Downhole air diverter can improve performance

Joe Mellott, AVB Systems

REDUCING THE ANNULAR bottom hole pressure in wells using incompressible fluids as the cuttings removal medium is not new. Many innovative ways have been used in the past 30 years to accomplish this task. However, very little research has gone into using this technology in pneumatic fluid drilling (hereafter referred to as air drilling). Because the pressures in these systems are much less and research has historically lagged behind incompressible fluid technology.

More than 10% of the wells drilled today use air as the cuttings removal medium which is significant when considering the amount of money spent. If air drilling operations must be abandoned due to problems much of the money saved as a result of the faster drilling rates is lost in the time, cost and problems resulting in converting to a liquid system. Once a section of hole is begun on air every thing possible should be done to TD this section on air.

There have been attempts to demonstrate the benefits, however, for one reason or another they failed. In theory, for a given amount of compressed fluid in the system (enough to transport liquids and cutting up the largest annular area), the more the annular bottom hole pressure can be reduced the more efficient the system is operating.

The Downhole Air Diverter (DHAD) has been able to increase the efficiency of the compressed air system improving drilling performance in most drilling situations where pneumatic fluid is used for cuttings removal by a more efficient use of the compressed air's energy.

The DHAD is a drillpipe or drillcollar sub equipped with two sonic nozzled valves strategically placed in the drillstring to divert a portion of the compressed pneumatic fluid from inside the drillstring into the annulus. Depending on the application and the specific goal there may be one or more of these diverter subs in the drillstring.

By diverting the surplus air traveling down the drillstring before it reaches the bottom hole assembly, the energy that would normally be wasted as friction is used to provide lift in the annulus, reducing BHP.

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Secondly, by reducing the annular friction hole erosion and sloughing can be minimized. Prior to introduction of the DHAD all the air traveling down the drillpipe had to go through the entire system resulting in unnecessary pressure in the bottom hole assembly and its annulus.

The IADC Underbalanced Operations Managed Pressure Drilling Subcommittee recently adopted a definition of Managed Pressure Drilling – "MPD is an adaptive drilling process used to precisely control the annular pressure profile throughout the wellbore." Within this context, the DHAD is a MPD tool.

DHAD BENEFITS

Less annular bottom hole pressure. The primary result of diverting a portion of the compressed air through the DHAD is the reduced bottom hole annular pressure. For any given circulating volume the lower the annular pressure at the bit the more efficient the air system is working. The lower bottomhole pressures are a direct result of the more efficient use of the compressed air downhole.

A large percentage of the air traveling through the bottom hole assembly is actually detrimental until it reaches the low velocity zone created when the compressed air reaches the annulus between the drillpipe and the wellbore full of formation cuttings. This excess air creates friction inside and outside the bottomhole assembly. This friction results in a pressure drop in the system from the top of the collars internally down to the bit and from the bit to the top of the collars in the annulus.

This friction pressure can cause hole erosion and puts back pressure on the bit and hammer tool leading to reduced drilling performance. Diverting the air through the nozzled valves reduces the annular bottom hole pressure in two ways. First, air bypasses the BHA internally and externally reducing frictional pressure losses.

Secondly, it reduces the pressure through the nozzle effect which aids in annular lift by using the diverted air's energy to create a Venturi Effect. This reduction can be as much as 70% even though the pressure reduction is sometimes small in value. This lift significantly improves penetration rates while mist drilling producing large amounts of water (up to 600 bbls/hr) by keeping this hydrostatic pressure off the bottom of the hole.

This reduction increases the pressure drop across the hammer tool allowing maximum efficiency.

Less surface drillpipe pressure. This drop is a result of the elimination of frictional pressure drop attributable to the

CASE STUDY: COMPARISON OF OFFSET WELLS

The following case study is a comparison of a recently drilled well in the northwest part of the Arkoma Basin in the Aetna Field versus a direct offset drilled with the same rig in 2003. The offset well is approximately 1,000 ft from the test well.

The test well utilizing the DHAD outperformed the offset well in all intervals and the offset well would not have been able to drill with the hammer tool and flat bottom bit with the high water influx rates encountered in the test well. Both wells took 15 total drilling days from spud to TD. However, the test well had to set intermediate casing requiring an additional two days and had almost 24 hours reaming time as a result of tight hole (the offset reduced hole size as a result of out of gauge hole). Therefore the test well actually took three less days drilling time than the offset saving the operator approximately $30,000.

