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Air Flow Analysis of Four Stroke Direct Injection Diesel Engines Based on Air Pressure Input and L/D Ratio

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Abstract: The air flow through engines is equally important to have accurate values for coefficients of discharge through the combinations of valves, ports and ducts of engines. In this air flow analysis is investigated of air flow is desirable for intake flow through the exhaust flow port using SuperFlow Flowbench. The air flow of the diesel engines can be quite measured under steady flow conditions for a range of pressures and valve Lift per Diameter (L/D). This syudy presents experimental results for air flow investigating in the intake and exhaust flow port of four stroke direct injection diesel engines. The airflow measurements and calculation are shown for various pressures, valve Lift per Diameters (L/D) ratio conditions at the intake port pipe to cylinder and cylinder to exhaust port pipe geometries. The result shown that, the increasing pressure input in port flow on fixed valve L/D can increase the air flow through engine cylinder.

Key words: Coefficient of discharge, correction test flow, test pressure, valve lift, diesel engines

INTRODUCTION

The importance of the diesel engine performance parameters are geometrical properties, the term of efficiency and other related engine performance parameters. A wide variety of inlet port geometries patterns used to accomplish this over the diesel size range (Heywood, 1998; Bakar *et al*., 2007; Kowalewicz, 1984; Stone, 1997; Ganesan, 1999; Ismail *et al*., 2008; Blair, 1999). The diesel engines port flow coefficient of discharge for a particular flow discontinuity is defined as the ratio of actual discharge to ideal discharge. In an engine environment, ideal discharge considers an ideal gas and the process to be free from friction, surface tension, etc. Air flow coefficients discharge are widely used to monitor the flow efficiency through various engine components and are quite useful in improving the performance of these components (Fleck *et al*., 1996; Superflow Technologies Group, 2004; Blair *et al*., 1995, 1998; Danov, 1997; Ismail *et al*., 2008; Blair and Gorden, 1999).

The air flow process into, through and out of the engines are unsteady (Ismail *et al*., 2008). Unsteady air flow is defined as that in which the pressure, temperature and gas particle velocity in a duct are variable with time. In the exhaust air flow of engine, the unsteady air flow behavior is produced because the cylinder pressure falls with the rapid opening of the exhaust valve or valves. This gives an exhaust port pressure that changes with time. In the induction or intake flow into the cylinder through an intake valve whose are changes with time, the intake port pressure alters because the cylinder pressure is affected by the piston motion causing volumetric change within that space.

This study presents the experimental results for air flow of four-stroke direct-injection diesel engines using SuperFlow Flowbench. The SuperFlow Flowbench is designed to measure air-flow resistance of engine cylinder heads, intake manifolds, velocity stacks and restrictor plates (Superflow Technologies Group, 2004). In the SuperFlow Flowbench, for four-cycle engine testing, air is drawn in through the cylinder head into the machine, through the air pump and exits through the vents at each side of the flowbench. The amount of flow is displayed in cubic feet per minute (cfm), liters per second (lps) or cubic meter per hour (cmh). The flow meter measures the pressure difference across an adjustable flow orifice in the flowbench. By selecting different ranges, the flow meter can be used to obtain high accuracy over reads 5-100% of any flow range selected in either intake or exhaust flow direction. The full scale flow measurement range of SuperFlow SF-1020 can be varied from 25+1000 cfm or 12 -470 lps.

In this experiment of air flow test in SuperFlow Flowbench, flow is tested consists of blowing or sucking

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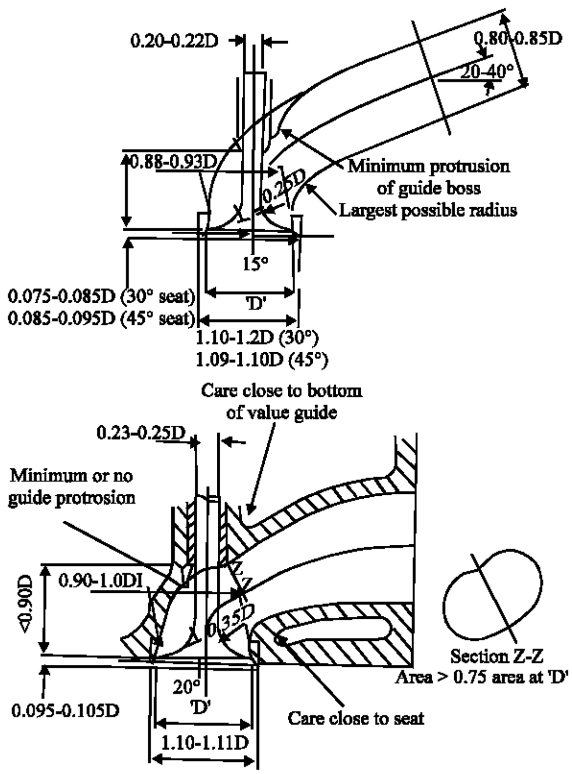

