

Research Article

Assessment of the Possibility of Using Industrial Hyperbranched Polymers as Reagents for Increasing the Capacity of Pipelines When Pumping Non-conventional Hydrocarbon

Liya Baybekova^{1,2,3} , Evgenii Kharitonov^{1,2,3,*} , Andrey Sharifullin¹ ,
Irie Battoy Tety^{1,2} 

¹Department of Chemical Technology of Oil and Gas Processing, Kazan National Research Technological University, Kazan, Russia

²Higher School of Petroleum, Almet'yevsk State Technological University, Almet'yevsk, Russia

³Department of Oil, Gas and Carbon Materials Technology, Kazan Federal University, Kazan, Russia

Abstract

Pipeline transportation of oil media is one of the most energy-intensive operations in the process of hydrocarbon development, and technological operations aimed at resource and energy saving in pipeline pumping processes have a significant impact on the technical and economic indicators of projects. The article presents the results of a laboratory evaluation of Boltorn industrial hyperbranched polymers for the possibility of increasing the throughput of an oil system of unconventional reserves and reducing the hydraulic resistance of the pipeline system during its pumping. As part of the research, 4 reagents were studied - Boltorn H311, Boltorn W3000, Boltorn P500, Boltorn H2004. Industrial additives differ in their chemical structure and molecular weight. The compositions of Boltorn industrial hyperbranched polymers were preliminarily studied on a model medium - diesel fuel for primary selection. Preliminary studies made it possible to select two reagents for further research - Boltorn H311 and Boltorn W3000, which were studied on a mixture of crude oil emulsion with diesel fuel with a final kinematic viscosity of 47mm²/s at a temperature of 25 °C. The maximum efficiency of Boltorn W3000 on an oil emulsion was 13.6% at a concentration of 200 ppm, for the Boltorn H311 composition on an oil emulsion - 12.7% at a concentration of 150 ppm. An additional measure of the effectiveness of throughput-increasing reagents is the assessment of the reagent's resistance to mechanical destruction. For example, for the Boltorn W3000 additive at a concentration of 200 ppm, the effectiveness of reducing hydraulic resistance was more than 800 circulation cycles, which confirms its long-term effectiveness with sequential pipeline pumping.

Keywords

Oil, Testing, Pipeline, Hydraulic Resistance, Hyperbranched Polymer, Hard-to-recover Reserves

*Corresponding author: kharitonov.eve@list.ru (Evgenii Kharitonov)

Received: 19 February 2025; **Accepted:** 17 March 2025; **Published:** 3 September 2025



Copyright: © The Author(s), 2025. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

1. Introduction

Efficient transportation of hydrocarbons through pipelines remains a critical challenge, particularly as the industry increasingly taps into unconventional reserves. The use of drag-reducing agents (DRAs) has emerged as a promising solution to improve pipeline throughput by minimizing hydraulic resistance. Among the various DRAs, hyperbranched polymers (HBPs) have shown considerable potential due to their unique molecular architecture and ability to significantly enhance flow properties.

The need for effective DRAs is underscored by the energy-intensive nature of pipeline transportation, which significantly impacts the technical and economic parameters of hydrocarbon projects. Traditional methods often fall short in addressing the complexities associated with transporting unconventional hydrocarbons, which typically exhibit higher viscosities and more complex flow behaviors than conventional crude oils [1-5].

Recent studies have highlighted the efficacy of polymer-based additives in reducing Drag reduction and improving the flow of hydrocarbons. For instance, Wang et al. demonstrated the Drag reduction characteristics of novel polymer-based additives, showing their potential to enhance oil pipeline transportation efficiency. Similarly, Salikh et al [6, 15]. (2020) investigated the effects of polymeric additives on the rheological properties of heavy crude oils, further corroborating the benefits of such additives in pipeline systems.

The application of HBPs, specifically, has garnered attention due to their mechanical stability and high performance over extended periods. Dusmetova et al. explored the use of HBPs for reducing hydraulic resistance in pipeline systems, noting significant improvements in throughput [1-3, 7, 16]. This aligns with the findings of Rabotinskaya, who detailed

the specific benefits of additives in transporting oil emulsions through pipelines [4, 17].

The comprehensive examination of additives and their impact on hydrocarbon transport can be found in several key texts. Kutyrev et al. provide an in-depth analysis of pipeline transportation techniques and the role of additives, offering valuable insights into optimizing pipeline operations [8]. Furthermore, Briscoe and Galvin discuss the broader context of chemical engineering in oil and gas processing, which includes the application of DRAs.

