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The Technology Study of Camshaft Treated by Laser Bionic Melting Process in Aqueous Media Cooling[1]

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Abstract: Biomimetic coupling wear resistance model was created according to biomimetic coupling phenomenon and biomimetic coupling theory, utilize the preparation of aqueous media by laser cooling techniques, process biological coupling unit on the gray cast iron surface according to the organism form, make the bionic coupled unit in accordance with the laws of organism combination, form bionic coupling surface which is similar to the organism form with material surface to improve the wear resistance of the camshaft. Studies show, the region which dealt with aqueous media by laser can get small grains, and grain size is uniform, hardness and wear resistance is improved.
Key words: bionic coupling; laser melting; camshaft

1. INTRODUCTION

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Camshaft is the largest friction parts of engine, when the engine working, its speed is high, its contact stress is great, and has problems in lubrication; especially the peach of camshaft is long-term works in high stress contact fatigue, very easy to produce the scratch, tear, cut off and early wear failure. Sometimes, it is broken in only several hours, even less time, cause sound issue to engine, and the result is to be repaired. Camshaft's work environment determines that it must have some strength and stiffness, a certain toughness, good wear resistance. Meanwhile, due to the structural characteristics of camshaft, it must have a good machining performance.

The new bionic materials which are man-made also have the advantages of high efficiency and low energy consumption. Since the 80s of the 20th century, Dr. REN of Jilin University, specializing in bionic non-smooth surface, found that bulldozer blade had relationship with reducing the soil sliding resistance (REN et al., 2003). In recent years, bionic non-smooth surface technology has been widely extended and applied to the train's brake rotors, car brake hub, and many studies on thermal damage, eager to resolve the friction and wear, abrasive wear and thermal fatigue of this problem (CHEN, 2001; REN et al., 2001). All the work was on bionic non-smooth surface to change shape, such as size, and elements of non-smooth concave shape. Further studies found that only by changing the single element biomimetic materials which we made is it very difficult to solve some complex problems in engineering system.

The paper according to the biological coupling phenomenon and bionic coupling theory is to create bionic coupled anti-wear model, and use preparation of aqueous media laser, imitate the organism table form made bionic body coupling unit on HT200 cast iron, let the bionic body coupling unit according to organism morphology combination rules, with the surface of materials form bionic coupling surface which is similar to biological body shape to achieve the purpose of improving wear resistance (WANG et al., 2010).

2. EXPERIMENT

2.1 Experimental Materials

The gray cast iron HT200 in this test is widely used in as metal matrix, Its microscopic structure is flake graphite + pearlite (Figure 1), depending on the molding process divided bionic coupling unit into laser surface melting unit (LMU). Table 1 shows the chemical composition of HT20.

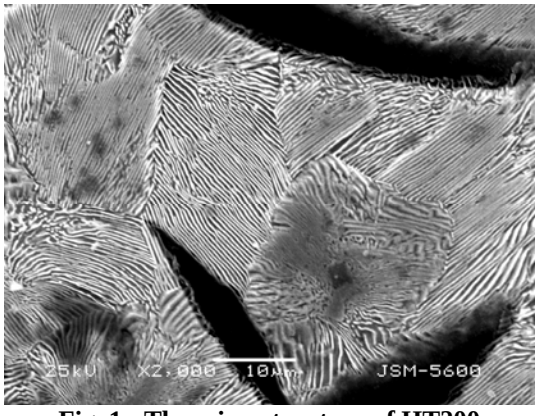


Fig. 1: The microstructure of HT200

Table 1: Chemical compositions of materials HT200（wt.%）

Components	C	Si	Mn	P	S	Cu	Cr	Fe
Percentage	3.250	1.570	0.920	0.060	0.059	0.500	0.270	Bal.

2.2 Sample Preparation

Use DK7732 CNC Cutting Machine process the HT200, size is 10×10×14 (mm）. In order to facilitate follow-up experiments and testing, the sample surface with sandpaper polishing, to remove machining marks left. With JHM-1GY-300B Type 2 +2 dimensional laser bionic preparation system process the sample with the method of bionic laser water film. Comparison sample for laser processing in air during processing through argon to prevent oxidation. Adjustment process by controlling the media, the laser parameters and table water storage containers can be processed bionic body coupling unit with different laser parameters, different water film thickness. The sample which was dealt with laser called bionic coupled sample, laser processing area was called bionic body coupling unit. In this study, the water film's thickness is 1.5mm, bionic unit laser parameters shown in Table 2. Through the orthogonal experiments, we get cold water film covered unit body's optimum parameters: current is 140A, laser diameter is 1.2mm, scan speed is1mm / s.

