LINER ROTATION JOB PLANNING

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INTRODUCTION

Twice before, at the 1977, and 1981 Southwestern Petroleum Short Course[1,2], I presented papers on liner cementing equipment and techniques. In the first paper I explained a method of rotating liners while cementing and reported that not many liners were being rotated; probably about 1 in 30 jobs were rotated or reciprocated. In 1981 I gave a paper explaining why a new sealed bearing made the rotation of liners more reliable; but still only 10% or less liners were being moved while cementing-rotated or reciprocated.

Now, five years later, probably more than 20% of all liners are rotated and/or reciprocated during cementation. Liners have been rotated successfully even in directional holes offshore in the North Sea. One recent job was successful in a 47° deviated hole on a floating drill ship. This paper will attempt to show how new state-of-the-art liner rotation equipment has made this increase in popularity possible. We have listed the six major categories of causes for unsuccessful liner rotation jobs and have given some suggestions how they might be prevented.

ROTATION vs. RECIPROCATION

Where and how should one move a liner while cementing? Several good papers[3-10] have been written, based on extensive laboratory and field test programs, proving movement during cementing is essential for 100% efficient mud displacement. The most popular mode of pipe movement since the 1940's has been reciprocation, because it is cheaper and easier to perform on drilling rigs, whereas rotation requires the operator to rent either a power swivel or power tongs because most power rig rotaries are too fast. Only diesel-electric rigs can slow rotation below 10 rpm. Also, it is difficult to measure torque on the rotary rig.

A laboratory study by McLean, Manry and Whitaker[5] in 1967 concluded that rotation was preferred over reciprocation, especially in an eccentric hole. Pipe rotation was shown to have exerted a drag force on the mud in the low side of the hole causing the mud to be pulled around to the high side making it more easily displaced by cement.

In reciprocation, the pipe exerts a certain piston force on the bottom of the hole and, if stuck on the upstroke, may leave some uncased hole. The main reason rotation is preferred over reciprocation on liner jobs is that the drill pipe and setting tool can be released from the liner prior to cementing, whereas, in reciprocation, the liner setting string must remain attached to the liner. This, of course, entails the higher risk of setting the liner hanger and disengaging the setting tool after placement of cement. Often, the setting tool and some drill pipe is covered by cement at this time. Present state-of-the-art sealed bearing technology has made rotation of liners more acceptable than reciprocation and has provided a higher rate of success.

THE SEALED BEARING ROTATION LINER HANGER

The new rotating liner hanger uses a sealed load bearing consisting of a composite self-lubricating Teflon/Nylon laminate material[11]. This bearing is shown in the left inset in Figure 1. The load rating of each bearing is determined by the dimensions and strength of its weakest component part. The ratings of bearings used in rotating liner hangers are given as functions of pressure or stress (P) times linear velocity (V) or R.P.M. They are expressed graphically as PV ratings. Simply explained, if the stress or pressure felt by the bearing is high (up to its ultimate static load rating), the velocity or R.P.M. must be kept low. The PV rating of a typical 7 in. OD X 9 5/8 in. OD size liner hanger bearing is such that a 150,000 lb. liner must be rotated no higher than 8 R.P.M. The maximum length of the liner that can be rotated at higher R.P.M. is necessarily shorter than for slower R.P.M. In the above case, if one wanted to rotate 15 R.P.M., he should keep the liner weight to 80,000 lbs. or less.

LINER HANGER SELECTION

Just a brief discussion of liner hanger selection should be given here. Liner hangers are either mechanically or hydraulically set. The hydraulic setting means usually is selected because of crooked or deviated hole conditions or because the well is being drilled from a floating vessel. Hydraulic-set hangers are also preferable for running liners through previously existing liners -- there are no friction wiper springs to break off when the hydraulic hanger enters the liner top.

