Analysis of Application of Pre-screwed Auger Wheels for Operative Increasing of Throughput Capacity of Oil Pipelines

Vitaliy Surikov, Yuri Lisin and Anvar Valeev

Abstract In the paper, the application of a pre-screwed wheel of centrifugal main oil pumps is observed. The pre-screwed wheel serves as a backup pump for the main impeller and creates a small head. In this case, the cavitations reserve of the main unit is significantly reduced. The increase of throughput capacity is due to two factors: a slight increase in pressure after the station, as well as a significant reduction in the pressure before the pumping station. The application of a pre-screwed wheel is proposed for the operative increase of a throughput capacity at a small value. Economical comparison of the following methods of increase of throughput capacity is made:

(1) use of a frequency-controlled drive
(2) use of anti-turbulent additives
(3) reduction of the settings at the entrance of stations with the help of pre-screwed wheels
(4) selective repair of sections
(5) restoring the pipeline capacity on the basis of determining the actual remaining life of pipelines without selective repair of sections. It is considered that the application of a pre-screwed wheel is characterized by low economic costs and small time of implementation and this method is perspective in oil industry.

Keywords Pre-screwed wheel · Throughput capacity · Oil pump
Oil pipeline

V. Surikov · Y. Lisin
The Pipeline Transport Institute LLC, 47a, Sevastopolskiy Prospect, Moscow 117186, Russia

A. Valeev (✉)
Ufa State Petroleum Technological University, 1, Kosmonavtov Street, Ufa 450062, Russia
e-mail: anvarvaleev@rusoil.net

A. A. Radionov et al. (eds.), *Proceedings of the 4th International Conference on Industrial Engineering*, Lecture Notes in Mechanical Engineering,
https://doi.org/10.1007/978-3-319-95630-5_53

1 Introduction

Oil production in Russia by 2016 reached record values for the post-Soviet period. So, in 2015, 534 million ton was produced, and in 2016—548.6 million ton, which is 2.9% more than in the previous year. Often, the oil and gas industry faces the task of short-term or insignificant increase in the volumes of oil pumping in certain directions, the capacity of which can be limited not only by the presence of limiting defective areas, but also by the long period of operation of pipelines (over 15 years). Sometimes increasing the quantity of pump is impossible due to pressure limit of pipeline. So, it is important to research and use methods of increasing of throughput capacity for oil pipelines. Application of pre-screwed auger wheels is very perspective. This method is applicable due to necessity of cavitations reserve for centrifugal pumps. Cavitations reserve for main pumping units equals usually 10–16 m.

A more efficient way of reducing of cavitations reserve for main pumping units is to install a prefabricated screw auger wheel at the fluid inlet to the pump impeller, which is an axial wheel (Fig. 1). Unlike a centrifugal impeller consisting of a larger number of short blades, the auger has several long blades, when passing between them, the vapor phase manages to condense and there remains a sufficient part of the blade surface to supply the liquid with the required head. Therefore, the prefabricated screw is able to pass large volumes of liquid vapors without significantly reducing the total head. The prefabricated auger increases the pressure at the entrance to the impeller and thus ensures its non-cavitations work. In order to improve the working conditions of the screw itself, the thickness of the blade at the liquid inlet into the screw is reduced, and its outer diameter is also increased. This paper is devoted to the analysis of the application of pre-screwed auger wheels in centrifugal pumps in oil pipelines in Russian Federation.

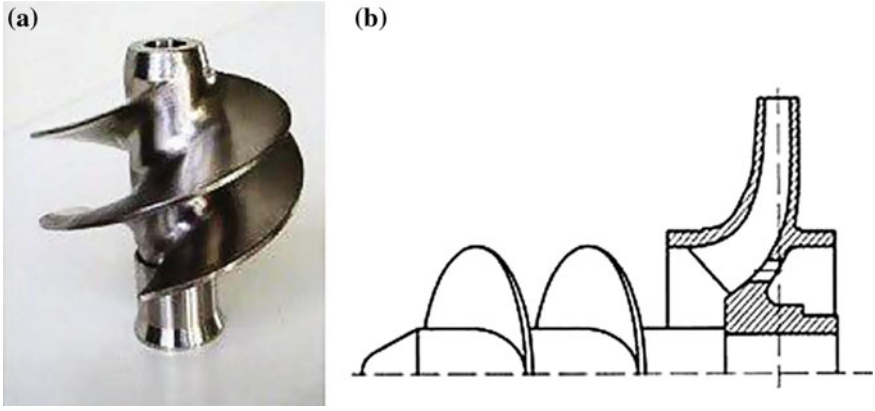

Fig. 1 **a** General view of a pre-screwed auger wheel; **b** Scheme of a pre-screwed auger wheel

