EVALUATION OF FILLER AND FIBERS CONTENT FOR FRICTION MATERIALS INDUSTRY

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ABSTRACT:

In the present study the epoxy resin was used as a matrix. Glass fibers and steel fibers were used with equal content at different ratios (2.5,5,7.5and 10%) as a reinforcing fibers, molybdenum trioxide and calcium carbonate as filler, zirconium oxide as abrasive material and copper sulfides as a lubricant.

The current work investigates the mechanical characteristics by increasing fibers ratio. The wear lost get more stable state with molybdenum tri –oxide adding more than Calcium carbonate .Wear test was carried out by using pin on disc device. Results showed that the friction coefficient, compression strength, impact resistance, young modulus and wear lost improved with the change of the filler and fibers ratio. The result showed that compression strength, impact resistant, wear lost, young modulus and hardness enhanced when molybdenum tri-oxide filler was used well than calcium carbonate using.

KEY WORDS: Epoxy, friction materials, $CaCO_3$, filler, MoO_3, brake disk.

الخلاصة :-

في هذا البحث تم استخدام الايبوكسي كمادة اساس والياف الزجاج والفولاذ بكميات متساوية وبنسب مختلفة (2,5,5,7,5,10) الياف تقوية واوكسيد المولبدنيوم وكاربونات الكالسيوم كمادة مالئة واوكسيد الزركونيوم كمادة حاكة وكبريتات النحاس كمزيت.

تم تحسين الخواص الميكانيكية بزيادة نسبة الالياف . فقدان البلى اصبح بحالة اكثر استقرارا في حالة اضافة ثلاثي اوكسيد المولبدنيوم من كاربونات الكالسيوم. تم اختبار البلى باستخدام جهاز pin on disk.بينت النتائج ان معامل الاحتكاك والبلى المفقود ومقاومة الانضغاط ومقاومة الصدمةومعامل المرونة تتحسن مع تغير نسبة الالياف والمالئ. بينت النتائج انه مقاومة الا نضغاط ومقاومة الصدمة و البلى المفقود ومعامل المرونة والصلادةتتحسن باستخدام ثلاثي اوكسيد المولبدنيوم افضل من استخدام كاربونات الكلسيوم .

1. INTRODUCTION:

Friction materials are divided into two types, dry materials and wet materials. Dry materials are meant to be operating mostly under dry conditions but also under wet conditions such as braking a car in the rain. Wet materials are designed specifically for use in a wet environment only such as wet clutches and oil immersed brakes [B. K. Satapathy 2002,D Chann 2004].
The purpose of friction brakes is to decelerate a vehicle by transforming the kinetic energy of the vehicle to heat, via friction, and dissipating that heat to the surrounding.[Mikael Eriksson 2007] As a part of the commercial truck or automobile, brake material have additional requirements, like resistance to corrosion, long life, low noise, stable friction, low wear rate, acceptable cost, dimensional stability, appropriate thermal properties, and light weight that will enable new technologies to raise the fuel efficiency of a vehicle without compromising its safety and reliability [P. J. Blau2001,Masoomi 2006].

Brake pads typically comprise the following subcomponents [Lille 2004, D Chann 2004]:

1. Frictional additives, which determine the frictional properties of the brake pads and comprise a mixture of abrasives and lubricants.
2. Fillers, which reduce the cost and improve the manufacture ability of brake pads.
3. A binder, which holds the components of a brake pad together.
4. Reinforcing fibers, which provide mechanical strength.

brake pad are classified into metallic pads, semi metallic and non-asbestos .Steel fibers, glass fibers, ceramic fibers, and carbon fibers appear to be the most suitable for use as reinforcing fibers in brake friction material while the high cost of the ceramic fiber lead to use a mixture of different types of reinforcing fibers with complementing properties such as using a mixture of steel fiber with glass fiber [Maurice 1973,Zhaobin 2007].