Fig. 1: Port area and shape (Heywood, 1998)

air through a cylinder head or other component at a constant test pressure. Then the flow rate is measured at various valve lift. A change can be made and then the component can be re-tested. Greater air flow indicates an improvement. If the tests are made under the same conditions, no corrections for atmospheric conditions or machine variations are required. The results of the experiment investigation may be compared directly. For more advanced tests, it is possible to adjust and correct for all variations so test results may be compared to those of any other head, tested under any conditions on any other SuperFlow flowbench. Further calculation can be made to determine valve efficiency and various recomm\ended port lengths and cam timing.

The port length and valve size illustration are shown in Fig. 1 and 2. The calculation can be cumbersome without a small electronic calculator, preferably with a square root key.

The total flow through the diesel engine is ultimately determined by the valve diameters. While well-designed smaller valves will out-perform larges valves on occasion, a good, big valve will always out-flow a good than smaller valve. Valve size is limited by the diameter of the engine bore. According to SuperFlow Technologies Group (2004), that in practice the ideal flow is never achieved but

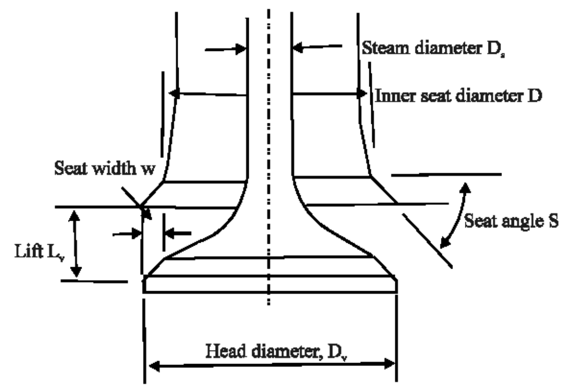

Fig. 2: Valve geometry (Heywood, 1998)

it does provide a guide-line for what an efficient port would be like.

If air flow losses are caused by port expansions, not contractions, it may wonder why the port should be necked down above the valve seat. The reason is the air must both turn 90° and expand as it flows out the valve into the engine cylinder. Humping the port inward just above the seat allows the air to make the turn outward toward the valve edge more gradually, reducing the total flow loss. According to (Superflow Technologies Group, 2004), source of flow losses the port are wall friction, contraction at push-rod, bend at valve guide, expansion behind valve guide, expansion in 25 degrees, expansion in 30 degrees, bend to exit valve and expansion exiting valve. The source of flow losses are wall friction 4%, contraction at push-rod 2%, bend at valve guide 11%, expansion behind valve guide 4%, expansion 25 degrees 12%, expansion 30 degrees 19%, bend to exit valve 17% and expansion exiting valve 31%.

MATERIALS AND METHODS

The experiment to measure and analyze the air flow of four stroke direct injection diesel engines using SuperFlow Flowbench is presented in this study. The specification of the selected four-stroke direct-injection diesel engine is shown in Table 1. In the experiment, the diesel engines cylinder heads are mounted onto the Flowbench by a cylinder adapter. The adapter consists of a engine cylinder replica about 86 mm, long with the same bore as the engine cylinder in 70 mm and a flange on one end. The flange is bolted to the flow tester and the upper flange is bolted or clamped to the test cylinder head. The flanges must be flat or gasketed to make an airtight seal. According to Superflow, the adapter cylinder clearance may be 0.06 inch or 1.5 mm, larger or smaller than the actual diesel engine cylinder.

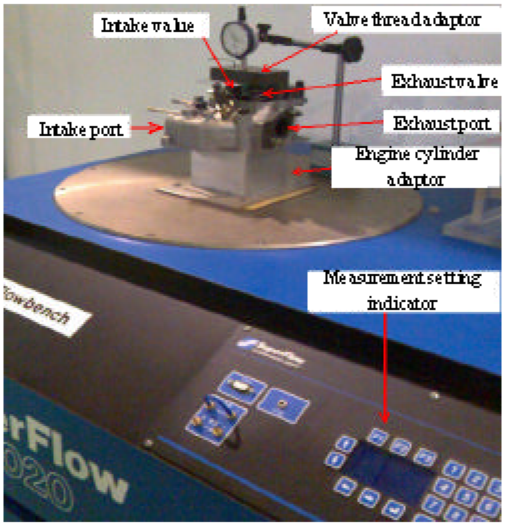

Fig. 3: Engine air flow measurement in test-bench

The adaptor and the thread to open and close the engine valve were developed from metal using CNC machine. As the thread is rotated, it pushes open the valve. In this experiment, in one rotation of the thread the valve is opened in 0.5 mm. Dial indicator may be mounted to the same fixture with its tip contacting the valve spring retainer to measure the amount of valve opening. The original valve springs used in this experiment (Fig. 3).

