The Research of Carbon Construction Steel at Laser Alloying

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***Abstract*: Relevance: The theme of machine components case-hardening when heated by a laser ray has been and remains currently relevant. Laser case-hardening is characterized by a number of exclusive advantages: hardening of hard-to-reach surfaces, ensuring local hardening, including "spot" one when a continuous layer of fragile material vulnerable to cracking and destruction doesn't form; the lack of deformations and warping of processed parts as well as finishing operations; getting desired properties both mechanical and chemical ones by introducing different elements in the uppermost layer of a product at its melting by a laser ray, i.e. at implementing laser alloying.**

***Index Terms*: Carbon, laser, construction steel.**

I. INTRODUCTION

The process of interaction of laser radiation with the metal surface is reasonably well studied. Physic phenomena occurring at different processing of metals with a laser ray relate to thermal processes, which are divided into several specific stages:

- absorption of light flux and transfer of its energy to the lattice of a solid body;
- heating of a substance;
- meltdown of a substance in the impact area of a laser ray;
- cooling of a substance after the impact of a laser ray. [1], [2]

A part of radiation falling on the material surface reflects, and a part of it penetrates inside. In the process of laser radiation impact, phase and structural transformations, diffusive, convective and chemical processes occur in the surface of the processed material.

Laser alloying is becoming more common in engineering as a method of increasing wear resistance, heat-resistance, corrosive resistance, high-temperature strength, and other operational characteristics. This method of surface processing allows saving up to 90% of the alloying material since only thin layers of alloy (expensive) steels on the surface of carbon or low-alloy (cheap) steels are melted by laser alloying.

Revised Manuscript Received on July 09, 2019
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It's known that three main groups of substances are used as alloying additives: non-metals, metals and alloys, chemical compounds (carbides, borides, etc.). [3]

Laser alloying with non-metal components (C, 19, B, 81) is the alternative to the traditional methods of carbonization, azotization, boronizing, siliciding, and the data on the successful use of laser alloying with carbon, silicium, nitrogen and oftener bohrium are published in the literature. There is much less data on the successful use of alloying the material surface with metals, including carbide-forming ones – chromium, molybdenum, wolframium. [4], [5]

II. ANALYSIS AND DISCUSSION

The paper contains the studies of the structure of carbon construction high-quality steel 20 (0,2 % C) and 45 (0,45 % C) after their laser alloying with chromium, molybdenum, wolframium. [7]

The tests were carried out using a CO_2 gas laser of Latus-31 type with a power output of 1000 W. The power density was kept constant ~ 105 W/cm2 at a speed of processing V = 0,4 cm/s.[8]

A layer of protective coat composed of alloying powder and binding agent (coal-tar varnish) in the ratio 1:4 was applied onto the precleaned and polished surface of samples.

The X-ray crystal analysis carried out using a DRON-UM1 unit showed that the structure basis is α-phase along with intermetallic compounds, carbides, oxides, which are present in the alloying bath depending on the alloying composition (Fig. 1-2).

