TEST RESULTS FOR HYDRAULIC DRIVES OF SUCKER-ROD PUMPING UNITS

Sergey Lavrenko, Ivan Klushnik and Vladimir Iarmolenko
St. Petersburg Mining University St. Petersburg, Russia
E-Mail: lavrenko_sa@pers.spmi.ru

ABSTRACT

The article analyzes the structural characteristics of drives for sucker-rod pumping units (SRPU) used in oil production. It has been proven that it is important to make the use of pumping units for oil production more efficient, i.e. to reduce specific power consumption when extracting formation fluids, to make pumping unit nodes more reliable, to implement intelligent monitoring and control stations for comprehensive assessment of well-SRPU system performance as well as to control drive parameters in a wide range. We hereby present the results of pilot tests of hydraulic SRPU. It is proven that hydraulic SRPU drives are optimal for developing newly commissioned wells, for periodic and short-term operation of wells, as well as removing asphaltene deposits.

Keywords: sucker-rod pumping unit; hydraulic drive; pilot tests; specific power consumption.

1. INTRODUCTION

Oil companies still face the challenge of making oil production equipment more efficient by reducing specific power consumption when extracting the formation fluid, by cutting pumping unit maintenance material costs, by making oil production equipment more reliable and reducing its accident rate.

As of today, more than 60% of wells in Russia and the CIS are operated using sucker-rod pumping units mostly equipped with mechanical drives, i.e. pumpjacks. Pumpjacks (PJ) are conservative equipment sets and their design has not been substantially changed over the last forty years. They have many advantages, including ease of operation and maintenance, longer periods of operation as well as low cost of units as a whole and components thereof [1-4]. However, significant amounts of metal per BPU, use of mobile nodes with significant moments of inertia, use of V-belt transmissions and asynchronous electric drives result in a number of disadvantages that have negative impact on the efficiency of SRPU operation. Conventionally the drawbacks of pump jacks are considered to be as follows:

- massive foundations are necessary but sometimes not an option due to unstable soils (marshy soils, permafrost, etc.);
- support reactions of the foundation to the operation of the drive have horizontal constituents which hamper the drive and necessitate adjusting its position relative to the well axis;
- installation and dismantling of PJ on well sites is costly and time-consuming;
- the variability and cyclic recurrence of external loads lower the power factor of asynchronous drives;
- limited speed range of the beam head forward motion;
- lower performance and lack of precision of control systems due to the asynchronous drive and V-belt transmissions in the kinematic chain of the PJ mechanism [5-7].

To eliminate such drawbacks, engineering service specialists at OOO LUKOIL-PERM have planned and carried out industrial tests of promising hydraulic SRPU drives.

2. THE CONSTRUCTION OF HYDRAULIC SRPU DRIVES

It is known that hydraulic drives help lower the amounts of metal in, and reduce the dimensions of machines and mechanisms as well as to improve the control properties of their control systems. Oilfields of OOO LUKOIL-PERM have been the site for pilot tests of hydraulic SRPU drives: *НПК-10-8-6* by OOO NPK, Perm, and *ГПШСН 80-3, 5 "Geyzer"* by OOO NPP PSM-Impex, Yekaterinburg.

Both drives are modular and consist of a hydraulic cylinder and a power pack; they are equipped with telemetry systems to enable remote monitoring of well and equipment parameters as well as to change the settings of the drive. Hydraulic drive dynagraphs are constructed by converting the hydraulic cylinder pressure into the rod load to eliminate the need for special dynagraphs.

НПК-10-8-6 drives, see Figure-1, are designed to induce reciprocating motion of the deep sucker-rod pumps plungers when pumping fluid from an oil well, with a maximum rod load of 80 kn. A drive is mounted directly on the string flange of the wellhead equipment to eliminate the need for centering and to prevent fluid leakage on the hydraulic cylinder rod. However, such mounting causes significant loads on the wellhead equipment, which limits the application of such drives. Hydraulic drive *НПК-10-9-6* allows changing the rod stroke steplessly from 0.1 to 6 m as well as changing the number of double strokes within a range of 0.1 to 6 min$-^{1}$. The oscillation frequency

VOL. 14, NO. 16, AUGUST2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

is adjusted by turning the power pack pumps on/off as well as by setting a pause at the end of each rod stroke. The power pack and the hydraulic control station are installed on a frame on the ground. Hydraulic drives type *НПК-10-8-6* use pneumatic balancing: when the rod string is lowered, the hydro-pneumatic accumulator is charged; the power thus accumulated is expended to lift the formation fluid [8-9].

