Designing the future: the benefits of additive manufacturing to oil and gas

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ABOUT THIS REPORT

Background

This paper attempts to reflect the challenges and significant opportunities relating to the greater adoption of 3D printing, also known as additive manufacturing, in the oil and gas industry.

It draws on information from a number of public reports and analyses, combined with Protolabs' own market research and interviews with oil and gas professionals, including members of operator, digital transformation and drilling sectors.

The paper identifies four key insights relating to 3D printing that emerged from the research and suggests solutions to them. It does not aim to answer all the questions, but simply to further the debate on the use of 3D printing in the oil and gas industry, the current inhibitors to its widespread deployment and the varying benefits and opportunities it can generate.

UNLOCKING 3D PRINTING'S FULL POTENTIAL

It is no exaggeration to state the market growth potential for 3D printing in the oil and gas industry is significant and growing.

To quantify the above statement, in June 2019 a report by market research and analysis provider SmarTech predicted growth of the 3D printing market in the oil and gas industry would represent a $2 billion opportunity by 2029, including a $975 million yearly revenue opportunity from 3D hardware sales.[1]

Furthermore, the World Economic Forum has estimated 3D printing could eventually save up to $30 billion of additional value to the oil and gas industry.[2]

However, while industries such as aviation are currently reaping the benefits of 3D technology[3], its adoption has remained relatively slow in oil and gas. One reason suggested for this has been widespread adherence to a culture that supports tried and tested methods of production and operation often referred to as "the race to be second". Other reasons raised include legal and regulatory requirements, the need for compliance with rigorous performance and safety standards, industry certification of 3D printing materials and the potential for misuse of intellectual property.

A general lack of appreciation of the significant technological and production advantages 3D printing can bring to oil and gas can be found across varying sectors of the industry. Indeed, a September 2020 report by industry body the Oil and Gas Technology Centre (OGTC) titled "Closing the Gap – Technology for a Net Zero North Sea" does not mention 3D printing.[4]

Yet the benefits of 3D technology to the oil and gas supply chain are considerable. Theses include the flexibility of design of parts, reduction of product development time and a reduction in resource requirements.

Additional benefits have been identified as:

- Rapid and accurate generation of prototypes and components, specifically where original moulding casts no longer exist
- Tool-less manufacturing
- Work with complex designs and geometries
- Potential improvement of designs for items such as pumps, valves, turbine components and sensoring equipment
- Suitability for work in relevant materials such as stainless steels, titanium and aluminium
- No, or fewer, subassemblies
- A leaner inventory (digital warehouse)
- Fast/just in time part availability
- Reduced downtime
- Compliance with strict industry risk certification and quality standards
- Lower carbon footprint through reduced transport needs and manufacturing emissions

A report from ResearchAndMarkets.com states stricter environmental norms, volatile oil prices and ever-increasing competition are encouraging companies to gravitate towards complex equipment designs to achieve operational efficiency. The ability to produce complex components, which may be impossible to manufacture using conventional processes, is turning 3D printing into a must-have technology for oil and gas.[5]

Initially 3D printing was largely limited to polymer-based products, which had limited appeal to the oil and gas industry. However, advances in metal-based printing are making the technology much more appropriate. Therefore, while the development of polymer materials for parts in the oil and gas industry is considered a more long-term opportunity, material development for metal 3D technologies holds the most significant potential immediately. These include robust and corrosion-resistant superalloys and stainless steels for use in the often-challenging environments where the oil and gas industry operates.

Speed of delivery from order receipt to manufacture to avoid lengthy procurement processes is regarded as a key advantage. As an indication of the timescales for 3D printed parts, Protolabs, the world's fastest digital manufacturer, is building a new 5,000 square metre facility in Germany which will support its ambition to deliver an increasing number of projects in as little as one day. This should be compared against traditional methods of order placement, component manufacture and delivery.

RESEARCH FINDINGS

As part of a programme to gain a deeper insight into the issues that have inhibited a more rapid uptake of 3D printing technology in the oil and gas industry, Protolabs conducted a series of interviews with industry professionals. These involved experienced personnel from the operator, digital transformation and downhole tool manufacturing communities. Downhole tool manufacturers were chosen as a supply chain sector that was likely to benefit significantly from greater 3D printing technology adoption.

