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Generation of Air Swirl through Inlet Poppet Valve Modification and To Enhance Performance on Diesel Engine

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Abstract: *To generate air swirl inside a direct ignition diesel engine combustion chamber an attempt is made to modify some possible changes in an inlet valves without disturbing the properties of valve material, which ensures an improved combustion and a noticeable improvements in emission levels at its exhaust gases. In order to select better and most suitable modifications in practicality the simulation through CFD is the most precisive and accurate way of selecting the optimum modification in inlet poppet valves.*
***Keywords*:** *Swirl, Turbulence, CFD analysis, thermal efficiency HC and CO*

I. Introduction

CI Engines are very useful for high load carrying capacity and torque transmission engines in the world. The power output to weight ratio is more compared to SI engines, but thermal efficiency is less compared to SI engines and is around 22% to 34% . So in order to utilize CI engines one should aim to increase its thermal efficiency as much as possible by some modifications in the engine design. Though the combustion in CI engine is heterogeneous , still we can optimize its combustion efficiency by ensuring heat utilization and marginal reduction in emission levels.

Here three varieties of inlet valves are used,
1. Base model (The conventional inlet poppet valves)
2. Model-1 valve (Inlet valve with 5 straight grooves on its poppet head)
3. Model-2 valve (Inlet valve with 3 masks and 3 straight grooves on its poppet head)
4. Model-3 valve (Inlet valve with 5 straight grooves with 3 fins on its poppet head)

II. Base model (conventional inlet poppet valves):

The conventional inlet valve is as shown above, consisting of combustion face which is exposed to a very high temperatures during the process of combustion. Valve is having a delicate part called seating which should be very accurate enough in dimensions and finishing so that accurate locking and sealing enhances the whole engine performances

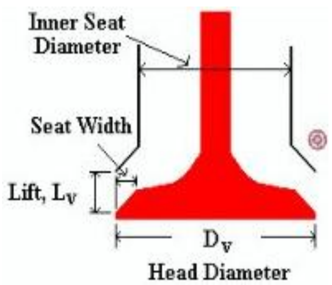


FIG-1

Model-1 valve (Inlet valve with 5 straight grooves on its poppet head)

Width of groove: 3mm
Depth of groove: 3mm
Outer dia of grooves: 22mm
Inner dia of grooves: 8mm

Fig-2

Grooving is the process of removing a small piece of metal on the valve head without disturbing the valve seating; the small cavities are called grooves. Here for analysis we have used 2-grooved valves, 3- grooved valve and 5- grooved valve, which are having the following dimensions:

Model-2 valve (Inlet valve with 3 masks and 3 straight grooves on its back)

Width of groove: 3mm
Depth of groove: 3mm
Outer dia of grooves: 22mm
Inner dia of grooves: 8mm
Angle of each mask: 45degrees.
Thickness of mask: 4mm
Width of mask: 4mm

Fig-2

In this type a valve consisting a grooves three in numbers with small pieces build on head as shown in fig-2.
This type of design utilizes a combination of small built-up pieces called MASKS and a CAVITIES called grooves. For analysis 2groove-2mask, 3Groove-3masks are simulated through CFD.

Model-3 valve (Inlet valve with 5 straight grooves with 3 fins on its poppet head)

Width of groove: 3mm
Depth of groove: 3mm
Outer dia of grooves: 22mm
Inner dia of grooves: 8mm
Dia of ring: 7.9mm
Length of blade: 6.5mm
Width: 4mm

Fig-3

In this type a small ring with blades are attached to valve as shown in figure-3. It uses a combination of grooves three in numbers and a freely rotatable ring with 3 blades. For CFD analysis the 3Groove-5bladed ring and 5groove-3bladed ring are simulated.

Simulation using CFD:

Simulation requires valve models, engine inlet manifold model, combustion chamber model, engine operating parameters. Discussion of each may become a very lengthy topics hence just explained through some neat sketches.

