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# THE APPLICATION OF LASER HARDENING MATERIAL

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***Abstract:***

*This article deals with the possibilities of heat treatment of the material, rather its part, to achieve the required properties, which are required in further activity. Particular attention is paid to laser treatment.*

## 1 Introduction (12 pt, bold)

In general, a material, more precisely expressed as a component, a product of a material, can be heat treated as a whole, in its entirety, or only in certain parts, which are to have other properties.

In practice, we encounter the fact that we need to strengthen the surface part of the material in some way. We divide coating methods on the basis of the application process, which is carried out by chemical or physical means. In principle, we know the application of PVD (Physical vapor deposition) and CVD (Chemical vapor deposition).

The main technological difference between these two methods, which limits or predetermines the suitability of their use for tool material, is the temperature of the process itself. With the PVD method, we operate with a working temperature below 500 °C, which guarantees that there will be no thermal influence and subsequent structural changes in the tool material (mainly HSS steel). [1][2]

The operating temperature of the CVD method is in the range of 1000 to 1200 °C, so it is suitable for coating material that has guaranteed temperature resistance in this range. Examples are sintered carbides. The applicability of the CVD method is extended by its various modifications, such as MTCVD (Middle temperature chemical vapor deposition), which means the application of technology at reduced (medium) temperatures. [3][4]

Hardening can be a process where we have a loose material that we strengthen, cure by a certain process, so that we create a solid structure of the material. The energy supplied by which we perform the hardening can be by means of a laser beam.

*Table 1 Ways of technology implementation PVD and CVD*

| **Methods of PVD** |
|---|
| Thermal induction |
| Plasma induction |
| Electron induction (electron beam) |
| Photon beam induction (e.g. laser) |
| **Principles of CVD** |
| Steaming |
| Sputtering |
| Ion implantation |

## 2 Use of a laser to harden steel

Martensitic stainless steels are widely used in industry. This is mainly in view of their high strength and good corrosion resistance. Precipitation hardened martensitic stainless steels have a very high strength compared to other stainless steels. This is about 3-4 times more than austenitic stainless steels (such as 304 and 316). Due to the poor processability due to the high strength and hardness caused by precipitation hardening, it limits the extensive use of stainless steels (precipitation hardened) as structural elements of complex shapes.

Powder bed laser fusion is an additive manufacturing technology that not only offers the benefits of producing complex and precise parts with a short delivery time, but also eliminates or limits the subsequent machining process. [5]

## 3 Hardening equipment

The mechanism used for hardening is very similar to a 3D printer. The movement takes place in the Cartesian space, where the individual movements are realized as translational in the x-axis and y-axis. The movement in the z-axis is carried out by translationally moving the bed of material. In this case, it is possible to change the position of the print head (3D printer) by a deflection device, since a laser beam is used for hardening. But even in this case, it is preserved that we use two degrees of freedom in the mechanism of movement.
Furthermore, it is necessary to ensure the addition of material (adding material) to the bed. This requires a mechanism with one degree of freedom that will ensure translational movement in one axis.
Unlike a 3D printer with this hardening device, it is still necessary to ensure that the given working space is in a closed chamber, so that such a chamber is filled with the required gas.
A schematic of the laser powder bed fusion process is shown in Fig. 1.

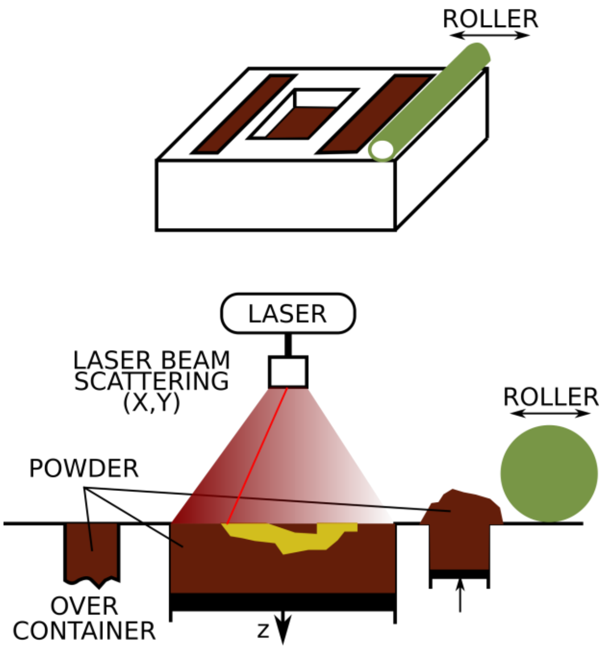


*Fig. 1 Schematic of the laser powder bed fusion process*

The scanning process can be different. It is necessary to optimize this process so that the created object has the best possible properties.
The basic types of laser scanning are according to the main directions. The scanning direction can be horizontal so that it takes place in one direction, it is also characterized in that it takes place in 0 degree. Another type of scanning is the previous horizontal only extended by another direction, so it is a horizontal way at 0 and 180 degrees. The other two methods of laser scanning are in the vertical direction, where the first method is at 90 degrees and the second vertical method is also in the opposite direction, so that 90 and 270 degrees are used. Another possibility of creating a pattern is the so-called a concentric pattern, which is created as an outer contour and it gradually progresses towards the inside of the object. Another pattern used is hexagonal, where the hexagons can be joined at an angle of 45 degrees to the load axis. [5][6]

A schematic illustration of possible laser scanning methods is shown in Fig. 2.