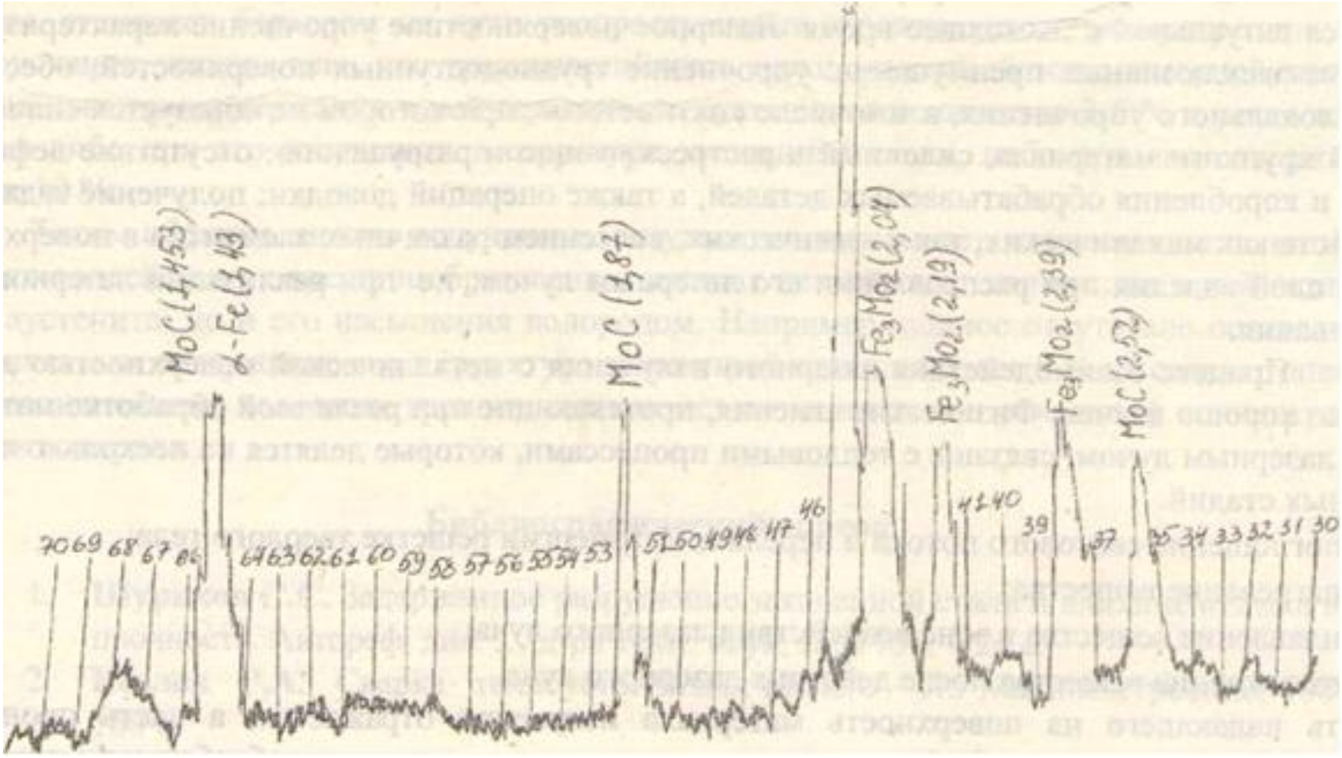

Fig. 1- The diffraction spectrum of steel 45 after laser alloying with molybdenum

