Downhole Motor

User`s Manual

Yancheng Xinyongjia Petroleum Machinery Manufacturing Co., Ltd.
I. Preface

This manual mainly introduces the work principle, structure, mechanical properties, proper use and maintenance of the downhole motor which allows users to carry out drilling and workover, so as to give full play to the mechanical and technical performance of the tool and improve the working efficiency of drilling and workover.

II. Work principle of the downhole motor

Downhole motor refers to a kind of positive displacement down-hole drill which takes drilling hydraulic pressure as the drive and turns the hydraulic energy into mechanical energy. When the pressure slurry passes from the slurry pump to the bypass valve, the bypass valve will be turned off with the entering of motor which forms certain pressure difference in its inlet and outlet, to push the revolution and rotation of rotor around the stator axis, and then transfer the rotating speed and torque to the drill through cardan shaft and transmission shaft, so as to realize the operation of drilling and workover.

III. Composition of the downhole motor

The downhole motor mainly includes four parts of bypass valve, hydraulic motor, cardan shaft and transmission shaft. Auxiliary facilities such as the anti-drop device are also installed on the top of the motor and under the bottom of the transmission shaft.

Downhole motor

Downhole motor refers to a kind of down-hole drill which takes slurry as the drive. The downhole motor mainly includes five parts of Drive shaft assembly, Motor assembly, Cardan shaft assembly, Anti dropping assembly and Bypass valve assembly.

When the pressure slurry passes from the slurry pump to the bypass valve, the bypass valve will be turned off with the entering of motor which forms certain pressure difference in its inlet and outlet, to push the revolution and rotation of rotor around the stator axis, and then transfer the rotating speed and torque to the drill through cardan shaft and transmission shaft. The performance of downhole motor mainly depends on the motor assembly.
3.1 Bypass valve assembly:

It is composed of the valve body, valve cover, valve element, spring, O-ring, ring washer and other parts. It aims to connect the drill string with the annulus in trip, and ensure non-pollution of the wellbay. When the slurry flow and pressure reaches the standard set value, the valve element will move down and turn off the bypass valve port. At this time, the slurry flow could turn the pressure into mechanical energy through the motor. When the slurry flow pressure is too small or the pump is stopped, the produced fluid pressure will be smaller than the elastic force of the spring. Then the valve element will be jacked up by the spring and the bypass valve port will be on the open position to connect the drill string with the annulus.

3.2 Hydraulic motor assembly:

It is composed of a single screw rotor and a stator. The rotor refers to an X head screw after mechanical processing which is with anti-corrosion and anti-wear coating on the surface. The stator housing is composed of the X+1 head interior screw rubber bushing of the internal wall cavity cement of alloy steel. Both the shape and the size of the rotor and stator shall be meshed, and these mesh points shall form the sealed cavity of motor along the axis, to conduct screw rotation in the stator along with the rotor. When the drilling fluid with certain energy passes, the cavity will move down along the axis with the continuous production of the upper inlet and the gradual disappearance of the lower outlet, so as to complete the energy transformation. In this way, the rotor will conduct eccentric revolution and rotation along the inner wall of the stator screw to finish the work of the motor. This is the basic work principle of the screw motor. There are single-head helix and multi-head helix for the rotor of the motor (There is one more head of the rotor helix than that of the stator). The less head the rotor owns, the faster the rotation speed will be and the smaller the torque will be; and the more head the rotor owns, the slower the rotation speed will be and the greater the torque will be.

Screw drilling motor is an important component of drill tools. Based on many practical and theoretical analyses, the pressure drop borne by each level of motor shall be less than 0.8Mpa for normal and effective work of the motor. (one lead of the motor as one level). The maximum pressure drop is 1.3 times of the rated working pressure, otherwise it may lead to bad effects such as the missing of motor, the quickening of rotation, the seriousness of wearing and even the thermal expansion, so that the motor may be damaged. Users shall pay special attention that the slurry flow
applied to the site shall be within the recommended using range, otherwise the stator wear will be increased greatly, so as to affect the service efficiency and life of the motor.

The performance parameters of the screw motor are the main ones for the downhole motor. The theoretical output torque of motor is in direct proportion to the pressure reduction of motor, and the output revolution number is in direct proportion to the input slurry flow. With the increase of the load, the revolution number of the drilling tool will be decreased. Therefore, only when the reading of the pressure gauge on the ground as well as the flow of the pump is controlled, can the torque and revolution speed of the down-hole drilling tool be in control.

