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STUDY ON THE BREAKDOWN OF MILLING BALLS MADE OF 13%Cr WHITE CAST-IRON WORKING IN STRONG ABRASIVE AND CLASH CONDITIONS

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ABSTRACT

The breakdown due to abrasion and clash of the milling balls made of 13% Cr white cast iron is a complicated process which depends on many factors, especially on the strength of the matrix and carbide phases. As shown, stresses created by abrasion and clash processes are concentrated mainly at the locations such as carbide/matrix boundary and around coarse carbide particles, leading to the cracks and breakdown there. The peeling off carbide particles can be a reason of scratches on the specimen surface. Heat treatment (quenching in oil and tempering at 2500 C for three hours) to transform a soft matrix (austenite) to a harder one (martensite) can be a good solution against abrasion. Concerning the impact, the solution should be the refinement of the carbide particles and their uniform distribution.

KEYWORDS

chromium white cast iron, milling balls, M_7C_3 carbides.

1. INTRODUCTION

The grinding balls made of chromium white cast iron is used in many industries such as cement manufacturing, mining, metallurgy ... The grinding balls are filled in about 40% volume of the grinding equipment. When the ball mill works, balls impact with material and grinds it into the fine powders. There are some processes within the grinding equipment: impact between the balls their self, impact between balls and the wall of the mill, impact between balls and the material, friction between balls, ball-wall friction pressure.

The failures that occurred in balls are flaking, spalling and loss weight. That ball failures depend on many factors such as alloy composition, heat treatment, microstructure, hardness on types of the balls, especially on the residual stress that forms and propagates during grinding operation [1-3]. For over 50 years, high chromium white cast irons alloys have been recognized for their high resistance to abrasive wear. However, the brittleness of white irons limits their applications at high impact. As known, the carbide types often presented in the high chromium cast irons are M_7C_3, M_3C, $M_{23}C_6$, and M_6C; with chromium composition above 12%, the carbide appeared mainly in the form of M_7C_3, which has a high hardness (1600 HV). Those carbides are present at the surface of samples will reduce the intensity of plastic deformation, thus the stress distribution must be changed.

Under conditions of heavy load, the materials impact and slips on each other, create on the surface stresses, causing plastic deformation and elastic deformation. It is then that the process of wear, peeling off the carbide particles, peeling off the matrix or both. Weakness or loss of mass during the sliding process is assessed by the break and separation of the carbide particles. This result has been proven in many studies. The chromium white cast iron has chromium content over 10%, mainly composed of austenite and M_7C_3 carbide. The hypoeutectic cast iron is the austenite crystal and the crystal M_7C_3. With hypereutectic cast iron, the component is the M_7C_3 primary carbide and the eutectic. During the crystallization process, the crystalline carbides appear at the end of crystallization [4-6].

Jimeno-Abendano described the mechanism of abrasive processes related to repetitive deformation [7]. The material has elastic deformation and plastic deformation, resulting in scratches on the surface and forming grooves. In the background, the carbides change the stress distribution, increase resistance to plastic deformation and elastic deformation, so the carbide reduces the density of the groove. However, carbides have a low compressive strength, cannot resist deformation, causing compressive stress and shear stress of the substrate [8]. In fact, the carbide is easily worn out as rough carbides on the ground. Hanlon and colleagues have suggested that when reducing the size of the carbide particles, it will reduce the depth of deformation and reduce the destruction of carbide and result in improved wear resistance [9].

The relationship between the carbide's structure and the wear resistance has been mentioned in the research [10,11]. Especially in the work by Bedolla Jacuide, Rainforth stated that in the course of sliding, abrasion occurs due to breakage and separation of carbide particles [10]. Thereby a nearly linear relationship was found between the depth of deformation, the destruction of carbide and the speed of wear; Also saw that deformation depth is suitable where exposed carbide particles are exposed [12]. The matrix structure has affected a special on the wear processes of chrome cast iron. The correlation between the amount of wear and hardness of the matrix after abrasion was determined and indicated. that in high-cast white chrome austenite turns hard to form martensite which plays a major role. Reduces wear speed.

Besides the effect of the carbide phase, it's worth to mention the effect of the matrix, which is responsible for keeping the carbide particles from peeling off. This work investigates the defects appeared in milling balls made of 13% chromium white cast iron working in high abrasion and impact conditions and proposes the solutions increase abrasion and impact strength for chromium white cast iron [13].

2. EXPERIMENTAL PROCEDURE

Chromium white cast iron alloy is manufactured at Thang Loi Casting Company, Nam Dinh. - The alloy, whose composition is given in Table 1, is melted in a medium-frequency induction furnace at 1550 ° C (± 50 ° C). The grinding balls were heated at 1050°C (±30°C) for three hours and then cooled in the oil, followed by tempering at 250°C for three hours [14]. The microstructure of the grinding balls before and after collisions was observed on the optical microscope (x1000) and scanning electron microscope (x 1500, secondary electron microscope images). The method of deep-etched corrosion and color etching techniques had been used.

