Int. J. Chem. Sci.: 14(S2), 2016, 681-686
ISSN 0972-768X
www.sadgurupublications.com

DESIGN OF THROTTLE BODY: A COMPARATIVE STUDY OF DIFFERENT SHAFT PROFILES USING CFD ANALYSIS

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ABSTRACT

Throttle body assembly plays a vital role in metering the air flow to the engine. It mainly consists of a butterfly valve to vary the flow area to control air flow rate through it. There is hardly any established procedure to design a throttle body assembly based on engine specification. In this project we intend to design and analyze the throttle body assembly using Computational Fluid Dynamics and compare two throttle body shaft profiles. To start with throttle bore diameter is calculated based on engine air flow requirements. The throttle body shaft configurations are modelled and using CFD analysis we arrive at the best configuration which will provide optimum airflow. The airflow rate for different throttle opening is predicted through detailed analysis. Finally, we intend to validate the results obtained from the flow analysis by fabricating the throttle body assemblies and testing them.

Key words: Throttle body shaft, Bore diameter, CFD Analysis, Airflow rate.

INTRODUCTION

A throttle body is the part of the air intake system in fuel injected automobiles that controls the amount of air flowing into the engine, in response to driver accelerator pedal input. The throttle body is usually located between the air filter box and the intake manifold, and it is usually attached to, or near, the mass airflow sensor. When the driver presses on the accelerator pedal, the throttle plate rotates within the throttle body, opening the throttle passage to allow more air into the intake manifold.

The largest piece inside the throttle body is the throttle plate, which is a butterfly valve that regulates the airflow. A butterfly valve is a valve which can be used for isolating or regulating flow. The closing mechanism takes the form of a disk. Operation is similar to

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that of a ball valve, which allows for quick shut off. Butterfly valves are generally favoured because they are lower in cost to other valve designs as well as being lighter in weight, meaning less support is required. The disc is positioned in the centre of the pipe; passing through the disc is a rod connected to an actuator on the outside of the valve. The disc is always present within the flow, so a pressure drop is always induced in the flow, regardless of valve position.

A butterfly valve is from a family of valves called quarter-turn valves. In operation, the valve is fully open or closed when the disc is rotated a quarter turn. The "butterfly" is a metal disc mounted on a rod. When the valve is closed, the disc is turned so that it completely blocks off the passageway. When the valve is fully open, the disc is rotated a quarter turn so that it allows an almost unrestricted passage of the fluid

Using CFD the flow characteristics of the air flow inside the throttle body can be assessed. Thus the project aims at bringing out the better profile by analyzing the simulation data and validating it through experimentation

Literature survey

In the paper 'DESIGN and Optimisation of Throttle Body Using CFD Analysis' by Suresh Kumar et al.[1] have carried out flow simulation of flow through throttle body and have optimized the throttle shaft configuration, studied effects of throttle opening on flow field and airflow rate, effects of bypass screw position on air flow field, engine performance and emissions and also effects of throttle bore diameter on airflow and engine power developed. This paper is the base paper for this project work which helped setting the goal for this project.

In the paper 'Modelling The Time-Dependent Flow Through A Throttle Valve' by Alsemgeest et al.[2] have carried out simulation of time-dependent flow through throttle valve to determine flow mechanisms for various throttle plate angles and compared results with hexahedral and tetrahedral meshes.

'Internal Combustion Engine Fundamentals' by John B Heywood[3] is a book that presents fundamentals and factual developments of the science and engineering underlying the design of combustion engines and turbines. This book helped us in understanding the basics of engine and using the parameters such as mean piston speed the throttle body was designed.

'Back to Basics' by Prof. Gordon Blake[4] which discusses the fundamentals and empiricism in engine design. This technical magazine helped us in understanding the relationship between mean piston speed and mean gas velocity which is an essential parameter in determining the throttle bore diameter.

Methodology

The methodology followed for completing this project is:

- Literature survey: Various research papers, journals and textbooks are to be referred to acquire knowledge in the subject.
- Determination of throttle body bore: A benchmark engine has to be selected and the throttle body has to be designed to meet its specifications.
- Modeling of various shaft profiles: The shaft profiles as well as their assemblies should be modeled in modeling software.
- Flow simulation: The flow through the model has to be simulated and analyzed using CFD solvers.
- Experimental validation: An experimental setup has to be fabricated and the simulation data has to be experimentally validated.

