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METHODS FOR REDUCING THE VISCOSITY OF CRUDE OIL FOR PIPELINE TRANSPORT

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Abstract- **Crude oil is a solution of hydrocarbons mixed with organic and inorganic compounds. Its quality (physical and chemical properties) differs from one field to another and even within the same field (at different depths).**
Also most of the time, crude oil is transported through pipelines in batches (depending on the quantity extracted and the field from which the crude oil is sent to the refinery), creating transport problems (especially in winter) due to the existence of pumping and paraffinic batches. combined with asphalt crude oil.
This paper presents the possibilities of reducing the viscosity of crude oil, so that the transport through pipelines can be carried out without problems.
The effects of mixing rates of crude oil and additives on viscosity are also analyzed.

Keywords – oil, pipeline, viscosity, mixing,

I. Introduction

Crude crude oil extracted in Romania differs both by the content of light hydrocarbons and by the ratio between the classes of hydrocarbons and the content in compounds with oxygen, nitrogen, or sulfur.

The classifications of crude oil made took into account [1]:
- chemical composition;
- the properties of crude oil or of some fractions present in the structure;
- content in different commercial fractions or processing possibilities.

Analyzing the crude oils from Romania, it is found that there is the possibility to classify them based on the yield of white products obtained from the processing of each category [2]:

-A1 - (24.3%) Hard, without paraffin, < 60% "white products",
-A2 - (16.5%) Hard, without paraffin, > 60% "white products",
-B - (8.4%) Semi-paraffin oil,
-C1 - (17.9%) Paraffin oil, <65% "white products",
-C2 - (30.9%) Paraffin oil,> 65% "white products",
-Condensate (2.0%).

Qualitatively, depending on the freezing temperature, the Romanian crude oils that are transported from the production source to the refineries (for processing) are of the type [3]:

* asphalt (A);
* semiparaffinous (B);
* paraffinase (C).

The methods required to ensure the pumpability of viscous crude oil are[4]:

1. Heating (hot transport);
2. Heat treatment;
3. Crude oil transportation solution;
4. Hydrotransport;
5. Emulsion reversal;

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6. Treatment with reducers (depressants);
7. Mixing with diluents.

Through these methods, very hard-to-pump oil is irreversibly transformed into easily pumpable oil.

The stability of the parameters (freezing point temperature, viscosity) depends on the transport conditions (oil temperature, soil, flow, pressure).

All the listed methods decrease the viscosity, but each has certain peculiarities that make the respective method more or less efficient. and dilution.

Hot pumping has the disadvantage of fuel consumption, so it is good to apply on pipes with a maximum length of 50 km, and the preheating temperature should not be excessively high (70-80°C) to does not favor (increase) evaporation losses.

In the case of transporting crude oil in solution (when the vapor pressure is high) the pumpability is better (the pressure drop is small), but the evaporation losses are high.

The treatment process with depressants is newer, it is effective, but from an economic point of view it is disadvantageous. The effectiveness increases if the oil depressant is heated before it is introduced, because the depressant will act on a solution of paraffin in the oil (by preheating the paraffin networks are destroyed).

The depressant process is effective, reduces the freezing point and keeps it constant, but this method requires costs to [5]:

a. fuel used for preheating crude oil;
b. procuring depressant;
c. plant for injecting depressant.

The most commonly used method is one in which viscous crude oil is treated with thinners (less viscous crude oil) - that is, the flushing of heavy, pumpable crude oil with light (more fluid) crude oil.

The effectiveness of the method is higher the lower the viscosity of the diluent used. Ideally, they should be used as diluents: gasoline, diesel, condensate.

The method has disadvantages, such as: the pressure drop on the route is high, the mixing is conditioned by the availability of a stock of low viscosity crude oil and by the required quality requirements for processing in the refinery.

Analyzing the quality of crude oil and its pumpability conditions through pipes (freezing temperature 7 degrees lower than soil temperature and viscosity of maximum 100 cSt) it is observed that [6]:

-type C (paraffinic) crude oil has a high freezing point and a large amount of white products,
-type A (asphalt) crude oil has high viscosity and large amount of heavy refining products

So for the transport of crude oil it is necessary to create mixtures by:

-dilution with low viscosity products to reduce the viscosity of type A crude oil,
-dilution with products that have a low freezing point, which reduces the freezing point of type C crude oil.

