Best Practices for Downhole Motor Operations in Coiled Tubing Applications

INTRODUCTION

The application of downhole motors with coiled tubing operations has become routine in today's expanded scope of coiled tubing services. Bearing in mind the relatively high cost of coiled tubing operations, emphasis needs to be placed on maximizing the reliability of all the components within the system. Many of the difficulties encountered could be avoided, given that all parties involved have an appreciation of the hazards and practices that can prevent problems from occurring.

This discussion is to provide a basic under standing of the concerns associated with running motors on coiled tubing, applicable to both workover and drilling. Topics include the performance characteristics of positive displacement motors, complementary components of the bottom hole assembly (BHA), and the various procedural and well data issues that impact the success of operations. The information provided is as specific as can be generally applied and refers not only to the engineered specifications of the equipment, but to related proven practices as well, based on field experience.

MOTOR PERFORMANCE

The positive displacement motor produces torque as fluid is pumped through its power section, consisting of the rotor and stator. It is the configuration of these two parts that determines the motor's operating characteristics of flow rate, speed, pressure differential and torque. Figure 1 depicts a cross-sectioned schematic of several rotor/stator configurations.

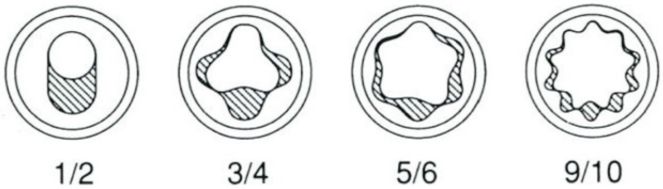
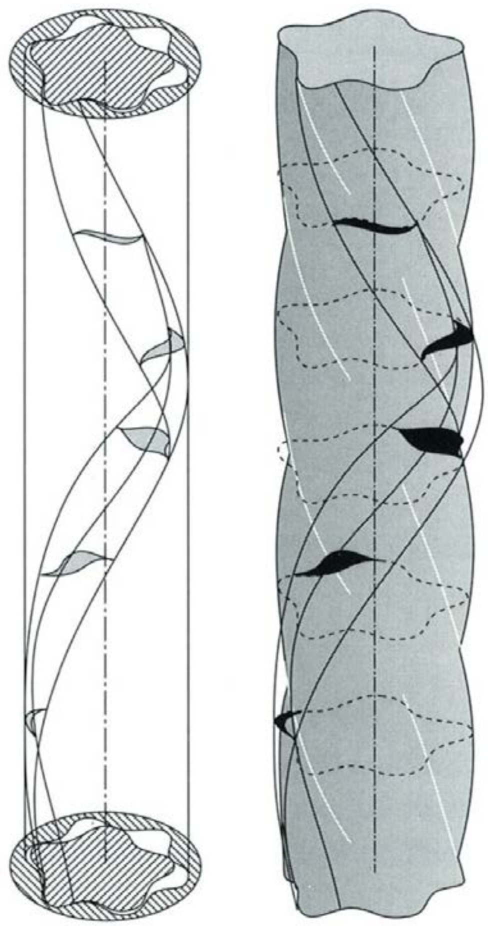


FIGURE 1

Torque production is associated with the attempt to maintain a given flow rate through the tool against the resistance created at the bit. As seen in Figure 2, the fluid passage through the tool is channeled through the power section, following the cavity that is created by the rotor, as it will have one less lobe than the stator.

The lobe configuration, patterned in a helix, provides a scaled chamber for the fluid. The chamber is created because the length of the helical pattern of the stator is longer than that of the rotor. One full revolution of the stator lobe helix constitutes a stage. Each stage within a power section provides additional torque, as the fluid trapped in each stage acts on the effective area of elastomer within that stage. Correspondingly, pressure differential is increased with additional stages.

FIGURE 2: Power Section Stage



The conventional power section consists of a one-lobe rotor matched with a two-lobe stator. This design produces high speed with relatively low torque output per stage. The multi-lobe configuration provides greater torque production within a shorter length, at a given speed. The multi-lobe configuration also acts as a gear reduction, providing the higher torque at a reduced speed, much like a planetary and sun gear arrangement.

