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FUNCTIONAL DIAGNOSIS AND ANALYSIS OF THE MANIFOLD ABSOLUTE PRESSURE SENSOR IN TURBOCHARGED COMPRESSION-IGNITION ENGINES

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Abstract : This paper presents the diagnosis and functional analysis of the MAP sensor used in turbocharged Diesel engines. The experimental study was conducted using the VCDS diagnostic platform through real-time monitoring and analysis of engine operating parameters under actual vehicle operating conditions. The obtained values were analysed in real time in order to evaluate the operation of the sensor and the turbocharging system
Key words : Combustion, diagnosis, MAP (Manifold Absolute Pressure), optimization, turbocharged compression-ignition engine, sensor, verification.

1. INTRODUCTION

Modern Diesel engines use advanced electronic systems to control turbocharger pressure and optimize the combustion process. Within these systems, the MAP sensor (Manifold Absolute Pressure) is responsible for transmitting the intake manifold pressure values to the ECU unit. This information is used for fuel injection adjustment, variable geometry turbocharger control, and engine performance monitoring.

Improper operation of the MAP sensor may lead to power loss, limp mode operation, increased fuel consumption, and the occurrence of turbocharging-related faults. For this reason, the correct analysis and diagnosis of this sensor represent an important stage in the verification of modern electronic management systems used in Diesel engines.

2. MATERIALS AND EXPERIMENTAL METHODS

During the experimental study, the VCDS diagnostic platform was used together with the communication interface connected to the vehicle ECU, in order to monitor the turbocharging system parameters and identify possible operating faults.[1] The parameter values were monitored in real time and compared with the values calculated by the engine control unit.

The experimental investigations were carried out on a 2016 Audi A7 powered by a 3.0 TDI V6 compression-ignition engine (CVUA engine code) rated at 320 HP (235 kW), equipped with a Bosch EDC17 electronic engine management system.[2] The turbocharging system is electronically controlled and continuously monitored by the ECU through the VCDS diagnostic platform.[3]

In the first stage of the experiment, measurements were performed at idle speed in order to determine the baseline values of the intake manifold pressure and verify the stable operation of the MAP sensor. Using the VCDS software, the actual pressure values, calculated pressure values, sensor voltage, and turbocharger actuator activation were monitored.

In the second stage, measurements were carried out under load conditions at an engine speed of approximately 2600 rpm in order to observe the variation of the boost pressure during acceleration. The obtained data allowed the comparison between the ECU-requested values and the actual values measured by the MAP sensor, as well as the analysis of the turbo system response depending on the engine operating regime.[4]

The VCDS platform (*VAG-COM Diagnostic System*) represents an advanced diagnostic system used for vehicles belonging to the VAG group. The tester allows real-time parameter reading, sensor value

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monitoring, dynamic data logging, and analysis of the operation of electronic engine components. *The Advanced Measuring Values* function enabled the comparison between ECU-calculated parameters and the actual measured values during engine operation both at idle and under load conditions (Figure 1, Figure 2, Figure 3, Figure 4).[5]

