Differences in the Torque Speed between Electric and Internal Combustion Engine

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Abstract. In the 21st century, it is quite modish to buy a high-performance car, and the performance of the car can be closely related to the engine, the acceleration, the efficiency, and it is also related to the engine, and these two kinds of factors can also be linked to the new notion is known as pressurization, so that is the reason why the manufacturer foster so many high technologies to make the air with higher pressure. There are four types of engines for cars discussed in this paper, turbocharged, supercharged, naturally aspirated and harmonic. A brief introduction to torque will also be given, including the concept of torque, the relationship between drive force and torque, and other knowledge of torque. Finally, the advantages and disadvantages of the different types of engines will be discussed and there will be a summary of choices for a private car around comfort, economy and safety.

Keywords: Engine; torque speed; driving force.

1. Introduction

The torque means that the engine refers to the torque output by the engine from the end of the crankshaft, the engine of the car all has pistons, and each piston goes up and down has four processes, the function that has down by the piston in each unit means the torque of the car, and here is the formula of the car's driving force: the torque multiple the gearbox gear ratio multiple the final gear ratio multiple the efficiency of the engine. The most important data of the car is the acceleration of the car, the most frequently heard by the people is called the time taken from 0 to 100 km/h, it is linked to the torque, because of a formula which will be mentioned in the introduction, the torque is proportional to the driving force, from the formula of Newton's second law, F = ma, if the mass of the object is uniform, then higher driving force, higher acceleration, there are many ways to increase the torque, including increase the air volume in the piston, this may increase the efficiency, the formula P = FV, namely the torque = force*radius, so the force = torque/radius, the linear speed of the rotate circle is 2πR*n with the rotate speed = 2πR*rpm/60. So, it is also equals to the πR*rpm/30, and here the approximate value of the pi, about 3.14, so if the unit of the power is kw, then it equals to tq*n/9550 (tq = torque), here will be a linear graph demonstrates the relationships between the rotate speed, pe, and the three different kinds of the efficiencies of the engines, and the η_v here means the inflation efficiency, and if the engine has high inflation efficiency, the formula for calculating this kind of efficiency is dMa/dMs, the dMa means that the mass of the fresh air which is aspired by the engine, the dMs means the air volume in the standard situation, this efficiency can only be high at a specific rotate rate, because at this rate, the piston can perfectly exploit the inertia of the air current, as the formula pV = nTR, and the higher mass of air, higher mole number, n of the air, then if the volume, v is uniform, the pressure can be bigger, and the torque can be bigger, so on order to keep the inflation efficiency as higher as possible at each rotate rate, then as the formula tq*n/9550, the power of the engine can be boosted. There are 4 different kinds of compression for the air.

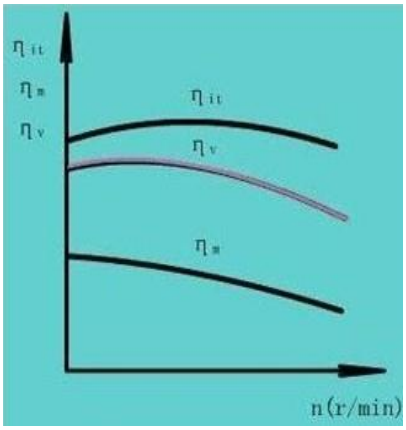


Fig. 1 Three different kinds of efficiencies of the engines [1]

2. The Difference between Four Internal Combustion Engine

2.1. How Does a Naturally Aspirated Engine Work?

This type of engine, as the name suggests, is actually an engine that draws air into the engine through different air pressures between the atmosphere and the combustion chamber. The disadvantage is that it depends on the air pressure in the combustion chamber, which is still lower than the atmosphere, so there is not enough air to make it very efficient compared to a turbo. But naturally aspirated, but the problem with turbocharged engines is that the wasted kinetic energy needs to be large enough to spin the turbine, and if the turbine is stationary, it may prevent air from entering the engine, so the drive is not as smooth as aspirated, so many cars use these engines, like the Chery.