Table 2: Laser processing parameters of the bionic unit

pulse time /ms	frequency /Hz	current /A	laser diameter /mm	scan speed/ mm/s
7.0	10	100、120、140	0.8、1.0、1.2	0.8、1、1.2

2.3 Experimental Methods

Along the direction parallel to the length cut bionic coupling unit cross-section, We can see it strictly with the metal image science, using JSM-5500LV scanning electron microscope observe its microstructure; use D/max-RC X-ray diffraction and Cu Kα radiation under the condition : 40 KV voltage, 40 mA of current and 40 ° / min scanning speed to observe the golden image and the compounds; use a JSM-5500LV SEM to observe the microstructure area of the alloy element, use vickers hardness tester (Model: 5104, made by the United States Buehler Co. Ltd.) measuring hardness.

Use MM-200 ring wear tester (which is made by Xuanhua Measurement Instrument) to do the dry sliding test, friction and wear tests were carried out at room temperature. Let the sample slide on GCr15 steel. The average hardness of steel 61-63 HRC, the internal diameter of 16 mm, external diameter 50 mm, 10 mm thickness, Wear test load of 8kg, speed is 400 r/min, rotation time of 30 minutes. Before each experiment, we must ensure that the surface roughness of 0.1mm steel ring around, use ultrasonic cleaning the sample in the condition of alcohol, experiments before and after drying the sample. Use electronic scale whose accuracy is 0.0001g to take the test, according to the overall difference among the three samples obtained an average weight loss before and after experiment. To get more accurate analysis of wear mechanism, use JSM-5500LV scanning electron microscope test the sample surface wear.

3. EXPERIMENTAL RESULTS AND ANALYSIS

3.1 Bionic structural characteristics of coupling units

Figure 2 shows bionic coupling unit cross-section shape. Observation shows that the coupling unit consists of two parts. One is the outer melting zone, because the complete melting of cast iron in the region, then precipitate crystalline in the rapid cooling conditions. As the heat conduction, around melting zone the solid phase materials was changed, namely the heat affected zone. Figures 3 and 4 are laser processing microstructure section scanning photos of melting zone section which laser processing in air and water film thickness on different conditions.

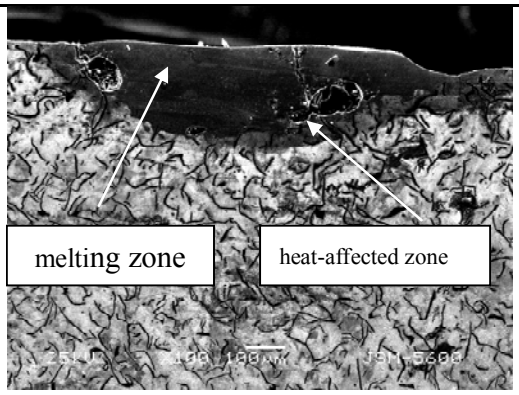


Fig. 2: The cross-sectional shape of bionic coupling unit

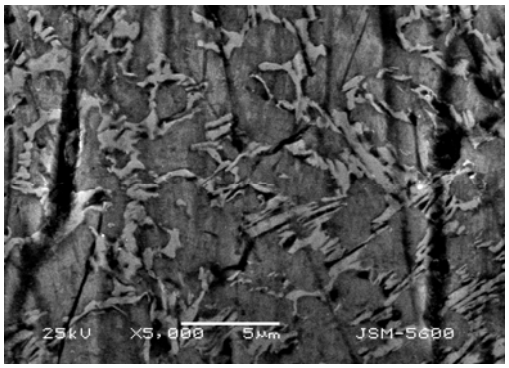


Fig. 3: The microstructure of air-cooled laser remelting zone

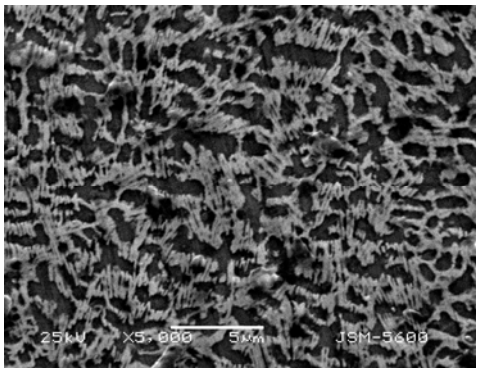


Fig. 4: The microstructure of laser melted zone in following the cold water film

Compared with the regional organizations which treated by laser, water film covered region has refined grains, some irregular mesh material and needle-like objects was disappeared. As can be seen from Figure 5, melting zone formed by a mesh of Fe3C and M and Ar, and transition zone formed by M, some Ar and some undissolved G, in unit area, grain was small and closely arranged, this result has consistency with Shen. ect.'s conclusion (SHEN & LI, 1991). This is caused by high cooling rate during the solidification.