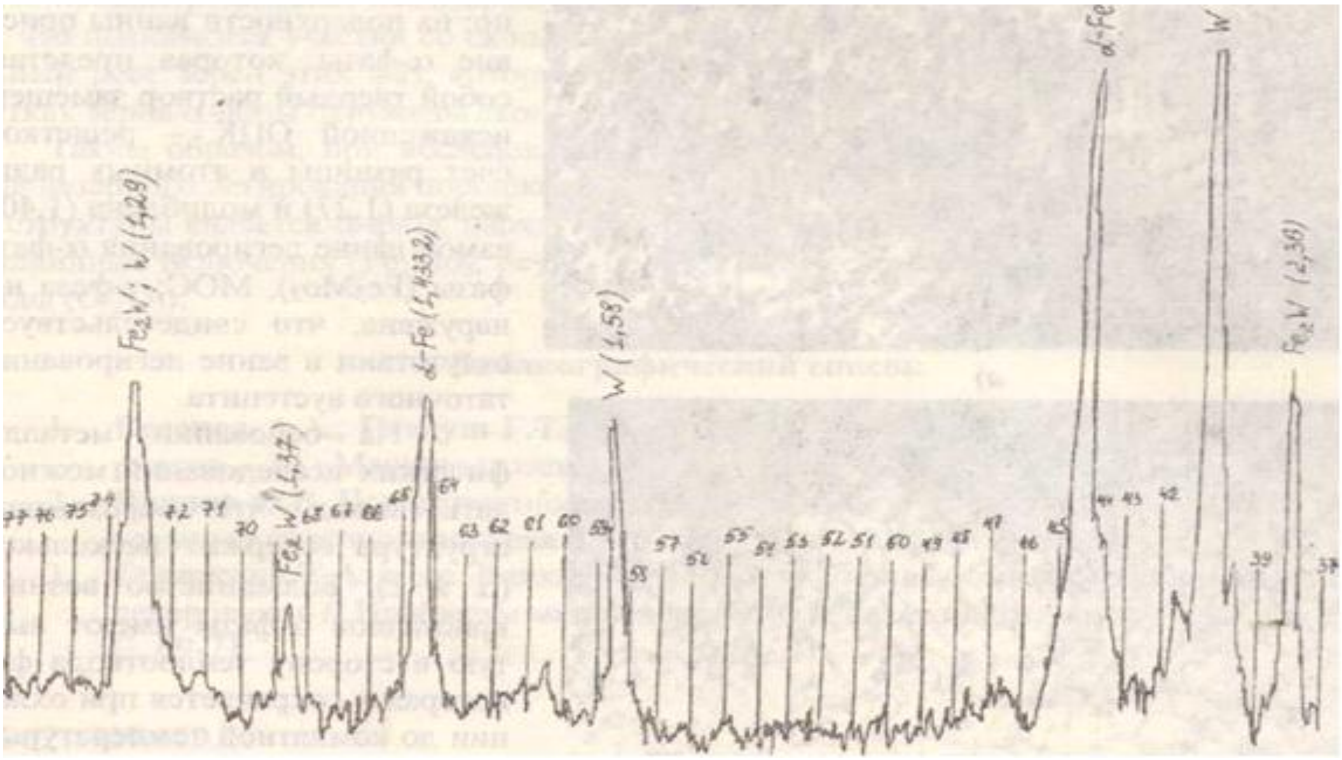

Fig. 2 - The diffraction spectrum of steel 45 after laser alloying with wolframium

Following the X-ray crystal analysis, it was found out that α-phase (substitution solid solution), O_2C_3, Cr_3C_2, Cr_2O_3 were formed on the surface of the bath when alloying with chromium. When alloying with chromium it was established that chromium sufficiently evenly distributes throughout the entire alloyed volume (Fig. 3, Fig. 4, a).

It can be explained by the fact that under condition of high speed of cooling of the solution, the carbon having a small atomic radius and forming addition solid solutions with ferrum manages to redistribute, and its content in different stages appears different, while chromium forming a substitution solid solution with ferrum, doesn't manage to redistribute. [9]

This results in the appearance of such phase condition when all forming phases in the alloyed layer (ferrit, martensite, austenite and carbides of both cementite type and special ones of MC3 type) have the same concentration of chromium.

The grains have a different shape and sizes varying from small polyhedrous to large elongated.