If these diluents are not present in the oil fields, or in order not to affect the quality of crude oil and therefore of refining products (because for diluting crude oil is usually used diesel or non-compliant gasoline or other crude oil with different properties - mixtures blend type) it is necessary to create oil additives (chemicals that added to crude oil improve their properties).

These additives are polymers or other chemical agents that alter the precipitation of paraffin crystals in solution by one of the following mechanisms:

-the modifier comes out of the solution at a temperature slightly higher than the equilibrium temperature of the paraffin solution;
-the modifier comes out of the solution at an equilibrium temperature of the paraffin solution and co-crystallizes with paraffin;
-the modifier comes out of the solution at a temperature slightly lower than the equilibrium temperature of the paraffin solution and is absorbed on the paraffin crystals.

The modifier present in the solution, acting by one of the above mechanisms, tends to keep the paraffin molecules as separate entities, by reducing the cohesive forces between the crystals and the adhesion forces between the paraffin crystals and other surfaces.

II. TECHNOLOGY TO REDUCING THE VISCOSITY OF CRUDE OIL FOR PIPELINE TRANSPORT

II.1. Hot transport of viscous crude oil (hot pumping)

One of the commonly used methods to reduce viscosity is to heat the oil to the temperature that ensures trouble-free pumping.

Irrespective of the economic side, heating is the universal solution to the problem of pumping paraffin oil, highly freezable and viscous, at any freezing temperature and at any temperature of the environment surrounding the pipeline.

Hot pumping requires a heating station both in the pumping stations and in the intermediate points along the route.

In order for hot transport to take place under normal and efficient conditions, the following must be observed:

1. temperature in the pipe> $t_{freezing\ point}$ (if a freezable oil is transported);
2. line temperature> $t_{admissible}$ * (if a high viscosity oil is transported).

* Note: The allowable temperature can be defined as the temperature at which the viscosity of crude oil has the highest allowable value for transport.

The thermal regime of the crude oil that is transported through the pipeline is non-stationary and depends on:

• the temperature of the environment in which the pipe is located (air, soil);
• variation of the pumping regime (stop-start, fault, flow changes);
• pumping mixtures with different characteristics.

II.2. Reduction of viscosity using the heat treatment process

Heat treatment is a process of transporting a crude viscous, which temporarily improves the flow properties of this type of crude oil.

The process involves preheating the oil to a certain temperature and cooling it to a certain speed.

The choice of heating temperature and cooling rate is established experimentally, depending on the properties of the transported crude oil.

By heating, the paraffin in the oil dissolves, and on cooling the asphalt-resinous components in the oil are adsorbed on the surface of the paraffin crystals that form, preventing the formation of a resistant structural network.

The efficiency of the method depends on the correct choice of the cooling rate and the content of asphalt-resinous substances in the crude oil.

Because the flow properties of the heat-treated oil return to their initial values over time, the process is effective only when the travel time of the pipe from the initial to the final point is sufficiently short in relation to the recovery time of the initial flow properties.

In other words, for the transport of heat-treated crude oil to be economically efficient, it is necessary that the recovery time mentioned be long enough, ie longer than the pumping time.

II.3. Reducing the viscosity of crude oil by transporting crude oil with gas in solution

The principle of the method consists in maintaining in the oil with high viscosity a quantity of dissolved gases.

It is known that gas oil in solution has a lower viscosity than degassed oil, the minimum viscosity being reached when the oil is saturated with gas.

To keep the gases in the solution, the pressure in the pipe must be higher than the saturation pressure (conveniently chosen).

The effectiveness of the method is aimed at reducing the pumping pressure.

The ratio between the pressure drop due to friction in the case of transport of gasified crude oil [H*] and the pressure drop due to friction in the case of transport of crude oil [H] is subunit, ie [7]:

$$(H^*/H) \leq 1 \tag{1}$$

Hence the following conclusions:

• in turbulent regime in rough pipes where the coefficient of resistance is independent of the Reynolds number; the process is not effective;

• in the case of smooth pipes, for a laminar or turbulent flow regime with Re $<10^5$, the process could have a positive effect but in somewhat more restrictive conditions.

