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Report on preliminary tests of heavy oil processing at "YARUS" equipment

Natural bitumen of Tatarstan fields has a high content of asphalt tar components and sulfur compounds (see Tab. 1), which significantly complicates the atmospheric-vacuum distillation due to corrosion of the equipment and the thermal degradation of high-molecular compounds. Thus preliminary dehydration and deasphalting is usually carried out to allocate asphalt resinous concentrate (ARC).

Table 1. Characteristics of Permian heavy oils of Tatarstan

Index	Value	
Density at 20°C	940 – 970	kg/m³
Viscosity at 20°C	400 – 5000	µPa·s
Total sulfur content	3,0 – 4,6	% mass
Resins and asphaltenes content	19 – 34	% mass
Oil mass fraction	66 – 81	% mass
Paraffins mass fraction	0,04 – 1,6	% mass
The pour point	от –18 до 0	°C
Coking	8,7 – 12	%
Yield of fraction, boiling up to 300 °C	8 – 33	% vol.

Fig. 1 shows a fragment of the scheme of highly viscous oil and natural bitumen processing, provided by Regional Science and Technology Center VNIIneft (Bugulma). The scheme has been tested on a pilot plant of Shugurovsky oil bitumen refinery and at the Institute of Oil Refining Problems (Ufa) and adopted as the basic scheme of the Program of Developing of Natural Bitumen Resources in the Republic of Tatarstan.

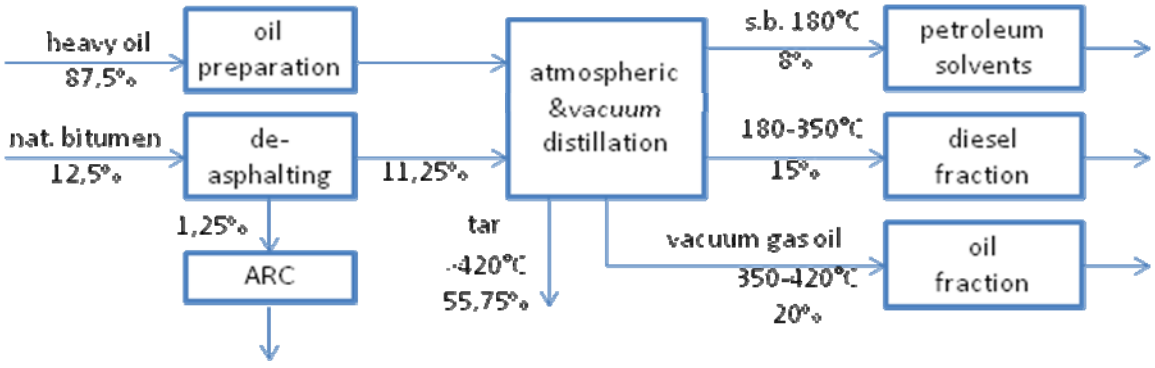

Fig. 1. Basic scheme of highly viscous oil and natural bitumen processing

Atmospheric and vacuum distillation has a small yield of light petrochemicals (10–20 %). Expensive processes of hydro cracking, catalytic cracking and thermal cracking used to increase the proportion of light products.

Processing of highly viscous oil at the **"YARUS"** reactor does not require pretreatment of raw material. The yield of light fractions is 75 %, the yield of viscous residue of gummy consistency is about 15 %, the yield of non-condensable light fractions is about 10 %.

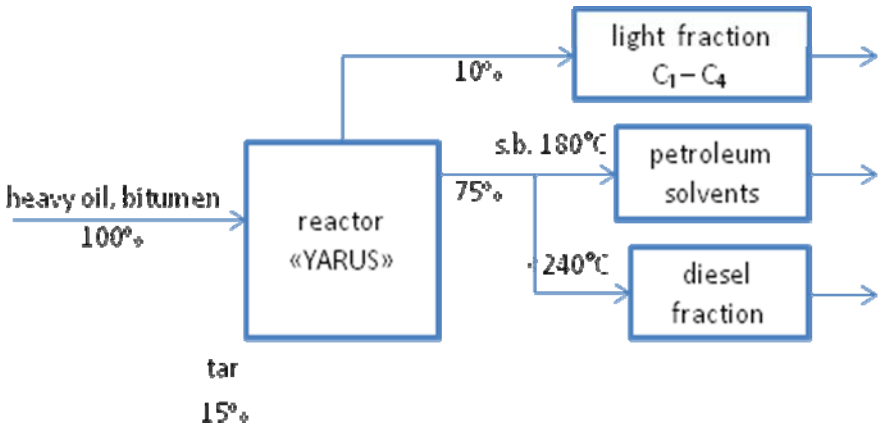

Fig. 2. Scheme of highly viscous oil and natural bitumen processing at the **"YARUS"** reactor

Table 2. Comparison of unit costs for different methods of highly viscous oil and natural bitumen processing

