WEAR TESTING OF ALUMINUM AA1060 ACCORDING TO ASTM G65 STANDARD

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Abstract

Actually, the study of the tribological behavior of materials of machine elements is necessary because the industry has increased the interest in making tribological systems more efficient. Wear is found in most of the production processes and can occur through various mechanisms, such as adhesion, abrasion, erosion, fatigue and impact. One of the main mechanisms is abrasive wear, which occurs frequently and appears when high hardness particles make contact with the ductile surface of machine elements, resulting in deformation and subsequent cutting and lifting the surface material. In this work, the wear testing is carried out according to the ASTM G65 standard to determine the wear coefficient (K) of four aluminum AA1060 specimens. In addition, wear measurements are made when the rubber wheel performs 2000, 4000 and 6000 revolutions to calculate the wear rate (Q) of the material.

Keywords: Wear Coefficient; Wear Rate; Aluminum AA1060; Abrasive Wear; ASTM G65;

1 Introduction

All the engineering projects that are developed today depend on the knowledge of the properties of the materials, because for an adequate design it is necessary to predict the behavior of the parts when they are subjected to certain working regimes. One of the main properties to take into account is the wear resistance of the materials because a large number of parts fail due to the weakening by wear to which they are subjected.

The study of the tribological behavior of materials of machine elements is necessary because the industry has increased the interest in making tribological systems more efficient [1]. Wear is a very common phenomenon that appears in the parts that are frequently subjected to relative contact. Although there are several mechanisms that produce wear, such as: adhesion, abrasion, erosion, fatigue and impact [2]; one of the most frequent is abrasive wear, which occurs when high hardness particles make contact with the ductile surface of machine elements, resulting in deformation and subsequent cutting and lifting the surface material.

One of the most widely used tests to evaluate the abrasive wear resistance of a material is the Standard Test Method for Measuring Abrasion Using the Dry Sand/Rubber Wheel Apparatus standardized by ASTM G 65 [3].

In this work, it is necessary to know the abrasive wear resistance of Aluminum AA1060 specimens, whereby the abrasion test of four aluminum specimens is carried out on a dry sand/rubber wheel machine (fig. 1) to determine the wear coefficient K and the wear rate Q.

Figure 1: Machine for Dry Sand/Rubber Wheel Test [4]

2 Wear Testing

According to ASTM G65 standard [3], the dry sand/rubber wheel abrasion test involves the abrading of a standard test specimen with a grit of controlled size and composition. The abrasive is introduced between the test specimen and a rotating wheel with a chlorobutyl rubber tire or rim of a specified hardness. This test specimen is pressed against the rotating wheel at a specified force by means of a lever arm while a controlled flow of grit abrades the test surface. This test method covers five recommended procedures which are appropriated for specific degrees of wear resistance or thicknesses of the test material. The test duration and force applied by the level arm is varied according to selected procedure. Specimens are weighed before and after the test and the loss in mass recorded. It is necessary to convert the mass loss to volume loss due to the wide differences in the density of materials. Abrasion is reported as volume loss per specified procedure.

2.1 Material Properties

The chemical composition of the specimen material was ignored but it was carried out five shots (fig. 2) to a sample with a Belec Spektrometrie Opto-Elektronik throwing the results showing in table 1.

Figure 2: Specimen Shots

According to the chemical composition the specimens are made of aluminum AA1060 [5] (density = 2.705 g/cm^3), because their alloy composition is among the following ranges [6]:

Aluminum (Al):	99.6 to 100%
Iron (Fe):	0 to 0.35%
Silicon (Si):	0 to 0.25%
Cooper (Cu):	0 to 0.05%
Vanadium (V):	0 to 0.05%
Zinc (Zn):	0 to 0.05%
Magnesium (Mg):	0 to 0.03%
Manganese (Mn):	0 to 0.03%
Titanium (Ti):	0 to 0.03%

The Vickers Hardness (HV) of a material sample was measured on a Shimadzu microdurometer by applying 100 g of charge for 15 s. The results of the five measurements and their equivalents are shown in the table 2.

