

Automatic Winding Machine for Repairing of Wells with Electric Centrifugal Pumps

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Abstract — The article deals with the results of field testings of the automatic winding machine for ECP cable in the process of down-lifting operations in the underground and overhaul repair of oil wells at the fields of Joint-Stock Oil Company Bashneft. During the overhaul or underground repair of oil wells equipped with ECP centrifugal pump installations, the mounting of the KRBK cable to the tubing body with special clamps is added to the technological process. This process requires stopping the process of lowering the tubing string. Thus, in the process of lowering the tubing string into the well, a synchronous operation of the mechanisms is necessary: cable feed (KRBK automatic winding machine) and the mechanism of movement of NK pipes. Taking into account the requirements of safety and provision of integrity and serviceability of the KRBK cable in the process of down-lifting operations in the underground and overhaul repair of oil wells, smooth stopping and starting of automatic winding machine is necessary, as well as the synchronous operation of the KRBK automatic winding machine and the system of lifting and lowering the column of the tubing. Abrupt stopping and starting of the work of automatic winding machine leads to tension and overvoltage of the cable, which is unacceptable and can lead to destruction of the cable as a whole (breakage, violation of insulation, integrity). For starting and stopping the cable drum (7-8 tons) the following is necessary: a sufficiently large power of the electric motor; gearbox. Moreover, the moment of inertia of the untwisted cable drum is long enough, which is the cause of failure of the gearbox, electric motor and belt drive. Considering the above said, the article proposes the kinematics of the automatic winding machine, which has passed field testings and allows smooth, synchronous operation being done, as well as eliminating damage of the KRBK cable and optimizing the expenses of maintenance and repair of the automatic winding machine.

Keywords — *automatic winding machine; underground repair; oil well; cable; installation of ECP electric centrifugal pumps.*

I. INTRODUCTION

The oil companies of Russia and other countries, the most common pumping installations for oil extraction are the installation of electric centrifugal pumps (ECP). More than 70% of the oil is produced by ECP installations. Reliable operation of ECP largely determines the efficiency of oil production. The efficiency of ECP installations in oil companies depends on many factors. These factors are: geological and engineering characteristics of the fields, a correct selection of all the equipment the ECP installation, a correct execution of repair works with ECP installations, their installation and the output mode, technical conditions of technological equipment for underground repair of oil wells (the equipment for underground repair of wells, automatic winding machine, cable KRBK), and the specialists. With the deviation of at least one of the factors, the ECP starts to work below the level achieved by this method in the production system, and ultimately it causes an increase of the cost of production and production expenses.

The cable winding machine is designed for mechanized rewinding of the cable during down-and-up operations on wells with submersible electric centrifugal pumps in the oil and gas industry. The cable winding machine is designed for using together with KPBP cables with a cross section from 10 to 35 mm² or with similar cross sections, laid on coils. The diameter of the coils is from 1700 to 2200 mm, the total weight is not more than 4-8 tons. It is also possible to use the machine to rewind the repairing cable.

Installation of the cable drum on the cable winding machine is carried out with the help of a special automatic machine – a crane or a crane-manipulator. On the axis of the drum expansion and driven sleeves are installed. With the help of a crane, the drum is mounted on the directing rollers.

A pulley is mounted on the gearbox shaft. From the pulley the shaft of the driving gear, with which the drum rotates, is driven by means of a V-belt transmission. From the shaft of the driving gear the rotation is transmitted to the shaft of the cable laying machine.

For removing the drum from the cable winding machine it is necessary to remove the drum from the directing rollers by means of the crane. When lifting or lowering the cable, the cable is passed through the plug of the cable laying machine, and the winding of the cable is done by laying it in rows.

After relieving the tension from the automatic winding machine, unloading and loading of the drum with the cable is carried out with the help of the crane or hydraulic manipulator. The hooking and moving of the drum must be done in such a way as to eliminate distortions and jamming of its individual parts and ensure its stable position. When installing the drum on the roller to correct his hands is prohibited. When repairing wells, the cable drum should be installed so that the drum, cable drum and wellhead are in the same vertical plane, which is checked by testing the cable through the roller in both directions.

The automatic winding machine should be installed in such a way that the cable drum is seen from the working platform at a distance of 15-20 m from the wellhead. At night, the drum should be lit at least by 15 Lux. The bending radius of the cable must be at least 440 mm. The cable roller is attached to the mast elements on a special bracket with a clamp or a special cable suspension. The use of random ropes is not allowed. Wedge and chain transmission, clutch must have a strong solid fencing. The cable passed through the roller must not touch the structural elements of the lifting unit and the ground.