Binder is the heart of a system which binds the ingredients formally so that can perform the desired function in the friction materials. [Philip , 2004,D.Suryatama 2007,]Quick mast 108 (Epoxy) used as binder in friction materials due to a good combination of mechanical properties such as high hardness, compressive strength, moderate thermal resistance, and creep resistance and very good wetting capability with most of the ingredients.[Rawa 2007].Abd al fatah 2000]

Semimetellic brake pads with a mixture of metallic and organic compounds having varying thermal expansion coefficients would require large amount of molybdenum trioxide to prevent cracking. molybdenum trioxide behave as lubricant at high temperature by reacting with sulfide to produce molybdenum sulfide therefore the wear lost decrease [B. K. Satapathy 2002].

The aim of the work is to improve the friction material mechanical properties by increasing fiber ratio also using molybdenum trioxide as new filler and comparing it with calcium carbonate to use it high application temperature.

2. EXPERMENTAL ANALYSIS:

Sample preparation is made by mixing materials which contain chopped fibers as indicated in table (1) with using a technique suitable mixing and then the sample is placed in molds and special tests are shed pressure on the sample and is placed in the oven at a temperature and for a 100^{o}C for 1 hour.

To prepare the specimens for impact tests, a die made of carbon steel (65mmX30mmX12.7mm) was used to cut the sample according to ASTM (D256) [6-8]. Impact test was conducted by Izod method. The cylindrical mold used for wear test was with 6mm diameter, and 10mm height as shown in figure (1).The wear test system (pin on disc) was used in the present study.compression sample die was made with the dimension (20×10×10).the shore hardness A test was used to measure the samples hardness. The average particles size range of calcium carbonate powder is (90-900) µm to determine the required size [D50:199.4] while molybdenum trioxide is(50-700)µm determined by using LBZA device to determine the required size [D50 :41.88µm] as shown in figures (3,4).Table (2) represent the properties of Molybdenumtrioxide, zirconiumoxide, calcium carbonate and copper sulphides. Figure (2) represent wear test samples. The shore hardness A test was used to measure the samples hardness. The compression device was used to measure the compression strength and young modulus.

3. RESULT AND DISCUSSION:

Figure (6) shows the relation between the wear lost and the time for the sample (1) which contain calcium carbonate under (4) kN load. When compared between the samples as shown in figures (3, 4, 5 and 6), the wear lost increase when the time increase. The ratio of the fibers is 2.5 percent which represent the minimum weight ratio of fibers as shown in figure (5)samples(1.c,1.m). The maximum wear lost occurs at the minimum weight ratio of fibers because of the decrease of the plateaus formed by the fibers. When the wear time increased the work done by the friction force is increased too. That’s led to transform the friction work to heat energy which increases the wear lost by the development of the circle fatigue cracks led to remove the material by brittle fracture. Epoxy matrix being thermoset the energy absorption is less as compared to the thermoplastics. Thermosetting composites cracks initiate at the filler–matrix interface and propagate very easily through the matrix towards the other filler–matrix interfaces. When the network of cracks intersects, the filler particles become loose and are removed in the form of wear debris. The resin also gets removed in the form of fine wear debris caused by brittle fracture of the resin.

The wear loss in the sample (1-m,2-m, 3-m and4-m) which contain molybdenum trioxide increase with time increased for the sample reason discussed ,Also the maximum wear lost occurs at the minimum weight ratio of fibers because thedecrease of plateaus formed by the fibers . The wear lost increased as the contact area increase and vice versa as in equation (1).

$$\Delta w = wear\ \mathrm{rate} * \rho * \mathrm{L} * \mathrm{A} \qquad (1)[\text{Abeer 2009}]$$

$\Delta w =$ Wear lost (kg)

L= sliding distance (m)

$\rho =$ Density (kg.m^{-3})

A= real contact area (m^2)

Filler particle are considerably harder than the surrounding matrix and can thus insulate the matrix against wear. Filler size, shape and matrix adhesion therefore also affect abrasion resistance. Loss of large or poorly bound filler particles by abrasion exposes the relatively soft surrounding matrix to wear. The effect is acute on the edge of the depression left by the dislodged particle. This is the area most susceptible to elongation, crack initiation and ultimate loss as shown with calcium carbonate therefore the wear lost increase when the speed increase as shown in **table(3)**.

