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THERMAL ENGINE AIR INTAKE SYSTEM

Abstract: *The paper presents a description for the air intake system for the thermal engines and the importance of this regarding the engine power, pollution level and acoustic behaviour. The first part of the research shows it at large all the components of the intake system and the rule of each part. The second part of the paper present detailed information about one of the most important part of the air intake system that is the air intake manifold.*

Key words: *air intake system, manifold, engine power, acoustic behaviour.*

INTRODUCTION

An intake system is a set of components that essentially allows an internal combustion engine to inhale, in the same way that the exhaust system allows it to exhale. Early automotive intake systems were simply inlets that allowed air to pass unimpeded into the carburettor, but modern systems are much more complex.

Modern naturally-aspirated intakes consist of at least four basic elements (an intake manifold, an air filter, a mass air flow sensor, and a throttle body), but they still perform the same basic function that simple air inlets did in early automobiles. Other intakes include components like turbochargers and superchargers to increase engine power.

2. DESCRITION AND COMPONENETS FOR THE AIR INTAKE SYSTEM

2.1 Air intake system for atmospheric engines

In the intake system for atmospheric engines (naturally aspirated), the air naturally enters into the combustion chamber and the system consists of the following elements: inlet scoop, upstream air duct, air filter, downstream air duct, throttle control and air intake manifold. Also we can have resonators included.

The air enters into the engine cylinders crossing the parts in the order mentioned above.

In fig. 1 are shown the elements of the air intake system for an atmospheric thermal engine. In our days, the atmospheric diesel engines have disappeared, because their efficiency being very low and, on the other hand, their ability to comply with the applicable law on compliance the pollution norm is limited.

In present, with an atmospheric gasoline engine, the maximum pollution standard Euro 6 can be achieved.

2.2 Air intake system for turbocharged engines

Other than those basic elements, supercharged and turbocharged engines include additional intake components. These systems differ from naturally aspirated engines in that they use either an exhaust-driven turbine (turbochargers) or an engine-driven pump (superchargers) to increase the volume of air that passes through the intake system.

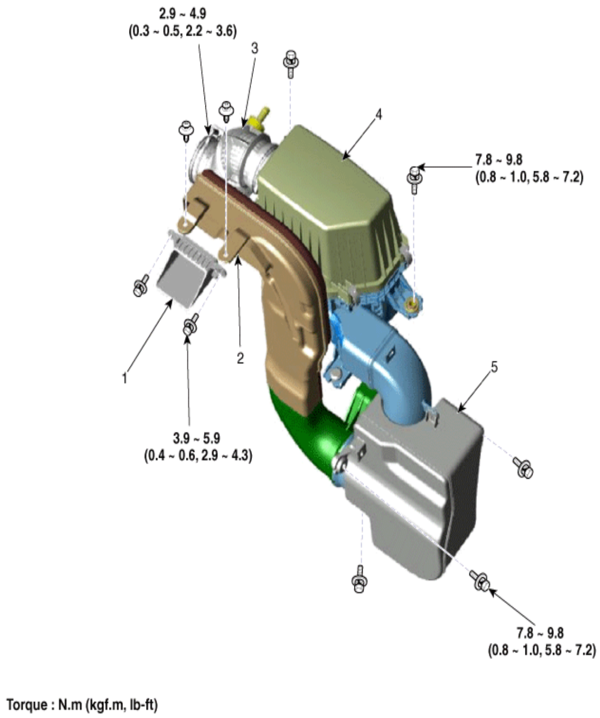

Fig.1 Naturally aspired engine intake system components [1]
1. Inlet scoop; 2. Upstream air duct; 3. Downstream air duct; 4. Air filter; 5. Resonator

In the intake system for turbocharged engines, the compressed air is forced to enter into the combustion chamber with a high pressure and the system consists of the following elements: inlet scoop, upstream air duct, air filter, downstream air duct, turbocharger, turbo outlet duct, intercooler, intercooler outlet duct, throttle control and the air intake manifold.

So, this type of air intake architecture is divided by two branch - low pressure branch (inlet scoop, upstream air duct, air filter and downstream air duct) and high pressure branch (turbocharger, turbo outlet duct, intercooler, intercooler outlet duct, throttle control and the air intake manifold) plus different types of resonators if it is necessary.

In fig. 2 are shown the elements of the air intake system for a turbocharged thermal engine.