It is strongly recommended a radiused inlet guide be installed to lead the air straight into the head on the intake side of a four-cycle cylinder head. The guide should be about one port width in thickness and be generously radiused on the inside all the way to the head of the diesel engine. The intake manifold of the diesel engine can also be used in the experiment. All experiment test data recorded on the SuperFlow test data sheet forms. Before beginning the experiment test, record the test data setup. The test data setup are head description, valve stem, valve diameter, valve area, stem area and net valve area. The calculation of experiment and analyze is based on Superflow (2004) and Ismail *et al*. (2008). To calculate the net valve area is equal with 0.785 multiple with valve diameter square minus stem diameter square.

All diesel engine valves in this test should be performed at the same ratio of valve lift to valve diameter or L/D ratio. Then the flow efficiencies of any valves can be compared, regardless of size. In this research, multiply L/D ratios are shown in Table 2. The L/D ratios are to obtain the valve lift test points. To perform the experiment is used the test orifice plate for calibration. Remove the test orifice plate from the flowbench and install the test head, cylinder adapter and valve opener for the actual

Table 1: Specification of diesel engine

Engine parameters	Value
Bore (mm)	86.00
Stroke (mm)	70.00
Displacement (cc)	407.00
Number of cylinder	1.00
Maximum intake valve open (mm)	7.095
Maximum exhaust valve open (mm)	7.095
Intake valve diameter (mm)	35.54
Exhaust valve diameter (mm)	29.04
Intake valve stem (mm)	7.00
Exhaust valve stem (mm)	7.00
Intake valve effective area (sq.cm)	9.531
Exhaust valve effective area (sq.cm)	6.235

Table 2: Valve lifts position in experiment

Test	Intake valve		Exhaust valve		L/D
No	Lift(mm)	Flow range	Lift (mm)	Flow range	Ratio
1	1.78	72.69	1.45	70.71	0.05
2	3.55	72.69	2.90	70.71	0.10
3	5.33	72.69	4.36	70.71	0.15
4	7.11	72.69	5.81	70.71	0.20
5	8.89	72.69	7.26	70.71	0.25

flow investigations. In this research, the dial indicator was set in zero with the valve closed. Then install either the intake manifold or an air inlet guide on intake port. The test pressure was setting on 165.1, 139.7, 114.3, 88.9, 63.5 of cm H2O and the test range is 4. The cylinder head leakage of the experiment setting on zero point based on first setting. The first leakage reading point is as a zero point. The intake and exhaust valve opened in the experiment of cylinder head air flow investigation the four stroke direct injection diesel engines is shown in Table 2.

To analysis of the air flow experiment results data, it is necessary to measure the corrected test flow. The corrected test flow can be compared to other experiment of the same head with the same setup without further calculations. In this experiment no atmospheric corrections. To obtain the valve efficiency, it is necessary to calculate the flow in cubic feet per minute (cfm)/square inch (inch^2) or liters per second (l/s)/square centimeter (cm^2) of the valve area and then to compare that flow to the best yet achieved. Potential flow of the engine intake and exhaust manifold investigation is using the potential flow chart in section 7 (Superflow Technologies Group, 2004) of valve flow potential per unit area based on the test pressure of experiment. To calculation of % potential flow is equal test flow divided by potential flow. The % potential flow can be used as an indicator of the remaining improvement possible.

To determine the air flow valve Coefficient of Discharge (CD) is divide the test flow per unit area by the maximum potential flow per unit area for the test pressure. The flow results of this experiment investigation plotted on graphs in this study. Circles are used to indicate the intake experiment test points. Triangles are used to indicate the exhaust test points.

RESULTS AND DISCUSSION

The air flow experiment investigation for intake valve lift is opened maximum in 8.89 mm, so more than the original intake valve lift maximum opened in 7.095 mm. The maximum exhaust valve lift in this experiment is opened in 7.26 mm, so more than the original exhaust valve were opened in 7.095 mm. The air flow performance of the intake valve and exhaust valve of the four stroke direct injection diesel engine in this research experiment investigation results shown in graphs in this study. Air flow through the engine is directly controlled by the valve lift. The farther the valve opens, the greater the flow, at least up to a point. In order to discuss a wide variety of valve sizes, it is helpful to speak in terms of the ratio of valve lift to valve diameter, or L/D ratio. According to Superflow (2004), stock engines usually have a peak lift of 0.25 of the valve diameter and for racing engines open the valves to 0.30 of the valve diameter or even 0.35 of the valve diameter. Up to 0.15 of the valve diameter, the flow is controlled mostly by the valve and seat area. At higher lifts the flow peaks over and finally is controlled by the maximum capacity of the port. Wedge-chamber intakes have lower flow at full lift due to masking and bends and are port-limited at a 15% lower level. To determine the flow rate for a particular valve, simply multiply the flow/area from the graph by the valve minus the valve stem area. The flow rate get is not the expected flow rate, but the rather the maximum potential flow rate for a particular head at the test pressure. If the flow reaches a maximum value at a lift of about 0.30 d, it may wonder why some cams are designed to open the valve farther, even as high as 0.37 d. The answer is in order to open the valve more quickly and longer at lower lifts, it is necessary to over-shoot the maximum head-flow point. The extra flow is gained on the flanks of the lift pattern not at the peak. If the introduction system is installed, the total flow will drop of from 5-30% depending on the flow efficiency of the system. By measuring the flow at each valve lift with and without the induction system, it is possible to accurately measure the flow efficiency. Frequently, the induction system will have even more room for improvement than does the cylinder head. The experiment results is shown in Table 3-7.

