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Produce Better Hydraulic Components with Metal 3D Printing

Complex hydraulic components made via metal 3D printing can incorporate details that would be difficult or impossible to duplicate through conventional machining, and weight and size are reduced without compromising performance.

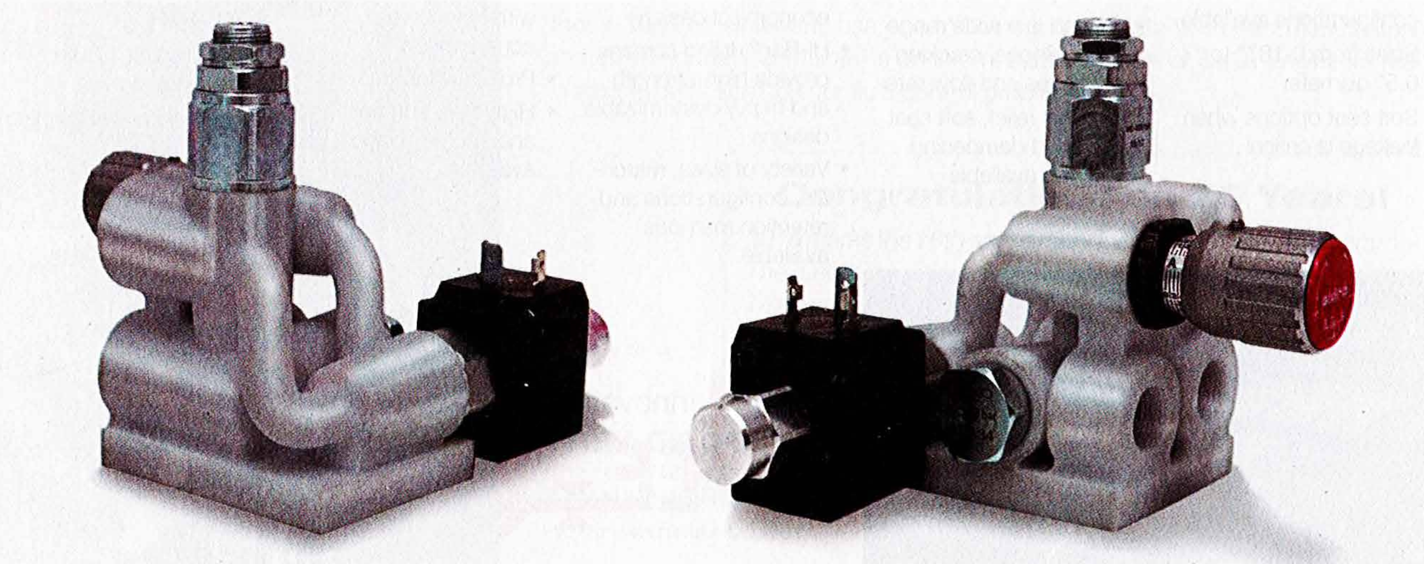
Hydraulic pumps, cylinders, and other actuators deliver greater power in smaller packages than engines, electric motors, and mechanical actuators. Hydraulic valves easily control direction, speed, torque, and force with anything from simple manual operation to sophisticated electronic controls.

Yet, production methods that create these hydraulic components have not kept pace with the expanding scope of their applications. Enter metal 3D printing—it offers new opportunities to capitalize on the high power density of hydraulic technology by improving the design and production of components such as manifolds, valve blocks, and valve spools.

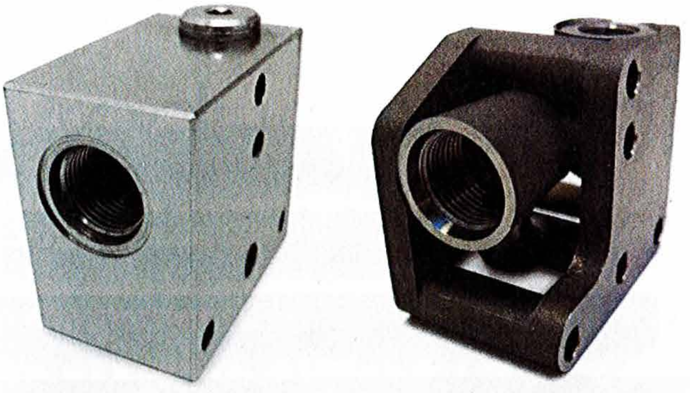
Three-dimensional printing, which began as rapid prototyping, has progressed beyond its original plastic materials to encompass many metal alloys. Although not practical or cost-effective for high-volume production, 3D printing offers many advantages when producing metal hydraulic components in smaller quantities and special designs.