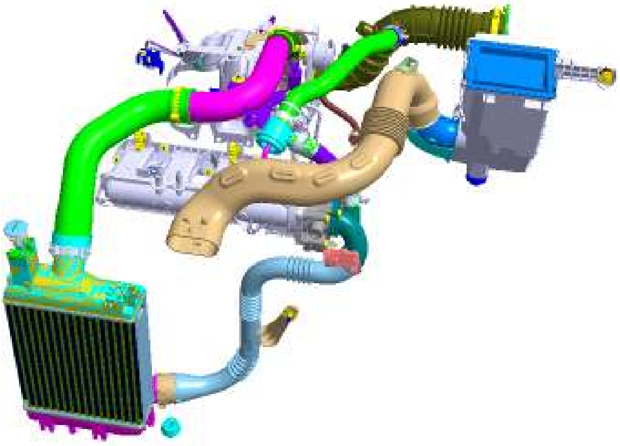

Fig. 2 Turbocharged engine intake system components

3. AIR INTAKE MANIFOLD

The air intake manifold ensures the optimal filling of the engine cylinders with a suitable mass of carburant consisting of fresh air and re-circulated exhaust gases. The intake manifold also carries out the function of integrating other engine supply control functions: fuel supply, fuel anti-evaporation system control, and engine operation point control. Hence, the air intake manifold can also carry out the function of engine supply mechatronic module, with the following advantages: compact size, cost, and assembly on the engine.

The intake manifold basically consists of a volume of thermoplastic material with high thermal and mechanical resistance, hooked up to the engine by means of duly sized conduits and made in injection molding technology and welding of vibrating parts. The technical solutions satisfy needs in terms of weight reduction and recyclable materials [2].

The air intake manifold is a major part of the air intake system. His basic function, as its name suggests, is to distribute the intake gases to different cylinders of the engine. This distribution, in terms of the air mass allowed (definition of the filling), must be maximum to optimize the performances and the most homogeneous possible to assure a minimum acyclic behavior to the engine.

The homogeneity of distribution is obtained by the connection node of the inlet ducts of the various cylinders, called plenum. Downstream of the plenum, the intake ducts or primary ducts are identical from one post to another. In the plenum, the patterns facing each post must have a maximum symmetry with respect to mass transfers, both in terms of aerodynamics and acoustic behavior (impedance), between the upstream distributor and the (s) cylinder (s) in the intake phase.

The optimization of the performances is specific to the air intake manifold of the atmospheric engine: it is the place of the acoustic phenomenons which allow the optimization of the air filling of the cylinders and give to the engine a typing very characteristic performance, in addition to the exhaust manifold and the distribution. This typing requires particular care on the dimensioning of the internal skin of the air intake manifold, in addition to the homogeneity of distribution: the length and the evolutive section of the ducts, as well as the volume of plenum participate in the acoustic agreements making it possible to increase the filling air cylinders by dynamic effects of pressure (reduction of pumping, feeding at the end of admission).

The air intake manifold of the supercharged engine is an element of the intake acoustics, in that it must not affect mass transfers between upstream and downstream. However, it incorporates aerodynamic functions to promote combustion according to the desired flow in the combustion chamber (swirl, tumble). These functions can be passive (linked to the dispatcher geometry) or active (integration of an active flap system in the air intake manifold).

4. DEFINITION OF THE INNER SKIN: AERODYNAMIC AND FILLING

4.1 Atmospheric engine (direct or indirect injection)

The air intake manifold plays a key role in the air filling of atmospheric engines. It controls the acoustic chords that improve the air filling at the closing of the intake valves (RFA) for given frequencies (or engine speeds). In order to better realize the filling function, it is imperative to respect the following characteristics:

- Plenum of the air intake manifold for an atmospheric gasoline engine;

  The volume of the plenum must be at least equal to the engine cylinder:

$$V\ (\text{plenum}) \geq V_{cyl} \qquad (1)$$

  In order to ensure optimum filling (differences in acoustics and minimum permeability), the appearance of the patterns at the outlet of each primary duct must be perfectly identical, if the air inlet in the distributor is lateral, or perfectly symmetrical if the air inlet is central. The plane of symmetry passes through the entrance (it is useless to want to optimize the recirculation zones, especially at the plenum end).

- Primary ducts of an air intake manifold for an atmospheric gasoline engine;

  The primary ducts of the distributor, with the cylinder head ducts, define the acoustic tuning frequency between the two resonators that are the combustion chamber and the distributor.

