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MODIFICATION OF THE INTAKE MANIFOLD OF A COMBUSTION ENGINE

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Abstract: *This paper deals with the issue of the variable length of the intake manifold for combustion engines. The part of it is also a demonstration of used constructions of mass-produced vehicles. The aim was to optimise the length of the intake manifold for the submitted combustion engine using the Ricardo Wave software and then to design its possible construction solution.*

Keywords: SI Engine, Intake manifold, Variable length, CAD design.

1. Introduction

When constructing the engine, the aim is both to reach high torque when the speed is low, and high rated power when the speed is maximum. The engine torque flow is adequate to absorbed air weight depending on the engine speed. An assisting means for influencing the torque is the geometric design of the intake manifold. The easiest way of supercharging lies in using the intake air dynamics. A standard intake manifold of multipoint injection systems consists of individual intake manifolds and a collection (intake) manifold with an air throttle. In this case, too, the short manifold enables high rated power at the same time with losses of torque in low speed; and the long manifold shows the opposite characteristics. Big capacity of the collection manifold produces (at certain torque) a partial resonance effect which improves the filling. However, it results in possible dynamic errors (deviations in mixture composition when there are fast changes in load). Almost ideal torque characteristics are obtained by using by the intake manifold with switching between different lengths (Bausshuysen, Schäfer, 2002), (Vlk, 2002). Resonance supercharging with an individual manifold for each cylinder means that each cylinder has its own separate manifold of a certain length usually connected to the collection manifold by the storage one. Energy balance is characterized by changing the intake piston movement to kinetic energy of the air column in front of the intake valve and its following change into pressure energy. For charging the column, vacuum and pressure waves are used. Let us describe what happens inside the intake manifold when charging. The intake valve opens, piston moves down and creates vacuum wave in the area of the intake manifold. It spreads in the resonance manifold towards its other end which leads to a storage. The size of the air pressure inside the storage is equal (approximately) to the atmospheric pressure. This is considerably higher than the air pressure size of the intake valve (Fig. 1a). The vacuum which, in the meantime, reached the storage takes with it the air which is situated inside the storage. The air then flows into the resonance manifold creates – in the place of the vacuum wave – a pressure wave of the same size which goes towards the intake valve. It can also be concluded that the vacuum wave at the end of the resonance manifold bounced back from the storage (Fig. 1b). The pressure wave goes through the resonance manifold and pushes the air towards the intake valve which is still open. This process takes until the pressure in front of the intake valve and the pressure inside the cylinder are equal. The reverse flow will be prevented from by closing the intake valve (Fig. 1c). To overcome the distance between the storage and the intake valve, the vacuum wave (or pressure wave respectively) needs some specific time (milliseconds). Both vacuum and pressure waves move at a speed of sound. Considering that the speed of sound does not change, neither the distance changes and the time is still constant. However, the time interval in which the intake valve is open (and depending on the motor speed) changes in a way that the more the motor speed increases the more this time interval shortens. It means that when the speed is higher, the pressure wave would reach the intake valve once it is already closed. In order to be able to

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shorten the time *t* (so that the pressure wave would reach the intake valve when it is still open) it would be necessary to shorten the distance (space) ***s***. The waves movement speed cannot be changed and shortening the distance ***s*** means to shorten the resonance manifold.

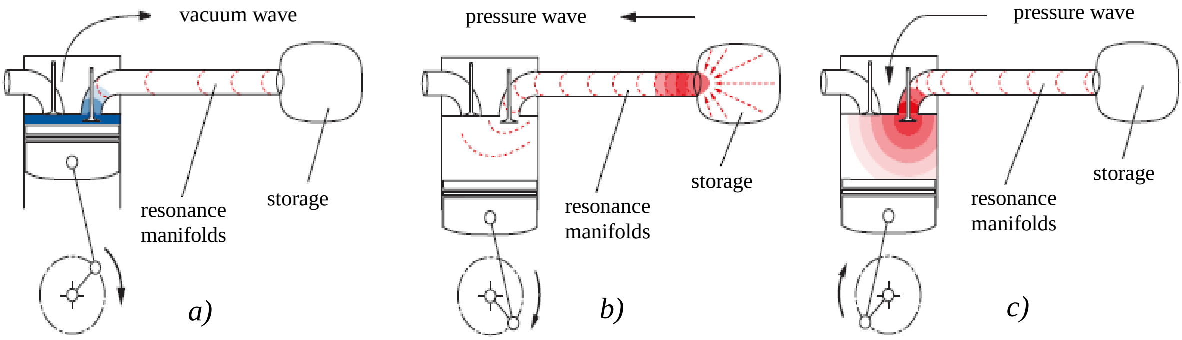

Fig. 1: Principle of resonance charging: a) creation of vacuum wave;
b) pressure wave which moves towards intake valve;
c) pressure wave going into the cylinder through open intake valve (Škoda Auto, 2001).

