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INVESTIGATION THE IMPACT OF A LASER ON THE CHERNOV-LUDERS LINES IN THE 40X9C2 STEEL

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The study presents investigation results of the hardening points impact, created on the model surface by means of a laser complex. The authors investigated the change in the steel microhardness in the area which is treated with laser processing and presented the model of stress-strain diagram. The article reveals a change in the yield point and the plasticity of the models as a result. The authors made a number of speckle photos showing the Chernov-Luders lines behavior.

Key words: 40X9C2 steel, plastic deformation, mechanical properties laser treatment, Chernov-Luders lines.

INTRODUCTION

It is known that the metal models is accompanied by macroscopic deformation localization images which are evolving in accordance with the stadiality of the loading branch and is unhomogeneous at each stage [1, 2]. At the stage of destruction, the points of localized deformation begin to move with a constant speed for each of them. However, at this stage, their speed depends on the coordinates of the place of origin of each focus, herein, the closer this place is to the zone of future destruction, the more slowly such focus moves. From the beginning of this stage, the focuses moving velocities are automatically synchronized in such a way to provide their simultaneous “arrival” to the autowave center-”collapse” and the place destruction and the existing time of the model before the destruction are deterministic phenomena carrying at earlier stages of plastic deformation [2,3].

The most notable examples of this are the Chernov-Luders line arising at the stage of easy glide and the contraction formed at the pre-destruction stage of the model.

An experimental attempt to influence on the formation of the Chernov-Luders line by changing the surface layer of the model was made within the framework of this work. It is inexpediently to conduct laser hardening of large surfaces, as the hardened layer can separate from the base metal, and also to be a stress concentrator where cracks will form at the attempt of the model deformation. This will lead to rapid model destruction [4, 5]. It was decided to create on the steel model surface (40X9S2) a system of inhomogeneities in the form of equidistant hardened focuses by means of spotted surface of laser hardening. This way there is an “outflow” of deformations. The focuses boundaries are limiting the cracks growth on the model.

EXPERIMENTAL STUDIES
Equipment and tools

The models of steel 40X9C2 with the size of the test portion 60x8x3 mm were prepared for the experiments. The creation of hardening focuses was performed in the form of dot matrix at a pitch of 0,12 mm on both sides of the workpieces with the help of the BlackLight installation. The pulse duration is 12 ms, the power density is 23,4 kW / cm2 and the spot diameter is 0,35 mm.

The samples with treatment at the whole surface of the working area, treatment of the half of the length and untreated witness-samples were in a set of prepared samples. The model with the whole treated surface is shown in Figure 1.

The universal testing machine of the LMF-125 kH series was used for carrying out the tension tests.

The double-exposure speckle photography method was usedfor studying the inhomogeneity of plastic yielding. As a result, a series of two-expository speclograms covering the whole model working area was obtained.

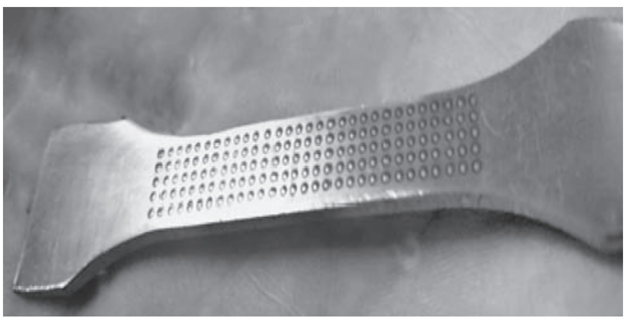

Figure 1 Models after the laser treatment

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RESULTS AND DISCUSSION

Figure 2 shows the photographs of the influence areas of the laser beam on the model surface. Figure 2a shows the influence area of the laser beam on the model surface. It is possible to distinguish two characteristic zones for laser emission-the laser impingement point (LIP) and the heat-affected zone (HAZ). There is a model material melting in the zone of laser action, as evidenced by the absence of the stripes left by the polishing tool before the laser treatment, that is, the heat treatment of the focus is hardening from the liquid phase (Figure 2a). The non-etching area, which indicates about very fine-grained structure is forming.

Figure 2b shows the cross section of the laser impingement point. The depth of the non-etching area is approximately 300 μm.

