

TCV- A Unique Solution for HD Commercial BSIV Diesel Engine for Range of Altitude Operation

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ABSTRACT

BSIV implementation for commercial vehicle in pans India effectively from April 2017. It's very challenging job for performance and emission engineer to meet engine performance & fuel economy with stringent emission norms for high power and torque density HD diesel engine. In Altitude, lack of air availability & combustion energy passes by mechanical waste gate, lead to lower boost at partial load in waste gate region; which in turn leads to poor engine performance & fuel efficiency and higher turbo speed. To control the turbocharger design speed limit various methodologies adopted like engine derating or optimizing the combustion parameters leads to poor vehicle performance. Combustion parameter optimisation is having limited scope for turbocharger speed control. In this paper we have identified the best cost effective technological solution "Turbo Control Valve (TCV) to meet the required boost pressure/airflow which leads to better engine performance and fuel efficiency at high altitude in part loads waste gate region. Adding to turbocharger speed is under the design limit & meeting the emission norms. Turbo control valve actuator concept will support us to control the position of waste gate according to the demand and the required boost pressure/airflow.

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INTRODUCTION

Diesel engine applications have achieved approximately a 50% market share in Europe and are beginning to gain a share of the U.S. market as well. The increased market share is due to its superior fuel economy, excellent driving performance, good acoustics as well as lower exhaust emissions. Advanced technologies such as common-rail, turbocharging, cooled EGR as well as sophisticated control algorithms have helped to increase the overall performance of the modern diesel engine. The primary goal of the future is to maintain the diesel engine as a propulsion source with highest fuel economy.

Turbochargers are widely used in car and commercial vehicles and off road as to makes smaller-capacity engines to higher power, improve fuel economy and higher torque. Turbo charger also helps to reduce the emission level as well. Turbocharger objective is to improve engine volumetric efficiency by increasing intake gas density and allowing engine more power. Turbocharger draws ambient air and compressed the ambient air. Resultant a larger mass of air entering into cylinders on each intake stroke. Which increase the power and torque of the Engine and the power required for the turbocharger is the kinetic energy of the engine's exhaust gases.

A waste gate is simply a turbine bypass valve. It works by diverting some portion of the exhaust gas around, instead of through, the turbine. This limits the amount of power that the turbine can deliver to the compressor, thereby limiting the turbo speed and boost level that the compressor provides. The Waste gate valve can be "internal" or "external". For internal Waste gates, the valve itself is integrated

into the turbine housing and is opened by a turbo-mounted boost-referenced actuator. An external Waste gate is a self-contained valve and actuator unit that is completely separate from the turbocharger.

BACKGROUND

Waste gate is used traditionally to control turbo speed and max boost pressure. Conventionally boost pressure are controlled by mechanical external waste gate. But conventionally mechanical waste is having some limitation like to control single pressure set point, at the lower which implies the single calibrated point must be restricted to the lowest value maximum - tolerable boost pressure of the engine, leaving untapped performance potential at all other point in the engine operating range.

Waste Gate Operational Zone

Waste gates are simply a valve that allows some of the exhaust gas to pass directly from the exhaust manifold to the exhaust pipe, but this is an effective way to increase boost pressure at low engine speed without over speeding at high engine speed as shown in [figure 1](#). At green zone where waste gate opens to control the turbo speed due to higher engine speed and torque. But for the orange zone, engine speed and torque both are lower, resultant lower boost, to cover lower boost waste gate will close and give required boost pressure.

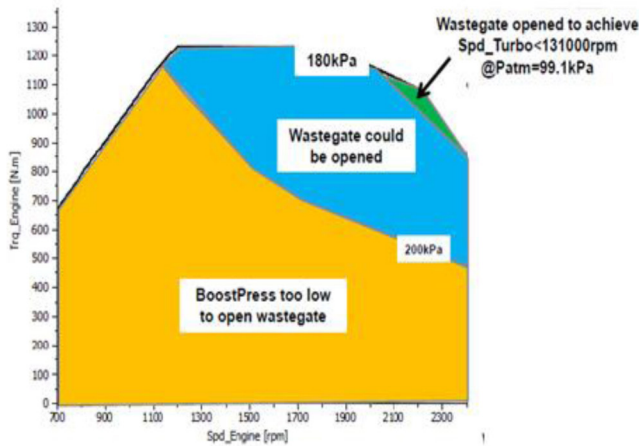


Figure 1. Waste gate operational zone

To meet the demand of required boost pressure at high altitude need to control the position of waste gate according to the demand which is possible with the help of electronically controlled feature we called as **Turbo Control Valve**. In either case, the actuator is calibrated (or set electronically with an electronic boost controller) by internal spring pressure to begin opening the Waste gate valve at a predetermined boost level. When this boost level is reached, the valve will open and begin to bypass exhaust gas, preventing boost from increasing.