In the superflow flowbench, the air flow from intake manifold to engine cylinder or air flow from engine cylinder to exhaust manifold based on valve lift is called correction test flow. The intake and exhaust air flow in an engine is illustrated in Fig. 4 and 5.

Correction test flow: The correction test flow from this experiment result is shown in Table 3-7 and the correction test flow trend of the experiment result based on pressure and L/D ratio shown in Fig. 6 for intake air flow and Fig. 7 for exhaust air flow.

Table 3 line 1 shows the correction test flow of air flow in intake flow and exhaust flow at 1651 mm or 65in H2O test pressure, Table 4 line 1 shows the correction test flow of air flow in intake flow and exhaust flow at 1397 mm or 55in H2O test pressure, Table 5 line 1 shows the correction test flow of air flow in intake flow and exhaust flow at 1143 mm or 45 in H2O test pressure, Table 6 line 1 shows the correction test flow of air flow in intake flow and exhaust flow at 889 mm or 35in H2O test pressure and Table 7 line 1 shows the correction test flow of air flow in intake flow and exhaust flow at 635cm or 25in H2O test pressure. In this experiment results shown that, increasing

Table 3: Intake and exhaust air flow calculation at 1651 mm H2O test pressure and range 4

Experiment object	Unit	------------------Intake system air flow performance-----------------						-------------Exhaust system air flow performance------------					
Corr. test flow	l/s	0	16.048	30.68	43.9	53.81	57.11	0	6.608	14.16	23.6	31.15	36.34
Test flow	(l/s)/cm2	0	1.68384	3.219	4.606	5.646	5.992	0	1.05975	2.271	3.785	4.996	5.829
Potential flow	(l/s)/cm2	0	2.86788	5.363	7.448	9.086	10.32	0	2.86788	5.363	7.448	9.086	10.32
%Potential flow	%	0	58.6245	59.94	61.75	62.04	57.96	0	36.8964	42.28	50.74	54.9	56.38
Coeff.Discharge	-	0	0.10349	0.198	0.283	0.347	0.368	0	0.06514	0.14	0.233	0.307	0.358
% velocity	-	3.9	4.2	4.1	5	4.5	4.1	0.8	0.8	1.1	1.1	0.8	0.8
velocity	m/s	6.342	6.86025	6.738	8.049	7.104	6.342	4.3	4.3	6.1	6.1	4.3	4.3

Table 4: Intake and exhaust air flow calculation at 1397 mm H2O test pressure and range 4

Experiment object	Unit	------------------Intake system air flow performance-----------------						-------------Exhaust system air flow performance------------					
Corr. test flow	l/s	0	11.8	25.96	38.23	47.67	51.45	0	5.664	12.74	21.24	28.79	33.04
Test flow	(l/s)/cm2	0	1.23811	2.724	4.011	5.002	5.398	0	0.90836	2.044	3.406	4.617	5.299
Potential flow	(l/s)/cm2	0	2.74351	5.129	7.122	8.691	9.873	0	2.74351	5.129	7.122	8.691	9.877
%Potential flow	%	0	45.0604	53.03	56.24	57.46	54.59	0	33.0591	39.79	47.75	53.05	53.57
Coeff.Discharge	-	0	0.08279	0.182	0.268	0.334	0.361	0	0.06074	0.137	0.228	0.309	0.354
% velocity	-	4	4.1	3.8	4.6	3.7	4.1	1.2	0.9	1.5	2.5	2.2	2.5
velocity	m/s	5.915	6.31143	5.763	6.86	5.61	6.189	1.86	1.31107	2.287	3.872	3.232	3.75

Table 5: Intake and exhaust air flow calculation at 1143 mm H2O test pressure and range 4