Engine operating parameters:

WATER COOLED, SINGLE CYLINDER, 4-STROKE DIESEL ENGINE SPECIFICATIONS:

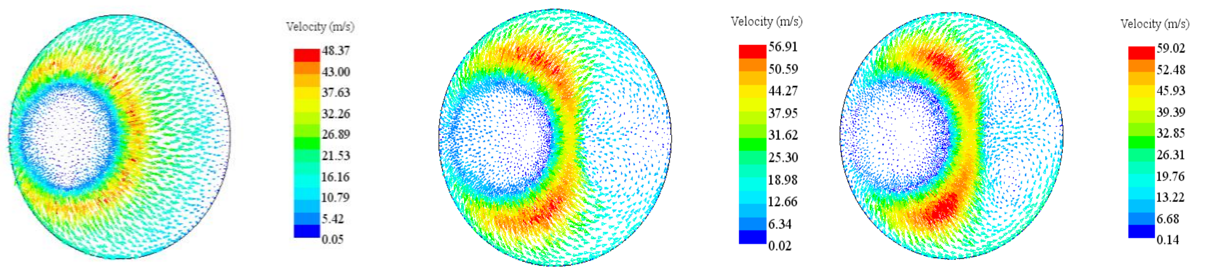
BHP = 5HP	= 3.68KW
Bore Diameter	= 80mm
Stroke length	= 110mm
Speed	= 1500rpm
Brake drum Radius	= 147mm
C.V of Diesel	= 45, 355 Kj / Kg
Specific Gravity of diesel	= 0.8225gms/cc
Orifice dia	= 15mm
Brake Rope dia	= 15.9 mm
Torque arm radius	= 0.2 mts
Compression ratio	= 16.5:1

Simulation By Using Cfd:

Here valve lift is considered as major criterion for simulation.
Total valve lift = 12mm
This 12mm is divided into 3 parts and called as
Low Lift (valve at 4mm downward movement)
Medium lift (valve at 8mm downward movement)
High lift (valve at12mm downward movement)
Hence CFD simulations were carried out for analyzing swirl, turbulence, velocity of inlet air and also pressure distribution inside the cylinder during suction stroke and are analyzed at different inlet valve lift positions in comparison with base model.

III. ANALYSIS OF SWIRL BY SIMULATION:

BASE MODEL:

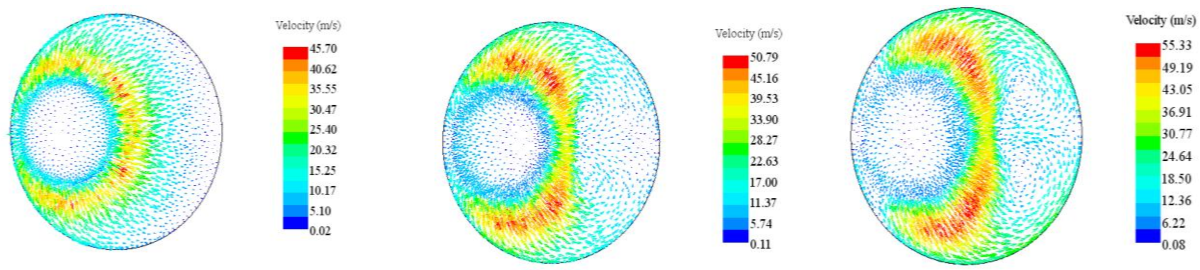


LOW LIFT MEDIUM LIFT HIGH LIFT

FIG-4

The swirl intensity is very less at the medium and at high valve lifts. Compare this intensity with the following model; we can notice that which type of valve will give better swirl intensity

