Research on Methods of Engine-pump Unit Efficiency Recovery in Plateau

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Abstract. This paper puts forward some specific and targeted methods that can increase the engine-pump unit efficiency according to different forms and reasons which cause the efficiency decline of engine-pump unit in plateau.

Introduction

Engine-pump unit is widely used to transport or fill the oil, when using in plateau, its efficiency declines [1]. It is caused by several reasons, the engine power decrease due to the atmospheric pressure decline; the pump performance reduces because of the pump suction capacity decrease and the input power reduction. Some specific and targeted methods should be taken to improve the adaptability of the engine-pump unit in plateau.

Methods to Improve the Engine Efficiency

Methods of New Type Engine

According to the working principle of engine, the following two methods are suggested to enhance the performance of new type engine in plateau.

Increase the Compression Ratio [2]. The intake pressure of the engine decreases when the altitude increases, the temperature, pressure and deflagration trend inside the cylinder goes down when the compression stroke finished. In order to improve the engine performance, the compression ratio should be increased when designing the new engine cylinder structure, the relationship between the allowable compression ratio and the altitude can be calculated by the empirical formula.

\[
\varepsilon_x = \frac{\varepsilon}{(1 - 0.00002257z)^{0.3}}
\]

Where: \( \varepsilon_x \) - allowable compression ratio;
\( \varepsilon \) - original compression ratio;
\( z \) - altitude.

Outfit Turbocharger. Turbocharger can increase the intake pressure of the cylinder, so the actual air pressure entering the cylinder is higher than ambient pressure, which can afford enough air needed for engine combustion. Outfitting a suitable turbocharger is widely used to solve the problem of engine performance decline in plateau, when designing a new engine, we
can choose a suitable turbocharger in order to increase the inlet pressure of the engine cylinder, which can recover the engine power and torque. There are many kinds of turbocharger such as exhaust gas turbocharger, supercharger, intake turbocharger, intake electric turbocharger and so on.

Engine performance is related to the interior fresh charge of the cylinder, where the fresh charge, pneumatic coefficient $\eta_v$ and air weight $\gamma$ is in direct ratio. The relationship between pneumatic coefficient and temperature follows the formula 2:

$$\frac{\eta_{v1}}{\eta_{v2}} = \left(\frac{T_2}{T_1}\right)^{0.25}$$  \hspace{1cm} (2)

Where: $\eta_{v1}$, $\eta_{v2}$ - pneumatic coefficient;
$T_1$, $T_2$ - intake air temperature.

According to the general state equation, rate of compressed air weight can be written as:

$$\frac{\gamma_1}{\gamma_2} = \frac{P_1}{P_2} \cdot \frac{T_2}{T_1}$$  \hspace{1cm} (3)

Where: $\gamma_1$, $\gamma_2$ - air weight rate;
$P_1$, $P_2$ - intake air pressure.

Thereby the engine export power can be show as the formula 4:

$$\frac{N_1}{N_2} = \frac{\gamma_1}{\gamma_2} \cdot \frac{\eta_{v1}}{\eta_{v2}} = \frac{P_1}{P_2} \left(\frac{T_2}{T_1}\right)^{0.75}$$  \hspace{1cm} (4)

The air temperature is generally between 50-60°C after charging, so the air temperature has little effect on the engine power, as long as the pressurized intake pressure can be strengthened to the standard pressure, the engine performance can be recovered to the normal state.

**Method of Active Engine**

According to the structural characteristics of the engine, the following methods are suggested to improve the engine performance in plateau.

**Adjust Ignition Angle.** When using in plateau, the air pressure and temperature decrease at the end of the compression stroke because of the reduction of the mixed gas quality in cylinder, the engine delay combustion period increases, so the fuel can't burn rapidly near the first stop point, which causes the rapid combustion period, slow combustion period and after combustion period delayed, then the engine power goes down. Therefore, increasing the ignition angle is reasonable, which can let the rapid combustion period, slow combustion period and after combustion period achieve the best condition, so it is helpful to increase the fuel combustion efficiency. The adjustment of the ignition angle is considered when the altitude is above 2000m, the ignition angle increases about 3° with each 1000m. There are kings of methods to adjust the engine ignition angle, the best one is to adjust by experiments.

**Adjust Injection Characteristics.** The air amount in cylinder reduces in plateau, at the end of the compression stroke, the air pressure and temperature are lower, the burning rate of the mixture slows down while the critical ignition temperature rises, so it becomes difficult to get the fuel on fire. When improving the injection pressure and velocity, the disturbance and air resistance becomes better, that will improve the oil spray, the engine power increases.
Adjust Mixture Concentration [3]. (1) Reduce the amount of fuel. Oxygen that gets into the engine cylinder reduces in plateau, if supplying the standard oil amount, it will form the rich or richer mixture because the excess air coefficient is down. When the altitude is under 2000m, the air-fuel mixture concentration can be adjusted according to low altitude area requirement. If the altitude is over 2000m, the oil amount should be reduced by 5% ~ 10% of every 1000m. However, this method only play a role in reducing fuel consumption, the reduction of engine power can not be solved.

(2) Increase the oxygen content. Adding oxygen molecules to the fuel can increase the oxygen content of the fuel within the cylinder, and it ultimately improves fuel combustion efficiency, methods of adding alcohol, DME fuel and combustion improver can be used. This method does not change the structure of the engine, it only needs to mix the fuel and oxygen content with a certain ratio. However, the method of adding alcohol need strict standard of the proportion of oil and additives, or it is likely to result in lower flash point of diesel, which undermines the oil quality. Another approach is to increase the oxygen content of the intake air, using engine oxygen-enriched technology to increase the intake air amount, which can increase the intake oxygen ratio.

Methods to Increase the Pump Efficiency

Method of Active Pump

The following methods can be used to enhance the active pump performance.

Use Additives to Improve the Adaptability [4]. Adding additives into the pumped liquid can enhance the delivery capacity and reliability of the pump in plateau. It was successful used on GELA pipeline, the additives improve the transmission capacity of the bottleneck segment. This effect is obvious when using in long-distance pipelines, but the effect of the pump needs further experimental research.

Adjust Operation Conditions of the Pump. The pump efficiency and performance can be improved if the pump is adjusted appropriately in plateau. There are methods such as ensuring the quality of the pump installation, controlling the seal gap, regular inspection, cleaning mechanical seals, reducing the resistance of the pump suction to prevent leakage caused by excessive wear, improving the flow part of the pump, reducing pump suction resistance and improving the suction capacity and so on [5-6].

Methods of New Pump[7-8]

When designing a new pump, we can improve the characteristics of the pump suction port and the suction capacity to enhance its performance, such as choosing a suitable suction flow path, using double suction pump, increasing the impeller inlet diameter rand inducer, install injectors and other methods to improve the pump suction ability.

Summary

According to the different forms and reasons which cause the efficiency decline of engine-pump unit in plateau., considering the feasibility and reliability of the various methods, based on the economy, this paper proposed specific and targeted methods such as increasing the compression ratio and outfitting turbocharger to enhance the performance of the new engine; methods of adjust ignition angle, adjust injection characteristics, adjust mixture concentration were suggested to enhance the performance of active engine; In order to
improve the pump efficiency, this paper suggests to use additives, adjust operation conditions and improve the characteristics of the pump suction to increase the adaptability of pumps.

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