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Novel Stabilizers for Casing Drilling Simplify BHA, Handling, and Cost

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Abstract

A novel technique for building stabilizers and wear bands directly onto casing for drilling is replacing multiple machined integral stabilizers. This is achieved with spray metal technology and the resulting blades, ribs and bands are at least as wear resistant as steel. Multiple stabilizers can be built onto a single joint of Range 3 casing to create the desired BHA.

The spray metal process is commonly used in other industries for corrosion and erosion protection using relatively thin layers. The novelty of this new process is that the wear metal can be built up, typically, to thicknesses of $\frac{3}{4}$ " (19 mm) and in any desired shape. This is a new use of the spray metal process for casing drilling because it has already proved successful in protecting drill pipe tube from wear in Extended Reach wells and in highly abrasive formations.

Laboratory and field test results indicate that the material is sufficiently robust to withstand normally anticipated downhole drilling forces and the open hole wear resistance testing indicates that it will deliver very satisfactory rotational and longitudinal resistance to abrasion. In one well drilled with casing the casing string was deliberately tripped at TD to inspect stabilizer integrity and to measure wear. Further laboratory work has been undertaken to compare the material's wear and frictional characteristics with plain tooljoint steel and some more commonly used wear resistant materials.

Casing drilling hundreds of wells per year will benefit significantly from the economies of scale which this new process offers. A single joint of Range 3 casing with the necessary stabilizers formed directly upon it is utilized instead of multiple short integral blade stabilizers (IBS) and casing pup joints. Rig time and HSE exposure is reduced through simplifying the BHA and its associated make up procedure. The spray metal stabilizers also provide operators with a significant cost reduction from traditional IBSs.

Operational Requirement

Casing drilling has been used in over a hundred wells in south Texas by an operator using a specially designed casing drilling rig(s). Early development focused on the intermediate hole section, typically from 550 feet to 8,000 feet, since this presented the greatest challenge with regards to downhole tools, drilling assemblies, and casing fatigue and or wear. With many of these wrinkles ironed out, the operator has recently focused on making the entire casing drilling process more economical and has continued to refine the casing drilling process with several service companies. One area of concern has been the stability, performance, and ultimately the cost of the bottom hole assembly in the 6 $\frac{1}{4}$ inch production hole. This hole section currently does not have a commercially retrievable drilling assembly that would facilitate directional operations so wells are designed to be vertical or are limited to directional work in larger casing sizes. With a majority of targets getting smaller it has become necessary to develop a more stable bottom hole assembly to ensure that once in the production hole the operator is able to consistently hit the target.

The BHA used by the operator in a 6 $\frac{1}{4}$ in. production hole comprised of a 6 $\frac{1}{4}$ inch PDC bit, a 6 $\frac{3}{16}$ inch near bit stabilizer, a 5 foot long pony joint made from 4 $\frac{1}{2}$ " 13.5# P-110, a 6 $\frac{3}{16}$ inch integral blade string stabilizer, another 10 foot long pony joint, and a second 6 $\frac{3}{16}$ inch integral blade string stabilizer. This assembly was modeled by a service company and indicated that with less than 3 klbsf weight on bit the assembly would buckle behind the top stabilizer and resulted in an unacceptably high side load at the bit. This model confirmed field results where production hole BHAs routinely have been built from 1° to 4° over the hole interval and have on occasion built considerably more resulting in missing the well target.

Based on the modeling the operator has decided to increase the number of stabilizers run from the original 3 stabilizer design to designs incorporating four to six stabilizers depending on offset well deviation, target size, and production hole length. In addition, some BHAs will contain 5" 23.2# P-110 casing for additional stiffness and available weight on bit. These changes with the current stabilizer and casing cost would result in a significant increase in costs. Faced with this dramatic increase in cost the operator immediately began investigating an alternative to the IBSs that are currently in service. Spray metal stabilizers were appealing for several aspects including a significant reduction in cost and enhanced safety while handling the BHA while still providing a solution that did not require crimping the casing and a minimal reduction in flow area.

Stabilization for casing drilling applications currently is provided by either machined IBSs or crimp on stabilizers (COS). Each product has advantages and weaknesses and a balance between performance and cost must always be considered when designing a BHA. The IBSs that were initially used in the production hole BHAs were machined from steal tubing and have proven themselves to be rugged and reliable. These have been run in conjunction with crimp on centralizers and wear bands that protected the casing further away from the bit. The primary driver to eliminate the use of IBSs is cost while there is also reluctance to rely solely on larger diameter crimp on stabilizers.