The wear loss in the samples which contain calcium carbonate close to the wear loss in the samples which contain molybdenum trioxide as Shawn in figures (6,7,10,11) because the minimum ratio of fiber when fiber ratio 5% and 10 % . The values of the wear loss for the samples which have fiber ratio 15% and 20% which contain molybdnumtrioxide get more sable state then that of calcium carbonate as shawn in figures (8,9,12,13) due to the good compatibility between epoxy and molybdenum trioxide because its behave as lubricant at high tempreture.

The hardness of the samples increases with the increases of the ratio of the fibers as shown in **figure (14)** The reason behind that is the high fiber ratios lead to increase the contact area between the matrix and the fibers due to the high aspect ratio of fibers so the density increase and hardness increase.

The samples that contain MoO_3fillers have higher hardness from the samples containing $CaCO_3$fillers. The reason behind that is the minimum average particle size of MoO_3 (50-700) µm compared with $CaCo_3$(90-900)µm and it has orthorhombic structure therefore it has good contact area with epoxy matrix and it has high density as shown in **figures (1,2).**

The impact strength of the samples which contain MoO_3 decrease when MoO_3 content decrease as shown in **figure (15)** because that filler have minimum particle size and high surface area which inter between molecules chains and fill the spaces so the impact strength decreasein spite of the fiber ratio increase.

The impact strength of the samples which contain $CaCO_3$increase when $CaCO_3$ decrease because it have average particle size(90-900) µm which may far between the molecules chains so the impact strength increase when $CaCO_3$ decrease as shown in **fig (15)**.

The young modulus increase with fiber ratio increase because higher surface area, greater aspect ratio, and higher loading (the latter two effectively increasing the surface area exposed to the polymer) will all increase the modulus. Fillers with strong chain attachments, through active sites provide the most resistance to the chain extension and separation required for elongation as shown in **fig (16).**

The ultimate compression strength decrease with fiber ratio increase and filler decrease because the hardness increase and the density increase due to crosslinks decrease with fiber increase.. The samples which contain MoO_3 have higher ultimate compression strength than $CaCO_3$ because the minimum particle size and high surface area of MoO_3 as shown in **fig (17) .**

Friction materials increase with fiber ratio increase because the fibers affect as abrasive materials .$CaCO_3$ have high hardness than MoO_3 therefore it have higher friction coefficients as shown in **fig (18).**

The comparative performance of Glass-Epoxy (G-E) composite systems interfaced with graded fillers has been examined by **Suresha et al, 2006**. The influence of two inorganic fillers, silicon carbide particles (SiC) and graphite, on the wear of the glass fabric reinforced epoxy composites under dry sliding conditions has been investigated. For increased load and sliding velocity situations, higher wear loss was recorded. . It was observed that the Graphite filled G-E composite shows lower coefficient of friction than the other two composites irrespective of variation in the load/sliding velocities. SiC filled G-E composite exhibited the maximum wear resistance.

4- CONCLUSIONS: CONCLUSIONS:

1. The $CaCo_3$ addition have lower wear lost than MoO_3 in friction materials especially at 20% filler ratio.
2. The $CaCo_3$ addition have lower stable wear resistance than MoO_3 in friction materials at high concentration of fiber content (20%).
3. The MoO_3 addition investigate hardnessat (15,10and 5) % of MoO_3beter than $CaCo_3$.
4. The higher impact strength the larger of MoO_3 content at 20% of MoO_3 .
5. The impact strength increase when fiber content increase in the case of using $CaCO_3$
6. The young modulus increase when fiber contentincrease.
7. Wear lost,impact resistance hardness,young modulus enhanced when fiber ratio increased.
8. Ultimate compression strength decrease with fiber ratio increase.

