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Advances in Casing Centralization Using Spray Metal Technology

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Abstract

The narrow window between pore pressure and fracture gradient, especially prevalent in deepwater drilling has resulted in the need for more and more casing strings to be set in offshore wells. To fit this increased number of casing strings into the finite space available between the conductor pipe and a production string capable of flowing a well commercially, the available space between the strings has narrowed to the point where casing connections must be either flush or near-flush; there is just not the annular space available for casing collars. For equivalent circulating density (ECD) management and a good cement job the open hole beneath the previous casing shoe is usually under-reamed, meaning that to centralize the new string in open hole a magician has to pull something out of his hat. That special something has to be able to pass through an annular space only a few eighths of an inch wide yet open out to some inches greater than the casing outside diameter (OD) in the open hole. It must also still be robust enough to withstand the forces involved in the running process.

Bowstring centralizers can do all of the above and have been around for a hundred years but today's wells have some special demands which this paper will address and propose a number of different novel solutions depending on exactly how much annular space is available to pass through and how much stand-off is required in the open hole.

This paper will discuss the positive location on slick casing of various centralization devices using spray metal, a technology new to this particular aspect of the industry and a very robust process with many advantages over traditional methods. Centralizers can also be built entirely out of the spray metal itself.

Developments are ongoing and the unwelcome lull in deepwater GOM operations during 2009 ironically allowed some time for developing new products. Casing centralization is also commanding more attention in the post-Macondo world.

Introduction

Typically oil and gas wells are drilled in sections, each having casing run into it to support that part of the well bore for the duration of its life. The casing also provides well control and, additionally, may be the conduit for well bore fluids to travel to the wellhead although this is normally through dedicated production tubing. To ensure formation isolation and prevent the possibility of well bore fluids traveling up the outside the casing it is invariably cemented in place, at least in part and especially across zones which require isolation. To achieve the best possible cement job the casing needs to be centralized, especially across potential producing zones, so that a uniform thickness cement seal is achieved in the annulus between the casing and the formation(s). An additional advantage of centralization is the avoidance of differential sticking, a hydrostatic pressure mechanism, which can sometimes irreversibly jam the casing when running into the hole.

Casing centralizers come in many forms to suit the needs of particular well characteristics. To be effective in all cases, they must be positively located in some way so that when the casing has been run to depth they are still where they were planned to be. Traditionally each joint of casing has a connecting collar forming the box end, the shoulders of which are sufficiently proud to act as very effective centralizer stops. As wells get more complex and the demands on the casing more stringent, the casing connections have become an integral part of the casing itself, initially with threads cut into a slight upset at either end, and now more and more often, particularly in deepwater drilling, perfectly flush pipe with the threads cut within the wall thickness of the casing itself.

Traditionally centralizers have been located on flush and near-flush casing using set-screw stop collars which have a limited holding capacity and can lose grip when centralizers are forced through particularly tight hole sections. Then there is another factor working against set-screws, the grade of the steel casing itself. As the design of wells becomes more demanding higher and higher grades of steel are required, up to Q-125 kpsi, the set-screws have a harder and harder time providing any real grip. The result of slipping stop collars can range from embarrassing to disastrous. For instance, if certain centralizers slip over a near-flush connection, they may well split, becoming a fish in the hole, and can even damage the casing connection itself. The combined result may junk that section of the well and require it to be re-drilled.

There are of course alternative solutions, one of which utilizes molded on epoxy stops or blades and another which utilizes centralizing subs, both of which will be discussed in more detail below.

Discussion

There are three main applications of spray metal technology currently being utilized on oilfield tubulars today:

1. Building centralizer and stabilizer blades directly onto the casing.
2. Locating third party centralizers on casing.
3. Current and future developments.

The Spray Metal Process

Before investigating these various applications we will look at the spray metal process itself, which is not new. In fact spray metal has been around for over 50 years but traditionally has been used to provide a thin protective coating against corrosion and erosion. The novel feature of the current applications is that shapes are being constructed, in some instances up to two inches (~5 cm) high, and it is this constructability feature, which, along with the proprietary material itself, has made this process patentable.

There are a number of different methods available for spraying metal and the one chosen for these applications, Twin Wire Arc Spray (TWAS), is one of the coolest. Through procedural controls, the temperature of the substrate never exceeds 300° F (~150° C). See Diagram No. 1. This application temperature is well below that at which any metallurgical changes might take place in the casing material and is also low enough so as not to harm the internal plastic coating of drill pipe. In addition the TWAS process allows the maximum depositional rate available. Each pass of the spray gun deposits approximately 0.005" (~0.125 mm) so multiple layers are required to build the significant features required. It should also be mentioned here that in no event is welding permitted on the thin wall sections of casing and drill pipe since this would induce local stresses and changes in the pipe material which could ultimately result in a mechanical failure.