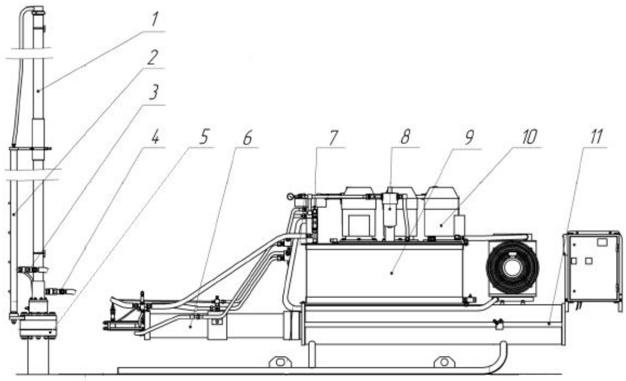

Figure-1. Hydraulic drive of sucker-rod pumping unit НПК-10-8-6:
1 - power hydraulic cylinder; 2 - mast frame; 3, 4 - quick pipeline couplings; 5 - wellhead equipment; 6 - auxiliary hydraulic cylinders; 7 - hydraulic control panel; 8 - filter; 9 - power pack; 10 - drive motors; 11 - power-pack frame.

Hydraulic drive *ГПШСН 80-3, 5 "Geyser",* see Figure-2, is mounted above the wellhead on foundation slabs. Power hydraulic cylinder is mounted on a ball bearing which has no immediate connection to the wellhead equipment. The power pack and the control station are placed in the shelter to make equipment operations safer and less affected by external factors. Placing the equipment in a shelter as well as equipping the power pack with a heating element enables self-launch of the unit after emergency power outages at temperatures below -20 °C.

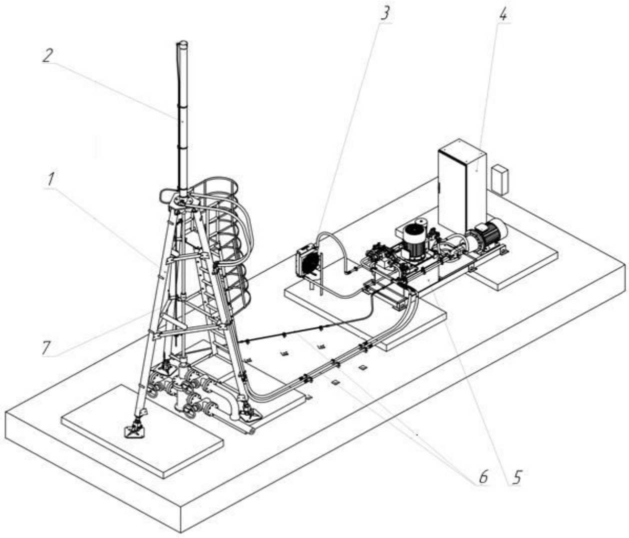

Figure-2. Hydraulic drive of sucker-rod pumping unit ГПШСН 80-3, 5 "Geyser":
1 - supports; 2 - power hydraulic cylinder; 3 - radiator; 4 - control station; 5 - power pack; 6 - high-pressure hoses; 7 - pump suspension node.

The oscillation frequency is adjusted by using a frequency converter within a range of 1 to 6 double-strokes per minute; stroke can be varied from 1 to 3.5 meters. Balancing is done by electrodynamic braking: during the rod downstroke, the drive motor operates in the turbine mode. The intelligent control system of *ГПШСН 80-3, 5 "Geyser"* allows connecting various peripheral devices like sonars for the comprehensive assessment of the ‘drive-well’ system performance [10].

3. COMPARATIVE TESTS OF HYDRAULIC SRPU DRIVES

Comparative tests of SRPU drives were carried out at the wells of the Sosnovskoye oil field of OOO LUKOIL PERM and the Oblivskoye oil field of TPP RITEK-Uraloil. The tests identified specific power consumption for the extraction of formation fluids when using conventional pumpjacks like *СК-8* and hydraulic SRPU drives type *НПК-10-8-6* and *ГПШСН 80-3, 5 "Geyser"*.

