Construction of the Simulation Model of Transportation Oil Products

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Abstract

New method of transportation of viscous petroleum products is proposed, ensuring their high average temperature and fluidity without the use of thermal insulation of the railway tank boiler and ground heating. A simulation model for the transportation of viscous petroleum products was constructed using a new method of modeling the physical process, allowing to estimate the amount of resources consumed

Keywords. Viscous oil products, railway transportation, simulation model.

1 INTRODUCTION

Oil and petroleum products are the most important component of freight transportation of Russian railway transport, yielding only coal in volume. According to data for 2018, oil and petroleum products account for more than 15.3% of the total volume of cargo delivered by RZD. The revenue from transportation of oil and petroleum products is 27.5% of the total income received by RZD [Khu19, Bal08].

2 CURRENT CONDITION OF TRANSPORT OF VISCOUS OIL PRODUCTS

The advantages of railway transport, which determine its demand, are as follows:

1. According to data for 2018, the main volumes of oil cargo transportation are in the Yamal-Nenets Autonomous District, Omsk Region, the republic of Bashkortostan, the Krasnoyarsk Territory and other regions of Siberia. The delivery of viscous petroleum products from oil refineries concentrated in the central part of the country to the end user or terminals is carried out mainly by rail. And there is no alternative to this situation at this time. In the future, taking into account the geographical capabilities of the country, is not anticipated [Car].
2. The ability to provide bulk cargo delivery by rail, unlike road transport, which has a maximum volume of one tank-vehicle cargo of 25 tons. At the same time, the specialized rolling stock in 45 wagons is able to carry cargo weighing up to 3000 tons [Zhe17].
3. The unisonality of transport in contrast to water transport.

Let us consider in detail the scheme of transportation of viscous oil products (Figure 1).

The most energy-intensive and expensive processes are heating petroleum products before unloading and draining, as well as cleaning the boiler of the railway tank from the remains of petroleum products with preliminary evaporation, disposal and disposal of a large amount of waste [Gon89].

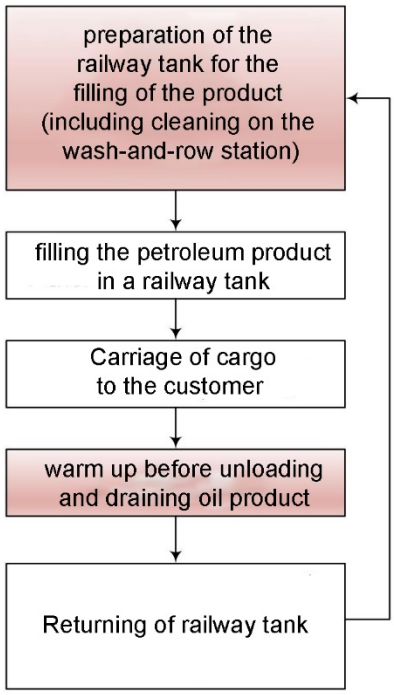

Figure 1: Scheme Of Transportation Of Viscous Oil Products.

A significant role here is played by:

- Long distances and low branching of railways, which lead to long-term transport duration.
- During transportation, transported oil products are cooled, and in dark petroleum products (masuts, oils, paraffin oil products, etc.) viscosity increases so much that their discharge without long and intensive heating necessary for the restoration of fluidity becomes impossible [Moi12, Bak04].

These problems lead to the fact that transportation of dark petroleum products is a labor-intensive, long-term and expensive operation, which causes low turnover of tank wagons, requiring expensive equipment and high costs of heat energy and water (steam).

2 Stratification Of Viscous Oil Products (New Transportation Model)

The most rapid cooling of viscous petroleum products in the first 20-25 hours after pouring into the railway tank, when the temperature of the petroleum product is high, and the viscosity is small [Zhe17].

