



REVIEW ON UTILIZATION OF OIL SHALE AND SHALE OIL PRODUCTION AT FUSHUN DEPOSIT

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The utilization of Fushun oil shale as raw material has been reviewed and the properties of Fushun shale oil and the developing history and the practical applicability of Fushun oil shale have been discussed. The complete utilization of Fushun oil shale sources has been evaluated.

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Mineral oils, however, contains in general smaller amounts of unsaturated hydrocarbons, nitrogen or oxygen compounds than shale oil. ⁶

Introduction

Oil shale is a solid-state organic-rich sedimentary and combustible rock with high ash content. ¹ Shale oil is derived via pyrolysis of oil shale which is widely distributed throughout the world and contains considerable amounts of heteroatomic compounds and unsaturated hydrocarbons. ²

As the demand for energy is greatly increasing throughout the world, oil shale, regarded as a potential energy source to substitute for oil and natural gas, has attracted Chinese researchers' attention for many years. ³ There is a considerable amount of oil shale deposits in *Fushun*, which rank the second in *China*. The amount of oil shale in *Fushun* is estimated to be 35 billion tons, and that of shale oil is 7.5 billion tons. ⁴

In this paper, the main properties, developing history, and practical applicability of *Fushun* shale oil are reviewed, including a detailed comparison between investment and profit of *Fushun* shale oil.

Discussion

Properties of *Fushun* shale oil

Fushun shale oil used as feedstock came from Shale Oil Refinery of *Fushun* Ming Group Co., Ltd. Table 1 shows the properties of *Fushun* shale oil samples. ⁵ The composition and properties include density, kinematic viscosity, wax content, elemental composition, asphaltene content, boiling range, etc., and the ratio of carbon to hydrogen generally varies between 7 and 8, which is very close to the relevant value of petroleum. Shale oil as fuel may become an important substitute of petroleum in the near future.

Shale oil contains a lot of unsaturated hydrocarbons and non-hydrocarbon compounds as well. *Fushun* shale oil has higher nitrogen content than that of *Maoming* or *Estonia*, while *Estonia* shale oil has higher oxygen content than shale oils from other sources. ⁶

Table 1. Properties of *Fushun* shale oil

Properties	Value
Density (20 °C), g/cm ³	0.9033
Kinematic viscosity (50 °C), mm ² /s	11.3
Solidification point, °C	33
Open cup flash point, °C	137
Phenol, %	3.1
Asphaltene, %	0.85
Wax, %	20.0
Resin, % (sulphate process)	42
Carbon residue, %	1.63
Elemental composition, wt%	
C	86.05
H	11.51
O	0.69
S	0.56
N	1.19
C/H	7.49
Basic nitrogen, %	0.6509
Boiling range:	
< 200 °C	3 %
200 °C – 350 °C	35 %
> 350 °C	62 %

Fushun shale oil contains less amount of light fraction, e.g. its gasoline fraction content is varied between 2.5 and 2.7 % and the amount of fraction boils below 360 °C is varied between 40 and 50%. Its wax and residual oil content were between 25 and 30% or 20 and 30%, respectively. *Fushun* shale oil belongs to the group of high nitrogen compound containing paraffinic oils with high wax content and setting point, and low asphaltene content.

The developing history of *Fushun* Shale Oil

Table 3 shows the developing history of *Fushun* shale oil. ⁷ There were low capacities (50 t/unit) and more numbers of retorting boiler (80 units) at Shale Oil Refinery of *Fushun* Ming Group Co., Ltd. in 1928.