Regulation of the Waste Gate Position

Normally the waste gate is a turnable flap being operated with actuator. Since the turbocharger is fitted on exhaust manifold which is very hot area, so a pneumatic actuator with low temperature sensitivity works with more accuracy for the operation of the waste gate flap. Inside the turbocharge control valve unit, there is a spring that holds the waste gate into closed condition. When the pressure given to pneumatic actuator, a force generated against the spring that opens the waste gate. the source of the pressure given to pneumatic actuator is the boost pressure of the turbocharger

Turbo control valve system uses the boost pressure without regulation for the pneumatic actuator. This system can only prevent too high boost pressure for the engine. The system is like a safety pressure relief. A regulation of boost pressure with such a system is not possible. For the regulation of boost pressure a variation of waste gate flap positions is required and that asks for a variable pressure on the pneumatic actuator. This variable pressure for the pneumatic actuator is done by the a solenoid valve called “**boost pressure valve**” or “**turbo control valve**”

Working of the Turbocharger Control Valve

TCV setup contains mainly a Pulse Width Modulated (PWM), electropneumatic proportional valve, which uses air pressure (Boost pressure) available from an engine. This 3-ways valve, controlled

through a PWM voltage signal (signal received from the engine control unit ECU) can be used to control several engines devices as for example a Turbocharger

Supply system to Waste Gate actuator -

- TCV-Inlet port:P1 (connected to the turbo boost - compressor)
- Air Exhaust port: P2(connected to air cleaner)
- TCV-Outlet port: P3 (connected to the WG pneumatic actuator)

Waste gate contain a spring which holds the actuator closed. Once the pressure reaches at required level on the actuator, the spring starts to be compressed and the waste gate starts to open. This pressure used to pilot the waste gate actuator can be taken from the outlet of the turbocharger compressor (boost pressure).

The purpose of TCV valve is to improve the controllability of the WG actuator by controlling the level of boost pressure from the turbo delivered to WG the actuator. Resultant improvement in the engine performance with improved turbo boost pressure at sea level and High altitude also.

TCV Valve can switch between to 2 different positions:

- Position 1: Turbo boost (P1 port) is connected to the waste gate actuator (P3 port)
- Position 2: Waste gate actuator (P3 port) is connected to the exhaust port (P2 port)
- By switching these PWM signal between these 2 positions, the outlet port delivers a pressure regulated between these two pressures available from the ports P1 & P2.

Normally TCV is in open condition, a short PWM signal from ECU will bring a high pressure on the solenoid outlet port: the WG actuator will be in opened position, then the boost pressure low. A long PWM signal will bring a low pressure on the solenoid valve outlet port: the WG actuator will stay in closed position, then the boost pressure high. The frequency of the modulation has a direct impact on the exhaust pressure pluses' levels. The fast controlling of TCV is done with the help of PID tuning.

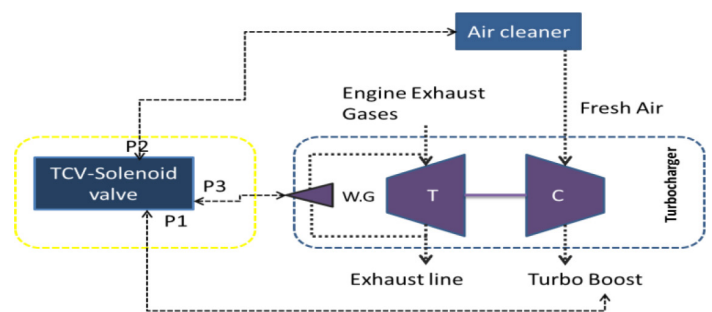


Figure 2. Working of Turbo control valve

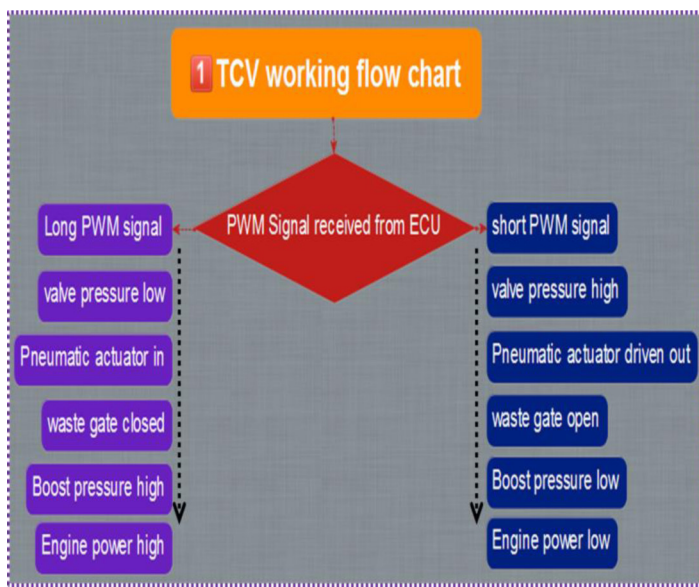


Figure 3. Turbo control valve flow chart working diagram

Working Function of Pulse Wide Modulation Valve

TCV voltage is normally getting switch on & off with certain frequency (normally X amount of switches per second). Variation in pressure at connector 3 (TCV inlet pressure) can be influence by the frequency and modulation. Low frequencies give a wide pressure regulation range, but high pressure pulses. High frequencies are positive for the pressure pulses (more but lower pulses), but a too high frequencies are bad for the pressure regulation (magnetic reasons) and the life time of the valve.

