

COMPARISON OF CHARACTERISTICS OF SPARK PLUG ENGINES FSI, TSI/TFSI TYPE OF VOLKSWAGEN COMPANY

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Abstract

The use of direct injection in spark ignition engines significantly facilitated the use of chargers in these engines. This resulted lately in the significant popularization of direct injection engines, initially freely sucking and in final result turbocharged. The greatest popularity on the market gained engines of Volkswagen Company, named FSI and TFSI / TSI. Application of Common Rail systems allowed not only improving the characteristics of the engine by increasing the accuracy in dispensing fuel into individual cylinders. The most important gain is the possibility of second injection of the fuel to the cylinder after the intake valve is closed. On the one hand it allows better control of the load in the cylinder, at first with the piston crown, and now with shaping the injection by the injector. On the other hand it allows creating a stratified mixture, at low load of the engine it reduces fuel consumption and work at high excess air ratios λ . Quickly it began to use the turbocharger in those engines due to the significant improvement in the operating characteristics of such engine. Profit from better filling of the combustion chamber can be used in different ways. On the one hand, you can replace engines naturally aspirated, with turbocharged with lower displacement, which leads to the improvement of the economics of such engine. On the other hand, after appropriate modifications to the design, you can add a charger to the naturally aspirated engine, retaining its capacity. Gains are then not only higher operating parameters, such as power and torque, but it also significantly improves the torque curve. It has big impact on the flexibility of the engine and the vehicle which is powered by it. Another gain is larger amount of work done by the engine.

Keywords: *transport, combustion engines, fuel injection, stratified injection, charge engines*

1. Introduction

Petrol engines recently lost competitiveness against turbocharged diesel engines. Previously used indirect injection technology, was a restriction in supercharging those engines, so that the most effective way of raising the torque of the engine was increasing its capacity, which resulted in the increase of fuel consumption, having negative repercussions on the profitability of the purchase. Application of common rail which injects fuel directly into the combustion chamber, has facilitated the use of turbocharging. This gave birth to so-called current trend of downsizing engines, which is replacing engines with large capacities, by low capacity units, reaching similar power thanks to turbo-charger. This resulted in the recovery of the market for gasoline engines, at the expense of market share of diesel engines. According to IBRM Samar in 2009, sales of new diesel vehicles

were about 5% lower than a year earlier. FSI engines on which are based the TSI units, breathed new life into sales of gasoline engines. These are engines with interesting technical solutions and are often awarded in various competitions. Engine 1.4 TSI Twincharger two years in a row (2009 and 2010) has been recognized as the best engine of the year by journalists from around the world.

2. Comparison of the characteristics of the engines naturally aspirated and supercharged

At the beginning it is worth to compare directly the turbo-charged engine which replaces the naturally aspirated unit in the manufacturers offer.