Table 2 The main processing of oil shale in the world⁶

Country	Place	Oil shale (t/d)	Shale (m/m)	Yield (%)	Production
China	Fushun	100	10-75	65	Fuel, low heat value gas shale ash
Estonia	Kivioli	100	10-100	68	Fuel, chemical production, low heat value gas shale ash
Brazil	Sao Mateus	1500 and 6000	6-50	85-90	Light oil, sulfur, high heat value gas shale semi-coke
Estonia	Narva	3000	0-25	85-90	Fuel, chemical production, high heat value gas shale ash
Australia	Stuart	6000	0-16	85-90	Light fuel, low sulfur light oil, high heat value gas shale ash

Capacities of retorting boiler increased as the years increased until 1956; however the numbers of retorting boiler decreased with the increase of year as shown between 1928 and 1956. On the other hand, capacities and numbers of retorting boiler between 1989 and 1995 kept at 100 t and 20 units, respectively. Numbers of retorting boiler only increased to 160 units in 2002.

Table 3. The developing history of Fushun shale oil

Year	Capacity of retorting boiler (t)	Numbers of retorting boiler
1928	50	80
1934	100	80
1939	180	60
1945	200	60
1954	200	60
1956	200	26
1989	100	20
1992	100	20
1995	100	20
2002	100	160

Comparing between investment and profit of Fushun oil shale

The Tables 4, 5 and 6 show the yields of the products such as shale oil, coal gas and oil shale residue, the consumption of *Fushun* oil shale per ton of product, and the total cost of *Fushun* oil shale per ton, respectively. One ton of oil shale produces 40-42 kg of shale oil, 80-160 kg of coal gas and 800-880 kg of shale oil residue, respectively. Other costs in Table 6 represent the highest cost for *Fushun* oil shale and include maintenance, the replacement or change of new equipment, etc. On the other hand, water consumption is the lowest cost factor.

Table 4. The yields of the production (1 ton of oil shale as feedstock)

Name of production	Shale oil	Coal gas	Oil shale residue
Yields (kg)	40-42	80-160	800-880

Table 7 shows the yields of shale oil, oil shale residue and tail mining (small particles of oil shale; $d \leq 12\text{mm}$) per year. *Fushun* oil shale provides different quality fuel materials, fuel gas and raw material for production of various chemicals. The residues of oil shale separation can be used for manufacturing bricks and cement. For example, heating 1 million tons of grounded oil shale at 500 °C produces 3.3 million tons of shale oil, 81.7 million tons of oil shale residual and 17.6 million tons of tail mining, respectively.

Table 5. The consumption of Fushun oil shale per ton

Oil shale (t)	Water (t)	Electricity (kWh)	Steam (t)	Gas (Nm ³)	Energy consumption (MJ)
24-26	7-11	370-400	1.8-2.5	2800-4000	24000

The practical applicability of *Fushun* oil shale

Fushun oil shale can be used directly as fuel in power plants to provide electricity. *Fushun* oil shale can also be separated into shale oil, fuel gas, and oil shale residue. Table 8 shows the chemical compositions of oil shale residue. The oil shale residue can be used to produce brick and cement, and for the recovery of different rare earth elements, such as Si, Al, Fe, Mg and Ca, and to produce different kinds of manure.⁸

Conclusion

Fushun oil shale and shale oil can be used directly as feedstock and fuel to produce high valuable products in order to meet Chinese energy requirements. Utilization of *Fushun* shale oil and oil shale provides less damage to the natural environment and increases the income of a petrochemical plant. The main benefits are as follows: (1) take the place of the traditional energy (coal and petroleum) and protect the local fragile environment; (2) both the local economic development and the local income are improved, as well as more job opportunities are provided.

Table 6. Total cost of processing of 1 ton of Fushun oil shale

Name	Oil shale	Material	Management	Salary	Water	Steam	Electricity	Others	Total
Unit/Yuan	61.95	97.30	111.0	93.0	25.00	100.00	123.3	271.73	883.28
Percent (%)	7.01	11.02	12.6	10.5	2.81	11.32	13.96	30.78	100

Table 7. The yields of shale oil, oil shale residue and tail mining per year (million tons at 500 °C)

Shale oil	Oil shale residue	Tail mining
3.3	81.7	17.6

Table 8. The chemical compositions of oil shale residue

Name	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	CaO
Content (%)	62.23	23.45	9.7	1.41	1.78

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