Figure 1 Experimental diagnosis performed on the vehicle using the VCDS platform

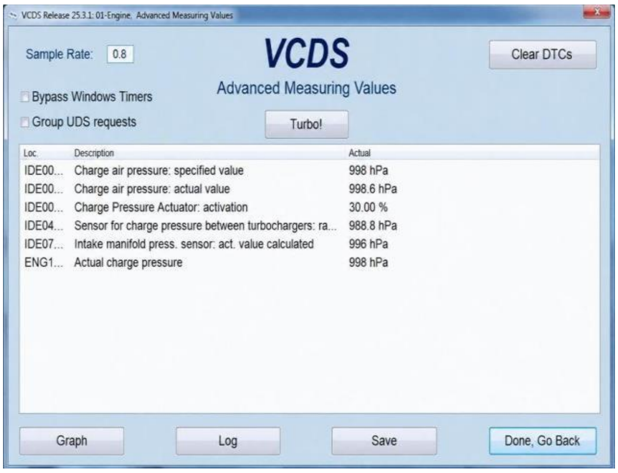

Figure 2 MAP parameter values measured at idle using the VCDS interface

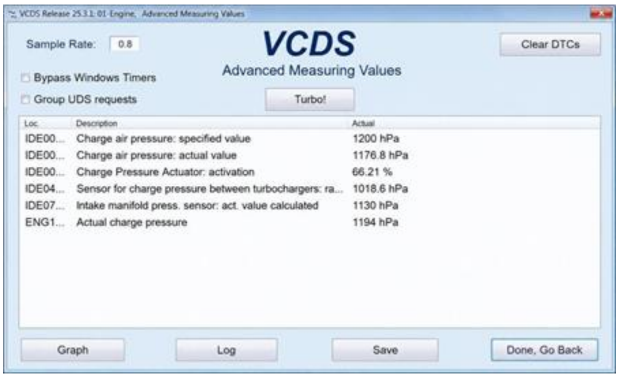

Figure 3 MAP parameter values under load at approximately 2600 rpm

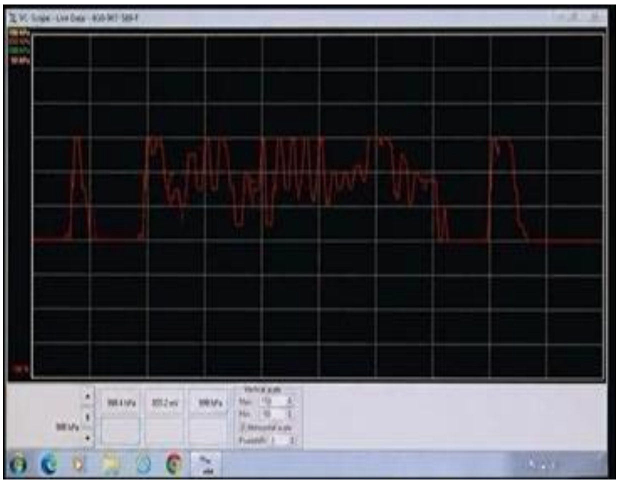

Figure 4 Real-time graphical analysis of turbocharging system parameters

Diagram interpretation:

From a functional point of view, the graph obtained using the oscilloscope-type function in VCDS shows the way in which the turbocharging system responds to ECU requests. The monitored signal highlights the variation in intake pressure and turbocharger actuator command during changes in engine operating conditions. The rapid increases in the curve indicate moments when the turbocharger is requested to increase pressure, while the more stable areas indicate pressure maintenance close to the requested value.The absence of sudden drops or excessive oscillations confirms that the MAP sensor transmits a coherent signal and that the turbocharger actuator responds correctly to the electronic command.

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Thus, the diagram confirms a normal correlation between the measured pressure, requested pressure, and turbocharging system command percentage (Figure 5).

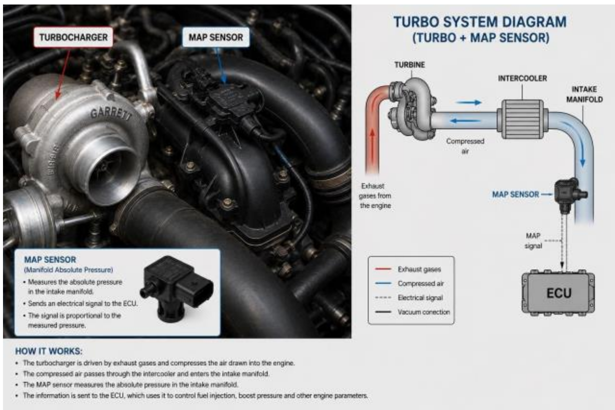

Figure 5 Functional diagram of the turbocharging system and MAP sensor positioning within the intake circuit

3. RESULTS AND DISSCUTIONS

The measurements performed using the VCDS software indicated stable operation of the MAP sensor both at idle and under load conditions. At idle, the measured pressure values remained close to atmospheric pressure, confirming the correct operation of the sensor and its monitoring system.

During the tests performed at approximately 2600 rpm, an increase in turbocharging pressure and variation in turbocharger actuator activation were observed. The values recorded through VCDS highlighted the rapid response of the turbo system and the stability of the signal transmitted by the MAP sensor.