3.3 Cardan shaft assembly:

It is composed of the petal cover, intermediate joint, steel ball and other parts. The upper part of it is connected to the rotor, and the lower is connected to the transmission shaft. It is used as a specialized connector transferring the mechanical property of motor in planetary motion to the transmission shaft.

After using the drill tool, it shall be demolished immediately with the check of any wear of the cardan shaft. In case it has exceeded the repair standard requirement, relevant parts shall be replaced, otherwise, it may lead to fracture of the cardan shaft due to excessive utilization, resulting in the incapability of normal work.

3.4 Transmission shaft assembly:

The transmission shaft transmits the rotation force of the motor to the bit, which is also used to bear the axial and radial load produced by the drill pressure. There are two kinds of transmission shaft assembly of the drill tool:

3.4.1 The bit hydrophthalmos pressure drop is 3.5Mpa, and the needle bearing positioning is adopted for both ends of the transmission shaft, and a structure of thrust ball bearing is in the middle to bear the pressure.

3.4.2 The bit hydrophthalmos pressure drop is 7.0Mpa. Transverse bearing positioning of cemented carbide is adopted on both sides of the transmission shaft assembly with the use of a series of bearing pack in the middle, so as to enhance the abrasion resistance and bearing capacity of the transmission shaft assembly and
extend its service life.

3.5 Anti-drop device:

In order to avoid the fracture of drill housing or the drop of components into the well in trip in case of any abnormal factors, an anti-drop nipple is added on the upper part of the screw and lower part of the bypass valve. The nipple housing cannot be damaged easily on the upper part of the screw motor and there is a suspender in the middle of it which is connected by a big round nut and a screw. The anti-drop device does not work in normal operation (with some stirring loss). Once the following housing of the anti-drop nipple is broken or removed with the screw and suspender moving down, the big nut in the middle of the nipple will fall on the hole shrinkage of the nipple housing, so that the screw can be hung and the slurry channel can be blocked, leading to the lifting of slurry pump pressure. In this way, people on the ground can find the problem in time and take relevant measures to prevent the loss expansion.

IV. Model description of the downhole motor:

For example: 5LZ165 × 7.0 refers to the downhole motor whose proportion of rotor head number and stator head number is 5:6 and the outer diameter is Φ165mm. The bit hydrophthalmos pressure drop is 7.0Mpa.

V. Main performance parameters of the downhole motor:
<table>
<thead>
<tr>
<th>钻具型号</th>
<th>外径尺寸</th>
<th>钻头直径</th>
<th>钻头长度</th>
<th>两段连接螺纹</th>
<th>头数</th>
<th>级数</th>
<th>流量</th>
<th>转速</th>
<th>工作压力</th>
<th>最大输出功率</th>
<th>输出功率</th>
<th>备注</th>
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<tbody>
<tr>
<td>5LZ4×7.5L-2</td>
<td>75.0</td>
<td>108.0</td>
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注：以上数据仅供参考，具体参数请根据实际工况和设备性能进行选择。
VI. Notice for use:

6.1 Workover and drilling technicians and drillers on the well site must understand the structural principle and operation parameters of the drill tool, and use the drill tool rationally in accordance with the requirements of the manual.

6.2 Requirements for the drilling fluid: The motor of downhole motor is volumetric, and the factor that determines the drilling performance factor is the input flow and pressure drop affecting on both sides of the motor rather than the type of the drilling fluid. Only a few physical and chemical properties of the drilling fluid could influence the service life of the drill tool. Generally, its performance cannot be affected. However, various hard particles contained in the drilling fluid must be confined, for it will accelerate the wear of bearing and stator motor, so as to reduce the service life of the drill tool. Therefore, the sand content in the slurry must be controlled below 0.5%.

The viscosity and specific gravity of slurry has small impact on the drill tool, but it is with direct impact on the pressure of the entire system. If the pressure with recommended discharge capacity is greater than the rated pump pressure value, the slurry discharge capacity shall be reduced or the pressure drop passing through the drill tool and bit is necessary to be reduced. Each model of drill tool has its own input flow range, and the drill tool can achieve the relatively high efficiency only within such range. Generally, the middle value of the input flow range shall be taken as the optimum input flow value.

6.3 Requirements for slurry pressure:

When the drill tool is hung in the air, the discharge amount as well as the pressure drop of slurry passing through the drill tool will not be changed. With the increase of drilling pressure under the will by bit contact, the circulating pressure of the slurry will be increased along with the pump pressure. The following formula can also be applied by the driller for operation:

\[ \text{Pump pressure of drilling} = \text{circulating pump pressure} + \text{load pressure drop of drill tool} \]

Circulation pump pressuring is operated when the drill tool does not contact the bottom of the well, which is also known as the off-bottom pump pressure. When the torque of the drill tool is increased, the pump pressure will be raised and the reading on the pressure gauge will be called the pump pressure of drilling. Off-bottom pump pressure is not a constant, which varies along with the change of the well depth and
slurry characteristics. However, the accurate value of the circulating pump pressure doesn’t have to be tested at any time in actual operation, which generally takes the off-bottom pump pressure after each time of contact as the approximate value, so as to completely satisfy the accuracy requirements of the formula.

