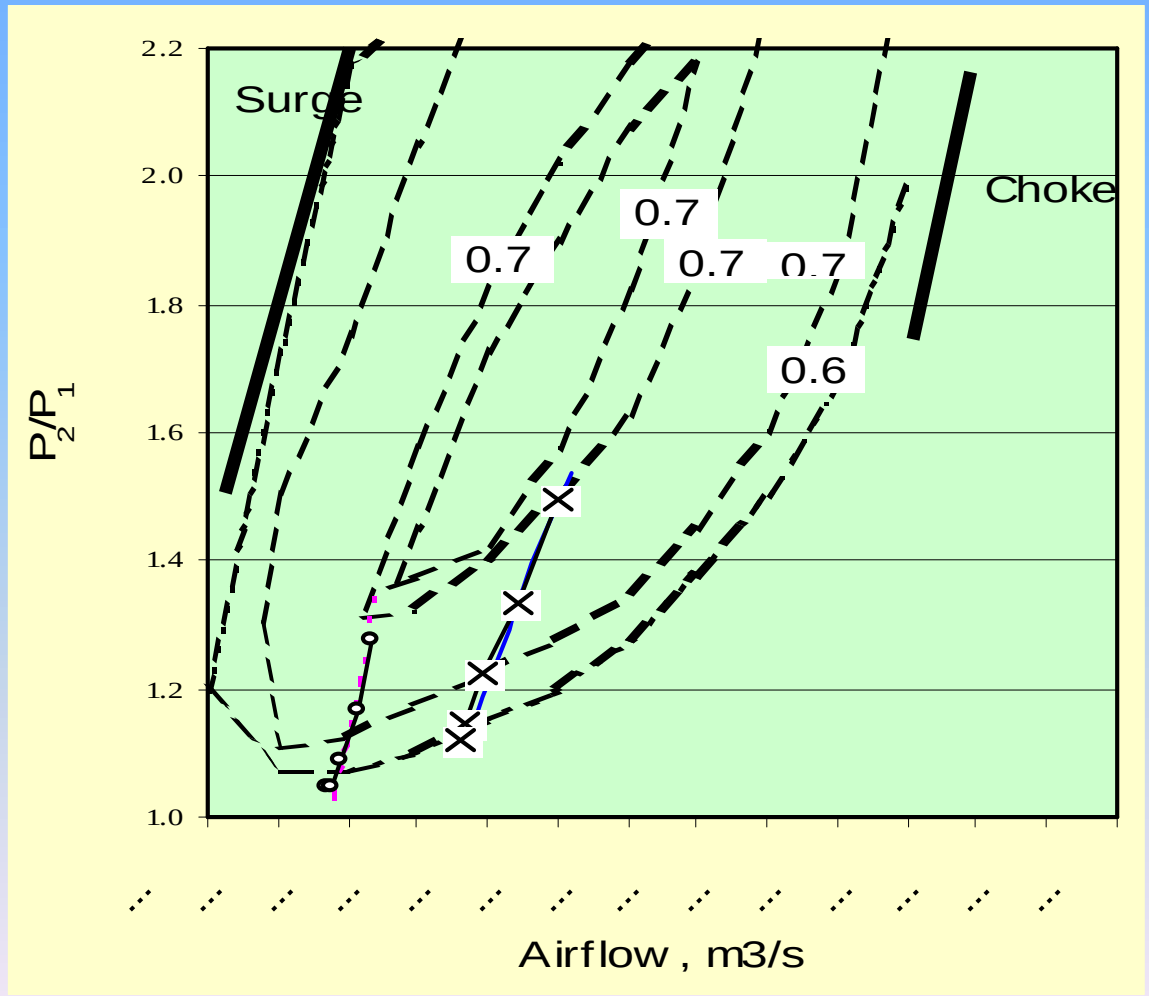


The change in smoke for the three models over the conventional manifold

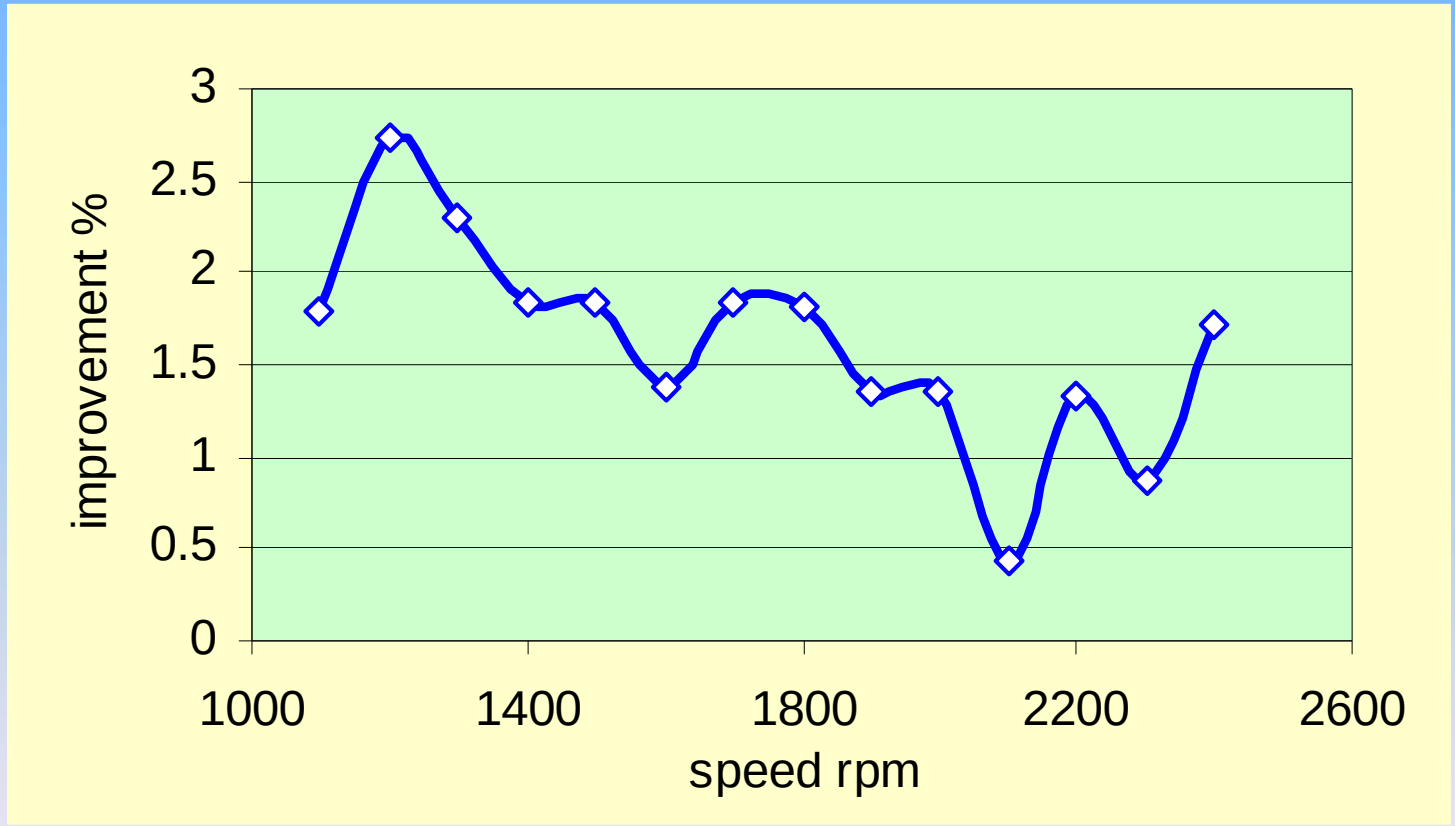