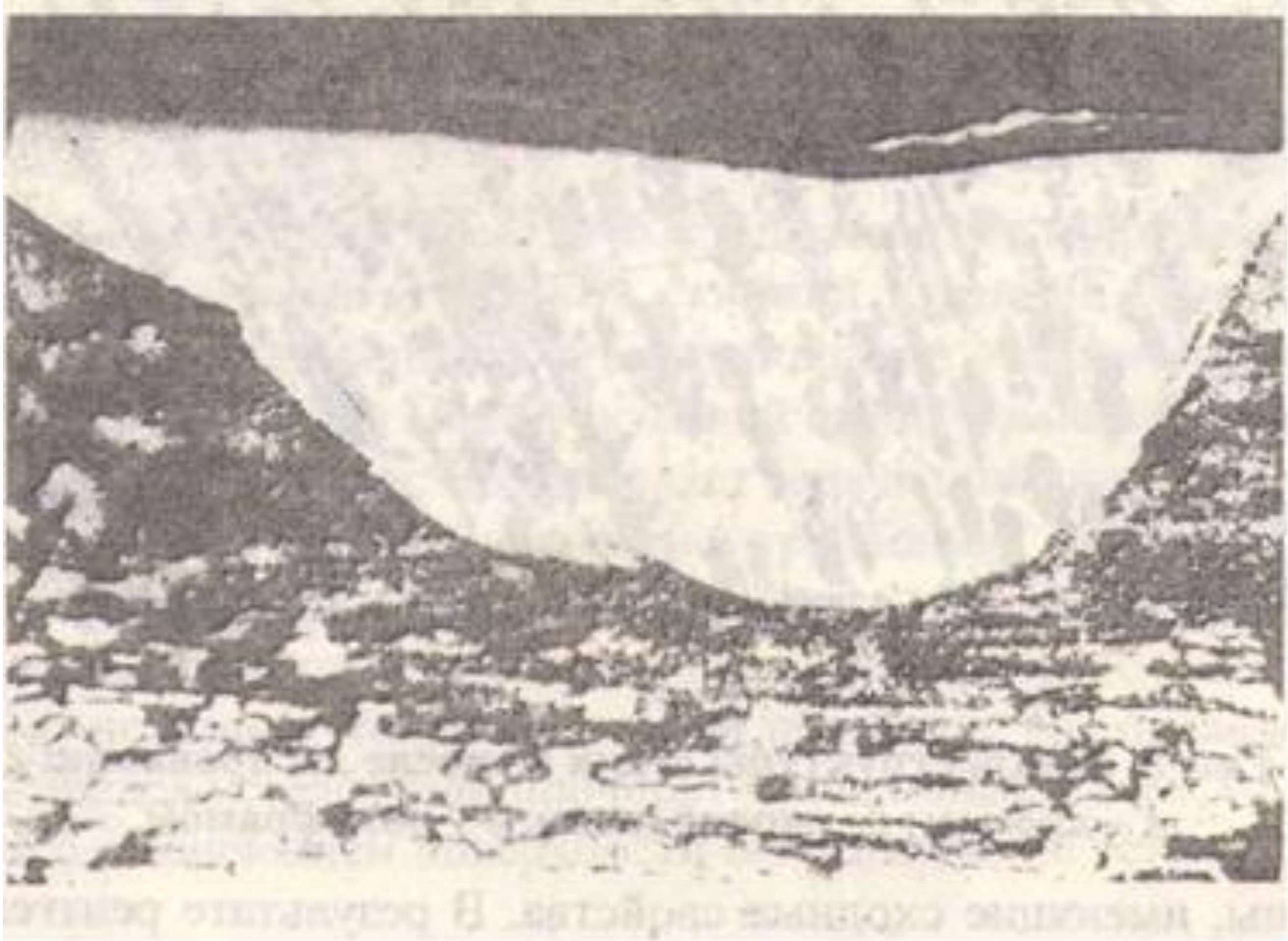

Fig. 3 – The external appearance of steel 45 after laser alloying with chromium

According to the X-ray crystal analysis data, the following phases were registered in the alloying bath (molybdenum): the presence of α-phase, which is a substitution solid solution with a distorted space-centered lattice – due to the difference in the atomic radii of

ferrum (1,27) and molybdenum (1,40), on the bath surface; α-phase, γ-phase (Re_3Mo_2), organometallic compounds in the bath itself; u-phase is not detected, which indicates the absence of retained austenite in the alloying bath.

Based on the metallographic studies it can be concluded that the formed structure contains several phases (α and β). The majority of originated crystals of α-phase has a shape elongated towards the heat removal, which preserved when cooling to the room temperature. Some part of the grains has a polyhedrous shape. [10]

It's obvious that these crystals are formed as a result of phase recrystallization of θ-phase in α-phase. θ-phase evolves in the form of very small particles both along the gain borders and in grains themselves (Fig. 3).

The phases formed at laser alloying with molybdenum are similar to the phases present in the Re-Mo diagram, however, there's no and can't be full correspondence with the stable diagram of Re-Mo since the structure in the alloying bath is not stable due to high rates of heating and cooling. [11]

The similar results are obtained when alloying with wolframium. It's known that wolframium and molybdenum are the elements of the same subgroup with similar properties.

