Valves in Exhaust Systems

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Introduction

The design of exhaust systems in cars sometimes necessitates us to have different types of mufflers either to avoid a resonance at particular engine speed or to accent a special type of sound, e.g. for sporty cars.

Using valves in exhaust systems gives the possibility to use two or more different types of mufflers within the same line, without additional muffler volumes.

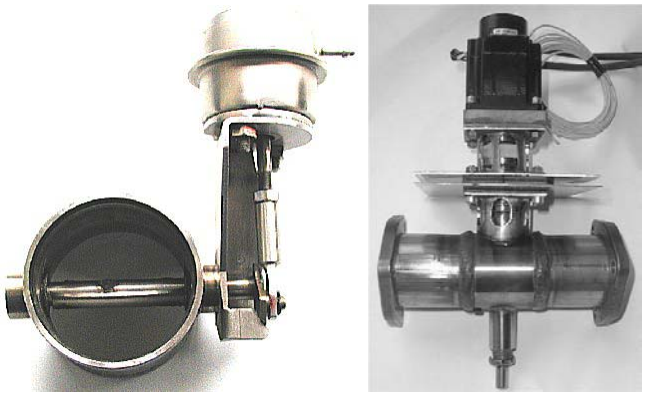
A second use of valves is to reduce the volume of mufflers in an exhaust system. The main duty of a valve in this configuration is to meet the required sound level in a pass-by test. At higher speeds the valve is switched open hence reducing the backpressure. Thus permitting a higher engine performance and a more dominant sound quality.

Different technologies

The types of valves are divided into two different groups:

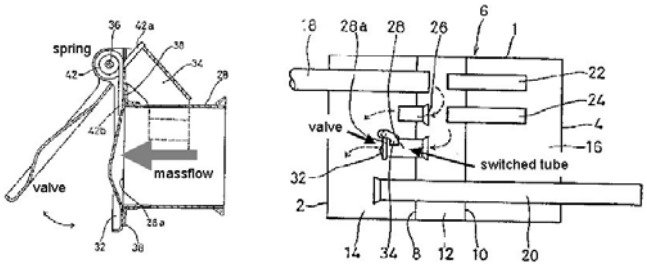
- (external) driven valves
- autonomous valves driven by backpressure or driven by the impulse of the mass flow (pat. by Zeuna Stärker)

The driven valves are equipped with an external mechanism to switch the valve. This can be done with a **vacuum system, stepping motor, solenoid** or other techniques.



Figures 1, 2: External driven valves; left = vacuum system; right = stepping motor

The autonomous valves separate in two different techniques. Firstly by using backpressure, having the main tube closed by the force of a spring until the pressure reaches a predetermined threshold and the valve is forced to open. By changing to this status the backpressure thus decreases and the valve is returned back to the closed status. Some kind of ringing effect occurs. To avoid this effect special damping must be provided.



Figures 3, 4: Examples of an autonomous valve driven by backpressure and its application in a muffler (US Patent Fa. Futaba 5,801,343)

The second type of autonomous valve – developed by Zeuna Stärker – uses the upstream impulse of the mass flow to operate a valve downstream. With this technique the acting forces are not depending on the status of the valve and exact functionality is guaranteed.

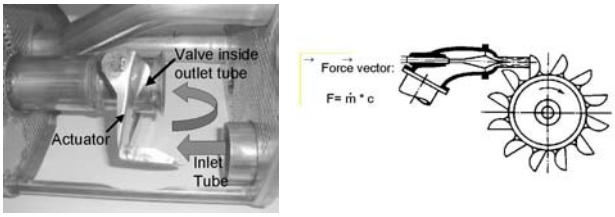


Figure 5, 6: Show a ZS-valve inside a muffler. The arrows indicate the mass flow driving the actuator and valve. The right figure shows the principle of actuation.

The following figure illustrates how a two-way muffler is designed, to achieve different sound targets.

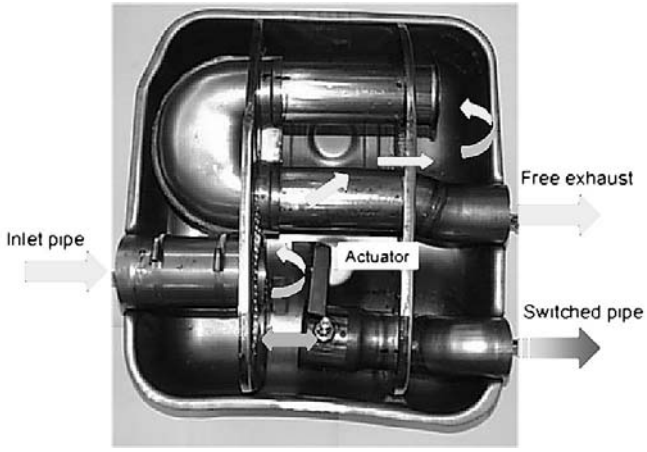


Figure 7: Muffler designed by ZS using an autonomous valve, which is driven by the impulse of the mass flow

The main difference between the muffler-design of figure 4 to the design of figure 7 is as follows. In figure 4 there is only a change in the diameter to reduce backpressure while the valve opens. With the design in figure 7 there is a combined change in a diameter and length of the tail pipes.

Backpressure, Performance and Sound Design

Backpressure

As mentioned previously, the opening of the valves will change the backpressure inside the exhaust system.