2.2. How Does a Turbocharged Engine Work?

The turbocharged engine means the engine that has a compressor that can be driven by the wastage gases from the engine, and actually that the compressor is two turbines that are connected to the same axle, the wastage may give the kinetic energy to the turbine that closes to the engine, then the turbine may be rolled and drive the other different type of turbine that compresses the air and increase the rate of the air into the engine, by doing this way, the mechanical efficiency of the engine may be boosted. The BMW has a specific technology, is called the single turbine with double vortex tubes, the first and the fourth pistons are connected to the same tube, and the second and the third pistons are connected to another tube, and the phase difference is 360 degrees and the second and the third also have a phase difference is 360 degree, and there will be a construction interfere, and the turbine has the rotate inertia, and the formula is the I = mr, so if the turbine is smaller, it can be driven at a low rpm.



Fig. 2 Structure diagram of a turbocharger [2]

2.3. How Does a Supercharged Engine Work?

This kind of engine has a similar work theory compared to the turbocharged, it also has an air compressor to compress the air, but the difference is that the compressor is driven by mechanical devices, the difference is that the force outputted by it has no lag compared to the turbocharged engine, the compressor is connected to the belt, so it may waste the energy of the engine, and there is friction between each mechanical compositors, the rotation rate of the turbine of the compressor is almost proportional to the rotation rate of the engine. One model of polo uses this type of compressor, and the compressor is called the G-type compressor, and there are two spiral blades in this compressor, and there is a camshaft in the center, the camshaft is connected to the compressing plate, this plate can be driven by the belt, if the cam point from the upside to the right-hand side, the inlet is opened, and then if the cam continues to rotate, the air between the two blades is compressed, the air will be transmitted to the engine. The same stage is repeated for the other inlet, since the inlet is 180 degrees opposite to each other, and the resultant force from the air is 0, so this kind of the engine can output the driving force more smoothly less noise. From Fig. 3, the relative position between the two blades can be changed with the rotation of the cam.

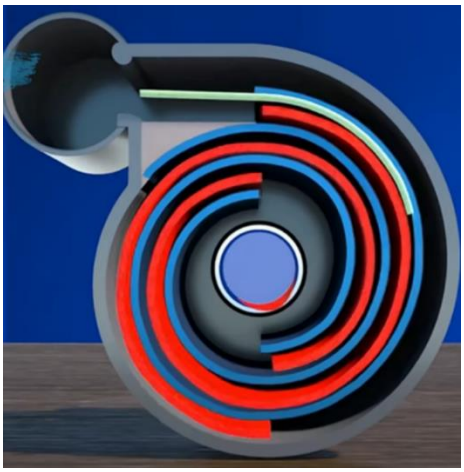


Fig. 3 Schematic diagram of working principle of a supercharged engine [3]

2.4. How Does a Harmonic Engine Work?

This kind of technology exploits the air wave, since the entrance for the air may be sometimes closed, as the air has the inertia, the air current may hit the air gate then it may be flatted into the wave. The length of the pipe can be changed, so it can change its frequency to get an appropriate pressure to the engine if the rotary valve is closed, it means that the rate of rotating is low, so the air can go through a long pipe to increase the torque of the engine, and also when the rate of rotation of the pistons is very high, the valve may be opened, then the air is enough in the engine to increase the combustion efficiency. Here is the structure graph and here the valve can be opened when the rotation speed is very high, then if the frequency of the air wave can be exploited well, it can be reflected in the chamber by itself.

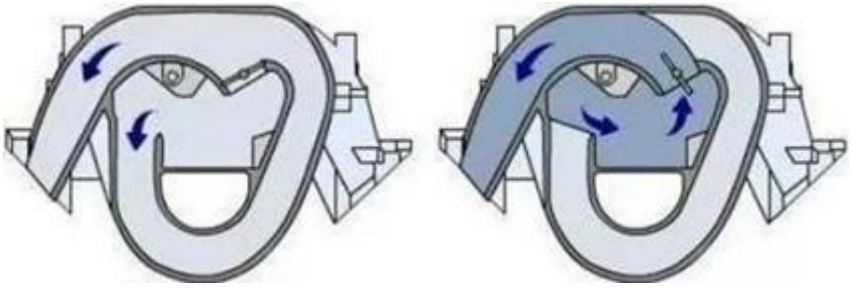


Fig. 4 Structure diagram of a harmonic engine [4]