Overall, it can be concluded that the higher the motor speed is the shorter the resonance manifold must be – it means that a long resonance manifold (torque position) is suitable for low and medium speed and a short resonance manifold (power position) is suitable for high speed. Resonance charging in the resonance area causes increasing of charging pressure by 15-30 kPa, therefore increasing the motor power is usually by 10 to 35 %. In 2005, this principle was used for example by the automobile manufacturer Porsche for Boxster S, Cayman S, 911 Carrera Coupe (the resonance charging and variable timing system VarioCam) where brake mean effective pressure was about 1.25 MPa. In the Fig. 2 there is an illustration of a technical solution of an intake manifold with a variable length of intake for a spark ignition non-supercharged motor (volume 2.0 l, power 85 kW) by Škoda.

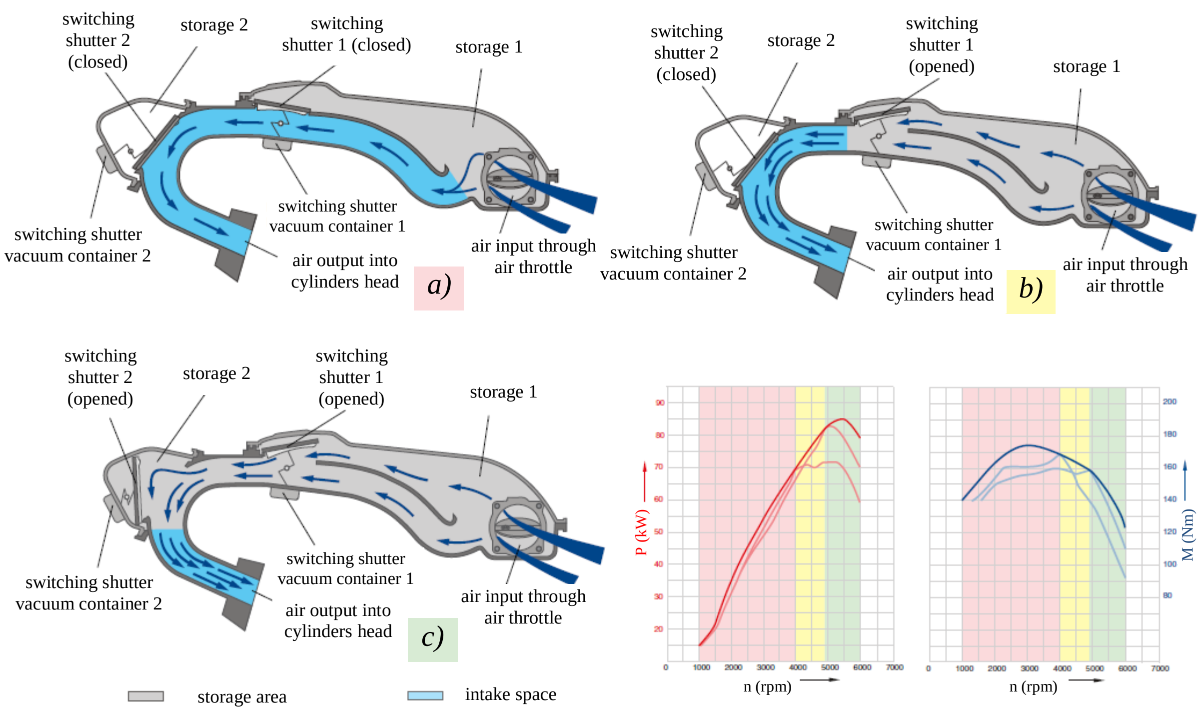

Fig. 2: Intake manifold with variable length of intake for spark ignition non-supercharged motor by Škoda: a) torque position (increasing of torque, speed range 780 – 4000 min^{-1});
b) power position – long space of intake (switching shutter 1 of intake manifold opens at 4000 min^{-1});
c) power position – short space of intake (switching shutter 2 of intake manifold opens at 4800 min^{-1})
(Škoda Auto, 2001).

2. Simulation calculation of a combustion engine

For making a modification of the intake manifold, the ŠA 1.2 HTP motor was chosen. This drive unit was chosen mainly because of knowing its simulation parameters which were already experimentally verified when doing the previous project. For making a simulation calculation, the Ricardo Wave software was used. This software uses the access 0-D for simulation of a motor cylinder and 1-D for modelling an intake and an exhaust manifolds. To reach results which are as close to reality as possible, it is necessary to create a simulation model as a complete scheme beginning with solid intake and ending with an exhaust including its equipment. The quality of the model input data significantly affects the results; therefore, the model was verified with the experiment.

