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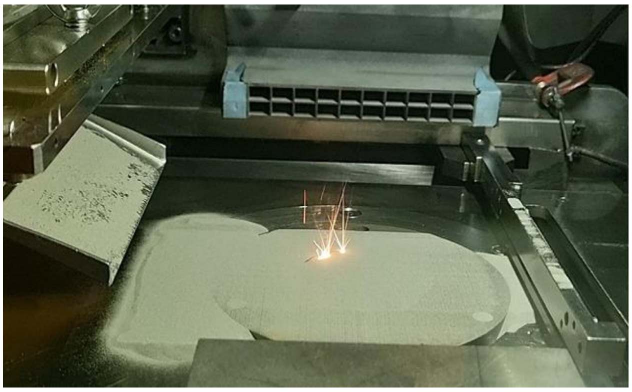
Method devised to control various microstructures using lasers in metal 3D printing



A joint research team led by Nanyang Technological University in Singapore has developed a manufacturing method for near-net-shape products that uses 3D printing to generate diverse microstructures that are precisely controlled in each part and optimize the characteristics of each part. By using a laser powder bed fusion method and varying the irradiation and scanning patterns for each selected region, they were able to generate diverse microstructures after solidification and reheating, resulting in customized properties. As a demonstration experiment, programmed laser irradiation and scanning patterns are applied to stainless steel to produce 3D metal products with areas of high and low strength where needed. The research results were published in the journal Nature Communications on October 30, 2023.

In the field of metal materials, by introducing high-density dislocations into the material through mechanical deformation and then recrystallizing it through heat treatment, it is possible to create textures with fine grain size and orientation. It produces various microstructures and has excellent properties. This is one of the core organization control principles of materials science. One example of this is the work that blacksmiths have done since ancient times, heating steel and hammering it into swords. However, in additive manufacturing methods such as 3D printing, the main purpose is to create complex shapes and internal structures that are difficult to achieve with conventional methods in a near-net shape without a wide variety of complicated processes. It is also difficult to apply structure control principles with processing heat treatment.

The research team set out to overcome this problem, focusing on the fact that dislocations are introduced by the rapid expansion or contraction of the metal during the melt-solidification process caused by laser irradiation. As a result of experiments and finite element method calculations, it was found that the introduced dislocation density can be increased by controlling the size of the metal molten pool and the laser irradiation pitch, and that the same principle of mechanical heat treatment as conventional methods can be utilized. Another advantage of 3D printing is that metal layers are stacked one after the other, allowing for precise control at various levels at each location.

As a demonstration experiment, the team created a method that selectively changes the irradiation and scanning patterns for each part of the laser powder bed fusion method and applied it to stainless steel. As a result, it was revealed that the microstructure after additive manufacturing and heat treatment can be freely controlled for each part of the product as designed, and that the microstructure that increases metal strength and the microstructure that has medium-low strength can be precisely arranged. Furthermore, its overall strength is improved by the synergistic interaction of high-strength and low-strength regions, and it has the potential to create materials that are stronger than what would be predicted by classical mixing rules for composite materials.

The developed method can realize various microstructure arrangements without using machining, cutting, surface treatment and so on, which reduces the manufacturing cost of near-net shape products and improves the distribution of alloying elements at the solid-liquid interface during the melt-solidification process. The research team hopes that this method can be used to manufacture parts with unprecedented characteristics, such as controlling and arranging various levels of conductivity and corrosion resistance in each part.

https://engineer.fabcross.jp/archeive/231201_metal-3d-printing.html