Crimp on stabilizers offer operators a far more economical option to IBSs. They can be purchased and applied at a fraction of the cost of IBSs but several detracting factors do exist. First, crimp on centralizers are crimped onto the casing and have come loose in the field. While this has not occurred often and is believed to be linked to severe downhole vibration it can pose a danger to tubular integrity. Second, crimp on stabilizers are designed on a sleeve that reduces the total junk slot area around the casing. This can be significant in depending on the bit diameter and outside diameter of the casing onto which the stabilizer is crimped.

Stabilizers formed by metal hard banding and applied by a twin arc spray technique allows the application of stabilizers directly onto casing without altering the metallurgical properties of the casing that would occur in a welding process. The unique formulation of the hard banding also allows a significant thickness of material, up to and possibly beyond 3/4" thick, without delaminating. In addition to the stabilizers being mechanically bonded to the casing the technology allows an operator to construct BHAs from standard range III joints of casing and eliminates the need to make up separate stabilizers and pony joints to form a BHA. The reduction in pipe handling also makes the casing running operation safer for the rig crew.

Solutions

A process of applying stabilizer ribs directly onto casing has been developed using spray metal deposition. This is a versatile process which allows stabilizer blades of virtually any shape, length, height and thickness to be built up on the casing. Also, since there is no circumferential band linking the blades together, the annular flow area can be significantly increased in situations where clearances are already minimal, i.e. 7 5/8 inch casing in 8 3/4 inch hole.

The Spray Metal Process

Spraying metal onto surfaces is a 50 year old technology which has traditionally been used to apply thin protective layers for the prevention of corrosion and erosion. Using the same techniques repairs can also be made to worn equipment or the resulting surface may simply be desired for a pleasing visual effect. Commonly it is found that building up layers more than a few hundredths of an inch thick results in spalling and the spray metal falls off. In this case a material has been developed with a low coefficient of contraction such that residual cooling stresses are low enough not to unseat it. There are a number of different methods in existence with which to spray metal and the one chosen in this instance is called the Twin Wire Arc System (TWAS). In the TWAS spray head two 1/16" (1.6 mm) wires are oppositely charged to form an electric arc between them; compressed air blows across the arc to deliver the resulting molten metal droplets onto the workpiece. See Figure 1. Typically each pass of the application gun delivers between 0.005" (0.13 mm) and 0.010" (0.25 mm) of spray metal to the workpiece meaning that the thicknesses required to create stabilizer blades require multiple passes.

The reasons for choosing TWAS as the spray metal method in this instance are as follows:

1. It is one of the lowest temperature spray metal applications and the resulting workpiece measured temperatures are low enough to protect the likes of the internal plastic coating on drill pipe, the delicate electronics within downhole drilling tools and well below any point at which metallurgical changes might occur to degrade oilfield tubular steel goods.
2. The rate of application is faster than of any of the alternative spray metal processes.
3. It is a proven and well established technology where a wide choice of potential applicators already exists.

Patents Pending

The material developed for this process, manufactured in the form of 1/16" wire, similar to TIG welding wire, combined with the use of TWAS to apply it to oilfield tubulars, is currently in the Patent Pending process on both sides of the Atlantic.

History of the Current Technology

The application of spray metal to downhole oilfield tubulars was developed initially to protect the body, or tube, of drill pipe from wear and to reduce drilling loads on the rig, in particular the torque required to turn the drill string. To date it has found its most use in Extended Reach Drilling (ERD) wells in Sakhalin for one major operator where the downhole environment is extremely abrasive. Other applications to drill pipe have been tested in Texas and Alaska. Two years ago, at this same conference, some casing was displayed sporting stabilizer ribs built up with spray metal and this operator has since run this material in their wells in Norway, Texas, Colorado and Alaska.

Laboratory Wear Test Procedure of the Spray Metal

A hard band evaluation procedure based on the DEA 42 "Maurer Test" protocol was used with several modifications that improve the accuracy and repeatability of test parameters, measurements, and results. While the individual test parameters and measurements are quantitative, the overall test results are largely qualitative. Individual test results are compared against base line tests of other materials to determine the relative performance of tested hard band materials. Prior test results for bare Drill Stem Tool Joints (120ksi Material) against L-80 casing and 60 Grit Aluminum Oxide (AlOx) stone were provided for comparison purposes.