The drive of an *НПК-10-8-6* sucker-rod pump, mounted at the Well #109b of the Oblivskoye oil field, was operated with the following parameters: rod stroke=2.5 m, number of double strokes=5 min^{-1}. Specific power consumption amounted to 24.4 kWh/m³, which is 1.9 times more than that of a pumpjack which had been in operation at that well before, see the Table. Excessive specific power consumption of НПК-10-8-6 is due to the shortcomings of the manner in which the hydraulic drive was controlled and balanced. The oscillation frequency is adjusted by setting a pause at the end of each rod stroke, which lowers the drive efficiency. Energy accumulated by the hydropneumatic accumulator while the rod string is lowered is objectively insufficient for any significant reduction in power consumed by the drive when lifting the formation fluid.

VOL. 14, NO. 16, AUGUST2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Table-1. Comparative tests of hydraulic SRPU drives: results.

No.	Oil field and well	Oblivskoye, well No. 109b		Sosnovskoye, well No. 404	
1.	**SRPU drive**	**СК-8**	**НПК-10-8-6**	**СК-8**	**ГПШСН 80-3,5 "Geyser":**
2.	Motor type	asynchronous			
3.	Motor power, kW	22	11	22	37
4.	Motor shaft rotation speed, RPM	970	1480	970	1480
5.	Rod stroke, m	2.5	2.5	2.5	2.5
6.	Number of double strokes, min^{-1}	5	5	5	5
7.	Duration of measurements, days	9	27	6	5
8.	Specific power consumption, kWh/m³	12.8	24.4	11.25	12.76
9.	Change in specific power consumption,%	100	190.6	100	113.4

In addition to these drawbacks, we have identified the substantial advantages of hydraulic drives НПК-10-8-6. In pilot operation, we recorded one case of the hydraulic drive turning off due to the rod string sticking because of asphaltene deposits in the well. The sampling device exuded gas with paraffin chunks. Rod load was 90 kN (upstroke) and 0 kN (downstroke, sticking). Injecting hot oil under pressure into the annulus gave no results, as it resulted in no fluid circulation. The hydraulic drive was launched in the well recovery mode, in which the upstroke and downstroke speed as well as the rod stroke (length) would be adjusted automatically to fit the load at the rod string suspension point. The oscillation frequency was 1 min^{-1}; the stroke at the beginning of the operation was 0.5 m. While the hydraulic drive operated, hot oil was being injected into the annulus. Over the two hours of automatic drive operation, the stroke length increased to the set value of 2.5 m, hot oil injection pressure fell, and fluid began circulating. In 2.5 hours after the operation began, the entire planned volume of hot oil was injected. In three hours, the rod load normalized, and the nominal SRPU operation mode was recovered.

Thus, the use of a hydraulic drive helped rinse the asphaltene deposits and restore fluid injection without current repairs. It should be noted that during the period of controlled operations, no SRPU stop was caused by failures of the hydraulic drive; total uptime amounted to 220 days.

Based on the results of measurements at the well No. 404 of Sosnovskoye oil field of the Oil and Gas Production Shop No. 10, *ГПШСН 80-3, 5 "Geyser"* and СК–8 pumpjack demonstrated similar specific power consumption. Specific power consumption increased slightly when operating the Geyser hydraulic drive due to use of small-stroke pumps, which worsened the operating conditions of driving motors in the turbine mode due to shorter constant-speed operating time and longer acceleration and braking periods.

Operational testing of Geyser hydraulic drives helped identify the nodes that limit the resource of these units. Lower reliability characterizes the pumps and the motors of power packs. The absence of rigid connections between the power cylinders with the wellhead fittings necessitates periodic centering of the supporting mast, the skew of which results to intensive wear of the seals, thus leading to fluid leakages on the power cylinder rod. Balancing with electrodynamic braking means significantly lower power factor, which has a negative impact on the operation of electric oil production machines [11–30]. At the same time, the mobility, ease of operation, wide adjustment range, sophisticated telemetry control and monitoring systems are the unquestionable advantages of such units.

