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Research Article

Abrasive Wear in Some High Fe-Cr-C Alloy in Cement Powder

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Abstract

The wear behavior in solid metallic materials is of high importance because of its connection with production cost. In this work, the behavior of wear and wear rate is shown in grinding balls produced from high Fe-Cr-C alloys produced by melting in medium frequency induction furnaces, and molding by automatic fleckless molding machine– Disamatic moldings machine. The total testing time is (12 hrs). The abrasive wear rate, which is the wear resistance multiplied by testing time in mg/Kg.hr. Two grinding balls of each of the three alloys: BC26, BC18, and BC13 are tested by rotating the balls with (50 Kg), cement powder inside a diesel working mixer of circular sections, inclined 45 and rotating by 30 rpm. Weighting and hardness testing results are found in the text, the chemical composition was tested by using spectra analyses type ARL 34000 OE. All the results obtained are shown in the tables and figures in the text. As a result, it can be stated that increasing Cr%, increases hardness, and decreases the wear rate, and the harder and higher the Cr% and C% it contains, the lower the wear rate and the higher wear resistance.

Introduction

Wear is the damaging gradual removal or deformation of material at solid surfaces [1]. Abrasive wear is also defined as the loss of material due to hard particles that are forced against and move along a solid surface [2]. Abrasive wear of metals occurs by plastic displacement of surface and the near-surface of material, martensitic steel with expected carbides in which the hardness of high C steels are high abrasion resistance [3,4]. Abrasive wear also occurs when a hard rough surface slides across a softer surface [5,6]. Abrasive wear plays a significant role in ore grinding in the absence of sulphites [7]. Wear is the progressive loss of material resulting from the mechanical interaction of the two sliding surfaces under load [8]. Annually a large amount of expenses is spent on industrial metal parts due to wear. The importance of wear research comes from that about 23% of the world's energy consumption originates from tribological contacts of which 20% is from overcoming friction, and 3% is from remanufacturing worn parts and spare equipment due to wear [9,10]. Worldwide, about 100 million Tera joules is used annually to overcome friction, and that is 20% of energy produced [11]. The largest quantities of energy are used by industry, 29% and in transportation 27% [12]. The wear process can be classified into different types according to tribological load and the materials involved i.e. abrasive, sliding, fritting wear, and material cavitations.

Wear is caused by a number of mechanisms such as abrasive, adhesive, surface fatigue, and trip logical reaction. In abrasive micro cuttings, repeated plugging and fracture of the base body caused by the counter body asperities or by hard particles in the interfacial medium lead to wear [13].

The main requirement of Portland cement is to have low iron content as Fe_2O_3 for white cement. Portland cement is one of the lowest-cost materials widely used over the last century [14]. Portland cement is obtained by heating the limestone, clay, and silica with some impurities at high temperatures in a rotating kiln, producing the clinker [15]. Cement powder can be produced by milling the clinkers to the desired finesse using grinding balls [16,17]. Portland cement is extensively used in the construction of nuclear waste facilities. The hardness of materials is one of the most important mechanical properties in wear [18].

Hard material indicates high wear resistance, wear ranking, martensitic steels –Fe-Cr-C shoes high abrasive resistance such as silicate-aluminates-compound [19, 20]. High Iron – Chromium-Carbon grinding balls are used in milling clinker by rotating on the axis of the mill [21]. Chromium is extremely hard and it is the third hardest element behind Carbon and Boron [22]. Chromium mostly chromites, produces Fe-Cr alloys with very high strength and forming hard solid solutions- carbides. The type of carbide form depends on the amount of carbon %, the higher the carbon content, the harder will be. High Cr–Fe, typically about 16%Cr results in high wear combined with high oxidation resistance [23,24]. The hardness of the material is one of the most important mechanical properties in wear and has been widely used as the criterion to determine abrasive wear resistance [25,26]. A metal with higher hardness has more wear resistance combined with higher mechanical strength [27]. The more wear resistant a material is the less quickly it loses material from its surface [28]. In other words, wear resistance refers to a material's ability to resist material loss by the same mechanical action. The wear of material has been characterized by weight loss and wear rate [29,30]. Abrasive wear testing conducted by many researchers mostly in wet conditions is according to ASTM [31-33] in 2016, 2020, and 2021 respectively. Grinding balls are used by the cement industry to transform the rock into fine cement. Abrasive wear is the result of friction between solid surfaces [34].