3. Torque Diagrams for Three Engines and Motors

3.1. Characteristics of Naturally Aspirated Engine Torque Diagram

Naturally-aspirated engines are characterized by relatively linear power output. During the operation of a self-priming engine, the piston moves downward, sucks in certain air, and the ignition combustion generates thrust to push the piston, which is torque output. Ideally, the amount of air sucked in each time at high and low speeds is certain, and the combustion also pushes the piston downward at the most appropriate time. However, due to the existence of various factors, it is impossible to achieve the ideal state; In the whole working cycle, there are one or even two points where the comprehensive energy of the engine's intake efficiency and combustion efficiency reaches the maximum, which is the maximum torque speed. Therefore, the point of self-priming maximum torque speed is also the point with the maximum comprehensive combustion efficiency, and the energy of gasoline is converted into mechanical energy as much as possible. Therefore, it will be relatively low at low speed but will become very high at high speed. The higher the speed, the greater the torque, which is opposite to the motor.

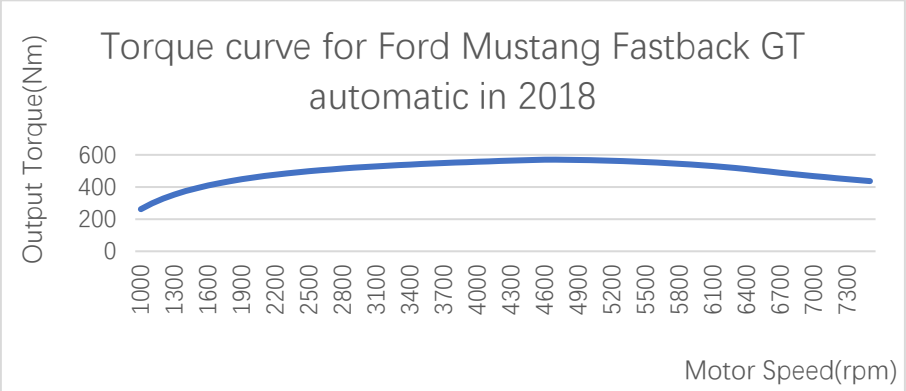


Fig. 5 Torque curve for Ford Mustang Fastback GT automatic in 2018 [5]

3.2. Turbocharged Engine Torque Diagram Features

The turbocharged engine power was very low before the turbine was involved. As the engine speed increases, the power of the engine will increase rapidly after the turbine starts to intervene. When the maximum torque speed range is reached, the torque of the engine will suddenly peak. The characteristic of turbocharging is that when the engine speed reaches 1500 rpm, the turbine will intervene. At this time, the vehicle can achieve the maximum torque. With the increase of the speed, the speed of the turbine is also increasing, and the pressure of the intake air to the engine is also gradually increasing. However, there are upper limits on the pressure and temperature that the engine block and other components can bear. Therefore, the turbine cannot supply the engine with unlimited air. Moreover, the turbine has its temperature and speed limits. When the speed exceeds 5500 rpm, the torque of the vehicle will suddenly drop and become weak to protect the engine and pressure. This problem usually does not occur because unless it is in the highest gear, it usually shifts at the speed of 5000 RMP.

