Cow-eye Microstructure Evolution of Laser Pulse processed For Ductile Iron

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Abstract

Pulsed laser beam with lattice distribution was used to modify surface processing for ductile iron. The microstructures around the graphite were observed using OM, and Nanoindentation and micro-hardness of that measured from surface to inner of sample. The result shows that the graphite ball has an important effect on cow-eye microstructure evolution either in light molten area or in phase change hardened area. It is not true that assuming the material is uniform during laser rapid heating and fast cooling for the graphite ball as a dependant composition phase. The microstructures of cow-eye is made up of fine remnant austenite in light molten area, and consisted of martensite and bainite in laser modified area. The cow-eye microstructure has a transformation from martensite and bainite to pearlite with the distance increasing from surface. At last, the microstructure evolution of cow-eye has been discussed.

Key Words: *laser pulse, surface modification, microstructure evolution, ductile iron, cow-eye structure*

1. Introduction

In the condition of convenient heat treatment, it is sufficient for carbon diffusion and austenitization, and matensite and other diffusing type phase transformation may be finished at a given cooling condition. The microstructure around graphite balls has undergone same temperature field evolution as matrix forming the uniform microstructure. It is obvious that laser pulse processing with very high heating and cooling velocity always leads to the temperature gradient change dramatically along distance from surface, affecting carbon diffusion and austenitization [1]. As a important consist phase, graphite have a independent heat transfer characteristic feature in comparison with matrix, especially during laser pulse acting on ductile iron, So it is possible to form some new microstructures. More works have been made on laser modification in recent years [2-4], but their works focus on technology and resultant materials properties. The investigation has showed that cow-eye microstructure formation usually occurs in laser pulse laser pulse processed for Ductile Iron, and the evidence can be used to distinguish the border of modification area [5]. In this paper, the microstructures around the graphite are investigated and discussed.

2. Experimental method

The materials for Experiment is ductile iron, the overall dimension of the sample is $9\times9\times15\text{mm}^3$. The original roughness is Ra.8um.No coating layer was adopted in laser processing course. On the basis of some preliminary tests, the technical parameters for laser pulse used are as follows. Laser energy distributes in a mode of 3×3 lattice, laser beam spot size is $1.3\times1.3\text{mm}^2$. Single pulse energy

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is 10J. Pulse width is 20ms, frequency 4Hz. The light spot moved velocity is 5.2mm/s. The above set of laser parameters could ensure that the surface roughness of sample in allowable range for applying to practical die and mould.

Single pulse was applied to process the surface of 9×9. The sample was cut into halves, then the transection microstructure around the graphite ball would be observed by optical microscope. Its microhardness is measured by use of a microhardness tester with a 25g load, and the nanoindenter is used to test the surface hardness in the local area with 1mN load and 1um nanoindentation depth.

3. Experimental results

In the laser area modified, the cow-eye microstructure has formed around graphite. The phase composition of that is not different from each other with distance from the surface. The microstructure of local light molten area near surface is formed by fine crystal (Fig.1), which is similar to recrystal shape, the crystal practically grow along the radical direction to surround with the graphite being as the center, this is a new microstructure formed.

In fig.2, nanoindentation are measured at the cow-eye boundary and laser hardened area (facial indentation are shown as triangle in Fig.2). Fig.3 shows the measure results of nanoindentation. The nanoindentation in curve 3 is higher than other region with a hardness larger than10GPa. It shows that this area is made up of slice martensite and hidden crystal martensite. The area curve 2 lies in is far from the surface, in witch the nanoindentation curve move down with an increase from surface distance. It can be seen that the spot with higher hardness lies in martensite area between two cow-eyes and others with lower hardness in the ring of cow-eye. It is also seen that the cow-eye structure changes from martensite and bainite to bainite and pearlite with the layer depth increase. It is similar for curve 1 comparing with curve 2, only some nanoindentation deference existed.

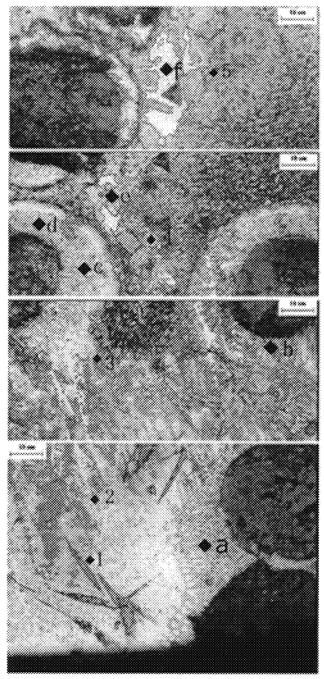

Fig.4 Microstructure and microhardness

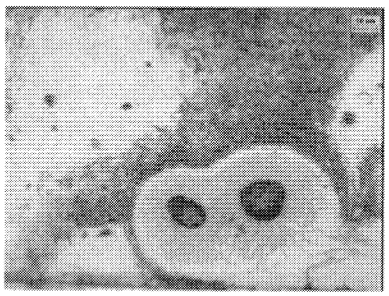
Fig.1 Microstructure around graphite in light molten area of surface