2 Installing Pre-screwed Auger Wheels

So, throughput capacity can be changed with a help of pre-screw auger wheels. According to this method, additional impellers of the screw type are added to the traditional impeller. The auger serves as a backup pump for the main impeller and creates a small head. In this case, the cavitations reserve of the main unit is significantly reduced. Thus, the increase in capacity is due to two factors: a slight increase in pressure after the station, as well as a significant reduction in the pressure before the station.

In the paper [1], it is shown that it is possible to increase the productivity of the pipeline by 1.2% by reduction of cavitations reserve of main pumps by 10 m. The screw wheel can be installed on existing main pumps by modernizing the pump casing. However, it is more expedient to replace the pump unit with a similar type with the provided screw wheel during the planned replacement of the equipment.

Figures 2 and 3 illustrate how the pressure varies along the length of the pipeline by reducing the head at the next station. Figure 2 shows the change in the head when the pre-screw auger wheel is installed only at the next station, and Fig. 3—when the pre-screw auger wheel is installed at the previous and following stations.

In Figs. 2 and 3: Q—throughput capacity, i—hydraulic bias, H^{in}—hydraulic head at the entrance of the following station, H^{out}—hydraulic head at the exit of the previous station, index 1 shows the parameters before installation of pre-screw auger wheels, index 2 shows the parameters after installation of pre-screw auger wheels.

In PJSC "Transneft" approbation of pre-screwed auger wheels at oil pumping stations was made. It is established that the installation of pre-screw auger wheels

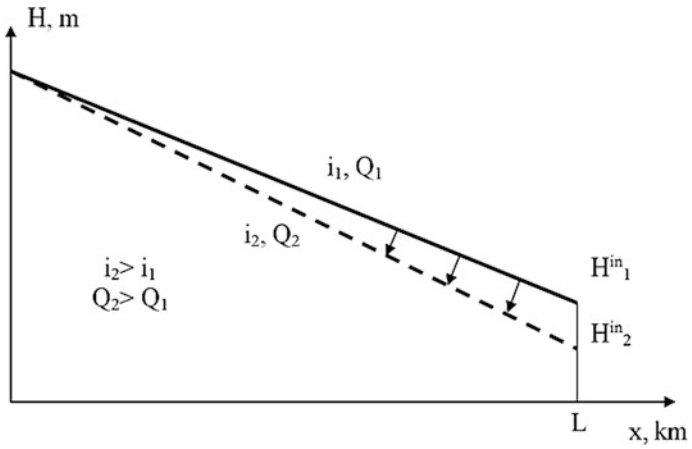

Fig. 2 Increase of throughput capacity when pre-screw auger wheel is installed only at the next station

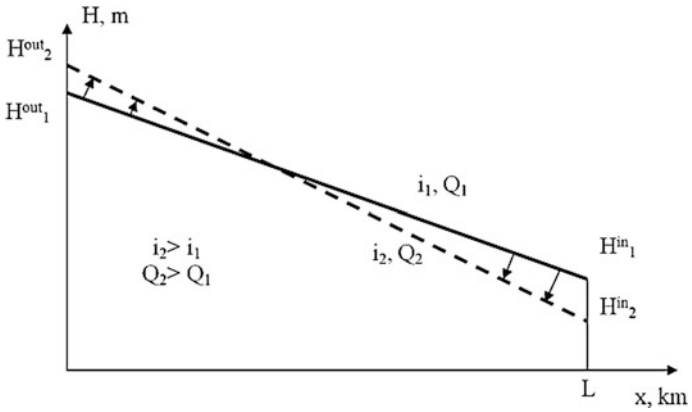

Fig. 3 Increase of throughput capacity when pre-screw auger wheel is installed only at the previous and following stations

Table 1 Upgraded pumps with pre-screw auger wheels installation

Pump	Year of manufacture	Cavitations reserve (m)	Throughput capacity (million ton/year)
18-DVS (before modernization)	1964	4.5	33.6
NGPNA 3600-120 (after modernization)	2012	2.5	36.9

makes it possible to reduce the cavitations reserve in various cases by 1, …, 16 m, depending on the pump type.

