Powder on Demand

Rapid-Powder-Switch enhances economic efficiency in laser metal deposition and paves the way for new processing strategies

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The use of a Rapid-Powder-Switch (RPS) during laser metal deposition leads to powder savings of up to fifty percent: With a short switching cycle of less than 200 ms, the powder is immediately available between processing cycles. Thus, surfaces can be coated precisely and only where required – efficient and resource-conserving.

Fig. 1 Checkerboard pattern by powder pulse coating

A key technology in laser metal deposition (LMD) is the powder feed unit consisting of the powder feeder, the powder transmission section and the powder nozzle. The whole feed system decides on the economic viability and justification of LMD for the proposed application. While powder nozzles are being constantly developed further, there is potential for improvement in the immediate powder supply. After the powder feeder is switched on, many seconds pass before the powder flows steadily out of the powder nozzle with a constant powder mass flow. After switching off the powder feeder, the powder still trickles for a few seconds. On the one hand, this is caused by the start-up time of the powder feeder; on the other hand the long distance from powder feeder to powder nozzle prevents the powder flow from stopping immediately.

Therefore, switching the powder feeder on and off between processing steps results in extended process times. As a result, the powder feeder keeps running for example during repositioning of the coating head to a different location or during an interruption of the coating process due to necessary cooling of the component to prevent distortion. The consequences are:

- Increased powder consumption for the process,
- limited recycling of the powder due to contamination,
- high costs for coatings,
- contamination of the system and component,
- and increased emissions.

Depending on the application, up to fifty percent of the filler material can be lost.

Company

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HD – Special Optics for Laser Technology was founded in 2005 by Harald Dickler. HD concentrates on development, design and marketing of special optics and solutions in the field of laser technology. In cooperation with the Fraunhofer Institute for Laser Technology, we shape the laser future. Examples for individual solutions and custom-made designs are more than fifty optics for "tailored blanks" and "tailored tube welding machines / systems", coaxial powder nozzles for "extreme high-speed laser material deposition (EHLA)", Rapid-Powder-Switch, mechanical adjustment unit for powder nozzles (off-axis nozzles).

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Fast switching cycle allows significant efficiency enhancement

HD Special Optics for Laser Technology has now succeeded in developing a Rapid-Powder-Switch (RPS) in cooperation with the Fraunhofer Institute for Laser Technology ILT (Fig. 2). Using the switch, the powder gas stream can quickly be turned on and off during the process with little to no time and resource loss and without affecting the laser beam. The powder which is not used for the process can be collected in a separate container and can be recycled. This opens up new production processes during LMD. This is achieved through

- rapid switching on / off of the powder gas stream,
- rapid switching between two powder gas streams,
- switching between two powder feed nozzles.

Consequently, the RPS enables a significant increase in powder efficiency and thus process efficiency. Not only resources are saved, but also a considerable amount of time.

RPS pushes laser technology forward in coating and repair sector

Fig. 1 shows a checkerboard pattern, which was made using the RPS. During the manufacturing process, the powder gas stream was switched on and off without switching off the laser beam. The processing time for the manufacture of this geometry was ten times faster in comparison to conventional processes. Moreover, a significant amount of additional material was saved.

This advanced powder supply is particularly suitable for repair of cracks and pores. So far, there are two methods to process those defects – either the entire surface is milled off and then re-produced applying laser cladding or the flaws are drilled and repaired using pulse coating. While the first method correlates with higher costs, the second method often involves inclusions between the basic material and the filler material, which only become visible

Fig. 2 Rapid-Powder-Switch (pneumatic)

in cross-sections (Fig. 3, top right). The problems of the latter method are traced to remaining powder. After the powder feeder has been switched on, the powder directly accumulates and does not melt when the first laser pulse reaches the bore. Therefore, depending on the load, the applied layer might peel off and the repaired component cannot completely fulfill its function and breaks. Since this method has only limited success, the customer often decides for the more expensive repair method.

RPS now offers a third repair method, which surpasses the conventional methods. In the so-called "add-on" mode, heat input takes place through laser radiation on the area to be processed. On a specified time, the powder can then quickly and automatically be switched on. In doing so no powder is left in the bore and, hence, a melt-metallurgical bonding without defects is generated and a wear-resistant layer is produced with little preparation and finishing work and a resource-friendly production. In short, the efficiency of the whole repair process is significantly improved.

Previously, the coatings of the inlet or outlet valve with blind bore at the shaft end (Fig. 3, left) were produced using plasma-transferred arc welding which did not meet the customer's requirements – a great number of rejects with less quality were manufactured. Using the "add-on" method, a wear-resistant layer could be produced with higher quality despite time savings (Fig. 3, bottom right). The whole coating process was automated and reduced to six seconds (two for preheating and four seconds for LMD). The low maintenance and reliability of the RPS ensured that the rejects were reduced to a minimum as well as increased lifespan.