The drill tool could produce the optimum torque in operation when the pump pressure of drilling reaches the maximum recommended pressure. If the drill pressure is increased continuously to exceed the maximum design pressure, the motor may be stopped. At this time, the drill pressure shall be reduced immediately to avoid any internal damage to the drill tool.

6.4 Torque:

The torque of the drill tool and the pressure drop produced by the slurry by passing the motor are in direct proportion, and the rotation speed is in direct proportion to the input flow. When the discharge capacity is determined with the increase of the torque and the unchanged of the rotation speed, the speed reduce of the drill tool from no load to full load will not exceed by around 10% in general.

VII. Method of application:

While selecting the drill tool and the combination program, the operation plan of workover and drilling shall be developed with full consideration of details such as the well track, bit type, specification, strata configuration and water conservancy computation. Before leaving the factory, the screws among each component of the downhole motor are all coated with anaerobic adhesive, and the torque is required to be tightened without the need of re-tightening before use.

7.1 Ground check before down-hole of the drill tool

7.1.1 In addition to the enhancement of connection between the short section and the bypass valve of the drill tool, other parts of the housing must be coated with anaerobic adhesive.

7.1.2 The bit shall be installed with the bit loading and unloading tool. Only the chain tong is allowed to turn the transmission shaft of the drill tool, and it shall only conduct counter-clockwise rotation to prevent loose of the internal thread.

7.1.3 The short section shall be lifted, the drill tool shall be placed in the rotary slip, and the bypass valve shall be located above the turntable with the installation of safety slips and the unloading of lifting short section.

7.1.4 Check the flexibility of the bypass valve: Press the valve element with the wooden stick, then release it, the valve element will be recovered to normal under the effect of the spring force. Repeat the pressing for 3 to 5 times, the valve element
without jam can be moved flexibly. Then start pumping under the turntable of the bypass port of the drill tool, to close the bypass port, start the motor, and drive the connector to rotate. When the pumping stops, the valve element shall be reset, and the slurry shall be poured out of the bypass valve port with normal work of the drill tool.

7.2 Place the drill tool down into the well:

7.2.1 The decentralization speed shall be controlled strictly in down-hole of the drill tool, to avoid reverse the motor by excessively fast speed, leading to the trip of the internal connecting screw thread. Meanwhile, the drill tool shall be avoided to be cracked up by the passing the sand bridge and the casing shoe. In order to present buckle transfer in operation, it shall be borne in mind during the unloading process that the rotary direction of the bit adapter is counter-clockwise. In case of any violation of this rule such as the reversing rotation of the turntable or the tightening of motor by the turntable, the internal parts of the drill tool will be loosen or removed, which users shall notice.

7.2.3 When entering downward to the deep well section or the high-temperature well section, and passing the sand well section, regular slurry circulating shall be conducted to cool down the drill tool, protect the stator rubber and avoid sand plug.

7.2.4 It should slow down when getting close to the bottom of the well by the drill tool. The drilling downward shall be carried on after the advanced circulating. Small discharge capacity shall be taken by the circulating initially before the large discharge capacity when the slurry is poured to the mouth of the well.

7.2.5 It is not allowed to churn drill or place the drill tool on the well bottom.

7.3 Start operation of the drill tool:

7.3.1 A height of 0.3 to 0.6 meters must be lifted on the bottom of the well to start the drilling pump. Write down the reading of the pressure gauge at this time and compare it with the calculated pressure value. It is also normal if the value is greater than the pressure with hydraulic calculation, which is caused by the sidetracking of bit.

7.3.2 Clean the well bottom. The bottom of the well must be “clean” enough, because any pile-up or sedimentary debris there will affect the rotation speed.

7.4 Drilling by the drill tool:

7.4.1 The bottom of the well must be cleaned completely before the drilling by the drill tool with the measurement of the circulating pump pressure.

7.4.2 The drill pressure shall be added slowly in the initial drilling. When it becomes normal, the driller can use the following formula to control the operation:

Pump pressure of drilling = circulating pump pressure + load pressure drop of
drill tool

7.4.3 The drilling speed should not be too fast at first. Because the driller tool and the bit are both tight at this time, and the well bottom hasn’t been cleaned yet, it is easy to produce bit balling.