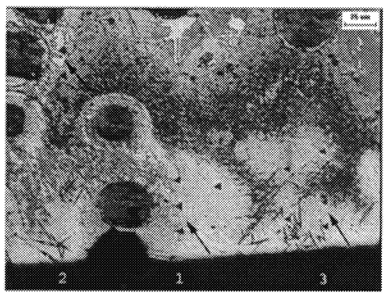

Fig.2 Nanoindentation hardness site

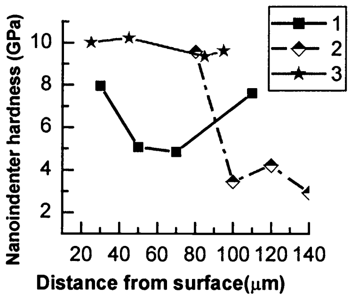

Fig.3 Nanoindentation hardness curve

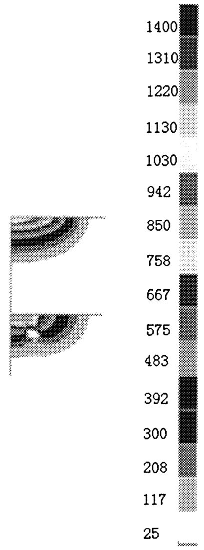

Fig.5 Effect of graphite on temperature field

Fig.4 is the overall photograph of sample transection from surface to internal. The microhardness of cow-eye structure and matrix at different depth are all shown in tab.1 as a comparison (1~5 matrix, a~f cow-eye). From fig.4, we can clearly see the microstructure change of matrix and cow-eye with distance from surface. The places c, d and e are in the same depth from surface, but the hardness of c and d (cow-eye area) is higher than that of e (matrix). Microstructure shows that the former are formed by martensite and bainite, the latter is pearlite. It is obvious that there is a relative higher temperature ring around graphite benefiting from diffusing type phase transformation. The place e may be regarded as the transition area for its lower microhardness. From the structure point of view, it is also as a criterion for judging the modified area boundary whether the cow-eye occurs.

Tab.1 Microhardness of coweye in laser modified area

Measuring Site	1	2	3	4	5
Hv (Kgf/mm^2)	946	835	919	480	347
Structure	M	M	M	B+P	P
Measuring Site	a	b	c (d)	e	f
Hv (Kgf/mm^2)	740	900	630	371	238
Structure	B+M	M+B	B+M	P	P

4. Discusstion

As above mentioned, cow-eye formed is a obvious evidence which shows the complexity in microstructure evolution during laser pulse acting on the ductile iron material. Ductile iron is no longer a kind of ordinary uniform material because of the graphite existing. The graphite is a kind of good conductivity for heat transfer comparing with matrix. As an important composing phase, especially on the condition of laser pulse rapid heating and fast cooling, the graphite ball has a very dramatic influence on temperature field. Fig.5 shows this effect to temperature (uniform —upper part, nonuniform —below part) at the end of heating within a pulse length. From fig.5, it can be seen that there is a relative iso-temperature border resulting in temperature difference between matrix and graphite. This can be one of important reasons forming cow-eye.

Cow-eye microstructure is not same each other along modified layer depth, this can be explained as follows. Although laser heat velocity is very high, carbon in carbide or graphite diffusing into ferrite would be always going. In the center of light spot, energy density is higher than that in the edge of light spot, due to zero level effect is difficult to be eliminated by binary optical transformation, so the light molten area occurs, graphite dissolved into ferrite, austenite contains more carbon. This can be lead to martensite point decline and mixed martensite, bainite structure. In the case of high temperature gradient, austenite obviously fine, if the temperature gradient is high enough, then carbon could not precipitate, at last, the austenite were remained (fig.1). When temperature gradient gradually descend, diffuse type phase transformation is not avoided.

5. Conclusions

5.1 In the case of laser pulse rapid heating and cooling, the temperature field around graphite ball is different from others in matrix area. This may be an important reason resulting in forming cow-eye.

5.2 On the above premise, the heat transfer for ductile iron must be regard as a nonuniform body during laser pulse heating and cooling.

5.3 Cow-eye structure is a mixing organization. The microstructure changes from martensite, bainite to pearlite with modified layer depth.

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