In our country, the process is not used due to the loss of volatile fractions that occur during transport and storage.

II.4 .Oil-water emulsion transport

The reduction of pressure losses when transporting crude oil with high viscosity through pipelines can be achieved by transporting it together with water [8].

The procedure can be performed by:

• concentric flow of crude oil and water through the pipeline;

• transporting crude oil in the form of an emulsion in water.

This can be done by producing a centrifuge, so that water with a higher density than crude oil is sent to the pipe wall.

As the viscosity of the water is lower than that of the crude oil, a reduction of the pressure drop in the pipe is obtained.

To carry out this process, the so-called spiral pipes are used, which have on the inner surface a thread made by welding helical metal strips.

The liquid in the pipe thus acquires a rotational motion that throws the water towards the wall.

The hydrotransport variant has not found application, because the construction of spiral pipes is difficult and the maintenance of the annular layer is not safe.

It also cannot be applied when there are intermediate pumping stations, because in pumps, oil and water, it would give rise to a very stable emulsion.

II.5.Transport by emulsion reversal

Another method proposed for pumping viscous crude oil through the pipeline is to invert the water - crude emulsion into a crude oil - water emulsion.

In principle, the process is quite simple, and it consists in injecting a non-ionic surfactant.

In a normal emulsion, the continuous phase is formed by the crude oil, and the water constitutes the discontinuous phase, being divided into fine particles in the crude oil mass.

The apparent viscosity of such an emulsion is approximately equal to that of crude oil.

In a reverse emulsion, water is what forms the continuous phase, the crude oil as a discontinuous phase being dispersed in the water mass.

The viscosity of this type of emulsion is much lower than that of a normal emulsion, so easier to pump.

Reversing the emulsion is done with special emulsifiers.

The method is less known and applied in our country.

II.6. Transport of crude oil with viscosity reducers

Depending on the content of different groups of hydrocarbons, crude oil is divided into:

I - paraffinic, II - naphthenic, III - aromatic.

In this case, we refer to the characterization of crude oils from the first group, in order to establish the main parameters for optimizing their pumping.

According to the paraffin content, depending on the freezing temperature of the oil fraction with viscosity ν_{50} = 0.52 cst, paraffin oils are divided into:

• low paraffinic oil thawing ≤ 16 °C;

• freezing paraffinic crude oil = 16 ÷ 20 °C;

• very paraffinic oil thawing> 20 °C.

III. Experiment and Result

To reduce the viscosity, we analyzed the possibility of oil mixtures

The principle of the method consists in mixing in certain proportions the hard pumpable crude oil with a light crude oil and determining the density and viscosity of the mixtures.

A viscous oil was mixed with a paraffin oil.

Table -1 Paraffin oil

Temperature	**Density d_4^t**	**Dynamic viscosirty**	**Kinematic viscosity**
°C	**-**	**cP**	**cSt**
2	**0,9640**	**12958,7**	**13442,6**
10	**0,9636**	**5853,6**	**6074,7**
20	**0,9631**	**2439,9**	**2533,4**
30	**0,9626**	**1099,6**	**1142,3**
40	**0,9621**	**467,03**	**494,8**
50	**0,9616**	**260,9**	**271,3**

Table -2 Light crude oil

Temperature	**Density d_4^t**	**Dynamic viscosirty**	**Kinematic viscosity**
°C	**-**	**cP**	**cSt**
2	**0,860**	**36,6**	**42,56**
20	**0,847**	**14**	**16,52**
50	**0,826**	**3,3**	**3,99**

Mixtures were made between the heavy pumpable crude oil and the light oil type in proportions between 5-30% (light crude oil).