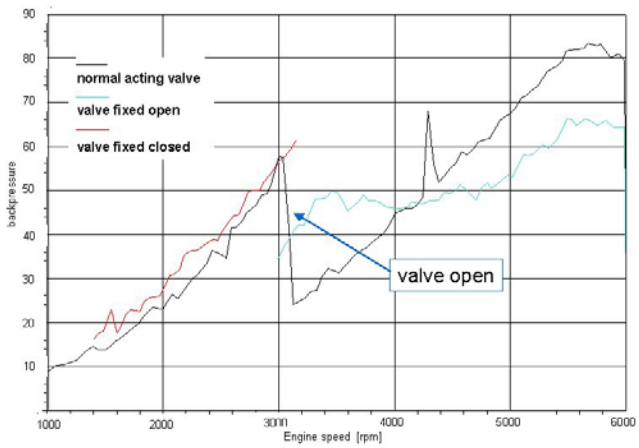


Figure 8: Engine speed vs. backpressure for a muffler with valve inside (black) in comparison to measurements with valve kept open (blue) or closed (red)

The backpressure of the muffler in figure 8 decreases by approximately 50% when opening the valve

Engine Performance

Reducing the backpressure will normally increase the performance of the engine. The following figures give an example for an extreme engine (12 cyl., 6 ltr., twin turbo charger)

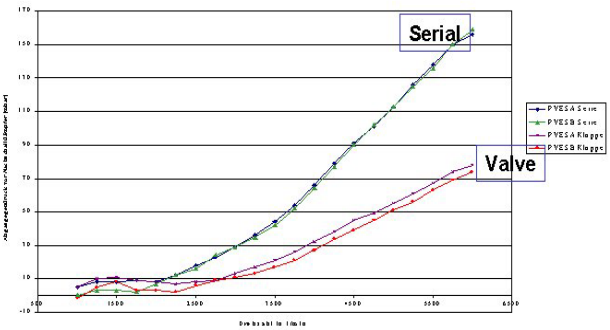


Figure 9: Comparison in backpressure between the old serial muffler and the new one with a valve for a high performance engine

For systems both with and without valves at low engine speeds up to 2000 rpm the backpressure remain the same. Above this speed the valve commences to open and the increase in backpressure of the system with valve is lower.

This special muffler with valve was designed such that it maintained the same sound levels at lower engine speed when compared to a standard muffler within the same volume. For higher speeds (e.g. after the pass-by distance) it allowed the sound quality to change to a sportier sound.

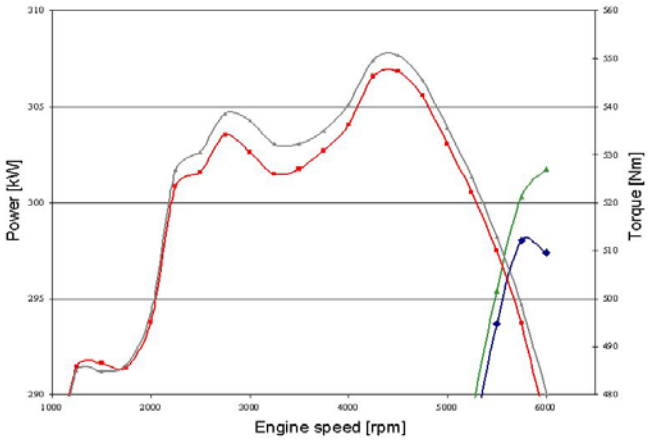


Figure 10: The gain in power and torque by using a muffler with valve against a standard system

As shown in figure 10 with open valve there is an increase in torque and engine power.

Sound Design

A high and rapid change of the backpressure will cause a very rigid change in sound (figure 11).

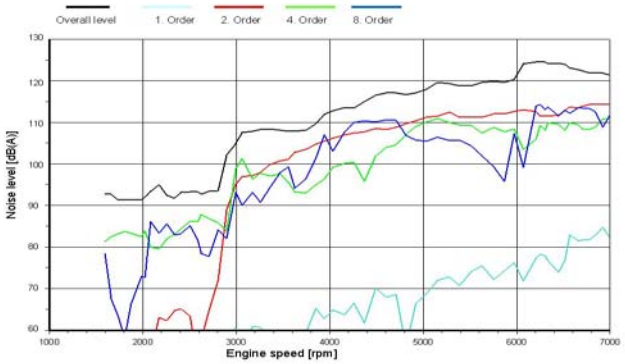


Figure 11: The change of sound at the orifice of a sporty car with an external driven muffler

Another example of using a valve is shown in figure 12. Here the valve is used for reducing a boom-noise in third order. The overall level is reduced slightly whereas the third order level is approximately reduced by 15 dB(A) at the resonance frequency

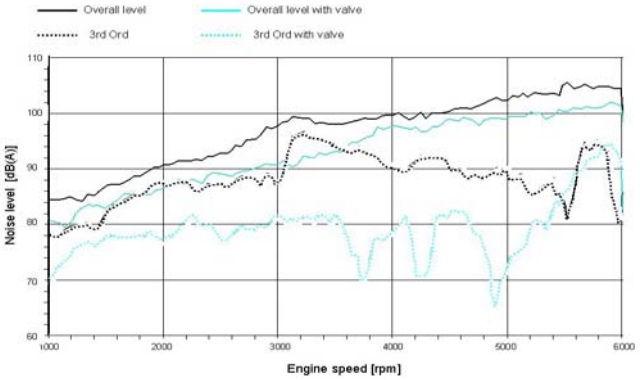


Figure 12: A comparison between mufflers with/without valve to reduce a third order boom-noise