Process name	**Unit energy costs**		
	Kg of fuel equivalent/ ton of raw	MJ/kg	kWh/kg
processing at the "YARUS" reactor			
Single	**49 – 74**	**1,44 – 2,2**	**0,4 – 0,6**
Double	**74 – 110**	**2,2 – 3,24**	**0,6 – 0,9**
Typical processes			
Refinery	**45 – 50**	**1,32 – 1,5**	**0,37 – 0,41**
Catalytic cracking	**25 – 30**	**0,73 – 0,88**	**0,2 – 0,24**
Hydrocracking	**30 – 40**	**0,88 – 1,2**	**0,24 – 0,33**

Electricity consumption for processing of 10 kg:
Heat source: electrical heating elements. Energy costs: 6 kWh
The cost of energy is: (6 kWh x 5 RUR/kWh) / 10 kg = 3 RUR/kg

Diesel fuel consumption for processing of 10 kg:
Let us take equal energy costs (6 kWh), then
(0.5 liter x 0.86 kg/liter x 27 RUR/liter x 45 MJ/kg x 0.278 kWh/MJ) / 10 kg = 1,45 RUR/kg

Fuel oil consumption for processing of 10 kg:
(0.5 liter x 6 RUR/liter) / 10 kg = 0.3 RUR/kg

Table 3. Comparison of energy costs (RUR/kg) for heavy oil processing at the **"YARUS"** reactor, using different heat sources.

Source of heating	Energy consumption for processing of 10 kg of raw material	Energy costs, RUR/kg
Electricity	6 kWh	3
Diesel fuel	0,5 liter	1,45
Fuel oil	0,5 liter	0,3

The specific energy consumption for processing of highly viscous oil is 2.2 MJ / kg for a single processing. Energy costs are 1.45 and 0.3 RUR/kg for using diesel fuel and fuel oil as a heat source, respectively.

Light fractions C_1 — C_4, resulting from the separation, can be used as a source of heating (fuel) to provide the processing. In this case, the cost of energy is not calculated. Also associated petroleum gas can be used (**"YARUS"** reactor is adopted to work on APG).

Preliminary tests of processing of highly viscous Ashalchi bitumen oil

Preliminary tests of processing of highly viscous Ashalchi bitumen oil on laboratory equipment "YARUS" were held 14.10.2014 in Kazan city. The feedstock in an amount of 10 kg was granted by TatNIPIneft. Characteristics of the baseline material and processed material are given in Table 4.

Table 4. Test results of processing of highly viscous Ashalchi bitumen oil (TatNIPIneft sample) on laboratory equipment **"YARUS"**

Index	Baseline material	Processed material		
		I	II*	
Density at 20°C	**960**	**840**	**800**	kg/м³
Viscosity at 20°C	**8,7**	**7,8**		unit
Initial boiling point	**+150**	**+28**		°C
Yield of fraction boiling up to +360 °C	**12 – 18 %**	**>85**		% vol.
Fractional composition				% vol.
initial boiling +110 °C		**5**		(gasoline fraction)
+125 …+240 °C		**70**		(diesel fraction)

* I- material obtained by single processing;
II- material obtained by double processing

Processing of highly viscous oil and natural bitumen at **"YARUS"** reactor can be used to obtain semisynthetic and synthetic oils directly on the production site. Compounding feedstock with a fraction of initial boiling +110 °C to about 10 wt % reduces viscosity and provides an oil product suitable for pipeline transport.

Viscosity is measured in relative units, where 1 unit corresponds to water viscosity measured at 20 °C. Viscosity value of 7.8 units is obtained after selection of the gasoline fraction. Compounding the feedstock with a fraction of 125–240 °C (diesel) results in the following viscosities: 5 % by mass – 8,0 units .; 10 % by mass – 7,2 units .; 15 % by mass – 6,9 units .; 20 % by mass – 6,4 units.

Oil processing at **"**YARUS**"** reactor has a low specific energy consumption (2.2 MJ/kg). The processing is performed in one step, requires no pretreatment of raw material. Processing is carried out at atmospheric pressure at a relatively low heating temperature (+240 °C). Substantial increase in the proportion of light fractions is received (75%).

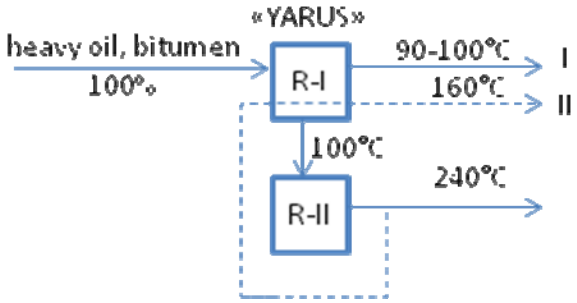

Fig. 3. Scheme of single and double heavy oil and natural bitumen processing at **"**YARUS**"** reactor

It is possible to conduct the double processing to increase the yield of gasoline fraction and virtually completely remove sulfur.

