3D printing - the future of maritime spare parts?

3D printing is one of the latest technologies hyped as the 'next big thing', with many eager to see it as the next great revolution in manufacturing. In the maritime context, could 3D printing help to make storage of spare parts on board a thing of the past? *Digital Ship* examines the possibilities

The world of 3D printing, also called additive manufacturing, is currently going through a growth explosion, with worldwide shipments of 3D printers set to grow by nearly half in 2013 as the technology increases its presence in mainstream industry.

According to research company Gartner, worldwide shipments of 3D printers (3DPs) priced less than $100,000 will grow 49 per cent in 2013, to reach a total of 56,507 units.

And this is just a starting point - Gartner notes that rapid quality and performance innovations across all 3DP technologies will drive enterprise and consumer demand to the extent that shipments will increase further in 2014, growing 75 per cent to 98,065 units, followed by a near doubling of unit shipments in 2015.

"The 3D printer market has reached its inflection point," said Pete Basiliere, research director at Gartner.

"While still a nascent market, with hype outpacing the technical realities, the speed of development and rise in buyer interest are pressing hardware, software and service providers to offer easier-to-use tools and materials that produce consistently high-quality results."

"As the products rapidly mature, organisations will increasingly exploit 3D printing's potential in their laboratory, product development and manufacturing operations."

"In the next 18 months, we foresee consumers moving from being curious about the technology to finding reasons to justify purchases as price points, applications and functionality become more attractive."

The research firm predicts that 3D printing will have a high impact on industries such as consumer products, industrial and manufacturing: a medium impact on construction, education, energy, government, medical products, military, retail, telecommunications, transportation and utilities: and a low impact on banking and financial services and insurance.

"The hype around consumer 3D printing has made enterprises aware that the price point and functionality of 3DP has changed significantly over the last five years, driving increased shipments beginning in 2014," said Mr Basiliere.

"Most businesses are only now beginning to fully comprehend all of the ways in which a 3DP can be cost-effectively used in their organisations, from prototyping and product development to fixtures and moulds that are used to manufacture or assemble an item to drive finished goods."

"Now that many people in the organisation, not only the engineering and manufacturing department managers but also senior corporate management marketing management and others, have heard the hype, they want to know when the business will have a 3D printer."

Further research by The McKinsey Global Institute has reiterated the point that the use of 3D printing is spreading quickly, pointing to the fact that the machinery is improving, the range of materials is expanding, and prices for both printers and materials are declining rapidly.

The price for a home 3D printer decreased by 90 per cent in just four years, with more than 6,500 3D printers shipped in the United States in 2012, the institute reported. The Institute notes that the machines are used mostly for assembling models and prototypes, but have also been used to make intricate aerospace components and even replacement human organs.

In its 18th annual report on additive manufacturing published last May, Wohlers Associates forecasted strong double-digit growth over the next several years, expecting the 3D printing industry to be worth $4 billion in 2015, to approach $6 billion worldwide by 2017, and to reach $10.8 billion by 2021.

With acceptance of the technology growing at such a rate, what might the implications be for the shipping sector?

In theory at least the maritime industry should be among those with the most to gain from this kind of technology - when your business premises are travelling across the oceans, popping down to a supplier's warehouse becomes slightly more difficult so the ability to manufacture items on site has a certain appeal.

Modern ships are continually required to order and stock large numbers of spare parts and supplies to make sure that they are not caught short when needs arise out at sea. Could 3D printing change the way that this process is managed?

Modern 3D printers can be small enough to fit on a desk top, or as large as a refrigerator, depending on their complexity

How it works

3D printing, or additive manufacturing, is a layering process. Rather than being created by casting or stamping, the object is built up layer by layer. Although the principle remains the same, the term covers a range of different techniques.

The birth of 3D printing, moving from the inkjet printers that printed with ink to those that could create objects using new materials, can be traced back to 1984 when Charles Hull invented a process called stereolithography - a type of printing that would allow a tangible 3D object to be created from digital data.

The early days of 3D printing in the 1990s saw the technology begin to be used for 'rapid prototyping', but evolved over the years into what is now called additive manufacturing.

The major difference in the systems moving in this direction is that in prototyping you are designing something with the parameters of the machine that will construct it later in mind, whereas additive manufacturing aims to create the finished article - letting you completely change the way you design parts.

RedEye, a 3D printing company already supplying services to the aeronautical and automobile industries, currently uses two main teclmiques in its 3D printing.

One of these, as Tim Thellin, project manager at RedEye, explains, is called Fused Deposition Modeling (FDM), while the other is Polyjet.

"(The FDM) process uses a thermoplastic material that is melted through a fine nozzle. It's like a hot glue gun except that a very precise and very fine extrusion comes out of that," he told *Digital Ship.*

"The other technology we use is called PolyJet. It's similar to 2D printing except that instead of printing out a pixel, you're actually printing out a voxel, which is just a three-dimensional pixel. It juts out the entire layer and then it 'cures' that layer with a UV light."

