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Design and fabrication of a machine for test in abrasive wearing according to ASTM G65 standard

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Abstract
In this work is discuss the design and construction of a "dry sand/rubber wheel apparatus" according to the ASTM G 65 Standard, in order to determine the abrasive wear of different materials. Wear damage which entails the loss of material is perhaps the simplest situation to describe quantitatively. The lost by attrition can be determinate by measuring the change of mass or dimensions of the test specimen. ASTM G 65 Standard is widely used by industry to assist the selection of materials for the service in abrasive wear environment. The choice of loads and sliding distance is detailed in A, B, C, D and E test methods described in this standard. The measurements of mass change by this method is usually quick and the materials cost can be low.

Keywords
ASTM G65, Abrasive Wear, Machine Design, Fabrication, Dry Sand – Rubber Wheel Apparatus

1. Introduction

The wear damage carries to replace machine parts causing a lost in the valuable time of productions. Therefore should be proposed serious studies related with the tribology. Thus, is possible predict future flaws when an appropriate evaluation method adopted for the different materials and machines according to its work cycle, in this manner is conserving the productivity, the industrial security and the decrease of costs.

Laboratory modelings of tribological behaviors are very importance, because facilitates the correct selection of the materials to use in frictional constraints and contributes to materials saving and increment its durability.

With this perception of necessities required in the industry, have been developed methods able to perform reproducible tests in any place. Due to this, organizations like ASTM, DIN, ISO, among others, have standardized these techniques, achieving with this, the general knowledge of the conditions of operation of the machines, of their dimensions and of all the operation parameters during the realization of the rehearsals.

ASTM G 65 standard for abrasive wear test is widely used by industry to assist in selecting materials for abrasive wear service. This test involves loading a specimen against a rotating rubber-rimmed wheel while a flow of abrasive sand is directed at the contact zone. Choices of loads and sliding distances are detailed in the test method. [1,2]

In Mechanical Engineering Faculty of the Central University "Marta Abreu de la Villas" of Cuba isn't had a tribologic laboratory that allows to make waste rehearsals in tribosystem. To will make this laboratory is necessary the design and production of the machines that will conform it. Then is performed the design and fabrication of a machine type "dry sand - rubber disk" for test in abrasive wearing according to the ASTM G 65 Standard.

2. Design

For design this machine was taken into account the characteristics of this test in order to determine the abrasive wear of different materials [3-5]. In the ASTM G 65 standard, the conditions to carry out these rehearsals are shown in table:

The fundamental elements of this machine are established in the ASTM G 65 Standard, whose scheme and main components are shown in Fig. 1.

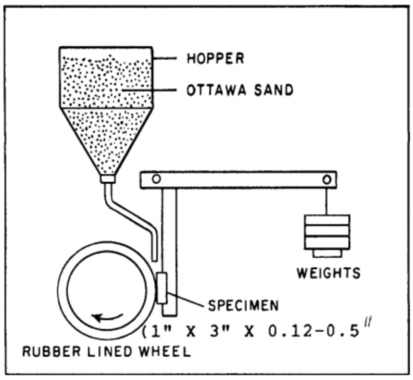

Fig 1. *Schematic Diagram of Test Apparatus [6-14]*

Table 1. *Test Parameters [6]*

Specified Procedure	Force Against Specimen* (N)	Wheel Revolutions	Lineal Abrasion (m)
A	130	6000	4309
B	130	2000	1436
C	130	100	71.8
D	45	6000	4309
E	130	1000	718

* Force tolerance is ±3 %.
Rate of revolution of the wheel: 200 ±10 rpm.
Sand flow rate: 300 to 400 g/min.

The model of this machine is provided by the following systems:

1) Mechanic System

It's taking upon of hold the specimens, support the dead loads that will be applied and transmit movement to the disk, this is achieve by means of the following elements:

- Specimen Holder.
- Lever Arm for apply the load.
- Motor drive system.
- Enclosure, frame and abrasive hopper.

2) Electric System

It's taking upon of supply the feeding energy to on/off the electric motor, for this be counted with certain devices to protect the control circuit.

2.1. Specimen Holder and Lever Arm

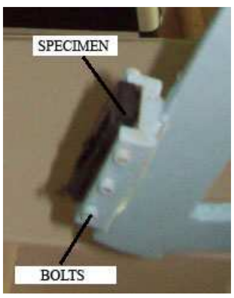

Fig 2. *Specimen Holder*

Specimen Holder is situated in the end of the Lever Arm (see Fig. 2) and permit to fit a specimen with bolds as is shown.

The system for load application is defined in ASTM G 65 Standard [6-8], although its design allows variations, in this case the lever arm is keep according to the standard (See Fig. 3).

Fig 3. *Lever Arm*

2.2. Motor Drive System

This system transmits the movement from the motor drive to the rubber disk; for it is used a transmission by pulleys and a reduction gear (See Fig. 4). The parameters of these transmissions of they give next.