The electric motor, the control unit and the body of the automatic winding machine must be grounded. Execution of electrical equipment must be explosion-proof. Before starting the automatic winding machine, it is necessary to check the absence of foreign objects on it. During the descent and elevation of the ECP unit, the operating personnel are obliged to act in accordance with the requirements of the instructional cards of advanced and safe methods of work during the current repair of wells. When screwing the tubing it is necessary to ensure that the string suspended in the well is not turned. Otherwise, the cable twisted around the pipes during the descent can get mechanical damage.

In the process of lowering the ECP, it is necessary to measure periodically (every 200 m) the insulation resistance of the engine with the cable, recording it in the logbook, and to monitor its changes. With a sharp decrease in the insulation resistance, the descent of the ESP must be stopped.

The minimum allowable insulation resistance of the entire installation after the unit is lowered into the well is 15 MΩ.

Descent and lifting operations with ECP shall be carried out with the control station turned off and measures taken to ensure safe working conditions for personnel. After the end of the descent operation a working team measures the insulation resistance of ECP (not less than 5 MΩ) before and after sealing the gland entry. The free end of the armor cable fixes on the column flange of the wellhead fittings, under the lower nut, runs

the cable from the head to the SU or the terminal box, fills the operating passport indicating the number of lowered tubings and the depth of the suspension (the amount of pipes), calls a representative of the CPU and the oil production for a trial run.

The cable should be lifted from the well and descend smoothly, without jerking and at a speed not exceeding 0.25 m/s. With the passage of the sections of the pipe column the wells with curvature of more than 1.50 per 10 m and with transition of the column to a smaller diameter of the pipe, the speed of ascent and descent should not be more than 0.1 m/s. The cable going to the well must be bent from the top of the drum. Winding, unwinding and laying of the cable on the drum in rows should be mechanized. When attaching the cable to the tubing pipes and screwing the pipes, the cable should not be twisted around the pipes, nor should the flat cable be twisted about its own axis.

To reduce the shrinkage of the ends of the insulation, in order to improve the quality of the splices, it is recommended to heat treat the ends of the insulated conductors. At a distance of 250-300 mm above and below each tubing sleeve and each splice, the cable must be secured with steel belts (blades or protectors), while avoiding slack and sagged cable inside the well. Clamps must be tighten until the initial deformation of the armor. Place The buckle of the clamps must be placed in the free space between the tubing and the cable, but by no means on the surface of the cable, the curved end of the clamp must be firmly pressed to the buckle.

Repair and adjustment of the automatic winding machine should be done after turning off the switch and hanging the “do not turn on - people work” sign. Repair works in the autoloader control unit of the automatic winding machine is allowed only to the electrician.

It is prohibited to lower the ECP unit into the well, if the automatic winding machine does not work in automatic mode.

During operation, it is strictly forbidden: 1) to install the automatic winding machine on the roadway; 2) to repair, cleaning and lubrication of the moving parts of the automatic winding machine; 3) to stop the drum with the help of levers and hands; 4) to direct, reset, loosen the belt or chain transmission; 5) install the drum with cable on the auto-winding machine manually; 6) work without grounding the auto-winding machine; 7) to carry out any work on the cable during the SPO cable any work on the cable works.

At atmospheric precipitation it is strictly forbidden to assemble the ESP installation, because of a possibility of moisture penetration. It is forbidden to touch the cable when testing the ESP electric motor.

II. EASE OF USE

One of the complex processes is the technological process of lowering (lifting) the tubing string together with a submersible electrocentrifugal pump with a cable connected to it. The equipment for rewinding a cable, used during the descent or ascent from the wells of a submersible centrifugal electric pump, was developed for performing this operation. The most widespread are the installations developed by Tat NII

Neftemash of the type UPK-2000 and OGPD Tuymazaneft of the type UNRKT-2M. These installations were produced in two versions: the wheel version of the CPC - 2000 and the sleigh version of the CPC - 2000SN.

The automatic winding machines of the cable have rigid kinematics of the drive of the drum (abrupt start and abrupt stop of the drum). The kinematic scheme of the installation for rewinding the cable used during the underground and overhaul of oil wells equipped with ECP installations. It is shown in figure 1.

