
Y
NOT
TAKE
THE NEXT
STEP?

Evan Sheline, ESP Completion Technologies, USA, shows how a new approach helps solve the problems caused by weaknesses in the standard ESP bypass system (Y-tool) design.

Artificial lift has become one of the fastest growing segments of the oil industry as flowing wells lose reservoir pressure and operators opt to install various artificial lift methods to maintain or increase production. Operators typically select electrical submersible pumps (ESP) for high flow rate wells because this method provides flexibility and reliability in the most challenging well environments. Currently there are more than 150 000 ESPs installed worldwide, and although the majority are simple, one-pump installations, there is a growing need to install tandem pumps or to access the wellbore below the ESP. The latter require an ESP bypass system; approximately 5% of the installed population utilise this approach.

ESP bypass systems (or Y-tools) are quickly becoming an essential piece of equipment in ESP installs. Being able to access the reservoir below the ESP, without the added cost of a workover, saves time and reduces the risk of reservoir formation damage associated with killing the well during workover operations. The ability to obtain dynamic producing pressure and flow rate reservoir data while the ESP is producing also allows engineers to increase reservoir performance. If needed, an ESP bypass system can also be used to install two ESPs in the same well bore, for production redundancy or to allow separate pumping flow regimes when local regulations require it.

Figure 1. *Standard Y-tool deployed with ESP system and bypass tubing.*

Improving a classic

The Y-tool ESP bypass system is a safe and proven technology, but can it be improved?

Since being introduced in 1987, very few advances have been made to the Y-tool bypass system. The standard design is widely available and is accepted 'as is' by most. But there are frequent problems that occur during the manufacturing process. Because the tools are cast in metal, flaws are often difficult to find, and in many cases these hidden flaws are only found as a result of failure.

Investment casting or 'lost wax' casting has to be used with Y-tools because traditional casting would cause a normal mould to break during the removal process. Single-use moulds can be broken apart to free the cast part from the mould; unfortunately this dramatically increases the cost over traditional casting or forging. The molten metal used in casting forms 'grains' during the cooling process. Solidification of this molten metal occurs in two steps: nucleation and crystal growth. During nucleation, solid particles form in the liquid metal. Then from these nuclei, a crystal structure grows throughout the moulded part. The process can be improved by controlling cooling rates or by inoculation (adding impurities to induce nucleation), but this only improves coarse-grained castings to fine grained castings.

The cast metal itself is still strong, but the presence of these grains means that there is some porosity in the metal, which decreases the strength of the part as a whole. Another danger of casting is hot tearing (or hot cracking). This phenomenon occurs when an irreversible failure (crack) forms in the still semi-solid casting, often caused by the inadequate compensation of solidification shrinkage by melt flow in the presence of thermal stresses.