Table 1: Chemical composition of the experimental 13% chromium white cast iron

Sample	Fe (%)	C (%)	Mn (%)	Cr (%)	Ti (%)	RE (%)
1	81.8	2.89	0.85	13.1	0.23	0.2
2	80.3	2.76	0.88	13.3	0.5	0.5

3. RESULTS AND DISCUSION

3.1 Microstructure of grinding balls made of 13% chromium white cast iron

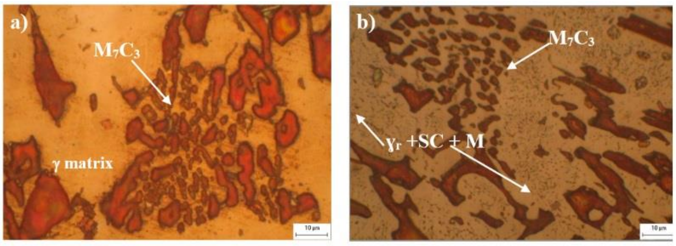

Figure 1: Optical microscope images of the as-cast (a) and after heat treatment (b) specimens

Figure 1 shows the optical microscope images of the casting (a) and heat treatment sample corresponding (b). The experimental 13% chromium white cast iron is hypo-eutectic iron. The as-cast microstructure of the specimen mainly consists of primary M_7C_3 carbides and eutectic carbides in a matrix of austenite (figure 1a) and there is also an amount of martensite, secondary carbides around carbides in a matrix of austenite (Figure 1b), in the alloy.

3.2 The fracture behavior of grinding balls

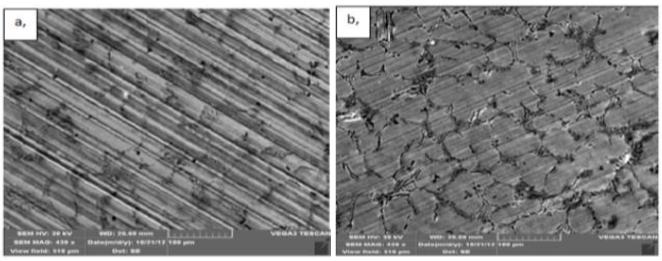

Figure 2: Micrographs of scratch grooves of samples surface: a) the casting; b) heat-treatment sample

Figure 2 shows the picture of scratch grooves in the specimen's surface; as seen, the scratch grooves in the as-cast specimen is deeper than that in the after heat-treatment one. When two abrasive surfaces slide each against others, they will produce surface friction and contact stress. Under heavy loading conditions, the specimen surface will be scratched, blistered, deformed [15]. The matrix of the as-cast specimen is mainly austenite, which is relatively soft, so under the condition of frequent impact and abrasion it must be subjected to high-intensity plastic deformation, thus can be easily distorted or deformed. As results, the matrix can keep the loading conditions the specimen surface will be scratched, blistered, deformed. The matrix of the as-cast specimen is mainly austenite, which is relatively soft, so under the condition of frequent impact and abrasion it must be subjected to high-intensity plastic deformation, thus can be easily distorted or deformed. As results, the matrix can keep the carbides particles from peeling off and can be scratched by themselves. On the other hand, the stress concentration at the boundary between a hard particle on a soft substrate can lead to crack formation [4].

Being quenched in the oil, the most fractions of austenite can transform into martensite, (M - black phase in fig.1b), and secondary carbides (SC). Although there exists some retained austenite (A_r) this matrix is much harder. As a results, the fracture and deforming processes of grinding balls occur at a slower rate (the shallow scratches in Figure 2.b).

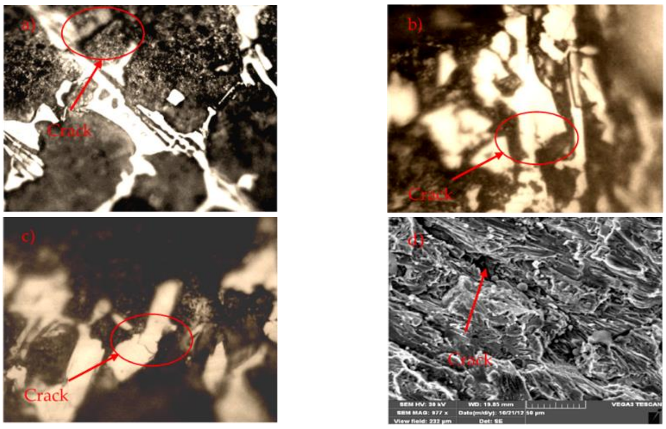

Figure 3: Fracture morphologies of impact specimens

Figure 3 shows fracture surfaces of the specimen after the impact test. The cracks can appear along the boundary between the carbide particles/matrix (figure 3a). In fact, under the same working load if two phases (in this case carbide and matrix) have different mechanical properties ~~so~~ they will be deformed differently [16]. The large difference in hardness between the hard phase (carbide particles) and soft phase (matrix) leads to the difference in their deformation under high impact load. The serious stress can concentrate on the boundary between these two phases resulting in the initiation and fast propagation of a crack along it. [5].

Note that cracks do not only initiate and propagate along the phase boundary but can also appear in coarse carbides (figures. 3b and 3c). The reason can be found in the fact that under the condition of frequent impact, stresses can easily concentrate around coarse carbides, and if the impact repeats many times, cracks can appear and growth at that location. As *carbides particles is not the main part absorbing the impact, so the matrix area with high density of carbide cracks, will be subjected to higher load and loses its stability. In the next impacts, the specimen will be cracked and broken.*

4. CONCLUSIONS

Study on the grinding balls, made of 13% chromium white cast iron and working in high abrasion and impact conditions shows that when the high *impact*-abrasive load is repeated many times, the stresses will be concentrated either at the carbide/matrix boundary, either around big carbide particles, leading to cracks and breakdown at these locations. The peeling off carbide particles can be a reason of scratches on the specimen surface. But if carbide particles are fine and distributed uniformly, the stresses appeared under abrasion and impact load must be smaller and distributed uniformly too, so the formation of cracks become more difficult, leading to longer life of the product.

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