Experiment object	Unit	------------------Intake system air flow performance-----------------						-------------Exhaust system air flow performance------------					
Corr. test flow	l/s	0	10.384	23.6	33.98	42.48	45.78	0	3.776	9.912	17.936	24.544	29.264
Test flow	(l/s)/cm2	0	1.089	2.476	3.57	4.46	4.803	0	0.606	1.589	2.877	3.936	4.693
Potential flow	(l/s)/cm2	0	2.480	4.634	6.438	7.86	8.93	0	2.480	4.635	6.438	7.857	8.926
%Potential flow	%	0	43.864	53.35	55.30	56.64	53.74	0	24.38	34.25	44.61	50.02	52.50
Coeff.Discharge	-	0	0.080	0.183	0.263	0.33	0.355	0	0.045	0.117	0.213	0.291	0.347
% velocity	-	4.1	3.9	43	4	3.5	4.3	1.4	1.4	1.4	1.4	1.4	1
velocity	m/s	5.61	5.2747	5.763	5.458	4.756	5.763	1.86	1.86	1.86	1.86	1.86	1.31

Table 6: Intake and exhaust air flow calculation at 889 mm H2O test pressure and range 4

Experiment object	Unit	------------------Intake system air flow performance-----------------						-------------Exhaust system air flow performance------------					
Corr. test flow	l/s	0	9.44	20.77	29.74	36.82	39.18	0	3.304	7.552	15.104	20.768	24.544
Test flow	(l/s)/cm2	0	0.990	2.179	3.120	3.863	4.111	0	0.530	1.211	2.422	3.331	3.936
Potential flow	(l/s)/cm2	0	2.184	4.094	5.681	6.941	7.878	0	2.184	4.094	5.681	6.941	7.878
%Potential flow	%	0	45.36	53.22	54.92	55.65	52.18	0	24.26	29.58	42.64	47.99	49.96
Coeff.Discharge	-	0	0.083	0.182	0.261	0.323	0.344	0	0.044	0.101	0.203	0.279	0.330
% velocity	-	6.1	5.4	5.8	5.4	4.7	5.1	3.7	3.1	4.4	3.5	4.1	3.5
velocity	m/s	7.23	6.46	6.86	6.46	5.61	6.07	4.39	3.75	5.27	4.18	4.94	4.18

Table 7: Intake and exhaust air flow calculation at 635 mm H2O test pressure and range 4

Experiment object	Unit	------------------Intake system air flow performance-----------------						-------------Exhaust system air flow performance------------					
Corr. test flow	l/s	0	7.552	16.99	25.02	30.208	32.10	0	1.42	3.78	10.86	16.52	19.82
Test flow	(l/s)/cm2	0	0.792	1.783	2.625	3.1696	3.367	0	0.227	0.606	1.741	2.649	3.179
Potential flow	(l/s)/cm2	0	1.851	3.460	4.807	5.867	6.665	0	1.851	3.460	4.807	5.867	6.665
%Potential flow	%	0	42.81	51.52	54.61	54.02	50.53	0	12.27	17.50	36.22	45.15	47.70
Coeff.Discharge	-	0	0.079	0.177	0.269	0.314	0.334	0	0.023	0.060	0.173	0.263	0.315
% velocity	-	6.1	6.5	6.6	5.7	6.1	6.9	5.6	5.1	3.9	6.3	5.7	4.9
velocity	m/s	6.19	6.62	6.62	5.76	6.19	6.98	5.61	5.12	3.96	6.34	5.76	4.94