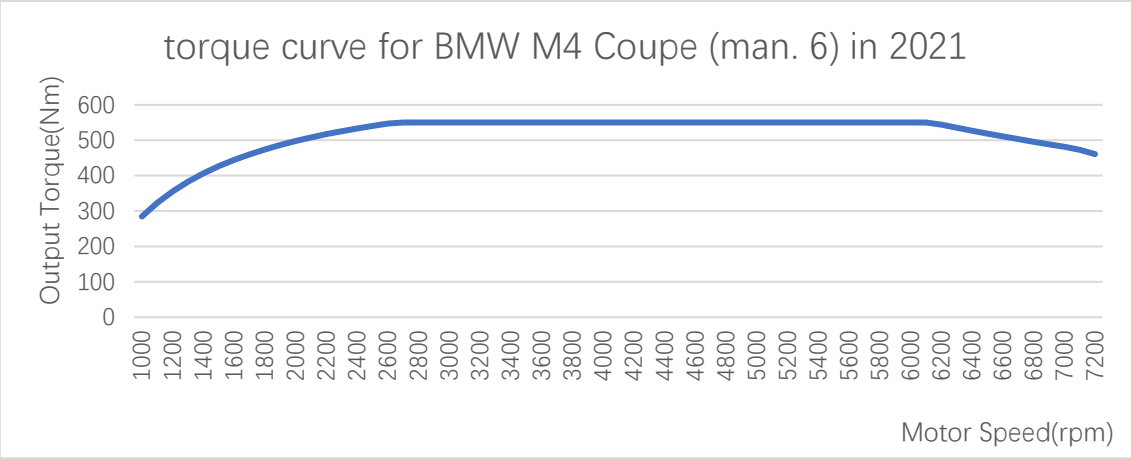


Fig. 6 Torque curve for BMW M4 Coupe in 2021 [6]

3.3. Supercharged Engine Torque Diagram Features

It refers to the problem that the intake efficiency of the naturally aspirated engine is low in the high-speed area. Mechanical supercharging uses the power of the engine itself to drive a compressor to boost the pressure. The supercharger will consume the power of the engine, and its speed will change with the speed of the engine, and there will be no supercharging lag. The effect is excellent when the engine is running at a low speed, but it is limited by the speed of the engine, and the supercharging will be insufficient when the engine is running at a high speed. So, supercharged engines have different power outputs.

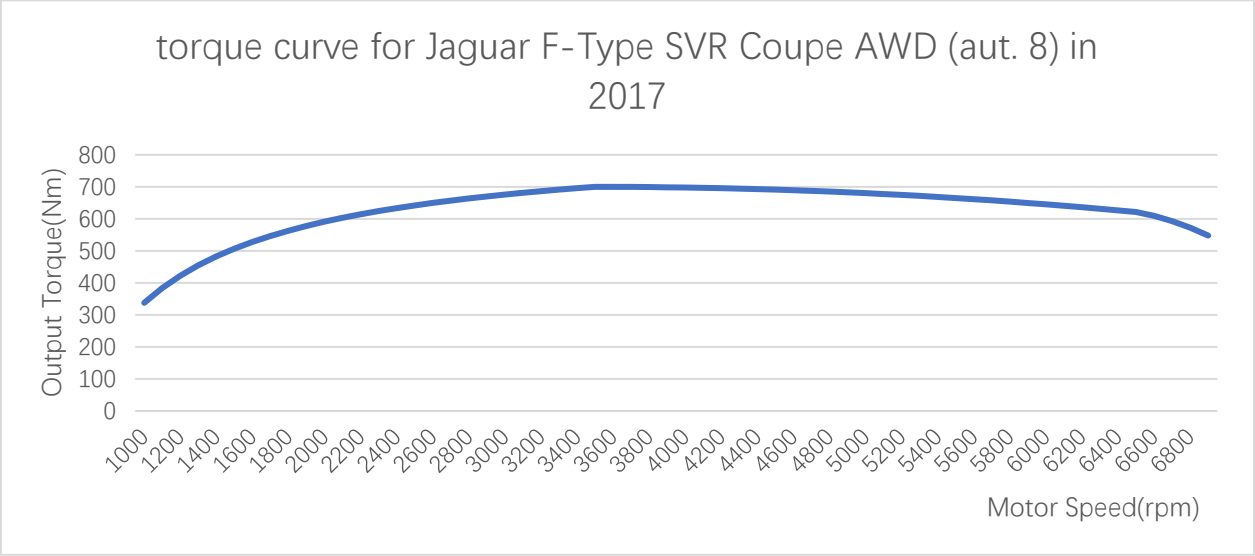


Fig. 7 Torque curve for Jaguar F-Type SVR Coupe AWD in 2017 [7]

