Benefits of Additive Manufacturing for the Oil, Gas and Maritime industries

Article

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Additive manufacturing has long held the promise of realizing a wide range of benefits. However, organizations in oil, gas and maritime industries had faced challenges in adopting this novel production technology due to a lack of a standard approach to achieving quality assured parts. To eliminate this barrier, twenty organizations. (Equinor, BP, Total, Shell, Kongsberg, TechnipFMC, Siemens, Voestalpine, Sandvik, Guaranteed, Vallourec, Aidro, SLM Solutions, Additive Industries, Quintus, HIPtec, Ivaldi Group, IMI CCI, Immensa Technology Labs, and the Advanced Forming Research Centre of the University of Strathclyde) collaborated in Joint Industry Projects to formulate requirements essential to producing high quality parts. Together this international consortium represented the entire value chain, from part design to end user, from material and process development to post processing and testing.

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The goals of the JIPs they collaborated in, were:

- to develop a guideline, formulating requirements necessary to introduce components made by AM.
  This guideline was presented on January 29, 2020, and is now being translated into a 'Recommended Practice' and 'Standard', by DNV-GL.
- to assess the economic benefits of AM over current manufacturing practices.
  This was realised by the delivery of a very detailed Business Impact Model which was developed alongside the guideline.

To prepare both deliverables, real life parts were produced to ensure practicality and compatibility of the guideline with operational and business practices. Metal parts printed were impellers (in Titanium and Inconel) a propeller blade (Inconel) and a crank pin (Stainless steel) via laser powder bed fusion (L-PBF), and cross overs, the same crank pin and a circulating head via wire and arc additive manufacturing (WAAM). This article highlights the results and benefits realised, based on the information from the part production as carried out during the project.

The article covers the initial reasons the partners had for selecting AM, and the activity and cost impact observed. We conclude with an overview of lessons learned.

Reasons for selecting AM

A number of objectives were given by the part owner, users and manufacturers, for the selection of AM as fabrication method. The reasons ranged from production cost benefits foreseen, to market opportunities, production efficiencies and supply chain benefits.

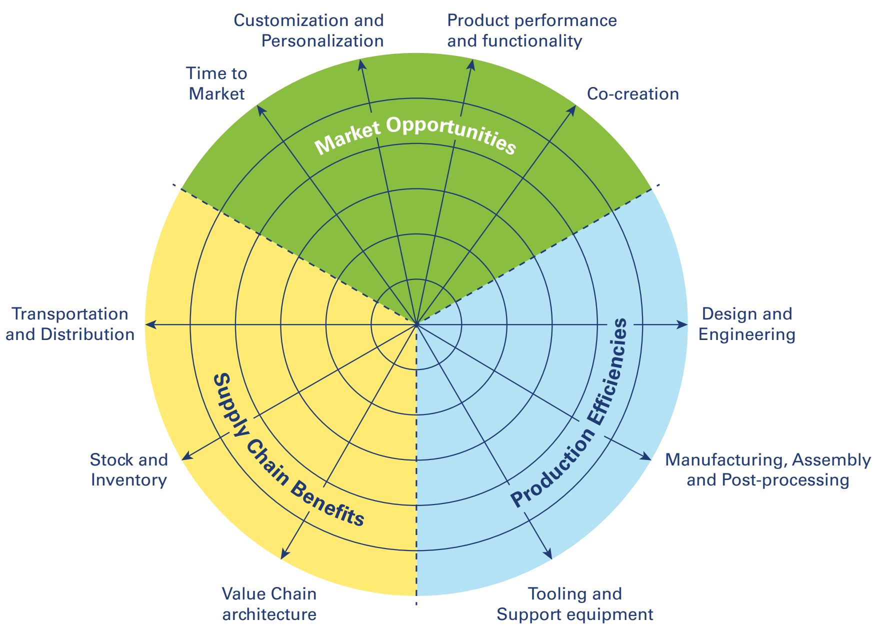
Regarding supply chain benefits, the main goals were to assess the possibilities to reduce lead time and delivery time, and minimize obsolescence. The possibility to produce on demand and on (or close to) location of use, could lead to reduced stock levels, reduced redundancy levels and lower warehousing costs. Digital warehousing opportunities (storing files, not parts) would also allow to refrain from many transportation activities, with a very positive effect on lead times and transportation cost.

Design optimization can lead to production efficiencies like reduced manufacturing and machining time, less material and a minimal need for tooling in the additive manufacturing process. The possibility to produce hybrid parts, for instance by adding features via AM onto standard products, can also lead to a more flexible production set up. In addition, the materials used and the specific additive manufacturing process could lead to improved corrosion and cavitation resistance.

The freedom in design that AM offers, can lead to the manufacturing of parts with improved quality. For instance lower weight parts are easier to maneuver. Or specifically tailored parts deliver better functionality.

Many of these benefits also translate into cost reduction. Less tooling will result in lower tooling costs, lower weight and improved maneuverability lead to less energy costs while operating the parts. These benefits simultaneously help to reduce the carbon footprint of AM-parts compared to traditionally manufactured parts.

During the project we assessed to what extend these objectives were indeed realized, or could be determined to be realistic.



