

Advantages of 3D-printing **heat exchangers**

Additive Manufacturing is well known for its applications in the aerospace, automotive, and motorsport industries. Its use in the oil & gas and chemical plant industries is growing, but it still remains a minimal utilization compared to traditional manufacturing methods. This article will present additively manufactured metallic solutions, and their benefits for various products, in particular for heat exchangers.

By Valeria Tirelli, CEO, AIDRO, Taino, Italy

The adoption of Additive Manufacturing (AM) can generate advantages in various areas. For example, fast prototyping, the acceleration of R&D, and the timely delivery of spare parts. The use of AM in situations that require lightweight, space-saving, and complex components will also be examined, where an improved flow performance is reached thanks to AM technology.

The subject covers a variety of processes in which material is joined or solidified under computer control to create a three-dimensional object, with material beingtypically added layer by layer.

Types of materials used/industries

A variety of materials is available for additive technologies, such as metals, polymers, composites, and ceramics. Certainly, AM processes and materials will increasingly gain a wider adoption in many industries during the coming years. These include technologies for prototyping, modeling, casting, and parts.

Here we cover established areas of AM in the oil & gas industry focusing primarily on the current adoption of metal AM technologies, such as metal powder bed fusion (PBF). Aidro Hydraulics & 3D Printing has recently expanded its services to cover the oil & gas industry due to the need within it for the production of valves, heat exchangers, and spare parts.

Advantages of using 3D printing

"AM is not always ready for large volume production," says Valeria Tirelli, CEO of Aidro. "We use it for special series or cases where shape and weight can make significant improvements to performance".

Key benefits of introducing AM include tool-less manufacturing, increased geometric freedom in part design, no or less sub-assemblies, non-physical inventory (digital warehouse), rapid spare part production, and for reducing downtimes.

"Using 3D printing we are also able to improve the flow inside, through new geometric shapes. For example curved canals and the ability to do away with 90° intersections, which are typical of traditional manufacturing. We have found many benefits with 3D printing, including low weight and improved flow. However, since it costs more, we need to find a balance with the applications that justify these costs. AM will not replace traditional production of easy and massive parts; more than anything else it will create new opportunities. This applies to many sectors in which the fast part availability and reduced downtimes are key factors: from oil & gas industry to chemical plants," Ms. Tirelli tells us.

When it comes to heat exchangers, the benefit of using additive manufacturing is providing a maximum heat transfer surface in a smaller space.

In the example, a comparison between a conventional heat exchange and a 3D-printed version with the same heat exchange.

Fig. 1.

One of the main goals of AM is to reduce a part's size. Compared to a traditional part, it's possible to reduce the weight between 20% and 50%, and in some cases more (as in Fig. 1, till 85% weight reduction), and consequently also the dimensions. In some applications not only lightness but also compactness becomes important. A heat exchanger fits inside a system, where there are a vast multitude of components. Oil & gas plants, for example, are increasingly filled with components, among them those for safety and environmental protection, which, increasingly reduce the available space for the whole system. With additive, the heat exchanger is designed and 3D printed to be installed exactly in the available space and has connections exactly where they are needed. Even the largest systems, in some cases, need small components adapted to the shape.

Designing the 3D printers of the future

"We are working to design new heat exchangers made with additive technologies, suited for general heating and cooling duties on offshore oil & gas installations. This product consists of a pack of metal 3D printed heat exchangers with port holes for the passage of two fluids. These heat exchangers provide space and weight savings compared with conventional heat exchangers. They often occupy just half of the space required for a standard part of equivalent heat transfer capacity. This is possible thank to the new internal design of the 3D printed parts," says Ms. Tirelli.

The internal structure of the heat exchanger can be designed using the unique shapes available with additive manufacturing, such as lattice structure.

Fig. 2 shows some examples of lattice structures.

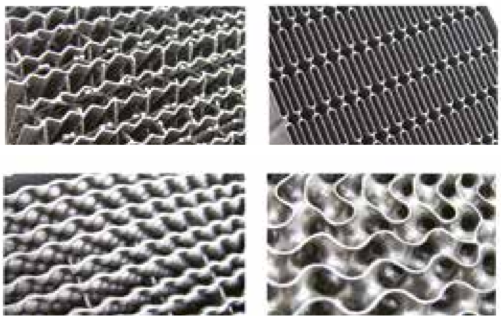


Fig. 2.

The 3D printed internal structures form the channels for the liquids to flow through, in the process promoting turbulence, which in turn improves heat transfer. Turbulence also helps to prevent fouling in the exchanger and keeps the channels clear.

The number of lattice structures and their shape in a given unit is determined by the flow rate, physical properties of the fluids, pressure drop and temperature program. Since the design is essentially free, the capacity of the heat exchanger can be increased by adding the internal trabecular shapes. This ensures that the exchanger can be sized precisely for a given duty and eliminates the need for expensive over-engineering.