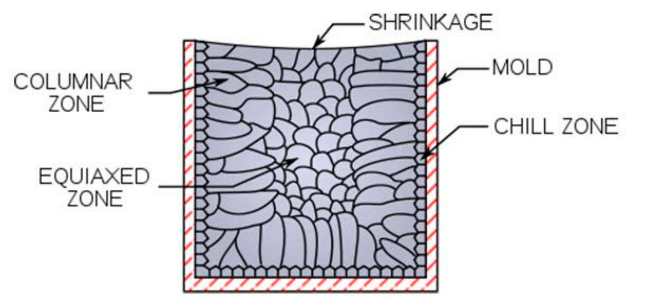

Figure 2. *Typical internal structure of cast parts.*

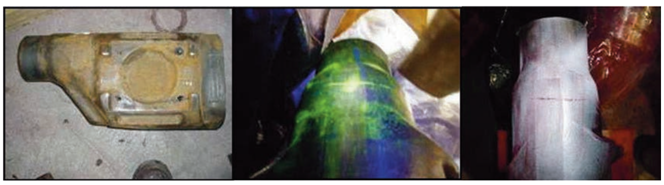

Figure 3. *Damaged cast Y-tool.*

The images in Figure 3 were taken during a tear down of a failed system. The casting had weak spots that cracked when put into well conditions. Since the entire tool is cast as a single part, proper inspection on the inside is extremely difficult and time consuming. Once out in the field, inspection escalates from difficult to nearly impossible. Inspection of cast parts is usually done via non-destructive testing methods such as magnetic particle or liquid dye penetrant. During magnetic particle inspection, a trained technician puts a magnetic field into the part, and surface or subsurface discontinuity in the material allows magnetic flux to leak. Ferrous iron is then applied to the part and if an area of flux leakage is present, then the particles will be attracted to this area and particles will build up. Liquid dye penetrant inspection will identify the presence of cracks or imperfections when subjected to special lighting as shown in Figure 6.

This test starts out with:

- Material with a surface-breaking crack that is not visible to the naked eye.
- Penetrant is applied to the surface.
- Excess penetrant is removed.
- Developer is applied, rendering the crack visible.

These methods of inspection are often successful at finding surface or even subsurface flaws, but do not allow engineers to properly evaluate parts. As a result, if any flaws are found, instead of repairs being made, the entire part might have to be scrapped. Frequently, hidden flaws lays deep in the flow passage where uneven flow or a bubble formed. These weak spots can grow and expand when deployed and eventually cause failure.

Due to the casting process itself, the materials available are very limited (primarily 13 chrome, 1% chrome and carbon steel). The many advances in oilfield materials (such as 17-4 PH, 410 SS, 2205 duplex stainless, inconel, monel) are not viable for cast tools.

The need to cast current Y-tools also severely limits the designs possible. Casting is, by its nature, an imprecise method of sculpting metal. Tight tolerances are impossible without going back with machine work. And since the inside of the Y-tool is inaccessible, they cannot be modified after they have been cast.

Lead times are also a major limiting factor with the current method of producing Y-tools. Industry standard lead times for

Figure 4. *CNC machines.*

castings are around sixteen weeks. This introduces a long delay in revisions and allows for very little flexibility. Custom Y-tools are impractical due to the high cost of running low volume castings, and currently only mass produced varieties are available.

These weaknesses are listed not because the Y-tool concept itself is flawed, but because there are weaknesses that arise from its manufacturing. These weaknesses need to be examined to identify the areas that can be improved. It is time for the next generation of Y-tool technology.

ESP Completion Technologies (ESPCT) designed a modular Y-tool to address the issues traditional Y-tools have with hidden flaws, lack of proper inspection, inflexible design and long lead times. A tremendous amount of flexibility and safety is added by machining the metal instead of casting.

The lead time for machined parts is a fraction of the lead time for cast parts (which, as mentioned earlier, is approximately sixteen weeks). A normal Y-tool can be produced in two weeks, or four weeks if special metallurgy or customisation is needed. This allows for great flexibility of design and allows the manufacture of custom Y-tools. It also allows for repairs to be done. If the top thread is damaged for example, that component of the Y-tool can be replaced for a fraction of the cost of a new one. The process of creating a mould and mass producing from that mould is often what takes longest in the casting process, but machined parts can be customised on a per production basis since no mould is necessary. With advanced computer numerical control (CNC) machines, production can also be automated for large volumes.

Since the main body is constructed in two parts, the insides of each part are now accessible and can be inspected. Precision instruments and a state of the art coordinate measuring machine (CMM) with multi-sensor technology let QC engineers measure down to micrometers.

Generally, any tools operating downhole can be subject to severe slurry and chemical erosion combined with abrasive wear. Many coatings have been developed that will increase hardness, corrosion resistance and part lifetime (like carbides, ceramics and QPQ). Until now, many of these treatments were unavailable for use in traditional Y-tools. Most treatments need direct access to the surface being treated, and that flow area is closed off and inaccessible in traditional Y-tools. This is because they are cast as a complete, closed off part. The new modular design of the Y-tool allows for these advanced coatings to be applied since the flow passage is accessible.