Table (1) Components of the samples batch

Batch	Sample number	Glass fiber (wt. %)	Steel fiber (wt. %)	Copper sulphides (wt. %)	Zirconium oxide (wt. %)	Quick mast 108 (Epoxy) (wt. %)	Molybdenum trioxide (wt. %)	Calcium carbonate (wt. %)
1	1-c	2.5	2.5	29	6	40	-	20
2	1-m	2.5	2.5	29	6	40	20	-
3	2-c	5	5	29	6	40	-	15
4	2-m	5	5	29	6	40	15	-
5	3-c	7.5	7.5	29	6	40	-	10
6	3-m	7.5	7.5	29	6	40	10	-
7	4-c	10	10	29	6	40	-	5
8	4-m	10	10	29	6	40	5	-

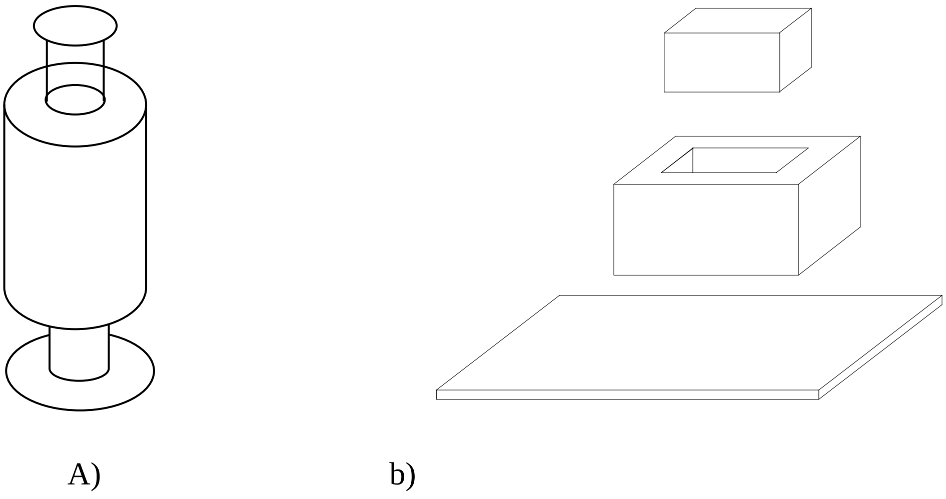
Table (2) represent the properties

Properties				
Molecular formula	MoO_3	ZrO2	$CaCO_3$	CuSO4 (anhydrous) CuSO4•5H2O (pentahydrate
Molar mass	143.94 g mol^{-1}	123.218 g/mol	100.0869 g/mol	159.609 g/mol (anhydrous)
Appearance	yellow or light blue solid	white powder	Fine white powder; chalky taste	gray-white (anhydrous)
Odor	Odorless		Odorless	
Density	4.69 g/cm^3, solid	5.68 g/cm^3	2.711 g/cm3 (calcite)	3.60 g/cm3 (anhydrous)[1]
Melting point	795 °C (1,463 °F; 1,068 K)	2715 °C	825 °C (aragonite) 1339 °C (calcite)	110 °C *decomp.* (·5H_2O)[1] <560 °C *decomp*
Boiling point	1,155 °C (2,111 °F; 1,428 K) sublimes	4300 °C	decompose	
Solubility in water	0.1066 g/100 mL (18 °C) 0.490 g/100 mL (28 °C) 2.055 g/100 mL (70 °C)	soluble in HF, and hotH_2SO_4	0.0013 g/100 mL (25°C)	1.055 molal (10 °C) 1.26 molal (20 °C) 1.502 molal (30 °C
Structure				
Crystal structure	orthorhombic		Isometric	

Thermochemistry				
Std molar entropy S^o_{298}	77.78 J K^{-1} mol^{-1}	50.3Jk^{-1}mol^{-1}	93Jk^{-1}mol^{-1}	1.502 molal (30 °C)[2]
Std enthalpy of formation $\Delta_f H^o_{298}$	−745.17 kJ/mol	-10803Jk^{-1}mol^{-1}	-12073Jk^{-1}mol^{-1}	159.609 g/mol (anhydrous)[1]

