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Research Paper Engineering

Design and Development of Inlet Manifold for Six Cylinder Engine for Truck Application

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ABSTRACT

Current design manifold for one of the truck engine is having less plenum volume which is not suitable for air requirement of engine and hence result in reduced volumetric efficiency. To simplify the design & make the component in pressure die casting & to increase the yield also to qualify the engine noise, performance and durability requirement and to reduce the part cost new inlet manifold is designed and developed.

KEYWORDS Helmoltz Tuning, Pressure drop, plenum volume, swirl number.

INTRODUCTION

Intake manifold connects the intake system to the intake valve of the engine and through which air or air–fuel mixture is drawn into the cylinder. It significantly affects engine performance: torque, Power, emissions, drivability and noise. Manage air flow, distribute fluids equally to all cylinders, and increase volumetric efficiency via air flow tuning. Minimize contributions to noise should meet engine & vehicle Platform Level Packaging Requirement. Inlet manifold profile should help to reduce the sudden raise in pressure waves which improve induction process and also eliminate the unnecessary turbulence and eddies inside the intake manifold. Intake manifolds consist typically of a plenum, to the inlet of which bolts the throttle body, with the individual runners feeding branches which lead to each cylinder. Important design criteria are low air flow resistance good distribution of air and fuel between cylinders runner and branch lengths that take advantage of ram and tuning effects; sufficient (but not excessive).

Figure 1: Typical Inlet Manifold

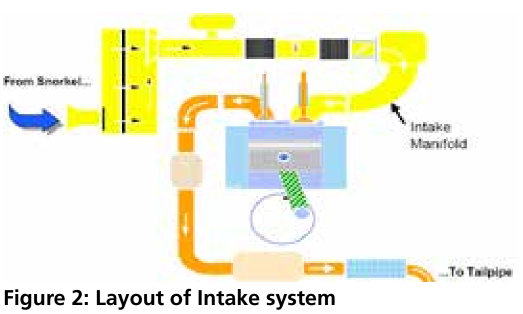

Figure 2: Layout of Intake system

OBJECTIVES

In this study we try to resolve the complex design of Gravity Die Casting model into Simple design which offers higher yield due to the improved process also new design is required for increasing the engine performance (reduced pressure drop & less swirl number) and increased durability life of component also we try to propose a design which promotes identical distribution of air to cylinder it should also keep the sudden rise in pressure wave at moderate level to reduce the turbulence and eddies generated because of design flaw. Runner Design will also be reviewed to offer minimum possible resistance and finally the design product should meet the Engine packaging, durability, performance and noise requirement.

PROBLEM DEFINITION

During study of one of the six cylinder engine for truck application for one of the OEM we found that Complex GDC Casting Inlet Manifold is having higher pressure drop and also contribute on increased swirl number as Existing design is not meeting the mid to low speed torque requirement and has considerable drop in induction efficiency at high speed due to turbulence and therefore a need of simpler improved design is required

METHODOLOGY

Various design concepts will be evaluated like equal runner length Design, Centre Feed Design, Dual Plenum design will be evaluated and also design requirement at air intake system level (Minimum Pressure Drop, Back Pressure). Initial concept will be made and then with the help of CFD we will try to optimize the shape and size and then through prototyping and bench test confirmation of performance will be done. Several geometric variations of the three main concepts were also simulated. Each intake was modeled to make as many aspects as comparable as possible. A goal of the paper was to focus on comparing plenum concepts which required separating the effects of runner length and restrictor design from the concepts. The choice Each intake was modeled to make as many aspects as comparable as possible. A goal of the paper was to focus on comparing plenum concepts which required separating the effects of runner length and restrictor design from the concepts. The choice of plenum layout directly affects the packaging and design of the runners and restrictor, thus the desire to determine the best suitable intake plenum concept first. With differences in engine, exhaust manifold, intake volume and runner length removed from the simulation, it was possible to determine the most desirable overall geometry that gave the best volumetric efficiency characteristics.[3]

Figure 3: Inlet Manifold types: Center Feed Design

Figure 4: Inlet Manifold Types: Conical Spline

Figure 5: Inlet Manifold Type: Side Intake Concept

Table – 1 Typical Engine Specification For Truck

Engine Specification for Truck	
No of Cylinders	6 - in line
Displacement [ltr]	7
Combustion system	4 Stroke, Diesel, Direct Injection
Fuel supply mode	Feed pump
Fuel system type	Common Rail
Fuel peak injection pressure [Bar]	1400
Crank Case Ventilation	Open type
Aspiration type	Turbocharged
Emission level	BS III
Compression Ratio	16: 1
Firing Order	1-4-2-6-3-5

BASIC DESIGN GUIDELINE FOLLOWED

Air flow capacity and engine power output are directly related. The air flow system must be sized properly to provide enough air flow to meet the power requirement of the engine. If the air flow system is too small, the engine will not be able to achieve its power target. If it is too large, low speed torque, as well as combustion performance may be compromised. While designing we consider Primary Design Requirement and Secondary design requirement. (See Fig. 6) [2]