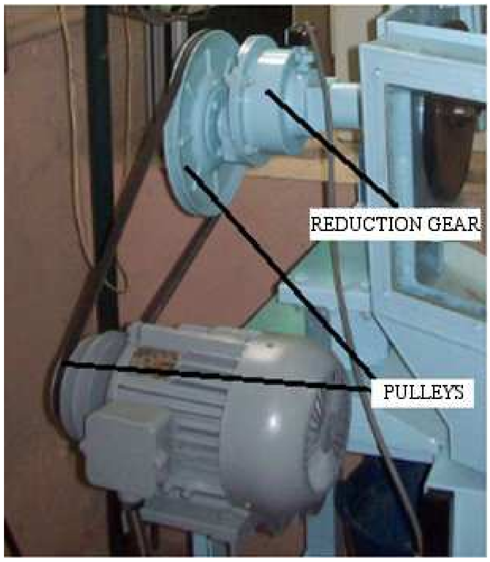

Fig 4. *Motor Drive System*

Motor:
Power: 1.3 kW (1.76 HP)
Speed: 1800 rpm.
Pulleys Transmission:
Belt type: Classical V-Belt class A
Transmission ratio, i: 3.67
Small pulley diameter, d: 90 mm
Large pulley diameter, D: 330 mm
Reduction Gear:
Transmission ratio, i: 2.4

Helix angle, β: 20o
Pinion, number of teeth, z1: 20
Wheel, number of teeth, z2: 48
Module, m: 2.5 mm
Rubber Wheel dimensions: The rubber disk should have a 228.6 mm of diameter (9 inches) and a thickness of 12.7 mm (0.5 inches).

2.3. Enclosure, Frame and Abrasive Hopper

The hopper (See Fig. 6) is making of a ASTM A570 Steel, grade 36 black steel sheet, and its design was made for a 20 L of capacity to provide the following parameters [3]:
Maximal sand flow rate: 400 g/min.
Maximal time of the test: 30 min.
Sand density: 1.6 L/kg.
Then the maximal capacity of sand request is:
(0.4 kg/min)(30 min)(1.6 L/kg) = 19.2 L
The sand flow required by the standard, it's fed by means of a nozzle (See Fig. 8) with an end diameter of 12.7 mm (0.5 in).
The whole machine and its main parts are shown in Fig. 5, where can be appreciate the frame and enclosure of it.

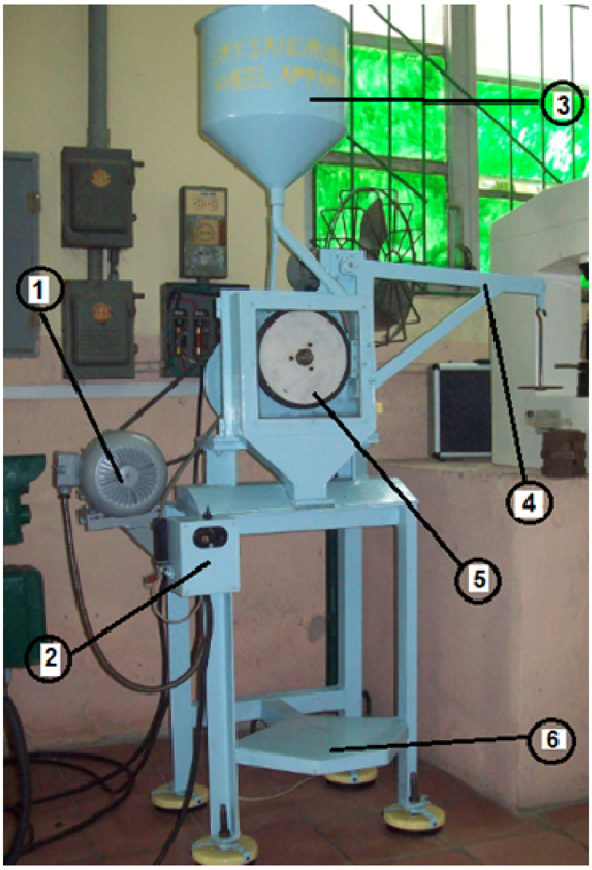

Fig 5. *Main Apparatus Parts*

1. Electric motor drive.
2. Switch and electric protection.
3. Sand hopper.
4. Lever arm.
5. Steel wheel covered in rubber.
6. Frame.

3. Results

According to the ASTM G 65 Standard [6], before carrying out the rehearsal it's necessary to verify the parameters of work.

Firstly was verified the rate of revolution of the rubber wheel, for this was used a SHIMPO DT-205L Laser Digital Tachometer (See Fig. 6). It was verified that the wheel rotates to 204 rpm like it was foreseen.

Fig 6. *SHIMPO DT-205L Laser Digital Tachometer*

Later was verified the sand flow rate, then was collected sand of the flow that it leaves for the nozzle during one minute and it was weighed in a SARTORIUS Digital Scale that has a precision of 0.1 g (See Fig. 7). The sand flow rate measured was 330 g/min, that it's inside the range 300 to 400 g/min established by the standard.