Cooling of cargo occurs due to mixed free-forced convection through the walls of the boiler of the railway tank. As a result, cooled during transportation, the load during unloading needs to be heated to restore fluidity. This problem is particularly acute in winter, which in some regions of the country can last up to 8 months [Mik77,Mon65]

Now, specialized railway tanks are used to slow down the freezing of viscous petroleum products: With a steam-heater cover, with stationary steam coils, with thermal insulation of the boiler walls, etc. Their disadvantage is that these railway tanks have a large mass of containers, which, creating excessive loads on the axle of wheel pairs, causes the need to reduce the weight of the load. The consequence of the use of specialized trains is the non-productivity of transportation and a very large, empty run, usually reaching 50% [Mor06].

One possible way to reduce the cost of railway transportation is to slow down the rate of cooling of viscous petroleum products during transportation by transferring them to stratified state at the time of loading. This non-equilibrium condition can be achieved by increasing the density of the cargo carried at the bottom of the railway tank even during loading. Directly in the places of interaction between the transported cargo and the walls of the boiler, the viscous oil product solidifies, forming a high-viscosity layer, which has a small thermal conductivity, which itself becomes thermal insulation.

As a result, the bulk of the product remains in a fluid state throughout the transport. In this case, when unloading into the warming-up, a small share of the transported cargo (not more than 10%) is required. The unloading and cleaning process is approaching summer time standards. The advantage of this type of transport is the use of the existing fleet of general-purpose railway tanks.

3 Simulation Model

To assess the cost effectiveness of the proposed mode of transportation, a number of simulation models of various processes of transportation of petroleum products were developed, allowing to conduct functional and cost analysis. As an instrumental environment was used the domestic platform Business Studio [Bis,Kse19].

The modeling used BPMN notation, which allows a very thin and precise description of the simulated business process.

With Business Studio, you can see how many times each process has been started, what processes are waiting to run, and why (lack of material resources), the average number of launches per day. The consumption of material resources (pair) is visible.

Let's consider one of the most expensive processes of transportation of oil products - cleaning of the railway tank from the remains of cargo, including preparatory operations, draining of residues and cleaning of the tank directly. The duration of the cleaning of the railway tank depends on the nature of the cargo, the period of delivery (winter or summer) and can amount to 5-6 hours in winter, unlike the summer time, when the cleaning of the tank takes only 1,5-2 hours.

We will carry out simulation of the process of cleaning the boiler of the tank-car in winter period at work of one drain device and average temperature of air -25℃. The result of the simulation is visible in Fig.2.

The diagram shows that during the past day, a composition consisting of 22 railway tanks arrived at the wash-and-row station. Of this number, 6 railway tanks were completely cleaned, another 17 are waiting for their turn.

In Table 1, it is shown that process "Steaming" was launched 21 times, in 18 cases it is completed, and in 3 it is being carried out at the moment. The queue was formed

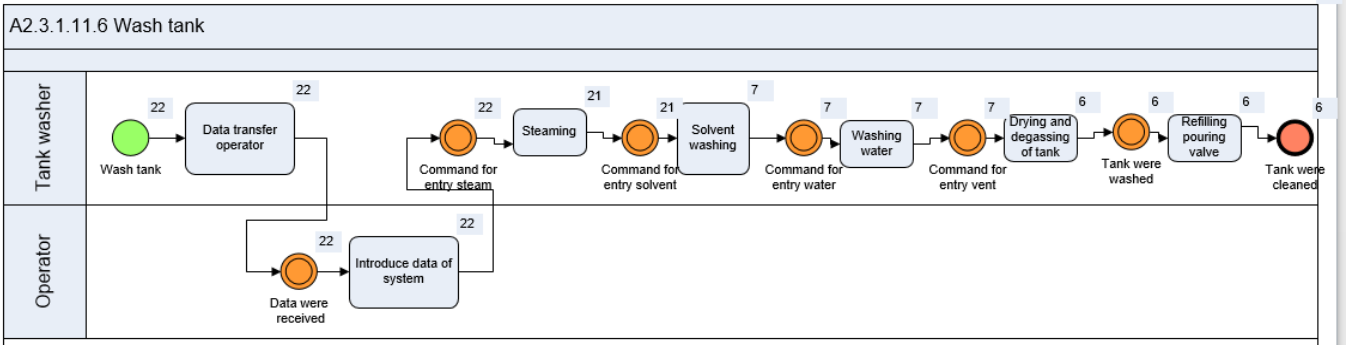

Figure 2: Simulation Of The Process Cleaning Of The Tank In Winter

during the "Solvent washing" process, which was launched 18 times, of which in 8 cases the process was completed, and in 10 cases railway tank wait for their turn.