- Smoke reduction is obtained up to 50% over the resonance speeds and average of around 25% over the operating speeds

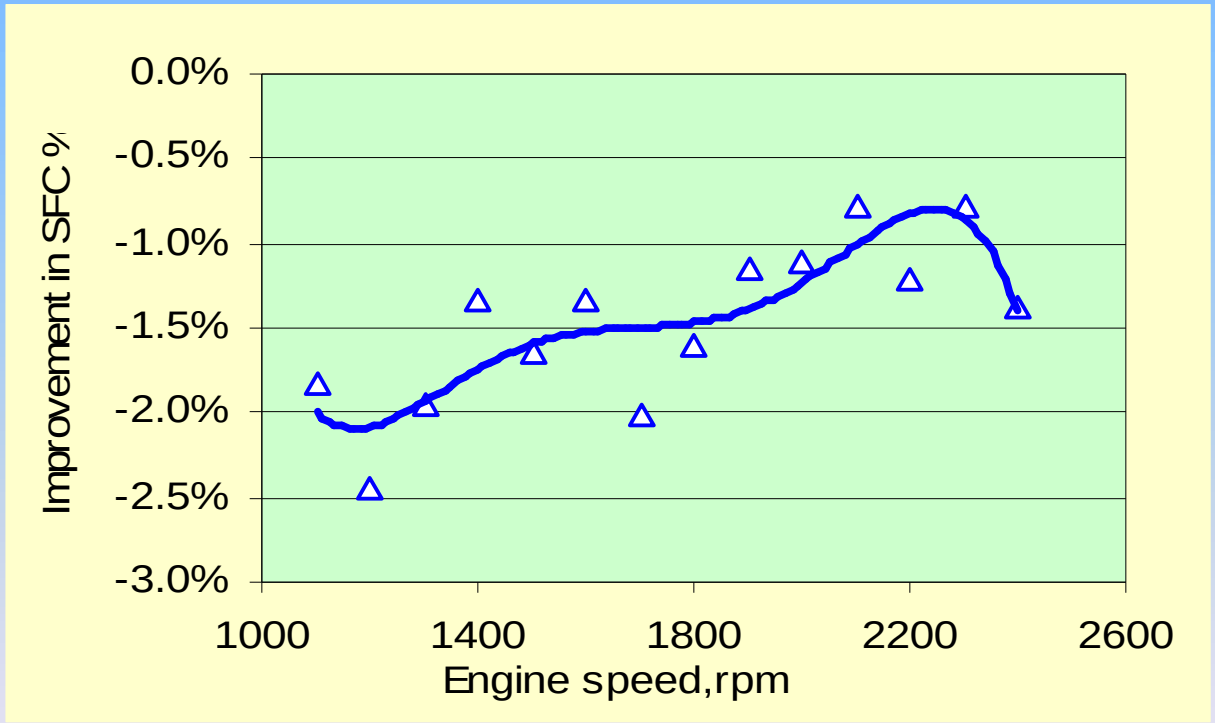
Blowup view shows the shifting of operation lines