Take two: fast switching between two powder gas streams

Using the RPS also allows for coatings that last very long such as the processing of hydraulic cylinders from offshore industry. Commonly, chromium plating using chromium(VI) is applied for this kind of coatings but due to strict conditions regarding its application, which took effect in the EU in September 2017, an alternative is needed. This is why LMD – more precisely extreme high-speed laser material deposition (EHLA) developed by researchers from Fraunhofer Institute for Laser Technology ILT [1] – is superseding this conventional method. For large-scale coatings, usually, the content in a powder hopper is not sufficient: The cladding process has to be interrupted, the powder feeder needs to be refilled and afterwards restarted. Besides the time loss, this interruption can lead to bonding errors during the resetting of the process to the transition point. The RPS helps to overcome this drawback. Two powder pots can be connected and, if necessary, switched back and forth without transition. Thus, the time loss as well as the risk of bonding errors are minimized and a multi-hour coating process can be realized without interruption.

Fig. 3 Powder pulse coating

While the application above describes the use and switching of powder of the same kind, also two different or related materials can be switched alternately. This is required for example in a "two-stage coating". That is a layer system, which is considered if a single material does not meet the desired total requirements or cannot be applied directly to the base material. Different materials are applied in succession as buffer layer and top layer. The extension of the procedure due to conversion and process equipment can be regarded as a criterion of elimination. With RPS, the two different powder hoppers needed for this application can be connected. So, without changing the component, wasting powder and losing production time, the layers can be applied. Fig. 4 shows a coating of combination of hard and soft metallic lasers to stop crack propagation.

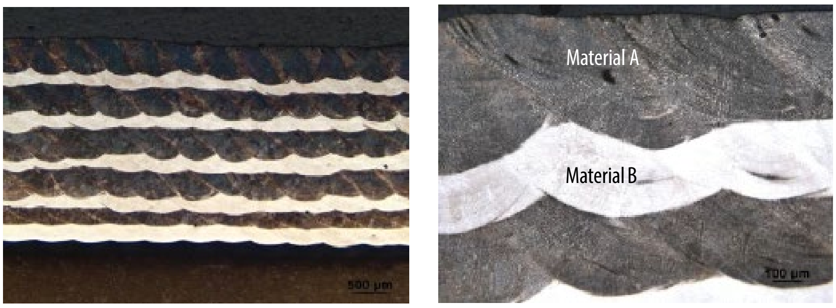

Fig. 4 Switching between two powder gas streams (Source: Fh. ILT)

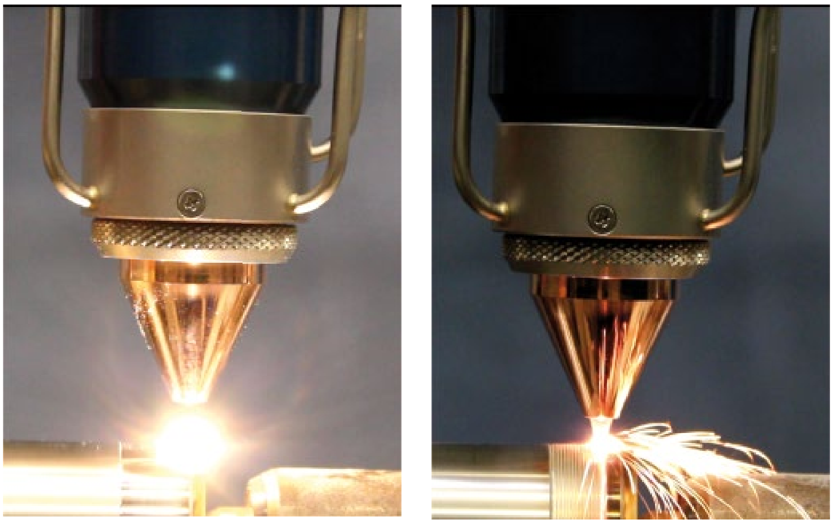

Fig. 5 Laser welding and cladding alternately using RPS

Focused on efficiency: switch between two powder nozzles

For LMD, several types of powder nozzles can be used. For example, off-axis powder nozzles are used when the cladding position is extremely poor or there is a lack of space for a coaxial powder nozzle. This powder feed is not direction-independent, so the deposition is limited to simple, straight weld beads. Trailing or leading processing steps vary according to the geometry, so this nozzle is only partially suitable for multi-layer coatings and different types of nozzles are required for one process. By connecting two different powder nozzles to the RPS, two nozzles can be in use simultaneously but only the relevant nozzle is fed with powder. Thus, the process time can be reduced and the efficiency increased.

RPS and Industry 4.0 go hand in hand

In the course of automation and with regard to industry 4.0 there is a great demand for machining strategies without tool change. The RPS is the answer to those future requirements: laser cutting, welding and cladding can be realized using only one processing head. Laserfact GmbH has already developed such a processing head – the combi-head – and has successfully demonstrated it at the AKL'16 – International Laser Technology Congress in Aachen. The powder was added or stopped by means of the RPS between the different processing methods laser welding and cladding. Without the switch, this process technology would not be feasible.

Additionally, besides laser applications, the RPS can also be used in other areas that process powder as for example thermal spraying.

DOI: 10.1002/latj.201700028

[1] *T. Schopphoven, A. Gasser, G. Backes:* EHLA: Extreme High-Speed Laser Material Deposition, Laser Tech. J. **14** (4) 2017; DOI: 10.1002/latj.201700020

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