Most liner rotation jobs are performed with mechanically set liner hangers like those shown or explained in this paper.(Fig. 1)

METHODS OF ROTATION

Three different methods are used to rotate liners[12]. Most popular is the power swivel, with 45% of the jobs utilizing this method, followed by the electric powered rotary table with 38%, and power tongs comprising the final 16%.

THE POWER SWIVEL

The most popular method to rotate liners has been a special power swivel with a self-contained plug dropping and cementing manifold. The power swivel is the most expensive of the three methods to use and requires more rig up and tear down time; however, it's the most reliable and gives the best torque information.

ELECTRIC DRIVEN ROTARY TABLE

An electrically driven rotary table (on a diesel-electric rig) that is calibrated for torque is the most simple method of rotation and least expensive. It has excellent power control at low RPM. This method separates the weight indicator from the drill pipe and the only indication of down-hole problems would be a drastic change in torque reading.

POWER TONGS

Casing power tongs are used on 16% of the jobs in our experience. They are cheaper than power swivels. If power tongs are chosen to rotate the liner, we recommend using an increased power oil supply (120 gal.) to keep the fluid from overheating. Power tongs, normally, are used only for making up casing, an intermittent operation, and some tong rental companies are reluctant to have them used for the continuous service necessary for liner rotation during cementation.

JOB SUCCESS

Any discussion of what constitutes a successful liner rotation job must necessarily be as objective as possible, which is very difficult. Any such decision should consider the job itself and its results.

Such things as bond logs and other cement evaluation studies are sometimes difficult to explain and certainly are not within the scope of this paper.

What we have tried to do in this paper and in a previous paper[12] describing field results of rotating jobs is to set a very strenuous requirement for job success: rotation throughout the entire job. If rotation could not be maintained until most of the cement had been displaced, the job was not considered successful. For example, a previous paper in 1985 by Arceneaux and Smith[13] stated that Sun experienced a 77% success rate where rotation was maintained throughout the displacement and 88% where rotation was initiated. They said liner rotation has improved the primary liner cement jobs and reduced the remedial cement work.

Unsuccessful jobs may be categorized as follows:

(1) insufficient starting torque
(2) deviation or hole problems
(3) centralizer problems
(4) differential sticking
(5) excessive torque increase
(6) other

We have concentrated on the reasons for unsuccessful jobs and have tried to plan each rotating job so the operator will have a realistic idea of the chance for success.

Insufficient Starting Torque

This is the number one cause of rotating liner job failures. When the rotary is to be used to rotate the liner, the operator should have a good method to calibrate the torque delivered. We suggest this be done by rigging up the casing power tongs with drill pipe dies and rotating the drill pipe off bottom at different rates such as 5, 10, 15 and 20 RPM recording the torque at each rate. Then the drill pipe slips are set and the table used to rotate the drill pipe at the same rates: 5, 10, 15 and 20 RPM, recording the torque gauge reading. By using the comparison of the rotary drive torque and the power tong torque, at the same RPM levels, the rig gauges may be calibrated.

In some cases, operators were unwilling to go high enough on the torque to initiate rotation because they failed to consider the effects of drill pipe frictional torque apart from torque delivered to the liner.

For example: a liner joint has a maximum allowable torque rating of 5500 lbf-ft. To rotate drill pipe and liner before hanging requires 3500 lbf-ft and to rotate the drill pipe and liner together before hanging requires an initial torque of 3500 lbf-ft. After hanging the liner and releasing the setting tool,we find the torque to rotate only the drill pipe is 1000 lbf-ft.Rotating the drill pipe and liner takes 4200 lbf-ft. To calculate the maximum allowable surface torque, the torque to rotate drill pipe only and torque to overcome friction must be added to the maximum permissable liner joint torque.