Table -3 Crude oil mixing heavy pumpable crude oil and the light oil (density variation)

Crude oil mixing heavy pumpable crude oil and the light oil	**density g/cm^3**		
heavy pumpable crude oil/ light oil (% volume)	**Temperature 2°**	**Temperature 20°**	**Temperature 50°**
80/20	**0,950**	**0,939**	**0,922**
75/25	**0,944**	**0,934**	**0,916**
70/30	**0,939**	**0,928**	**0,910**

Table -4 Crude oil mixing heavy pumpable crude oil and the light oil (viscosity variation)

light oil / heavy pumpable crude oil (% weight)		**5/95**	**10/90**	**15/85**	**20/80**	**25/75**	**30/70**
Viscozitate	**2°C**	**6105,3**	**3954,8**	**2589,5**	**1222,9**	**1076,6**	**830,5**
cP	**50°C**	**121,3**	**115,8**	**60**	**51,1**	**40,7**	**22,4**

The density of mixtures of petroleum products, when the properties of the components are known, can be calculated with the relation:

$$d_{am} = \frac{1}{100}\sum_{1}^{n} V_i d_{4i}^{t} \qquad (2)$$

Where V_i is the volume ratio of component i measured at standard density.

Table- 5 Density variation with the percentage of diluent and the temperature of mixing of heavy pumpable crude oil and the light oil measured values and values determined by equation 2

Crude oil mixing heavy pumpable crude oil and the light oil %, volume	Density, g/cm^3 (Temperature 2°)	Density, g/cm^3 (Temperature 20°)	Density, g/cm^3 (Temperature 50°)	Density, g/cm^3 (Temperature 2°), calculated with relation 2	Density, g/cm^3 (Temperature 20°), calculated with relation 2	Density, g/cm^3 (Temperature 50°), calculated with relation 2
100	0,964	0,9631	0,9616	0,964	0,9631	0,9616
80	0,95	0,939	0,922	0,9432	0,93988	0,93448
75	0,944	0,934	0,916	0,938	0,934075	0,9277
70	0,939	0,928	0,91	0,9328	0,92827	0,92092
0	0,86	0,847	0,826	0,86	0,847	0,826
Total amount	4,657	4,6111	4,5356	4,638	4,612325	4,5707
Arithmetic mean	0,9314	0,92222	0,90712	0,9276	0,922465	0,91414
Differences between the arithmetic mean, the measured value and the determined one				-0,0038	0,000245	0,00702
Percentage difference %				-0,38	0,0245	0,702

The differences between the densities at mixtures determined by measurements and those calculated by the above relation (2) are insignificant.

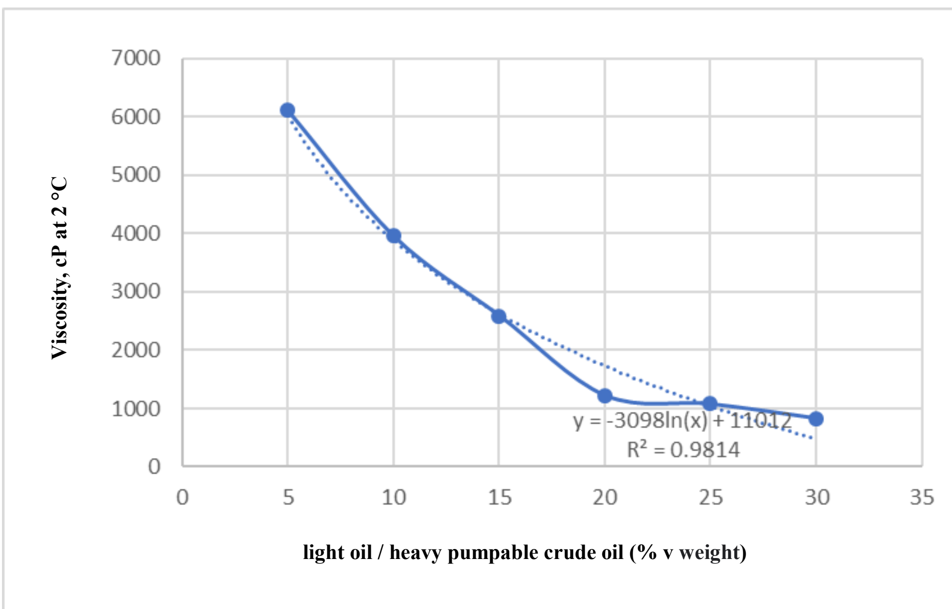

Figure 1. Variation of the viscosity (cP) of the mixtures depending on the mixing rate of light crude oil / heavy crude oil and depending on the temperature of crude oil (gravimetric mixing rate of light oil / heavy pumpable crude oil (% v weight))