4. CONCLUSIONS

OOO LUKOIL-PERM specialists have carried out pilot tests of promising drives for sucker-rod pumping units and have drawn the following conclusions. Hydraulic SRPU drives are optimal for developing newly commissioned wells, for periodic and short-term operation of wells, as well as for removing asphaltene deposits. The mobility and smaller amounts of metal compared to mechanical pumpjacks make drive mounting less costly and time-consuming. Enhanced telemetry and control system enable comprehensive drive-well system assessments as well as wide-range adjustments of the hydraulic drive operating parameters. However, some problems are still relevant. Power consumption has to be lowered; the design of hydraulic SRPU drives needs improvements, while its nodes have to become more reliable.

The key factor that hinders the implementation and widespread use of hydraulic SRPU drives are their high cost compared to pumping jacks with asynchronous motors. Oil companies are facing adverse price conditions in oil markets, which necessitate cuts in costs and expenditures when buying oil production equipment. One way to cut the costs of hydraulic SRPU drives is to use domestic components for manufacturing rather than their imported counterparts.

REFERENCES

[1] Sof'ina. N. N, Shishljannikov. D. I, Grishina. I. O, Kornilov K. A. 2015. Jekspluatacionnyj kontrol' i diagnostirovanie oborudovanija po parametram pitanija jelektroprivoda na primere shtangovyh skvazhinnyh nasosnyh ustanovok. Gornoe oborudovanie i jelektromehanika. (9): 26-31.

[2] Shishljannikov. D. I, Sof'ina N. N. 2016. Obosnovanie racional'nogo sposoba kontrolja parametrov raboty i tehnicheskogo sostojanija shtangovyh skvazhinnyh nasosnyh ustanovok. Izvestija VUZov. Gornyj zhurnal. (4): 82-88.

[3] Molchanov A. G. 2010. Mashiny i oborudovanie dlja dobychi nefti i gaza: Ucheb. dlja vuzov. 2-e izd., isp. i dop. M.: Izdatel'skij dom Al'jans. p. 588.

[4] Rishmjuller G., Majer H. 1988. Dobycha nefti glubinnymi skvazhinnymi nasosami - per. s nem. Ternic. p. 244.

[5] Andreev. V. V, Urazakov. K. R, Dalilov V. U. 2000. Spravochnik po dobyche nefti. Moskva: Nedra. p. 374.

[6] Molchanov A. G. 2014. Puti dal'nejshego sovershenstvovanija shtangovyh skvazhinnyh nasosnyh ustanovok. Burenie i neft. (2): 5-16.

[7] Ivanovskij V. N. 2011. Jenergetika dobychi nefti: osnovnye napravlenija optimizacii jenergopotreblenija. Inzhenernaja praktika. (6): 18-25.

[8] 2010. Privod shtangovogo skvazhinnogo nasosa gidravlicheskij PShSNG–80–6 (NPK10–8–6). Rukovodstvo po jekspluatacii. Perm': OOO "NPK. p. 15.

[9] Isachenko. I. N, Gol'dshtejn. E. I, Nalimov G. P. 2002. Metody kontrolja sbalansirovannosti stanka-kachalki na osnove izmerenija jelektricheskih parametrov. Neftjanoe hozjajstvo. (1): 60-61.

[10] JeSU i jelektrooborudovanie GPShSN Gejzer, modifikacija s jelektrodinamicheskim uravnoveshivaniem. Rukovodstvo po jekspluatacii GPShSN 80-3,5 JeSU RJe. Ekaterinburg: OOO "NPP "PSM-Impjeks". 2013. p. 57.

[11] Sof'ina. N. N, Shishljannikov D. I. Kornilov K. A. 2016. Ocenka tehnicheskogo sostojanija uzlov gornogo i neftepromyslovogo oborudovanija metodom vozbuzhdenija rezonansnyh kolebanij. Gornoe oborudovanie i jelektromehanika. (9): 34-36.

[12] Zvonarev. I. E, Fokin. A. S, Ivanov S. L. 2012. Verojatnostnyj podhod pri ocenke jenergoresursa transmissij gornyh mashin. Zapiski Gornogo instituta. T. 195. pp. 249-254.

[13] Barkov. A. V, Barkova. N. A, Borisov A. A. 2012. Metodika diagnostirovanija mehanizmov s jelektroprivodom po potrebljaemomu toku. SPb. Sevzapuchcentr. p. 68.

[14] Gur'ev. P. A, Nuss S. V. 2006. Metodika i programmnoe obespechenie diagnostiki sostojanija jelektrotehnicheskogo oborudovanija. Vestnik Permskogo gosudarstvennogo tehnicheskogo universiteta. Geologija. Neftegazovoe i gornoe delo. (1): 165-175.