3.4. Characteristics of Motor Torque Diagram

Squirrel cage induction machines have a rich history as the most widely used machines in industry. With their simplicity, low cost and ruggedness, they are a good candidate for most applications including traction. Other key advantages of these machines include high peak torque, good dynamic response, and very low maintenance requirement in all aspects of operation [8]. In a certain speed range, the torque of the motor is constant. Within a certain speed range, the torque of the motor will not change due to the change of the speed, and the maximum torque is always output before 6000 rpm. Even when there are only a few dozen revolutions per minute, the maximum torque is almost constant. Tesla Motors is divided into front and rear motors. Tesla uses a kind of hybrid excitation permanent synchronous machine instead of a pure permanent magnet motor. Switch different driving schemes under different working conditions to achieve a wider torque output range. Since the graph

is based on Tesla's all-wheel drive version, its torque is divided into front and rear motors, and the total torque can be calculated. The rear motor is the main motor, which is mainly used for vehicle driving, so it reflects the characteristics of the motor. As the speed increases, the torque will gradually decrease. The front motor only plays an auxiliary role, and only outputs 100nm torque from beginning to end, so there is no obvious reduction. These machines are characterized by three distinct operational regimes, namely constant torque, constant power, and reduced power regions, that are determined by the design choices that are made with respect to the machine design and power electronic control [8].

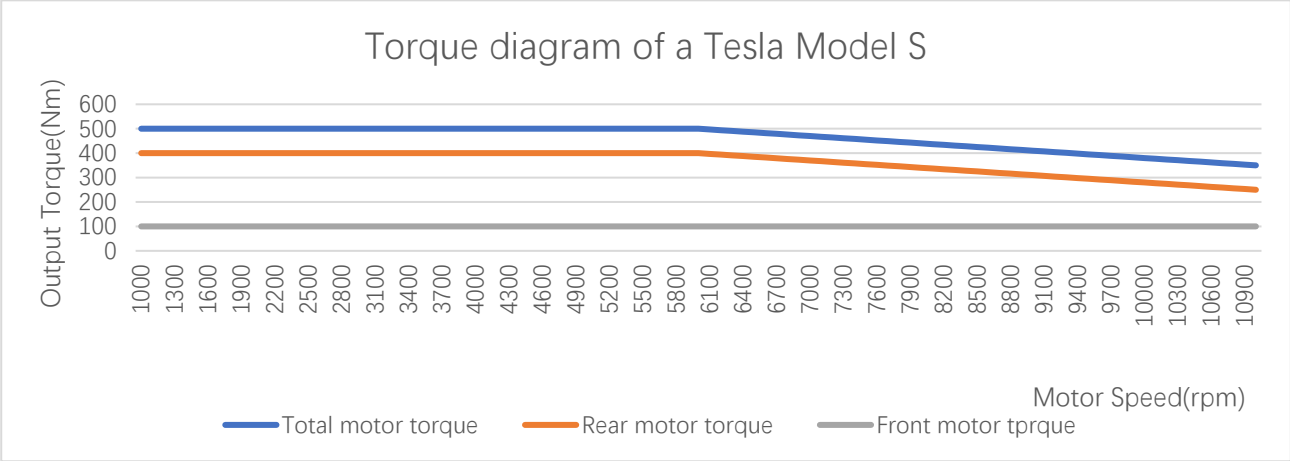


Fig. 8 Torque diagram of a Tesla Model S [9]

3.5. Conclusion

The principle of the self-priming engine is that the piston pumps air only, and the air also has inertia. To a certain extent, with the increase of the frequency of the piston moving up and down, the intake efficiency decreases. The turbo engine is driven by exhaust gas to pump air into the cylinder. Therefore, after the turbine is pressurized, even with the increase in speed, the intake efficiency is still higher than that of the naturally aspirated engine. At low speed, the intake air of the engine is small, so it cannot output strong torque. This situation continues to a certain speed until the intake air reaches the maximum value of the system design, and the maximum torque will be output.

The front and middle parts of supercharging are very similar to naturally aspirated because supercharging starts to work when the engine is started. The magnetic circuit of the motor will be saturated, and the torque is the same concept as the magnetic flux, so the torque is proportional to the size of the motor. The torque of the motor is mainly selected by the manufacturer when designing and configuring for you. Generally, electric vehicles have only a fixed speed ratio reduction gearbox, and there is no gearbox, so they cannot shift gears. The torque must meet the requirements under the most severe working conditions. Under the condition of full load, the vehicle shall be able to start on a steep slope and have a certain acceleration ability. Moreover, more advanced electric vehicles also pursue high performance and naturally will be equipped with larger motors.