Preparation of the pipe to be treated is necessary in the form of grit blasting to clean the pipe of any protective coatings, oxides or contaminants. A minimum roughness profile is necessary which provides a key pattern for the initial layers of spray metal to adhere to. The bond between the spray metal and substrate is primarily mechanical along with some ionic forces. Scanning Electron Microscopy (SEM) has shown no traces of fusion taking place at this interface.

The spray material developed for this process, which comes in the form of a 1/16" (~1.5 mm) cored wire, is a proprietary mixture of iron and other elements commonly found in today's casing-friendly hard metals. While hard metals are typically welded onto drill pipe tooljoints to provide wear protection, this material, when applied by TWAS, exhibits many of the same beneficial characteristics which include good wear resistance and a low coefficient of friction.

1. Building Centralization Directly onto the Casing

When a section of hole has been drilled in a typical oil or gas well it is necessary to run casing across that section and cement it securely in place. One of the requirements to deliver a good cement job is to centralize that casing in the hole to ensure as even a thickness of cement around the pipe as possible. There are numerous casing centralizing tools available "off the shelf" to suit most needs for the common pipe and hole sizes and economics generally forbid custom manufactured devices where an unusual combination of sizes is encountered. Some of the unique attributes of spray metal applied centralizers are their dimensional flexibility and freestanding nature. Since the blades, typically three helical blades to give 360° centralization, are freestanding, the area between them is maximized for the return flow path up the annulus between the casing and walls of the well bore for the return flow of drilling mud and cement. This becomes more critical where the annulus is already small, i.e. when the difference between the diameters of the casing and hole size is very close. Typically any commonly available centralizer is built onto some form of collar to join all the blades together and then slid onto the

pipe.

See Figure No.2 for a typical spray metal centralizer.

For technical and economic reasons a small percentage of oil and gas wells drilled lend themselves to a different drilling process where the casing itself is used as the drill string. This may apply to the entire well or just one section, often through the reservoir itself and especially where this is already depleted. Most of the casing still needs to be centralized in the well bore so the integral centralizers discussed in the previous paragraph are very appropriate as these rotate with the casing during the drilling process. Towards the bottom of the casing string heavier centralization is required where the casing is in compression and, by building the diameter of these (what we will now refer to as) *stabilizers* closer or equal to the gauge of the hole, these stabilizers help to keep the angle of the hole constant, be it vertical, already deliberately deviated or horizontal through the reservoir. Similar sets of spray metal blades are also being built directly onto certain casing drilling bits as near-bit stabilizers. These additional stabilizers have been shown to improve hole angle holding ability and to ensure straight hole drilling.

The main alternative to provide such stabilization for drilling with casing is to machine an integral bladed stabilizer (IBS) from heavy wall tube, cut threads on the ends and then add this into the casing string. Typically a Drilling Program will call for the location of these stabilizers to be at very specific points above the bit which then also requires having short lengths of casing (pup joints) prepared to be inserted between the IBSs. Unnecessary connections in the casing string also introduce additional potential failure points. Metal sprayed stabilizers overcome this inconvenience since they are built directly onto the full lengths of casing, exactly where required, and can be treated like normal joints of casing during transport and handling at the rig site. Using only full length joints of casing also becomes an added safety feature for the rig crews by reducing their exposure to pipe handling and preparation time at the rig site.

See Figure No.3 for a typical spray metal stabilizer.

2. Locating Third Party Centralizing Devices

Any casing centralization program must specify the number and dimensions of centralizers required. It will also have very specific locations for them and there are various means for providing this location. Traditionally, and still in most of the oil and gas wells drilled today, casing comes with a connecting collar at the box end. The shoulders of these collars can be very effectively utilized for locating centralizers. It may however be inconvenient for handling and make-up so the centralizers are more often located away from the connection and located in place with set-screw stop collars. The holding capacity of such stop collars is limited, especially with higher grade steels where the set-screws struggle for grip, and if problems are encountered downhole during the running process then the centralizers may quite possibly slide up the casing, but only as far as the next connecting collar.

Enter near-flush and/or entirely slick casing connections where the connecting threads are cut into the wall of the pipe itself, near-flush having a small upset to accommodate the connection. The primary reason for the use of these casing connections is specifically because of the lack of annular space between one casing string and the next, there simply is not the annulus to accommodate conventional casing connection collars. Removing this “back stop”, should a set-screw stop collar slip, can lead to an embarrassing situation when one centralizer slides into the next and so on. There have been numerous instances where the casing has been pulled for operational reasons, only to find sometimes ~30 centralizers on one joint of casing. This can become even more serious in the case of near-flush connections since sliding a stop collar, and/or the centralizer itself, onto the gently sloping shoulders of such a connection can cause the collar and/or the centralizer to split and come loose from the pipe. Numerous hole sections have been lost in this way, requiring a side-track to be drilled.