7.4.4 The torque produced by the drill tool is in direct proportion to the pressure drop of the motor, so the torque can be increased to strengthen the drill pressure.

7.4.5 Uniform bit feed could ensure the smooth curve of the well section and the orientation longitude.

7.5 It should be removed from the well hole with the check of the drill tool:

7.5.1 The bypass valve is open when the drilling starts. The drilling fluid in the drilling column is allowed to be poured into the annulus, but the well fluid cannot be excluded by the drill tool itself. Therefore, a section of weighted drilling fluid shall be added on the upper drilling column before the lifting, so that the well fluid can be discharged successfully.

7.5.2 The drilling speed shall be noticed when it begins to drill to avoid any damage of the drill tool by the jam.

7.5.3 After drill tool is lifted to the bypass valve position, each part on the bypass valve port shall be unloaded, the top of the bypass valve shall be flushed with clean water, then press and release the valve element with the wooden stick or handle, to make it move smoothly upward and downward without jam. After the washing, the short section shall be tightened and lifted with the extraction of the drill tool.

7.5.4 The bearing clearance of the drill tool shall be measured. If the value exceeds the maximum tolerance, it should be repaired with the replacement of a new bearing (the axial clearance of the bearing shall be adjusted for the workover and drilling).

7.5.5 Remove the drill tool and flush the bit from the transmission shaft port. Clean the transmission shaft strainer and bearing, then place the drill tool flatly with normal maintenance for future application.

If it is laid up or unused for a long time, it is recommended to inject a small amount of mineral oil in the drill tool for rust resistance (diesel shall not be added).

VIII. Failure analysis of the drill tool:

As is stated above, the circulating pressure variation of the drilling fluid can be reflected on the upright tube pressure gauge, so as to help personnel on site to identify the situation and problems on the well bottom. It is verified by the truth that correct judgment could save a lot of time and cost consumption. Various factors in the integrated use of the drill tool can be reduced to the following table for users’ reference.

Failure analysis table of the drill tool:
<table>
<thead>
<tr>
<th>Anomalies</th>
<th>Possible causes</th>
<th>Judgment and treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>A sudden pressure increase of the pressure gauge</td>
<td>Motor stall</td>
<td>The drill tool shall be lifted to about 0.5m with the check of the circulating pressure. The drill pressure shall be gradually increased, which is very normal, only indicating that the motor has been stalled before.</td>
</tr>
<tr>
<td>Jam of the motor and transmission shaft, and block of the hydrophthalmos</td>
<td>When the drill tool is lifted off the well bottom, the reading on the pressure gauge is still high, then the drill tool shall be checked or the bit shall be replaced.</td>
<td></td>
</tr>
<tr>
<td>Reading on the pressure gauge increases gradually (abnormal pressure drop that increased with well depth or well temperature)</td>
<td>Block of the hydrophthalmos</td>
<td>Extract the drill tool out of the well bottom and check the pressure again. If it is still higher than the normal circulating pressure, try to change the circulating flow or move the drill pip up and down. If still inapplicable, the drill tool shall be used to check and repair.</td>
</tr>
<tr>
<td></td>
<td>Bit wear</td>
<td>Drill deeper and observe carefully. If still inapplicable, the bit shall be taken out and replaced.</td>
</tr>
<tr>
<td></td>
<td>Stratum change</td>
<td>Lift the drill tool slightly. When the pressure is the same as the circulating pressure, go on to work.</td>
</tr>
<tr>
<td>Gradual reduction of the reading on pressure gauge</td>
<td>Loss change of the circulating pressure</td>
<td>Check the slurry (well fluid) flow</td>
</tr>
<tr>
<td></td>
<td>Drill pipe damage</td>
<td>Lift the drill tool slightly. When the reading on pressure gauge is lower than the circulating pressure, increase the pump pressure appropriately. If still inapplicable, it shall be taken out of the well hole for check.</td>
</tr>
<tr>
<td>No drilling footage</td>
<td>Motor failure</td>
<td>Increase the reading on pressure gauge, extract the drill tool out of the well bottom, check the circulating pressure, and gradually increase the drill pressure.</td>
</tr>
<tr>
<td></td>
<td>Bypass valve in the position of “open”</td>
<td>The reading on the pressure gauge is a little lower. Lift the drill tool slightly to start and stop the slurry pump for twice. If still inapplicable, the bypass valve shall be checked or replaced.</td>
</tr>
<tr>
<td></td>
<td>Cardan shaft damage</td>
<td>It is usually with pressure fluctuation. Lift the drill tool slightly to make the pressure fluctuation range smaller. Taken out of the drill tool for check and replacement.</td>
</tr>
<tr>
<td></td>
<td>Bit wear</td>
<td>Replace it with a new bit.</td>
</tr>
</tbody>
</table>
IX. Maintenance of the drill tool:

The service life of the drill tool is dependent not only on the malicious design and precise manufacturing, but also on the correct use and strengthened maintenance. The well mouth of the drill tool shall be with maintenance after use of each time. As for those whose bearing clearance is greater than the maximum tolerance, they shall be delivered back to the maintenance station for demolition and check.