Process	Launched	Completed	in process	Awaits implementations	Awaits in a queue	Expected the material	The average number of starts per day	The average number of completion per day
A2.3.1.11.6 Wash tank	22	6	16	-	-	-	22	6
A2.3.1.11.6.1 Data transfer operator	22	22	0	0	0	0	22	22
A2.3.1.11.6.2 Intoduce data of system	22	22	0	0	0	0	22	22
A2.3.1.11.6.3 Steaming	22	21	1	0	0	0	22	21
A2.3.1.11.6.4 Solvent washing	21	7	0	0	14	0	21	7
A2.3.1.11.6.5 Washing water	7	7	0	0	0	0	7	7
A2.3.1.11.6.6 Drying and degassing of tank	7	6	1	0	0	0	7	6
A2.3.1.11.6.7 Refilling pouring valve	9	6	1	0	0	0	6	6
TOTAL	107	91	2	0	14	0		

Table 2 shows how much steam was used during the "Washing water" process. In total, this process was started 6 times. In the column "Operand" we see the steam flow for each running process. In the column "Output Value" is reflected how much steam was used.

Table 2: Calculation Of Steam Consumption In Winter

Process	Date and time	Operation	Input valve	Operator	Operand	Output valve
A2.3.1.11.6 Wash tank inst.№1	03.12.2019 04:40:00	A2.3.1.11.6.5 Washing water	0	+	859,4854	859,4854
A2.3.1.11.6 Wash tank inst.№2	03.12.2019 07:40:00	A2.3.1.11.6.5 Washing water	859,4854	+	836,8943	1696,3798
A2.3.1.11.6 Wash tank inst.№3	03.12.2019 09:50:00	A2.3.1.11.6.5 Washing water	1696,3798	+	820,7522	2417,132
A2.3.1.11.6 Wash tank inst.№4	03.12.2019 12:40:00	A2.3.1.11.6.5 Washing water	2517,132	+	823,4373	3340,5693
A2.3.1.11.6 Wash tank inst.№5	03.12.2019 15:40:00	A2.3.1.11.6.5 Washing water	3340,5693	+	832,5056	4173,0749
A2.3.1.11.6 Wash tank inst.№6	03.12.2019 18:10:00	A2.3.1.11.6.5 Washing water	4173,0749	+	810,3542	4983,4291

With the new loading system, petroleum products come to the end user in a hot state and practically does not need heating during draining. Therefore, the cleaning process will be similar to the summer time of the year. Let us carry out simulation at work of one drain device and average temperature of air 18℃. The result of the simulation is visible in Fig.3.

The wash-and-row station received a composition consisting of 20 tank wagons. Of these, when one is working with one drain device, completely cleaned 16.

The Table 3 show the average number of launches per day and the material consumption.

The process "Washing water", for example, was launched 17 times, of which 16 are completed, and 1 are waiting in the queue.

It is clear from Table 4 that during the cleaning of 16 tank wagons in summer less steam was spent than the winter period for cleaning 6 railway tanks.

The final Table 5 shows the amount of steam used to clean the tank during summer and winter periods, depending on the climate zone, calculated using the Business Studio platform.

Three climatic zones are allocated for clarity of calculation.

1. The 1st climatic zone, to which the south the country belongs with a duration of winter period up to 3 months and an average temperature of -9,5℃ and a summer period with an average temperature of + 30℃.