4. The Advantages and Disadvantages of Different Engines or Motors from Torque Diagram Viewpoint

4.1. Advantages and Disadvantages of Naturally Aspirated Engines

First, people are talking about why the overall torque picture of a naturally aspirated engine looks like this, and then people should start by looking at the overall way it works. First of all, people usually use a traditional cylinder engine as an example, so the cylinder is moving back and forth during operation. Then, take the cylinder of a syringe as an example, and the cylinder, through the negative pressure of the back-and-forth movement, draws fuel and air into the cylinder block and compresses and explodes. And then it burns and explodes, and it transfers that force to the pistons,

and the pistons push the links and give the car power [10]. Because a naturally aspirated engine air inlet is completely by the negative pressure suction air in the cylinder of the engine, so the car engine operation of the whole process is very smooth, when the engine speed to high, the piston games faster, so the inlet velocity will be faster, then every time the reciprocating motion of piston also can become faster, it led to the greater the naturally aspirated vehicle speed, the higher torque. Here, people consider what affects the torque of a naturally aspirated engine. This gives the roll ratio and flow coefficient of the cylinder head, and four different cylinder heads on the same engine can be installed to study their effects. From this, people can see that different cylinder heads have a greater influence on the engine power, and the higher the flow coefficient, the greater the air intake and the higher the power performance. At the same time, the deviation of the roll ratio also affects the power of the engine. The greater the roll ratio, the fuller the combustion in the cylinder, which can make the vehicle more powerful at low speed, because the car's air intake at high speed is already very large [11]. The advantage of the naturally aspirated engine, of course, the manufacturing cost is low, but because of its output characteristic, if somebody wants to get a larger power, it will need to be better than a supercharged engine with larger displacement, so their fuel consumption is higher, of course, will naturally aspirated car ride for linear output torque and feel very comfortable, more appropriate as an ambulance, Buses and some luxury cars.

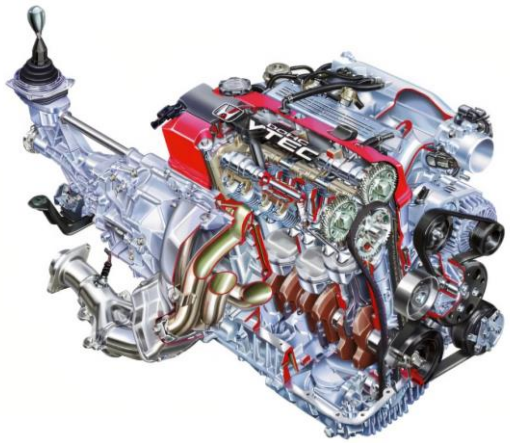


Fig. 9 A naturally aspirated engine [12]

4.2. Advantages and Disadvantages of Turbocharged Engine

Next, for a turbocharged vehicle, it is important to explain what a turbo is. A turbo is composed of two parts: a turbine chamber and a supercharger. The turbine chamber inlet is connected with the exhaust manifold, and the exhaust port is connected with the exhaust pipe; The supercharger intake is connected to the air filter pipe, and the exhaust is on the intake manifold. The turbine and the impeller are respectively installed in the turbine chamber and the supercharger, and the two kinds of coaxial rigid connection. Exhaust gas from the engine will drive the impeller on the side of the turbocharger. When the impeller rotates faster, the impeller on the other side will also rotate rapidly, to improve the air intake into the combustion chamber [13]. Now it is known how turbocharging works, talk about the pros and cons of turbocharging when it comes to getting a lot of power from a small displacement engine. If advantages, so the first point is fuel efficiency because in the same power, has turbocharged technology blessing of engine discharge is much smaller, so will save a lot of oil, for example, 2.0 L turbocharged engine now has close to the actual output power and torque 3.5 L naturally aspirated engine. Of course, in addition to the advantages, turbocharging technology also has many disadvantages. For example, turbocharging will lead to higher engine compartment temperature, which may accelerate the aging of some parts in the engine compartment, especially plastic and rubber products, such as many gaskets. Second, the turbo engine is often accompanied by turbo lag, turbo lag time depend on the set-up of the turbine and the size of the turbine, and the degree of advanced technology, such as 50 years ago BMW2020 is one of the earliest car use turbo technologies in Germany, at the time the car turbo lag of up to 20 seconds, but along with the progress

of science and technology. Now many car manufacturers of engine turbo lag time have been less than two seconds, there are some factories will eliminate turbo lag on roots, such as using two sets of the charging system to eliminate the turbo lag, or is in the normal join an electronic turbine, based on the electric drive. This also eliminates turbine hysteresis.