Based on the rotor/stator configuration, the motor's speed will correspond to the flow rate until restricted, as with weight on bit. As weight is applied to the bit, this torque demand will be seen as differential pressure, illustrated in Figure *3.* If weight on bit continues to increase, the motor's speed will decrease to a point of stall. Stall occurs when the resistance to rotation produced at the bit overcomes the scaling capacity between the rotor and stator, at which point the flow bypasses the normal flow path through the power section.

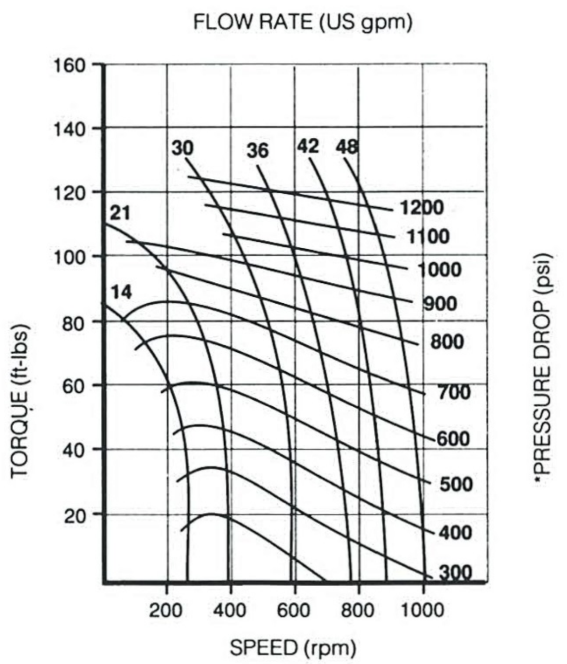


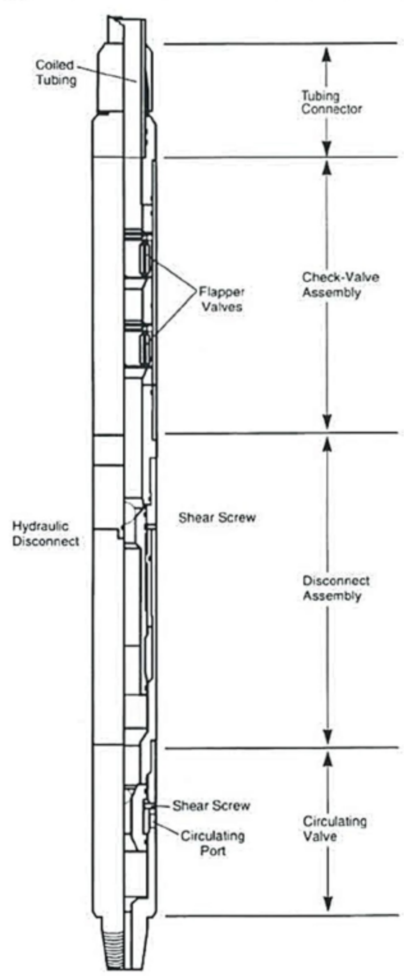
FIGURE 3

The other components of a motor consist first of a transmission, which can be of various designs - all serving to convert the eccentricity of the rotor's precession into a concentric rotation. Connected below the transmission is the output shaft, which is supported by both radial and thrust bearings. The thrust bearings must absorb the downward force of the rotor, created by the fluid's flow through the helical lobe design, as well as the upward force created by weight on bit.

For durable motor performance, each of motor's components must be engineered compatibly with the motor's other components, thus achieving desired performance characteristics with predictable wear patterns.

BOTTOM HOLE ASSEMBLY

When a motor is attached to coiled tubing, additional attention to detail and caution is necessitated. Individuals who are accustomed to running other tools on coil do not always appreciate the additional stresses that the motor creates, most notably torque and vibration. In Figure 4 a typical workover motorhead assembly



is shown, including the connector; check valve assembly, hydraulic disconnect and circulating valve.

