Introduction

The ability to move tools into the borehole and selectively withdraw them is central to the drilling process. Whether a particular depth objective can be reached or the required casing can be installed depends on hole conditions and the equipment being used.

Hoisting and running in

The ability to move tubulars and tools in and out of the hole requires equipment with sufficient capacity to overcome the loads imposed by the work being done. Generally the highest loads will be experienced when pulling the drilling assembly out at total depth or when running casing.

Significant hoisting loads include the mass of the traveling equipment and anything suspended from the traveling equipment. Some examples include:

- Traveling blocks and line;
- Swivel or top drive;
- Casing running tools (CRT);
- Drillstring;
- Casing string;
- Riser string.

Significant braking loads include the mass of traveling equipment and anything suspended from the traveling equipment, as well as rotating inertia. Some examples of rotating Inertia include:

- Drum;
- Flanges;
- Gear train;
- Motors, etc.

In addition, when considering total loads, one must include system friction:

- Gear or chain losses;
- Bearing loss;
- Drilling line reeving efficiency;
- Resistance caused by friction between the drilling assembly and the wall of the hole.

System capacity can be addressed through three elements: hoisting power, braking capacity (stopping) and component strength. Hoisting power is the ability to move a load at a particular speed. Braking capacity is the ability to stop a moving load, while component strength is the ability to withstand a load without failure.

To differentiate between power and component strength, consider the example of a train pulling a line of cars. If an 'engine' with several thousand horsepower is attached to the cars with the steel couplers, the cars will move forward with the train. However, if the cars are attached to the same engine with soft line (fiber rope), it is quite likely that the soft line will part and the load will not move. So, even with sufficient power and traction, failure of an element in the system can prevent task completion and potentially cause damage or injury. Conversely, attaching the cars with steel couplers to an engine with insufficient horsepower will not cause a failure, but the train will not move.

In the case of a drilling rig, the system may be thought of as a chain, as there are many elements working together to hold the load. Further, if any one link lacks sufficient strength, the entire system will fail. In a conventional drilling rig, the system comprises:

- Drawworks structure;
- Drilling line;
- Crown block;
- Travelling block;
- Hook;
- Swivel or top drive;
- Tubulars;
- Mast;
- Substructure.

Each element has a strength limitation, the load at which failure will occur. Under certain circumstances, the drawworks capacity and loads imposed by the drilling or casing operation may exceed the strength of a system component. The well planning process should include an examination of the expected loads, and provide for appropriate components to withstand expected loads. In addition, it is good practice for the drilling contractor (owner/operator of the equipment) to provide an easy reference chart detailing the maximum loads (pull) allowed for each component. The maximum pull should represent the physical limit of the component, reduced by some safety factor. The safety factor provides a margin for unknowns such as equipment wear, instrumentation inaccuracy, or sudden loads etc. The initial planning process should account for the known loads, such as planned tubulars at the expected total depth, but also estimate hole drag.

Once drilling has begun, the driller, who is operating the equipment, must be aware of the lowest capacity element in the chain, and ensure that loads do not exceed that capacity. The driller primarily relies on the weight indicator to show the load on the system and must continually compare the actual load with the maximum allowed.

Power available to the system determines whether the load can be moved and how fast. In a conventional drawworks rig, the drum rotates and reels in the drilling line to move the blocks. The power at the drum can be supplied by an electric motor, an internal combustion engine or hydraulics. However, in all cases internal friction in the drawworks and drive reduces available power. The available power at the hook is further reduced by losses in the cable reeving through the crown and traveling block. The load or weight on the blocks is a function of the single line pull (drawworks capability) multiplied by the friction-adjusted mechanical advantage provided by the block and tackle system.

Pipehandling

The majority of drilling is performed with jointed pipe; that is, the pipe is provided in fixed lengths that must be connected together to allow drilling to proceed. Pipehandling is the process whereby the tubulars are moved from the storage racks to the drilling floor and then in and out of the hole. Handling pipe is one of the main causes of personnel injury at the rig site.

Pipehandling includes moving and connecting tubulars for drilling; moving, disconnecting and reconnecting for bit trips; and moving, disconnecting and returning the tubulars to the storage racks.

Make up and break out

Jointed pipe typically used for drilling has male ("pin") and female ("box") threads that are screwed together to provide a mechanical connection to transmit the drilling torque and tension. This connection also provides a pressure tight path for the flow of drilling fluid. In order to make up or break out pipe, tools are required that have the appropriate size and strength to spin the threads together and achieve the torque required to create the connection. When connecting or disconnecting the pipe, the string must be suspended above and below the connection.

The rotary table or bowl, which is supported by the substructure, suspends the lower part of the drillstring with slips gripping the pipe. Each of these components has load rating, and size that must be appropriate for the load and size of tool to be handled. The swivel, top drive or elevators will support the upper part of the connection to make up or break out. The final requirement to make and break a connection is a tool, or tools, which can apply torque to the joint and rotate the connection free. They must be chosen to match the size of tubular being handled, and have sufficient strength to withstand the torque required to complete the connection.

Racking

When it is necessary to replace the bit or modify drilling components, the drillstring must be pulled from the hole and stored, allowing the bit or bottomhole assembly to be changed. The pipe may be laid down or stood back in the mast (racked). Racking can be conducted by vertically raising one joint (singles), or multiple joints connected together (doubles or triples), reducing the number of connections required. The racked joints are stored between "fingers" that hold the pipe in place. The number of joints to be stood together (whether singles, doubles or triples) and the maximum joint diameter in the fingers are usually calculated at the outset.