During the evaluation test, a hard band test specimen is rotated against a simulated well bore at a specified rotational speed and normal contact force. Drilling fluid is pumped over the tool joint and casing or stone interface to lubricate and cool the hard band specimen during the wear test. Sand is mixed into the drilling fluid to simulate typical drilling returns. The equipment instrumentation continuously monitors and records the normal force, number of rotations, rotational speed, and applied torque. In addition, specimen and well bore dimensional measurements are made at specified intervals. These measurements are used to calculate the wear rates of the hard band and well bore and the dynamic coefficient of friction between the hard band and well bore.

The hard band is typically evaluated against L-80 casing and 60 grit AlOx stone. However, a 220 grit AlOx stone was also used in the Spray Metal evaluation program. As a result, three tests were conducted on the Spray Metal material:

1. Spray Metal against L-80 Casing at 250 lb/in
2. Spray Metal against 60 Grit Stone at 100 lb/in
3. Spray Metal against 220 Grit Stone at 100 lb/in

Laboratory Test Parameters and Results

Wear rates are highly dependant on the normal force per inch of contact and the number of rotations. As a result, a standard relative rotational speed of 160 rpm is used with a standard normal force of 250 lb/in against casing and 100 lb/in against stone. Table 1 summarizes the test parameters for each evaluation test.

The average radial wear rate of the tool joint or hard banding and the well bore casing or stone was calculated along with the coefficient of friction between the materials. Table 2 summarizes the wear and friction factor test results.

In the cased-hole simulation, the Spray Metal material reduced the casing radial wear rate by 17.5% in comparison to a bare steel tool joint. In the cased-hole simulation, the Spray Metal material wore at a slightly slower rate than the L-80 casing; however, the Spray Metal wear rate was significantly higher than the bare tool joint. The coefficient of friction between the Spray Metal and casing was also slightly higher than the coefficient of friction between the tool joint and casing.

In both open-hole simulations, the Spray Metal material wore significantly slower than it did during the cased-hole simulation. Some of the difference may be the result of the reduced side load used for the open-hole simulations. However, the Spray Metal wear rate was only 3% of the bare steel tool joint wear rate under identical open-hole test parameters. The coefficient of friction between the Spray Metal and stone was also significantly lower than the coefficient of friction between the tool joint and stone.

Laboratory Test Conclusions

Under the tested conditions, the Spray Metal material did not show any propensity to fracture or spall off the tool joint. This indicates good material fracture toughness and high adhesion to the tool joint. Due to the low application temperature of the thermal spray methodology the Spray Metal material may be applied in specific geometries and a wide range of thicknesses.

Based on the excellent wear protection offered in the open-hole test simulations, the Spray Metal material would be highly suitable for fabricating metallurgically bonded centralizers and stabilizers to be used in the BHA. Based on the cased-hole simulation, the Spray Metal material would also offer protection to the drill string and casing under cased-hole conditions and could be used for wear bands on the drill string and drill string connectors.

Field Testing

The operator began field testing spray metal stabilizers in 2006 with the initial stabilizers being designed and used for a directional well in Norway. No wear data was collected from the test since the stabilizers were not recovered from the well. The first field test where spray metal stabilizers were run in a well and returned to surface occurred in 2007 in south Texas. In south Texas spray metal stabilizers have been used in 5 wells and they have resulted in less deviation per well based on an average displacement per foot drilled.

In the initial test the operator used on joint of 7 5/8 inch 47.1 lb./ft. P-110 sprayed with three stabilizers to form a packed hole assembly. The stabilizers each had three blades with 14 inches of gauge length that were spiraled 120°. Each of the stabilizers went in the hole with an outside diameter of 8 11/16 inches. 2,073 feet of 8 3/4 inch hole was drilled successfully to casing point with an inclination of 1° which is comparable to the directional performance of BHAs with IBSs. Each stabilizer was gauged after returning to the surface and the average wear across the three stabilizers was 1/8 inch. Figure 2 shows one of these stabilizers after the spraying application.