In the above case it takes 700 lbf-ft to overcome bearing and friction plus 1000 lbf-ft to rotate only the drill string. All 1700 lbf-ft torque is above the top liner joint and must be added to the maximum permissible liner joint torque of 5500 lbf-ft. Therefore, the maximum surface torque to initiate rotation is 7200 lbf-ft. Even though rotation during the job will probably be much less, efforts to achieve the starting torque must be made. Stopping at any lower torque figure would be considered an unsuccessful job -- a failure to rotate.

We have not experienced any joint failures using the higher values obtained by this approach.

Deviation or Hole Problems

Severe dog-legs should be avoided for liner rotation success. Sometimes these dog-legs can be smoothed out or enlarged by reamers and every effort should be made to do so if successful rotation is to be achieved. We don't believe hole deviation in and of itself is any hindrance to rotation; we have rotated successfully in a 47° offshore well, as mentioned above. The gradual build-up of a high angle hole is not bad; whereas one simple dog-leg can prevent rotation of a liner.

Caving or bridging problems are serious enough for any casing cementing job -- for liner jobs they can be very serious. The operator should use every effort to clean and stabilize the hole before running liner.

Centralizer Problems

The next highest cause of unsuccessful liner rotation may be attributed to a category widely referred to as centralizer problems. The only evidence we have sometimes are pieces of centralizers found in junk baskets on top of the liner or in a few cases retrieved on the setting string. Some liners have been run halfway in the hole only to come out with no centralizers on the liner.

Although only about 14% of the unsuccessful jobs were attributed directly to centralizer problems, we looked at the overall success ratio of jobs which did or did not use centralizers[12].

Forty percent (40%) of the jobs in our study used centralizers; 60% did not. If a job had centralizers it was 27% more likely to be unsuccessful.

We are certain from our field experience that some centralizer designs and installment procedures are much better than others. Choose a good well-tested brand; install them on the pipe body, not around the collars; and put stop rings well above and well below each centralizer to insure that they don't rub against the stop rings while rotating.

Although a statistical case can be made for leaving off centralizers, this is not our intention. The purpose of this paper is to improve primary cementing success and we are reluctant to omit one way to accomplish this (centralization) in favor of another (rotation).

Excessive Torque Increase

When the cement begins to travel up behind the liner, torque generally increases. Probably a correlation could be made between the torque increase and how high the cement has risen, if all other factors such as hole size, rheology, formation types, etc. were constant. In a few jobs, this increase has become excessive and rotation discontinued. Knowing exactly how high one can go on the torque would help solve this problem. Preflushes to condition potential fluid loss zones have been very helpful in lowering torque.

Differential Sticking

The problem of differential sticking usually is associated with some loss circulation indications; by solving the loss circulation one can prevent different sticking. Rotating liner hangers have been an advantage in some wells where it was believed that by keeping the liner moving, sticking was inhibited.

Other Causes of Unsuccessful Jobs

Twenty-three percent (23%) of jobs where rotation was stopped early or could not be achieved we classified as "Other". These include jobs where sloughing shale was present; where the hanger just wouldn't hang; one where the power swivel hose became plugged; and some jobs where no single factor could be assigned. It should be noted that close clearance liner rotating jobs have a higher failure rate than others.

THE DOUBLE SPLINE METHOD

Fig. 1 is a drawing showing the most popular method of rotating liner hangers -- used in about 61% of our jobs. This method allows the operator to rotate before and after hanging the liner. The first step in Fig. 1 shows the setting tool holding the weight of the liner with the rotating dogs in the upper spline; rotation can be achieved now if the liner stops and one needs to rotate to get off a ledge or go through another liner. In the second step in Fig. 1, the liner setting tool is released and the rotation dogs are positioned in the lower spline. This is the operating rotational position. There is an intermediate position (not shown) where the drill pipe can be rotated by itself for torque calibration.