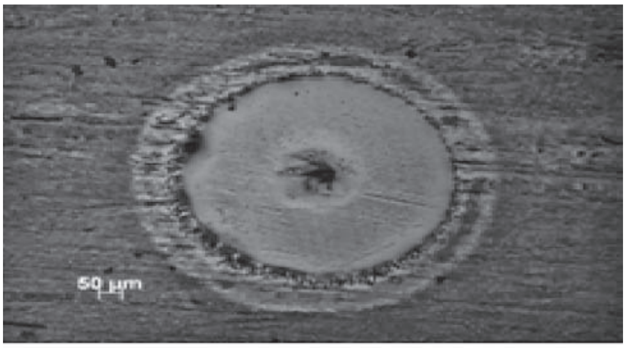
Figure 3 shows the results of microhardness testing in the area of the laser treatment, and near it. The testing was made from the center of the strengthening to the border of the model. As it can be seen from the diagram, the machined steel has the increased microhardness from 280 MPa to 1 050 MPa. The higher microhardness at the periphery of the hardening point is associated with high cooling rates in comparison with the center.

Plastic deformation under the models stretching begins with the occurrence and movement of the Luders lines in them.

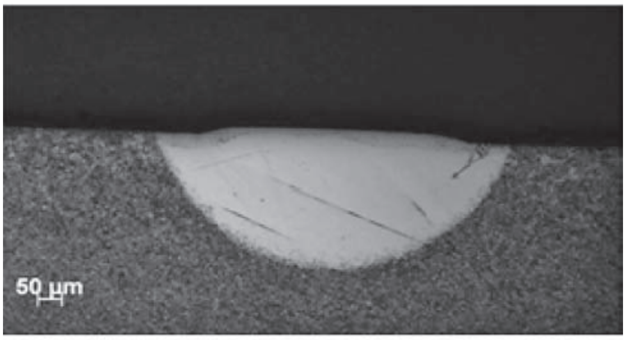
Figure 4 shows the characteristic tensile curves for the initial and processed models. The stretching diagrams (Figure 4) of the initial and half processed models, the signs of the presence of yield strength are seen, while it is practically absent in the fully-processed model. Also, the diagram shows the dependence of the model plasticity on the number of strengthening focuses, with their increase, plasticity sharply decreases. There is no neck formation stage, an explicitly evolving stage of the initial model in the diagram of the fully processed model.

The tensile diagrams of the initial and half processed model are almost identical up to that time (deformation of the order of 6 %), while the motion of the Luders line does not reach the processed area of the model 2. Further, there are such values in the tension models that the cracks appear in the processing focuses. Tensions begin to decrease and the model breaks down in the area of focuses concentration.

An easy sliding stage is observed at a low grade in a fully processed model. The Luders line arises on the unprocessed part of the model at the movable shackle and disappears at the processed part. The increasing tensions in the focuses lead to their cracking, so that the module decreases.



a)



b)

Figure 2 Strengthening focus: a) top view; b) cut-away view

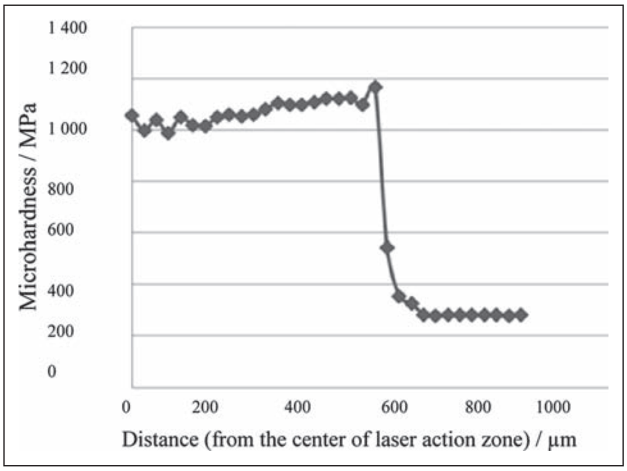


Figure 3 A change of steel microhardness in the area, subjected to laser treatment

