

IMPROVING THE OPERATION OF THE DEEP PUMP ON PISTON RODS BY MODIFYING THE THRUST VALVE

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Summary

For a long time during the history of oil production, deep pumps on piston rods have been the first, and in many cases, the only choice when it comes to mechanical exploitation methods. The correct selection of each individual element of the system enables optimization, which entails benefits in the form of increased efficiency and reduced production costs. The currently applied system of deep pumps on piston rods at the "T" bed ensures stable production and realization of annual production plans without major problems. This paper presents the method of optimizing the system for the mechanical method of exploitation with deep pumps on piston rods. Calculations were made for 2 wells with the lowest pump efficiency, in order to define the application of a new system of deep pumps with changed technical characteristics (double pressure valve).

By installing a submersible pump with changed technical characteristics during overhaul, these two wells also showed a significant improvement in the duration of the inter-overhaul period.

Key words: submersible pump, optimization, equipment calculation, pressure valve.

INTRODUCTION

The oil in the reservoir is under a certain pressure, which enables the fluid to move from the reservoir to the well and further through the production system to the surface of the field. When the reservoir energy is weakened to such an extent that the reservoir pressure is no longer sufficient to enable fluid flow through the well, pipeline and surface equipment, i.e. when production has reached the minimum economically profitable value, it is necessary to provide additional energy for continued exploitation. If the production of fluids is realized with the use of additional energy, such a method of exploitation is called mechanical.

For a long time in the history of oil production, piston rod submersible pumps have been the first and, in many cases, the only choice when it comes to mechanical extraction methods. This is the reason why piston rod deep pumping is the oldest and most used type of mechanical oil extraction method worldwide. In general, about two-thirds of all production wells in the world use this method to obtain fluids.

In the first part of the work, the underground and above-ground equipment of the deep-water pump is presented and the operation of the entire plant is described, while in the second part, in

the wells of the "T" deposit, and in order to improve its utilization, an analysis of the operation of the existing equipment was performed, as well as calculations using the "RODSTAR" software, which will define the application of the new system of deep-water pumps with a double pressure valve on the selected deposit.

1. SYSTEM FOR DEEP PUMPING ON PISTON RODS

The mechanical method of oil production using deep pumps on piston rods, which is shown in Figure 1, is the oldest method of obtaining fluid from wells to the surface, and it is also the most widespread in practice in the world (over 80%). The basic principle of the submersible pump is based on the transfer of drive energy from the surface to the immersion level of the submersible pump by mechanical means, i.e. piston rods. The submersible pump, by transforming mechanical work into potential energy, raises the pressure of the fluid. The pressure at which the fluid from the reservoir enters the pump is called the suction pressure, and the pressure at the fluid exit from the pump is the discharge pressure. The difference between pressure and suction pressure is called pumping pressure, and it represents an increase in the potential energy of the fluid.

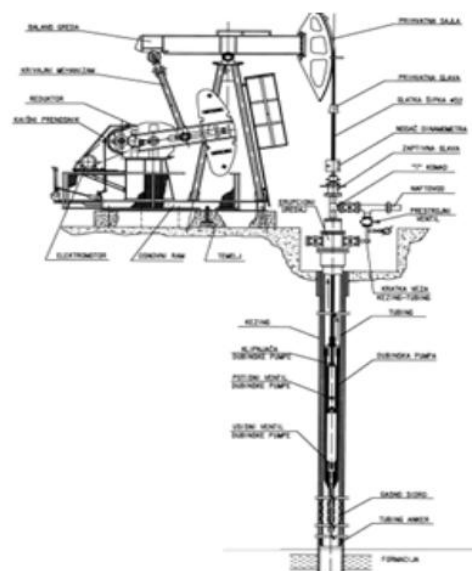


Figure 1. Components of a conventional deep pumping system on piston rods [1].

1.1. Work cycle of the submersible pump

The alternating movement of the piston rods in the well is caused by the movement of the smooth rod on the surface, and the piston rods, when moving, force the piston to also move alternately through the cylinder. The cycle begins when the piston begins to rise from the bottom of the cylinder. As the piston is raised, the difference in volume between the suction and discharge valves increases, causing the fluid contained in the cylinder to expand and thereby reducing the pressure in the pump cylinder. The drop in pressure causes the discharge valve to close, and the expansion cycle continues until the pressure drops below the suction pressure. When the intake pressure exceeds the pressure inside the cylinder, the ball on the intake valve is lifted from the intake valve.