"YARUS" is a lowcost unit. Capital intensity is estimated at RUR 1.0 mln for the installation of refining capacity of 10 thousand tons per year in the industrial mode of production.

One possible use of **"**YARUS**"** is the injection of distillate directly into the heavy oil reservoir as a diluent of heavy oil in order to increase recovery factor.

Processing of fuel oil M-200

Fuel oil M-200 is sour, viscous fuel oil, derived from the heavy oil residue, coal and oil shale. Increased viscosity of fuel oil M-200 creates difficulties with its use.

Preliminary tests of processing of fuel oil M-200 on laboratory equipment **"YARUS"** were held in November, 2014 in Kazan city. The feedstock in an amount of 4.644 kg was processed without pretreatment. Characteristics of the baseline material and processed material are given in Table 5.

Table 5. Test results of processing of fuel oil M-200 on laboratory equipment "YARUS"

Index	Baseline material	Processed material		
	fuel oil	I	II*	
Density at 20°C	**0.89–1.0**	**804**		kg/м³
Viscosity at 100°C	**8–80**			mm² / s
Initial boiling point	**30**			°C
Sulfur content	**0.5–3.5**			% mass
Yield of fraction boiling up to +360 °C		**51.2**		% vol.
Fractional composition				% vol.
initial boiling +60 °C			**8**	(gasoline fraction)
+60 …+100 °C			**14**	(gasoline fraction)
			18.1	(diesel fraction)
			4.5	(oil)

*** I- material obtained by single processing;**
II- material obtained by double processing

The yield of gasoline-diesel fraction with boiling up to 360 °C is 51.2 % mass. at primary processing. The yield of bitumen fraction with oleaginous consistency is about 11 % mass. The yield of tar with viscous consistency is about 11 % mass, the yield of light non-condensable gases is about 28.4 % mass. The results are shown in Table. 6.

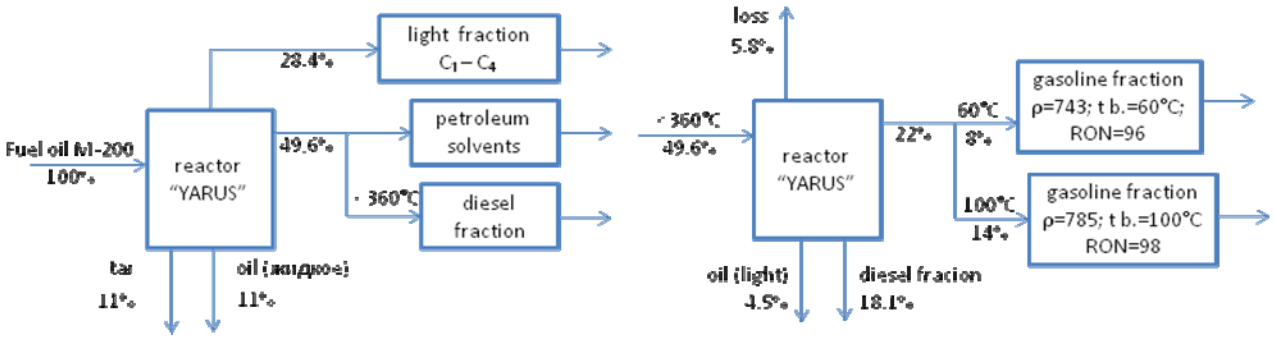

Fig. 4. Scheme of single and double processing of fuel oil M-200 at "YARUS" reactor

Table 6. Test results of processing of fuel oil M-200 on laboratory equipment “YARUS”

Processed material			
I		**II***	
	% mass		% mass
light fractions	28.4		
<360°C	49.6	**loss**	5.8
gasoline-diesel ρ=803		**gasoline fraction** (ρ=743; tн.к.=60°C; RON=96)	22 8.0
		gasoline fraction (ρ=785; tн.к.=100°C; RON=98)	14.0
		diesel fraction (cetane number = 47)	18.1
		oil (light)	4.5
oil	11		
tar	11		
*** I- material obtained by single processing; II- material obtained by double processing**			

The yield of gasoline-diesel fraction with boiling up to 360 °C with density of ρ = 804 kg/m³ is 22 % mass at secondary processing (including 14.0 % mass — gasoline density ρ = 743 kg/m³, initial boiling +60 °C, research octane number RON = 96; 8.0 % mass — gasoline density ρ = 785 kg/m³, initial boiling +60...+100 °C, research octane number RON = 98). The yield of the diesel fraction with cetane number 47 is 18.1 % mass, the yield of the light oil fraction is 4.5 % mass, loss is about 5.8 % mass. The percentage by mass is given in relation to the amount of feedstock (fuel oil M-200). The results are shown in Table. 6.

Processing schematic diagram is shown in Fig. 4.