# Hybrid manufacturing for closed impellers

**One part. One machine. Two manufacturing processes combined. Sulzer is developing a hybrid manufacturing process for closed impellers in which subtractive milling and additive material buildup are combined. Sulzer has applied for patents for the process. Extremely reduced lead times and innovative part geometries are the main advantages.**

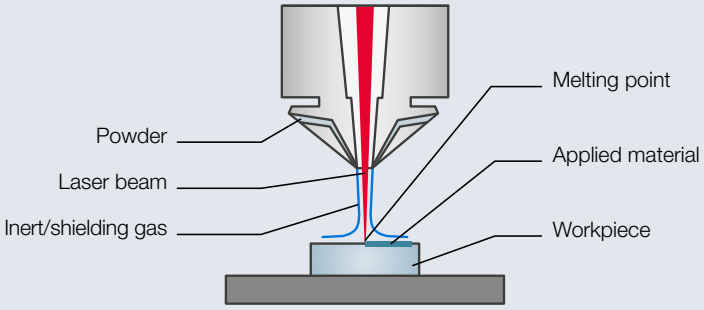
*“Hybrid impellers produced in 48 hours is our goal.*

To date, the best way to produce closed pump impellers has been to use casting technologies because of their unique geometry. Features such as a high wrapping angle and twist of the blades lead to high performance when pumping common fluids like water or oil. This optimized geometry does not allow the internals of an impeller to be machined from a forged material. The restricted accessibility for the tools prevents to use of classical, subtractive manufacturing technologies like milling or electric discharge machining (EDM) without compromising the original impeller geometry. Casting was – up to now – the traditional way to manufacture closed impellers.

## Limitations in casting production

Even with state-of-the-art casting technologies, there are risks of defects on the surface and inside the metal, a fair but sub-optimal surface quality and geometry. These issues affect the overall performance of the part and determine the extent of post-casting manufacturing costs – such as surface treatment and balancing. The average lead time for casting is about 35 days.

## Principle of laser metal deposition (LMD)




Laser metal deposition is a process where the laser generates a weld pool on the component surface. A nozzle then automatically adds metal powder. This creates beads that are welded to each other, and can form structures on existing bodies. For LMD, a wide variety of materials in powder form is available. In general, all materials that are weldable with conventional welding methods can be used. The LMD method has been in use at Sulzer already since its early years, mainly for repair welding of used components.

Fig. 1 Principle of laser metal deposition.

With so-called rapid casting technologies, the lead time to produce a finished part is still quite long, taking about 25 days. Optimizing the time to market is important for Sulzer and its customers and it has become the driving reason to seek a new, time-saving manufacturing method.

## Parameter setting for LMD

For the LMD process, many production aspects are important: the material specification, production settings, quality control, and performance tests. The settings include metal powder feed, process speed, laser power setting, focal position, material deposition height, and much more. The optimization of these parameters is very important and constantly monitored by sensors on the LMD machine to guarantee material buildup without imperfections. Only constant quality control of the process and the initial performance tests allow Sulzer to guarantee the high quality of the parts, which have to withstand high loads over their lifetime in the pump.

## Sulzer as a pioneer for hybrid manufacturing

The solution to much faster and better impeller production is a combination of two production technologies. Sulzer uses the LMD method for material buildup, which is followed by 5-axis milling to achieve high-quality surfaces and accuracy. As a pioneer in innovative manufacturing methods, Sulzer already operates such a hybrid manufacturing process.

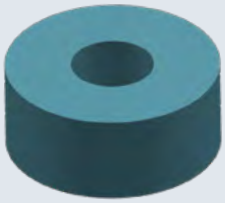
## Laser metal deposition plus 5-axis milling

The potential for hybrid manufacturing processes is significant. Since its first introduction, major 5-axis machine tool manufacturers are developing hybrid machines. With a hybrid process, the amount of additive buildup can be limited. This helps to keep costs of the process reasonable. Additive buildups quite often need support structures – but with hybrid manufacturing, these structures are often not necessary due to the variable build direction. Thanks to the final

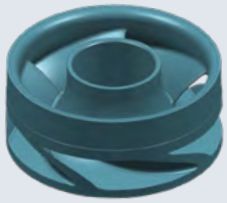
## Working steps of hybrid manufacturing

For hybrid manufacturing, additive and subtractive methods are combined in one machine. The patent-pending hybrid production process for a closed impeller starts with a small wrought billet (Step 1), which is machined to its final geometry with 5-axis milling operations (Step 2). This milling step is only possible because the radial dimension of this core part is smaller than the size of the final impeller. Thus, all channels are accessible with milling tools. When the impeller core is finished, the remaining geometry for the final impeller is radially built up via laser metal deposition (LMD). The added material is later milled to the final geometry and surface quality. Depending on tool accessibility, this additive step with subsequent final machining can be repeated several times in order to grow the impeller radially to its final diameter (Step 3).