3D printing has many potential advantages over traditional manufacturing, including the fact that it can be used for the production of small numbers of items rather than the large numbers usually involved with a factory production line.

The items created using modern technologies can also be dynamic, including moving parts that do not need to be assembled - for example, in 2008 the first person successfully walked on a 3D printed prosthetic leg that had all of its parts, such as the knee, foot and various sockets, printed in the structure without any assembly.

"Complexity is not really an issue with this technology," says Mr Thellin.

"You can produce a complex shape that can't be injection moulded, for example. The shapes can have undercuts, internal holes, internal cavities, things that can't be injection moulded."

"You can build an assembled part all as one piece, without having to print them individually and then assemble it after. You can build that part, it's already functional, and you can put it right into enduse, into the application as needed, without somebody having to assemble all pieces together. So you reduce the labour and the time to get that part to where it needs to be used."

The RedEye project manager says that 3D printers could be taken on board ships and that the Fused Deposition Modeling teclmology could work even in rough seas. Smaller 3D printers are not much bigger than a 2D printer and can fit on a desk top, while others can be the size of a large industrial refrigerator.

"The FDM technology has been tested in zero gravity/' he notes.

"And the FDM technology proved to work very well. The system itself could build under zero gravity for example, it could build with some movement to it and it didn't affect the part coming out of it."

It should be noted that, in contrast to FDM, competing teclmologies using resin or powder need a stable environment.

The type of spare parts in question would also have a significant effect on the viability of 3D printing technology in the maritime setting. From the outset at least rubber or plastic items with reasonably simple designs would seem the most realistic target.

ShipServ's rankings of the top 20 Product category searches by maritime buyers on its ShipServ Pages system over last five years show that Auxiliary Engine parts are at the top of the list in terms of spares.

While this category might be quite specialised and feature parts a little complex for the early days of on board 3D printing, the second placed category, Valves, is probably more suitable in terms of what could be produced with reasonable ease today.

From an engineering point of view a valve could be reproduced without great difficulty if it was done accurately and with sufficient strength to hold up to the pressure it would encounter when in use.

Other categories in the top 20 list, such as Pumps at number 5, Metal, Steel & Rubber Supplies at number 14, and Pipe Repair Products and Pipes & Tubes (numbers 17 and 18 respectively), could also conceivably benefit from the ability to 3D print spares on board as required using current technologies.

Limitations

The real limitations for 3D printing in its current state rest elsewhere.

"Because it's a layering process, it may not be as strong as an injection moulded part. Injection moulding is going to make more of a uniform part," Mr Thellin admitted.

"You don't want to have super-thin features or walls. You want to build those up so that there is enough volume there to have the strength requirement."

"(However), if you have a part that is designed correctly and built correctly, it will match pretty closely (to) the quality of an injection mould part. It could be anywhere from 80 per cent of the strength value or greater."

Mr Thellin also notes that, "today in general the process is slow." For instance, it may take four to six hours to make a small air louver for a car. He predicted however that speed would increase over time.

Another obstacle may reside in the size of the data necessary to build a part.

"Typically we start with a three-dimensional file that comes from a CAD (Computer-aided design) application. That file is then converted into an STL (STereoLithography) file; it's the industry standard file format, it's just a 3D representation of a CAD file," Mr Thellin explained.

"We take that file into our proprietary software, where we actually slice it into the layer resolutions we're going to build it as. It then calculates the tool path that it's going to use to lay down that plastic bead."

"So the STL file can range anywhere from a few hundred kilobytes all the way up to 200-300MB, they can get pretty big depending on how big the part is and how fine the resolution is on all the features. And that would be about the same for the tool path files we actually build on the system. Those typically range from a couple megabytes to 100-200MB in general."

Transmitting this amount of data to a ship would require a significant amount of bandwidth and, while it would presumably only be undertaken by someone using a flat-fee service and would therefore not directly impact any airtime bills, it would still constitute a large amount of traffic.

Therefore, the most likely scenario would see a ship maintain a local database of digital files for the specific spares on board, given that terabytes of storage is significantly cheaper than even the cheapest satcom contracts.

"For storage, all it would require is a simple file server. You would just have to have a lot of space to keep all the geometries you want to keep in a digital inventorial so to speak," said Mr Thellin.

Potentially, such a set-up could link with something like the Shipdex initiative, the non-profit project aiming to create digital databases to simplify the effort involved in populating planned maintenance databases.

Shipdex files already include drawings and schematics for various shipboard components - why not also link a 3D printing file within the same database?

"Shipdex has standardised the exchange of technical manuals in electronic format, including a spare parts catalogue, which means we have an electronic XML file for every spare parts catalogue and the file contains the list of all spare parts with relevant information," said Marco Vatteroni, manager of Shipdex.

"For every spare part it could be possible (where requested) to attach the relevant 3D file and send them on board, together with all the Shipdex documentation."

"Moreover, Shipdex data can be automatically uploaded into a CMMS (computerised maintenance management system) and then the 3D files could also be available in (the software's) database."