Many of the assemblies on the market today were not designed with adequate attention devoted to motor applications, resulting in numerous failures. These failures have normally occurred in the hydraulic disconnect or in the tubing connector. Each of the components must withstand the axial loads that can be delivered through the coil at depth. They must also withstand the maximum stall torque produced by the motor, seen as reactive torque by all parts above the motor: Reactive torque, coupled with vibration, can act as a hammer that will beat apart loosely toleranced mating faces, particularly evident in hydraulic disconnect failures.

There are a variety of tubing connectors on the market, several of which are adequate for motor operations. Ideally, the connector device will not only provide reliable axial and torsional load capacity, but it also should minimize deformation of the tubing and allow quick and simple installation.

In a drilling or fishing operation, the components below the connector will include such equipment as collars, jars, MWD tool, and orienting tool. The positioning of such accessories is subject to well conditions and individual dis- cretion.

In a workover application, the check valve assembly would normally be attached directly below the connector, providing back pressure control. Two valves normally are included for added safety. Flapper type valves are used to permit drop ball passage.

The hydraulic disconnect is included below the check valves to provide a controlled emer- gency release device in the event the tools become stuck. Actuation of the release permits the operator to disengage the tools, with the option to reconnect with a retrieval tool in a fishing operation.

Below the disconnect, the circulating valve is included to allow an increased circulation rate for assurance of hole cleanout. Normally, the maximum allowable flow rate for the motor is well below the rate that the coil's friction loss limitations would otherwise permit. Often the motor's maximum flow rate docs not allow annular velocities that assure complete removal of cuttings. The circulating valve can be activated when the target depth has been achieved. isolating the motor from the flow by a seated drop ball and allowing the flow rate to be increased to the coil’s limitation. This valve also provides isolation of the motor for the displacement of fluids that would be damaging to the motor’s internal components, such as methanol diesel or acids.

The selection of tools to be run below the motor could lead to lengthy discussion and debate, but the following points should be considered in selecting these tools.

- Consider the compatibility of diameters, including tubular restrictions when working in cased hole, BHA component diameters, and deviation if working in open hole.

- If a roller cone bit is to be run, consider its ability to withstand the motor’s rpm level and plan inspection trips accordingly.

- When a fixed cutting head is to be used, consider that all motors provide relatively high rpm, compared with conventional rotary or power swivel drilling. Therefore, good penetration rates can normally be achieved without an aggressive cutting structure. An aggressive cutting structure can be counter to good penetration rates, due to increases in the frequency of motor stalls.

- Underreamer applications with motors on coil provide excellent cost savings opportunities, but should be carefully selected for best performance. Issues to be considered include:

Length. The longer the tool below the bit box is, the greater is the tendency to stall the motor, due to increased side loading of the output shaft, wasting horsepower.

Debris traps. The tool's design should minimize the potential for cuttings to become lodged in areas that could cause blades to be locked open.

Positive blade retraction. Blades that are allowed to hang freely when not hydraulically activated represent a hazard for hanging up in downhole equipment or perforations.

Pilot mill. If the tool has a pilot mill leading the blades, it should be as close to the blades as possible, as it presents the potential to stray from the center line or the bore, in turn point loading the blades, particularly when blades are staggered and spaced far apart.

Durability. The tool design, particularly that of the blades and hinge arrangement, must be strong enough to withstand more than any torsional loads the motor can produce because any bending or the blades will normally prevent their retraction, preventing the return through restrictions.

OPERATIONAL CONSIDERATIONS

Before running a motor on coiled tubing, numerous points should be considered, most of which appear too obvious to note, but are stressed because they continue to be often ignored, causing delays and job failures. A clear and achievable objective should begin the process, including a detailed schematic or the well or well plan.

The compatibility of all tools should be established. The first consideration is that of hole size or tubular restrictions that will determine diameters.