Number	HV	HB	N/mm^2
1	37.20	35.34	364.8
2	31.52	29.94	309.1
3	32.97	31.32	323.3
4	36.69	34.86	359.8
5	36.79	34.95	360.8
Average	35.03	33.28	343.5

Table 2: Material Hardness

2.2 Procedure

Before performing the tests, the machine parameters were checked according to the standard. The wheel speed of 208 rpm was measured with a SHIMPO DT-205L Laser Digital Tachometer.

For the test was used silica sand which was properly sieved to achieve the required grain size. The sand flow was verified by weighing in a "Sartorius" digital scale the amount of sand that came out of the nozzle in one minute. The sand flow was 330 g/min.

The normal force applied in specimens of 45 N, according to the D procedure [3], was measured with a Kraftmessgerate Halle Dynamometer.

No.	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Sn	Ti	Pb	V	Co	Al
1	0.088	0.278	<0.001	<0.001	0.008	<0.001	<0.001	<0.001	<0.001	0.027	<0.001	0.005	<0.001	99.59
2	0.077	0.253	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	0.027	<0.001	0.005	<0.001	99.63
3	0.086	0.261	<0.001	<0.001	0.006	<0.001	<0.001	0.002	<0.001	0.027	<0.001	0.005	<0.001	99.60
4	0.081	0.252	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	0.025	<0.001	0.004	<0.001	99.63
5	0.079	0.285	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	0.028	<0.001	0.005	<0.001	99.59
	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Sn	Ti	Pb	V	Co	Al
Ave.	0.082	0.266	<0.001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	0.027	<0.001	0.005	<0.001	99.61

Table 1: Chemical Composition of Specimen

It was decided to use procedure D, in which an abrasion distance of 4309 m would be obtained, achieved with 6000 revolutions of the rubber wheel with a diameter of 228.6 mm (9 in). The test was divided into three steps each of 2000 revolutions in order to know the behavior of the wear rate.

Wear testing was performed to four aluminum AA1060 specimens with the dimensions shown in table 3.

Measurements of Specimens Dimensions (mm)			
Number	Long	Width	Thickness
1	54.0	24.1	2.85
2	54.0	23.5	2.25
3	53.8	23.7	2.35
4	54.4	23.4	2.15

Table 3: Specimens Dimensions

The four specimens were previously prepared (0.8 μm Ra) and cleaned with Toluene (non-polar solvent).

After the test was carried out, it was verified that the wear pattern produced on the specimens coincides with that specified according to the standard (fig 3). In this case the nonuniform pattern of specimen four indicates improper alignment of rubber rim to the test specimen. This condition may reduce the accuracy of the test. However, specimen four was not discarded because the results obtained in it are quite similar to the other specimens.

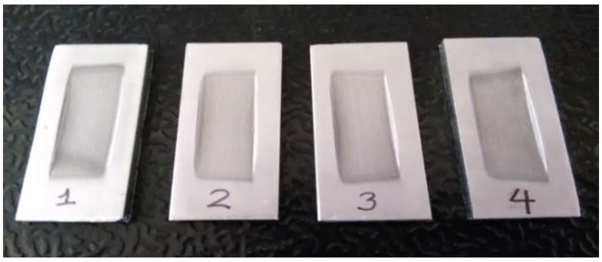

Figure 3: Wear Scar of the Specimens

During the test the specimens were weighed at the start and every 2000 revolutions of the steel wheel using a Sartorius digital scale having an accuracy of 0.0001 g, the results are shown in table 4.

Measurements of Weight (g) at n revolutions				
Number	Start	2000	4000	6000
1	16.8329	16.4989	16.2403	15.9701
2	16.4683	16.1422	15.8853	15.6742
3	16.6281	16.3125	16.0588	15.8062
4	16.1048	15.8030	15.5580	15.3171

Table 4: Measurements of Weight

The results of the measurements of the loss of weight for each specimen are shown in table 5.