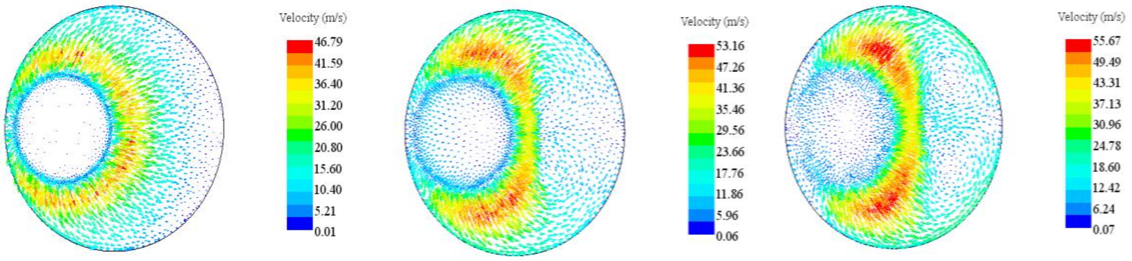
STRAIGHT GROOVES



LOW LIFT MEDIUM LIFT HIGH LIFT

FIG-5

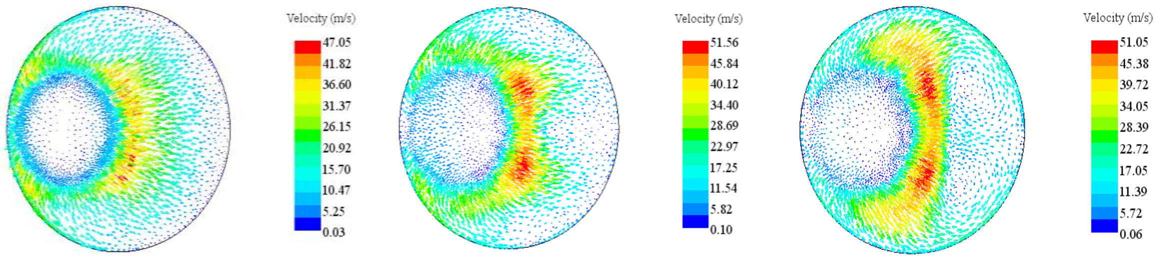
5 Curved Grooves



LOW LIFT MEDIUM LIFT HIGH LIFT

FIG-6

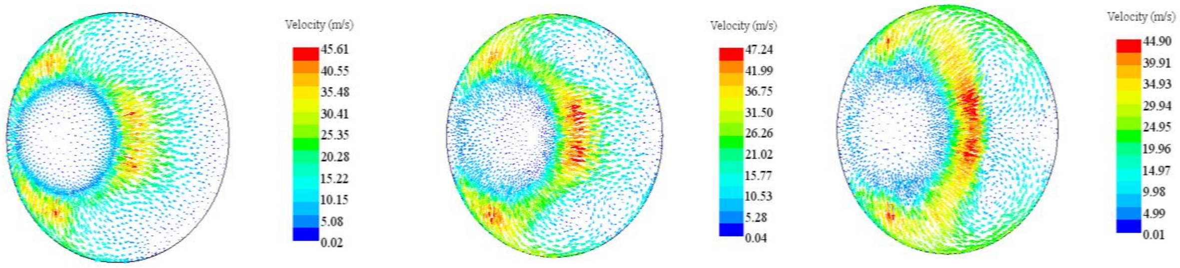
2 Grooves 2 Masks



LOW LIFT MEDIUM LIFT HIGH LIFT

FIG-7

3 Groovs 3 Masks

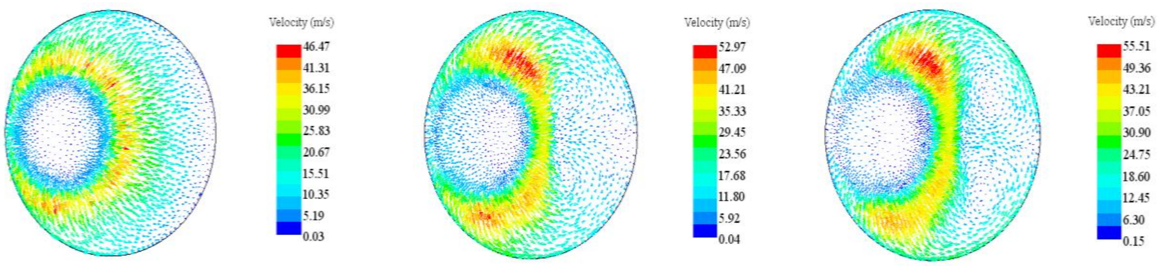


LOW LIFT MEDIUM LIFT

HIGH LIFT

FIG-8

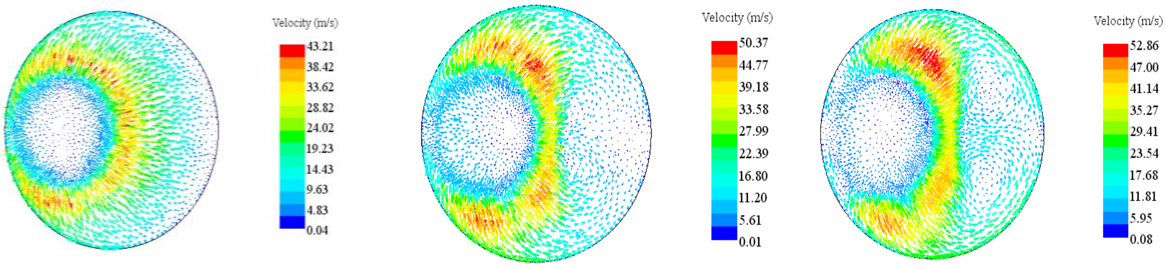
3 Grooves 3 Fins



LOW LIFT MEDIUM LIFT HIGH LIFT

FIG-9

5 Grooves 3 Fins



LOW LIFT MEDIUM LIFT HIGH LIFT

FIG-10

Hence a table of swirl ratios and turbulent kinetic energy can Give ideas to optimize the swirl through inlet valves: the tables are as follows

		Valve movement (full 24mm)					
		Valve lift in (mm) Forward			Backward		
Base Model		4.00	8.00	12.00	16.00	20.00	24.00
	Swirl Ratio	2.08	1.76	1.50	1.37	1.36	0.95
	Tumble Ratio	15.21	15.64	15.69	17.29	30.15	1.63
	TKE(j/kg)	8.85	57.14	95.05	111.55	61.81	5.49
	Mass Flow Rate(kg/s)	0.0290					

TABLE-1

		Valve movement (full 24mm)					
		Valve lift in (mm) Forward			Backward		
Five Straight		4.00	8.00	12.00	16.00	20.00	24.00
	Swirl Ratio	1.72	1.62	1.45	1.49	1.36	0.83
	Tumble Ratio	14.64	15.96	16.57	17.50	30.21	1.68
	TKE(j/kg)	8.68	53.25	90.09	107.13	54.92	11.87