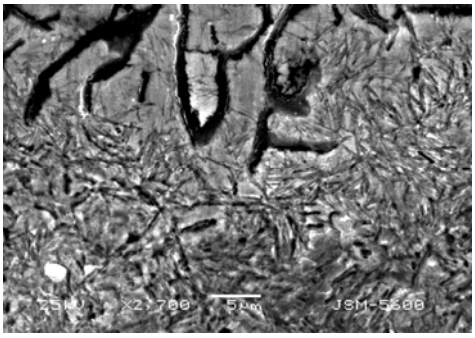


Fig. 5: Microstructure of heat affected zone

The microstructure of heat affected zone as shown in Figure 5, while the heat-affected zone can clearly see the martensite appears. Heat affected zone is M + AR + G (graphite), layer organization highly uneven. Increase along the layer depth, martensite'size and retained austenite's volume has significant difference, around graphite,coarse martensite, residual austenite increased; Away from graphite. Martensite thin and residual austenite reduced. Melting layer has a very high hardness, the hardness can be above Hv1000, with the laser scanning speed increased and increased with metamorphosis hypoeutectic white structure's refinement [77].

Figure 6 is the result of XRD after and before melting. It shows that the matrix phases before melting are graphite, cementite and α-Fe. The phase after melting is much martensite, cementite and γ-Fe. The hardness and strength of martensite are higher, so the abrasive resistance of the material is improved.

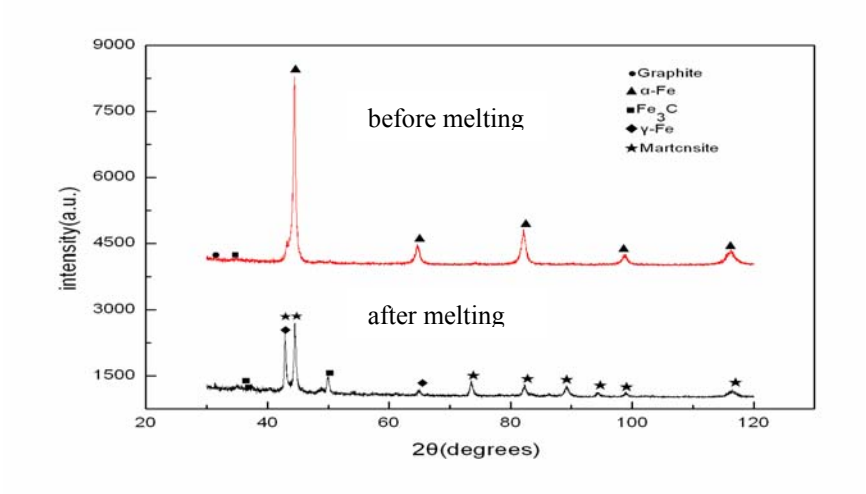


Fig. 6: XRD characterization

3.2 Microhardness bionic coupling unit

Figure 7 shows the laser processing unit's microhardness curve of air-cool and cold water filmed, Hardness was measured along the laser direction (from top to bottom of unit), it got from polishing each bionic samples' different locations, the average microhardness of the matrix is 350HV and the bionic unit is much higher, the highest can reach 730HV, the cold water film covered unit's maximum hardness which treated by laser is higher than air cooling. However, the penetration is smaller.

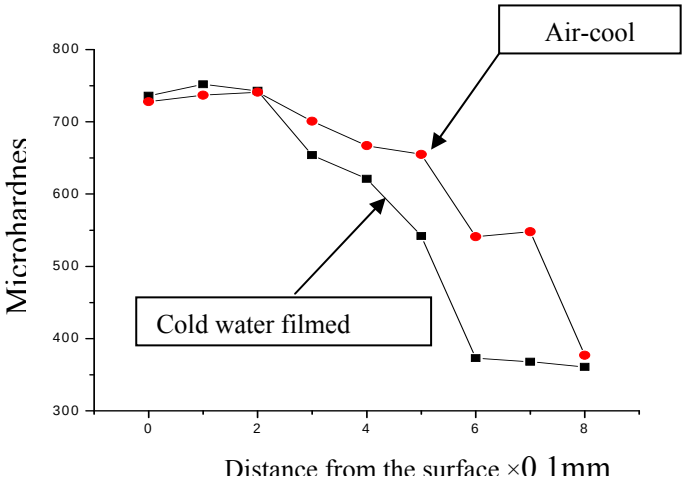


Fig. 7: Microhardness curve

3.3 Friction and Wear Properties

3.3.1 Wear mass loss

We divided the wear resistance into 3 groups: one is untreated, the other two groups were air-cooled laser processing unit sample and the bionic coupling sample which was treated by cold water film covered laser.