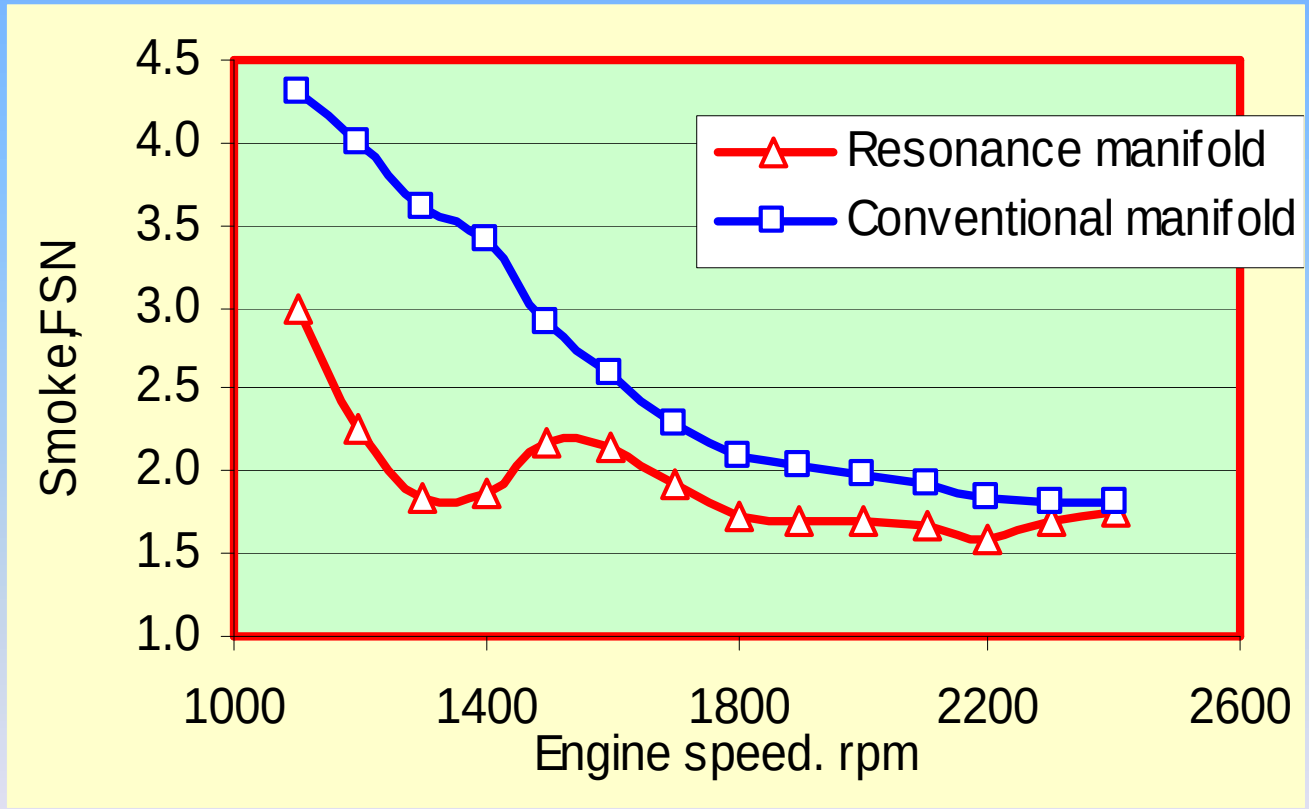
Relative change in torque with resonance manifold to conventional manifold using model 3