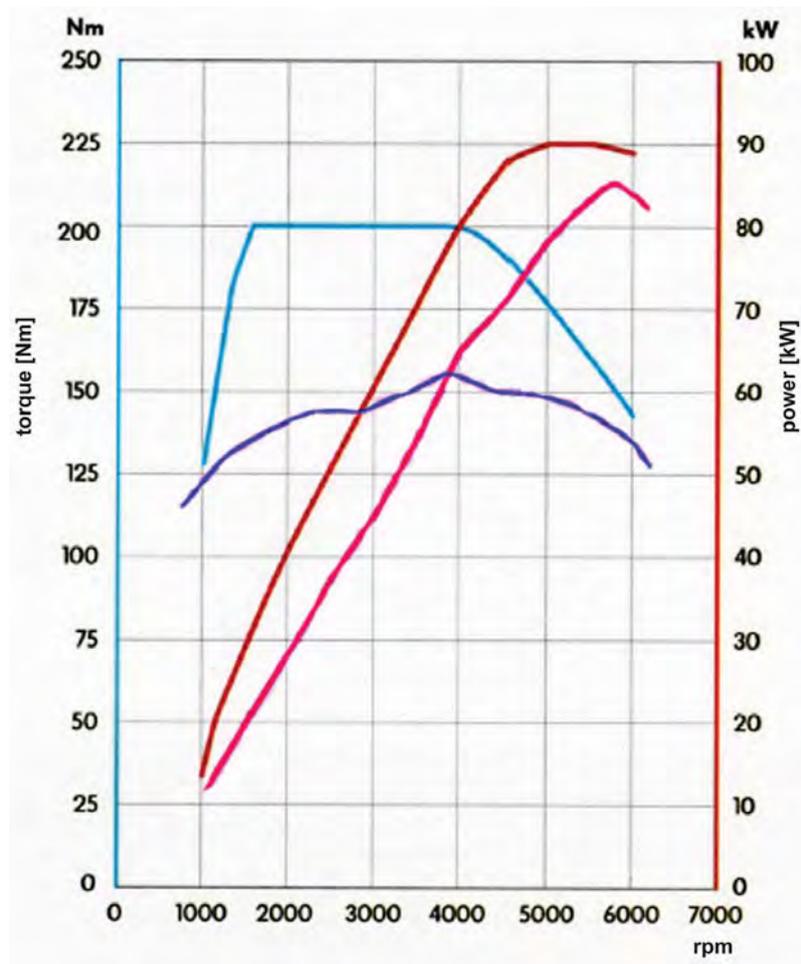


Fig. 1. Comparison of characteristics of the 1.6 FSI engine with the 1.4 TSI

Light-red colour indicates the characteristics of power of the 1.6 FSI engine, and the purple its torque. Dark-red colour indicates the engine power of 1.4 TSI and blue, its torque. It is clear that the curve under the turbo-charged engine is steeper and more quickly reaches its maximum. Faster gaining power by the engine with an increase of its rpm is a positive result. It allows to quickly cruising the vehicle at lower engine speeds, thereby saving the engine and fuel. But the most significant and distinctive difference is the torque curve and its maximum value. In addition to a noticeable jump of the maximum value (about 45Nm), it is kept constant at the high engine speed range (from about 1500 to 4000 rpm). The turbo-charged engine shows a very steep growth of the torque curve in the initial engine speed range (1000-1500 rpm). This is achieved by using a small, high-speed turbocharger. It quickly reaches maximum performance, strongly improving the degree of filling cylinders. Such torque curve allows dynamic drive and smooth overtaking a car, even at low engine speeds. In relation to the naturally aspirated unit there's no need to reduce a gear to

achieve a good acceleration. This has a very positive impact, on both the durability of the engine, and its fuel consumption. Such a large range of flat torque curve gives even better operating characteristics than liked by some drivers, turbocharged compression ignition engines.

It's also worth to consider the impact of supercharging the engine, without changing its displacement.

In the graph, the thicker lines are marked characteristics of the power (red) and torque (blue) of the turbo-charged engine, and the thinner lines shows characteristics of the same capacity engine, but without the turbocharger. As in the case of comparing engines with different capacities, turbocharged engine has steeper power characteristics, and it reaches the maximum value much earlier. Naturally aspirated engine develops its maximum power for a moment before the end of its range of rating speed, while the turbo-charged one is able to maintain maximum power over some range of rotation. A similar situation exists in the case of the torque curve. By turbocharging the engine reaches full torque in a large range, from 1800 to nearly 5,000 rpm. In the absence of supercharge, the maximum torque is reached at 3,500 rpm, but values close to its maximum value are maintained in the range 2,500-4,500 rpm. As with the smaller capacities, supercharge significantly increases the range of maximum torque, improving ride comfort and flexibility of the engine.