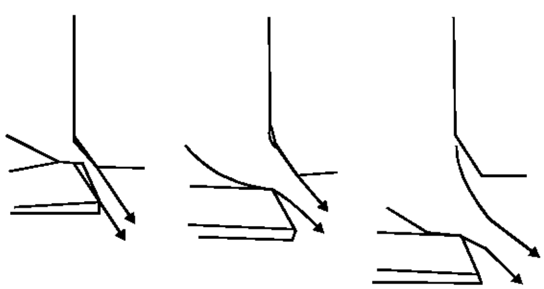

Fig. 4: Intake air flow in intake valve lift

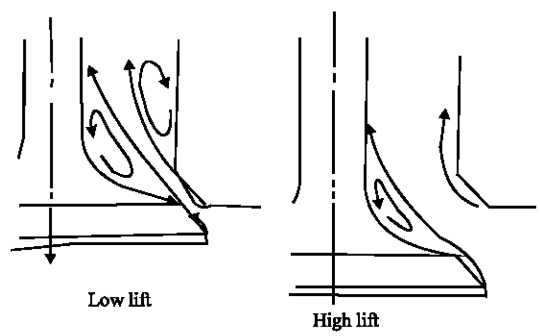

Fig. 5: Exhaust air flow in exhaust valve lift

valve lift from 0L/D until 0.25L/D or 0 mm until 8.885 mm for intake valve lift and 0 mm until 7.26 for exhaust valve lift can be increasing the correction test flow in the intake flow and exhaust flow. Table 3-7 shows that the correction test flow trend from 0L/D until 0.25L/D is increase and after 0.25L/D is stabile or horizontal. It is shown that the maximum correction test flow of the engine is near after the maximum intake valve lift or exhaust valve lift at 7.094 mm. The maximum nominal of correction test flow of the engine is shown in Table 3-7 line 1 and column 6. Table 3 shows the nominal maximum correction test flow is 57.112 liter per second for intake flow and 36.34 liter per second for exhaust flow at 1651mm H2O test pressure, Table 4 shows the nominal maximum correction test flow is 51.45 liter per second for intake flow and 33.51 liter per second for exhaust flow at 1397mm H2O test pressure, Table 5 shows the nominal maximum correction test flow is 45.784 liter per second for intake flow and 29.264 liter per second for exhaust flow at 1143 mm H2O test pressure, Table 6 shows the nominal maximum correction test flow is 39.176 liter per second for intake flow and 24.544 liter per second for exhaust flow at 889 mm H2O test pressure and Table 7 shows the nominal maximum correction test flow is 32.096 liter per second for intake flow and 19.824 liter per second for exhaust flow at 635 mm H2O test pressure.

The experiment results of correction test flow trend shown in Fig. 6 for intake correction test flow and Fig. 7

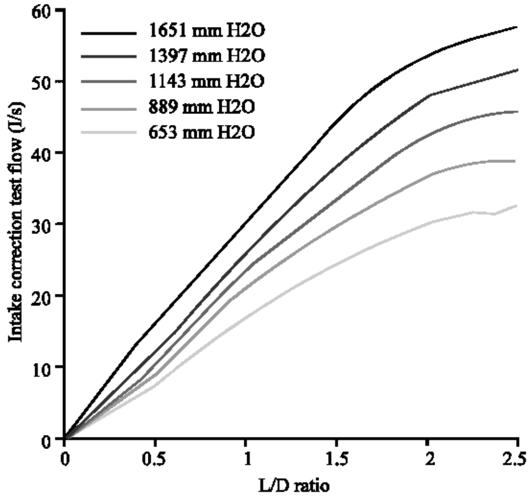

Fig. 6: Intake correction test flow in variation pressure

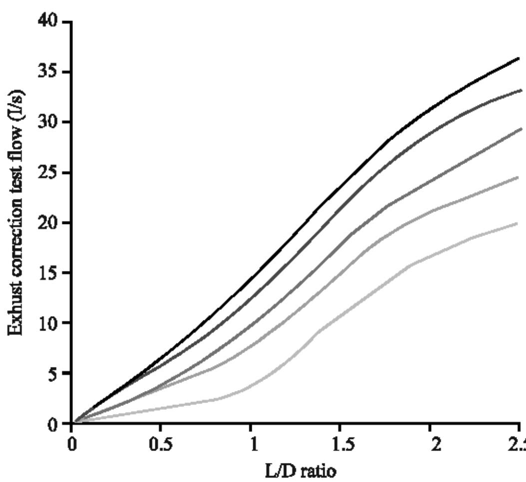

Fig. 7: Exhaust correction test flow in variation pressure

for exhaust correction test flow. In Fig. 6 and 7 shows that increasing the valve lift and test pressure can be increasing the correction test flow or air flow in intake manifold or air flow in exhaust manifold, but after the maximum valve lift, the correction test flow is stabile and can't increasing.

Test flow and potential flow: The test flow or in valve air flow of the superflow flowbench is the air flow from intake valve through to engine cylinder or air flow from engine cylinder to exhaust valve divide by the effective valve area. The test flow from this experiment result is based on difference pressure and difference valve lift per diameter (L/D). The experiment calculation results are shown in Table 3-7 line 2 and line 3. The test flow and potential flow trend of the experiment result based on pressure and L/D

