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Laser beam shaping for modification of materials with ferritic-martensitic structure

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Abstract

A identify conditions of laser heating for warm forming of materials with a ferritic-martensitic structure was performed. The laser source was a fiber laser with maximum output power of 1500 W. The beam was transformed to an elliptical ring with use a plano-convex lens and axicon. Study of the microstructure allowed revealing fibrous structure of metal, formed during the manufacture of blanks by rolling. Place of plastic deformation is characterized by a local decrease the thickness profile. To eliminate of this defect, is advisable to use the diffractive optical elements, which redistribute the power density of a laser beam.

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Keywords: laser action; beam shaping; diffractive optical elements; structure; dual phase steel

1. Introduction

One of the most specific characteristic of laser irradiation consist on the possibility to concentrate, in the focused spot, higher density of energy as any other heat source. Thus laser beam treatment is one of the progressive method for improvement of physical and mechanical properties of materials. Current status of achievements in the area of physical characteristics of laser beam processing is presented in various papers and monographs [1-3]. Reference

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books [4-6] described in detail application of laser devices in diverse product technologies. It is shown that such important characteristics of metallic materials, as tensile strength, fatigue strength and wear resistance are structurally-sensitive, i.e., can be controlled by proper changes in the material structures by laser action. However, questions of laser modification of metallic materials are considered, as a rule, only in terms of their hardening, caused by heat or deformation. This approach was justified earlier, when the aim was to increase the strength of the use of structural and functional materials. At present, in connection with the development and wider use of high-strength materials there are problems associated with the need of softening their various local sites, for example, to carry out the forming operation. Only few works are devoted to investigation of the process of softening controlled with changes in the structure of these materials [7-10]. Even the term «laser annealing», which in a broader sense means changing the structure of solids by laser radiation of varying duration in the literature usually refers to a pulse oriented crystallization of semiconductor structures by laser radiation of nanosecond duration.

At present, more and more applications of high-strength dual phase ferritic-martensitic steels with a controlled amount of martensite have the most favorable combination of durability and plasticity compared to other low-alloy steels [11]. At the same time these have good corrosion resistance in atmospheric conditions, slightly aggressive media (in weak salt solutions, acids) and have high mechanical properties. A dual phase ferritic-martensitic structure can be modified by using various combinations of heating and cooling parameters. Advantages of one regimes are connected with a possibility of martensitic hardening of steels with a low content of alloying elements or with receiving higher hardening when aging materials, others – in higher combination of durability and plasticity, etc. For realization the different treatment conditions appropriate to use laser beam shaping systems with a controlled power density distribution. The purpose of this research is to determine the advisability of laser beam shaping for modification of materials with ferritic-martensitic structure, in particular, their warm forming.

2. The material under study

DP1000 steel has been used in this study. The chemical composition of the material is given below in Table 1.

Table 1. Chemical composition of the DP1000 steel, max wt %.

Chemical element	C	Si	Mn	P	S
max wt%	0.18	0.8	1.8	0.02	0.01
Chemical element	Al	Nb-Ti	Cr-Mo	B	Cu
max wt%	0.015 – 1.0	0.1	1.4	0.005	0.2

3. Results and Discussion

The laser source was a fiber laser YLR-1500 with maximum output power of 1500 W [12]. In order to resemble the target zone the beam was transformed to an elliptical ring by optics consisting of a plano-convex lens and an axicon, which was projected onto the surface at an angle of 45°. The plano-convex lens is part of the optical scheme of laser machining system that serially manufactured. Outer borders of this ring were defined by parameters 38 mm and 26.7 mm, and inner borders were defined by 15.2 mm and 10.7 mm, shifted by 0.76 mm against the outer ellipse. The experimental studies were realized on a servo bending press TruBend 7018 with maximum. force 180 kN. The experiments were performed at 1500 W of laser power, applying varied heating times. After heating, the upper tool is being moved down with ~100 kN force and 10 mm/s speed.

Analysis of the samples microstructure was performed using an optical microscope METAM-LV increasing to 200 times. Study of the microstructure allowed revealing fibrous structure of metal, formed during the manufacture of blanks rolling. Fig. 1 shows etched microsection of cross-section of the heat affected zone after warm forming steel DP1000 sample thickness of 1.5 mm.