This study aims to evaluate the potential of industrial HBPs, specifically Boltorn H311 and Boltorn W3000, to enhance pipeline throughput by reducing hydraulic resistance. By conducting laboratory tests on these polymers with model mediums and actual hydrocarbon mixtures, we seek to determine their effectiveness and optimal concentrations for practical application in the industry.

In conclusion, the integration of advanced polymer-based additives like HBPs into pipeline systems represents a significant advancement in the transportation of unconventional hydrocarbons. This research contributes to the growing body of knowledge aimed at improving the efficiency and sustainability of hydrocarbon transport, ultimately supporting the broader energy industry's efforts to meet global demand.

2. Materials and Methods

As part of the research, laboratory tests of industrially produced hyperbranched Boltorn polymers were carried out to determine the possibility of increasing the throughput of hydrocarbon systems.

Table 1. The characteristics of Boltorn brand reagents.

Characteristics	Brands of Boltorn GRP			
	H311	W3000	P500	H2004
Viscosity, Pa (°C)	40 (23)	1(23)	12-15 (23)	14-20 (25)
Theoretical molecular weight, g/mol	5700	9000	1800	3200
Water content	10%	-	<0.5%	<2%
Solubility	Polyether, polyether polyols	Emulsifiers, soluble in alkyds, in cosolvents, xylene	Toluene, polyether polyols	in Most polar solvents
Appearance	Yellow liquid	Yellow wax	Transparent liquid	Yellow liquid
Functionality	-	-	Mixed hydroxyl	Hydroxyl and fatty acids
Hydroxyl number, mg KOH/g	230 - 260	-	560 - 630	105-125

Characteristics	Brands of Boltorn GRP			
	H311	W3000	P500	H2004
Acid number, mg KOH/g	--	10	-	7

The characteristics of Boltorn brand reagents are given in Table 1.

Assessment for increasing the throughput of reagents on a laboratory bench [9-15], in which liquids are pumped through a circulation cycle, which is a pipeline system with a pump and a source tank. The final efficiency of the reagent is assessed by reducing the pressure drop and changing the flow rate [12-15].

Due to the high initial value of the kinematic viscosity of the oil of Kondurchaneft JSC, it turned out to be impossible to develop a turbulent flow regime on a laboratory bench; therefore, to evaluate the effectiveness of hyperbranched polymers, a mixture of "oil - diesel fuel" with a ratio of 1:7 was taken. The final kinematic viscosity was $V = 47 \text{ mm}^2/\text{s}$.

The results of the physical and chemical analysis of crude oil of Kondurchaneft JSC are shown in Table 2.

Table 2. Physics-chemical properties of oil.

Options	Indicators		
Structural and group composition	Paraffins, %	Resins, %	Asphaltenes, %
	34.74	8.53	17.26
Water content, %	42		
Density at 20°C, kg/m ³	967		
Kinematic viscosity at 25°C, mm ² /s	1120		

The primary assessment of the effectiveness of the reagents consisted of sequentially running the reagents in a model installation at one concentration - 200 ppm in a model liquid - hydrotreated diesel fuel with a kinematic viscosity $V = 4 \text{ mm}^2/\text{s}$ at 25°C.