As in the case of IBSs for the casing drilling scenario discussed previously, there is a similar solution available for centralizing slick and near-flush connected casing using centralizing substitutes (subs). In this case a thick wall piece of pipe, of the same grade as the casing itself and with the same connections cut, has a low shoulder and grooves machined on the outside into which is fabricated a bowspring centralizer. These subs then have to be bucked onto the casing, usually in a yard prior to being shipped to the rig. Given the cost and individual properties of these subs it is usually impractical and unaffordable to maintain a significant inventory of all the possible combinations of casing size, grade, weight and connection so there is some production lag time in getting these produced for a particular job. If last minute changes are made to the casing program then there can also be considerable waste involved.

Spray metal stop collars overcome many of the drawbacks of the scenarios mentioned above since they are built directly onto the operator's casing. As well as obviating the need for separate centralizing subs, spray metal collars have a holding capacity in the region of 100,000 lbs (~45 t) sometimes an order of magnitude greater than the alternatives.

Different aspects of the well bore design will call for different types of centralizer to be utilized. In conventional

wells, most especially onshore, the diameter of the open hole below the last string of casing will be marginally smaller than the inside diameter (ID) of the previous string of casing. In these situations a solid body centralizer may be used with a spray metal stop collar above and below.

See Figure No.4 for a typical solid body centralizer with spray metal stops above and below.

As tolerances get tighter the bowspring centralizer starts to come into play. Commonly, especially in offshore wells, it is normal to under-ream the open hole section below the last string of casing to improve the cement job on the next casing string. This means that for ideal centralization in the under-reamed hole the centralizers must be compressed while running in through the previous casing then open back out to the full ID of the new hole beneath. Where tolerances allow it is best to build a stop collar *inside* the bowspring where it effectively *pulls* the centralizer into the hole, reducing the starting and running forces and allowing rotation of the pipe if necessary to work it down.

See Figure No.5 for a typical Rotating Bowspring Centralizer with Internal Spray Metal Stops.

As annular tolerances get tighter still it is not possible to build a stop collar inside the centralizer and collars must be built outside allowing the bowsprings to lie completely flat against the casing when compressed to pass through the previous string of casing. This arrangement still allows for rotation of the casing string if necessary to work it down but centralizer starting and drag forces will be higher when pushing as opposed to pulling each centralizer into the previous string of casing.

See Figure No.6 for a typical Rotating “Close Tolerance” Bowspring Centralizer with External Spray Metal Stops.

The next two examples represent the current state of the art in “very close tolerance” centralizers and the means for locating them. The centralizers featured are cut by laser from specially fabricated thin-wall tube, then the bows cold formed and the whole assembly heat treated. Rectangular anchors of spray metal are built *inside* each window of the centralizer so that, once again, they *pull* the assembly into the hole. The guide rings at either end of the device are built to the same diameter of the centralizer end collars and help center the assembly to prevent any possibility of the leading end collar hanging up on any sharp shoulders. The whole assembly is bi-directional so that if the casing has to be worked up and down the centralizer will be *pulled* in either direction. Although this assembly has considerable resistance to rotation, this is considered “non-rotatable” since, in so doing, there is a danger in potentially bending and breaking the individual bows which could prove disastrous for the casing running process.

See Figure No.7 for a typical Non-Rotating “Very Close Tolerance” Bowspring Centralizer with Internal Spray Metal Stops and External Guide Rings.

The final example features the same type of single piece centralizer as above, only now the locating stops are external which allow rotation of the pipe, to work it through tight spots or tar, while the centralizer remains stationary. The particular dimensions of this arrangement deserve mention as they are the closest known in the oilfield today. The casing shown is 11.875” (~302 mm) and this must pass through the previous string of casing with a drift ID of 12.250” (~311 mm). The centralizer end collars and stops are built to ~12.200” (~310 mm). Such was the concern of one major operator that the spray metal stop collars were fluted to improve return mud flow, especially should the casing not make it to total depth (TD) and circulation have to take place around the collars whilst still inside the previous casing string. There is no other known material that can be applied to the exterior of casing in this way and deliver the necessary holding capacity. During the initial development of this arrangement some spray metal got onto the centralizer itself and, when tested, the starting and drag forces appeared 20% lower than normal. This serendipitous moment is now repeated deliberately on all the external faces of these centralizers to deliver lower frictional forces and also to provide some additional wear resistance to the bows as they slide through the previous casing string.

See Figure No.8 for a typical Rotating “Very Close Tolerance” Bowspring Centralizer with External Spray Metal Stops, fluted to improve return mud flow. Also showing transport protection.

