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Characterization of microhardness on ductile iron modified by laser with space array

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Abstract Pulsed laser beams with two-dimensional array (3×3 and 7×7)distribution by binary optical elements was used to modify surface processing for ductile iron. The statistical method was proposed to describe the characters of microhardness distribution of modified area. The hardness distribution of modified transect processing for ductile iron was studied by conventional testing method and statistical method, respectively. The analysis showed that conventional test curve of microhardness was involved in the testing sites, so it couldn't correctly describe the microhardness distribution of materials in the case of multiphase，however, the statistical method for microhardness test was apt to determine the case depth of modified layer and describe the characters of microhardness distribution in comparison with that of conventional method.

Keywords: laser pulse, surface modification, ductile iron, case depth, microhardness

INTRODUCTION

Surface modification by laser is one of the most effective methods to enhance the synthetically mechanical properties and extend the service life of materials. One main object of laser modification is to obtain deeper case depth and enough wearing resistance. So, it is very important to evaluate the case depth and microhardness distribution of modified area in order to optimize the laser processing technology and objectively evaluate the modification effect. In this paper, pulsed laser beams with two-dimensional array (3×3 and 7×7) distribution by binary optical elements was used to modify surface processing for ductile iron. Then, the description methods of Microhardness distribution were analyzed and discussed. And the reasonable testing methods for Microhardness distribution and case depth was proposed especially in the case of of ductile iron with multiphase treated by laser with space array.

EXPERIMENT

1.Proceeding The integrated laser intelligent manufacturing system was used in experiment[1]。The laser beam was transformed into specified shape with 3×3（spot size1.3×1.3mm^2）和 7×7（spot size 3×3mm^2）array, in which the strength of laser was almost symmetrical distributed [2]。

The specimen was ductile iron （C3.4％，Si2.5％）with a size of 9×9×15mm^3 and no coating layer on the surface.
The HXD-1000 microhardness tester (load 25g and dwell time 15s) and nanoindentater (specified indentation depth 2μm) were adopted to test the microhardness distribution on transection of laser

modified area [3] .

2.Processing parameters Single pulse with a repeat rate of 4Hz and a wave shape of rectangular. The peak power is up to 5KW for 3×3 array and 2Kw for 7×7 array. on the other hand, the pulse duration is 24ms for 3×3 array and 80ms for 7×7 array, respectively.

3. Description of method The modified area was usually a area with a semilunar shape, the usual micrhardness test method used was that measuring microhardness along the line in which the case depth of modified layer was deepest. The experiment (Fig.1) showed that the microhardness distribution was not uniform because of ductile iron with multiphases in the modified area treated by laser beam with space array. So the microhardness distribution curve was involved in the measured sites in transection of sample laser modified [3].

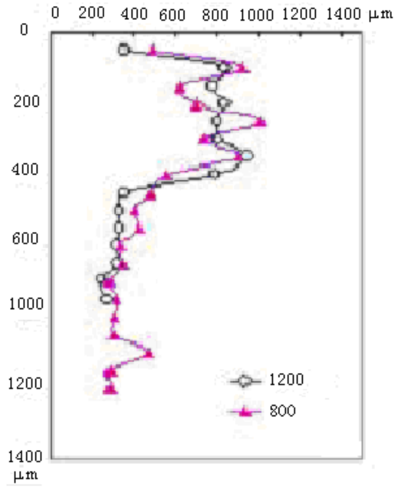

Fig.1 Microhardness Distribution with General Method at 1200μm & 800 μm from Modification Area Edge

In order to determine the case depth of modified layer and describe the microhardness distribution in reasonable method, based on above, the statistical method of Microhardness test was proposed, in which the grids are divided into with a space 30μm×30μm or 30μm×50μm in the transect of modified area, and the size of the grid was only determined by both indentation diagonal and graphite size. The Microhardness was tested in these intersections of grids along the laser beam till the Microhardness approximating 300HV (the matrix hardness determined by specified proceeding condition). As a result, the contour map drawn out by Suffer softwear showed the practical Microhardness distribution from the Microhardness distributive data obtained, where let the length of grids as y-axis along the depth in modified transect and the width as x-axis, respectively. The area within Microhardness beyond 400HV, was called modified area, while the case depth would be determined by following steps. A special line in parallel with modified surface (X-axis) may be drawn out, in which Microhardness of more than 50% intersections beyond 400HV, then the distance from X-axis to which was so called case depth. This was known as statistical method.

RESUTLS

Fig.2 to Fig.7 were the test experiments and results. The test sites and microhardness distribution were illustrated in Fig.2 , Fig.4(Vickers hardness), Fig.3 and Fig.5 (nanoindentation results)。It was obviously that the microhardness interlaced in transaction, which to some extend described the microstructure distribution characters, also proved the relation between microstructrure and beam spot array distribution.

As microhardness test methods was conerned, both methods obtained almost same results (see the contour maps fig.4 and fig.5). But in fact, the latter (nanoindentation test) should be more convenient to use in practice because of its high automatization level in experiments. Nevertheless, the former might avoid those graphite sites to be better reflect the characters in micrhardness of modified matrix. While based on harness measuring theory, a certain space should be kept between indentations which was the basics compartmentalizing the grids [4]. As the experiments results, 30 or 50μm space were suitable between grids.

The measuring showed that the case depth of treated layer was about 250μm in Fig.4 and Fig.5 on the condition of 3×3 array. It might be sure that the case depth of modified layer might be expressed as certain value by statistic methods.

