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UTILIZATION OF RETORT GAS AS FUEL FOR INTERNAL COMBUSTION ENGINE FOR PRODUCING POWER

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This paper describes the utilization of surplus Fushun retort gas as fuel for internal combustion engine for producing electric power, the composition and quality of Fushun retort gas, the characteristics of the internal combustion engine, as well as the in-situ utilization of the retort gas as engine fuel.

Introduction

Shale Oil Plant of Fushun Mining Group, Ltd. is the only one oil shale retorting plant for producing shale oil in China now [1, 2]. In 2003, shale oil produced exceeded 100,000 t. The retort gas evolved from the Fushun type retorts goes through the condensing and recovering system where the shale oil is condensed and collected [3]. After this, a part of the gas is used as fuel for heating the recuperator. The remaining gas accounts for about 150–200 Nm^3/t oil shale; a part of this remaining gas is sent to the central station to be used as boiler fuel for producing steam for plant and household use (about 15,000 m^3/h in summer, and 30,000 m^3/h in winter). However, the other part of the remaining gas, so-called surplus gas, (about 12,500–20,000 m^3/h), is not utilized and is vented from the cooling water tower to the open air. It causes environmental impact and is also energy-squandering.

Utilization of the surplus gas as internal combustion engine fuel for producing electric power is a good way to protect environment and save energy. The electric power produced can be supplied for the plant use, thus giving economic profit.

Fushun Retort Gas Composition

The Fushun retort surplus gas has low calorific value – about 800 $kcal/m^3$ (3,160 kJ/m^3), the temperature 50–60 °C (in winter12 °C), and pressure 3 kPa. The gas composition (vol.%, on dry basis) is as follows: CO_2 18.4, C_nH_m 1.4, O_2 1.6, CO 2.8, CH_4 4.6, H_2 9.9, N_2 61.3, water content is about 59%.

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Internal Combustion Engine Characteristics

The internal combustion engine selected for *in-situ* testing is manufactured by the Machine Works of Shengli Oil Field Co. The engine 40GFPT/I has the following characteristics:

It is equipped with an internal pre-combustion chamber that enhances ignition capability and increases combustion velocity, therefore enabling high-efficient use of the low-calorific gas.

Numerical electronic ignition technique is adopted, it is suitable for the engine equipped with multi-cylinders. The ignition capability and ignition time can be well adjusted at the optimum working conditions for each cylinder separately; the air and gas mix ratio for the mixer can be well adjusted by microelectronic control technique, even in the case when the combustible composition of the gas varies in the range of 30%, or in the case when the gas calorific value decreases greatly.

The combustion engine set is designed to have water cooling; at first the air and gas are mixed, then the mixture is passed through a pressure booster to enhance its pressure, through a water-cooling apparatus to decrease its temperature and then introduced into the cylinders for combustion. The gas pressure required for such type engine is not high (the pressure higher than 100 mm H_2O is enough). The engine equipped with pressure booster costs 10% more than one without it, but its power efficiency is 30% higher.

The Requirements for the Gas Quality for Its Use in the Engine

The gas to be used in that internal combustion engine should be filtered, the liquid involved should be separated, gas pressure should be stable and its temperature low. After pretreatment, the impurities should be low (in mg/m^3): H_2S <20–50, oil <20, NH_3 <20, solid particles should be smaller than 5 μm, and their content <30 mg/m^3.

In-situ Internal Combustion Engine Test

The *in-situ* internal combustion engine (type 40GFPT/I, 40 kW) test was made using pretreated surplus retort gas. The pretreatment included separation of oil and water, and filtration. The gas is send to the engine station where it passes through cooling apparatus and two series of back-flash arresters. After mixing with air it passes through pressure booster and water cooler as described above.

It was shown that the engine starts quickly, runs stably, and the power produced reaches 64% of the rating value. It was stated that for generating 1 kWh, 3.3 m^3 gas are required, corresponding to about 11,000 kJ (3,300 $kJ/m^3 \times 3.3\ m^3$). Hydrogen content of the gas accounts for 6–10%, an ideal value, indicating that it is easy to ignite and not easy to get back-flash, i.e., the gas is suitable for burning in such type internal combustion engine, and it is not necessary to add any other supplementary high-calorific fuel.