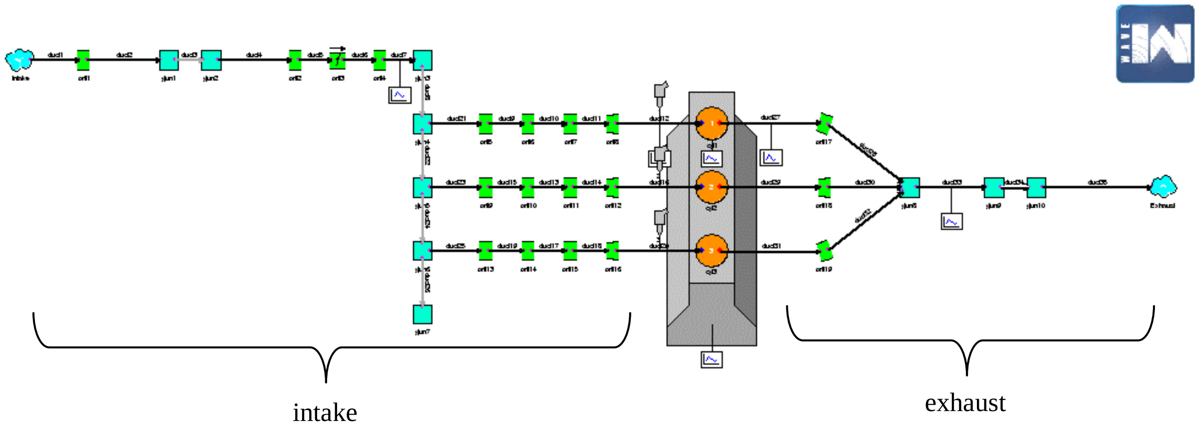

Fig. 3:Simulation model of combustion engine.

The length of the intake was calculated in estimated realisable range which means from 100 to 800 mm. First, the dependence of authoritative motor parameters (such as torque, effective power, and also volumetric efficiency) was performed on the length of the manifold in various modes (speed) of the motor. Then, the most suitable lengths of the intake manifold were chosen. The next step was to discover the optimal cross-section area. The conception of an intake manifold with continuous-variable length was rejected by reason of a required larger installation area. Finally, the simplest two-stage variant of the intake manifold was chosen because according to the simulation calculations the three-stage variant would not lead to a more substantial improvement of the motor cylinder charging. From the results of the simulation and by reason of production the choice was as follows: the suitable length of the long branch of the intake is 690 mm and the diameter of the circular cross-section area is 30 mm; the suitable length of the short branch of the intake is 326 mm and the cross-section is 35 mm (Reichrt, 2015). These pieces of knowledge were also used when creating the construction design of the intake manifold.

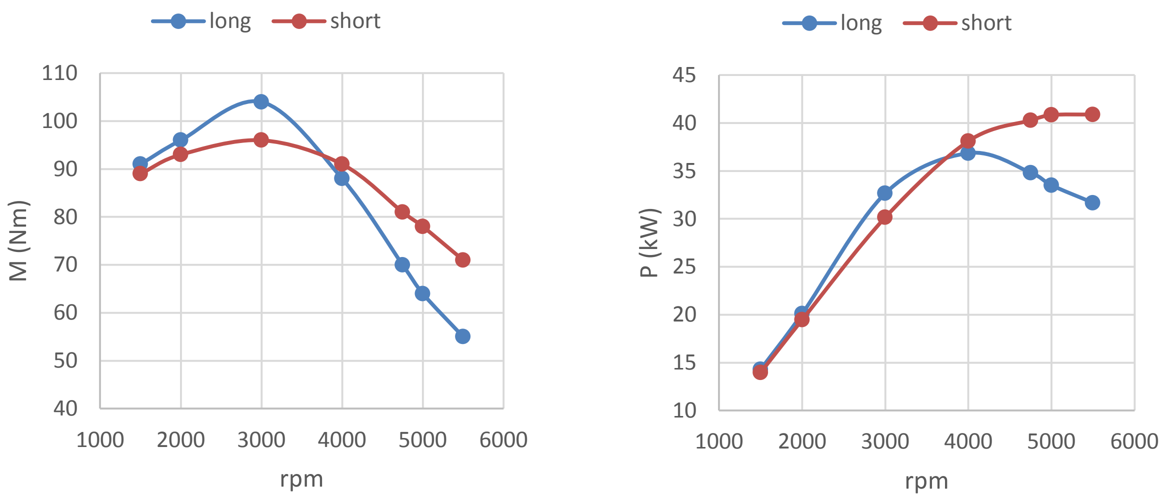

Fig. 4: Graph of torque and power of combustion engine in dependence of speed for both of the chosen values of intake manifold length.

3. Construction solution design of a variable intake manifold

The resulting 3D model of the intake manifold was made of three main parts by reason of manufacturability. An important aspect is the choice of dividing planes. These main parts are stuck together and for precise fitting are used grooves in individual parts which fit together. The change of the length of the intake manifold is covered by a rotating gate valve which is located in the short branch of the manifold. An electromagnetic valve would be used to control the gate valve.

Fig. 5: 3D model of designed variable intake manifold (Reichrt, 2015).

4. Conclusions

The simulation results show visible advantages of a variable intake manifold. The torque value when the speed is lower was increased and also the power when the operational speed of the combustion engine is higher rose. The charging efficiency values in full range of engine speed was also increased and the specific consumption of fuel when the speed is high decreased slightly. This positive effect only appears when taking into consideration the full load characteristic of the engine; when taking into consideration a partial load, dynamic in the intake manifold is not used because of using the air throttle. If a variable intake manifold was used in a motor with higher swept volume, even larger improvement of power parameter would appear.

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