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CAUSE ANALYSIS OF CRACKS IN DIESEL ENGINE CRANKSHAFT BLANK

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Preliminary Note – Prethodno priopćenje

Through comprehensive analysis, crack propagated along the nitride in the form of planar clusters, which caused the metal to layer on the parting surface. There are deep decarburization layer on both sides of the crack of crankshaft blank, and the crack line is soft and thick. The process of quenching and cooling, only when the transformation amount of martensite reaches a certain amount, can cracks be formed. At such a low temperature, even if cracks occur, decarburization and obvious oxidation won't occur on both sides of the cracks. If there is oxidation decarburization on both sides of the crack, it can be confirmed that the crack has existed before quenching, and the crack belongs to non quenching crack.

Keywords: crankshaft, analysis, defect, heat treatment, stress

INTRODUCTION

The crankshaft is an important part of the engine and the key part of the engine power transmission. It can be said that the quality of the crankshaft determines the service life of the engine.

Therefore, through the macro analysis, microstructure analysis, comprehensive analysis and fracture scanning metallographic analysis of the fracture crankshaft blank, fracture causes of the crankshaft blank are studied.

Crack location of scrapped crankshaft: connecting rod journal, Figure 1.

MACRO ANALYSIS

After sampling the fractured crankshaft journal on the saw machine, it was found that the crack originated from the position near the parting surface, and the inclusions at this position would be concentrated. The crack is relatively thick and appears to be one at first sight. However, after careful observation, the crack is not continuous, and multiple cracks expand at the same time, and finally converge and tear into one. One end of the crack extends to the transition position between the journal and the fillet, which is close to the hot spot of induction hardening. Due to the skin effect, overheating is easy to occur near the hot spot. See Figure 2.

MICRO METALLOGRAPHIC ANALYSIS

The microstructure of the fractured crankshaft was analyzed, and it was found that the matrix structure was lamellar pearlite + reticular ferrite, without other abnormal structure and overheating phenomenon. The microstructure is obviously normalized with grain size of 6-8. Near the crack, there is obvious oxidation decarburization phenomenon around the crack, as shown in Figure 3.

A large number of nitride inclusions were observed near the crack, Harm of nitrides: nitride inclusions are characterized by high hardness, not easy to deform and

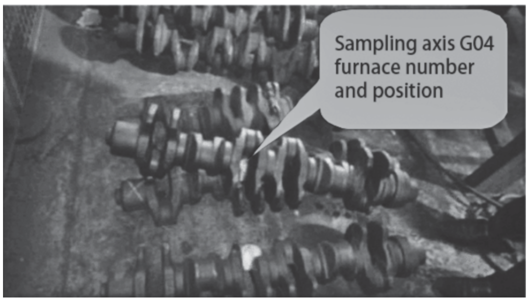

Figure 1 Crack location of scrapped crankshaft blank

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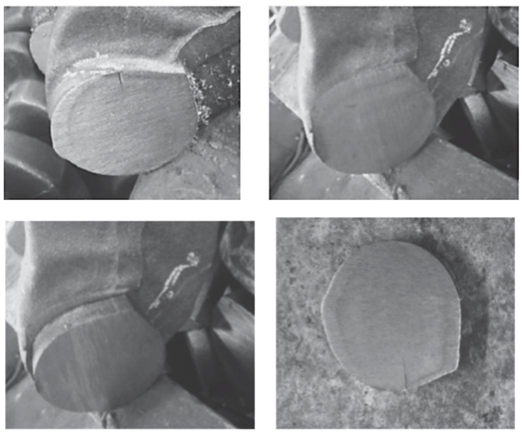

Figure 2 Group diagram

distributed in groups. With the increase of nitrides, the brittleness of steel will increase obviously, and the geometric nitrides will form the crack source of brittle transgranular fracture of steel. The most obvious physical characteristics of nitrides: when the heating temperature is lower than 1 200 °C, the morphology of nitrides does not change.