Post-well evaluation concluded that the wear on the stabilizers was attributed to the construction of the blades. Figure 3 shows the same stabilizer in Figure 2 after tripping it out of the hole. Looking at the cross section of the blades they resembled a triangle. This meant that the load bearing surface of each stabilizer blade at gauge was less than 1/4" in width. It was decided that a larger bearing surface was needed and the blade width was increased. Current designs specify a minimum blade width of 3/4" in the gauge portion of the blade. This provides a larger bearing surface to distribute the side forces imparted by the stabilizer onto the formation. In addition, abrasion resistance testing performed by a third party has indicated that a load of 100 pounds per linear inch is well within the hard banding's capabilities so stabilizer gauge length is also a function of side load anticipated through BHA modeling plus a safety factor.

After the initial field test where the casing was tripped to surface to evaluate stabilizer wear and the positive results from laboratory testing it was decided to test the stabilizers in the production hole and evaluate stabilizer performance based on hole deviation since these casing strings would not be tripped to surface. Four additional test wells were chosen and in each well three spray metal stabilizers were sprayed onto a single joint of 4 1/2 inch 13.5 lb./ft. P-110 casing. Each was used in the production hole in conjunction with a PDC bit and oil-based mud. A singles rig that had drilled the majority of the offset wells was used along with a consistent set of drilling parameters and drilling practices. The offset and test wells were drilled with similar strings of 4 1/2 in 11.6 lb/ft and 13.5 lb/ft P-110 casing. Drilled intervals ranged from 1,000 to 1,700 feet in measured distance and were all drilled successfully to target depth. These four wells were compared against 13 direct offset wells drilled with casing. Figure 4 shows a 6 3/16" spiral stabilizer on 4 1/2" casing with 3/4" gauge blade width.

The average departure in feet per foot drilled with the spray metal stabilizers in 6 1/4 inch and 6 inch production hole with 4 1/2 inch casing was 0.030 ft/ft compared to the average integral blade performance of 0.036 ft/ft. The surface casing test drilled with 7 5/8" casing and a 8 3/4 inch bit was excluded from the comparison since the offsets to that well were drilled with a conventional rig. Table 3 lists and summarizes the departures recorded for IBSs and Spray Metal.

Conclusions

Casing drilling hundreds of wells per year will benefit significantly from the economies of scale which this new spray metal process offers. A single joint of Range 3 casing with the necessary stabilizers formed directly upon it is utilized instead of multiple short IBSs and casing pup joints. Rig time and HSE exposure is reduced through simplifying the BHA and its associated make up procedure. The spray metal stabilizers themselves also provide operators with a significant cost reduction from traditional IBSs. Given the reduced cost and relatively similar drilling performance to IBSs, moving forward, spray metal stabilizers will replace IBSs in casing drilling BHAs for this operator in South Texas.

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Table 1: Test Parameters

Test	Parameter	Average (Mean)	Standard Deviation
Tool Joint vs. L-80 Casing	Side Load	247 lb/in	18 lb/in
	Relative Rotation Speed	159 rpm	0 rpm
Spray Metal vs. L-80 Casing	Side Load	246 lb/in	11 lb/in
	Relative Rotation Speed	160 rpm	1 rpm
Spray Metal vs. 220 Grit Stone	Side Load	100 lb/in	7 lb/in
	Relative Rotation Speed	157 rpm	1 rpm
Spray Metal vs. 60 Grit Stone	Side Load	98 lb/in	15 lb/in
	Relative Rotation Speed	157 rpm	1 rpm
Tool Joint vs. 60 Grit Stone	Side Load	96 lb/in	11 lb/in
	Relative Rotation Speed	160 rpm	0 rpm

Table 2: Spray Metal Evaluation Results (Tool Joint Provided for Comparison)

Materials		Target Side Load (lb/in)	Average Radial Wear Rate (in/hr)		Average Friction Factor
A	B		A	B	
Tool Joint	L-80 Casing	250	0.0008	0.0160	0.077
Spray Metal	L-80 Casing	250	0.0118	0.0132	0.083
Spray Metal	220 Grit Stone	100	0.0021	0.0015	0.074
Spray Metal	60 Grit Stone	100	0.0045	0.0020	0.095
Tool Joint	60 Grit Stone	100	0.1535	0.6575	0.146

Table 3: Drilled Hole Departure Comparisons, Spray Metal vs. IBS

Case #1 Well	Prod Hole Departure (ft)	Departure per Depth (ft/ft)	Stabilizer Type
WK WARREN 4	6.63	0.005	IBS
MATA THOMAS GU 2	40.77	0.028	IBS
WK WARREN 1	47.30	0.031	IBS
WK WARREN 5	61.19	0.036	Spray Metal
WK WARREN 2	52.22	0.038	IBS

