

# Analysis of Engine Selection for Underground Internal Combustion Scrapers

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**Abstract:** As the core component of underground internal combustion scraper, whether the engine is selected appropriately or not directly affects the power, economy, noise, reliability, life and environmental protection of the whole underground scraper. This paper takes the existing WJ-1 underground internal combustion scraper of a company as an example, through the market positioning, power demand analysis, legal and regulatory requirements analysis and space arrangement analysis, combined with the characteristic parameters of three kinds of engines, establishes three-dimensional model through UG, and carries out the comparative analysis of different schemes, and finally selects the optimal scheme.

**Keywords:** underground internal combustion scrapers; engine; vehicle performance parameters; UG; selection analysis

## 1. INTRODUCTION

As an important shovel loading and transporting machinery and equipment in underground mines, the high or low efficiency of its work directly affects the efficiency of the mine<sup>[1]</sup>, as the main power source of the diesel engine, its performance is good or bad to determine the efficiency of the underground combustion shovel, so how to make the engine to play the most efficient is one of the most critical issues. This paper takes the existing WJ-1 underground combustion scraper of a company as an example to match the engine selection.

## 2. Vehicle parameters and performance requirements

The underground internal combustion shovelling machine is mainly used for mining and shovelling, and it is widely used in mines without explosive medium and underground projects (section size of the roadway: width×height≥2500×2500mm; turning radius: ≥4500mm; slope: <12°), such as mine and roadway excavation and slag discharge, etc. It is strictly prohibited to be used in places with gas, coal dust and other flammable gases. Underground internal combustion scrapers are strictly prohibited to be used in places where there are flammable and explosive gases such as gas and coal dust. Its vehicle parameters and performance requirements are shown in Table 1.

## 3. Engine selection

Underground engines are different from vehicle engines and generator sets in daily life, their performance parameters are all quite different, and the state requires different standards for them<sup>[2]</sup>. For non-road mobile machinery, the state requires that its emission standards should meet the national requirements of the fourth stage, in order to do a good job in the company's product planning and technological upgrading, the selection of diesel engines for underground internal combustion shovelling machines is analysed.

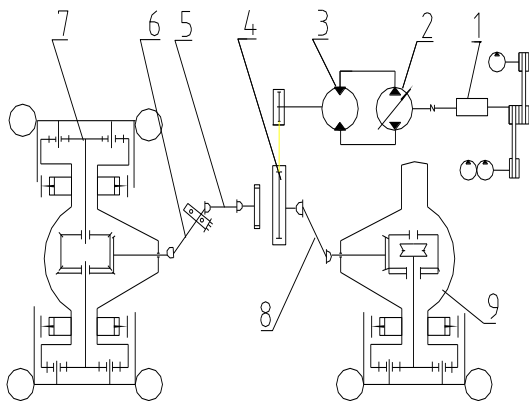
**Table 1 Vehicle parameters and performance requirements**

Bucket capacity	1.0m <sup>3</sup>
Rated load capacity	2000kg
Maximum shovel extraction force	≥42kN
Maximum traction	≥50kN
Maximum unloading height	≥1000mm
Minimum unloading distance	≥840mm
Working device action time	≤14s
Maximum Climbing Angle	≥12° (heavy duty)
Minimum Ground Clearance	≥190mm
Turning radius (outside)	≤4500mm
Maximum speed	7±1km/h
Rear axle swing angle	±6° to ±8°
Lifting capacity	≥24kN
Maximum lifting height	≤3100m
Power of the whole machine	42kw
Static tipping load	≥4000 kg
Transport status external dimensions (L×W×H)	5938×1330×1965mm
Weight	≤6800kg

### 3.1 Structural characteristics of the travelling system

The travelling system consists of hydrostatic transmission and mechanical devices such as drive axle. The diesel engine

rotates and the charge pump works to supply oil to the control system, axial piston pump and parking brake system. Axial piston pump displacement control valve A is in the middle position, axial piston pump swash plate is in the zero position, no oil discharge and no oil suction, play the role of working brake; when the working resistance exceeds the limit value of pressure limiting valve D, the oil pump swash plate automatically return to the middle position, the pump is in the working brake state, play a safe role in protecting the oil pump. Manoeuvring valve A controls variable valve A to control the oil discharge direction and flow size of the axial piston pump, so that the motor forward and reverse to drive the front and rear axles with the required number of revolutions, so that the scraper can move forward and backward at any speed. The working principle of transmission system is shown in Figure 1.