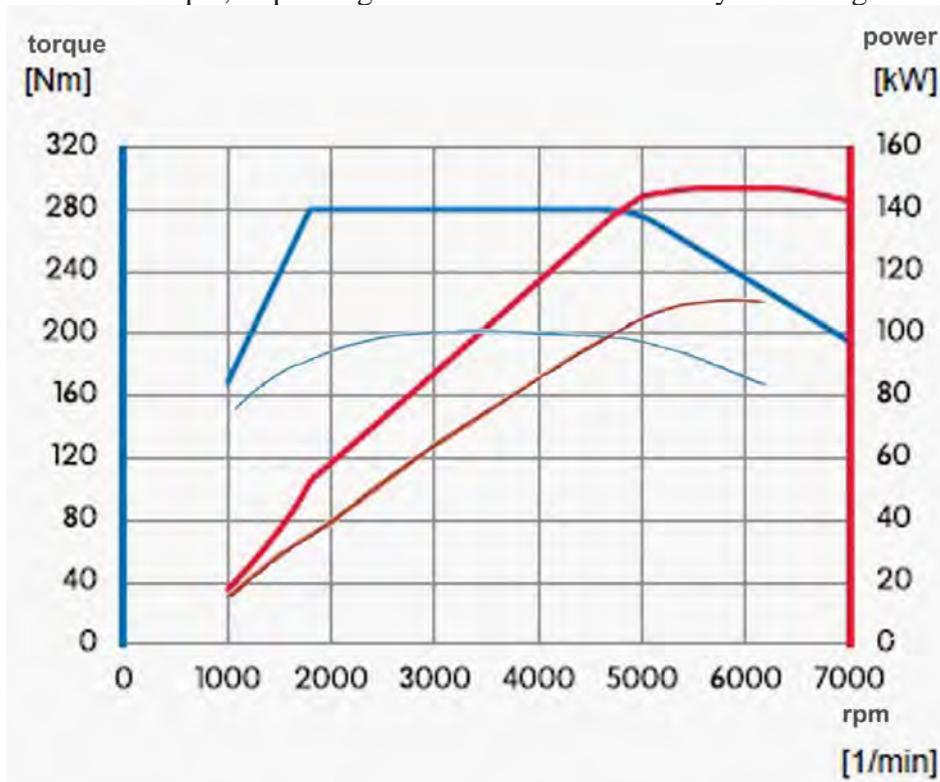


Fig. 2. Comparison of characteristics of the 2.0 FSI engine with the 2.0 TFSI

The manufacturer claims fuel usage in the city for a naturally aspirated version at 11.3 l/100 km, while for the 11 turbo-charged versions of 11 l/100 km. Reports gathered from users by the service autocentrum.pl not show large discrepancies with these claims. According to the users of this service, the maximum average fuel consumption, they managed to get for the version naturally aspirated is 11.4 l/100 km, which is a value coinciding with the manufacturer's claim. In the case of turbo-charged version, the report shows the maximum average fuel consumption of 12.3 l/100 km. It's value little different from the manufacturer's data, but nevertheless the difference in fuel consumption between these engines is less than 1 l/100 km. Probably, this involves not only improving the efficiency of the engine thanks to turbocharging, but also increase the range of accessible, high values of torque. This eliminates the need to maintain high engine speed while overtaking, which may have a positive impact on fuel consumption.

3. Comparison of characteristics of the manufacturer with the dyno charts

It is worthwhile to compare the characteristics provided by the manufacturer, to the actual plots made on the engine dyno. This allows verifying if the engine manufacturers claims, have representation in the case of units produced and sold on a massive scale. This can also show if differences between engines and profit of the engine downsizing remains at the same level, or undergoes some changes.

It's good to start comparison from naturally aspirated engine, which may be a reference to the supercharged engines with smaller capacities. It is easily seen that the shape of curves is similar to the data declared by the manufacturer. The difference, however, appears in the case of values. In fact, the engine has parameters lower than declared. Maximum power is lower of 5 kW, and the torque of 10 Nm. The differences are approximately constant along the curves, additionally can be noted that, in fact, the engine develops its maximum torque at higher revs than declared. Deviation from the declared value may be due to fuel the engine used in the measurement, because the manufacturer recommends the use petrol with octane value 98, and the measured engine used fuel with octane number 95. Changing fuel could affect actual curves by slightly increasing them, and close them to their declared values. This shows the high requirements of naturally aspirated engine with direct injection, on the quality of the fuel mixture, what increases cost of using it.