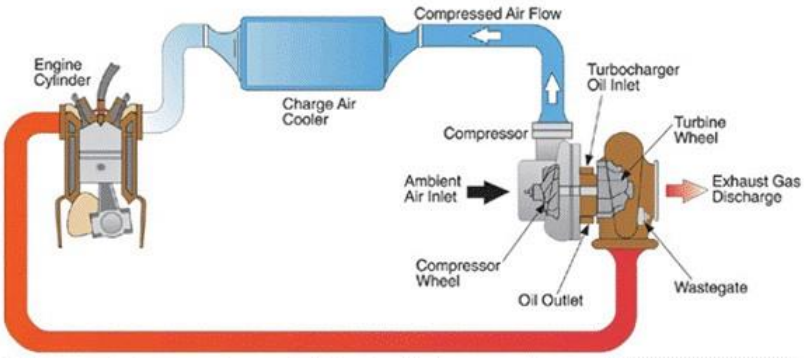


Fig. 10 A turbocharged engine [12]

4.3. Advantages and Disadvantages of Supercharged Engine

Talking about mechanical pressurization, which involves the range is very wide because mechanical pressurization is divided into different categories, someone will discuss it one by one, but there is no denying is relatively more fuel consumption, mechanical pressurization for the turbo is by automobile exhaust gases from the engine drive, and mechanical pressurization is dependent on the supercharger. Therefore, the fuel consumption of the supercharged engine is not much smaller than that of the naturally aspirated engine, but the engine exhaust volume is indeed smaller, although it is still very fuel consuming. There are two flange rotors in a Roux compressor, which are engaged with each other. When the driving shaft meshes with the passive shaft flange rotation, vacuum or negative pressure is generated between the flanges, from which the air will be sucked in, and then transmitted between the turbocharger inlet and its exhaust port [14]. A large amount of air will enter the intake manifold and build up to create positive pressure. But this kind of design of the supercharger is not continuously inhaled air, but the intermittent suction, and the rotor flange heavy body, need to consume more crankshaft torque, efficiency is not high, and this type of supercharger compressed air discharge compressor will hum, generally need to install the noise reduction device to reduce noise. Luo-type superchargers are usually large and mounted on top of the engine. They are popular in high-powered cars because they fit on the outside of the bonnet. However, it is the least efficient mechanical supercharger, for two reasons: on the one hand, it is heavier, increasing the weight of the car, on the other hand, it can only intermittently inhale air, and not smoothly continuous inhalation of air. The double spiral turbocharger is also known as a Roots blower, and the Lutz mechanical supercharger is very similar, the double spiral mechanical supercharger through two similar to a group of turbine transmission meshing flange rotor suction air, the air in the supercharger is also concentrated through the rotor flange suction. Different from the Lutz supercharger, the double-spiral mechanical supercharger will continuously compress the air in the rotor housing, not like the Lutz supercharger's intermittent suction air. The reason for this is that these rotors have a taper, which means that as the air flows from the supercharger intake to the exhaust, the airway becomes smaller. With the contraction of the airway, the air is pressed into a smaller space, so that the compression of the air can be continuous, which not only improves the compression efficiency of the supercharger but also makes the supercharger need not be built very largely. Due to the shape of the rotor flange, it is necessary to carry out precision machining in the manufacturing process, which makes the manufacturing cost of this turbocharger rise. As with the Lutz mechanical supercharger, the double helix supercharger is generally installed above the engine, but some will choose to be installed on the side of the engine. Because its working principle is very similar to that of the Lutz supercharger, the

