Lasercusing

Will it make removing metal by machine and casting a thing of the past?

Ko Buijs, Metallurgical Consultant, Van Leeuwen Stainless, The Netherlands

Introduction

An increasing amount of attention is being focused on digital manufacturing techniques that are, for example, used to quickly manufacture prototypes or small-scale series from various plastics and metals. Examples of these techniques are: SLS (Selective Laser Sintering), FDM (Fused Deposition Modelling) and SLA (Stereo lithography). SLM (Selective Laser Melting) is a brand new technology that is also called 'LaserCusing'. This technology has been developed by the German company, Concept Laser. The word Cusing is a combination of the words 'Fusing' and 'Casting'. This article provides you with an insight into this new and remarkable method of manufacturing complex products from stainless steel and other metals without removing metal by mechanical means.

ConceptLaser

ConceptLaser is a subsidiary of the German company Hofmann in Lichtenfels that, for example, manufactures complex imoulds for the car industry, domestic appliances and electronic consumer products. However, the increasingly complex geometry of the imoulds has presented Hofmann with many technical challenges. The cooling of injection-moulded components in the imould was also time-consuming because cooling ducts could not be integrated in certain inserts using conventional manufacturing techniques. ConceptLaser has therefore developed a 3D laser machine that builds up products layer by layer from all kinds of metals in an inert nitrogen atmosphere with the aid of a solid-state laser (see figure 1). This is called the SLM technique.
The modular construction of the ConceptLaser makes it very versatile. In addition to being used for building up products, the machine can also remove material by laser milling and perform engraving, thus making it unique in its class. Figure 2 shows a plastic part of a vacuum cleaner cover, with the insert from the imould still present. The cooling duct in this insert that, thanks to LaserCusing has been made possible, is clearly visible. The material is 1.4404 stainless steel, and the dimensions of the insert are 80 x 45 x 70 mm. The construction time was 25 hours, and the finishing including polishing, took 8 hours. It should also be noted that the building up process continued overnight without the need for human intervention.
Figure 3 shows a wafer pattern that has been produced by laser milling, and figure 4 shows a plastic knob that has been engraved using the same laser.

Figure 1. The ConceptLaser SLM-machine with three workbenches for cusing, laser milling and engraving.

Figure 2. A mould insert with cooling duct made using LaserCusing.

Figure 3. Laser milling

Figure 4. Using laser to engrave a coated plastic knob.

LaserCusing is essentially different from SLS because unlike sintering, the metal powder is directly fused layer by layer, so that you can actually think of this as a kind of minuscule local moulding. This produces high-density (> 99.7%) products that have excellent mechanical properties. Figure 5 shows magnified photographs of these two processes. SLS products are mainly used for rapid prototyping. Products produced by LaserCusing (SLM) can also be used as a finished high-quality industrial component and for rapid tooling. The products manufactured with laser, offer a good alternative for smaller series that you have to cast or forge, thus dispensing with the many additional costs associated with constructing casting models, core boxes, the smelting of metal and the time-consuming finishing as well as NC programming.

The process

Essentially, the process consists of the following: On a special workbench that is incorporated in the machine, a thin layer of the desired metal powder is automatically evenly spread in the construction chamber. An STL file then enables the laser to only fuse those particles where material must come. Immediately after the fusing by laser, a new layer of metal powder is applied that, in turn, is locally fused to the underlying layer that has already solidified. In this way, you build up a product, layer by layer, and you are not restricted by the complexity of the geometry (see schematic diagram in figure 6). You can thus design a component in a CAD program and allow it to be built up in 3D, in order to obtain the end product. In fact, the computer uses special software to convert the three-dimensional file into so-called slices that are, in turn, fused by the machine in order to produce a 'hard copy', i.e. an end product. You must however still process the product further by giving it a finish, because the surface is rather rough due to metal powder particles that have ended up on the border of the fusion. Oxidation is not a problem because oxygen is not present. The components that you can presently manufacture using LaserCusing have a maximum size of 350 x 300 x 200 mm, and this takes place inside a construction chamber. The laser beam has a diameter of 0.2 mm and an accuracy of +/- 50 µm. The layer thicknesses can vary between 25 and 100 µm with this having a corresponding effect on the surface roughness.

