

Article

# Decarburization in Laser Surface Hardening of AISI 420 Martensitic Stainless Steel

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**Abstract:** Decarburization deteriorates the surface mechanical properties of steel. It refers to the loss of carbon from steel's surface when exposed to an open-air environment in elevated-temperature conditions. Despite the short interaction time and fast thermal cycle of the laser surface-hardening process, decarburization may still occur. This paper investigates if decarburization occurs during the laser surface hardening of AISI 420 martensitic stainless steel. For comparison, surface-hardening results and decarburizations in a conventional air furnace-heated hardening process (water-quenched and air-cooled) of the same steel material were also investigated. Decarburization seems to have occurred in the laser surface hardening of AISI 420SS. However, the decarburization might not be significant, as the hardness of the steel's surface was increased more than three times to 675 HV during the laser surface hardening, and the hardness drop due to decarburization was estimated to be only 3% with the decarburization depth of 40  $\mu\text{m}$ . Simulations using ThermoCalc software to get the carbon concentration profiles along the depth for both laser-hardened and furnace-heated samples were also investigated.

**Keywords:** decarburization; carbon loss; laser hardening; furnace heat treatment; stainless steel; simulation



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## 1. Introduction

Decarburization is a surface degradation phenomenon that involves the removal of carbon at the near top surface area of a steel during exposure to air at an elevated temperature and defined time as temperature–time-related processes [1]. This loss can largely influence the material properties of the material surfaces, such as lower strength, lower wear resistance, and lower fatigue resistance [2,3]. Decarburization remains a persistent problem in high-temperature heat treatment processes in industrial operations such as forging and rolling. Any process of high-temperature treatment of steel without a protective atmosphere can lead to decarburization [4].

Laser surface hardening is a surface modification method which induces a laser beam onto the material surfaces to improve its surface hardness and wear resistance [5]. Unlike the conventional heat treatment, laser surface hardening generates martensitic phase transformation on the targeted surface through rapid heating and cooling without affecting its bulk material. This method is widely used in automotive and heavy machinery industries in increasing the wear resistance of gears, bearings, and shafts [6]. Despite the short interaction time in the rapid heating kinetics of this process, there is still a possibility of carbon loss at the near top surface of the induced area. Carbon at a high temperature is more active with oxygen atoms compared to with iron atoms. The decarburization reaction between [C] and [O] would occur in the near-surface region producing CO gas. Some studies have reported the possibility of decarburization after laser surface treatment as one of the reasons for the degraded surface mechanical properties. Yan et al. [7,8] investigated

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