[15] Sidel'nikov. L. G, Afanas'ev D. O. 2013. Obzor metodov kontrolja tehnicheskogo sostojanija asinhronnyh dvigatelej v processe jekspluatacii. Vestnik Permskogo nacional'nogo issledovatel'skogo politehnicheskogo universiteta. Geologija. Neftegazovoe i gornoe delo. (7): 127-137.

[16] Usachev. O. I, Ginzburg. M. Ja, Egnus. A. E, Pavlenko V. I. 2014. Bestransmissionnyj jenergojeffektivnyj privod reduktora stanka-kachalki // Neftegazovaja vertikal. (17-18): 100-103.

[17] Jelektrodvigatel sinhronnyj VDPM-SK-22V. Instrukcija po montazhu. Moskva: OOO "RITJeK-ITC. 2012. p. 11.

[18] Stancija upravlenija tipa VLT-SALT. Pasport. Perm': OOO "Pogruzhnye privodnye sistemy". 2012. 8 P.

[19] Sungatullin. A. A, Norkina. O. A, Sadykova. R. R O. 2011. Problemah povyshenija jeffektivnosti remontnogo hozjajstva predprijatij neftegazovogo kompleksa // Neft' i gaz Zapadnoj Sibiri. Materialy Mezhdunarodnoj nauchno-tehnicheskoj konferencii. T. 4. Tjumen': TjumGNGU. pp. 251-254.

[20] Sidorov. V. A, Kravchenko. V. M, Sedush V. Ja. 2003. Tehnicheskaja diagnostika mehanicheskogo oborudovanija. Doneck: Novyj mir. 125 s.

[21] Verzhanskiy. A. P, Yungmeyster. D. A, Lavrenko. S. A, Isaev. A. I, Ivanov A. V. 2014. Mechanized complexes for roadway development at mines of

"Metrostroy" JSC (Saint-Petrsburg). Gornyi Zhurnal. (5): 94-99.

[22] Lavrenko. S. A, Yungmeister. D. A, Shishlyannikov. D. I, Iusupov G. A. 2015. Simulation of the process of destruction of the array of cambrian clays by cutters actuating device of sinking machinery in terms of OJSC Metrostroy St. Petersburg. International Journal of Applied Engineering Research. 10(7): 16409-16417.

[23] Trifanov. G. D, Shishlyannikov. D. I, Lavrenko S. A. 2016. Assessment of Ural–20R machine use efficiency while developing potash salt fields. ARPN Journal of Engineering and Applied Sciences. 11(19): 5722-5726.

[24] Vasilyeva M. 2019. An overview of development trends for the pumping equipment of mining and processing enterprises. Obogashchenie Rud. (1): 51-56.

[25] Alexandrov V., Vasilyeva M. 2018. Effieciency of Using Polyurethane-lined Pipes in Hydrotransport Systems of Slurry Tailings. Journal of Physics. (1118): 12002-12002.

[26] Nefedov Y. V., Klepikov I. V. 2018. Occurrence Regularities of Nitrogen Defects in the Ural Type Crystal Diamonds from Different Regions. Key Engineering Materials. (V 769): 201-206.

[27] Kuvshinkin S. U., Ivanova P. V., Zvonarev I. E. 2018. Relationship of dynamic properties of mine excavator hoisting mechanism versus design parameters of operating equipment. International Conference Complex Equipment of Quality Control Laboratories 2018 //Saint-Petersburg: Mining University. 1118: 1-5.

[28] Zvonarev I. E., Ivanov S. L. 2017. Evaluation of losses in transmission of machinery for development of mineral deposits in conditions of variable load. International Conference on Innovations and Prospects of Development of Mining Machinery and Electrical Engineering 2017, IPDME 2017/ под ред.Zadkov D. A. //Saint-Petersburg: Saint-Petersburg Mining University, T 87, C 22024 - 22024.

[29] Zyrin V. O., Ilinova A. A. 2018. Problems of unconventional gas resources production in arctic zone / Espacios. 39(42): C 17-25.

[30] Zyrin V. O. 2018. Electrothermal complex for heavy oil recovery: Analysis of operating parameters. International Journal of Mechanical Engineering and Technology. (9): 1952-1961.