1-Diesel engine 2-Variable pump 3-Variable motor 4-Reduction gearbox 5, 6, 8-Driveshaft 7-Wheelside planetary reduction 9-Differential transmission

Figure 1 Drive train schematic diagram

### 3.2 Engine characteristics

In the harsh underground mining environment, the engine operates under great pressure due to humidity, temperature, dust and other factors<sup>[3]</sup>. In order to ensure the stable operation of the engine, the characteristics of the engine are studied, and it is found that the output torque of the engine is directly proportional to the power and inversely proportional to the rotational speed. Therefore, when selecting an engine, it should be chosen among the engines with lower rated speed as well as those whose output power remains constant. In this paper, the engines of three manufacturers are investigated and their characteristic parameters are shown in Table 2.

### 3.3 Rated speed

The output speed of the engine will affect the selection of hydraulic components, and the parameter performance of some machines is even the same as the optimal speed of the engine, so the impact of the speed on the hydraulic system should be considered when selecting the relevant machine. Firstly, consideration should be given to whether the permissible speed range of the hydraulic pump is satisfied; secondly, the engine speed will affect the flow rate of the hydraulic system, so the impact of other factors on the machine should be taken into account<sup>[4]</sup>. The Deutz D914L04 engine, which is equipped with the WJ-1 underground internal combustion scraper that the project company already has, has

Table 2 Engine characteristic parameter table

factory owners	model number	engine capacity	power (output)	number of revolutions per minute	emission standard	sizes
YTO (Luoyang) Diesel Engine Co.	YTN 4Z-G80 Y6/7 Q-U4	4.75	60	2200-2300	national four-wheeler	811×696×725
Yanmar Engine (Shanghai) Co.	4TN V98 CT-CVC TY	3.319	53.7	2000-2500	national four-wheeler	774×599×834
Dongfeng Cummins Engine Co.	B3.9 FR97 303	3.9	60	1600-2500	national four-wheeler	778×753×882

a rated speed of 2300 r/min, and the speeds of the three engine models investigated are all within a reasonable speed range.

### 3.4 Control methods

The control of the engine mainly refers to the control of the engine throttle, which is divided into two control methods: electronic control and mechanical. Electronic control is divided into electric injection and direct injection. Mechanical control is through the throttle to control the amount of fuel, the control accuracy of this method is poor and serious fuel consumption. The three engines studied are all electronically controlled.

### 3.5 Emission standards

All three engines meet the requirements of the National IV emission standard for non-road mobile machinery.

## 4. Engine space arrangement

### 4.1 YITO diesel engine

According to the power demand of WJ-1 underground internal combustion scraper, YITO Diesel Engine Co., Ltd. recommends the model YTN4Z-G80Y6/7Q-U4, with a rated power of 60KW, and carries out the product design through the three-dimensional modelling software UG to complete the

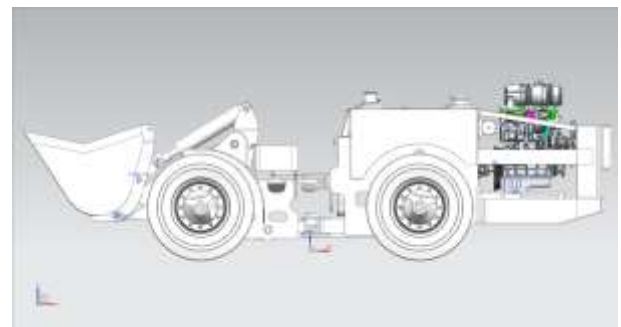


Figure 2 A tow diesel engine layout

whole vehicle layout of the engine, and its engine layout is shown in Figure 2.