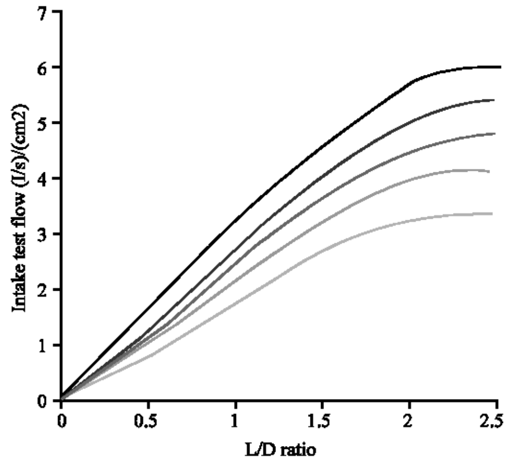

Fig. 8: Intake test flow in variation pressure

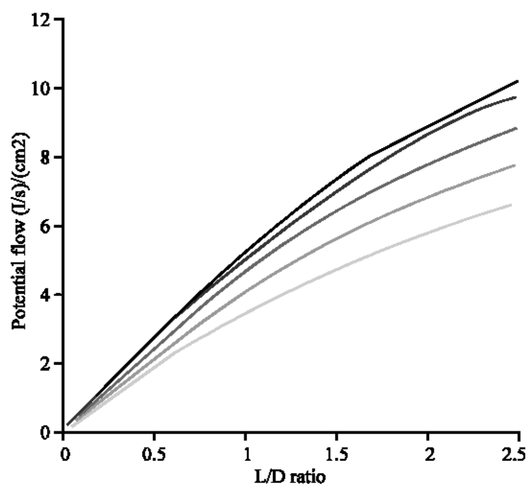

Fig. 9: Potential flow in variation pressure

ratio shown in Fig. 8 for intake test flow, Fig. 9 for potential flow and Fig. 10 for exhaust test flow.

Table 3 line 2 and line 3 shows the test flow of in valve air flow in potential flow, intake flow and exhaust flow at 1651 mm or 65 in H2O test pressure, Table 4 line 2 and line 3 shows the test flow of in valve air flow in potential flow, intake flow and exhaust flow at 1397 mm or 55 in H2O test pressure, Table 5 line 2 and line 3 shows the test flow of in valve air flow in potential flow, intake flow and exhaust flow at 1143 mm or 45in H2O test pressure, Table 6 line 2 and line 3 shows the test flow of in valve air flow in potential flow, intake flow and exhaust flow at 889 mm or 35 in H2O test pressure and Table 7 line 2 and line 3 shows the test flow of in valve air flow in potential flow, intake flow and exhaust flow at 635 mm or 25 in H2O test pressure. In this experiment results shown that increasing the valve lift from 0L/D until 0.25L/D or

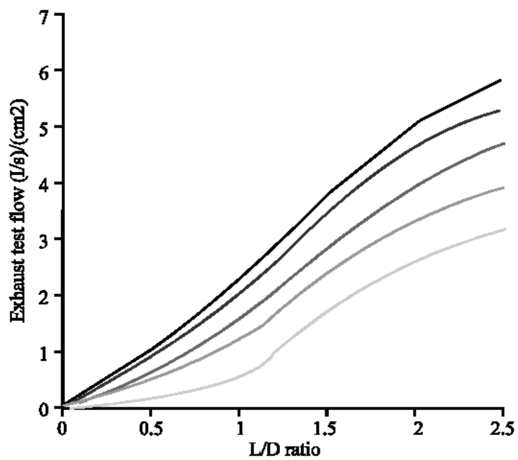

Fig. 10: Exhaust test flow in variation pressure

0 mm until 8.89 mm for intake valve lift and 0 mm until 7.26 mm for exhaust valve lift can be increasing the valve air flow or test flow in the potential flow, intake flow and exhaust flow. Table 3-7 line 2 and line 3 shown that, the test flow trend for potential flow, intake flow and exhaust flow from 0L/D until 0.25L/D is increase and after 0.25L/D is stabile or horizontal. It is shown that the maximum test flow or valve air flow of the diesel engine is near after the maximum intake valve lift or maximum exhaust valve lift at 7.094 mm.

The nominal maximum of air flow in valve is shown in Table 3-7 line 2 and column 6 for intake air flow and column 12 for exhaust air flow and Table 3-7 line 3 and column 6 and column 12 for potential flow. Table 3 shows the nominal maximum flow is 10.32 (l/s)/(cm^2) for potential flow, 5.992 (l/s)/(cm^2) for intake valve air flow and 5.829 (l/s)/(cm^2) for exhaust valve air flow flow at 1651 mm H2O test pressure. Table 4 shows the nominal maximum flow is 9.873 (l/s)/(cm^2) for potential flow, 5.398 (l/s)/(cm^2) for intake flow and 5.299 (l/s)/(cm^2) for exhaust flow at 1397 mm H2O test pressure. Table 5 shows the nominal maximum flow is 8.926 (l/s)/(cm^2) for potential flow, 5.398 (l/s)/(cm^2) for intake flow and 4.693 (l/s)/(cm^2) for exhaust flow at 1143 mm H2O test pressure. Table 6 shows the nominal maximum flow is 7.878 (l/s)/(cm^2) for potential flow, 4.111 (l/s)/(cm^2) for intake flow and 3.936 (l/s)/(cm^2) for exhaust flow at 889 mm H2O test pressure. Table 7 shows the nominal maximum flow is 6.665 (l/s)/(cm^2) for potential flow, 3.368 (l/s)/(cm^2) for intake flow and 3.179 (l/s)/(cm^2) for exhaust flow at 635 cm H2O test pressure.