	Mass Flow Rate(kg/s)	0.0279					

TABLE-2

		Valve movement (full 24mm)					
		Valve lift in (mm) Forward			Backward		
Five Curved		4.00	8.00	12.00	16.00	20.00	24.00
	Swirl Ratio	1.82	1.62	1.42	1.46	1.36	0.87
	Tumble Ratio	15.74	15.76	16.07	17.70	30.74	1.63
	TKE(j/kg)	8.61	55.87	91.78	109.72	54.02	5.77
	Mass Flow Rate(kg/s)	0.0286					

TABLE-3

		Valve movement (full 24mm)					
		Valve lift in (mm) Forward			Backward		
2Grooves2Mask		4.0000	8.0000	12.0000	16	20	24
	Swirl Ratio	1.55	1.25	1.09	1.08	0.97	0.70
	Tumble ratio	15.12	16.32	15.71	16.69	30.07	1.54
	TKE(j/kg)	8.65	38.26	85.45	99.08	33.92	3.84
	Mass Flow Rate(kg/s)	0.0266					

TABLE-4

		Valve movement (full 24mm)					
		Valve lift in (mm) Forward			Backward		
3Grooves3Mask		4.0000	8.0000	12.0000	16	20	24
	Swirl Ratio	1.43	1.38	1.29	1.35	1.11	0.87
	Tumble ratio	15.28	16.09	16.29	17.59	14.23	0.49
	TKE(j/kg)	8.26	23.55	71.18	82.40	56.32	1.48
	Mass Flow Rate(kg/s)	0.02351					

TABLE-5

		Valve movement (full 24mm)					
		Valve lift in (mm) Forward			Backward		
3Grooves3Fin		4.0000	8.0000	12.0000	16	20	24
	Swirl Ratio	2.28	2.39	2.06	1.98	1.84	1.22
	Tumble Ratio	14.86	17.59	14.90	15.73	16.32	1.98
	TKE(j/kg)	9.01	51.85	86.72	100.84	59.66	10.48
	Mass Flow Rate(kg/s)	0.02763					