2. The 2nd climatic zone, to which the Primorsky region belongs, the central, western and northwestern parts of the battle with a duration of the winter period up to 5 months and an average winter temperature of -10℃ and summer temperature of +25℃

Figure 3: Calculate The Number Of Process Cleaning Of The Tank In Summer

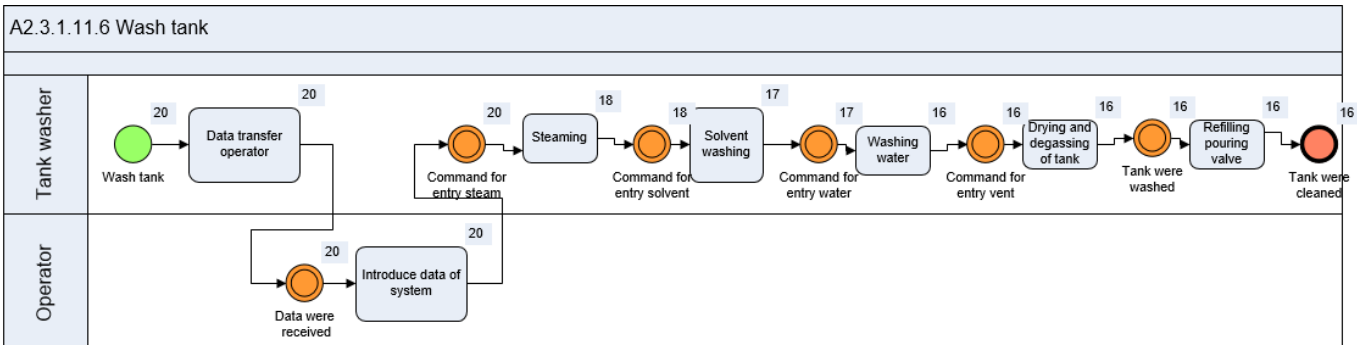

Table 3: Calculate The Number Of Processes Running In Summer

Process	Launched	Completed	in process	Awaits implementations	Awaits in a queue	Expected the material	The average number of starts per day	The average number of completion per
A2.3.1.11.6 Wash tank	20	16	4	-	-	-	20	16
A2.3.1.11.6.1 Data transfer operator	20	20	0	0	0	0	20	20
A2.3.1.11.6.2 Intoduce data of system	20	20	0	0	0	0	20	20
A2.3.1.11.6.3 Steaming	20	18	2	0	0	0	20	18
A2.3.1.11.6.4 Solvent washing	18	17	0	0	1	0	18	17
A2.3.1.11.6.5 Washing water	17	16	1	0	0	0	17	16
A2.3.1.11.6.6 Drying and degassing of tank	16	16	0	0	0	0	16	16
A2.3.1.11.6.7 Refilling pouring valve	16	16	0	0	0	0	16	16
TOTAL	127	123	3	0	1	0		