Considering that the modernization of an existing pump by installing a pre-screw auger impeller can cause complexity, a complete pump replacement can be a more rational and efficient solution. In addition, a significant part of the pump park in Russia is of a greater age, so the installation of new pumps with higher parameters is more promising. At the oil pumping station in PJSC "Transneft" modernization was made, during which the old pump was replaced with a new one with an additional pre-screw auger impeller. This made it possible to significantly increase the capacity of the pipeline (Table 1). The installation of the auger and the reduction of the cavitations reserve by 2 m made it possible to further increase the pipeline's throughput by 9.8% [2, 3].

The given data confirms the prospects and efficiency of using pre-screwed auger wheels to increase the pipeline capacity.

3 Economical Comparison of Installing Pre-screwed Auger Wheels and Other Ways of Increasing if Oil Pipeline Throughput Capacity

Economical analysis of the following methods of operative increase of throughput is made in this section. The methods of operative increase of the pipeline capacity are considered: the use of a frequency-controlled drive, the use of anti-turbulent additives, the reduction of the settings at the entrance of stations with the help of pre-screwed wheels, selective repair of sections, and the work on restoring the pipeline capacity on the basis of determining the actual remaining life of pipelines without selective repair of sections.

The following initial data is taken for assessment: pipeline 530 × 10 mm; the density of oil—900 kg/m^3; length of the pipeline—150 km; installed pumps HM1250-260; To increase the design pressure by 1%, it is necessary to replace 0.35 km of the pipeline; the estimated period is 10 years; The capacity to implement the methods is 1250 m^3/h.

The following cost parameters are taken: the replacement of 1 km of the pipeline with 50 million rubles; 1 ton of anti-turbulent additives—52.6 thousands of $; the cost of installation of the frequency-controlled drive—175 thousands of $; installation of pre-screwed auger wheels—87.7 thousands of $; carrying out works to restore the capacity of the pipeline on the basis of determining the actual remaining life of pipelines—175 thousands of $; the tariff for pumping oil is 0.281 $ per 100 ton of km; the tariff for electricity is 0.0368 rubles/kWh.

The results of the calculations are given in Table 2.

Analysis of the data in Table 2 shows that selective repair of sections is characterized by much higher costs, which exceed the additional revenue. Also, this method is characterized by the longest implementation time. Therefore, this method will not be considered further. The remaining data are illustrated in Fig. 4.

Application of anti-turbulent additives showed usual results—this method is beneficial in the case of short increase of capacity. But a significant increase in capacity during the duration of time proves to be unprofitable due to the high cost of the anti-turbulent additives.

The use of the frequency-controlled drive and the restoration of the pipeline capacity based on the determination of the actual residual life of the pipelines show positive results in 1–3 years of implementation, since they require low investment costs, and additional operating costs are low or absent.

Reducing the settings showed the best results, but this method has a limited range of implementation (usually no more than 5% increase in throughput).

The positive economic effect of the applied methods is shown in Fig. 5.

Table 2 Economic estimation of methods of operative increase of carrying capacity of the pipeline, thousands of $

Methods of increasing of throughput capacity	Increasing of throughput capacity (%)										
	1	2	4	6	8	10	12	14	16	18	20
Installation of frequency-controlled drive	358	366	382	399	416	435	454	475	496	519	543
Use of anti-turbulent additives	123	288	748	1391	2225	3260	4505	5970	7664	9597	11,777
Restoring pressure without selective repair sections	183	191	206	223	240	257	275	294	314	334	355
Installation of pre-screwed wheels	95	103	119	135	152	169	–	–	–	–	–
Selective repair of sections	5622	11,156	22,224	33,293	44,364	55,435	66,507	77,580	88,654	99,730	110,806
Proceeds	398	796	1592	2387	3183	3979	4775	5571	6366	7162	7958