TABLE-6

		Valve movement (full 24mm)					
		Valve lift in (mm) Forward			Backward		
5Grooves3Fin		4.0000	8.0000	12.0000	16	20	24
	Swirl Ratio	1.86	1.62	1.60	1.52	1.33	0.83
	Thumble Ratio	14.63	14.89	14.68	16.71	28.45	1.24
	TKE(j/kg)	9.25	50.39	88.58	97.18	54.07	7.07
	Mass Flow Rate(kg/s)	0.02729					

TABLE-7

Here by observation of swirl and turbulent kinetic energy in above tables and graphs one can choose the best type of valve which will give optimum results among all varieties.
Hence we can go for 5GROOVED TYPE, 3GROOVED-3MASKED TYPE AND 5GROOVED-3FINNED TYPE INLET VALVES for physical models.

Physical model preparation:

1. Same valve material is selected for making fins and masks on the inlet valves because of;
2. It can with stand high temperature up to 800^0C to 1000^0C.
3. It is wear resistant.
4. Grooving is done by CNC machines.
5. Masks are welded by TIG welding set up.

Type-1 valve (physical model):

Fig-11 (Valve With 5 Grooves)

Type-2 valve (3 finned valves):

FIG-11 (VALVE WITH 3GROOVES AND 3MASKS)

Type-3 valve (3 finned valves):

FIG-11VALVE WITH 3 FIN

IV. Experimental Set Up (Test Rig):

Kirloskar Make Four Stroke Single Cylinder Diesel Engines Of Av Series.