Calculation of the Power to be Generated when Using the Whole Quantity of Surplus Retort Gas

As indicated above, the whole plant produces 12,500 m^3 surplus retort gas per hour. For consuming such quantity of gas, it is designed to equip eight sets (type 500GF-RW, each with twelve cylinders) of internal combustion engines, each set combined with 500 kW electric generators (four sets are built already). The actual power to be generated for long run by each set is assumed to be 320 kW. Considering eight sets to run 8,000 hours each year, the total power generated each year will reach about 20 million kWh.

At present shale oil plant consumes every day about 65,000–80,000 kWh, i.e. yearly (330 working days) consumption accounts for about 21.5–26.4 million kWh. It means that if the plant will be equipped with eight set of 500GF-RW combustion engines and generators for consuming the total surplus retort gas, the yearly power generated, 20 million kWh, will almost meet the total yearly power requirement of the plant (21.5–26.4 million kWh).

The main parameters of the 500GF-RW engine and generator are as follows:

Rating power, kW	500
Rating revolution, r/min	1000
Rating voltage, V	400
Rating current, A	900
Rating frequency, Hz	50
Rating factor, cosφ	0.8
Gas consumption, MJ/kWh	11

Technical and Economical Study on Surplus Gas Combustion and Power Generation

Estimation of Capital Costs

Capital costs estimated for 8-set type 500GF-RW engines and generators are as follows, yans:

Engine &Generator	6,800,000
Gas Treating	160,000
Machine Building	144,000
Control Room	64,000
Foundation	48,000
Electric Cable	160,000
Dividing Chamber	32,000
Cooling Tower	120,000
Cooling Pond	50,000
Cooling Piping	48,000
Cooling Pump	40,000
Installation	160,000
Step-up Transformer	200,000
High-Tension-Switch	40,000
Others	80,000
Total	**8,146,000**

Estimation of Benefit

Yearly profit for the 8-set 500GF-RW is as follows: →

Production:	Power	20,480,000 kWh
	Income	**8,396,800 Yuan**
Operating Costs:	Wages	275,000 Yuan
	Lubricating Oil	218,400 Yuan
	Depreciation	1,129,000 Yuan
	Maintenance	677,000 Yuan
	Management	120,000 Yuan
		2,419,400 Yuan
Profit		**5,977,400 Yuan**
Investment recovery time		**1.36 year**

- Yearly electricity produced is 320 × 8000 × 8 = = 20,480,000 kWh.
- Yearly income: electricity-selling cost accounts for 0.41 yuan/kWh, yearly income is 20,480,000 × 0.41 = 8,396,800 yuan.
- Wages: for 11 workers and technical staff, yearly payment is 11 × 25,000 = 275,000 yuan.
- Lubricating oil payment: assuming lubricating oil consumption for one year for each set to be 3,900 kg with the price 7 yuan for kg, totally: 3,900 × 8 × 7 = 218,400 yuan.
- Depreciation: assuming 7 years for depreciation, then for each year it is 8,146,000 × (1 – 0.03)/7 = 1,129,000 yuan.
- Maintenance: assuming it to be 60% of the depreciation, yearly maintenance is 1,129,000 × 60% = 677,000 yuan.

Conclusions

Retort gas produced at Fushun shale oil plant is partly used by Fushun retorts themselves for heating and pyrolysis of oil shale, a part of it is used in boiler for producing steam for the plant use. The surplus gas formerly vented to the open air wastes energy and causes environment pollution. Recently it is tried to burn it in internal combustion engine combined with electric power production. The *in-situ* test indicates that the gas burns well, the engine runs well and the power generation efficiency is high. Preliminary feasibility study shows that if the whole surplus gas of the plant is utilized for burning and power generation, the electricity obtained will be almost sufficient for the plant use and brings significant economic profit.

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