Within a constant frequency the time-parts of current applied and not applied can be varied. A long part-time for current applied gives a long time-part for connection between low pressure level and connector 3; the pressure level at the pneumatic actuator will be low.

A short part-time for current applied gives a short time for connection between low pressure level and connector 3 and a longer part-time for connection of high pressure level and connector 3; the pressure at the pneumatic connector is low. The boost pressure of a turbo charger can be influenced by a waste gate driven by a pneumatic actuator driven by a turbo control valve driven by a pulse wide modulation.

TCV Assembly Line Diagram

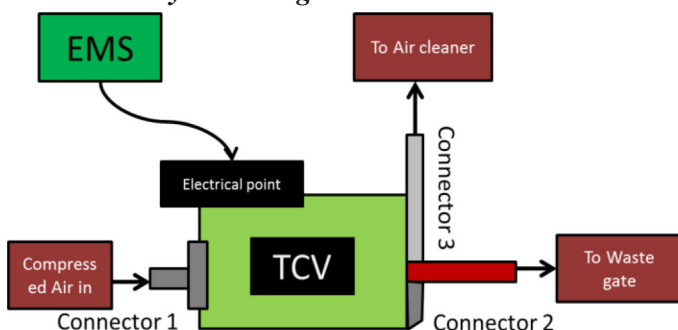


Figure 4. Pictorial view of Turbo control valve

TCV Installation Details on Engine

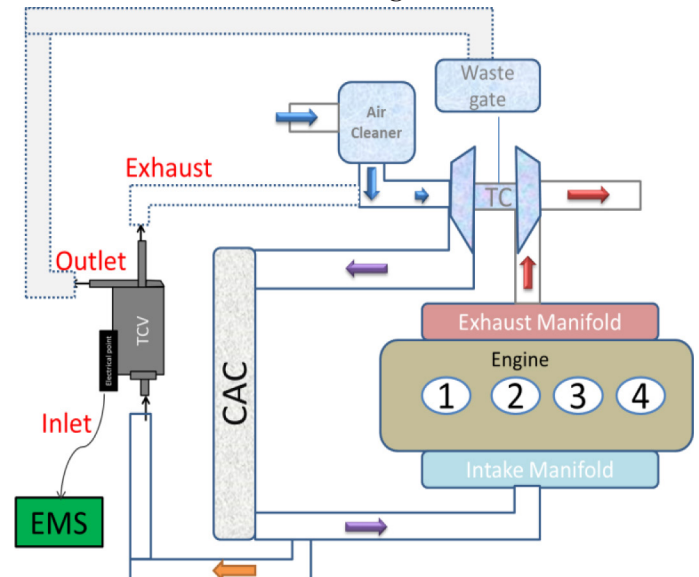


Figure 5. Turbo control valve diagram on Engine

TCV Controlling Strategy

TCV is being controlled by EMS software, based on the boost pressure demand received at intake manifold. The controlled software contains the boost pressure set point at each operating point as shown in below mention figure 6

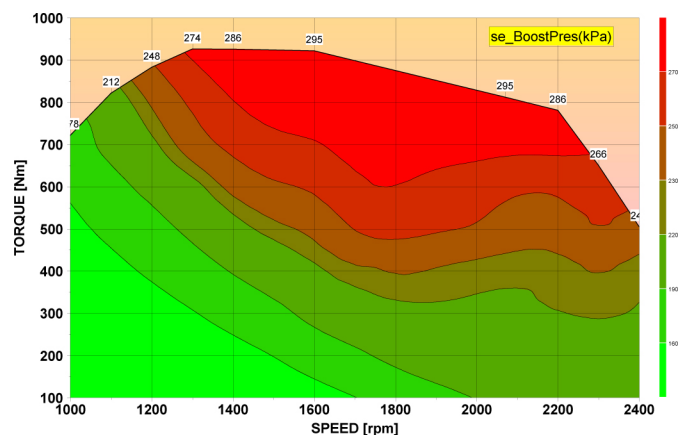


Figure 6. Boost pressure diagram for complete zone

If intake boost pressure is higher with respect to set boost point then waste gate is opened by the controller and reached up to the set point. For the fast response and more stability of TCV valve, PID (Proportional-integral-derivative) tuning comes into the picture. More accuracy into PID tuning gives fast response and stability of TCV valve. With the help of PID tuning Duty cycle is being calibrated at the required TCV Response and stability.

Vehicle Load Response with TCV

The time taken by the engine at a particulate speed from min torque to max torque called Engine load response time. For smooth and fast vehicle drivability TCV plays major role. Proper tuning gives