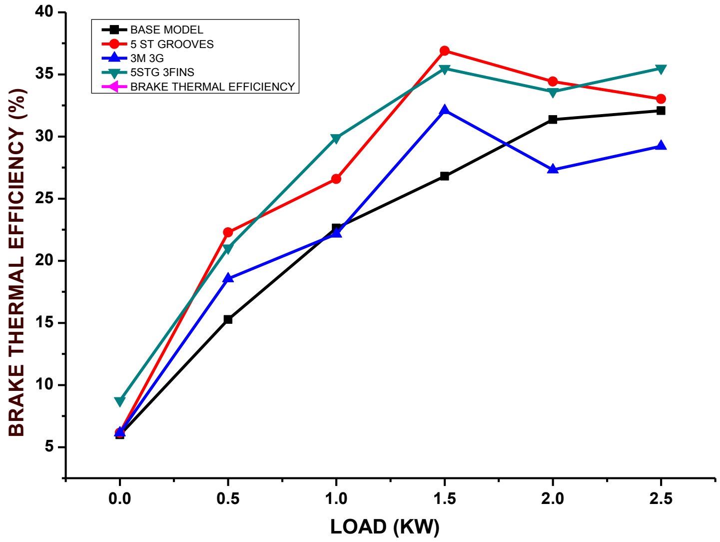
FIG-12TEST SET UP

V. Experimental Analysis:

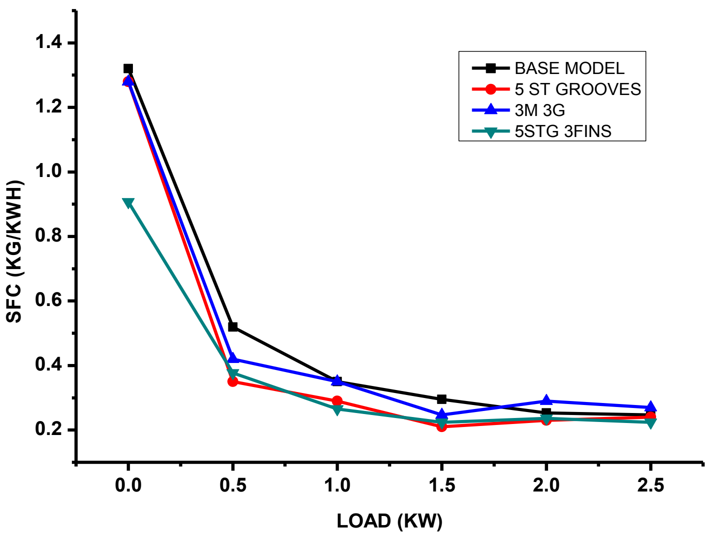
TABLE-8

TYPE OF VALVE MODEL	BRAKE THERMAL EFFICIENCY %	INDICATED THERMAL EFFICIENCY %	MECHANICAL EFFICIENCY %	SFC kg/KWH	CO %	HC PPM
BASE MODEL	6 TO 32	32 TO 45	18 TO 71	1.3 TO 0.519	0.11 TO 0.06	130 TO 80
5 STRAIGHT GROOVES	6.15 TO 36.9	32.13 TO 54.22	19.15 TO 73.14	1.28 TO 0.21	0.14 TO 0.01	110 TO 10
3 GROOVES 3 MASKS	6.15 TO 32.11	32.13 TO 48.05	19.15 TO 73.14	1.28 TO 0.24	0.11 TO 0.05	160 TO 30
5 STRAIGHT GROOVES WITH 3 FIN	8.74 TO 35.5	33.34 TO 52.1	26.2 TO 74	0.907 TO 0.22	0.178 TO 0.035	115 TO 25

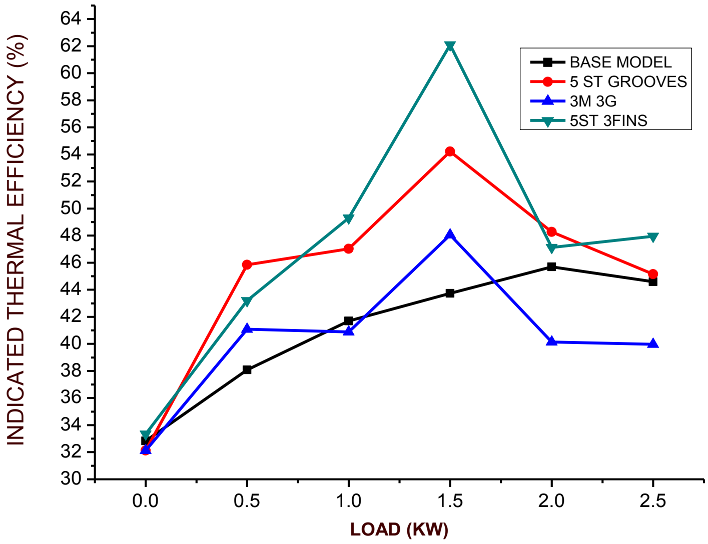
GRAPHS



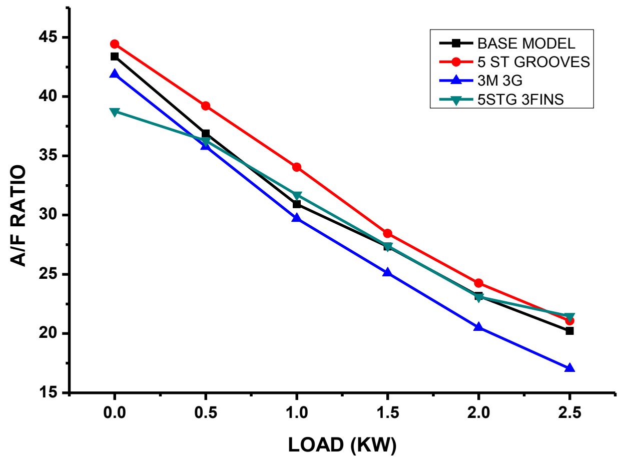
Graph-1 (Brake Thermal Efficiency Vs Load)