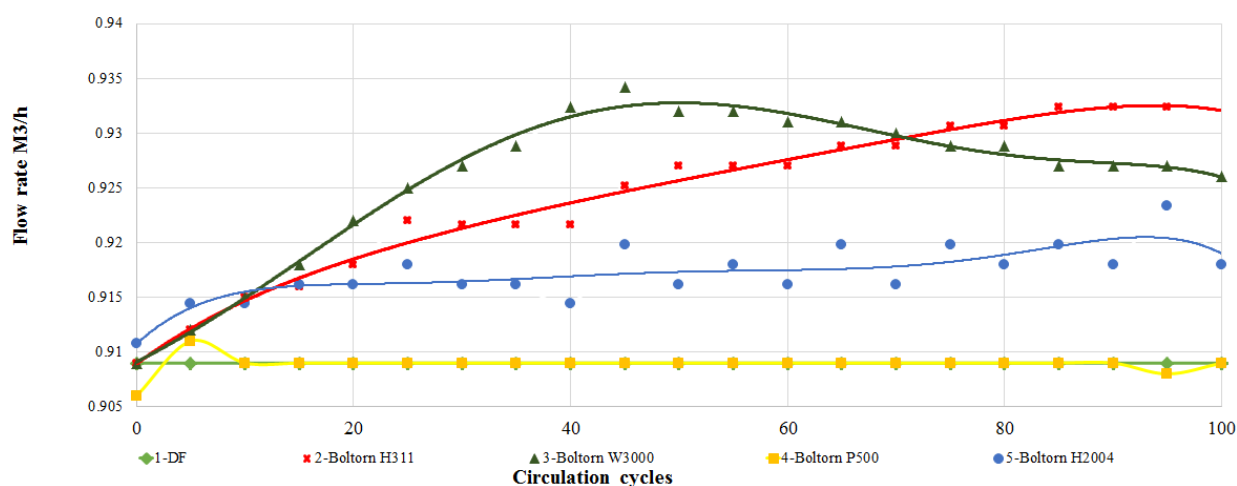


Figure 1. Dependence of diesel fuel consumption on the addition of Boltorn additives with a concentration of 200 g/t: 1 - diesel fuel (DF); 2 - DF + Boltorn H311 (200 ppm); 3 - DF + Boltorn W3000 (200 ppm); 4 - DF + Boltorn P500 (200 ppm); 5 - DF + Boltorn H2004 (200 ppm).

The results of hydraulic studies of Boltorn hyperbranched polymers on a model fluid are presented in Figure 1.

According to the results of preliminary tests, the most effective reagents were Boltorn H311 and Boltorn W3000. For a more in-depth analysis and determination of the working concentration of the Boltorn H311 and Boltorn W3000 reagents,

solutions with concentrations of 10, 30, 50, 60, 80, 100, 120, 150, 170, 200, 220, 250 ppm were prepared and each of them was tested for oil emulsion system.

The results of the analysis of the hydrodynamic efficiency of the Boltorn H311 and Boltorn W3000 reagents on oil at various additive concentrations are presented in Figure 2.

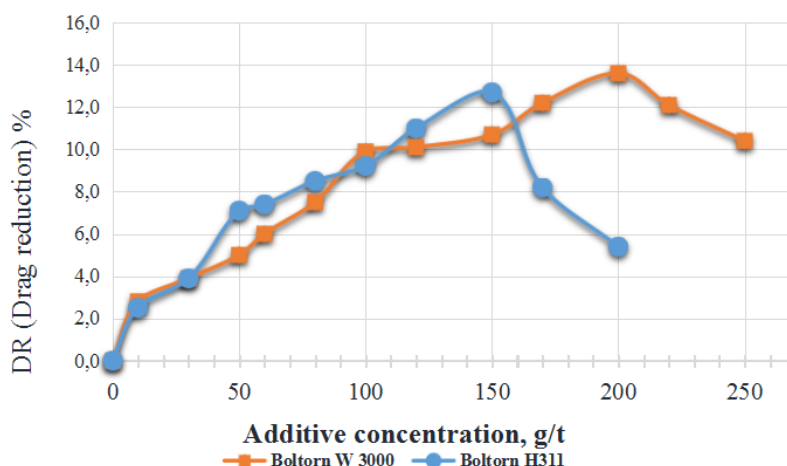


Figure 2. Dependence of the indicator of reduction in hydraulic resistance in oil on the addition of Boltorn additives with different concentrations: 1 - oil + Boltorn W3000; 2 - oil + Boltorn H311.

The maximum efficiency of Boltorn W3000 was 13.6% at a concentration of 200 ppm, for the Boltorn H311 composition - 12.7% at a concentration of 150 ppm. The effectiveness of both reagents turned out to be close and differ by no more than 15%, which confirms their possibility of use as agents for increasing the throughput of pipeline systems of hard-to-recover reserves - TRIZ, incl. and emulsion media with high water content.

An additional important characteristic of the use of reagents as agents for increasing the throughput of pipelines is resistance to destruction during transportation and maintaining maximum efficiency.

Technically, this indicator on a laboratory bench is determined by pumping time - circulation cycles, at which the level of maximum efficiency is maintained.

For the Boltorn W3000 reagent at a concentration of 200 ppm, cyclic pumping of paraffin oil was carried out, the results of which are shown in Figure 3.