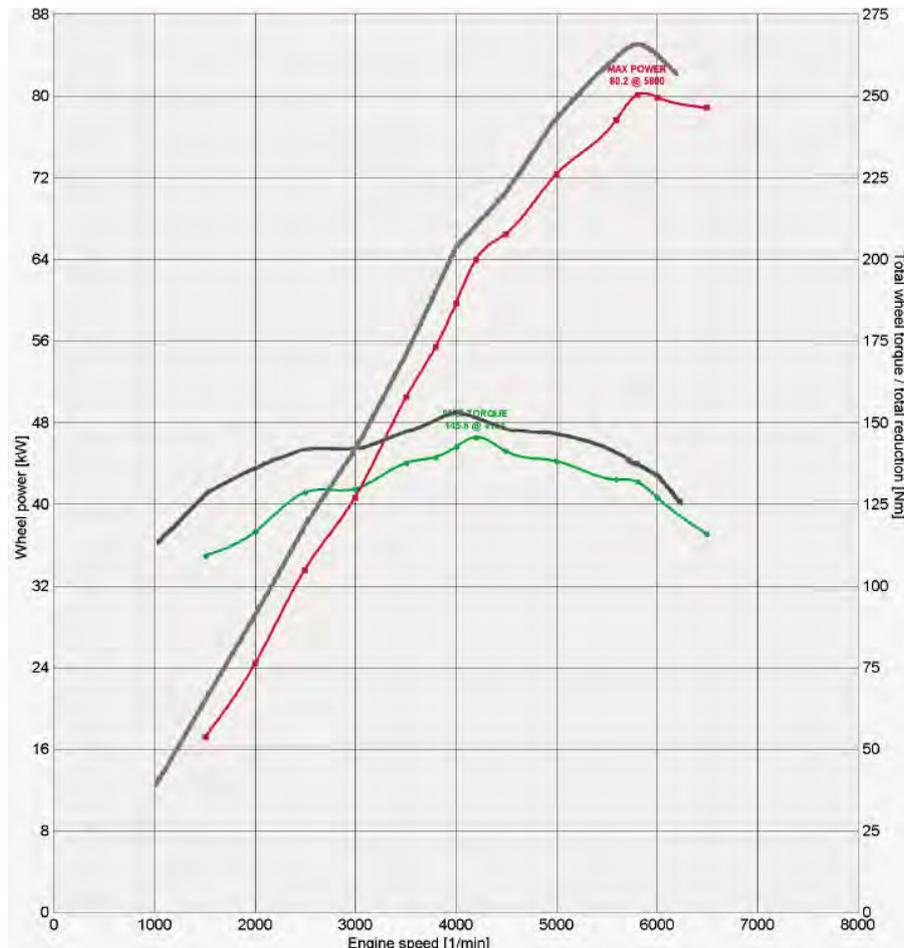


Fig. 3. Comparison of the characteristics of the 1.6 FSI; green - the actual curve of torque, red - the actual curve of power, curves marked in gray are provided by the manufacturer

The manufacturer in the 1.4 TSI Twincharger, recommends the use of fuel 98 octane numbers. In this measurement is used fuel with octane value of 98.

It is easily seen that the 1.4 TSI twincharger engine develops slightly higher maximum power

than declared by the manufacturer. However, it can be clearly seen that the difference in favour of actual performance is only at the maximum value. In most parts of the graph of power the curve from the measurement reaches a lower value than declared. A more noticeable difference occurs in the torque curve. Comparisons of the maximum torque values are lower in actual unit. Reached values are lower of 15 Nm. Curve of the torque on a substantial part of engine speeds is lower in the measured engine. Chart shows a decrease of torque at engine speed around 1.800 rpm.