Less complex machinery, such as valves, may be among the first spares that the technology could be applied to

Another alternative to maintaining a database of all of the parts on board would be to reverse engineer specific components as required, Mr Thellin says.

"If you could digitally scan the part, that would be another way to get it to a 3D file where it could be buildable as a replacement part," he explained.

Scanning would create a file within a CAD-type interface where you might have to do some slight editing, Mr Thellin says, with the file then converted into the STL format.

Of course, the cost involved with these technologies today are still an obstacle. Scanners cost a couple of thousand dollars for low end technologies, and up to $10,000 to $50,000 for high-end machines. A high-performance 3D printer itself may cost between $10,000 and $500,000.

In addition to the cost there is also the issue of compliance with various rules and regulations to consider - for example, depending on the classification society that the vessel is registered with there may be specific requirements or recommendations about the types of spares that need to be carried on board for various systems.

While machinery such as engines or turbines might be potentially be more flexible when it comes to changing the rules, safety systems in particular, such as fire safety systems for example, are likely to require physical stores of spares for a long time to come regardless of the ship's ability to 3D print these parts on board.

Time frame

The issue of how soon this technology might be ready to make a practical contribution to spare parts management on board is one that divides opinion, with some insisting that 3D printing has reached a stage where it could be used on-ship today, while others are sceptical of seeing any significant headway for the technology in maritime in the next decade.

Mr Thellin of RedEye is among those excited about the current possibilities, as he believes that a 3D printer could be used to produce a spare part at sea immediately.

"I would argue that that could happen right now," he said, adding that it could make sense financially in current conditions, compared to the costs of shipping a part to a distant vessel.

"If you compare those costs relative to the cost of having a machine on board being able to produce that replacement part on demand, it seems like financially you could put together a whole of a lot that would justify it. I believe you could do that today."

On the other side of the fence is Hans Oxvang Mortensen, senior manager at MAN Diesel & Turbo, a manufacturer of some of the systems and spare parts that would be part of any grand 3D printing future.

Mr Mortensen's company already has experience of 3D printing technology, having used such systems i !self already as part of its production operations, though primarily as a prototyping technique.

"We have invested in 3D printing for the last year and half," Mr Mortensen said.

"The 3D printers are mainly used for design purposes - that means identifying design details and visualising design elements."

For example, MAN has already 3D printed the prototype of a water mist catcher and installed it on a test engine for evaluation purposes.

"Normally we would manufacture this in various forms of steel or iron," said Mr Mortensen.

"But in this case, we manufactured it on our 3D printer as a plastic component. This worked very well for our testing."

Mr Mortensen notes that using this technique saved the company "a lot of money" compared with creating the prototype in steel and iron, evaluating the cost difference in this case to be in the region of €5,000.

However, despite these successes, Mr Mortensen believes that the industry is still some distance from being able to apply this technology to replace spares in a practical manner.

"It wouldn't be relevant (for) spare parts at the present stage, but only as a prototype testing facility," Mr Mortensen said.

"We do look ahead to the very promising scenario but it is very much related to the development of material technologies, and also to the development of the size and price of the components you can print."

Mr Mortensen thinks that it is still more economical to store spare parts on board or have them delivered, rather than 3D printing them, and points to the continuing requirement to keep certain spare parts on board as likely to hinder 3D printing development.

"Anything related to the safety or propulsion of the ship, they have to have the spare parts on board. That would be a general requirement from all classification societies," he said.

Mr Mortensen also suggests that other spare parts are so large that they need to be made in a factory, while smaller items will suffer from the competition offered by current cheaper production processes.

"Why should a ship install a relatively expensive printer on board?" he asks. "In many cases, the logistics is far enough to support the ship with the spare parts."

Some of Mr Mortensen' s strongest reservations about 3D printing in the marine environment as it currently stands, relate to the materials available, particularly in relation to steel parts - obviously a major component in a variety of ship spares.

"It can be done today but the quality is not at a decent level. It still needs some technological development before that could be relevant," he said

"It could be relevant for emergency spare parts or prototype spare parts like fuel nozzles or different kinds of valves and so on."

"But very many of these components actually need a surface grinding also. We still need the improvement in the surface quality of 3D printing. Or you would have to, on board the ship, be able to do some grinding."

In the end, Mr Mortensen says that he sees possible applications for 3D printing in maritime only if material technology improves, and only for smaller components.

"Stilt I would say, you are a minimum 10 years ahead of the reality," he said.

Regardless of which side of the argument is more convincing when it comes to the suitability of 3D printing for maritime use at the moment the technology is certain to see significant development in the years ahead, likely to lead to better and stronger materials and the ability of the printers to handle more sophisticated designs.

Eventually this should lead to a scenario where most spare parts could be realistically produced on board the ship. However, by that time it may be too late - once the consumer can print their own flat screen TV or family hatchback without having to have it physically delivered from half the world away the shipping industry as we know it will be facing a whole host of new challenges to its survival.

Perhaps 3D printing an entire newbuild ship itself for the cost of a few tons of printer toner will then be the only answer…

Source: Digital Ship - December 2013