Four key insights were identified from the interviews:

A conservative industry culture

The industry's conservative approach when considering new processes or technology is well recognised. As one interviewee said: *"Fundamental drilling technology is 90 years old and there is considerable resistance to change."*

Risk aversion was identified as the key driver behind the industry's conservatism. One interviewee commented: *"There's generally a race to be second... there's not been a wide adoption of something like 3D printing... because they're waiting for somebody else to do it."*

Another interviewee described a typical oil industry conversation to emphasise this point: *"'So, have you done it with YY Operating Ltd yet? Let me know when you've done it with them and then I'll sign up.' That is the culture."*

The principle motive behind the risk-averse nature of the industry was identified as safety. However, the variability of oil and gas commodity prices and the current tightening of margins is also affecting the risk appetite of the supply chain, as evidenced by this statement from a drilling expert.

"Things are tight, there's no additional funding to start investing in these things. Also, because contracts at the moment are only maybe for a couple of years... for a rig, you'd have to have a payback period quite quickly. You can't budget for five to ten years anymore because the oil price is so unpredictable."

However, a greater acceptance and adoption of new technology, including digitalisation, has been cited as a solution to improving cost efficiency and the longevity of the industry, particularly in mature regions.[6]

Greater trust and understanding in the industry of the benefits of 3D printing is required if adoption is to reach its potential growth. Increased and widely publicised examples of proven successes in the deployment of these technologies can support companies in their procurement decisions.

Safety, reliability and quality assurance

Safety is the most critical issue in the oil and gas industry across the board. When it comes to 3D printing, the safety and reliability of the processes and products is paramount.

The equivalence of 3D printed parts to the original parts in terms of certified approval from the original equipment manufacturers (OEMs) and quality assurance was listed as one of the top factors for supporting the adoption of 3D printing.

Certification by independent, industry-recognised bodies can give operators the confidence that the products they are using are safe and support production optimisation.

As an example, Protolabs recently achieved 'Qualification of Manufacturer' certification from independent risk management and assurance expert DNV for its direct metal laser sintering (DMLS) technology, specifically for use with the superalloy Inconel 718 for harsh offshore and onshore environments. The award means the company is the first certified manufacturer in the world using powder bed fusion technology.

Inventory issues

The ability for 3D printing to potentially address inventory issues on offshore assets was raised by the interviewees. Being able to manufacture spare parts "just in time" on the rig, was seen as a way of reducing the need for large amounts of spare stock and also reducing non-productive time or downtime.

Against the backdrop of net zero legislation and a focus on the industry's social licence to operate, the opportunity to reduce carbon emissions through eliminating the unnecessary transportation of materials and spare parts was recognised as important. The avoidance of customs import costs, some times up to 20%, was also seen as an advantage.

Some interviewees noted while the ability to 3D print replacement parts offshore or remotely would appear beneficial, the speed of the process would have to outweigh the costs and time of sourcing a traditionally manufactured part and transporting it.

With the average day rate for a rig currently between $150,000 and $180,000, the opportunity to avoid costly downtime through rapid component availability is clearly attractive. However, to demonstrate the feasibility of this solution, the scale of the problem needs to be more accurately quantified.

Lack of knowledge and awareness of 3D printing technology

The lack of knowledge of 3D printing, particularly at senior levels in the oil and gas industry, was acknowledged by some of the interviewees. One commented: *"There is a lot of ignorance in the oil and gas industry around new technology – people just don't understand the possibilities. Companies are often embarrassed about the lack of knowledge."*

A drilling expert who attended technology conventions said he had never heard of 3D printing technology being marketed to the oil and gas sector. This was corroborated by a digital transformation expert. *"We were looking at top technology priorities with a number of operators... 3D printing didn't even hit the radar."*

The lack of awareness of 3D printing is concerning and must be addressed if the oil and gas industry is to make the most of the range of technology benefits available to it.