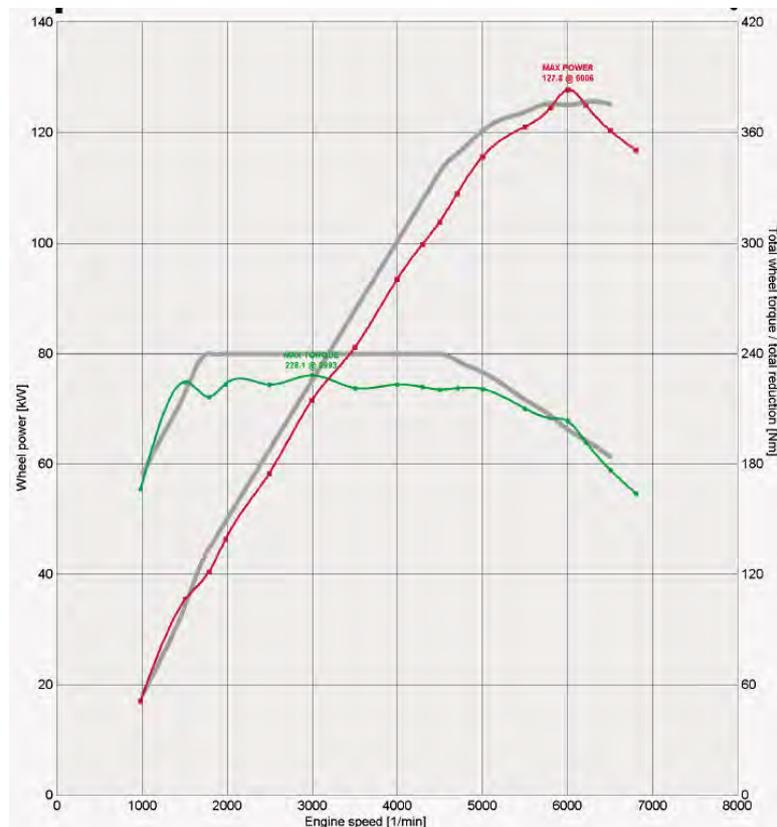


Fig. 4. Comparison of the characteristics of the 1.4 TSI twincharger; green - the actual curve of torque, red - the actual curve of power, curves marked in gray are provided by the manufacturer

This shows that the combination of two types of supercharge, not only raises the value of maximum power and torque, but also improves the course of the curves, especially of the characteristics of torque at low engine speeds. We should see how it looks for a larger engine cylinder capacity and performance.

As an example, it may serve a 2.0 TFSI engine, with claimed 147 kW and 280 Nm of torque.

As is clear from the measurements, 2.0 TFSI engine develops maximum power of 10 kW in more compared to the manufacturer's declaration. Also, the maximum torque is higher by 19 Nm. Measurement is started at a slightly higher engine speed, but the power graph is gaining rapidly on values and at level of 2000 rpm equates to the manufacturer's chart. At medium engine speeds the power curve coincides with the declared course, and at high engine speed, above 4200 rpm is gaining an advantage, and shows slightly higher value than declared. In case of the torque curve, the graph is gaining rapidly and achieves the declared value, and even a bit higher than that at 2200 rpm. Torque curve, maintains a fairly equal and continuous shape, similar to the stated by the manufacturer, but in almost the entire range above 2000 rpm is slightly ahead of his values.

From a comparison of actual characteristics it can be postulated that the better effect can be achieved by adding a small supercharge to the engine with more capacity than the big supercharger to a small engine.

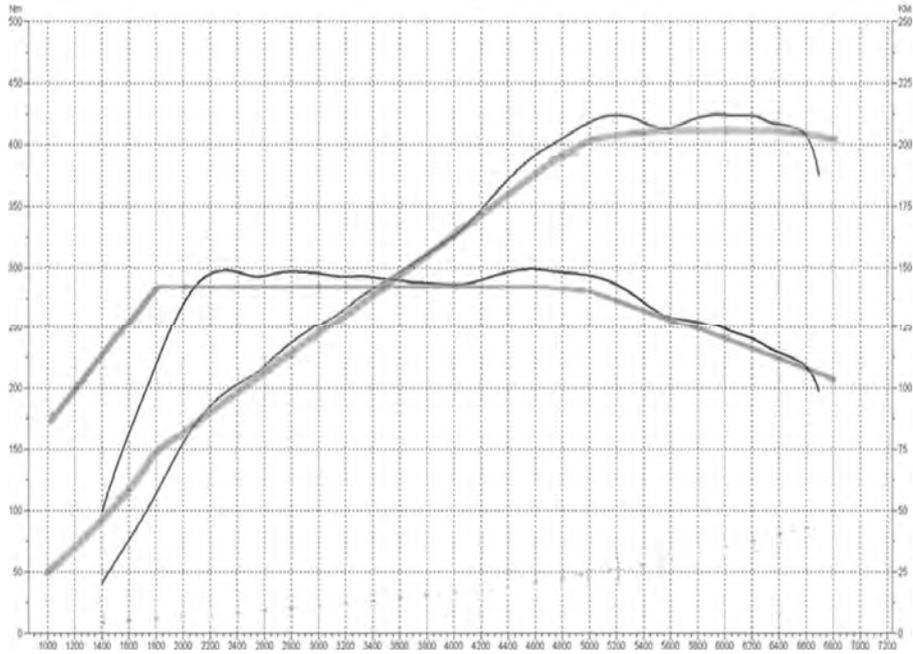


Fig. 5. Comparison of the characteristics of the 2.0 TFSI; blue - the actual curve of torque, red - the actual the actual curve of power, curves marked in gray are provided by the manufacturer