Then the fluid, which is in the well, enters the cylinder through the suction valve and fills the space, during which the piston rises up. This represents the intake part of the cycle, during which the pressure under the piston and the thrust pressure remain constant, and they are equal to the difference between the intake pressure and the pressure drop through the intake valve body (seat, ball and assembly). At the very top of the cylinder, the piston changes its motion and begins to move towards the intake valve, which causes a decrease in the volume in the cylinder between the intake and discharge valves and the fluid inside the cylinder is compressed, which causes an increase in the pressure inside the pump.

The reverse flow and increase in pressure force the intake valve to close and the compression cycle continues until the pressure inside the cylinder exceeds the pressure above the discharge valve. Then the pressure valve opens and the piston moves down through the fluid in the pump cylinder. This part is called the discharge part of the pumping system, during which the pressure inside the cylinder remains constant, and is equal to the sum of the discharge pressure and the pressure required for the movement of the fluid through the pressure valve and inside the piston. During the discharge cycle, the piston moves towards the bottom of the cylinder. The relationship between the distance traveled by the piston and the change in pressure caused by the fluid inside the pump depends on the compressibility of the fluid mixture inside the cylinder. If the fluid is almost incompressible, then a very small change in volume, due to the small movement of the piston, causes large changes in pressure. In the case that the fluid is more compressible (a mixture of gas and liquid), a change in volume is necessary for the pressure to decrease or increase, that is, to close and open the valve. This required volume is achieved only through increased movement through the cylinder (Figure 2).

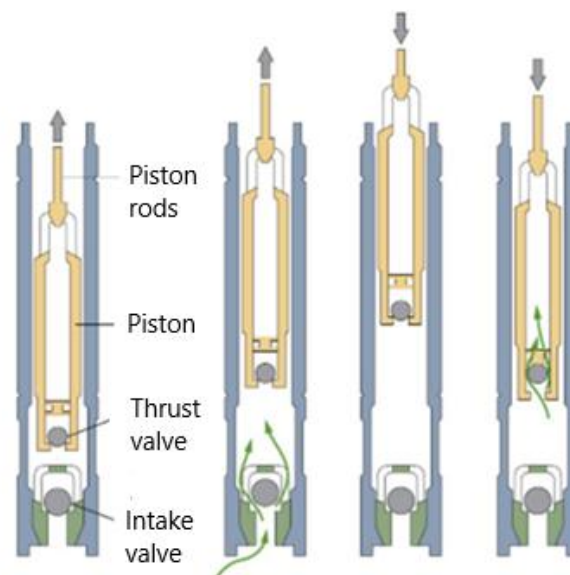


Figure 2. *Display of expansion, intake cycle, compression and push cycle [2].*

1.2. Submersible pump valves (suction/discharge)

The suction valve (Fig. 3) of the submersible pump is installed at the bottom of the cylinder, and is designed to work on the ball and seat principle. Its role is to allow the cylinder to be filled

with fluid from the reservoir when the piston is moving upwards, or to prevent its return when the piston is moving downwards. Due to the impact of the ball on the seat, both the ball and the seat are of special construction and are made of high-alloy steel with special surface treatment. This is very important, because any small damage or change in shape results in leakage, and thus in reducing the efficiency of the pumping process. For new valves with different diameters, the deviation of the shape of the ball from ideal circle must not be greater than 1 to 4 μm . [5,18].



Figure 3. *Construction of the suction valve [5]*

Analogous to the suction, the discharge valve (Figure 4) works on the ball and seat principle. Its role is to allow the passage of liquid from the cylinder to the piston when the piston is moving down, and not to allow it to return when the piston is moving up [5]. With the pressure valve, there is also the option of installing a double valve. The mentioned benefits of installing such a construction also apply to the pressure valve, with the fact that, in the case of installing a double pressure valve, when the pump works without a level ("fluid pound"), the ball and seat of the upper valve are protected from mechanical damage during a sudden change in pressure when the pump cylinder hits the fluid. Also, this design of the pressure valve prevents the occurrence of "gas lock", as the weight of the fluid column is held by the upper pressure valve and thus enables easier opening of the lower pressure valve. Everything that is stated for the suction valve, with regard to the operating conditions, also applies to the pressure valve.