COMPREHENSIVE ANALYSIS

Thermal stress and tissue stress

During quenching, the surface structure of the journal changes as follows: pearlite + ferrite—austenite--martensite, austenite is face centered cubic, pearlite, ferrite and martensite are body centered cubic, that is, austenite volume is less than pearlite volume, ferrite volume is less than martensite volume, When the microstructure transforms from austenite to martensite, the volume can expand by up to 4%. Therefore, in the quenching process, the change of the surface structure volume of the journal is: the volume decreases when heating and expands when cooling. As the temperature is lower than 1,200 °C, the morphology of nitrides does not change. In the process of matrix structure change, nitride inclusions are quite different from metal in elasticity and plasticity, and can not deform with the change of matrix structure. More and more stress will be generated around it, which will break itself, or break away from the interface of matrix and produce microcracks. With the development of microstructure, microcracks occur and develop into voids and voids. The continuous expansion makes the adjacent voids connected with each other and leads to fracture.

Stress concentration

At the joint of crank and journal, when heated, the same heating temperature is more likely to produce heat concentration than other positions of journal, thus overheating. As cooled, the cooling speed is faster due to the effect of coolant, and it is easier to produce retained austenite, which can continue martensitic transformation during tempering, resulting in a lot of stress. When the stress exceeds the material limit, it is easy to crack.

During the whole deformation process of forging, the defects and inclusions in the center of the raw material converge towards the parting surface and flash and are densely distributed at the cutting edge. For forging deformable non-metallic inclusions, such as sulfides and most silicates, they exist in sheet form along the metal extension direction on the parting surface; As for the non-metallic inclusions, such as nitrides, which can not be deformed in forging, they exist in the form of face like clusters along the direction of metal extension on the parting surface, resulting in metal delamination at the parting surface. Therefore, the high stress during quenching is easy to cause through cracks on the parting surface. At the same time, defects and inclusions converge on the parting surface, which also reduces the phase transition temperature and makes it easier to overheat. According to the previous analysis of the microstructure near the crack, it is found that a large number of nitride inclusions are caused by this reason. Of course, the high nitride content of materials is the main reason.

Effect of overheated microstructure

The harm of overheated structure mainly includes: the strength of the material is reduced, and it is easy to crack under the action of tensile stress during quenching and cooling.

ANALYSIS OF RESULTS AND CONCLUSION

Characteristics of quenching cracks: during quenching, when the huge stress generated by quenching is greater than the strength of the material itself and exceeds the plastic deformation limit, cracks will occur. The quenching cracks observed under the microscope may be intergranular or transgranular, some are radial, others are single line or network. Quenching cracks caused by rapid cooling in martensite transformation zone are usually transgranular distribution, and the cracks are straight and there are no branching small cracks around. Characteristics of non quenched cracks: during quenching and cooling, only when the martensite transformation reaches a certain amount, can cracks be formed. At such a low temperature, even if cracks occur, decarburization and obvious oxidation will not occur on both sides of the cracks. Therefore, if there is oxidation decarburization on both sides of the crack, it can be confirmed that the crack has existed before quenching, and the crack belongs to non quenching crack. If the cracks exist before quenching and are not connected with the surface, such internal cracks will not produce oxidation and decarburization, but the lines of the cracks are soft and the end is round and bald, which is easy to be distinguished from the strong and sharp features of quenching cracks. The content of nitride in raw materials is too high, and the nitride inclusions exist in the form of planar clusters along the metal extension direction on the parting surface during forging. The crack propagates along the nitride in the form of planar clusters, resulting in metal delamination at the parting surface.

There are cavities around the grain boundary, which is caused by the melting of the grain boundary, i.e. over burning. Before forging, the steel may be heated at high temperature for a long time, or due to the deformation thermal effect, the steel may overheat and burn, resulting in coarse grains and grain boundary oxidation. The oxides, second phase particles and widmanstatten structure on the grain boundary lead to brittle materials, and intergranular and transgranular cracking occur easily when the crankshaft is stressed.