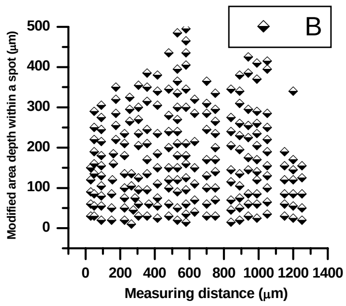

Fig.2 Test Positions for Vickers Hardness

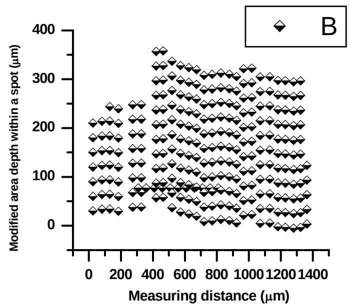

Fig.3 Test Positions for Nanoindentation

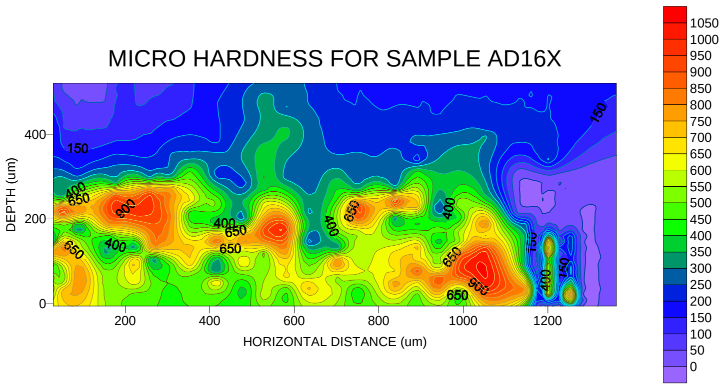

Fig.4 Vickers Hardness Distribution (DOE3×3)

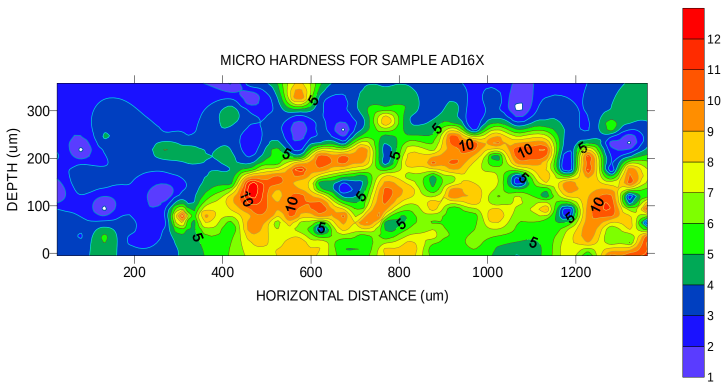

Fig.5 Nanoindentation Distribution（unite Gpa, DOE3×3）

Fig.6 and Fig.7 were the results treatmented with 7×7 array, and the case depth was about up to 400μm. From above, some relation would be seen between beam array distribution and microhardness distribution. The 7 beams of light corresponded with the 7 martensite areas in transection, it proved that the beam distribution played an important role in microstructure forming and distribution during laser pulse modification.

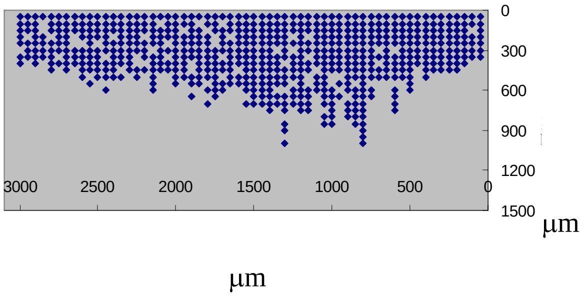

Fig.6 Test Positions for Microhardness (DOE7×7)

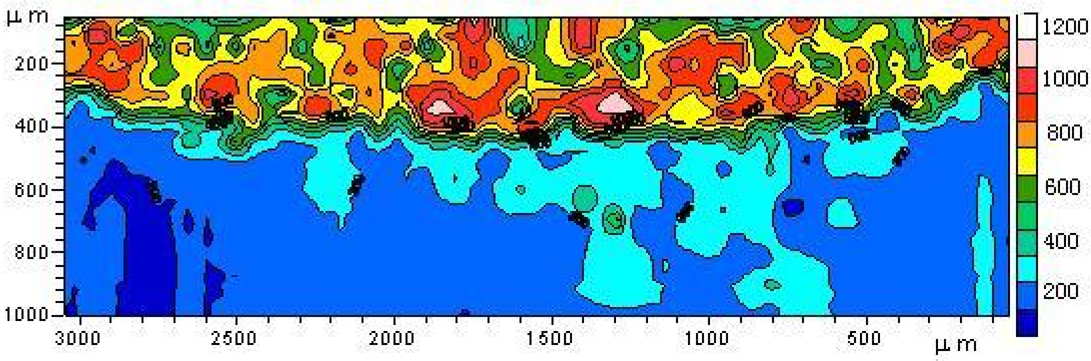

Fig.7 Vickers Hardness Distribution (DOE7×7)

CONCLUSIONS

In this paper, the physical definition of statistical method was put forward based on experimental results. The analysis showed that conventional test of microhardness couldn't correctly describe the character of microhardness distribution in the case of multiphase because of involving in the testing sites，however, the statistical method for microhardness test was apt to determine case depth of modified layer and describe the characters of microhardness distribution in comparison with that of conventional method. On the other hand, the method would supply with some references for evaluating the case depth of hardening layer and laser processing technology.

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