To highlight the differences between engine operation at idle and under load conditions, the values of the main parameters monitored through VCDS were centralized in the following table.

Analysing the values presented in the Table 1, the difference between engine operation at idle and under load conditions can be observed. At idle, the actual and calculated MAP pressure values are close to atmospheric pressure, indicating stable intake system operation and reduced turbocharger demand. Under load conditions, at approximately 2600 rpm, an increase in MAP pressure and turbocharger actuator activation percentage can be observed, confirming the turbo system response to ECU requests.

Table 1. Comparison of turbocharging system parameters at idle and under load

Monitored parameter	Idle	Load (~2600rpm)
Actual MAP pressure	998 hPa	1197 hPa
Calculated MAP pressure	994 hPa	1121 hPa
MAP sensor voltage	0.85 V	0.88 V
Turbocharged actuator activation	30%	68.47%
Engine speed	850 rpm	~2600 rpm
Operating conditions	Stable conditions	Increase in turbo pressure

The recorded data highlighted an effective pressure of approximately 1197 hPa and a calculated intake manifold pressure value of approximately 1121 hPa. The turbocharger actuator activation reached approximately 68 %, while the MAP sensor voltage remained stable between approximately 0.85 V at idle and 0.88 V under load conditions. The limited variation of the sensor voltage confirms the stable electrical behaviour of the MAP sensor and the correct conversion of pressure values into electrical signals transmitted to the ECU.

The values presented in Table 1 represent the representative operating values recorded during the load test performed at approximately 2600 rpm. The values displayed in Figure 3 correspond to a specific acquisition moment captured during the dynamic measurement process. Small differences between the numerical values shown in the table and those visible in the VCDS screenshot are caused by the continuous variation of boost pressure during engine operation and by the real-time sampling rate of the diagnostic platform.

From a diagnostic perspective, the values obtained during the experimental tests indicate normal operation of the MAP sensor and turbocharging system. However, in practical applications, several failure modes may affect the sensor performance and lead to incorrect

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pressure measurements. One of the most common faults is signal drift, where the sensor gradually deviates from its calibrated values, causing discrepancies between the actual and ECU-calculated boost pressure. Electrical faults such as short circuits, open circuits, or unstable supply voltage may also generate implausible sensor readings and trigger diagnostic trouble codes. Another relevant failure mode is delayed sensor response during transient operating conditions, where the MAP sensor reacts slower than expected to rapid pressure changes caused by acceleration or turbocharger activation. Such behaviour may lead to inaccurate boost pressure control and reduced engine performance.

The stable values obtained during the present study, together with the absence of abnormal fluctuations in the recorded signals, indicate that none of these failure modes were present during the experimental tests.[6]

4. CONCLUSIONS

The conclusions obtained following the experimental tests confirm the correct operation of the MAP sensor and the analysed turbocharging system. The values monitored through the VCDS platform highlighted an appropriate correlation between the pressure requested by the ECU unit and the actual pressure measured in the intake manifold, both at idle and under load conditions at approximately 2600 rpm.

At idle, the MAP pressure values remained close to atmospheric pressure, while the turbocharger actuator activation percentage had low values, indicating minimal demand on the turbo system.

Under load conditions, an increase in turbocharging pressure and turbocharger actuator command percentage was observed, demonstrating the correct system response to engine operating requirements.

The analysis of the recorded values and the interpretation of the diagram obtained using the VC-Scope function highlighted the stability of the signal transmitted by the MAP sensor and the absence of abnormal intake pressure fluctuations.

The small differences between the actual values and those calculated by the ECU confirm the proper operation of the sensor and the efficiency of the electronic turbocharger control system.

The use of the VCDS platform proved effective for monitoring intake system parameters and for the rapid diagnosis of possible turbocharging system faults. The method used in this paper may represent a practical basis for future studies regarding the analysis of sensors used in the electronic management of modern Diesel engines.

5. CREdit authors statement

Conceptualization: M.B.-G., D.T, I.G;

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Visualization: M.B.-D., D.T;

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