  The length of primary conduit it is usually around 450mm (on the distributor, excluding the cylinder head) for a P_{max} ~ 5500 rpm.

  The zero of the curvilinear abscissa is given by the splitter - breech interface.

  For a length D_1, where D_1 is the equivalent diameter of the cross-section at the zero curvilinear abscissa, the cross-section at the neutral fiber must be constant (or weakly convergent in the flow direction according to the clearance angle given by the process).

  In this zone, the gas velocities are maximum and must not exceed 100 m / s (120 m / s for a sports engine) and fall below 90 m / s.

From the curvilinear abscissa D_1, the cross section to the neutral fiber must evolve linearly towards the final section given by the equivalent diameter D (fig. 3).

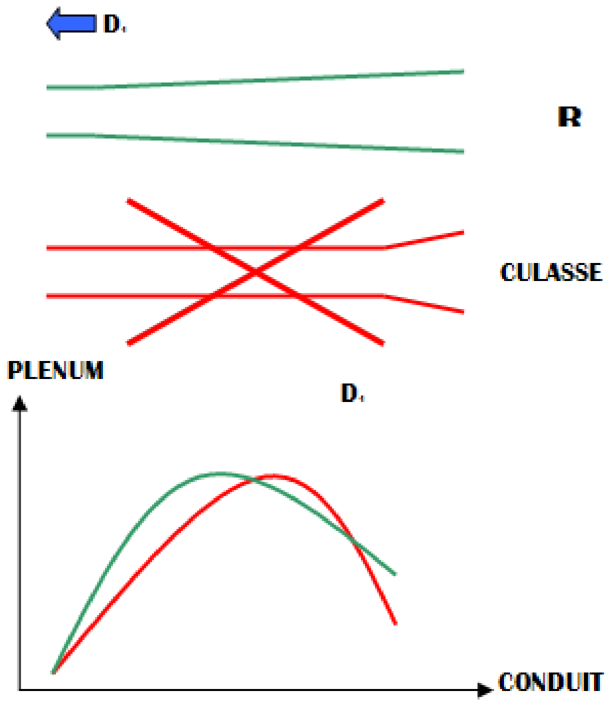

Fig. 3 Influence of the geometry of primary ducts on the shape of the torque curve

- Parallel plenum resonator (remote air filter);

The acoustic waves not reflected by the plenum are transmitted upstream of the line. Part of these waves will then be reflected on the air filter volume, placed upstream of the plenum, so:

- When the air filter is installed directly on the throttle body, the acoustic length defined by the filter volume is close to that defined by the plenum. Acoustic resonance is broadly similar.
- When the air filter is placed away from the air intake manifold (generic case of the filter implantation on the body), the acoustic length defined by the filter volume is greater than that of the primary ducts, and defines a tuning regime more low. We then observe two lobes on the torque curve: the first corresponding to the harmonics of the filter, the second to those of the plenum (fig. 4).

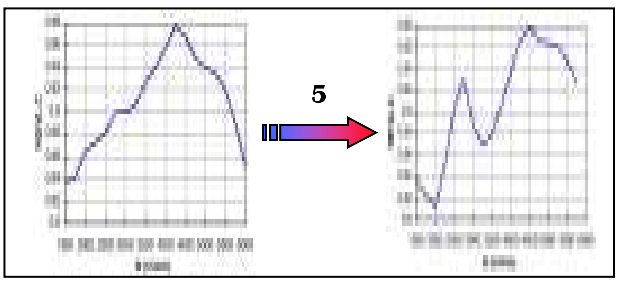

Fig.4 The increase of the air-plenum filter distance generates a hollow of torque

The hollows of torque are harmful to the agreement. In order to eliminate these undesirable effects for the customer, and within a certain limit of air filter - plenum distance, a parallel resonator plenum calibrated in frequency on the anti-resonance characterized by the hollow filling is used (fig. 5).