**Step 1**
The wrought billet is clamped into the hybrid machine.



**Step 2**
Subtractive manufacturing (5-axis milling) of the impeller core.



**Step 3**
Completed impeller. The yellow part is added with LMD, followed by subsequent milling steps.

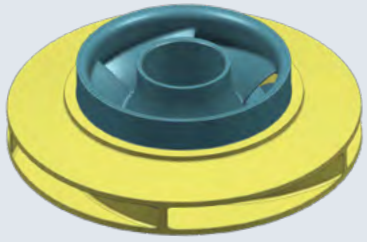


Fig. 2 The main manufacturing steps of a closed impeller with hybrid manufacturing.

5-axis milling, the material surface quality complies with the accepted industry standards. Because of the high geometrical precision, these hybrid-manufactured parts require less post-processing efforts.

The hybrid manufacturing method allows Sulzer to speed up product development cycles. The engineering teams can produce prototypes much faster and get customer feedback quickly from field tests. The subsequent product optimization increases the quality of the Sulzer products. For computer-aided manufacturing (CAM), Sulzer uses adapted software tools to

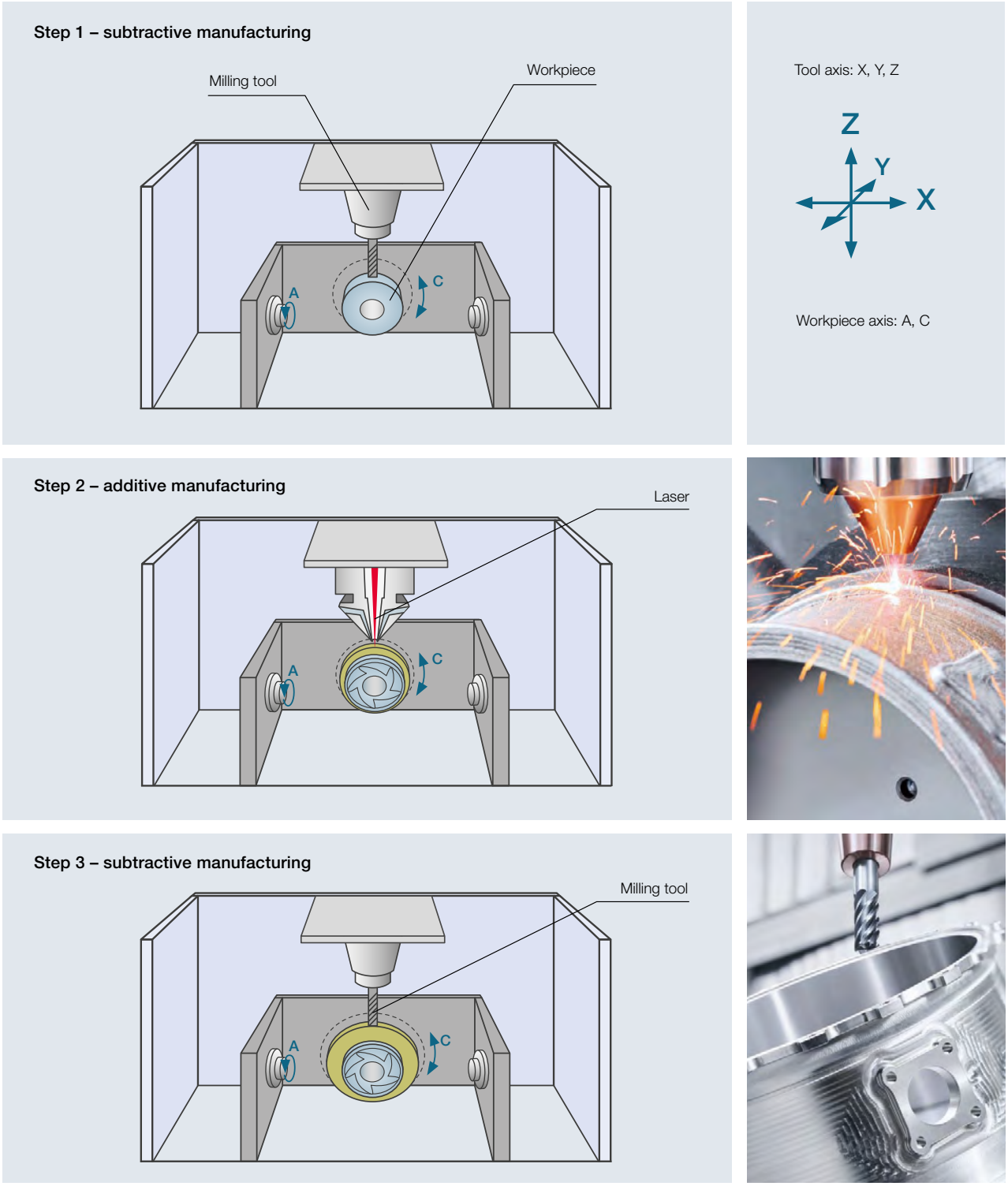



Fig. 3 Working steps during hybrid manufacturing.

improve hybrid manufacturing processes. Applying the material in layers requires a definition of the layer buildup. In other words, after designing a part the program has to cut the part geometry into multiple slices, which, depending on the part geometry, can have three-dimensional shapes. The buildup is done layer by layer in defined regions and creates the part.