DESIGN DETAIL

Good air flow efficiency implies low restriction and effective utilization of the intake manifold runner area. Good air flow efficiency implies low restriction than effective utilization of the intake manifold runner area. A good guideline for judging an intake manifold is the amount of flow loss it provides from the cylinder head port flow. Good intake manifolds generally cause a flow loss of 10% or less on the flow bench in the low speed range, the valve events play the most significant role in engine output..In the mid-range, the intake manifold tuning mechanisms are most effective in boosting volumetric efficiency.(See Fig 6, 7) [2,3,4]

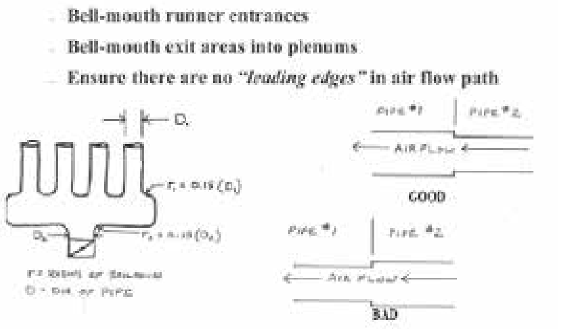

Figure 6: Runner Entrance Design Criteria

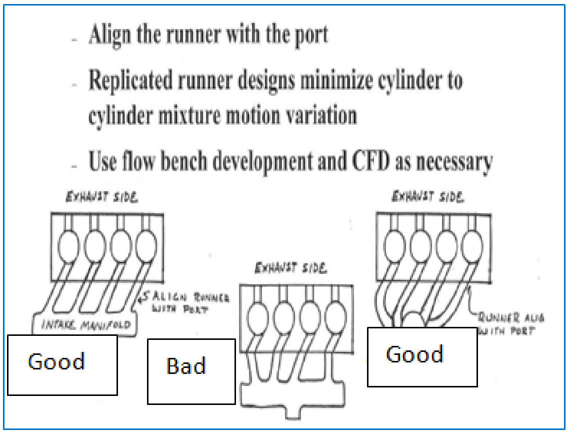

Figure 7: Runner Length Design Criteria

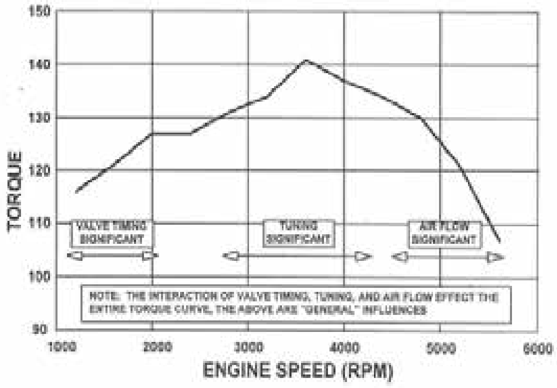

Figure 8: Torque Vs Speed Manifold design Zone

RESONANCE TUNING

Resonance tuning is effective at low engine speeds. Inertial tuning is effective at mid and high engine speeds. Low speed torque gain: long runners and / or small runner diameters. High speed torque gain: short runners and / or large runner diameters.Resonance tuning is effective at low engine speeds

Inertial tuning is effective at mid and high engine speeds Low speed torque gain: long runners and / or small runner diametersHigh speed torque gain: short runners and / or large runner diameters. The arrangement of plenums and runners combined with the dynamics of periodic air flow utilize physical tuning mechanisms to alter volumetric efficiency Resonance Tuning is a function of firing frequency Inertial Tuning (Helmholtz Ram) is not a function of firing frequency Small diameter runners usually improve combustion increasing runner taper reduces the effective runner length and improves air flow efficiency throttle body noise results from pressure pulsation in the induction system. The pleasability of this sound depends on the configuration of the intake manifold. The critical feature is the length of the flow path from the throttle body to each intake valve. If the lengths are nearly the same, the sound approaches a pure tone, which increases with engine speed. If the lengths are different, the sound has a less pleasing quality.[2]

CFD BOUNDARY CONDITION AND METHODOLOGY

Inlet mass flow rate was decided as follows:
Inlet mass flow rate = m / No. cylinder / No. stroke
m :air flow rate corresponded to the condition at rated power operation =0.42kg/s.
No. cylinder: number of cylinder =6.
No. stroke : number of stroke = 4.