The high content of inclusions at the fracture edge is due to incomplete deoxidization and slag removal dur-

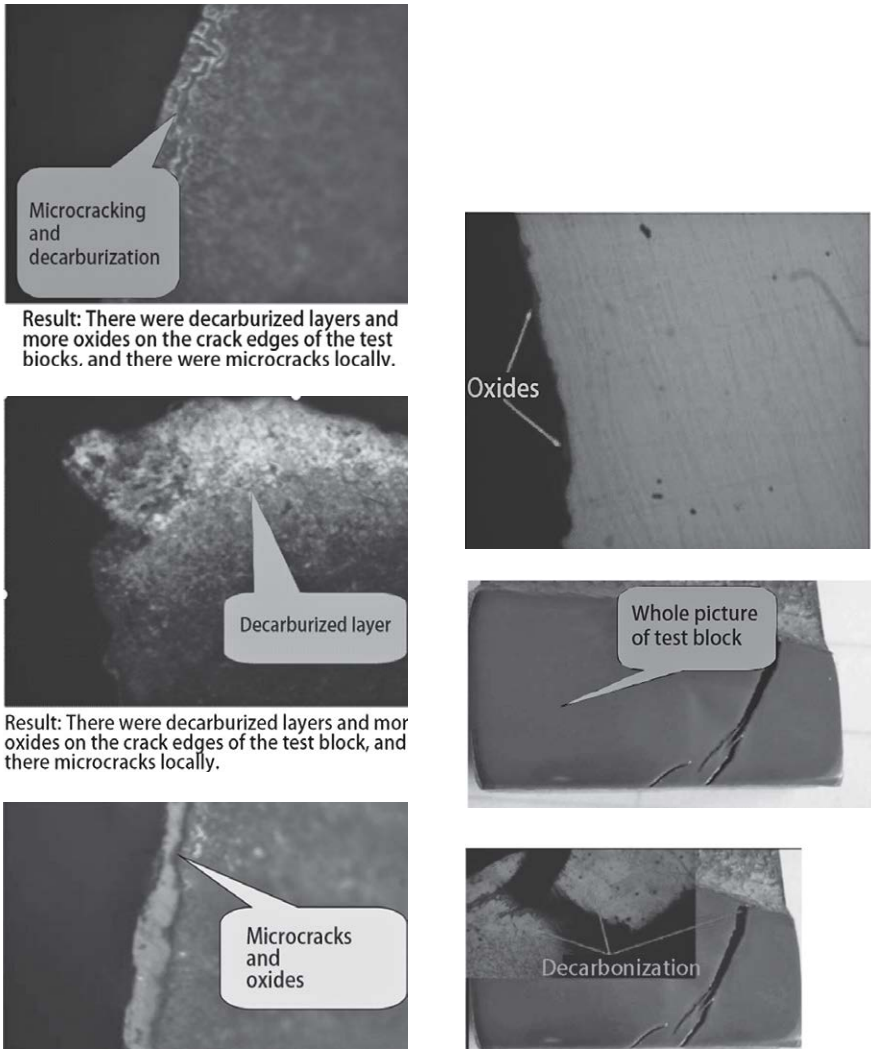

Figure 3 Group diagram

ing steelmaking, and there are many inclusions in the steel, such as silicate, calcium carbonate and spherical oxide. These inclusions gather on the grain boundary, weaken the grain boundary, and cause intergranular cracking of crankshaft under stress. There are deep decarburized layer on both sides of the crack, and the crack line is soft and thick, which conforms to the characteristics of non quenching crack. The fracture is caused by the overheating or burning after the heating temperature is too high before forging.

The heating temperature of billet before forging should be strictly controlled, and the holding time under high temperature should be shortened as far as possible to prevent the steel from overheating and burning.

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Note: The responsible translator for English language is Guojun Liu, Anshan, China