An additional benefit of the modular design and availability of coatings is increased flow through the Y-tool. Cast parts are rough when they come out of the mould and the flow paths inside are inaccessible for smoothing. Machined flow paths are smoother, more accurate than cast ones, and many coating types increase the lubricity (measure of the reduction in friction) of surfaces, which further increases flow.

The tighter tolerances that machined parts can hold make smaller Y-tools possible. They can be designed with the ESP and bypass tubing closer together, and the OD of each closer to the OD of the Y-tool body itself. When trying to fit systems into wells, fractions of an inch can make the difference between a design working or failing. The tolerances in casting of tens of thousandths of an inch cannot match the tolerances that machines can hold (anywhere down to two thousandths of an inch).

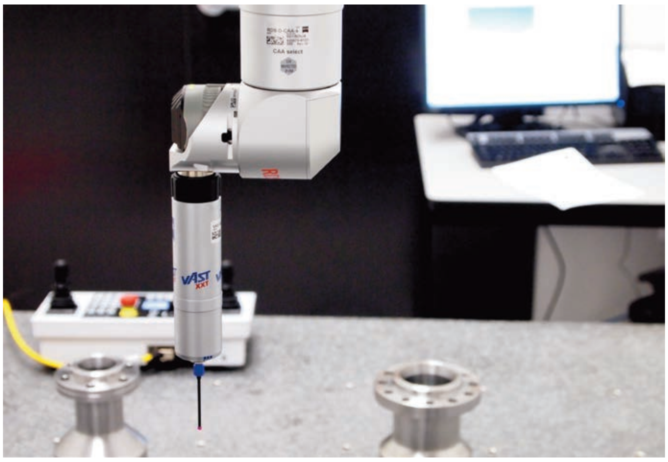

Figure 5. *A CMM machine at ESPCT.*

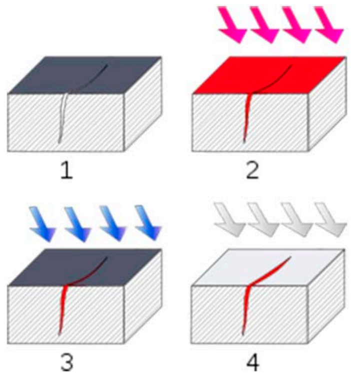

Figure 6. *Dye penetrant inspection steps.*

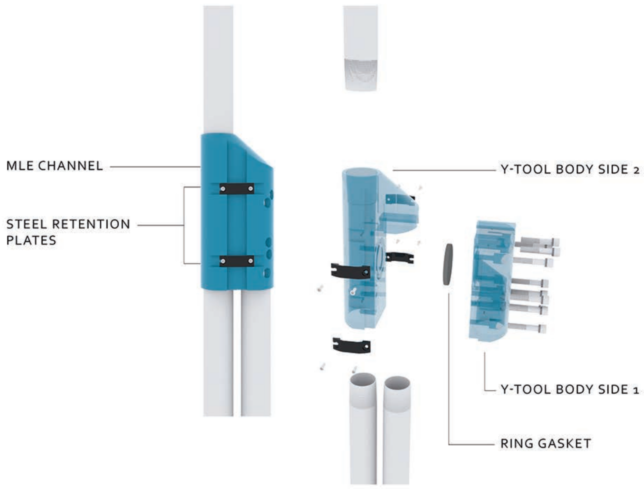

Figure 7. *ESPCT modular Y-tool (Patent Pending).*

Conclusion

Traditional Y-tool technology has been proven to be effective and safe over its existence, but has undergone very few improvements since its introduction. This new modular design goes a long way to address the weaknesses present in current designs. The argument for this design is to avoid the old idiom of being ‘penny wise, pound foolish’. A very small percent of Y-tools fail as described above, but each time they do, the cost can be in the millions. OT