compressed air discharged from the exhaust port will roar as well as the Lutz supercharger. Generally, noise reduction devices must be used to eliminate these sounds. Centrifugal mechanical supercharger through the use of impeller rotation, the airspeed into the narrow compressor housing. The shape of the impeller is very similar to the rotor of a turbocharger compressor, and its speed is amplified by the input shaft transmission, which can reach 50 to 60 thousand revolutions per minute. Air is drawn in at the hub of the impeller, and the centrifugal force generated by the impeller's rotation causes the air to diffuse outward. This air will keep the impeller at high speed and low pressure. A diffuser is a set of fixed blades around an impeller that convert high-speed, low-pressure air into low-speed, high-pressure air. When air molecules hit these blades, they slow down, reducing the airflow and increasing the pressure. As with any centrifugal supercharger, it provides a small range of supercharging to assist the engine at low engine speeds, and the air is bypassed when the engine slows down. The point is that the same as Roux and twin-screw, it can provide effective supercharging at any engine speed. But because the petrol engine for fuel and oxygen under a relatively small proportion of compressed into the mixture and combustion, so in the low-speed working condition has become a hot topic of many people, and centrifugal in the low-speed range cannot actually like Corus, double spiral supercharger supply enough oxygen to provide combustion, Therefore, the centrifugal turbocharger is considered to be used in large displacement engines, and in the starting stage does not need a too much-forced intake of the engine to match, which can also avoid the tire in the engine starting stage skid. The supercharging efficiency of a centrifugal mechanical supercharger is the highest of the above three kinds of mechanical supercharger, and the temperature of the air after supercharging is generally higher than the first two kinds of high, often needs to install an inter cooler to reduce the temperature of compressed air. Because of its small size and lightweight, the supercharger can be mounted at the front of the engine rather than at the top. Like several other superchargers, it will produce a distinctive roar when working, and noise reduction devices should be added if necessary. Since this mechanical supercharger and turbocharger are highly similar, many people will think that this is a turbocharger. But from the compressor driveway, it is a real mechanical supercharger.

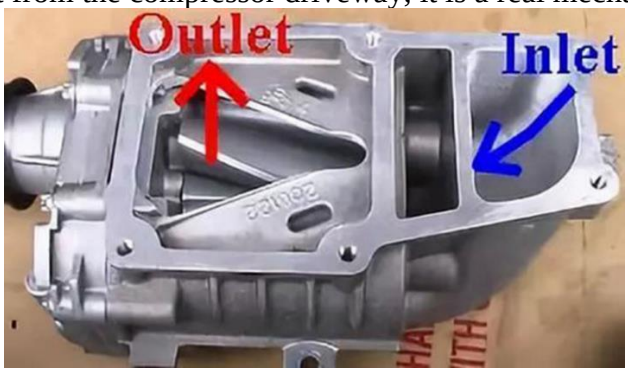


Fig. 11 A supercharged engine [12]

4.4. Advantages and Disadvantages of Motor

The electric motor is the most important part to provide power to the electric car, and some characteristics of the electric motor make the EV completely different from the conventional diesel locomotive because the characteristics of the torque of the electric motor are that it will keep the maximum torque at medium and low speed, and then its torque will gradually decline at high speed [15]. Therefore, often electric locomotive when accelerating or carrying heavy items will have more advantages, also have a weakness, but the motor is the motor and battery pack is too heavy, so some racing, including some of the field, is not very suitable for electric vehicles, rescue vehicles and, of course, maybe in the future which day after significantly reduced the weight of the battery and motor [16], field rescue vehicles, including racing cars, are increasingly powered by electric motors.

5. Conclusion

Although the naturally aspirated engine is the most primitive, it is also because of its primitive, simple structure and low maintenance cost that it is widely used in rescue vehicles, and also in some entry-level sports models, because naturally aspirated vehicles are easier to drive. Turbocharging is more suitable for today's environmental standards, and its power characteristics have led to many racing cars using turbocharged engines. For supercharging, many Americans like this method to enhance their car, although the car will become more gas intensive, it can keep the car's strong power. In the case of motor drive, some stances reckon that the current technology is not mature enough, and many special vehicles cannot use the motor drive, because the motor and battery pack are too heavy, so there are not a lot of experimental electric vehicles in the field of racing, freight transport, and field rescue.

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