Loss of Weight (g) at n revolutions			
Number	2000	4000	6000
1	0.3340	0.5926	0.8628
2	0.3261	0.5830	0.7941
3	0.3156	0.5693	0.8219
4	0.3018	0.5468	0.7877
Average	0.3193	0.5729	0.8166

Table 5: Loss of Weight

As established by ASTM G 65 [3], the final report of this test should be made on the basis of volume loss. For the determination of volume loss is used the equation 1. The results of this calculation are shown in table 6.

$$Volume\ loss, mm^3 = \frac{mass\ loss\ (g)}{density\ (g/cm^3)} \times 1000 \quad (1)$$

Wear rate (Q) was obtained by dividing the volume loss recorded at the end of each abrasion test between the total slip distance, the results are shown in table 6.

Volume Loss (mm^3) at n revolutions				Wear Rate (mm^3/m)
Number	2000	4000	6000	
1	123.48	219.08	318.96	7.4×10^{-2}
2	120.55	215.53	293.57	6.8×10^{-2}
3	116.67	210.46	303.84	7.1×10^{-2}
4	111.57	202.14	291.20	6.8×10^{-2}
Average	118.04	211.79	301.89	7.0×10^{-2}

Table 6: Volume Loss and Wear Rate

As can be seen in figure 4, the measurements of the volume lost recorded at 2000, 4000 and 6000 revolutions of the wheel present a linear behavior in the four specimens. This clearly indicates a wear rate uniform throughout the worn volume of the material of the specimens.

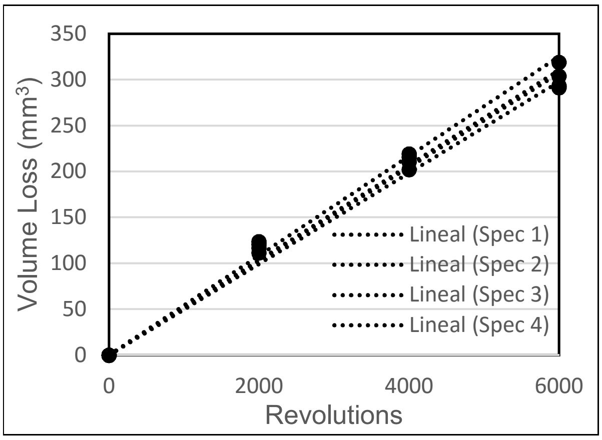

Figure 4: Volume Loss at n Revolutions of the Wheel

The wear phenomena are very complicated to model and it is difficult to follow analytical methods that resemble the actual conditions in practice, consequently the wear modeling is usually experimental in nature, for it is determined the coefficient of wear K based on the Archard's law (see equation 2) which is one of the most used models for abrasive wear [7].

$$K = \frac{V \quad H}{P \quad L} \tag{2}$$

where:
K = wear coefficient,
V = volume loss, mm^3,
H = hardness, N/mm^2,
P = normal force, N, and
L = lineal abrasion, mm.

Wear coefficient ($K = 5.35 \times 10^{-4}$) and wear rate ($Q = 7.0\text{x}10^{-2}\ \mathrm{mm}^3/\mathrm{m}$) approximately coincide with the 60/40 brass material which is reported in the literature [7-11].

3 Conclusions

In the case of the specimen four their nonuniform wear pattern indicates improper alignment of rubber rim to the test specimen. Although, this condition may reduce the accuracy of the test. However, specimen four was not discarded because the results obtained in it are quite similar to the other specimens. Even so it should be noted that the least volume loss was obtained on this specimen although similar values were obtained in the specimen two.

The material of the specimens is sufficiently uniform throughout its volume in terms of wear resistance, since the volume losses obtained for 2000, 4000 and 6000 revolutions of the wheel for each specimen respond to a linear behavior. This clearly indicates a wear rate uniform throughout the worn volume of the material of the specimens.

Wear coefficient ($K = 5.35 \times 10^{-4}$) and wear rate ($Q = 7.0\text{x}10^{-2}\ \mathrm{mm}^3/\mathrm{m}$) approximately coincides with those of other materials reported in the literature. This allows to have a great certainty in the precision of the results. This material does not have a high abrasive wear resistance, like 60/40 brass, which does not allow its use in operations where high abrasion resistance is required.

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