## Closed pump impellers produced in 48 hours

To optimize the parameters and to automate the toolpath programming, Sulzer joined forces with a company producing very similar closed impellers for turbo compressors. The two companies are working cooperatively in Zurich, Switzerland, on preliminary studies and proofs of concept. Together, they have already produced the first impellers with the new method.

With the dedication and experience of both companies, Sulzer is convinced that it will be able to achieve the ambitious goal of producing high-quality stainless steel closed impellers within 48 hours in the future. This is a radical drop from the current standard of 25–35 days using traditional casting methods.

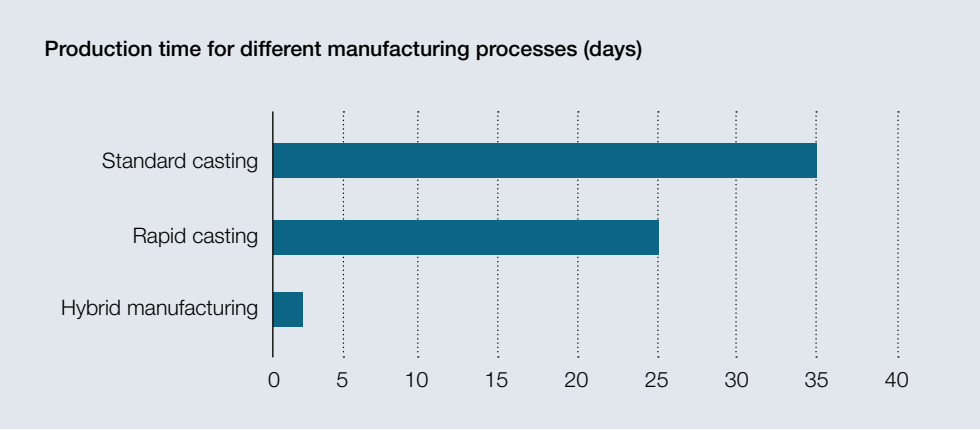



Fig. 4 Comparison of production lead times for closed impellers with different manufacturing processes.

Robin Rettberg,
Winterthur, Switzerland

Of course, hybrid manufacturing is neither limited to impellers alone nor to single materials. Therefore, future developments aim to use hybrid manufacturing for other pump components or to use different materials within one part.

One example of the use of different materials is the application of a wear-resistant coating via LMD during the manufacturing process. For example, this coating can be applied in the respective impeller area to replace an impeller wear ring. The hybrid manufacturing method has a big potential for cost-effective manufacturing in our industry and will find its way into all fabrication halls of Sulzer.