In the present work, a friction test of dry cement powder with high alloy Fe-Cr-C grinding balls of three grades of the given alloys is used through different periods of time running in a movable mixer. The weight in each period is checked and the wear rate is calculated by dividing the weight loss of each ball by its initial one.

Material and methods

The instruments used for the spectra–chemical testing were the spectra analyzer type ARL-34000-OE, and the mixer, for checking. The chemical compositions are shown in Table 1. For weighing initial and individual weights an accurate weighing device was used. The results are presented in Tables 1-3.

The experiment starts by introducing the weighted grinding balls with 50 Kg of dry powder Portland cement in the mixer. The mixer then starts rotating with a speed of 30 rpm. The rotating mixer is inclined by 45° in order to keep grinding balls rotating with cement freely. After every three hours, the mixer was stopped and cleaned and all grinding balls were weighed. The same procedure was repeated every three hours through 12 hrs of the test. All results are presented in Table 2. Differences in weight in each grinding ball during 12 hrs of the test are shown in Table 3. The mixer with grinding balls and cement powder is shown in Figure 1. The relation between the weights in all periods of the test is clear as shown in Figure 2. The relation between Chromium contents and wear rates for the tested balls, as well as the hardness in HV units are presented in Figure 3.

Table 1: Chemical Composition of tested balls –spectro –analysis-Wt.%

Alloy	C	Si	Mn	Cr	Mo	P	S	Ni
BC 26	2.50	0.62	0.40	26.20	0.10	0.02	0.02	0.067
BC 18	2.25	0.70	0.37	16.20	0.40	0.03	0.02	0.20
BC 13	1.80	0.80	0.50	9.25	0.02	0.01	0.01	0.10

Table 3: Hardness in HV units tested balls at starting and after 12 hrs.

Alloy	Initial Hardness HV	Hardness HV after 12 hrs. testing	Difference HV	Deferent %
BC 26	690	730	+40	5.8
BC 18	620	650	+30	4.8
BC 13	555	575	+20	3.6

Results and discussion

The achieved results from testing the six grinding balls, whose chemical composition is revealed in Table 1. Each tow ball is from one alloy. The three alloys are BC26, BC18, and BC13. All of them contain high Cr% at different levels. The results reveal that the highest Cr% is in BC26 alloy and the lowest in BC13. All the tested balls are hard enough, they seem that they are quenching and tempering. Generally, their microstructures consist of eutectic Cr–carbide with secondary carbides and martensite with the rest of the impurities and retained austenite. The hardness of the balls increases as retained austenite decreases, and as Chromium and Carbon content increases, Cr has three main carbides, to form carbides, to increase corrosion and wear resistance, and to achieve the stable structure of the alloy at high temperatures. Abrasive wear of high Cr cast iron is lower than that of had field steel due to the presence of M7C3 carbides [35]. According to the above data, the wear rate or wear resistance is affected by the surface tested, Cr% and C% contents, and the hardness of tested grinding balls.

The material loss from the three tested alloys during testing times is shown in Figure 2 and in Table 2. From that, it

Table 2: Results obtained from wear tests of high Cr-C-Iron alloys.

No.	Iron alloys	Starting Weight(g)	Weight at Testing Time (g)				Av. Lost Wt (mg)	Wear resist (mg/kg)
			3 hrs.	6 hrs.	9 hrs.	12 hrs.		
1	BC 26	534.256	533.860	533.750	533.690	533.760	1.00	2.00
2		495.102	494.840	493.720	493.610	493.550		
3	BC 18	898.715	898.325	897.100	896.700	896.300	0.907	2.50
4		915.636	915.120	914.625	914.921	913.386		
5	BC 13	262.851	262.355	251.755	261.212	261.821	0.932	4.00
6		257.742	257.416	257.242	256.921	256.819		

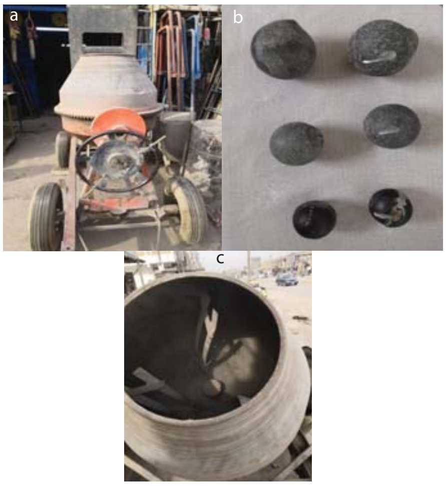

Figure 1: Testing of grinding balls with the mixer petrol driving unit. a) Mixer used in the experiment. b) Tested Grinding balls. c) Grinding mixer in working position