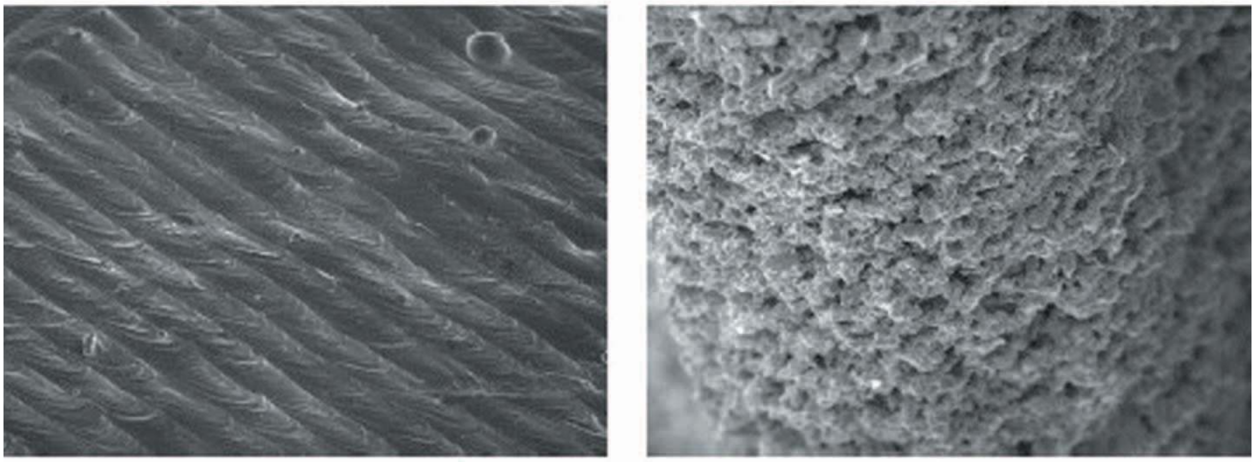

Figure 5. The difference between LaserCusing (on the left) and laser sintering (on the right) of 1.4404 stainless steel (magnified 100 x)

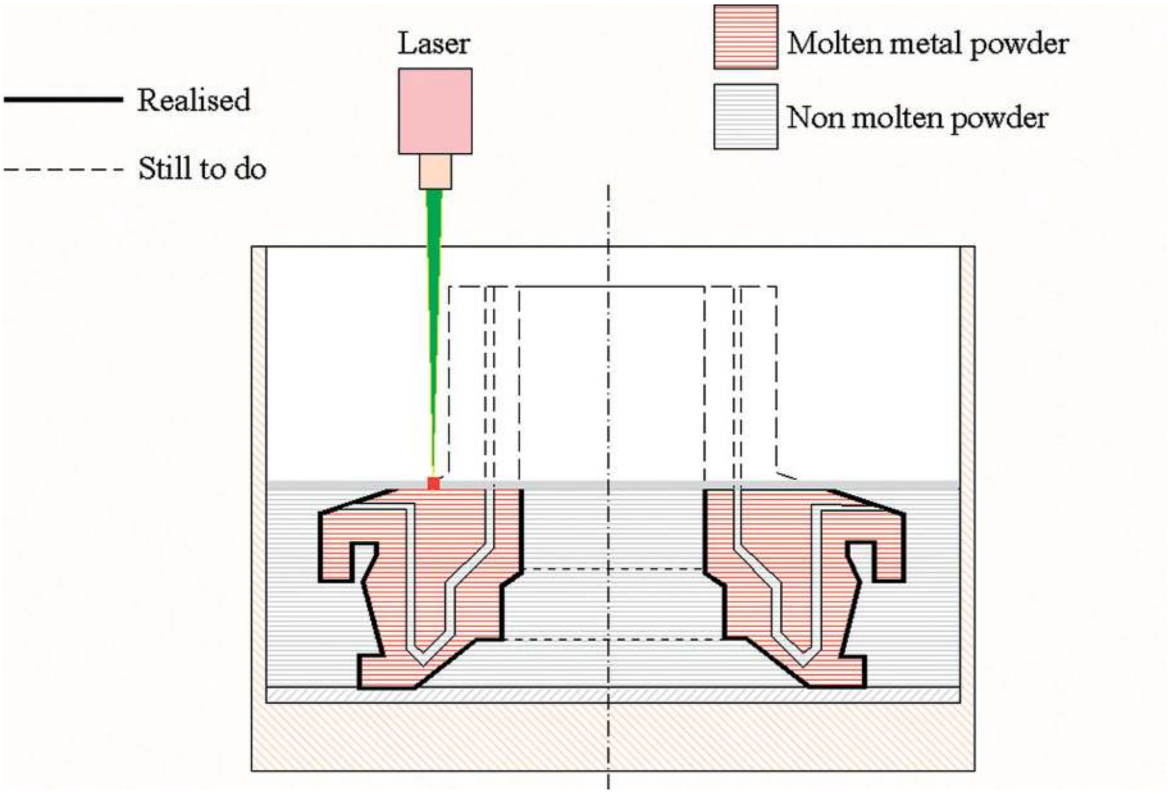

Figure 6. Schematic diagram snapshot of LaserCusing. A cylindrical product with cooling ducts is built up layer by layer. Drawing: N.W. Buijs