Test Well

Depth	Interval	Bit Type	Total Air/ Air rted cfpm	Water influx bbls/hr	Ave P rate ft/hr
0-560	Surface	15" HT & FB bit	3000/1000	0-300	50
560-2600	Intermediate	11" HT & FB bit	3000/1000	0-350	70
2600-2900	Intermediate	10 5/8" IB	3000/1400	350	60
2900-3441	Production	7 7/8" HT & FB bit	2000/800	0-50	50
3441-6000	Production	7 7/8" IB	2000/1000	50	45

Direct Offset

Depth	Interval	Bit Type	Total Air cfpm	Water influx bbls/hr	Ave P rate ft/hr
0-543	Surface	15" HT & FB bit	3000	0-300	40
543-2578	Production	11" HT & FB bit	3000	0-40	60
2578-3233	Production	10 5/8" IB	3000	40	17.5
3233-4905	Production	8 3/4" HT & FB bit	3000	40	35
4905-6300	Production	8 1/2" IB	3000	40	30

diverted portion of air in the drillcollars, bit and collar annulus. Depending on the individual scenario the drillpipe pressure can be reduced as much as 50%, resulting in less compression cost, increased bit life and increased penetration rates. The reduced back pressure when using a hammer tool and flat bottom bit results in lower surface pressure to achieve maximum benefit of the hammering effect.

As the hole diameter decreases, these frictional pressures increase significantly, becoming the major contributor to surface drillpipe pressure. The actual amount of surface drillpipe pressure reduction is dependent on many factors and does not necessarily reflect the more important drop in annular downhole pressure that is realized. Only part of the frictional energy drop inside and outside the bottomhole assembly is noticed at the surface since a major portion is converted to useful energy through the DHAD nozzles providing lift in the annulus.

Reduction or Elimination of low velocity zones in the annulus. By diverting the air into the low velocity zone before it reaches the collars it increases the velocity above the collars where it is needed to transport the cuttings without eroding the hole. With proper adjustment the annular velocities can be designed to gradually increase all the way to the surface so no low velocity zone is created above the drillcollars. If a specific zone uphole has had severe erosion problems in the past, additional air can be diverted through a drillpipe air diverter placed at a strategic location in the drillstring to insure effective cleaning of the eroded area as the well is drilled deeper. Using the DHAD to accomplish this task rather than putting additional air through bottom hole assembly saves money and reduces further hole erosion.

Reduction of erosion potential of the air traveling through the bottom hole assembly. Depending on wellbore and drillstring configuration the velocity in the drillcollar annulus actually may increase as a result of diverting a portion of the air. This is accomplished by the reduction in bottom hole annular pressure. At the same time it also reduces the erosion potential because the air traveling in the collar annulus is less dense resulting in less kinetic energy and more velocity. The detrimental effect of the air is reduced while the beneficial effect is the same or more.

Reduction of the downhole fire potential as the result of a mud ring or cuttings build-up. By eliminating the low velocity zone above the collars, the DHAD may help clean this area enough to prevent the sticky cuttings build-up and reduce the downhole fire potential as the result of the diesel effect.

Aids in use of a hammer tool and flat bottom bit to control hole angle in vertical wells. A flat bottom bit and hammer tool have been used for many years to control hole deviation in vertical wells. The hammer effect is what helps to keep the bit on the low side of the hole and keep the hole vertical. However, if the hole builds angle, the standard practice has been to hold weight off the drillstring and not close the hammer tool. This practice is no different than drilling with a tri-cone bit and may actually contribute to angle build-up.

The only way to effectively use the hammer tool to keep straight is to reduce air through the hammer tool requiring less setdown weight to fully close the hammer. By deploying the DHAD above the drill collars and diverting a major portion of the total volume of air there is enough velocity to clean the hole and it requires less setdown weight to fully close the hammer tool helping to reduce hole angle.

FLUID DRILLING MODEL

In order to predict surface and downhole conditions under various scenarios so the benefits of using the DHAD could become a reality in the field, a "Pneumatics Fluid Drilling Model" was developed. This model is patterned after work done by Angel as shown in the 2001 Update of the Air and Gas Drilling Manual. Comparison of the model's results to actual field numbers has been extremely close. With the aid of the model any number of variables can be changed and the results to the whole drilling system quickly evaluated.