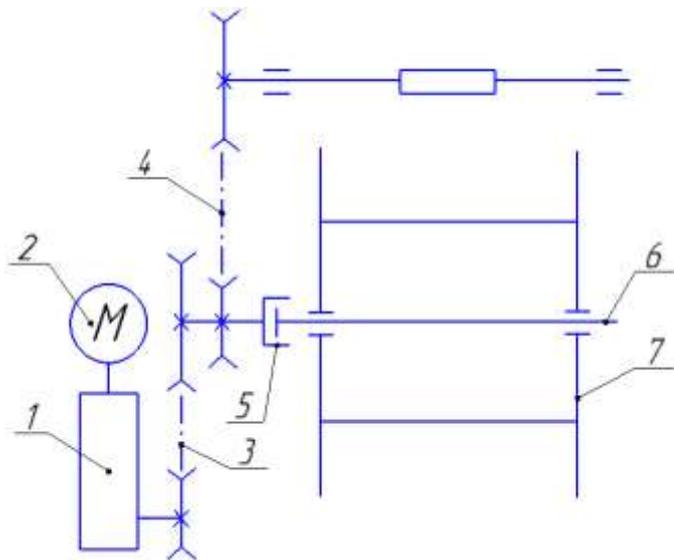


Fig. 1. The kinematic scheme of the automatic winding machine for cable rewinding, used during underground and major repairs of oil wells, is equipped with ECP installations: 1. drive motor, 2. two-stage cylindrical gearbox, 3. chain transmission of the drum drive, 4-chain transmission of the cable stacker drive, 5-twin half-couplings, 6-drum axis, 7-drum for a cable.

The process of lowering or lifting tubing string together with electric pumps connected to the cable is complicated due to necessity of preservation of the cable from damage. Cable damage can occur for the following reasons: in case of disagreement of the beginning of the descent or rise of the tubing string with the beginning of the cable feed from the drum during the lowering of the tubing string or with the beginning of winding of the cable on the drum when lifting the column. That means, in both cases the cable tension is manifested, which can lead to damage. The permissible tension force of the cable when rewinding should be no more than $P=1.5$ kN. The damage of the cable is also possible at different rates of descent (rise) of the tubing string into the well and at the unwinding (winding) speed of the cable. Cable of the ECP installation should have a speed of rewinding of the cable from the drum (on the drum) no more than $0.25 \pm 10\%$ m/s. Damage means destruction of the cable ECP, namely the breakage of strands, insulation fault and armor. Cable installation ECP is attached to a well tubing string with steel belts. The reliability of the cable attachment to the tubing pipe is important, otherwise it can lead to damage of the cable during the descent of lifting operations during the repair works on ECP. For supplying electric energy to the centrifugal pump of the ECP installation the following brands of cables are

used: PBAR – cable with polyethylene insulation, armored and round, as well as PBCP, CPPAPS, etc.

At first glance, the cable construction has a strong and reliable basis, but despite this, there are cases when after the descent of the electric center pump to a predetermined depth in the well, the cable gets destroyed (broken insulation, broken core, etc.).

If we consider the characteristics of the installations for rewinding of the cable (table 1), the installation of the CCP-2000SN does not have a high center of gravity, which ensures stable, vibration-free operation of the entire installation without vibration during rotation and stops of the drum with a cable of 60 kN. When the capacity of the drum installation for rewinding the cable reaches 2000 m, the process of this amount of the cable into the well is accompanied with a large number of stop and start. It should be noted that the drive in the rotation of the drum requires a large initial torque. And then, in the process of rotation, the drum has a sufficiently large moment of inertia. Due to the absence of a braking device on the cable rewinding unit, the drum stops after disconnection due to the resistance of the kinematic drive chain. Taking into account that this technological process of starting and stopping is repeated during the down-lifting operation of the tubing string into the well, all this generally leads to intensive wear of the drive units of the installation for rewinding of the cable.

A synchronous operation of two technological operations is necessary for optimization of the expenses on conducting the underground repairworks of wells with the replacement of the centrifugal pump: the speed of the descent (ascent) of the column tubing and the feed rate of the cable from the unit to rewinding of the cable.