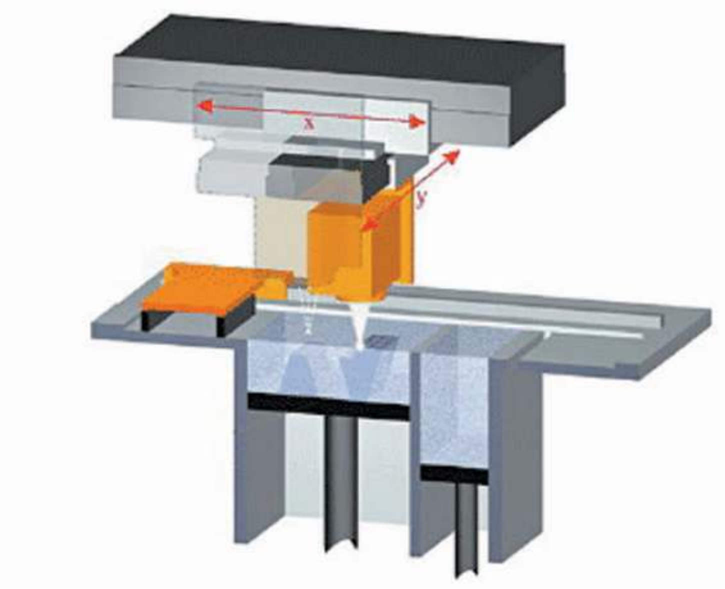

Figure 7. The inside of the laser with dosage unit for the powder

Figure 7 shows the special workbench that provides a dosed layer of metal powder each time that fusion occurs at the desired locations using a laser beam. Laser is an acronym for 'Light Amplification by Stimulated Emission of Radiation'.

The laser produces a concentrated monochromatic coherent beam of light that has a high energy density. This is light with one wavelength and these waves that are in phase with each other so that, in this case, the metal particles fuse.

Virtually all of the powder that is not yet fused can be re-used, so that hardly any metal waste is produced.

Type of products

Although LaserCusing was primarily developed for complex-shaped imoulds and mould inserts, a plan to use this in several market sectors was also conceived at the same time. This plan focused on small casting and forging series, with the objective of no longer having to manufacture expensive models or forging imoulds. In relation to casting, this can provide significant benefits because, in addition to dispensing with the need for an expensive model and core box, you also no longer require liquid metal or intensive finishing. Moreover, breakdowns are ruled out when using LaserCusing, you waste virtually no material, unlike the casting process. Although the LaserCusing takes quite a long time, the silent system can however operate almost continuously. It is common practice to build up a

Figure 8. Cross-sectional view of 56x56x15 mm injection mould in 1.4404 stainless steel

Figure 9. Cross-sectional view of mould insert with cooling ducts

Figure 10. Component in tool steel

Figure 11. Machine component 45x25x20 mm in 1.4404 with a construction time of four hours.

few test pieces at the same time, so that if desired, all kinds of destructive and non-destructive tests can be performed.
The mechanical values are generally significantly better than for casting. However, it should be re-emphasised that LaserCusing allows you to construct much more complex models than is possible using conventional manufacturing techniques. For example, it only recently became possible to make cooling ducts with an internal spiral shape, using a manufacturing technique. Such cooling ducts make injection moulding much more efficient because plastic components that have already been moulded can now be removed earlier from the imould, thus increasing the production. This due to the fact that these cooling ducts allow the imoulds to cool 10 to 15% more quickly. Moreover, the dimensional accuracy is much higher than for casting or forging, and you can also manufacture several products at the same time in the construction chamber. The time-consuming NC programming of manufacturing centres is also no longer necessary.
You can also manufacture hybrid products by building another component on top of an existing component. This is also possible using different metals as long as these can be joined to each other using thermal welding techniques. A good example is grade 7 titanium that is used because of its extremely good durability against crevice corrosion thanks to the 0.2% palladium that is present in this material. Because this valuable alloying element is only required on the surface, LaserCusing enables you to apply a layer of grade 7 titanium to a grade 2 titanium component, so that you save a lot of valuable material. You can also make combinations of carbon steel and stainless steel and/or nickel alloys. This also enables you to save a lot of valuable metal.