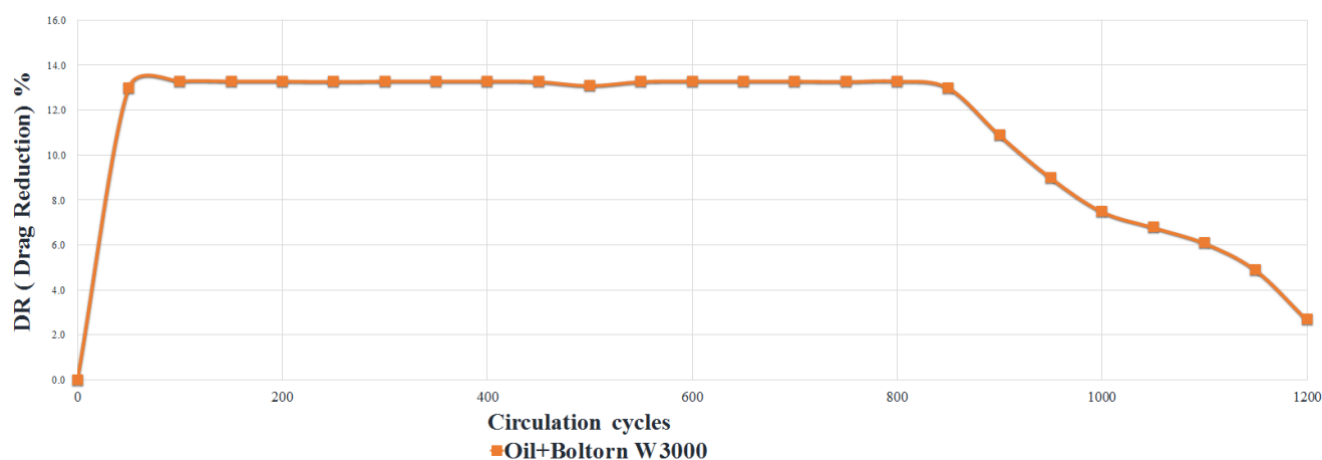


Figure 3. Dependence of the reduction in hydraulic resistance on oil with Boltorn W3000 additive (200 ppm) on circulation cycles.

Based on the results of testing the Boltorn W3000 reagent

at a concentration of 200 ppm, it was determined that the

compound is capable of maintaining stable efficiency in laboratory conditions for up to 800-900 circulation cycles when exposed to a gear pump, which confirms the high resistance to mechanical destruction of the reagent.

3. Conclusions

Four grades of commercially available hyperbranched Boltorn polymers were tested to see if they could improve the throughput of unconventional reserves - oil emulsions with high viscosity and water content. The study established that the effectiveness of the reagents is directly proportional to the molecular weight of the polymers and with an increase in the molecular weight of hydraulic fracturing in the active phase, their effectiveness increases.

It turned out to be most effective in increasing the throughput of the oil system Boltorn W3000 was 13.6% at a concentration of 200 ppm. The assessment of resistance to mechanical destruction during sequential pumping and repeated circulation through the pump was more than 800 units, which confirms the high stability when pumping over long distances in the case of industrial use of the reagent and the elimination of additional dosing when passing through pumping stations.