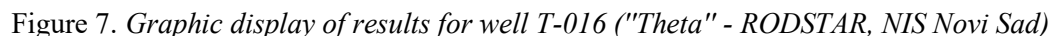
Figure 4. *Construction of pressure valve [5]*

2. ANALYSIS OF OIL PRODUCTION WITH THE EXISTING TYPE OF PISTON ROD DEEP PUMPS IN THE WELLS OF THE "T" RESERVOIR

The currently applied system of submersible pumps on piston rods on the "T" bed ensures stable production and realization of annual production plans without major problems. However, in

NOTE: Displayed bottom minimum stress calculations do not include buoyancy effects (top minimum and maximum stresses always include buoyancy)

Figures 7 and 8 show, on the left, a graphic representation of the expected surface and depth dynamogram based on the calculation results, while on the right is a diagram of the expected load on the reducer during one stroke of the hook.



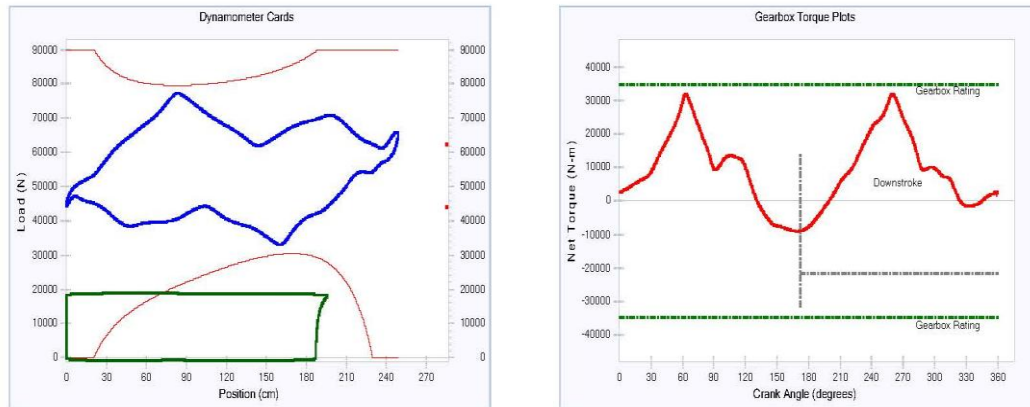


Figure 8. Graphic display of results for well T-061 ("Theta" - RODSTAR, NIS Novi Sad)

The efficiency of the pumps of the selected pool of wells ranged within narrow limits, and the average efficiency of the installed pumps, which represents a measure of the influence of both the characteristics of the reservoir fluid being pumped and the technical characteristics of the pump, was around 57 %.

From the entire pool of wells, two candidates, T-016 and T-061, with the lowest pump efficiency of 40 %, were selected for the installation of a pump with modified technical characteristics.

3. ANALYSIS OF OIL PRODUCTION USING A MODIFIED TYPE OF PISTON ROD DEEP PUMPS IN THE WELLS OF THE "T" RESERVOIR

In order to increase the efficiency coefficient, new calculations were made. Using the same input data, as in the previous case, with a variation related to the technical characteristics of the pump (double pressure valve), a series of calculations was made with the same software for the selected well candidates of the reservoir "T". The best efficiency of the pump itself was achieved by installing a double pressure valve. The results of the new calculation for wells T-016 and T-061 are shown in Figures 9 to 12. The result of the calculation showed a pump efficiency of 70 %, which is an increase of 30 % compared to the currently used pump.

NOTE: Displayed bottom minimum stress calculations do not include buoyancy effects (top minimum and maximum stresses always include buoyancy)

Figure 9. Calculation results for well T-016 ("Theta" - RODSTAR, NIS Novi Sad)

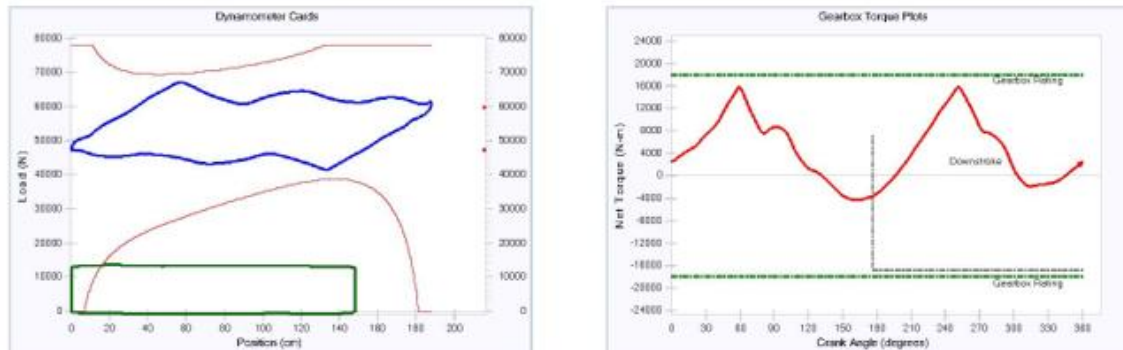


Figure 10. *Graphic display of results for well T-016 ("Theta" - RODSTAR, NIS Novi Sad)*