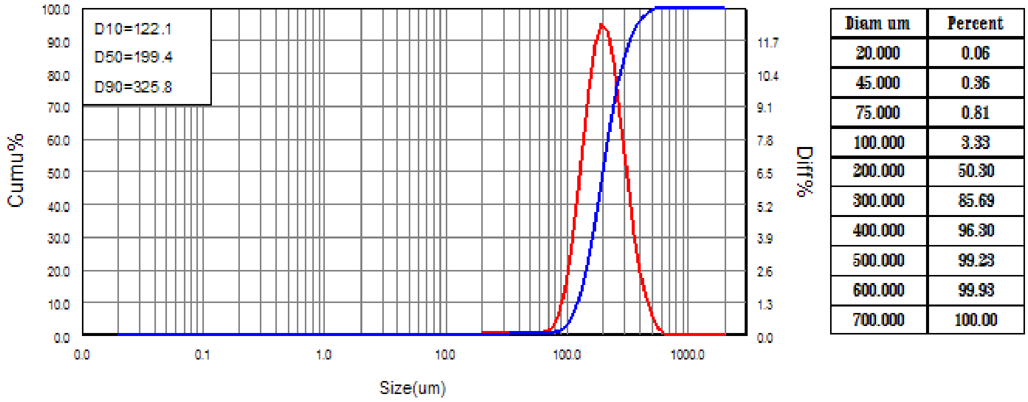
Table (3) represent the weight loss at different speeds

Sample No.	Weight loss at speed 20 m	Weight loss at speed 40 m	Weight loss at speed 60 m	Weight loss at speed 80 m
1-c	0.0001	0.0002	0.0003	0.0005
1-m	0.0002	0.0002	0.0003	0.0004
2-c	0.0001	0.0002	0.0004	0.0006
2-m	0.0002	0.0004	0.0006	0.0007
3-c	0.0002	0.0002	0.0004	0.0005
3-m	0.0002	0.0003	0.0004	0.0006
4-c	0.0001	0.0002	0.0003	0.0005
4-m	0.0002	0.0003	0.0005	0.0006



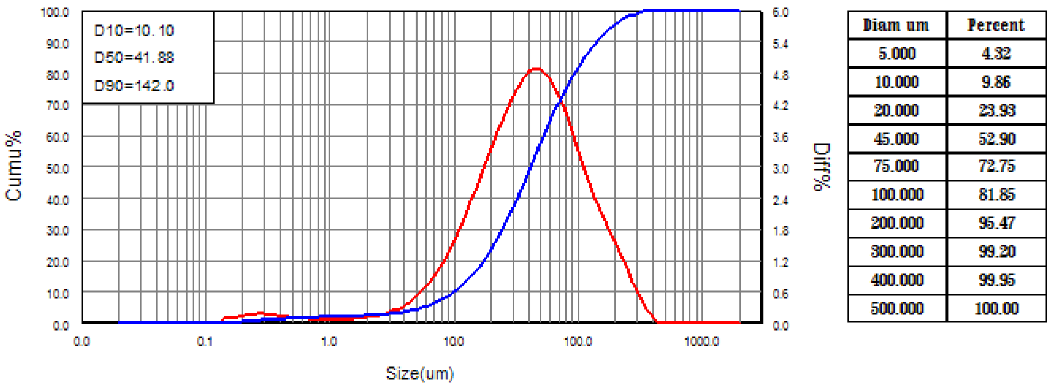
Figure(1) a) wear mold b) impact strength mold

Fig (2) wear test samples



Diam um	Percent
20.000	0.06
45.000	0.36
75.000	0.81
100.000	3.33
200.000	50.30
300.000	85.69
400.000	96.30
500.000	99.23
600.000	99.93
700.000	100.00

Figure (3) LBZA chart of particle size analysis of $CaCO_3$



Diam um	Percent
5.000	4.32
10.000	9.86
20.000	23.93
45.000	52.90
75.000	72.75
100.000	81.85
200.000	95.47
300.000	99.20
400.000	99.95
500.000	100.00

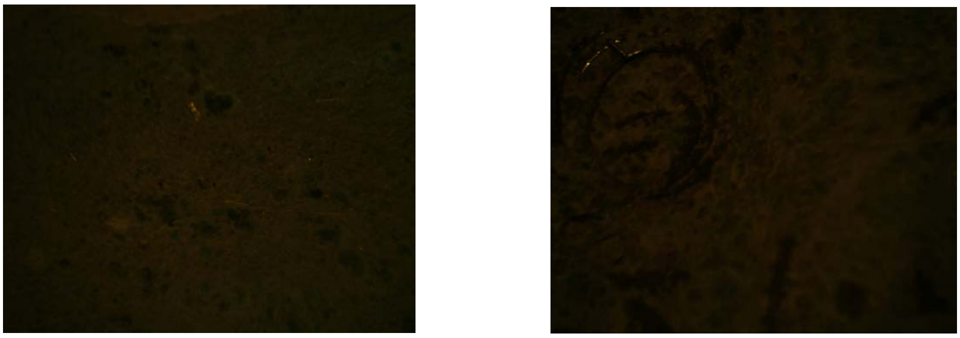
Figure (4) LBZA chart of particle size analysis of MoO_3