Case #2 Well	Prod Hole Departure (ft)	Departure per Depth (ft/ft)	Stabilizer Type
TEX MEX RR CO 599 6	40.87	0.022	Spray Metal
TEX MEX RR CO 599 1	62.38	0.026	IBS
TEX MEX RR CO 599 5	53.05	0.039	IBS
BMT 162	57.82	0.052	IBS
TEX MEX RR CO 599 4	74.44	0.054	IBS

Case #3 Well	Prod Hole Departure (ft)	Departure per Depth (ft/ft)	Stabilizer Type
GLORIA BENAVIDES BMT A 6	17.62	0.022	IBS
BMT 197	17.28	0.026	Spray Metal
BMT 180	29.41	0.038	IBS
BMT A 23	39.36	0.052	IBS

Case #4 Well	Prod Hole Departure (ft)	Departure per Depth (ft/ft)	Stabilizer Type
WK WARREN 4	6.63	0.005	IBS
MATA THOMAS GU 2	40.77	0.028	IBS
WK WARREN 1	47.30	0.031	IBS
WK WARREN 3	52.79	0.034	Spray Metal
MATA THOMAS GU 1	65.87	0.039	IBS
TAUBMAN 1	76.52	0.047	IBS

Case #5 - 7 5/8" 47.1# Casing & 8 3/4" Bit Well	Surface Hole Departure (ft)	Departure per Depth (ft/ft)	Stabilizer Type
BMT B 10	16.74	0.008	IBS
BMT B 3	18.99	0.009	IBS
BMT B 8	19.17	0.009	IBS
BMT B 11	34.36	0.016	Spray Metal

Production Hole*	Surface Hole Departure (ft)	Departure per Depth (ft/ft)
Average Spray Metal	43.033	0.030
Average IBS	47.954	0.036

* Excludes surface test in Case 5 and duplicate wells in Case 1 & 2

Figure 1: Schematic of the Twin Wire Arc Spray (TWAS) Process

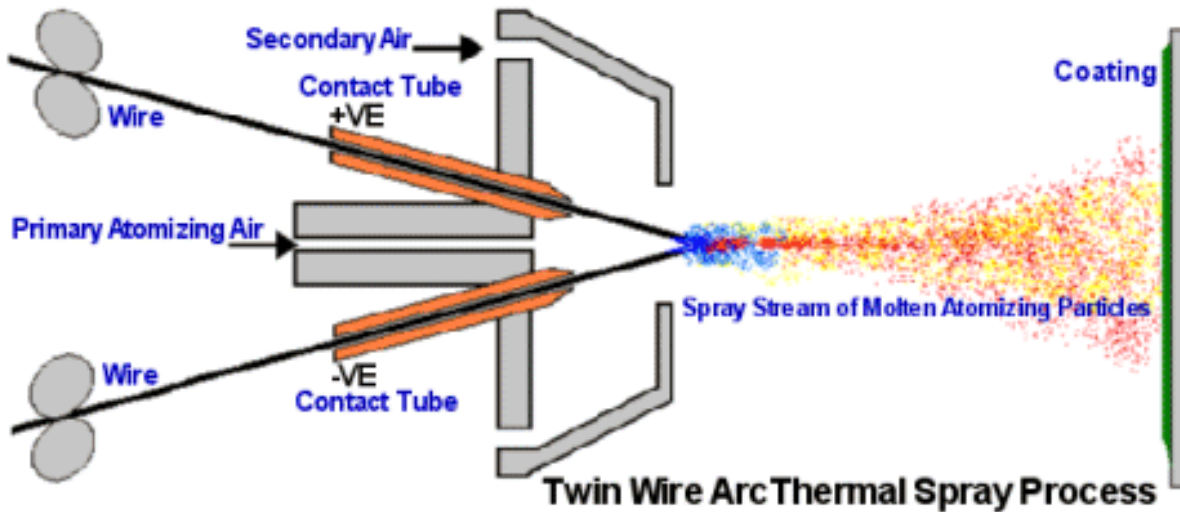


Figure 2: 8-11/16" Stabilizer on 7 5/8" Casing, as Sprayed



Figure 3: The same Stabilizer as in Figure 2 after Drilling over 2,000 feet



Figure 4: 6-3/16" Spiral Stabilizer on 4 1/2" Casing with 3/4" Gauge Blade Thickness