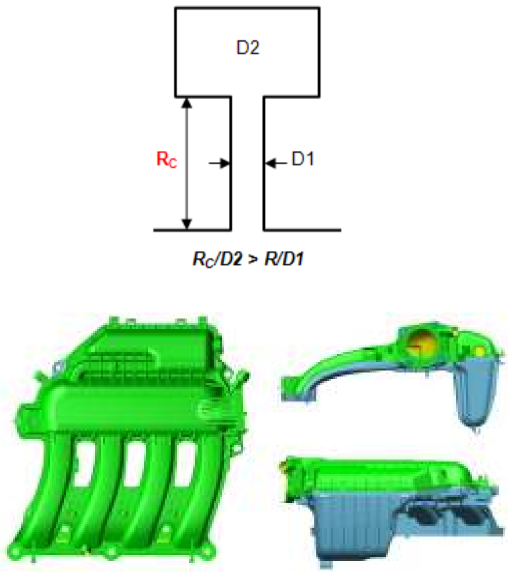

Fig. 5 The parallel plenum resonator

4.2 Turbocharged engine (indirect or indirect injection)

The air intake manifold does not have a key role in the air filling of turbocharged engines. The air filling of the cylinders is ensured by the turbocharging, except at low speed where the atmospheric filling makes it possible to compensate the deficiency of turbocharging. To do this, the necessary acoustic length is important and cannot be achieved by the primary ducts.

Acoustic tuning is then performed on the turbo air cooler. For this purpose, in addition to its air distribution function, the air intake manifold of the turbocharged engine must be "transparent" to the acoustic waves. To promote air filling of a turbocharged engine, the following design rules must be followed:

- Plenum of the supercharged engine distributor;

  The volume of the plenum must check:

$$V_{cyl} / 3 \leq V\ (\text{plenum}) \leq V_{cyl} / 2 \qquad (2)$$

  In order to ensure optimum filling (differences in acoustics and minimum permeability), the appearance of the patterns at the outlet of each primary duct must be perfectly identical, if the air inlet in the air intake manifold is lateral, or perfectly symmetrical if the air inlet is central. The plane of symmetry passes through the entrance (it is useless to want to optimize the recirculation zones, especially at the plenum end).
- Primaries of the turbocharged engine air intake manifold;
- Diesel direct injection;

  The primaries ducts are non-existent on the distributor: direct connection radius between face 200 and plenum.

- Indirect gasoline injection.

To minimize the dispersion of richness, the length of the primary conduits must be greater than 150mm on the distributor.

This type of architecture induces 40% to 50% of pressure losses from station to station but these losses are transparent.

Variable-Length Intake Manifold (VLIM) is an internal combustion engine manifold technology. Four common implementations exist. First, two discrete intake runners with different length are employed, and a butterfly valve can close the short path. Second the intake runners can be bent around a common plenum, and a sliding valve separates them from the plenum with a variable length. Straight high-speed runners can receive plugs, which contain small long runner extensions. The plenum of a 6 or 8-cylinder engine can be parted into halves, with the even firing cylinders in one half and the odd firing cylinders in the other part. Both sub-plenums and the air intake are connected to a Y (sort of main plenum). The air oscillates between both sub-plenums, with a large pressure oscillation there, but a constant pressure at the main plenum. Each runner from a sub plenum to the main plenum can be changed in length. For V engines this can be implemented by parting a single large plenum at high engine speed by means of sliding valves into it when speed is reduced.

As the name implies, VLIM can vary the length of the intake tract in order to optimize power and torque, as well as provide better fuel efficiency.

There are two main effects of variable intake geometry:

- Venturi effect - At low rpm, the speed of the airflow is increased by directing the air through a path with limited capacity (cross-sectional area).

  The larger path opens when the load increases so that a greater amount of air can enter the chamber. In dual overhead cam (DOHC) designs, the air paths are often connected to separate intake valves so the shorter path can be excluded by deactivating the intake valve itself.
- Pressurization – A tuned intake path can have a light pressurizing effect similar to a low-pressure supercharger due to Helmholtz resonance. However, this effect occurs only over a narrow engine speed range which is directly influenced by intake length. A variable intake can create two or more pressurized "hot spots."

When the intake air speed is higher, the dynamic pressure pushing the air (and/or mixture) inside the engine is increased. The dynamic pressure is proportional to the square of the inlet air speed, so by making the passage narrower or longer the speed/dynamic pressure is increased [3].

5. CONCLUSION

The intake manifold is the last, and arguably the most important, part of your engine’s air intake tract. It’s here where the air or air/fuel mixture that exits the throttle body or carburetor respectively is distributed to each individual cylinder head intake port. How well the intake flows and how evenly the air or air and fuel are allocated are critical to your engine’s power output and your vehicle’s performance [4].

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