Without the limitations of conventional machining, parts can be designed for the most efficient combination of production and performance. And internal channels can be optimized for higher flow and lower pressure drop. It's also possible to produce several different prototypes within hours to determine the best design. Furthermore, components can be made from a variety of materials, including stainless steel (from AISI 304 to AISI 316L), aluminum, titanium, and new materials still under development. Sources of potential leakage from auxiliary drilling and subsequent plugging are eliminated.

Although hydraulic components can be produced either by traditional manufacturing or 3D printing, traditional manufacturing is a subtractive process that starts with a larger piece of material, usually a metal casting or bar. Material is removed, generally by CNC machining, to leave the desired shape. Excess material often is left in place to save the expense of removing it, resulting in parts that weigh more than necessary.



1. **3D-printing this hydraulic valve block in stainless steel reduced its size and improved flow.** *(Courtesy of Aidro SrL)*



Subtractive method
Machined from solid bock

Additive method
3D printed

2. The hydraulic valve on the left was machined from steel, and then zinc plated for corrosion resistance. The redesigned valve (right) was produced by 3D printing in stainless steel. The 3D-printed version weighs 60% less but maintains the same strength as the machined part. The conventional part could have been made lighter by machining away (subtracting) unneeded material, but with much higher production costs. *(Courtesy of Aidro SrL)*

Machining also is limited in its ability to produce many desired configurations. Passageways in conventional manifolds often must be positioned to prevent cross-drilled channels from intersecting and allow enough material between channels to provide adequate strength. Auxiliary holes drilled to connect internal passageways may need to be plugged, creating the potential for a future leak.

Three-dimensional printing, by contrast, is a form of additive manufacturing, which builds up the desired part layer by layer. With 3D printing, flow channels can be placed exactly where they are needed, and in optimum size and shape. Until now, flow channels, particularly in components such as valve spools, generally have been circular because they are machined with rotating cutters. By building a component in layers, designers can specify configurations that would be difficult or impossible using conventional manufacturing methods.

For example, flow paths can be made with cross-sections that are square instead of round, increasing flow capacity by 20% with the same channel width. Channel design can be optimized to achieve greater flow within a smaller space. Passageways connecting internal channels don't have to be machined from outside a manifold, eliminating the need for hole plugs.

The process uses a computer-controlled laser to melt each layer of metal as it is deposited to build up the part. According to Alberto Tacconelli, Managing Director at Aidro SrL (*www.aidro.it*), Taino, Italy, the most appropriate type of metal 3D printing for hydraulic components, at the moment, is powder bed fusion, either by direct metal laser sintering (DMLS) or selective laser melting (SLM).

DMLS heats the metal powder to the point that particles fuse together on a molecular level. The porosity of the sintered material is controllable. And DMLS can be used with a variety of alloys, allowing functional prototypes to be made out of the same material as production components. With SLM, the metal powder is not merely fused together, but is actually melted into a homogenous part by a high-power-density laser. Because of reduced porosity, parts made with SLM can be stronger, with greater control over crystal structure. However, the process is said to be feasible only when using a single metal powder.

WHEN IS METAL 3D PRINTING APPROPRIATE?

Tacconelli cites these points to consider when deciding whether or not to produce a part using 3D printing:

Quantity—Traditional manufacturing is more suitable for large-scale production, whereas 3D printing may be more economical or practical for small volumes of complex or specialized hydraulic components.

Production lead time—Subtractive processes, such as CNC machining, may require lead times of 30 to 60 days to produce a component from metal bar stock, or as long as six to 12 months if a casting is needed. For 3D printing, hydraulic components can be printed on demand in a matter of days. If the printed parts require tooling, lead time may increase up to one or two weeks.

Prototyping—With 3D printing, several different variations of a prototype can be produced at the same time, making it possible to evaluate design alternatives.

Material selection—Hydraulic components must have adequate strength and corrosion resistance to safely handle the high pressures typically found in hydraulic systems. Three-dimensional printing can offer a broader selection of materials, including stainless steel (AISI316L), aluminum, titanium (Ti6Al4V), Inconel (625 or 718), and maraging steels.

WHAT ABOUT MATERIAL PROPERTIES?

Because metal 3D printing is relatively new to the field of hydraulics, it raises the question of how the material properties of 3D-printed parts compare to those made by traditional processes. Although typical mechanical properties such as tensile strength, yield strength, and modulus of elasticity appear to be comparable, depending on material choice, the high pressures often encountered in hydraulic systems merit additional consideration.

With proper material choice and design, components can be made to withstand these pressures, but they also may encounter shock and pressure pulsations, which are more difficult to accommodate. Manifolds, for example, often have been made from ductile iron or other ductile materials to handle these pulsations, but these materials do not lend themselves to the additive-manufacturing process. Iron and carbon steel materials also fall into that category, because the source material must exist in powder form.