Abbreviations

DRAs Drag-reducing Agents
HBPs Hyperbranched Polymers

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] E. V. Kharitonov, A. V. Sharifullin, L. R. Baibekova, A. F. Maksimov, M. V. Godyashcheva, Bulletin of the Technological University, 25, 10, 27-30 (2022). https://doi.org/10.55421/1998-7072_2022_25_10_27
- [2] E. V. Kharitonov, L. R. Baybekova, A. V. Sharifullin, M. V. Godyashcheva, Bulletin of the Technological University, 25, 10, 36-39 (2022). https://doi.org/10.55421/1998-7072_2022_25_10_36
- [3] G. I. Dusmetova, A. V. Sharifullin, L. R. Baybekova, E. V. Kharitonov, G. F. Sagitova, Specifics of the use of additives in pipeline transport of oil emulsions, South Kazakh University named after. M. Auezova, Shymkent, 2023. 172 p.
- [4] T. I. Rabotinskaya XV International Scientific Conference "Severgeocotekh-2014" (Ukhta, Russia, March 26-28, 2014). Ukhta, 2014. pp. 83-87.
- [5] Y. Wang, 42. Y. Chen, J. He, P. Li, C. Yang, Energy and Fuels, 24, 3, 1502-1510 (2010). <https://pubs.acs.org/doi/10.1021/ef901339k>
- [6] I. Sh. S. Salikh, A. K. Ishimbaev, I. I. Mukhamatdinov, A. V. Vakhin, Exposition Oil Gas, 2, 21-24 (2020). <https://runeft.ru/upload/iblock/75d/0q14g4r1m6sxgkdowsc42dtyipfqf3hz.pdf>
- [7] E. V. Kharitonov, L. R. Baybekova, A. V. Sharifullin, Business Journal Neftegaz. ru, 105, 12, 97-99 (2020). <https://magazine.neftgaz.ru/articles/transportirovka/652335-adsorbtsionnye-protssessy-i-snizhenie-gidravlicheskogo-soprotivleniya/>
- [8] G. A. Kutyrev, A. F. Maksimov, A. A. Busygina, I. I. Idiyatov, L. R. Valiullin, S. R. Galliamova, V. V. Biryulya, A. R. Gataulina, M. P. Kutyreva, Bulletin of Technological University, 22, 20, 5-12 (2017).
- [9] E. V. Kharitonov, G. O. Burova Pipeline transport of hydrocarbons: materials of the IV All-Russian. scientific-practical conf. (Omsk, October 30, 2020). Publishing house Omsk State Technical University, 2019. pp. 20-25. https://elibrary.ru/download/elibrary_49882331_89816720.pdf
- [10] E. V. Kharitonov, L. R. Baybekova, A. V. Sharifullin. Oilfield chemistry: materials VII Int. scientific-practical Conf., XV All-Russian. scientific-practical conf. (Moscow, November 19, 2020). Publishing house of the Russian State University of Oil and Gas, Moscow, 2020. pp. 73-75. https://elibrary.ru/download/elibrary_48608247_54913155.pdf
- [11] E. V. Kharitonov, L. R. Baybekova, A. V. Sharifullin G. I. Dusmetova. Pipeline transport of hydrocarbons: materials IV All-Russian. scientific-practical conf. (Omsk, October 30, 2020). Publishing house of Omsk State Technical University. Omsk, 2020. pp. 31-35.
- [12] G. I. Dusmetova, A. V. Sharifullin, V. N. Sharifullin, E. V. Kharitonov, Oil Industry, 4, 117-120 (2017). <https://doi.org/10.24887/0028-2448-2017-4-117-120>
- [13] G. I. Dusmetova, G. O. Burova, E. V. Kharitonov, L. R. Baybekova, A. V. Sharifullin, N. V. Lyzhina, Oil Province 1, 17, 227-237 (2019). <https://doi.org/10.25689/NP.2019.1.227-237>
- [14] Computer program of the Russian Federation 2018663928 (2018).
- [15] Wang, Y., Chen, Y., He, J., Li, P., & Yang, C. (2010). Drag reduction Characteristics of a Novel Polymer-Based Additive for Oil Pipeline Transportation. Energy & Fuels, 24(3), 1502-1510. <https://doi.org/10.1021/ef901238w>
- [16] Salikh, I. Sh., Ishimbaev, A. K., Mukhamatdinov, I. I., & Vakhin, A. V. (2020). Effect of Polymeric Additives on the Rheological Properties and Drag reduction of Heavy Crude Oils. Exposition Oil & Gas, 2, 21-24.
- [17] Rabotinskaya, T. I. (2014). Specifics of the Use of Additives in Pipeline Transport of Oil Emulsions. In Proceedings of the XV International Scientific Conference 'Severgeocotekh-2014' (pp. 83-87). Ukhta, Russia.

Biography

Liya Baybekova - PhD, assistant professor of CTPGP (Chemical Technology of Petroleum and Gas Processing), KNRTU, head of the laboratory of RPPTH CSTR HE ASPI (research on the problems of pipeline transport of hydrocarbons at the Center for Scientific and Technical Research, Almet'yevsk State Petroleum Institute).

Evgenii Kharitonov - PhD student in the Department of Chemical Engineering of Petroleum and Gas Processing, KNRTU (Russia), Engineer at the laboratory of RPPTH CSTR HE ASPI (research on the problems of pipeline transport of hydrocarbons at the Center for Scientific and Technical Research, Almet'yevsk State Petroleum Institute).

Andrey Sharifullin - Professor of the Department of Oil and Gas Processing (Chemical Technology of Oil and Gas Refining), KNRTU (Russia).

Irie Battoy Tety - Petroleum Engineer-Process Engineer, Master's degree Student of Oil and gas business at Almet'yevsk State Petroleum Institute.