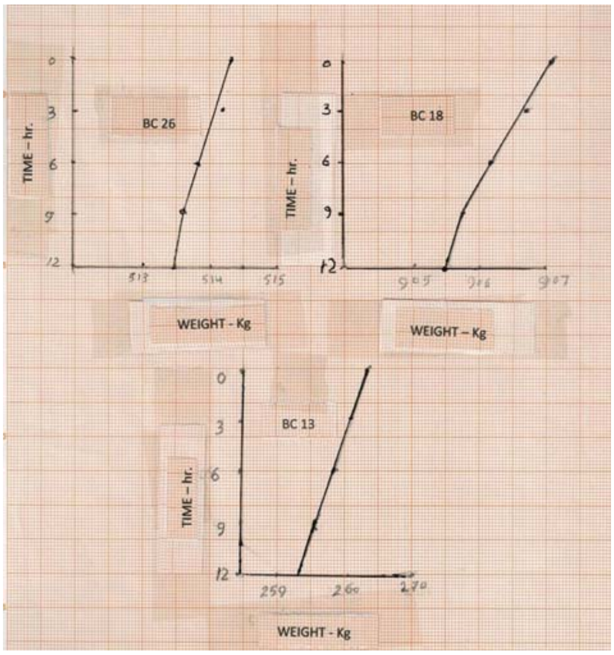

Figure 2: Abrasive Wear behavior relative to time – BC26, BC18, and BC13 Alloy.

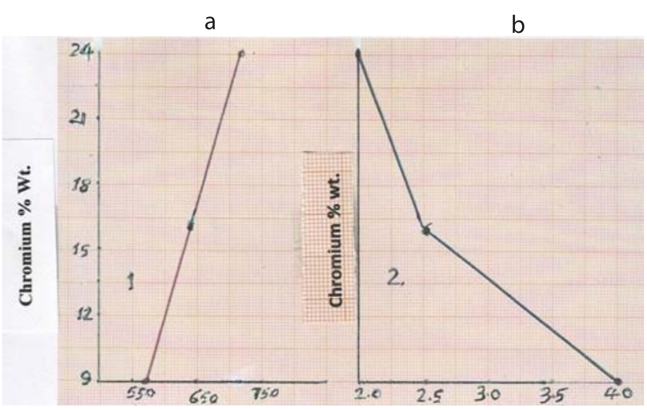

Figure 3: a) Relation between Cr% and Hardness – HV. b) Relation between Cr% and Wear rate (mg/kg). b shows that the wear rate in alloy BC26 is lower when Cr is in a higher range of 16% to 24%.

is clear that the loss in materials or the - wear - increased by the testing time, but in different amounts depending on the nature of the alloy i.e. less wear rate in BC26 (2.00 mg/Kg) and the most material loss in BC13 alloy (4.00 mg/Kg) due to the facts referred to in above. The relationship between Cr% and both wear rate and hardness is shown in Figure 3. It reveals that hardness in HV is directly proportional to the Cr% while the wear rate has two different stages of increasing. The first up to 16% the increments are slower than that of the higher (16-24)% of Cr. This can be explained because in the lower ranges of Cr, there may still be some amount of retained austenite in the structure, and by decomposition of retained austenite with increasing Cr%, faster precipitation of secondary Cr-carbides and martensite results from austenite decomposition, and both of them are harder than the first range, so faster decrement in wear rate is taking place.

By evaluating the results, the behavior of abrasive wear could be revealed. Finally, in Table 3 some small increases in hardness (40-20) HV can be observed, this may be due to plastic deformation accumulated on the ball surfaces. That hardness difference is more (40Hv) in BC26, (30Hv) in BC18 and the lowest in (20Hv) in BC13. After hardening and tempering the structure consists of Cr carbides martensite and traces of retained austenite; to ensure this fact, longer testing time is needed.

Conclusion

According to the results obtained from the tests and analyses, the following conclusions can be stated; The high hardness of Fe-Cr- C- alloys in cement milling grinding balls, results in low abrasive wear and high wear resistance. The microstructure consists of Cr carbides, Martensite, and traces of retained Austenite. The higher the Cr contents the lower the abrasive wear rate. To achieve a stable structure at high temperatures, it is used in the production of parts used where aggressive wear conditions. The higher C increases the formation of Cr Carbides.

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