According to the layout of the engine in the figure, the post-processing module of the diesel engine is too high, and the engine has more space available on the left and right in the rear frame, in order to avoid blocking the driver's view, the post-processing module of the diesel engine can be mounted on the side of the engine.

## 4.2 Yanmar engines

According to the power demand of WJ-1 underground internal combustion scraper, Yanmar Engine (Shanghai) Co., Ltd. recommended model 4TNV98CT-CVCTY, with a rated power of 53.7KW, and through the three-dimensional modelling software UG for product design, complete the engine layout of the whole vehicle, and its engine layout is shown in Figure 3.

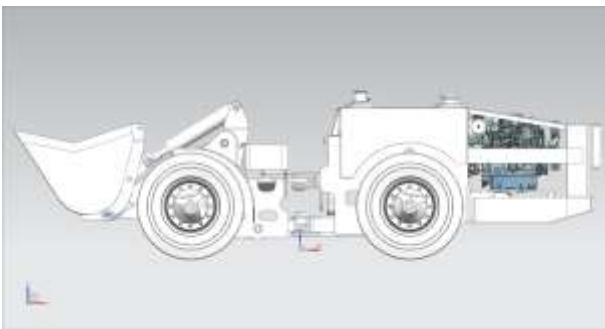


Figure 3 Yanmar engine layout

Based on the arrangement of the engine in the diagram, the engine can be adapted to the original rear frame.

## 4.3 Cummins engines

According to the power demand of WJ-1 underground internal combustion scraper, Dongfeng Cummins Engine Co., Ltd. recommends model B3.9 FR97303, with a maximum sustained power of 59KW and a maximum sustained rotational speed of 2500r/min, and product design is carried out through the three-dimensional modelling software UG, to complete the whole vehicle layout of the engine, and its engine layout is shown in Figure 4.

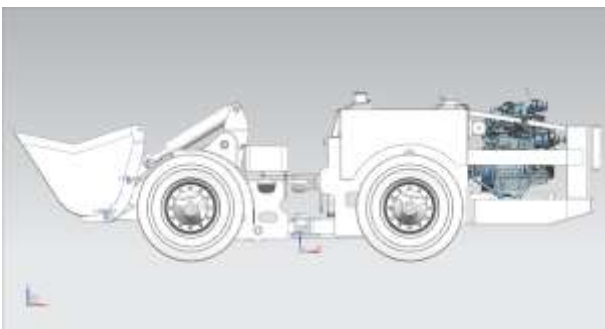


Figure 4 Cummins engine layout

Based on the arrangement of the engine in the diagram, the engine can be adapted to the original rear frame.

## 5. Engine Peripheral Equipment Selection and Configuration and Precautions

The working environment of underground internal combustion scrapers is complicated, and the configuration of peripheral equipments of each system of the engine is not the

same, especially the cooling system and the hydraulic system, the water tank of the cooling system generally shares a cooling fan with the hydraulic oil radiator of the hydraulic system, and the combined radiator assembly, and the shape and structure of the products produced by different manufacturers are different, so the engine suppliers in principle only provide the bare engine, and the peripheral equipments of each system are configured by the host factory itself, and the good configuration of each system will affect the performance of the engine. The host factory to configure their own, and the configuration of each system will affect the performance of the engine<sup>[5]</sup>.

