Vibratory–percussive disassembly in recovery of electric-centrifugal oil well pumps

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Abstract. Repair of borehole centrifugal pumps involves complete disassembly and removal of steel parts from a long steel casing made of thick-walled pipes. In this paper, the technology of removal of steel parts from the pipe using a pneumatic hammer with impactor portion 400 kg in weight at the compressed air flow rate not more than 3 cubic meters per minute is discussed.

1. Introduction
It is expedient to operate high-rate wells using centrifugal pumps [1–4]. Given medium to high drainage of formation fluid (100–500 m³/day and more), centrifugal pumps offer the higher economic efficiency and the easiest maintenance. A centrifugal pump is put into a well beneath the fluid level in oil well tubing and actuated by electric motor arranged below and supplied via a special cable. The motor arranged directly at the pump allows transmission of great power. In a casing string with a diameter of 168 mm at a pump head of 1000 m, the useful power of the centrifugal well pump exceeds 100 kW.

Centrifugal well pumps with a head of 1915 m ensure fluid withdrawal to 125 m³/day from wells with internal casing diameter of 130 mm; at the head of 550 m—900 m³/day from well with internal casing diameter of 148.3 mm.

Withdrawal of highly corrosive fluids uses centrifugal well pumps with basic parts made of materials resistant to corrosion.

Overhaul life of centrifugal well pumps at medium and high drainage is longer than that of sucker-rod pumps and makes on average 260–320 days, for instance, at reservoirs in Bashkiria and Tatarstan [5, 6].

2. Features of centrifugal well pumps operation
A centrifugal well pump installation (Figure 1) consists of a hydraulically protected compensator of submersible electric motor; sealed protector; multi-section pump; flat and round cables fastened to the tubing by steel belts; back valve facilitating priming after the pump stop; bleed valve to drain fluid from the tubing in order to simplify pump removal; as well as equipment of the well mouth, operator station, transformer and various ancillary facilities. The electric pump unit is placed down the well on the oilwell tubing. The submersible motor is supplied via the round cable running from the ground surface down the tubing to the pump unit and passing into the flat cable. The flat cable is used with intent to reduce total diameter of the electric pump unit in order to ensure easy and damage-free up and down motion of the pump in a well. Round cables can be totally replaced by flat cables of the proper cross-section [7, 8].
Centrifugal pump installations operate in wells with different internal diameter of casing strings, from 121.7 to 148.3 mm.

The diameter constraint necessitates the increase in length of the electric pumping units at the motor capacity up to 250 kV. The range of diameters for the pumping units is 116–142.5 mm, the length can be more than 25 m (Figure 2).

The basic components of an electric centrifugal pump (ECP) are the impeller and diffuser (Figure 3). The impeller increases potential and kinetic energy of fluid flow by speeding it up in the blade system of the impeller and by build-up of pressure.
Small dimensions of centrifugal pumps dictate that diffusers are always designed as guide vanes. The key function of the diffuser is fluid withdrawal from the impeller, speeding down the fluid flow rate and simultaneous conversion of the kinetic energy to the potential energy (pressure build-up), transition of the fluid flow to the next impeller or to the discharge connection. Designs of impellers and guide vanes, as well as the pump performance depend on the planned feed and head of a stage.

Sequentially connected on the common shaft, the ECP stages are arranged in the casing (thick-wall tube). Usually, ECP casings are manufactured with one of three outer diameters: 92.5, 102 and 103.5 mm.

Repair or recovery of ECP requires that impeller and guide vanes are removed from the casing. After long-term operation of a pump, removal of the parts from the casing, specifically, guide vanes arranged inside the thick-walled tube with minimum clearances, is greatly difficult the clearances are clogged with sand. In this case, sand particles should be milled to finer fractions in order that these parts are taken from the casing. Actually, it is anything but simple to apply each guide vanes with the force sufficient for sand milling and the part removal from the thick-walled tube.

Another problem of the same technological difficulty is removal compacted soil from the pipe driven with its open end to the full length of a pass. The method used to clean the pipe makes use of simultaneous counteraction of percussion and static pressure on the plug [9]. This method ensures removal of soil plugs even from tubes of small diameters of 40–100 mm [10].