Rig design limits pipe racking in the derrick in two ways. Space limitations on the rig floor are one consideration. The load (weight) limitation of the rig floor, which is supported by the substructure, is the second consideration. The load limitation for the racking area may be affected by loads carried in the rotary table, depending on the design. This information is available from the manufacturer's rating. When the load rating of the rig floor is known, the number of joints or length of pipe that are safe to rack on the floor can be calculated by dividing the load rating by the linear mass of the tubulars or the weight per joint. The number of joints cannot exceed the physical space available for the pipe to stand or the manufacturer's load rating.

This calculation should be performed as part of the rig selection process to ensure that total depth can be reached safely with the planned tubulars. Pipe is often racked on the floor while casing is being run, so the combined load must be compared to the manufacturer's allowable loads.

Auto-handling

Pipehandling is one of the most hazardous operations performed while drilling and completing a well. Even though the drawworks, assisted by other power devices, performs the hoisting, pipehandling is a physically demanding activity. Consequently, manufacturers offer devices to automate or mechanize some or all pipe-handling functions.

When moving from well to well, the pipe is commonly transported on flatbed trucks, then loaded onto simple storage racks (pipe racks). Alternatively, pipe may be stored for transportation in 'tubs', or steel frame boxes, which constrain the pipe and make lifting and transportation easier. The tubs may be simple boxes which require some external method to lift the pipe out of the box, or it might have a built-in hydraulic system which moves one row of pipe up to the level of the catwalk on command. The pipe is then rolled to the catwalk where traditionally, a worker will attach a sling and cable winch to the joint to pull it up the catwalk and onto the floor.

Presently, two mechanized systems exist to move the pipe from the catwalk to the floor. The pipe arm system is equipped with grippers that clamp onto the pipe so that as the pipe arm pivots up to the floor, the joint of pipe is carried with it. To allow drilling in the conventional 'pin-down' orientation, the pipe must be rolled onto the pipe-arm grippers with the pin pointing to the V-door. (The V-door is an opening at floor level in a side of a derrick or mast. It is typically opposite the drawworks and is used as an entry to bring in tubulars onto the rig floor).

Pipe arm systems currently work in 'single' mode; that is, only one joint is moved to the floor at one time. As well, pipe-arm equipped rigs generally do not rack pipe on the floor, but lay the pipe down during each trip. The second and most common mechanized method for moving pipe to the floor is the powered catwalk. These systems employ a moving carriage, which pushes the pipe up the V-door and delivers the box end to the floor, where it can be picked up with the elevators.

Rotating the connections together and making up to recommended torque has been mechanized in some form from the development of rotary drilling. Originally the pipe would be rotated together with the aid of a spinning chain, then made up with the cathead-powered tongs ("manual tongs"). The addition of a permanently mounted "kelly spinner" and the use of cable-suspended pipe spinners improved safety statistics dramatically. Manufacturers moved the process forward by combining the pipe-spinning function with a mechanized wrench capable of making up connections to required torque specification. With this method, the spinning chain and the heavy and awkward manual tongs were replaced.

Racking pipe involves:

- Disconnecting pipe to be racked from the pipe in the hole by floor hands;
- Drawworks operated by the driller;
- Manually moving pipe to the racking position by the derrickman and floor hands in concert.

Although this process has been refined over time, and with experienced crews has become extraordinarily efficient and rapid, it is physically demanding and prone to incident. The development of fully automated pipe racking for land rigs has been delayed by space and budget limitations. These limitations are generally overcome on larger floating rigs.

Two available systems can replace the derrickman function. The first is a complete system capable of picking up a stand after it is disconnected and placing it in the racking position without human effort. The second requires the stand's pin end placed into the racking position conventionally, i.e., with floor hands and drawworks, but pivots the stand into the racking system.

Tubulars

Current drilling technology utilizes various types of rotary bits. (See separate chapter in the 12th edition of the IADC Drilling Manual on Bits.) The bit can be rotated by a surface device, a subsurface device (downhole motor or rotary seerable system), or a combination. (Downhole motors and RSS are discussed in the chapters on Downhole Tools and Directional Drilling.)

To rotate the bit from the surface, either a rotating table or a top-drive system is used. The rotating table engages a kelly bushing through which a hexagonal or square Kelly bar is fitted. The Kelly bar makes up to the drillstring. When the table is rotated, the string rotates with it. The primary rotary table capacity is the weight of the string that can be supported in the slips while rotating or static. However, as torque is being transmitted through the table to the pipe while drilling, available horsepower and drive capacity limit rotating power.

The rotary table has a significant limitation: it is not possible to rotate (forward or backwards) and also hoist the pipe. This limitation becomes particularly problematic in difficult hole conditions, and led to the development of top-drive systems, which can drive the string from the top. Top-drive capacity comprises (maximum string load, rotating torque, and internal pressure capacity. Because the top drive is capable of rotating the string in both directions while hoisting, it is necessary to evaluate the combined stress capacity of the tubulars (simultaneous tension and torsion), as well as limit activities to some fraction of the connection make-up torque to ensure the pipe does not unintentionally separate downhole.

Hoisting Equipment

Drawworks

The drawworks is the primary hoisting machine on the drilling rig used to lower and raise the drill or casing strings. The drawworks converts the power source into a hoisting operation and provides braking capacity to stop and sustain the weights imposed when raising or lowering the drillstring. The drawworks is a machine with a power source, power transfer and speed reduction, large diameter drum, brakes and associated auxiliary devices.

The drawworks is typically driven by DC or AC motors or diesel/gas engines that are coupled to the power transfer and speed reduction system.

Figure RP-1: Typical drawworks. Courtesy Canrig.