Company:NIS
Well:TT-061
Disk file:TT-061.rsdw
Comment:

RODSTAR 2018 REL 1
© Theta Oilfield Services, Inc. (gotheta.com)
NTC NIS - Naftagas

INPUT DATA				CALCULATED RESULTS (TOTAL SCORE: 78% GRADE: B-)					
Target Prod. (m³/D): Run time (hrs/day): Tubing pres. (kPa): Casing pres. (kPa):	7.5 24.0 600 10	Fluid level (m from surface): (m over pump): Stuf box fr. (N): Pol. rod diam. 1.25" (31.8 mm)	1550 303 445	Production rate (m³/D): Oil production (m³/D): Strokes per minute: System eff. (Motor->Pump): Permissible Load Power (kW): Fluid load on pump (N): Fluid load tvd (m from surface): Pol. Rod Power (kW):	7.5 1.7 3.27 29% 9 18012 1548.8 2.7	Peak pol. pod load (N): Min. pol. rod load (N): MPRL/PURL: Unit struct. loading: FRHP / PLHP: Buoyant rod weight (N): NNo. 082 , Fo/SKr: 201	71343 38060 0.533 79% 0.30 44136		
Fluid Properties		Motor & Power Meter		Required prime mover size (speed var. not included)			BALANCED (Min. Energy)	BALANCED (Min Torq)	
Water cut: Water sp. gravity: Oil density (g/cm³): Fluid sp. gravity:	78% 1.011 0.89 0.9842	Power meter Elect. cost: Type:	Dentel \$ 0.06/kWh NEMA D	NEMA D motor: Single/double cyl. engine: Multicylinder Engine:			10 HP 8 HP 10 HP	8 HP 8 HP	
Pumping Unit:UP90				Torque analysis and electricity consumption		BALANCED (Min. Energy)	BALANCED (Min Torq)		
API Size:C-310-202-118 (Unit ID CUSTOM) Crank hole number: Calculated stroke length (cm): Crank rotation with well to right:	#4 (out of 5) 248.8 CCW	Peak g/bax torq (N-m): Gearbox loading: Cyclic load factor: Max. cb moment (N-m): Counterbalance effect(N): Daily electric use (Kwh/Day): Monthly electric bill: Electr. cost per m³ fluid: Electr. cost per m³ oil:			32980 94.2% 1.669 58091.9 51179 106 \$194 \$0.847 \$3.852			26309 75.2% 1.545 66010.1 58003 108 \$198 \$0.864 \$3.929	
Tubing And Pump Information				Tubing, Pump And Plunger Calculations					
Tubing O.D. (mm): Tubing I.D. (mm):	73.025 62.001	Upstr.: rod-fl damp. coeff.: Dnstr.: rod-fl damp. coeff.:	0.100 0.100	Tubing stretch (cm): Prod. loss due to tubing stretch (m³/D): Gross pump stroke (cm): Pump spacing (cm from bottom): Minimum pump length (m): Recommended plunger length (m):					.0 .0 194.1 46.3 4.9 1.5
Pump depth (m): Pump conditions: Pump type: Plunger size (mm):	1853 Full Insert 38.1	Tub anch. depth (m): Pump vol. efficiency: Pump friction (N):	1853 72% 890	Rod string stress analysis (service factor: 0.9)					
Rod string design									
Diameter (mm)	Rod Grade	Length (m)	Min. Ten. Str. (kPa)	Fric. Coeff.	Stress Load %	Top Maximum Stress (kPa)	Top Minimum Stress (kPa)	Bot. Minimum Stress (kPa)	# Guides/Rod
22.2	TEN D Allow	439	827371	0.2	60.9%	182752	99253	67453	0
22.2	TEN D Allow	283	827371	0.4	51.3%	143786	64591	50151	3
19.1	TEN D Allow	512	827371	0.4	63.5%	167239	64977	31559	4
19.1	TEN D Allow	256	827371	0.2	49.1%	108829	24250	13703	0
19.1	TEN D Allow	229	827371	0.4	43.9%	85630	4964	-1274	3
19.1	TEN D Allow	134	827371	0.2	37.6%	60805	-11279	-3121	0

NOTE: Displayed between minimum stress calculations do not include buoyancy effects. All minimum and maximum stresses always include buoyancy.