Application of high forces to the first guide vane (end most in the line) results in its failure and damage of the inner cylindrical surface of the casing, which is discarded as a consequence. Therefore, in repair maintenance, an ECP is dismantled by hitting on the casing (tube) end, or by throwing the pump to a hard surface from a height more than 1 m. The casing is imparted with acceleration after hitting or deceleration after throwing, while inner parts hold immobile relative to the casing due to inertia or move toward its outlet. As a result, internal stresses arise between the inner surface of the casing and the seating surface of the guide vane. Under the action of these stresses, internal contact bonds are broken as sand particles are milled, and the parts are removed from the casing tube.

To throw ECP casing from height, the devices should have height more than the length of the casing. Furthermore, a mechanism is required to turn the casing into vertical position, including grip and hoist engine. In throwing, the impact frequency is much lower than one impact per second. Efficiency of impeller and guide vane removal is low at high expenditures.

It is simpler and more efficiently to remove impellers and guide vanes from pump casings using pneumatic hammers with variable impact force at minimum frequency [11], which can be sourced by compressors of minimum air flow rate, at level of 3 m$^3$/min.

3. A pneumatic hammer application

For driving a pipe with a diameter of 100 m in soil a length to 40 m, it is recommended to use Typhoon-40 (T-40) pneumatic hammer with an impactor portion weight of 40 kg and unit blow energy of 400 J (Figure 4). The tests of T-40 in horizontal operation show that the hammer impact frequency is within the range of 2.5–5.8 Hz (air flow rate 3.6–6.5 m$^3$/min); the lower limit of stable operation in debugging of T-40 is 1.8–2.1 Hz (air flow rate 2.6–3 m$^3$/min).

![Figure 4. Typhoon-40 air hammer with the striking piston 40 kg in weight.](image-url)
Typhoon-40 air hammer was manufactured and delivered under a contract to Pyt-Yakh town in Khanty Mansi Autonomous Okrug—Yugra, 100 km away from Surgut. Inside Severnaya industrial zone, in an engineering building, a special test bench was constructed for implementing the technology of ECP disassembly using T-40 air hammer (Figure 5).

![Figure 5. ECP disassembly test bench.](image)

The test bench for disassembly of ECP and removal of impeller and guide vanes from the pump casing consists of a guide U-section put on supports (tyres) of different height to obtain a reverse slope. At one end of the U-section, an energy absorption device is arranged on a frame connected with the U-section. ECP casing is laid in the U-section and thrust on the energy absorption device made as a piston chamber 210 mm in diameter filled with wood chips [12]. At the other end of ECP casing, an adapter flange with a nested receiving socket with discharge opening is arranged. T-40 air hammer is connected with the receiving socket via a nozzle with the conical seating surfaces using a tension puller containing steel-wire ropes and turnbuckles. Compressed air at a pressure of 0.6 MPa is fed from an electric compressor at a rate of 3 m³/min to the air hammer along a hose with a diameter of 32 mm and 20 m long.

The procedure of ECP disassembly and removal of impeller and guide vanes includes stages below:
1. Placement of ECP in the U-section, installation of the flange, receiving socket, nozzle, air hammer and tension puller;
2. Compressed air feed to the air hammer;
3. Breakage of bonds holding guide vanes in the ECP casing under impact impulses imparted to the casing and displacement of parts in the line of the slope (backward) by gravity into the receiving socket;
4. Removal of impeller and guide vanes from the socket through the discharge opening.

Average duration of disassembly cycle for one ECP is 20–25 min.

4. Conclusions
1. Application of pneumatic hammer to disassembly of electric centrifugal pumps at an industrial scale has totally proved security and high efficiency of removal of the pump parts from its steel casing under the action of impact impulses.
2. Variable impact force of the air hammer with the piston weight of 40 kg enables using compressed air source as a low-power electric compressor with a capacity not more than 3 m³/min without reduction in the process efficiency and at the same energy of unit blow.

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