The surface is quite rough after LaserCusing because metal powder particles are always obtained in the 'grey area', and these particles become loosely attached to the desired product.
You can use ultrasonic filing and radiation techniques to significantly enhance the surface quality, and in some cases, additional processing operations such as turning, milling, grinding and/or (electrolytic) polishing are desirable.
Aluminium is also an excellent material to process using LaserCusing. Figures 8, 9 10 and 11 show various components that have been created using this technology.
Table 1 shows the time difference between using LaserCusing and conventional processing of complex mould insert. It should also be noted that the LaserCusing process does not require human intervention.

Laser milling

You can therefore also use the same machine for 3D laser milling, and for products that have a maximum size of 800 x 500 mm.

	Conventional method in hours	LaserCusing in hours
Programming	25	0.25
LaserCusing	—	17.5
Rough milling	12	—
Fine milling	11	—
Electrode milling	16	—
Laser milling	22	—
Finishing and polishing	6	12.0
Total number of hours	94	29.75

Table 1. Time difference, conventional versus LaserCusing

The maximum weight of the work piece is 500 kg, and the exposure field is 450 x 450 mm. The laser beam has a diameter of 0.05 to 0.1 mm, and this produces an accuracy of +/- 20 µm and a layer thickness of 1-5 µm. Because the surface quality is extremely good, after the LaserCusing, you can also remove additional material by means of laser milling (see figure 3). The accuracy of laser milling is approximately 2.5 times higher than LaserCusing. Thus, in various situations, it is better to first build up, and then to use laser in order to obtain the desired product.

Fittings and appendages

Moreover, all kinds of components for appendages and complex accessories for pipes such as, for example, outlet fittings, can now also be manufactured. For example, weldolets, nipolets, sockolets, latrolets, threadolets, elbolets etc. that can are available in a multitude of varieties because they must always be able to fit on different sizes of run pipes. You can also store the geometry of these outlet fittings or other products in a digital STL file on your computer so that build up these products in 3D as desired. The possibilities are endless; for example, special flanges, components for shut-off valves, etc. After the product has been manufactured, if required, you can also process it further using laser to add markings such as quality, dimensions, logo, etc. since the machine can also be used for engraving. This is particularly suitable for all kinds of stainless steel. In the near future, it is conceivable that much bigger products will also be manufactured as soon as this is dictated by the market. In this respect, it is quite likely that for example, complex pump impellers will be manufactured that will enable higher pump capacities because the limitations associated with casting will have been eliminated. LaserCusing will thus play an increasingly important role when replacing the casting and forging process. LaserCusing is also extremely environmentally friendly since harmful vapours are not given off. More importantly, less energy is required because you the amount of material that is used for SLM is reduced to a bare minimum, with no waste whatsoever. Conversely, for the casting process, you require a lot of extra material, and this is still the case for the new arrivals that still require many cutting operations, not to mention the "non-starters" that get left behind.

Costs

Because the machine is relatively expensive, consideration has been given to installing a similar machine in the Netherlands so that all kinds of assignments can be performed for third parties. Moreover, clients will probably be able to send their STL files via e-mail. In this way, you can deliver a complete product relatively quickly.

Conclusion

The development is in full swing, and in addition to the existing materials, in the near future, you will also be able to manufacture products from nickel and copper alloys as well as titanium. ConceptLaser is convinced that, within the next few years, 30% of all mould inserts will be manufactured using LaserCusing. And you should also not forget about the hybrid products.
The development of direct manufacturing and rapid tooling will also show great promise. Moreover, there is also a market for copying products in 3D, by first using a laser scanner in order to obtain a matrix image serves as a basis. For example, just think of broken machine components that are no longer available in the trade, and that after being temporarily joined together, can be scanned and reconstructed. In addition to the industrial applications, a great deal of interest is expected from the medical sector because you can use LaserCusing to manufacture implants that fit better. ■

About the author

Ko Buijs is a recognized metallurgical / corrosion specialist on stainless steels as well as special metals. He works for Van Leeuwen Stainless. In addition, Mr Buijs is a lecturer for various organisations such as steel associations, technical high schools and innovation centres. He has published over 100 papers in a number of technical magazines. In close co-operation with Barsukoff Software Mr Buijs has developed the computer programme Corrosion Wizard 2.0. Info www.corrosionwizard.com

For additional information, please contact:

Somatech Applicaties b.v. in Ede (importer: ConceptLaser) Mr. Marco van de Graaf, tel. +31 (0)318 58 25 00,
or the author of this article Ko Buijs, tel. + 31 (0)6 519 90 189
and e-mail: nwbuijs@hetnet.nl.