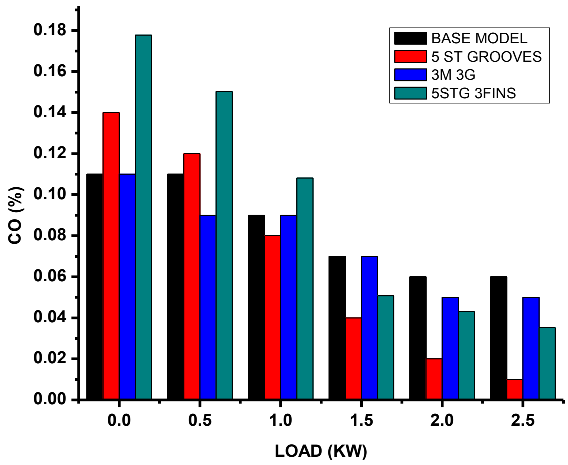
Graph-2 (SFC Vs LOAD)



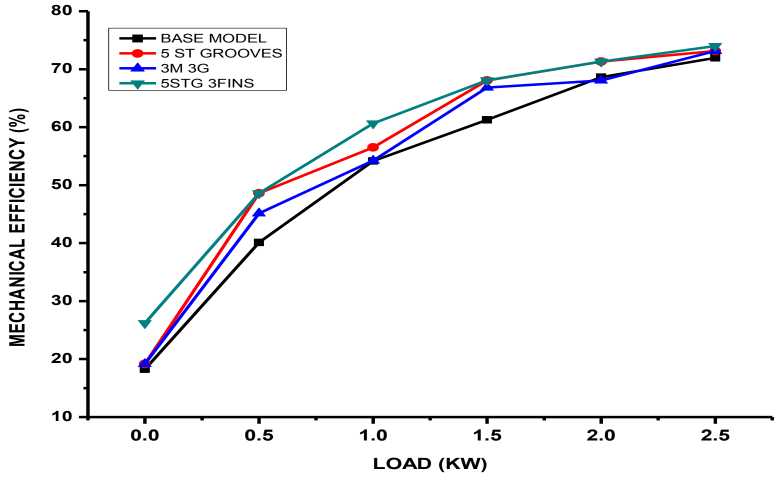
Graph-3 (INDICATED THERMAL EFFICIENCY Vs LOAD)



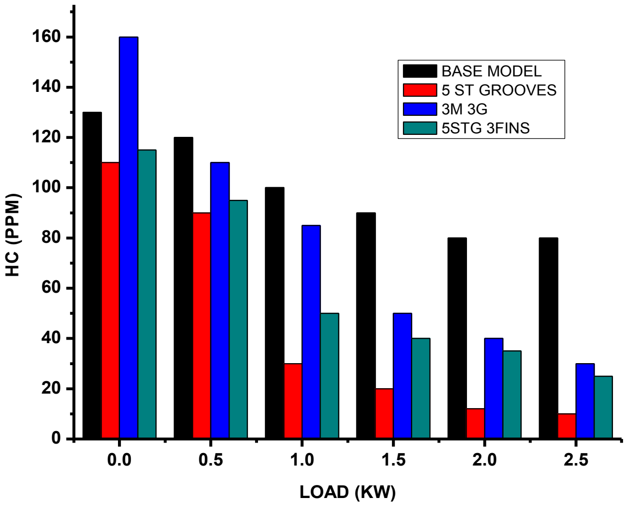
Graph-4 (A/F Vs LOAD)



Graph-5 (CO Vs LOAD)



Graph-6 (MECH. EFFICIENCY Vs LOAD)



Graph-7 (HC Vs LOAD)

VI. Conclusions

1. Optimization of inlet air to the engine can be done by means of inlet poppet valves.
2. CFD simulation can advise better results.
3. Masking of inlet valves improves swirl rate and intern brake thermal efficiency of engine.
4. Fins also increase the swirl rate and hence we can get better thermal efficiency.
5. Pollution levels are also decreased with all varieties of valves when compared to conventional valve.
6. Manufacturing cost of masks and grooves are less and can easily prepared

VII. Future Recommendations

1. The shape of masks and grooves can be changed and to be checked.
2. The design and shape of fins blades can also be thoroughly studied.
3. The inlet valve rotation during process can be made static to enhance good swirl rates.
4. The engine valves can be modified to generate air swirl at the entrance for better performances.
5. Engine size can be made compact for same capacities with use of less air , i.e., with lower volumetric efficiencies and at high swirl rates for the same capacity, the engine can be made compact in size

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