TABLE I. TECHNICAL CHARACTERISTICS OF INSTALLATIONS FOR REWINDING OF THE CABLE

Technical characteristics	CPC-200 PM	CPC-2000 SN
The maximum length of the transported cable, m	2000	2000
Maximum weight of transported cable drum, kg	5800	6000
Cable rewind speed, m/s	$0.25 \pm 10\%$	$0.25 \pm 10\%$
he tension of the cable when rewinding, kN	1,5	1,5
Weight with cable drum, kg	9800	10500
Installation weight, kg	4000	4500
Overall dimensions, mm		
- length in working position	7850	8950
- length in transporting position	6850	7850
- width	2360	2500
- height with cable drum	3000	3800

If we consider the technical characteristics of installations for rewinding of the cable (table. 1), we can surely say that along with the advantage of each of the installations, there are disadvantages. It can be noted that the installation on the sleigh has a sufficiently high stability, which is important for the kinematics of a rotating drum with the weight of 60 kN. It also should be noted that the speed of rewinding from the rotating drum and the speed of descent of the tubing string into the well should be 0.25 m/s. The permissible difference between the

speed of descent of the tubing string and the speed of rewinding of the cable from the rotating drum should be within $\pm 10\%$. It should be considered that the capacity of the drum is 2000 m of cable, that means with the length of one pipe tubing it will be more than 200 times of disconnections and connections for a descent and the same amount for a rise. In the period from switching on to switching off (lifting one tubing), the drum has time to gather momentum, and considering its mass, we can imagine that the drum will have a sufficiently large inertia at the time of stopping. The loads that are detected when the drum stops (inertia damping) are destroying for the kinematics of the installation for rewinding of the cable.

III. RESULTS AND DISCUSSIONS

Taking into account requirements of ecological safety of the environment and traffic regulations, the installation for rewinding of the cable UNRCC-2M was refined and improved at the facilities of OGPD Tuymamaneft ANC Bashneft and passed the field test of automatic winding machine in underground repair works of oil wells. Delivery of automatic winding machine for cable ECP with weight of 45 kN and the drum with a cable with weight of 60 kN was carried out by separate vehicles. The cable together with the drum were delivered to the well by special vehicles MT-6M. This vehicle is mounted on the chassis of the car KrAF-255B and is designed for mechanized loading, unloading and transportation of equipment of the installations ECP. Delivery of the automatic winding machine is carried out by means of the specialized car PS-6,5 M.

Kinematic scheme of the installation for rewinding the cable IWRC-3M are presented in figure 2. The automatic winding machine has a common frame, on which the drive part and the drum support stand are mounted. This arrangement provides a minimum height of the center of gravity of the entire installation, which ensures its reliable stability in the operation of the rotating drum with cables. An electric motor with the power of $N = 3.2$ kW and $n = 960$ rpm is used for ensuring the operation of all components of the automatic winding machine.

The friction transmission is used for the main drive for the drum with cable. The principle of operation of the automatic winding machine is as follows: the drive motor 6 transmits torque through a two-staged cylindrical reducer by means of a chain drive 11 to the drive shaft 3. There are two friction drums on the drive shaft, which transmit torque to the drum with the cable at its flange. On the friction shaft there are two friction discs $\varnothing = 25$ mm, $L = 400$ mm. The distance between the disks is equal to the width of the cable drum and is equal to 1800 mm (figure 3). From the drive shaft 3 of the chain drive 2 and 10, torque is transmitted to the shaft of the cable stacker 8. The cable stacker is a two-way shaft for moving the cable stacker parallel to the axis of the drum. The drum is placed on the automatic winding machine after the frame 9 is installed. The drum is laid on racks that have 2 bevels for rigidity.