As a result of the X-ray crystal analysis, it was found out that wolframium (ρ-phase) mainly leaves on the alloying bath surface, as well as α-phase in small amounts; there are α-phase, θ-phase in the alloying bath itself.

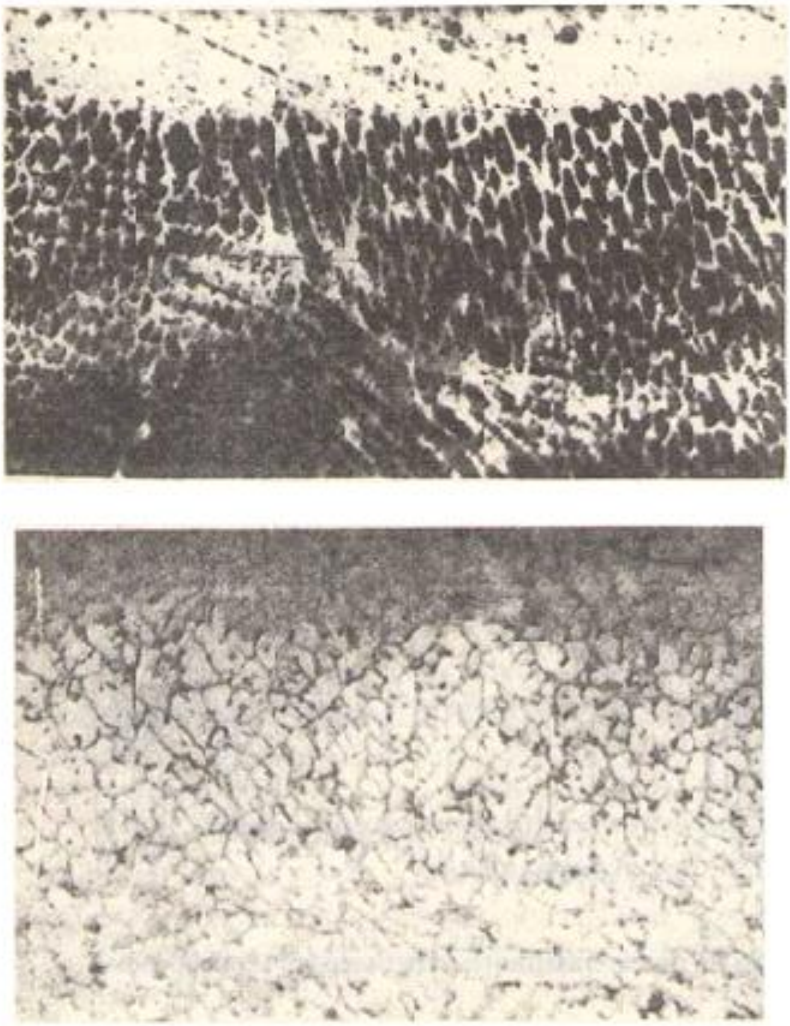

Fig. 4 – Microstructures of steel 45 after alloying: (Re_3\U_2), \US, J:$_2$.

The metallographic studies showed (Fig. 4) that a highly dispersed structure with polyhedrous grains, which are connected to each other and formed towards the heat removal, is being formed. [13]

III. CONCLUSION

Under conditions of a high gradient of temperatures and quick heat removal, the direction of the crystal growth is determined. γ-phase, forming both in the grain and along its borders, evolves in the crystals of α-phase.

The concentration non-uniformity (when increasing the thicknesses of the protective coat) is that the sites with the accumulation of both α-phase and β-phase appear, in doing so, the parallel growth of the grains of these phases takes part, which grow and connect to each other.

The grains of the α-phase in individual segments are surrounded by the accumulation of ε-phase.

Thus, when studying the structure of carbon construction steel after laser alloying with the powders of chromium, molybdenum and wolframium, it was found out that the structure basis is α-phase along with intermetallic compounds (Re_2Mo_3, Re_2, Re_3), as well as carbides (Cr_2C_3, MoC, A_7C, YC_2) and oxides (CT_2O_3), which are present in the alloying bath.

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