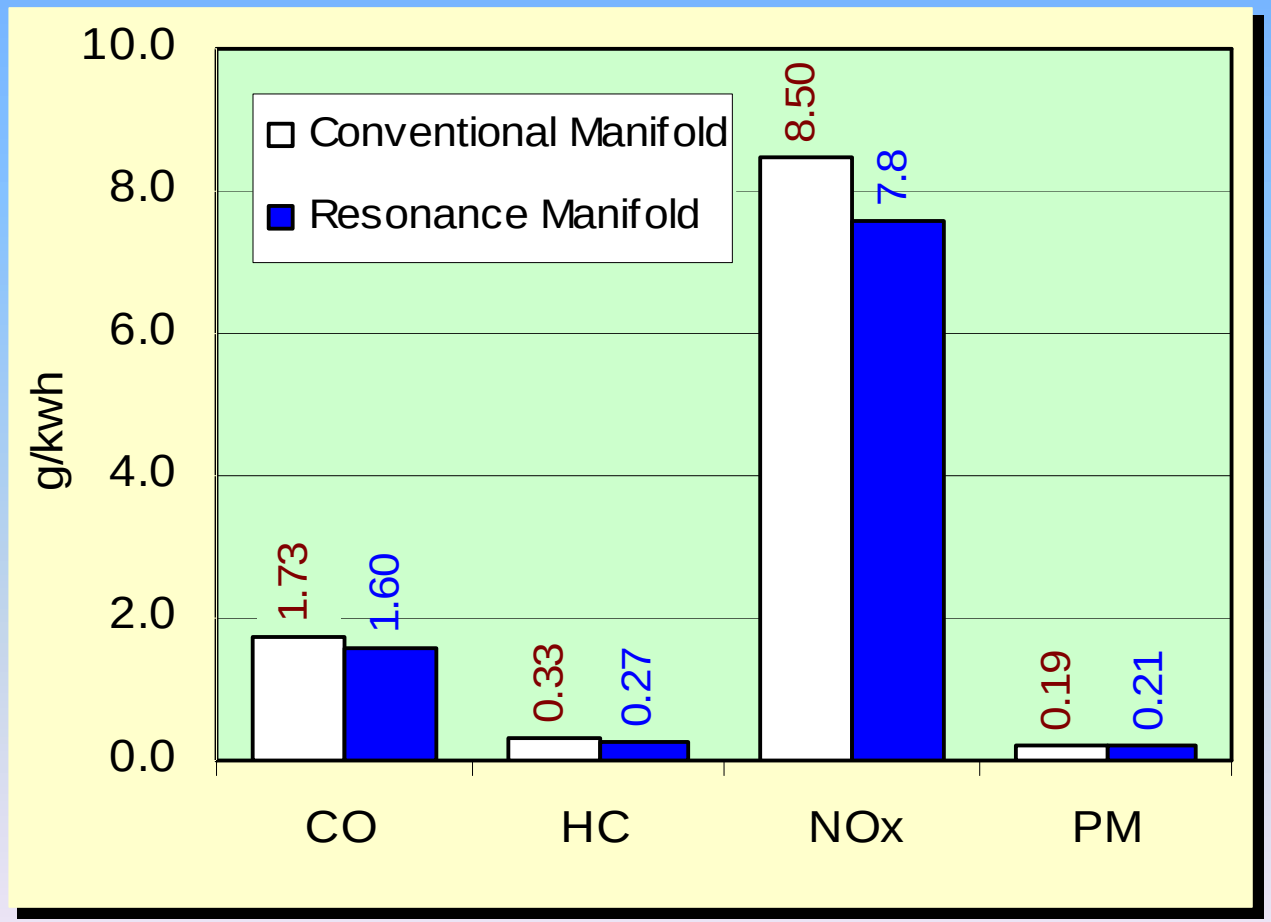
Relative change in SFC with resonance manifold compared to conventional manifold using model3



Difference in smoke using model3



Comparison of emission values between conventional manifold and resonance manifold.



Conclusion

- Significant increase in volumetric efficiency of an average of 6% and 8% in the lower speeds range.
- Smoke is reduced by an average of 25% and 50% in the resonance speed range.
- Reduction in the NOx emissions around 8%.
- SFC reduction is sustained in the lower speed range by 1.5%.

Conclusion contd…

- Considerable improvements in overall emissions shows better combustion
- Possibilities of more improvements can be obtained if emission and resonance speeds match
- Careful and simple design of CCS make this system more affordable in Automobiles

Conclusion

- Combining both the methods, substantial advantage can be realized at lower speed range in smoke and torque without any loss at higher speed range. The obvious benefit is improved drivability

Thank You!!

- Your queries and suggestions for improvements are highly welcome.