The motor’s maximum stall torque must then be compared to the coiled tubing’s size. An established safety factor is to ensure that the motor's maximum stall torque, when multiplied by two, does not exceed more than 80% of the coil's nominal torsional yield. This provides protection against excess fatigue or failure or the coil.

Downhole hydraulics must be defined to ensure that unacceptable pressures will not be required, given the flow rates that are determined with the fluid that is to be used. All pressure drops in the system should be defined. If insufficient annular velocities are then anticipated, the procedures should include periodic gel sweeps and a conservative penetration rate that will not exceed hole cleaning capacity or the system.

The downhole working environment for the motor is the final determining consideration prior to committing to the procedure. The fluids used in the job must be determined as compatible with the motor. Generally stated, any fluid that is destructive of, or will cause swelling of a nitrile based elastomer can be expected to shorten the motor's life, or even prevent it from performing. The list of detrimental fluids includes, but is not limited to: diesel, methanal solutions, and crude oils with high aniline points and low aromatics. Some compensation for swelling can be done with the motor's power section, but questionable fluids should always first be discussed with the manufacturer.

Any use of compressible fluids such as air or nitrogen will require the addition of foam or lubricating mist for lubrication. Downhole motors have proven to perform with compressible fluids. but a loss or efficiency and less precise performance control should be expected.

The bottom hole temperature represents one of the most dramatic influencing factors on motor performance. Motors are often run beyond their temperature specifications, but as temperatures approach 300°F(149°C) the predictability or useful life becomes increasingly less definable. Cooling the motor by pumping while running in the hole is helpful, but is not an option when running underreamers, and it has minimal impact with small diameter coil and limited pump capacities through the smaller motors.

GENERAL PROCEDURAL OUTLINE

Once it is established that a downhole motor is to be used and the operating conditions have been defined. procedures can then be detailed. The procedures listed here are to provide a general guideline for operations intended to prevent the dangers of tools lost in hole, as well as damage to the tools or downhole equipment.

Rig Up Procedure

- Ensure that the coil is clean.
- Inspect all tools on location.
- Drift ID's of motorhead assembly with drop balls.
- Inspect O-rings.
- Attach tubing connector to coil.
- Pull test tubing connector.
- Retighten tubing connector.
- Make up motorhead assembly.
- Attach bull-plug with relief valve.
- Pressure test motorhead assembly.
- Make up motor.
- Displace any air from coil at low pump rate.
- Surface test motor (not done in freezing temperatures).
- Make up bit, mill or underreamer.
- Pull BHA into lubricator (if applicable).
- Nipple up lubricator and pressure test surface equipment.
- Start in hole.

General Operating Procedures

- Run in hole at 50-100' per minute (following safety regulations) not exceeding 20’ per minute through any accessories.
- Establish starting depth. i.e., lightly tag. monitoring for weight loss.
- Pick up approximately 50’ and establish circulating pressure.
- Feed coil extremely slow until pressure increase is indicated.

It is at this point where patience is critical, in that motor stalls can be expected to occur repeatedly until a cutting pattern is established. Coil should be fed at a rate that attempts to maintain a 300-400 psi differential above the off bottom circulating pressure. As Figure *5* illustrates, applied weight will be indicated by an increase in pressure, which will decline as the weight is drilled off. The ideal procedure is to feed the coil precisely in time with the penetration rate, maintaining a relatively constant pressure differential.