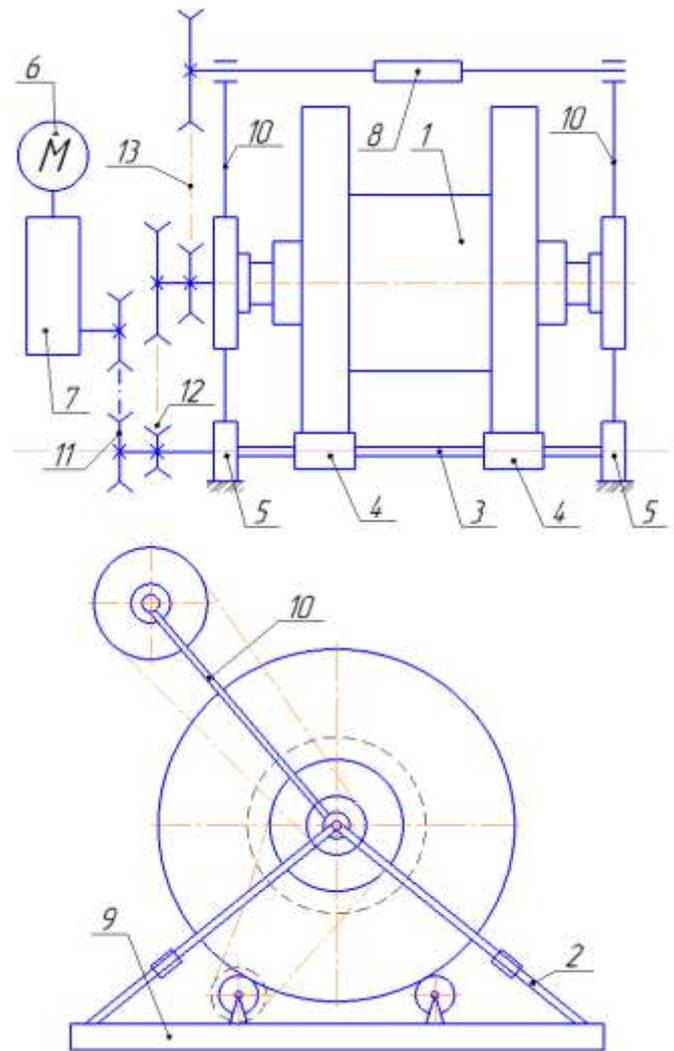


Fig. 2. Kinematic scheme of the installation for rewinding the cable IWRC-3M: 1. drum with the cable, 2. drum support clips, 3. leading friction shaft, 4. clutches, 5. friction shaft supports 6. drive electric motor, 7. gearbox, 8. cable drum laying on the drum, 9. frame of the automatic winding machine of the cable, 10. rack of the stacker shaft support; 11. chain transfer to the drive shaft, 12. chain transmission of the first stage to the cable stacker, 13. chain transmission of the second stage to the shaft of the stacker.

Starting and stopping of the electric motor can be carried out from the control panel, which provides for turning on and off the motor in manual and automatic modes, as well as turning off the motor in emergency modes and short-circuit currents. The cable layer ensures that the cable is evenly laid when it is rewound. The pulling roller is designed to pull the cable and give it the right direction from the cable winding machine to the wellhead, as well as cutting the cable in an emergency, for which the roller is equipped with a special limiter-knife. During repair works of a borehole the installation for rewinding the cable is installed at 25-30 m from the mouth of the stacker in the direction of the bore against the suspension roller.

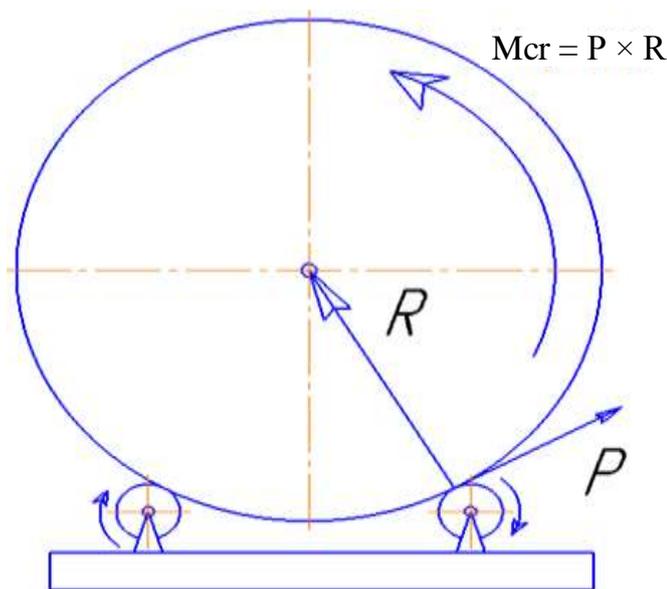


Fig. 3. Scheme of torque transmission to the cable drum by means of friction transmission.

IV. CONCLUSION

The thoughtful analysis of the operation of cable rewinding installations of domestic and foreign production shows that the kinematics of the drum rotation was changed. It allowed reducing the effect of the inertial load on the kinematics of the drum rotation, namely on the reducer, chain transmission. The power of the electric motor drive unit decreased by 2 times: it had been 7.5 kW, then became 3.2 kW.

As result, by reducing the inertial load the reliability of the installation and service life increased, and hence the quality of down-and-up operations during repair works of oil wells which are equipped with electric pumping units.

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