3. Current and Future Developments

While the majority of spray metal’s current downhole oilfield usage has been covered above, other avenues of research are being followed. In particular a solution is being sought for the mid-body tube wear of drill pipe when used in long, high angled hole sections which may require the drill pipe to be put in compression to apply weight to the bit, when it will inevitably buckle and cause abnormal tube wear. This is a procedure which was unheard of 25 years ago and would likely have got a Driller dismissed back then but is now common practice, if not essential, in the thousands of tight gas and oil wells being drilled today. Bands of spray metal applied to the middle of each joint of drill pipe can help prevent tube wear and also reduce the torque necessary to rotate the drill string. Testing is ongoing in the Barnett and Bakken shale plays.

There are many downhole tools used in the drilling process which wear down through natural abrasion and erosion and which may not be salvageable with welded hard metal due to their thin wall nature. Spray metal is being used to build up worn tools, steel and non-magnetic, to bring them back to their original OD and return an otherwise junked tool back into

service. Welding onto such complex shaped, and sometimes thin walled, tools might cause distortion or premature failure. Spray metal is another tool in the box to help the downhole tool supplier achieve longer life and income from his equipment.

Conclusions

Spray metal is not a new technology but has found new use in the petroleum well construction industry and, through some novel applications, is providing better technical and commercial solutions than previously available. In certain situations it is providing an enabling technology where nothing was available before. Many of its applications can be likened to an extension of the casing material itself, almost as if some desired shape or form was “grown” on the pipe. Many of its applications are the exact reverse of machined solutions where the majority of material must be removed to leave the desired form. These machined solutions also require additional connections to be cut and the finished product bucked onto the casing, introducing more complexity and more potential leak paths. Starting with plain casing and “growing” the desired forms directly onto it with spray metal is simpler, more robust and the most elegant solution available today.

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References

1. IADC/SPE 112776, 2008, Novel Stabilizers for Casing Drilling Simplify BHA, Handling, and Cost, David Limbert, ConocoPhillips, et al.

Figures and Diagrams

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

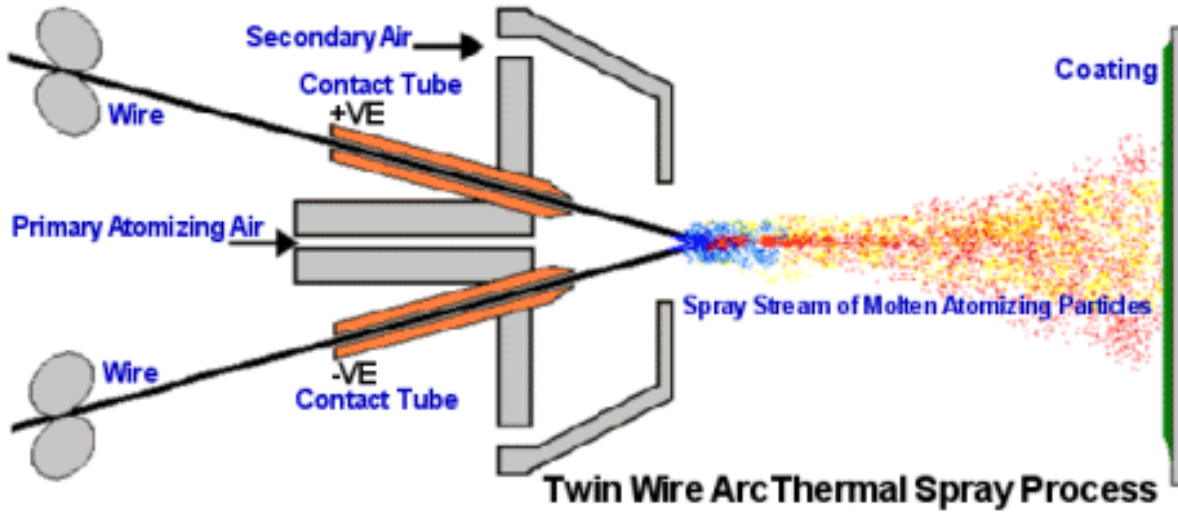


Figure 2: Typical Spray Metal 3-Blade Helical Casing Centralizers



Figure 3: Typical Spray Metal 3-Blade Helical Casing Stabilizer



Figure 4: Typical Solid Body Centralizers with Spray Metal Stops Above and Below



Figure 5: Typical Rotating Bowspring Centralizers with Internal Spray Metal Stops



Figure 6: Typical Rotating “Close Tolerance” Bowspring Centralizers with External Spray Metal Stops



Figure 7: Typical Non-Rotating “Very Close Tolerance” Bowspring Centralizer with Internal Spray Metal Stops and External Guide Rings



Figure 8: Typical Rotating “Very Close Tolerance” Bowspring Centralizers with External Spray Metal Stops, fluted to improve return mud flow. Also showing transport protection