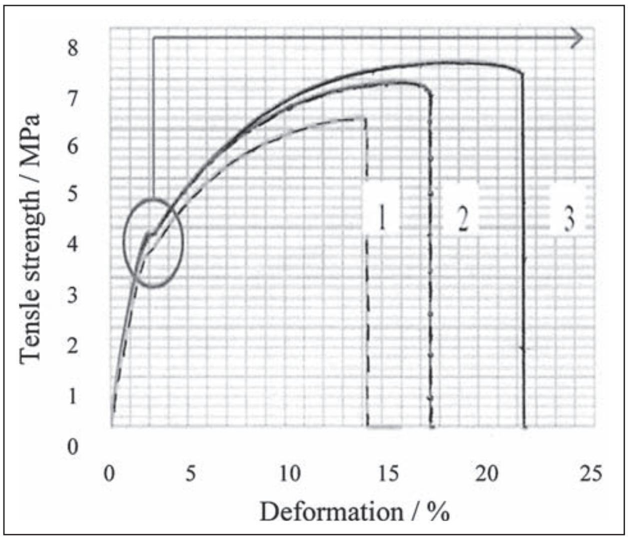


Figure 4 Diagrams of stretching models with different processing types: 1- completely processed; 2- half-processed; 3- without treatment.

a)

b)

c)

Figure 5 The occurrence and direction of the Luders lines in the models: a-initial; b-half-processed; c-fully processed

The appearance of lines in all models begins on the one-hundredth second after the stretching start. Three Luders lines (Figure 5a) fluently moving along the full length of the model are immediately forming in the initial sample. Hereafter there are no any changes on the speclogram of the unprocessed model. The model disruption occurred with the formation of a neck in the middle of the working area.

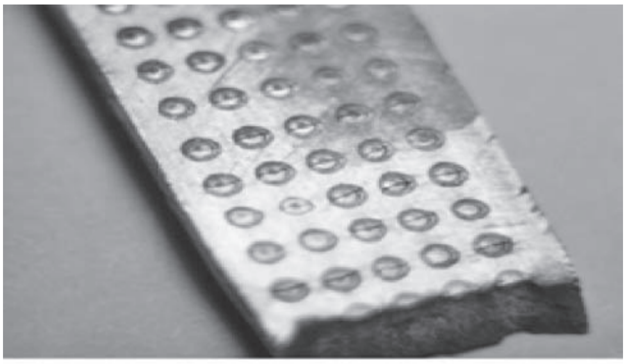
In a half-processed model, the line arises at the shackle from the unprocessed side and starts moving toward the center of the model (Figure 5b) in 12 seconds after the movement beginning. Another one Luders line moving towards the first formed at the edge of the treated area. A distinction begins to occur after the collapse of these lines in the tension diagrams of models 2 and 3 (almost identical up to now). Two more lines appear in a half-processed model on the edges of the working area, in untreated areas, moving to the shackles, after which a break occurs.

At the same time only one localization line, in a narrow transition zone between the fixed grip and the treated area could form in a fully processed model.

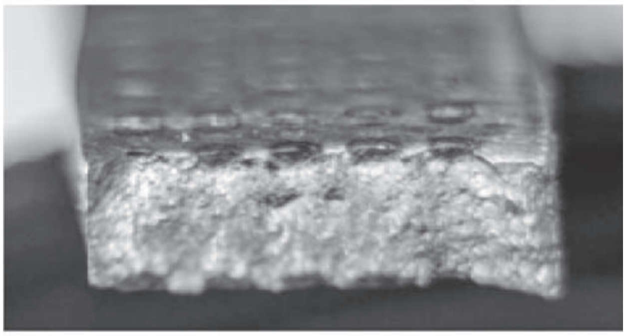
With further load increase in the processed models, in view of high hardness and low plasticity, the focuses were not deformed, and a crack appeared in them. It moved forward, but stopped at the edge of the processed and unprocessed area, which subsequently led to a disruption. Unprocessed model disrupted with the formation of pronounced neck.

CONCLUSION

The given steel processing type is superficial. The hardening points by the total volume are much smaller than the model itself. The focuses area is no more than 5 % of the cross-sectional area of the model in the section. The Luders line cannot pass through the area of the hardening points at the models stretching (Figure 6). That leads to its suppression (see the stretching diagram of models 2 and 3). By means of the suppression localization, the loading diagram changed quite significantly. It became possible to dispose of the easy glide stage in the whole processed model. That indirectly indicates that the stadiality of the loading curve may be a consequence of deformation localization [5]. At the same time, the hardening focuses in the present form are the stress concentrators and areas of formation of cleavage cracks, reducing the strength and plasticity of the models, which points at the need to optimize the structure and, as a consequence, the material processing rate for their formation.



a)



b)

Figure 6 The models after the testing. a) view of the hardening focuses matrix in the section; b) hardening focuses after the experiment.

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Note: The responsible for England language is Nataliya Drag, Karaganda Kazakhstan