Design and specification

The design procedure aims at designing the throttle body with optimum dimensions. Initially a benchmark engine had to be chosen. The engine we chose was the Maruti Suzuki Swift Petrol engine

Benchmark engine specifications

Table 1: Engine specifications

Engine capacity (V_d)	**1197 cc**
Max power	85 hp@6500 rpm (N)
Bore (B)	73 mm
Stroke (L)	71.5 mm

Cont…

Engine capacity (V_d)	**1197 cc**
Inlet port diameter (D_i)	34 mm
Torque (T)	115 Nm

Visualisation of back flows downstream of the throttle valve

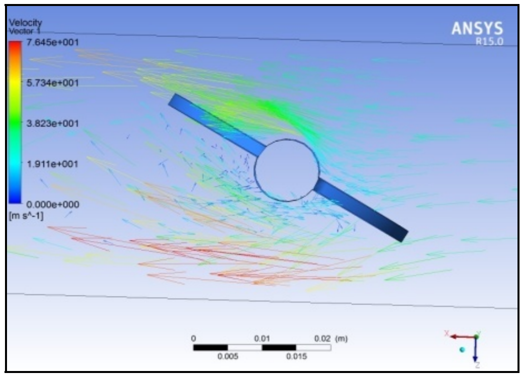

Fig. 1: Vector plot of circular profile

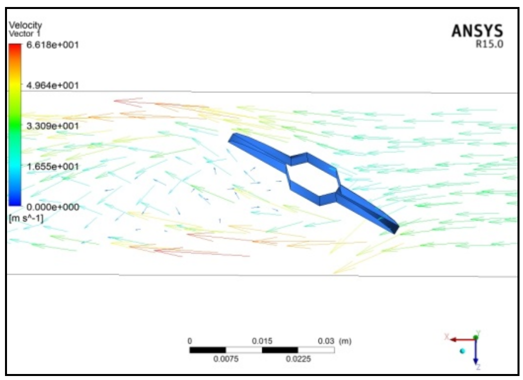

Fig. 2: Vector plot of rectangular profile

Observations

Once the assembly was done, to carry out the experiment the air blower was attached to the inlet pipe. When the blower is switched on the manometer shows height difference due to the pressure drop across the valve. The readings were taken at 30, 45, 60 & 90 (wide open) opening of the valve. The pressure drop is calculated using manometer formula & was taken for across the valve and for across the system as well. This was done for both the circular and rectangular profiles throttle bodies.

Table 2: Pressure drop across the butterfly valve

Angle	30^0		45^0		60^0		90^0	
	H (mm)	**P (Pa)**	**H (mm)**	**P (Pa)**	**H (mm)**	**P (Pa)**	**H (mm)**	**P (Pa)**
Circular	152	1489.6	72	705.6	24	235.2	9	88.2
Rectangular	121	1185	67	656.6	22	205.8	9	88.2
ΔP		304.6		49		29.4		0

Table 3: Pressure drop across assembly

Angle	30^0		45^0		60^0		90^0	
	H (mm)	**P (Pa)**	**H (mm)**	**P (Pa)**	**H (mm)**	**P (Pa)**	**H (mm)**	**P (Pa)**
Circular	149	1460.2	103	1009.4	55	539	13	127.4
Rectangular	115	1127	70	686	51	499.8	70	68.6
ΔP		333.2		323.4		39.2		58.8

RESULTS AND DISCUSSION

The major focus on the simulation were on the sudden pressure drop created across the butterfly valve at various valve opening angles and the presence of backflows which adversely affect the flow through the throttle body. The results from the simulation were compared with data obtained from the experiment. The conclusion drawn is as follows:

- The flow simulation showed the pressure drop across rectangular shaft profile to be less than that across the circular profile, which is similar to the result obtained from the experiment.
- The highest difference in pressure drop across the butterfly valve was expected 30^o valve opening which was in agreement with the experimental result.
- The difference in pressure drop for both shaft profiles decreased suddenly after 30^o of valve opening as predicted.
- The pressure drop difference at 45^o, 60^o and 90^o of valve opening were not as significant as that seen at 30^o valve opening.

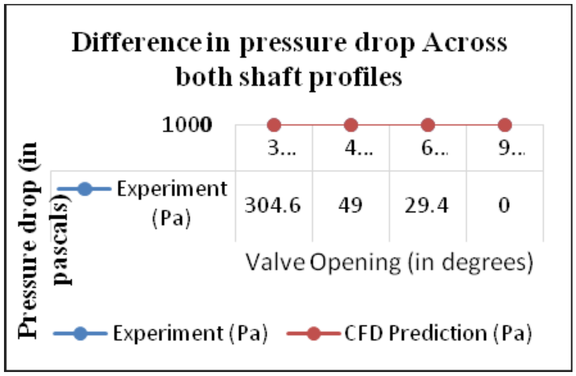

Fig. 3: Comparison chart for theoretical and experimental pressure drop

CONCLUSION

The throttle bore parameters were calculated using flow equations and was modeled. The flow through the throttle bodies each with different shaft profiles were simulated and compared experimentally. Data obtained from both showed the rectangular shaft profile to have less pressure drop as compared to the circular one. The throttle body with rectangular shaft profile showed better flow characteristics with minimal backflow and reduced turbulence downstream of the butterfly valve thus proving to be the better choice. An internal combustion engine equipped with such a throttle body will have better breathing capacity which would mean an improvement its Performance, fuel economy and emissions.

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Accepted : 01.07.2016