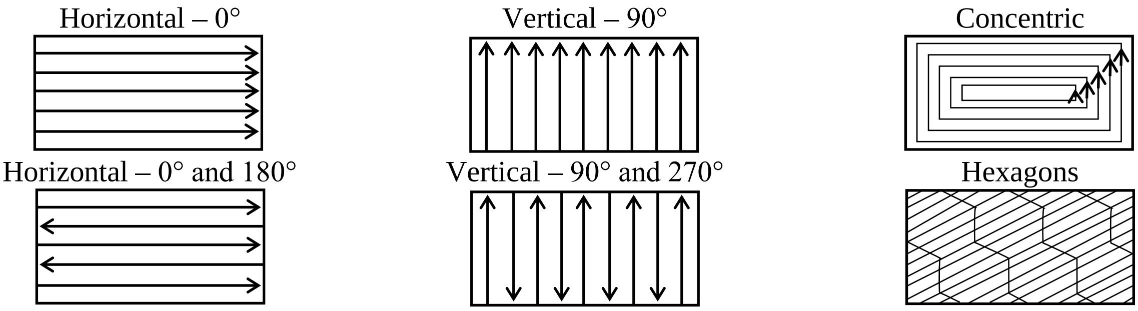


*Fig. 2 A schematic illustration of possible laser scanning methods*

The laser curing process is performed in a gas chamber (e.g. argon or nitrogen) to prevent possible oxidation.

The powder material used can be of various types and also modified in a certain way, which also depends on the properties of the final object which we produce in this way. During the hardening process, various phase transitions of this material take place.

Powders can be obtained from gas atomization (atomized in argon and nitrogen) or atomized in water. Gas-atomized powders have spherical particles, while water-atomized powders have a mixture of hemispherical and rounded shapes with relatively pure particles without satellites. The atmosphere of the building (argon or nitrogen) is necessary to prevent oxidation of the powder during the hardening process at elevated temperature. [5][7]

The effect of different atomizations of the medium on the microstructure of the powder is huge. It is made by a nitrogen atomized powder, austenite is easier to obtain than an argon powder, and a water atomized powder can obtain a maximum volume fraction of austenite in three atomization modes. [5][8][12]

During the creation of the object itself, there are many influencing factors that affect the quality and mechanical properties of the final product. In addition to the already mentioned influencing factors, it is possible to consider the orientation of the object itself, as well as the used method of the scattered laser beam, which is shown in the Fig. 2. Another influencing factor is the amount of energy density used in the hardening process.

From the point of view of evaluating the hardening process itself, it is necessary to perform various measurements and tests. Mechanical and metallographic properties are evaluated. Furthermore, it is possible to evaluate the influence of process parameters on hardness. The orientation of the building, the time intervals between the layers and the energy density can influence the thermal history that occurred during production, resulting in a different retained amount of austenite in the microstructure, showing a different microhardness. The correlations between scanning speed, hatch spacing, cut thickness and microhardness have a declining trend. Volume percentage and size of Cu precipitates play an important role in changing the microhardness. [5][9]

During the transition from the original state directly to the aging heat treatment (without solution treatment), the change in hardness values depends on the amount of retained austenite, which is dictated mainly by the original atomization state of the powder. [5][10]

The amount of austenite retained can greatly depend on different production conditions. The volume percentage of retained austenite can significantly affect material strength, toughness, tensile strength, and elongation to failure. As the content of the retained austenitic phase increases, the tensile strength and hardness of the parts decrease, while the retained austenite is beneficial in improving hardening and elongation at break due to the effect of transformation-induced plasticity (TRIP). [11]

If we consider the orientation of the samples, then compared to the horizontal, the vertical sample has a small volume per unit volume and a large porosity. In the case of a vertical sample, the weak interfacial layer is perpendicular to the direction of the tensile load, provided there is an easier path for the pores to grow and merge. However, in horizontal samples, these layers are parallel to the load axis, which prevents the opening and widening of the cavities. [5]

The increase in strength can be attributed to the relatively higher density of the part produced at the higher density of laser energy, which produces sufficient heat to melt the powder, and the fraction of the martensitic phase increased in the part made of water-atomized powder. The hardening effect is attributed to the heat treatment on the strength (yield strength and tensile strength) of the second phase precipitate in the matrix, as well as other changes in the characteristics of the microstructure, phase volume fraction (relative volume fraction of martensite to retained austenite), grain size and morphology. In addition, cavities, pores, and unmelted areas (i.e., weaker metallurgical bonds) between the layers can be attributed to the entrained depth of the entrained gas and the lower laser. Such cavities have a clear effect on the mechanical properties of the materials, in particular their elongation at break and fatigue properties. [5]

It is important for components to pay attention to their fatigue behavior. This is mainly because fatigue failure is the most common manifestation of failure in many engineering components and structures. Fatigue failure is the result of cyclic (repeated) loading and can occur when the stress is much less compared to the monotonic failure caused.

## 4 Conclusion

This article presents the material curing process. The mechanism is similar to a 3D printer, where curing is carried out by means of a laser beam, the material itself is powdered and the process takes place in a protective atmosphere. The final quality of the cured article is influenced by several factors, such as: the type of powder material used, the orientation of the cured article, the laser beam scattering method used, the amount of energy density of the curing beam used.

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