GENERAL COMMENTS AND CONCLUSIONS

It has been my experience over the past 34 years of liner hanger work that most drilling foremen are somewhat frightened about running liners. I think this is because they run about twelve to one more conventional casing strings than liner jobs and more things can go wrong on a liner job than on a normal or conventional casing job. Their job is over most of the time when the casing (or liner) is set and the production or completion people take over, so one can hardly blame them for wanting to get the job over with least amount of difficulty. The idea of rotating a liner was not received very well when I brought it up to some drilling people in the late 60's. Now it is different.

It is important to remember certain things when planning any liner job, especially in making a decision about rotation, reciprocation or conventional jobs. First of all, cement and mud are mortal enemies -- keep them separated.

A liner rotating job requires foremost a good hole. The drilling foreman knows if the hole is crooked, has sloughing problems, loss circulation problems, or is not stabile. A preflush and /or spacer is necessary to prevent contact of mud and cement. The preflushes are thin fluids that range from fresh water, to water containing surfactants and fluid-loss additives. Diesel is sometimes used as a wash when using oil-based muds[14].

Not every liner should be rotated. In the days when our company was running many long drilling liners in West Texas and Oklahoma, we were lucky to get some of them in the well the clearance was so close and the drag so much. We ran many 7 3/4 in. O.D. liners over 8,000 ft. long in an 8 1/2 in. I.D. drilled hole. Moving the liner while cementing would have been unthinkable.

There are many other places where production liners and some drilling liners should and can be rotated: for many of the most obvious reasons. By using good common sense and good job planning there is no reason to fear a liner rotation job.

REFERENCES

1. Lindsey, H. E., "Liner Cementing Equipment and Techniques", Southwestern Petroleum Short Course, April 21-22, 1977.

2. Lindsey, H. E., "Recent Developments in Tools for Liner Movement During Cementation", Southwestern Petroleum Short Course, April 23-24, 1981.

3. Jones, P. H. and Berdine, Denis, "Oil Well Cementing - Factors Influencing Bond Between Cement and Formation", Drilling and Production Practice, API (1940) pps. 45-63.

4. Howard, George C. and Clark, J. B., "Factors to be Considered in Obtaining Proper Cementing of Casing", Drilling and Production Practice, API (1948), pps. 257-272.,

5. McLean, R. H., Manry, C. W. and Whitaker, W. W., "Displacement Mechanics in Primary Cementing", Journal of Petroleum Technology, February, 1967, pps. 251-260.

6. Clark, C. R. and Carter, L. G., "Mud Displacement with Cement Slurries", Journal of Petroleum Technology, July, 1973, pps. 775-783.

7. Haut, R. C. and Crook, R. J., "Primary Cementing: The Mud Displacement Process", SPE 8253, presented at the 54th Annual Fall Technical Conference of SPE, Las Vegas, Nevada, Sept. 23-26, 1979.

8. Teplitz, A. J. and Hassebrock, "An Investigation of Oil-Well Cementing", Drilling and Production Practice, API (1946), pps. 76-103.

9. Howell, F. R., "Liner Reciprocation While Cementing", Drilling-DCW, July, 1979.

10. Garcia, J. A., "Rotating Liner Hangers Helps Solve Cementing Problems", Petroleum Engineer International, Sept., 1985, pps. 38-48.

11. Scalzi, L. M., U. S. Patent No. 4,190,300, issued Feb. 26,1980.

12. Lindsey, H. E. and Durham, K. S., "Field Results of Liner Rotation During Cementing", SPE 13047, presented at the 59th Annual Technical Conference and Exhibition, Houston, Texas, Sept. 16-19, 1984.

13. Arceneaux, M. A. and Smith, R. L., "Liner Rotation While Cementing: An Operator's Experience in South Texas", SPE/IADC 13448, New Orleans, LA, March 6-8, 1985.

14. Bradford, B. B., "Attention to Primary Cementing Practices Leads to Better Jobs", Oil and Gas Journal, Oct. 21, 1985, pps. 59-63.