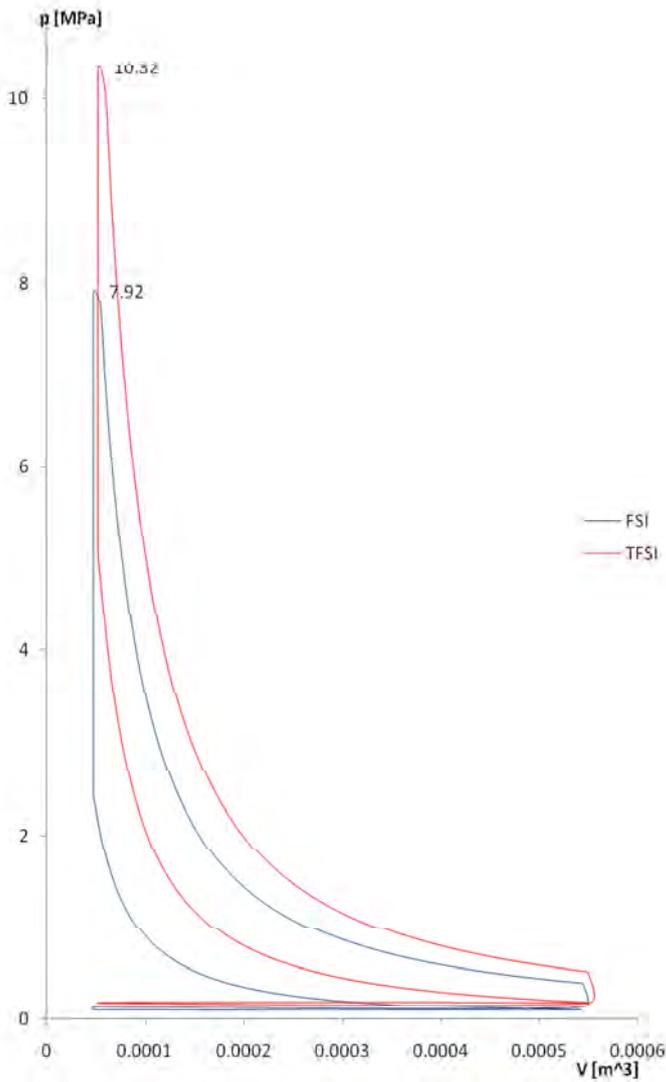


Fig. 6. Comparison of closed indicator diagram of 2.0 FSI engine with 2.0 TFSI

Comparing the supercharged engines with naturally aspirated ones, it is worth considering, what is the impact of charging on the work done by the engine. The easiest way is to show on the closed indicator diagram, which will show work done by the engine, in the form of the changes of pressure in the cylinder as a function of capacity. The graph of this type consists of two isentropes (compression and expansion), two isochores (delivering and carrying away of heat), and filling and exhaust factor lines from the cylinder (exchange factor). In the case of an engine naturally aspirated exchange factor process, limited by lines of carrying away and delivering, work is negative. In turbocharged engine, due to the pressure in the system, this work is positive.

These curves are determined, for two Volkswagen engines. These are engines of same capacity, the 2.0 FSI and the 2.0 TFSI.

Comparing these two graphs, we can see clearly higher pressures achieved by the turbo-charged engine. This implies with a greater quantity of the factor in the combustion chamber, which is being more compressed. Slightly lower minimum volume of the combustion chamber in a turbo-charged engine is associated with a lower compression level. Despite of the decrease in level of compression, thanks to turbocharger it reaches higher pressure levels. The entire turbo-charged engine diagram is slightly lifted in relation to the graph of naturally aspirated engine. This shows a positive impact of the turbocharger on the engine.

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