CFD Technique used for the analysis includes comparison of velocity profile at the outlet port also comparison of vortex generation at the outlet crossection. Design Improvement done and named as concept A,B,C with removal of sharp corners and increased radius of walls to decrease the deflection near the wall. Model B flow is more deflected by the wall near the outlet than model A and it reduces effective outlet area. Flow in port #5 is less deflected by the wall than in port #4. [4]

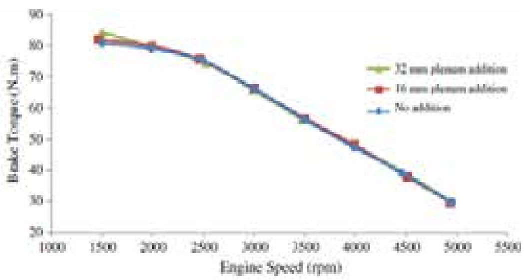

Figure 9: Effect of Plenum Volume on Brake Torque

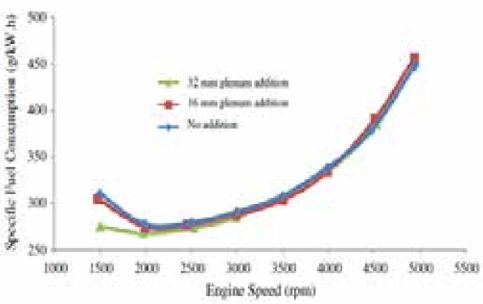

Figure 10: Effect of Plenum Volume on Specific Fuel Consumption

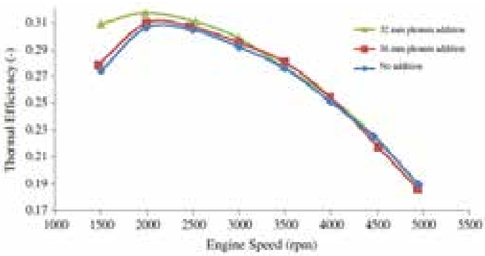

Figure 11: Effect of Plenum Volume on Thermal Efficiency

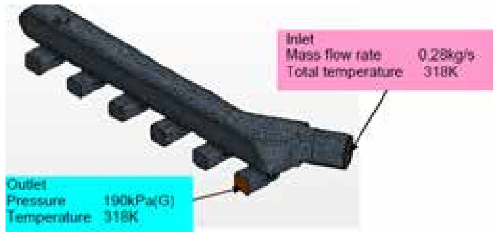

Figure 12: Boundary Condition for CFD Analysis

CFD DESIGN IMPROVEMENTS

Good Design of Manifold can be insured as seen from CFD Analysis by reducing the sharp corners in runner outlet area also vortex flow to be reduced by reducing the dead plenum and collector volume as indicated vortex on the section S2 of Model B and it causes less uniform stream lines . This is the additional effect on increasing the pressure drop

CONCLUSION

On the basis of the comparison between Model A and Model B, Model C was designed to reduce the pressure drop. Differences between Mode B and Model C are the shape around the outlet and the collector shape near the inlet. The former is to reduce the flow deflection at the outlet of each port and the latter is to reduce the vortex. Model C flow is less deflected by the wall near the outlet than Model B.

Some modifications of design (Model C) were made to reduce the pressure drop and CFD calculation was performed again. CFD result showed the pressure drop of Model C is smaller than that of Model B and

Almost same as Model A except for the case of port #1. Pressure drop between the inlet and the outlet for different inlet manifolds. Pressure drop of Model B is larger than that of Model A except for the case of port #5. Pressure drop of Model C is smaller than that of Model B and almost same as model A except for the case of port #1. All these Design Improvements was validated using performance bench test and through proto samples and finally the target pressure drop is achieved with increased plenum volume and improved runner section.

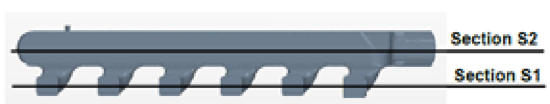

Figure 13: CFD Section study for Improvement with model (A= 3.5 lit., B=4 lit. & C=4.5 lit. with different runner section design)

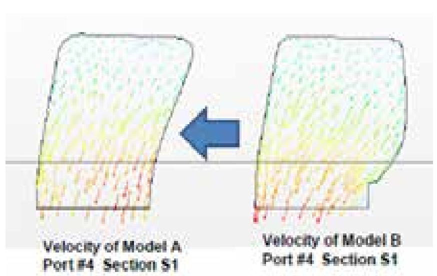

Figure 14: Runner Section Improvement through CFD Technique

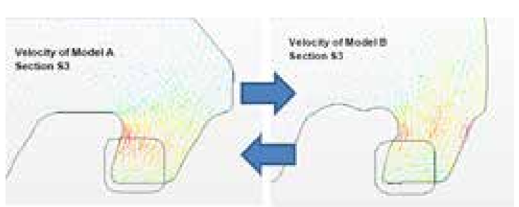

Figure 15: Reduced pressure drop by section Improvement

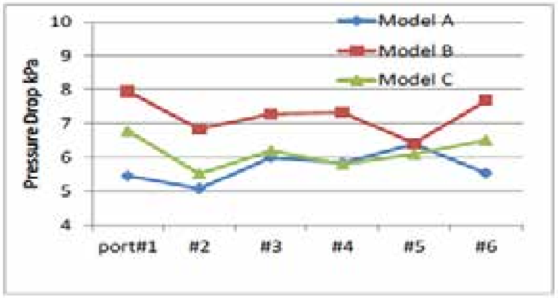

Figure 16: Comparison of pressure drop for Design A, B, C

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