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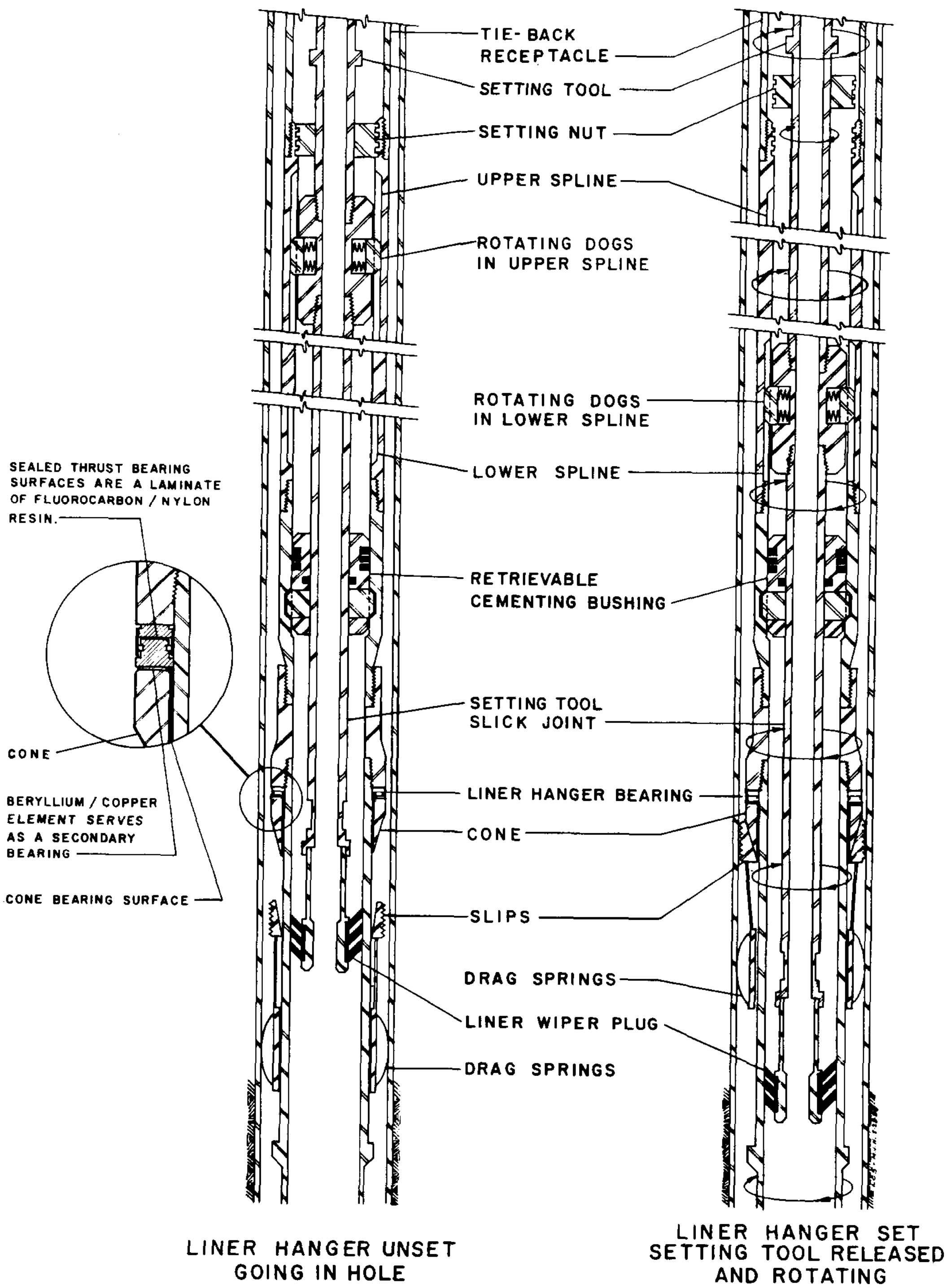

Figure 1 - Double spline method