The experiment results of intake air test flow trend, potential air flow trend and exhaust air test flow trend shown in Fig 8-10. The graphs shows that increasing the valve lift and test pressure can be increasing the valve air flow or test flow in potential flow, intake valve air flow and

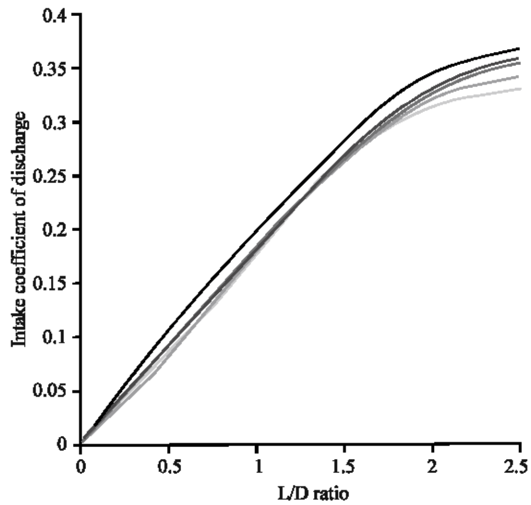

Fig. 11: Intake CD in variation pressure

exhaust valve air flow, but after the maximum valve lift the intake valve air flow and the exhaust valve air flow is stabile.

Coefficient of discharge: The Coefficient of Discharge (CD) of the air flow test from this experiment result is shown in Table 3-7 line 5. The CD trend of the experiment result is shown in Fig. 11 for intake CD and Fig. 12 for exhaust CD. The CD investigation is based on difference pressure and valve lift per diameter. Coefficient of discharge in this experiment results shown that, increasing the pressure and valve lift from 0L/D until 0.25L/D or 0 mm until 8.89 mm for intake valve lift and 0 mm until 7.26 for exhaust valve lift can be increasing the coefficient of discharge in the intake CD and exhaust CD.

Table 3-7 line 5 shows that, the coefficient of discharge for intake and exhaust flow trend from 0L/D until 0.25L/D is increase and after 0.25L/D is stabile or horizontal. The nominal maximum CD is shown in Table 3-7 line 5 and column 6 for intake valve flow and column 12 for exhaust valve flow. Table 3 shows the nominal maximum coefficient of discharge is 0.368 for intake flow and 0.358 for exhaust flow at 1651mm H2O test pressure. Table 4 shows the nominal maximum coefficient of discharge is 0.361 for intake flow and 0.354 for exhaust flow at 1397 mm H2O test pressure. Table 5 shows the nominal maximum coefficient of discharge is 0.355 for intake flow and 0.34674 for exhaust flow at 1143 mm H2O test pressure. Table 6 shows the nominal maximum coefficient of discharge is 0.344 for intake flow and 0.329 for exhaust flow at 889 mm H2O test pressure. Table 7 shows the nominal maximum coefficient of discharge is 0.334 for intake flow and 0.315 for exhaust flow at 635 mm H2O test pressure.

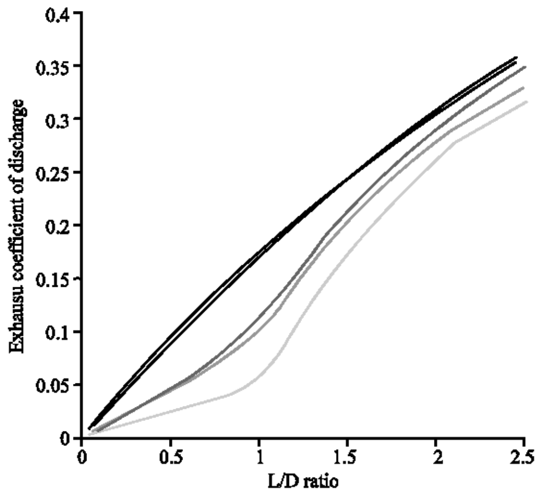

Fig. 12: Exhaust CD in variation pressure

The experiment results trend is shown in Fig. 11 and 12. These graphs shown that, increasing the valve lift and test pressure can be increase the coefficient of discharge in intake manifold or in exhaust manifold, but after the maximum valve lift, the coefficient of discharge is stabile and can't increasing.

CONCLUSION

The air flow in various test pressures and L/D ratio has been investigated in this experiment. The experiment results shown that, the correction test flow, air flow, test air flow, potential flow and coefficient of discharge in the intake port and exhaust port flow of the four stroke direct injection diesel engine provided the best in the maximum valve lift per diameter is in 0.25L/D and in highest test pressure. The experiment results shown that, increasing the valve lift and test pressure can be increasing the air flow and coefficient of discharge in intake manifold system and in exhaust manifold system, but after the maximum valve lift per diameter is over than 0.25L/D, the air flow and coefficient of discharge is stabile and can't increasing.

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