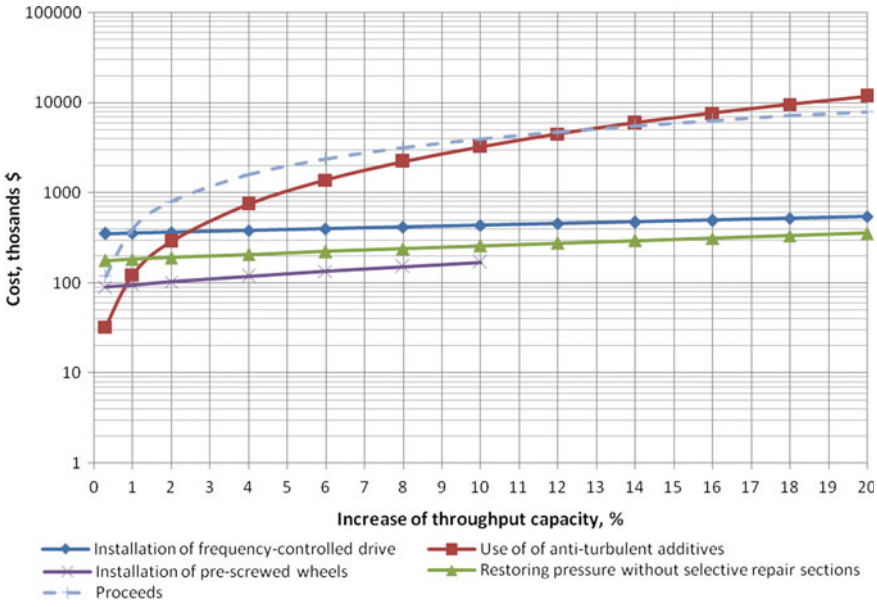

Fig. 4 The cost of implementing operational methods to increase the throughput capacity of the pipeline

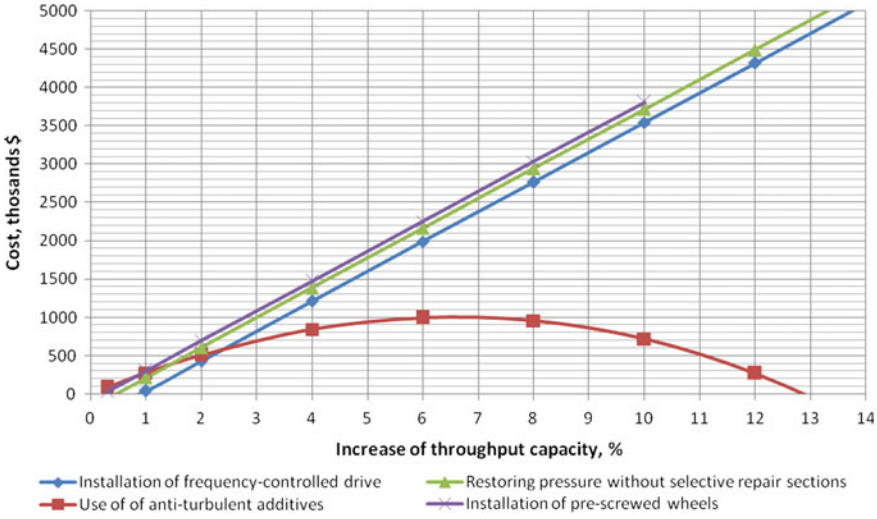

Fig. 5 Positive economic effect from the implementation of operational methods to increase the throughput capacity of the pipeline

4 Conclusion

Economical comparison of the following methods of operative increase of throughput is made in this section. The methods of operative increase of the pipeline capacity are considered: the use of a frequency-controlled drive, the use of anti-turbulent additives.

Thus, it can be concluded that using pre-screwed auger wheels can increase the pipeline's throughput. This method is characterized by low economic costs and small time of implementation. It requires only replacing the impeller, which needs not more than a few days, taking into account delivery, replacement, and transportation.

References

1. Rakhmatullin ShI (1973) Increasing the productivity of the existing main oil pipeline by improving the suction capacity of the centrifugal pump NM 7000-210. Transp Storage oil oil Prod 4:15–19
2. Sherbatenko IV, Ivanova EP, Surikov VI (2006) Choosing the parameters of the pump wheel pump with the maximum cavitation quality. Chem Petrol Eng 3:19–23
3. Sherbatenko IV, Ivanova EP, Surikov VI (2007) Choosing the optimum grating density of the worm blades of the pump. Chem Petrol Eng 6:29–33