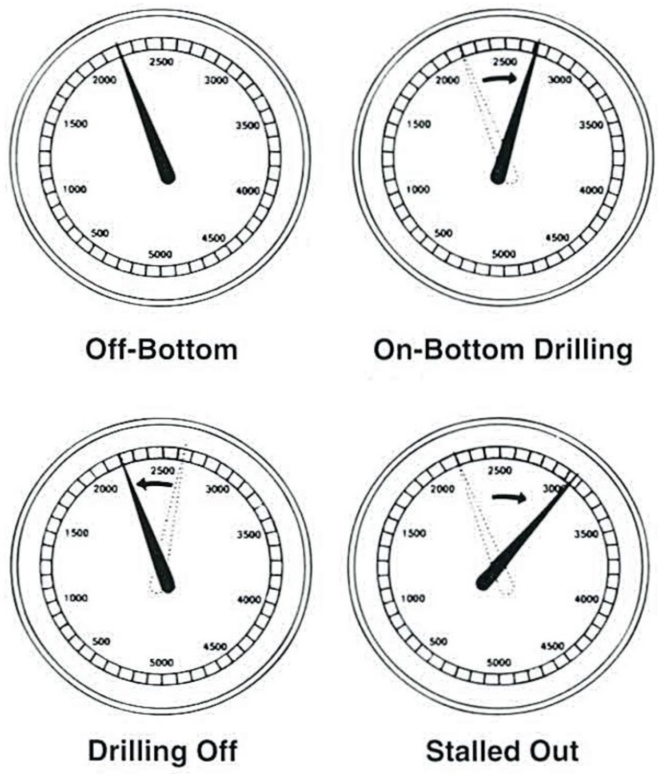


FIGURE 5: Pump Pressure Gauge

Despite the effort, however, stalls will likely occur, reflected by a significant pressure increase, which will damage the motor if not promptly corrected. To eliminate the potential for a tool backoff, it is important to shut down pumps and bleed pressure before picking up off bottom. Having cleared the cutting surface from bottom, the operator can then attempt to resume his drilling procedure.

- Pump gel sweeps as dictated by annular velocities.
- Upon reaching target depth, activate circulating sub.
- Circulate bottoms up, at least one full circulation.
- Any necessary chemicals can be displaced.
- Pull out of hole and rig down.

COMMON PROBLEMS

As indicated earlier, motor operations on coiled tubing continue to experience an undue level of problem jobs. The type of failures noted here represents those most commonly reported. They are presented in no particular order and do not necessarily represent a complete list, but they do address the issues discussed here.

Premature Motor Failure. Causes include: poorly engineered or poorly manufactured motors, pump rates well above specification, temperatures well above specifications, poor or no solids control, excessive stalling or extended pump time in stall, pumping chemicals that the elastomers cannot tolerate, and running oversized bits and mills.

Hydraulic Disconnect Failure. The most common failure appears to result from poor design, but failures also have occurred where undersized assemblies were run with larger diameter motors. Improper assembly, service, and inspection procedures have also been evident.

Tubing Connector Failures. Poor design has been responsible for some failures, but more often poor make-up or test procedures have caused the failure. Occasionally, the connector fails as a result of excess pull, but this is usually an intentional effort done as a last resort with stuck tools.

Tools Stuck In Hole. Although this is often simply attributed to poor annular velocity, it is more often a reflection of inexperience or poor judgment. Many jobs have been successfully completed with available annular velocities far below what might be considered acceptable, but they were executed with extreme caution and patience. Tools are often stuck because the operator assumes that, as long as the penetration rate is progressing smoothly, there is no reason not to continue drilling ahead.

Where annular velocities are known to be inadequate, periodic gel sweeps are a must, sometimes as often as every 10' of penetration. Mechanical failures also account for stuck tools, particularly with underreamers that fail to close clue to tool damage or trapped debris. Running in hole or pulling out too fast has also contributed to such problems where lack of caution was apparent in passing through a restriction.

SUMMARY

Downhole motors have demonstrated a tremendous added versatility for coiled tubing services, and they offer significant potential of which many in the industry are not yet fully aware. It is therefore important to the continuing development of their applications that the performance of motors be evaluated in the framework of prudent application and procedure. It is also important that downhole motors not be considered as generic tools, because the performance and reliability can vary dramatically from manufacturer to manufacturer.

In reviewing the application of motors on coiled tubing, it becomes apparent that the tools below the coil are better viewed as a system – and that the system is heavily dependent upon sound operating practices to ensure high success rates.