9.1 Drill tool demolition

9.1.1 In case it is confirmed by the technicians about the failure of the drill tool after use and the drill tool cannot be used in the well any more, it shall be sent to the repair station for demolishing and repair immediately.

9.1.2 The drill structure shall be fully understood before demolishing to be in accordance with the orders and requirements.

9.1.3 The demolishing of the drill tool involves two parts including the housing and the internal transmission connection. As the cardan shaft housing and motor transmission shaft housing screw joint, the cardan shaft and rotor, and the strainer thread of transmission shaft are all coated with anaerobic adhesive, the torque shackle shall not be increased arbitrarily in demolishing, instead, it shall be done as soon as the connecting part is heated to 250 to 300℃ by the blow lamp. Besides, wire brush shall be used to clean the residual adhesive on the thread timely.

9.1.4 Before removal, the tools shall be prepared and the record shall be made, which includes the drill tool number, use unit, footage number, operating time, use well depth, well temperature, axial clearance and repair reasons.

9.2 Repair and maintenance of the bypass valve assembly:

9.2.1 Clean and check each component. In case of any trenches, bites and coating peeling, it shall be replaced, and all the o-rings shall be replaced as well.

9.2.2 The bypass valve shall be replaced in case of any washout of the mesh hole.

9.2.3 The spring should be replaced after 100 hours of use.

9.2.4 The surface of assembling parts shall be coated with butter, and the valve element shall be moved for several times after assembly without jam.

9.3 Repair and maintenance of the motor components:

9.3.1 Demolish the rotor, and clean the stator cavity as well as the thread surface.

9.3.2 Any adhesive removal or peeling of the stator rubber shall be checked. In case there is peeling along with the appearance of many trenches, the stator shall be
9.3.3 The surface coating of the rotor shall be checked for any peeling, rust, wave and trenches. In case of the above phenomena, it shall be replaced.

9.3.4 After cleaning and inspection, the stator surface shall be coated with butter and the stator shall be installed into the stator. The motor part shall be inclined to 30° for leakage volume and torque test, so as to determine whether the motor shall be re-allocated.

9.4 Repair and maintenance of the transmission shaft parts:

9.4.1 If the bearing clearance exceeds the specified value or the rollaway occurs significant groove, pock, edge peeling or any low of steel ball fragmentation, the whole set of multi-row thrust ball bearings group should be replaced.

9.4.2 It is prohibited to mix old and new balls and use the steel ball groups that haven’t been selected.

9.4.3 Check the inner and outer ring of the upper and lower radial bearing. In case of any weld layer peeling on the surface, the alloy block will be damaged seriously with the diameter grinded by more than 1mm, so a new radial bearing shall be replaced with.

9.4.4 Check the transmission shaft. In case of any trenches and cracks on the surface, a new transmission shaft shall be replaced with.

9.5 Assembly of the drill tool:

After the assembly of the bypass valve, motor, cardan shaft, and transmission shaft after repair and maintenance, the housing and the internal transmission unit shall be connected in order with the cleaning of thread and coating of anaerobic adhesive, so as to ensure that the torque can be tightened according to the specification after the completion of process such as the transmission shaft clearance.

X. Notes for goods ordering:

If you hope to achieve the satisfactory use effect of the drill tool, you shall not only pay attention to the quality conditions and technical performance of the drill tool itself, but also the use purpose, environmental and medium conditions, driller tool combination and other closely related factors. Therefore, the correct selection of the drill tool model and structural form in ordering is extremely important.

In case of any doubts in selecting drill tool model, please contact with us immediately.

In order to provide you with the right product timely, please confirm the
following few questions when ordering:

10.1 Whether you need be provided with accessories (such as lifting short section)

10.2 If possible, please provide the following information when ordering for the convenience of our service track:

① Using unit of the drill tool
② Using well position, purpose and estimated time of the drill tool
③ Well structure, drilling selection and slurry conditions in utilization