ACCURATE MANUFACTURING OF HIGH STRENGTH PARTS

While the uptake of 3D printing in oil and gas has been slow, it has been steady and is growing. Projects being undertaken by several major players including Shell, BP, Total, GE Oil & Gas, Siemens Energy, Woodside Energy and Baker Hughes, to name just a few.

Shell has identified that managing spare parts is a major logistical challenge, especially offshore, and has developed a 3D printing lab at the Shell Technology Centre in Amsterdam. This was recently awarded a best practice qualification for its powder bed fusion 3D printing facility. The centre houses three main areas of activity: spare parts printing, novel design and rapid prototyping.

Shell has also used 3D printing to validate the design of structures, such as on the seabed of the Coulomb field in deep water Gulf of Mexico. The project's foundation mud-mat featured hinged 'wings' that were folded up during transportation and opened up to full size once deployed on the seabed. A 3D printed scale model identified an issue with a bolt in the hinge that prevented proper alignment, therefore avoiding construction issues and cost overruns.[7]

Baker Hughes, recently joined with Würth Industry North America (WINA) to offer design, digital inventory, and customized 3D printing services.[8] Amongst other major oil and gas supply chain companies, GE is also active in the 3D printing market.

Acceptance of the benefits of 3D printing is therefore gaining momentum in the oil and gas industry.

CASE STUDY:

Protolabs and Rotork Gears - fast prototyping, precision engineering and certification compliance

Rotork Gears specialises in producing actuators and related flow control equipment for every sector of the oil and gas industry, including production, processing, distribution and storage.

Rotork was commissioned with identifying and designing how to reduce valve leaks for a petrochemical refinery. The solution was a bespoke and patented housing designed to prevent fluid leaks from a valve stem and emissions into the atmosphere. The expectation is that this innovative product will have a significant impact on leak detection and containment and will support leak management and maintenance processes.

Designing and prototyping

Speed was important for this project. To enable quick testing Rotork needed a 'proof of concept' prototype to be completed rapidly. Protolabs, an accredited supplier, was chosen as the production partner because of its trusted ability to deliver within the specified timeframe.

Having prepared the CAD model at Rotork, the files were uploaded to Protolabs' quotation system. The housing prototypes were then made using CNC machining in just four days from receipt of order.

Engineering meets electronics

The project provided an opportunity for Rotork's mechanical and electrical engineers to share expertise and work in a cross-discipline environment. It also created significant cost savings for the end user.

Strengthening relationships

In addition to the leak housing project, Rotork is working with Protolabs to manufacture plastic housing prototype for the electronics. Once the design and in-house testing is finalised, field trials for both products will commence to ensure they meet the strict European certification standards. It is anticipated that a 'real' valve will be trialled later this year in what Rotork has described as a landmark project.

CASE STUDY:
Protolabs supports effort to break speed record

Protolabs' customer Alex Degnes is determined to build the world's most powerful two-stroke engine, and Protolabs is giving him a helping hand with their direct metal laser sintering (DMLS) metal 3D printing service.

The Norwegian native is currently evolving his two-stroke superbike 'Experimental Test Vehicle One' including building a brand new engine. His sights are set on the Bonneville Motorcycle Speed Trials, where he hopes to break the current 91mph speed record for his 50cc category and accelerate beyond 100mph.

Alex has always been extremely hands-on. However, he realised that if he was going to create the world's most powerful two-stroke engine he needed to call in expert outside help and turned to Protolabs for assistance.

"When I had the initial idea for the engine design I thought I may need to get it 3D printed. But I like to do things myself, so I did some research into investment casting and purchased a plastic 3D printer," said Alex.

Having printed a model and then casting a cylinder in aluminium, Alex encountered problems with porosity and the investment casting, which failed to meet his detailed requirements.

"I knew with 3D printing, I could do all the exciting things I really want to do and save on crucial weight in a way that's not possible with casting, for instance utilising a honeycomb structure inside solid parts. I came to the conclusion that I really should get this part 3D printed and contacted Protolabs. I'm so glad I did."