Each of the three samples has a choice of wear test. Figure 8 is the average quality of different samples. It can be seen in the same slide situation, bionic coupling laser treatment samples compared with the untreated samples decreased the amount of wear as much as 44.8%, the cold laser treatment of water film covered's wear volume is smaller .

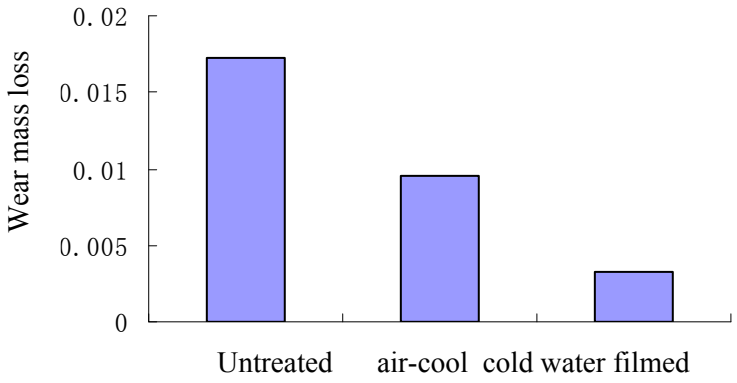
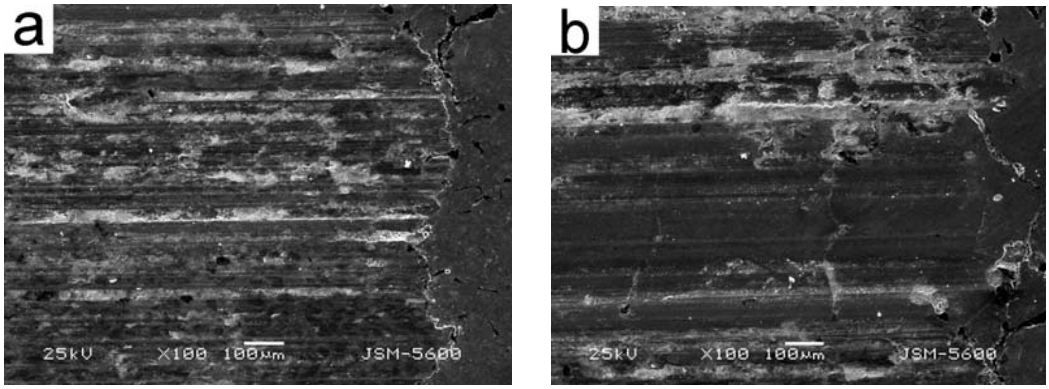


Fig. 8: Sample mass loss

3.3.2 Wear mode

Figure 9 (a) is the scanning electron microscope photographs with gray cast iron laser remelting in the air weared with 45 steel. The figure shows, the wear morphology treated in the air shows clear glue and abrasion characteristics, is adhesion wear and abrasive wear of the cutting, the surface produce a strong plastic deformation and material transfer, there is solid phase welding, cutting severely and a large number of deep groove scratches appeared in the wear surface. From Figure (b) we can see, cover cold water film covered only shows the abrasive wear which is caused by the role of micro-cutting, furrow shows thin shape, plastic deformation and material transfer is not obvious. Water film thickness increased, the number, width and depth of furrows are reduced. This is mainly because of the organization in the water compare with the organization in the air, unit body structure refinement, which has a higher hardness and strength can reduce the shedding of debris, can prevent the surface of the plastic deformation effectively, also can prevent abrasive and grinding embedded oxide, avoid shear failure to extend the width and depth directions. In addition, these high hardware modules in the friction process body can withstand higher friction stress, eased wear between the units, so it reduced the friction coefficient and wear rate, make the sample's wear resistance improved greatly.



(a) Air Cool **(b) review of cold water film**

Fig. 9: Laser remelting cast iron water film wear morphology of biomimetic samples

4. CONCLUSION

1st. Bionic coupling unit includes melted zone and heat affected zone. Melting zone formed by Fe3C，M and Ar, and the heat affected zone formed by graphite, M and Ar composition;

2nd. Matrix's average hardness is 350HV, the bionic unit is much higher. The unit which dealt with air-cooled laser melting technology's maximum hardness can reach 740HV, and the unit which dealt with cold water film covered's maximum hardness can reach 750HV.

3rd. Bionic coupling unit wear is much higher than that of untreated samples, cold water film covered the smaple's wear resistance is much higher.

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