Fig 7. *SARTORIUS Digital Scale*

Lastly, was verified that the weights placed in the hook of the distal end of Lever Arm that cause the force established in the contact point of the specimen with the rubber wheel. This can be verified placing a KRAFTMESSGERATE HALLE Dynamometer in this point such as shown in the Fig. 8. It was verified that in that point was applied 45 N like it establishes by the ASTM G 65 [6] Standard for the D procedure.

Fig 8. *KRAFTEMESSGERATE HALLE Dynamometer*

Also are carried out the rehearsal to a cast iron specimen. Then was used the method B of ASTM G 65 Standard [6] (See Table 1).

Chemical analysis of the material was done, obtaining a chemical composition shown in Table 2.

Table 2. *Chemical Composition of the Specimen Material*

C	Fe	Si	Mn	S	Cu
5.50	80.97	0.57	0.379	0.133	0.047

Cr	Mo	V	Ti	Mg
0.059	0.008	0.009	0.029	0.007

As a result of the metallographic analysis was determined that the specimen material has a ferritic structure containing lamellar graphite inclusion with long straight between 60 and 120 µm, has a uniform distribution and the amount between 5 and 8% (See Fig. 9)

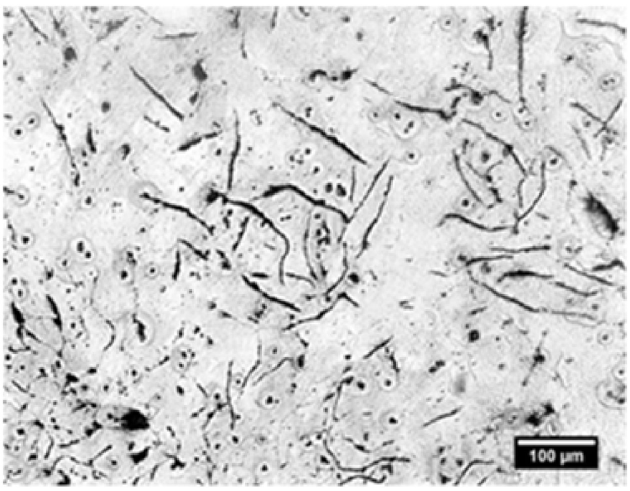

Fig 9. *Structure of Specimen Material*

The hardness measuring was performed to the specimen material resulting of 165 HV.

For tests, four specimens were made according to the standard [6] with the dimensions of 7.62 x 2.54 cm (3 x 1 in).

After performing the tests can be observed the results in one of the specimens (See Fig. 10) and a microscopic image of the wearing surface (See Fig. 11). Traces produced by the abrasive particles to slide along the surface of the cast iron specimen are clearly shown in both images.

Fig 10. *Specimen Test Result*

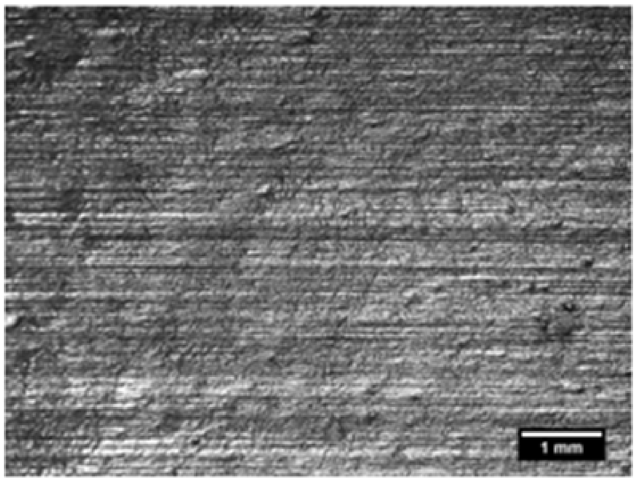

Fig 11. *KRAFTEMESSGERATE HALLE Dynamometer*

To process the results, the mass loss was measured in each specimen subtracting the final weighing to the initial weighing. As established in ASTM G 65 Standard [6] the final report of this test should be shown in terms of volume loss according to the mass loss measured. These results are reported in Table 3.

Table 3. *Mass and Volume Loss on Test*

Specimens	Start Mass on Test (g)	End Mass on Test (g)	Mass Loss on Test (g)	Volume Loss (mm^3)
1	80.4355	80.1856	0.2498	37.5339
2	62.0816	61.8276	0.2540	38.1955
3	79.7355	79.4629	0.2726	40.9925
4	79.3658	79.1003	0.2655	39.9248

4. Conclusions

The design and construction of the dry sand - rubber wheel apparatus complies with the established work parameters in the ASTM G 65 standard, allowing abrasive wear testing with good results.

The design and construction of the machine is much economical than importing it. In his manufacturing were used recycled materials, including the transmission and engine. The cost of this kind of machine outside the country hovers around 8000 USD without considering his transportation and other costs.

The manufactured machine is very important in Tribology Laboratory of Mechanical Engineering Faculty of the Universidad Central "Marta Abreu de Las Villas", it can be used for teaching and research purposes related with knowledge consolidating in abrasive wear that can acquire students on various materials.

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