Activity and cost impact

Benefits

Design and engineering is positively impacted by AM. More efficient prototyping, in terms of engineering activities, throughput and costs are observed. Next to this, machining can be eliminated or significantly diminished, as AM delivers near net-shape parts. For instance, near net-shape manufacturing of the crank pin resulted in reduced machining time and costs for that part.

As production of quality assured additively manufactured parts can be achieved, operational benefits in the supply chain are within reach.

The use cases in our project all offer possibilities for improved lead times and decreased stock levels and thus for lower warehousing costs. Lead time reductions can be impressive. For the propeller blade, for instance, the lead time from casting and machining (20 weeks) to printing and machining (4 weeks) was reduced by 75%. The cost impact foreseen is significant (up to 30% lower costs). But significant benefits will not come from printing an occasional component. Only when AM is used for a large number of parts the bottom line impact will be substantial.
For a number of parts in our project weight reduction and the accompanying lower material use reached between 30 - 70% (propeller blade, circulating head, impeller). Not only does this save on material costs, but also the carbon footprint is positively impacted.

Product groups that hold promises for large scale application of AM for components are for instance valves, piping systems, hydraulic systems, nozzles and tooling. Various downhole and topside components were indicated to show possibilities and benefits for using AM.

Switching costs

Next to the benefits expected, a move to AM also brings switching costs and novel activities to be carried out.

Impeller for Equinor in Titanium 64, produced by Additive Industries using their MetalFab1 metal 3D Printer

Even when the part to be produced is known and in use for some time already, redesign is necessary to support the AM production. For instance, the impeller we produced was redesigned a couple of times, to overcome initial printing and part quality issues. Design for AM is a competency which is not yet widespread. Those switching to AM will need to invest in training to acquire these skills.

Materials for additive manufacturing are often different from those traditionally used. Based on the requirements the part should meet, a selection of the best process and the optimal material will be carried out. After some time this will be a known process, but initially analysis takes time.

The materials themselves are often somewhat more expensive than 'comparable' materials for conventional manufacturing technologies.

For a number of our parts the higher material costs were offset to a large extend by the reduced material volume required for the AM part. For instance, a weight reduction of 70% was observed when producing the propeller blade, compared to the original part.

Often, and also in our project, the actual production is carried out by a service bureau that already has machines in place. As the AM technology is relatively new and the number of machines sold is limited, the machine costs are currently rather high. When the technology matures and becomes more wide spread, machine costs are expected to decrease over time.

AM requires post processing activities. For instance, metal AM processes like heat treatment or hipping are required. Laser Powderbed Fusion (L-PBF) requires operators to remove support structures. Although Wire and Arc Additive manufacturing (WAAM) can normally be performed in open air, for certain more reactive alloys production under atmosphere is required to ensure part quality. Especially when these activities are carried out for a 'series of 1', the relative cost of these activities is high. When larger series are produced and can be heat treated or hipped in one batch, amortization of costs over more parts will lead to reasonable cost levels.

Conclusions and lessons learned

The value of AM for the Oil, Gas and Maritime industries is currently primarily found in the supply chain. Limiting the number of parts on stock, made possible by improved delivery times, lowers the amount of capital that is locked up in parts and warehouses.

When redesigns lead to less material used, both material cost and carbon footprint benefits are foreseen. In the JIP ProGRAM we observed the fact that quality assured fast delivery of redesigned parts is possible. But we need to be realistic and indicate that an immediate switch over to AM for the majority of components is not possible. Nevertheless, supported by the accepted guideline that DNV-GL developed, the growth of AM produced components we foresee in the coming years will be very large.

Although quality wise AM production is feasible for a large number of components in many product groups, we still have a way to go to achieve large scale cost benefits over traditionally manufactured components. Manufacturing and qualification costs are often considerably higher than for traditional manufacturing technologies. Post processing and testing costs often 'ruin the business case'.

But in many cases the benefits of AM with regards to more efficient use, increased functionality, lower maintenance, warehousing and transportation costs, offset the manufacturing and qualification costs. In due time this will lead to positive business cases, as the technology will rapidly become a trusted alternative in the Oil, Gas and Maritime industries. Process qualification, instead of single part qualification, will open the door for a wider portfolio of AM parts and components, that will see faster qualification and/or certification than nowadays observed.

For the bottom line impact, an elaborate calculation is required. In the near future for many parts or components we will keep seeing (somewhat) higher production costs than for traditional manufacturing. But due to the benefits of AM in the use phase (improved functionality) and in the supply chain (fewer parts on stock) the 'life-time business case' is positive.
The 3D Printing Business Impact Model (3DBIM), that we created alongside the development of the guideline by DNV-GL, is supporting exactly that.

3DBIM pinpoints variations in activities of AM versus traditional manufacturing, for each of the phases in the value chain, from design and engineering up to maintenance, use and end of life.

As the Oil, Gas and Maritime industries can now use the DNV-GL guideline to trust the quality of the parts produced, the 3DBIM model comes in handy to decide if AM is also business wise the preferred way forward.

The JIP team during the final project meeting
(Oslo, Norway, January 2020).

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