## 5.1 Fuel supply system

Fuel supply system includes fuel tank, ball valve, oil-water separator, fuel coarse filter and fine filter, etc., of which the fuel coarse filter and fine filter, generally provided by the engine manufacturer, the ball valve and the oil-water separator in the fuel supply system is not a necessary component, can be used according to the actual situation, the ball valve is installed between the fuel tank and the oil-water separator, in order to the system for maintenance and replacement of the cartridge cut off the oil circuit, to avoid a constant flow of fuel out of the fuel tank. Avoid a steady flow of fuel tank fuel out, oil-water separator installed before the coarse filter, mainly filtered out of the fuel water and larger particles of impurities, to ensure that the quality of fuel into the engine to reduce the failure rate of the engine, which is particularly necessary for the EFI engine<sup>[6]</sup>, oil-water separator selection is mainly considered when the filtration accuracy and flow, the flow of the filter must be greater than the flow rate of the engine oil pump. The flow rate of the selected filter must be greater than the maximum flow rate of the engine oil pump, and the filtration precision is generally about 10 $\mu$ m. The capacity of the fuel tank should be as large as possible under the conditions of the structure to minimise the number of times of refuelling during the operation, in order not to suck the impurities at the bottom of the tank into the fuel system, the suction port of the fuel tank from the bottom plane should be between 10-20mm.

## 5.2 Air intake system

Engine air intake system according to the different intake methods are divided into natural intake, turbocharging, supercharging after water cooling and supercharging after air - air-cooled four, the first three types of intake for the host plant only need to choose a good air filter and filter blockage alarm switch or indicator can be; supercharging after air - air-cooled is currently the most advanced kind of intake, which makes combustion is more fully, more efficient, greater output power to achieve higher emission standards. It makes the combustion more complete, the efficiency higher, the output power higher to reach the higher emission standard. However, the intercooler often need the host plant to select their own configuration and connection, due to the harsh working environment, it is recommended to use two-stage filtration of the air filter, preferably with a cyclone structure of the pre-filter, in the engine allows the maximum differential pressure, the pre-filter volume flow should be greater than the engine in the rated speed of the intake volume, and according to the engine requirements of the maximum permissible loss of suction pressure, the choice of filter blockage alarm switch or indicator, generally stipulate that the intake resistance of the air intake switch or indicator. According to the maximum permissible suction pressure loss required by the engine, the filter element blockage alarm switch or indicator should be selected, and the air intake resistance should be less than 5kPa

in general. For air-to-air air-cooled intake system, it is necessary to ensure that the intercooler has sufficient heat dissipation capacity and heat dissipation reliability (the temperature of the air entering the engine after the intercooler should be less than 60°C in general).

### 5.3 Exhaust system

Exhaust system is relatively simple, the main consideration of the muffler selection, according to the engine's maximum exhaust volume, the muffler not only to meet the requirements of the engine's exhaust back pressure (exhaust resistance less than 10kPa), but also in the muffler inserted into the engine exhaust noise to the national standards allowed within the scope of the muffler insertion loss of mining machinery is generally 10-20dB.

### 5.4 Cooling system

Engine outlet thermostat at the water flow has two flow directions, when the engine temperature is low, the engine cooling water does not flow directly through the radiator to the water pump, as the engine water temperature continues to rise, the thermostat valve began to open from the engine out of the water part of the water through the outlet pipe to the water tank, cooled by the cooling and then through the inlet pipe to the water pump, when the water temperature rises to a certain temperature (greater than the thermostat full open temperature) When the water temperature rises to a certain temperature (greater than the thermostat full open temperature), all the water from the engine flows to the water tank to participate in heat dissipation and cooling, which ensures that the engine as soon as possible and stabilised at the optimal operating temperature of 79°C-95°C).

## 6. Conclusion

Taking the existing WJ-1 underground internal combustion scraper as an example, analysing its original vehicle parameters, performance requirements and structural characteristics of the original driving system, combining the characteristic parameters of the three engines researched in the market, carrying out the product design through UG three-dimensional modelling software, and taking into account the

precautions on the selection of the engine peripheral equipment, it is concluded that the recommended model of the Dongfeng Cummins Engine Company Limited, B3.9 FR97303, is the optimal solution for the project upgrade, and also provides the basis for the company's later unmanned scrapers. is the optimal solution for the project upgrade, and also lays the foundation for the company's unmanned scraper in the later stage.

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