With AM, it's possible to produce gyroid shapes that are not feasible with conventional manufacturing method. This form is inspired by nature, enabling designs architectures to be achieved previously not possible. This allows heat exchangers to be created that can operate cost effectively at higher temperatures and pressure. Aidro's new heat exchanger is made in nickel alloy and was designed specifically for the additive manufacturing process.

Fig. 3.

Depending on the duty and the nature of the working environment, the heat exchanger can be printed in various metals, such as stainless steel, inconel or titanium.

Fig. 4 shows a heat exchanger 3D-printed in aluminum AlSi10Mg, providing a lightweight solution for a non-corrosive environment.

QUALITY CONTROL AND NDT ON 3D-PRINTED HEAT EXCHANGERS

The most common technique for NDT is a Computed Tomography scan that can reveal potential defects, crack and residual powder.

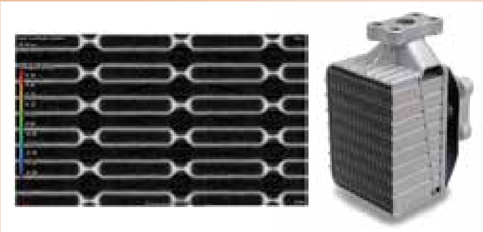
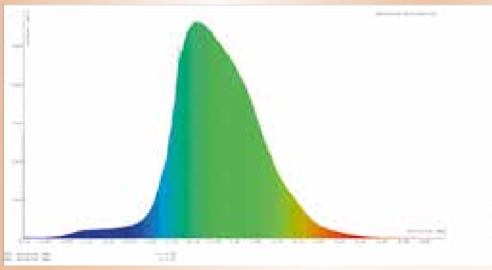


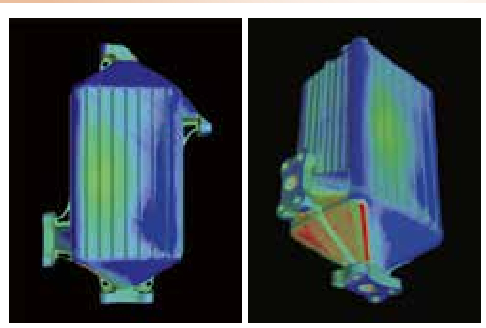
Fig. 5. The wall thickness is 0.4 mm and the CT scan shows a perfect linear structure without any defects.

Fig. 6. The dimensional control can be carried out with a 3D test scan for the external dimension



In Fig. 7 the deviation curve of the external shape of the heat exchanger, where the blue zone has less material than the original drawing and the red zone has extra material. Acceptance of a possible deviation should be analyzed and evaluated in each case and application.

The internal shapes and any other possible deviation are analyzed with an X-ray or CT scan.



The growing interest of the Oil & Gas industry in 3D printing is also well described in the SmarTech Report about the trends in additive manufacturing in oil & gas for the years 2018–2019. SmarTech Analysis is a leading provider of industrial analysis and market forecasting data to the additive manufacturing industry. In the report, the company reports that the increasing adoption of AM technologies by key oil & gas industry suppliers will result in $2 billion worth of opportunities by 2029, including $975 million yearly revenue from AM hardware sales.

The report explains that investors are ready to buy into the AM market for the oil & gas industry providing there is a better outlook for their industry after the current ' challenging period.' Like so many other leaders in manufacturing and production, those in the oil & gas industries will seek to take advantage of the massive benefits offered by AM technology. While affordability is a major boon, 3D printing and AM processes also allow for the creation of new products that may be stronger yet lighter, and which were previously impossible. Moreover, with its advent complex geometries can be created and turnarounds in production are often exponentially faster, and parts—as well as refinement of designs—can be completed without a middleman.

Founded nearly forty years ago, Aidro's main specialization is in valves and hydraulic systems. About six years ago, however, the company invested in additive manufacturing technologies to explore new prototyping and tooling applications. Today, the company has a dedicated AM team of engineers and a department that uses metal AM systems to produce functional parts and, in particularly, heat exchangers.

Future development of AM: need for guidelines and standards

The growing interest in AM is accompanied by a growing need for regulations. "We have participated in working groups that aim to lay out guidelines and standards for qualifying metal 3D printed parts for the industry. One task group is organized by API (American Petroleum Institute) to define the Qualification of Additively Manufactured Metallic Materials for use in the Petroleum and Natural Gas Industries, inside the API 20S.

A second group is part of a Joint Innovation Programs (JIPs) focused on 3D printing of functional production parts for the Oil, Gas and Maritime industries. Participating companies in the project include giants such as Equinor, BP, Total, Kongsberg Marine, Shell, TechnipFMC, Vallourec, IMI CCI and members specialized in additive manufacturing,"" Ms. Tirelli tells us. «