Figure 11. Calculation results for well T-061 ("Theta" - RODSTAR, NIS Novi Sad)

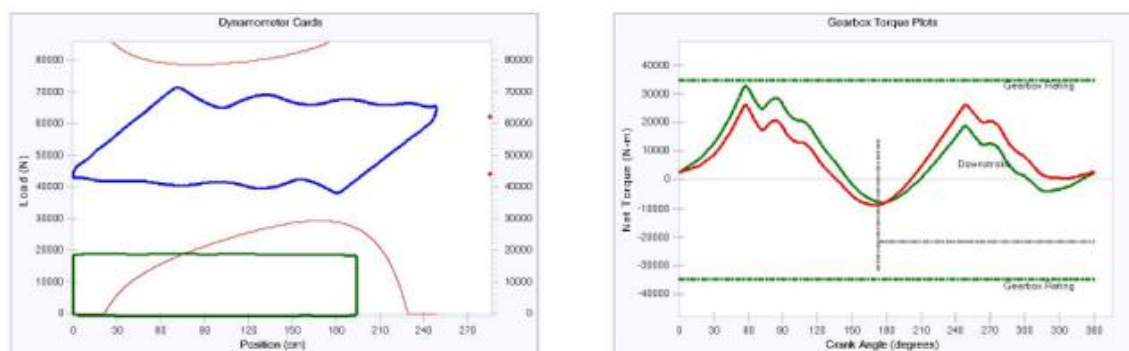


Figure 12. *Graphic display of results for well T-061 ("Theta" - RODSTAR, NIS Novi Sad)*

In addition to the greater efficiency of the system for deep pumping on piston rods while maintaining the same produced amount of fluid, by installing a double pressure valve in deep insert pumps on piston rods with upper seating, it is possible to optimize the pumping parameters, which are very important for pumping conditions in obliquely directed wells, as well as the use of a smaller pump diameter, which also enables the optimization of above-ground equipment.

The obtained results of the calculation of the deep pumping system were in accordance with the expectations and showed a significant improvement of the operation of the entire system. This improvement came about due to the better airtightness of the pressure valve, which results in

the same fluid production, with the possibility of reducing the diameter of the pump and/or optimized operation of the overhead equipment, and the positive effects of this are: less wear of the moving parts of the hook, less load on the reducer, less load on the structure of the hook, increasing the stroke length of the piston in the pump cylinder, safer operation of the hook from the HSE point of view, a weaker electric motor is needed, less wear of the smooth rod and its sealing elements, extension of the working life of piston rods and their couplings due to fewer cycles of load changes, extension of service life of tubing in case of contact with piston rods due to reduced number of cycles, extension of service life of pump valve assemblies due to reduced number of cycles, extension of service life of pump cylinder and piston due to reduced number of cycles.

CONCLUSION

Based on all calculations and practical checks on the existing wells of the "T" reservoir, a decision was made to install insert pumps with an upper seating and a double pressure valve in all wells that will be drilled on the "T" reservoir, in order to achieve more efficient operation of the complete system, instead of insert pumps with an upper seating and one pressure valve.

During the purchase of equipment for submersible pumps on piston rods, several seats and balls for pressure valves were specially ordered, in order to test them in wells in combination with all other equipment that was currently in stock in the company's warehouses.

Pumps with changed technical characteristics, by adding another pressure valve, were installed during the overhaul of the wells, and the data of actual measurements coincided again with the results from the calculations.

Both candidate wells, where the double pressure valve was installed, also showed a significant improvement in the duration of the intermediate overhaul period.

In the case of well T-016, the interim overhaul period, before the installation of a deep-seated pump on piston rods with upper seating and a double pressure valve, was 105 days, and after that 401 days, with a note that the well is still in operation.

In the case of well T-061, the interim overhaul period, before the installation of a deep-seated pump on piston rods with upper seating and a double pressure valve, was 143 days, and after that it was 655 days, with a note that the well is still in operation.

Due to the same characteristics as all other wells in the "T" oil field, the same type of pumps will be successively installed in all other wells of the oil field during the overhaul.

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