Table 4: Calculation Of Steam Consumption In Summer

Process	Date and time	Operation	Input valve	Operator	Operand	Output valve
A2.3.1.11.6 Wash tank inst.№02	03.12.2019 05:10:00	A2.3.1.11.6.5 Washing water	401,768	+	418,703	817,471
A2.3.1.11.6 Wash tank inst.№03	03.12.2019 06:20:00	A2.3.1.11.6.5 Washing water	817,471	+	429,2333	1246,7043
A2.3.1.11.6 Wash tank inst.№04	03.12.2019 07:40:00	A2.3.1.11.6.5 Washing water	1246,7043	+	392,7268	1639,4311
A2.3.1.11.6 Wash tank inst.№05	03.12.2019 11:50:00	A2.3.1.11.6.5 Washing water	1639,4311	+	413,4642	2082,8953
A2.3.1.11.6 Wash tank inst.№06	03.12.2019 12:40:00	A2.3.1.11.6.5 Washing water	2052,8953	+	412,3968	2465,2922
A2.3.1.11.6 Wash tank inst.№07	03.12.2019 13:40:00	A2.3.1.11.6.5 Washing water	2465,2922	+	403,5332	2868,8254
A2.3.1.11.6 Wash tank inst.№08	03.12.2019 14:50:00	A2.3.1.11.6.5 Washing water	2868,8254	+	401,3142	3270,1396
A2.3.1.11.6 Wash tank inst.№09	03.12.2019 16:00:00	A2.3.1.11.6.5 Washing water	3270,1396	+	410,0197	3680,1594
A2.3.1.11.6 Wash tank inst.№10	03.12.2019 16:30:00	A2.3.1.11.6.5 Washing water	3680,1594	+	405,8139	4085,9732
A2.3.1.11.6 Wash tank inst.№11	03.12.2019 17:30:00	A2.3.1.11.6.5 Washing water	4085,9732	+	421,1948	4507,168
A2.3.1.11.6 Wash tank inst.№12	03.12.2019 18:50:00	A2.3.1.11.6.5 Washing water	4507,168	+	410,0919	4917,26
A2.3.1.11.6 Wash tank inst.№13	03.12.2019 19:50:00	A2.3.1.11.6.5 Washing water	4917,26	+	403,3065	5320,5664
A2.3.1.11.6 Wash tank inst.№14	03.12.2019 21:00:00	A2.3.1.11.6.5 Washing water	5320,5664	+	393,7696	5714,3361
A2.3.1.11.6 Wash tank inst.№15	03.12.2019 22:00:00	A2.3.1.11.6.5 Washing water	5714,3361	+	414,0233	6128,3593
A2.3.1.11.6 Wash tank inst.№16	03.12.2019 23:00:00	A2.3.1.11.6.5 Washing water	6128,3593	+	400,7783	6529,1377

3. The 3rd climatic zone, which includes the regions of Siberia and the far East, with a winter period of up to 8 months and an average temperature of -22℃ in winter, and in summer +18℃.

Table 5: The amount of steam used to clean the tank in different climatic zones

		1st climate zone	2nd climate zone	3rd climate zone
Summer season	Number of railway tanks, pcs	17	17	18
	Consumption of steam is only, kg	5375,68	6041,54	7061,10
	Consumption of steam on average for one railway tank, kg	316	355	392,28
Winter season	Number of railway tanks, pcs	5	5	5
	Consumption of steam is only, kg	5603	5798,35	6647,98
	Consumption of steam on average for one railway tank, kg	1120,6	1159,67	1329,6

The data obtained using the simulation model correspond to the data obtained from the calculation [Tkt16].
The Figure 4 shows the change in the vapor mass (G) from the ambient temperature (t) at the thickness of the oil deposits on the walls of the tank 0,02m.

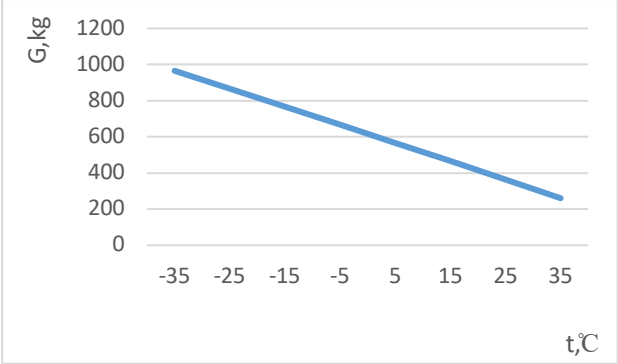

Figure 4: Changes In Steam Mass From Ambient Temperature

4 Conclusion

A new way of transportation of viscous petroleum products is proposed. A simulation model for the transportation of petroleum products was constructed, allowing to estimate the amount of resources necessary for heating the oil product before unloading and during the cleaning of the railway tank.

Advantages of the built model:

1. For the first time a new method for modeling physical processes was used.
2. To build the simulation model, a new tool was used, which was previously used exclusively for modeling economic business processes.
3. The domestic Business Studio platform was used as a tool environment.
4. The data obtained from simulation are consistent with the data obtained from the calculation.
5. In the future, for more complete calculations, it is planned to integrate a process that takes into account external factors into the existing model.

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