Alex ordered an AlSi10Mg aluminium cylinder, produced using Protolabs' DMLS service. AlSi10Mg is a typical casting alloy with good casting properties and is most often used for cast parts with thin walls and complex geometries.

It is an excellent choice for substitution of casted parts, is lightweight and has good thermal properties. The alloy offers good strength, hardness and dynamic properties and is often used for parts subject to high loads. Parts in Aluminium AlSi10Mg can be machined, spark-eroded, welded, micro shot-peened, polished and coated if required.

Alex's design was received, the piece manufactured and shipped by Protolabs within a couple of days.

"I'm absolutely delighted with the part, it's just perfect. It exceeded my expectations. What I'm really impressed with is the fact that the model wasn't really designed for 3D printing. I thought that I would have to do some design changes to make it printable, but Protolabs printed it perfectly."

TAKING THE OIL AND GAS SECTOR FORWARD

Several major operators and supply chain companies are showing increasing interest in 3D printing technology. To date, this has predominantly been to support new product development processes and reduce product development time.

Rapid prototyping and bespoke engineering support are recognised as key benefits of 3D printing, which plays to the strengths of those 3D printing companies that can work with complex novel designs and a range of materials. The ability to deliver engineering solutions to the oil and gas industry, including OEM manufacturers, in various sections of the supply chain is also seen as a key benefit.

The development of metal-based printing - such as Protolabs' direct metal laser sintering (DMLS) technology and its use with superalloy Inconel 718, which is a high-strength corrosion nickel chromium, or stainless steel 316L for less extreme environments – significantly increases the relevance of 3D printing to the oil and gas industry. Particularly as even 3D printed Inconel 718 can be used at temperatures between -252°C and 704°C due to its ability to create a thick, stable passivating oxide layer at high temperatures. Inconel has good tensile, fatigue, creep and rupture strength and, as a 3D printed metal, can exceed the mechanical properties of its cast and wrought counterparts.

One opportunity for growth in 3D printing is the manufacturing of spare parts where the original moulding casts no longer exists.

Another would be the use of 3D printing to review and explore design possibilities to increase efficiency, create more robust designs and unlock decarbonisation benefits for parts such as pumps, valves, components for turbines or sensoring equipment.

The development of robust metal-based printing creates potential benefits for companies such as the providers of downhole tool technologies. These tools often operate in conditions of extreme pressure and temperature, so proof of the durability and reliability of 3D-printed components would be required to pass the most stringent tests of equivalence with existing products. The ability of 3D printing companies to work to the highest standards of quality and reliability is important for the safety-conscious oil and gas industry. Evidence of quality certifications, accreditations and standards achieved will support industry confidence.

Although the remote printing of spare parts has been suggested in our findings as a potential benefit, deployment of the decentralised "3D printer on a rig" would appear to be a longer-term ambition. Adoption will depend on the ability of 3D printing companies to overcome several factors, not least industry cultural barriers.

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CONCLUSION

The opportunities that 3D printing present to the oil and gas industry are considerable and are expected to grow.

A major hurdle facing the 3D printing sector is the pervading culture of conservatism. This is supported by questions about material reliability, safety, quality assurance and a fear of investing in the 'new' especially in the current challenging financial climate.

To overcome these issues and gain more widespread acceptance it is up to the 3D printing sector to prove its credibility through more examples of successful industry applications and validation of processes and procedures by recognised independent industry bodies.

3D printing can have a critical role to play in sustaining the longevity of the global oil and gas industry through increasing financial efficiencies, delivering unequalled precision engineering to the highest standards of quality and reliability, supporting greater safety and reducing carbon footprint.

Maybe it is time for the industry to put its trust in a new and better way.

For further information, please visit www.protolabs.co.uk

[1] GlobeNewsWire (2019) SmarTech Analysis Announces New Report for End Users of Additive Manufacturing in Oil and Gas Sector (globenewswire.com) https://www.globenewswire.com/news-release/2019/06/26/1874801/0/en/SmarTech-Analysis-Announces-New-Report-for-End-Users-of-Additive-Manufacturing-in-Oil-and-Gas-Sector.html
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