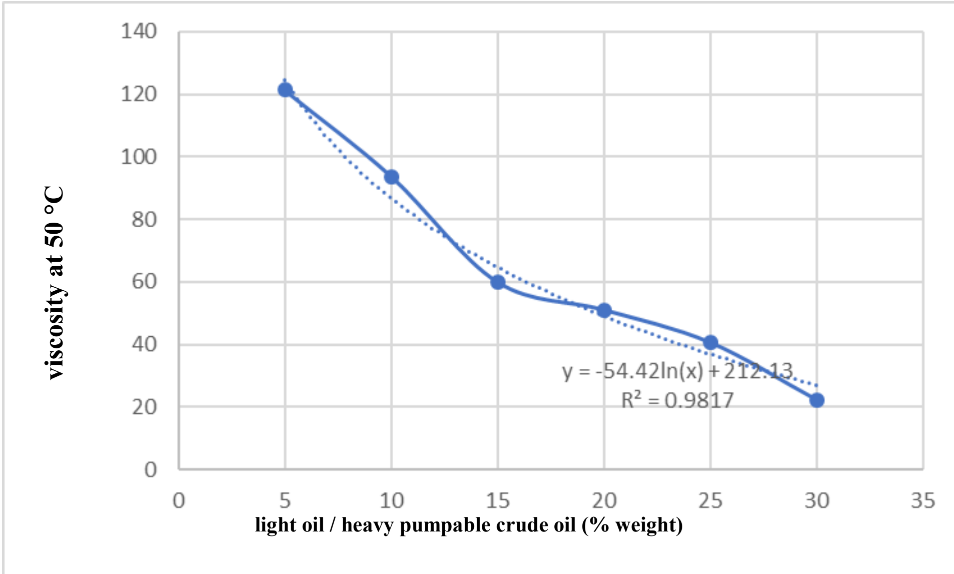

Figure 2. Variation of the viscosity (cP) of the mixtures depending on the mixing rate of light crude oil / heavy crude oil and depending on the temperature of crude oil (gravimetric mixing rate of light oil / heavy pumpable crude oil (% v weight))

Table-6 Equation of variation of the viscosity (cP) of the mixtures depending on the mixing rate of light crude oil / heavy crude oil and depending on the temperature of crude oil (gravimetric mixing rate of light oil / heavy pumpable crude oil (% v weight))

Parameter x	Parameter y	Equation	R^2
Viscosity at 2°, cP	**Ratio light oil / heavy pumpable crude oil (% weight)**	**y = -3098ln(x) + 11012**	**0.9814**
Viscosity at 50°, cP	**Ratio light oil / heavy pumpable crude oil (% weight)**	**y = -54.42ln(x) + 212.13**	**0.9817**

IV.CONCLUSION

The most common method for reducing viscosity is when viscous crude oil is treated with thinners (less viscous crude oil) - that is, flushing heavy, pumpable crude oil with light (more fluid) crude oil.

The effectiveness of the method is higher the lower the viscosity of the diluent used. Ideally, they should be used as diluents: gasoline, diesel, condensate.

The method has disadvantages, such as: the pressure drop on the route is high, the mixing is conditioned by the availability of a stock of low viscosity crude oil and by the required quality requirements for processing in the refinery.

In this paper presenting mixtures between heavy pumpable crude oil and light oil in proportions between 5-30% (light crude oil).

Analyzing the densities of the mixture, a linearity of the density variation with temperature is observed.

The density of mixtures of petroleum products, when the properties of the components are known, can be calculated with the relation.

$$d_{am} = \frac{1}{100}\sum_{1}^{n} V_i d_{4i}^t$$

Where V_i is the volume ratio of component i measured at standard density.

The differences between the densities at mixtures determined by measurements and those calculated by the above relation are insignificant (below 0.05%).

Finally, I also studied the viscosity of heavy / light oil mixtures.

The mixing ratio of maximum 30% of crude oil creates the possibility to decrease the viscosity by more than 80%.

Logarithmic the viscosity values can be observed a linearization of the measured data.

The final analysis of this topic indicates that the treatment of hard-to-pump crude oil is absolutely necessary either by using additives or by using solvents (which is a cheaper option, but creates problems in crude oil refining).

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