This gives one the ability to fine tune the system design in minutes rather hours. The mathematic calculations have not lent themselves to easy field application but with this drilling model field application has been simplified. The model can be used to design an air system with or without the DHAD in place so that benefits of the diverter can be demonstrated graphically.

FIELD EXAMPLE

A well in North Alabama was being drilled to 9,000 ft. The surface hole diameter was 17 ½-in.. The rig had 4-in. drillpipe (3.476-in. ID) and 6 ½-in. drillcollars (2 ⅜-in.ID). The operator was drilling with a hammer tool and flatbottom bit with a ½-in. choke in the hammer. Fifty-six hundred cfpm of air was being pumped down the drillpipe to the bit.

As the Pneumatics Fluid Drilling Model predicted the booster output pressure at the surface was 565 psia to get a 350 psi pressure drop across the hammer tool. Drillstring geometry contributed significantly to the high surface pressures, however, by diverting 2,700 cfpm of this air through a DHAD the pressure drop inside the drill collars would have been reduced by 70% and surface pressure could have been reduced to 440 psi resulting in a direct savings of 100 hp/hr of energy and $300/day in fuel.

Air velocity beside the drill collars would have actually increased as a result of diverting the air without increasing the erosion potential because the air traveling through the bit is less dense. Bottomhole cleaning and hammer tool performance would have also improved significantly with the lower BHP's in the annulus.

CASE STUDIES

Mist Drilling. A well was being mist drilled at a depth of 4,800 ft to a projected TD of 6,800 ft. Drillpipe pressure was 300-330 psig and the drill rate was 40 ft per hour. The operator was concerned that drillpipe pressure would continue to increase, exceeding booster pressure output and requiring the well to be mudded up. Misting operations were performing poorly requiring excess cleanout time after connections.

A DHAD was installed in the drillstring 500 ft above the bit at the top of the 6 ½-in. collars. Nozzles were sized to divert 900 CFPM through the DHAD (30% of total air). Drillpipe pressure after installing the DHAD dropped to 240 psig, which closely matched the pneumatic drilling model predictions.

Based on this surface pressure drop, the annular bottom hole pressure was reduced from 200 psig to 120 psig, a 40% drop. Hole cleaning and bit penetration was improved with this drop in bottomhole pressure. Misting operations also improved. The well was TD at 6,800 ft on one bit and it showed no adverse wear as a result of diverting the air.

7,500 ft Atoka test in eastern Oklahoma with plans to continue on through the Wapanucka to 9,000 ft if the well could be safely TD on air.

A DHAD was placed in the drillstring at drillout on the intermediate casing in an attempt to prevent fill and erosion problems. The upper portion of hole from 3,850 ft to 6,650 ft was drilled with a flat bottom bit and hammer tool. Penetration rates were kept at approximately 60-70 ft/hr for fill control. The DHAD was designed to divert 800 SCFM with the remaining 1,000 SCFM going through the hammer tool.

Drilling with the Downhole Air Diverter in the hole went well with the hammer tool. The hole experienced no fill problems in the unconsolidated shale sections above the Atoka Sands. Field comments were that it was staying exceptionally clean on bottom.

The operator kept the hammer tool in the hole 700 ft deeper than expected based on the lack of fill. The flat bottom bit had very little wear and was in excellent condition drilling 2,700 ft in approximately 40 hrs averaging 68 ft/hr.

There was only 2 ft of loose fill on bottom on the bit trip. At 6,750 ft the flat bottom bit was pulled and a tri-cone bit was run. The tri-cone insert bit drilled 60-100 ft/hr depending on hole deviation. The DHAD was diverting 800 CFPM into the annulus above the collars. Drilling continued to 8,600 ft with a very clean hole. From 8,600 ft to 9,000 ft, 3 ft of light fill was noticed on connections but there was no indication of sticking problems. The insert bit showed little wear after drilling 2,200 ft diverting 44% of the available air through the DHAD. A comparison of the caliper log of the well to an offset drilled in 2000 showed considerably less washout. ■

Well Data

8 ⅝-in 32#/ ft
Intermediate casing @ 3850′

7 ⅞-in.hole size

5-in.drillpipe

500′ 6 ½-in.drill collar

1800 CFPM air on hole
(2700 CFPM available)