(1.c)

(1.m)

(3.c)

(3.m)



(4.c) (4.m)

Figure (5) the sample surfaces after wear test.

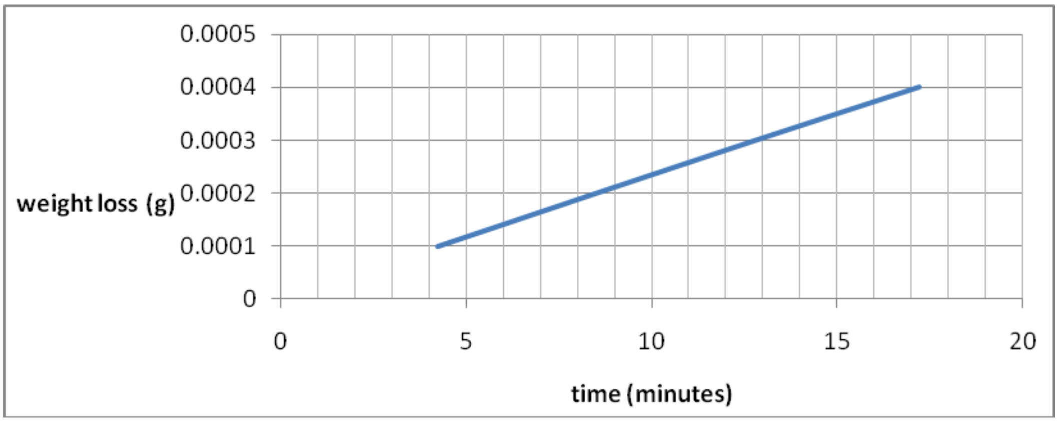


Figure (6) the relation between the weight lost and time for the sample (1-c) under load (4) KN and speed 20 m

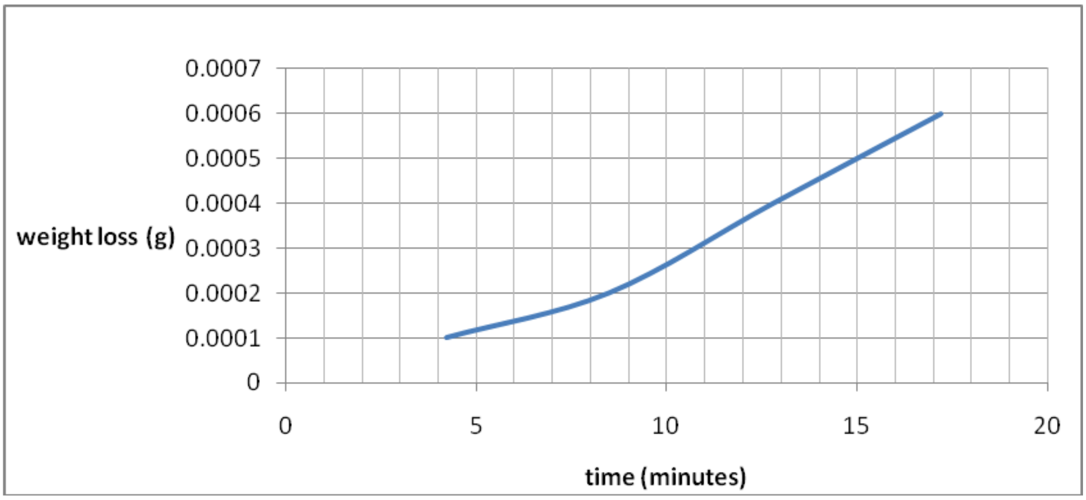


Figure (7) the relation between the weight lost and time for the sample (2-c) under load (4) KN and speed 20 m

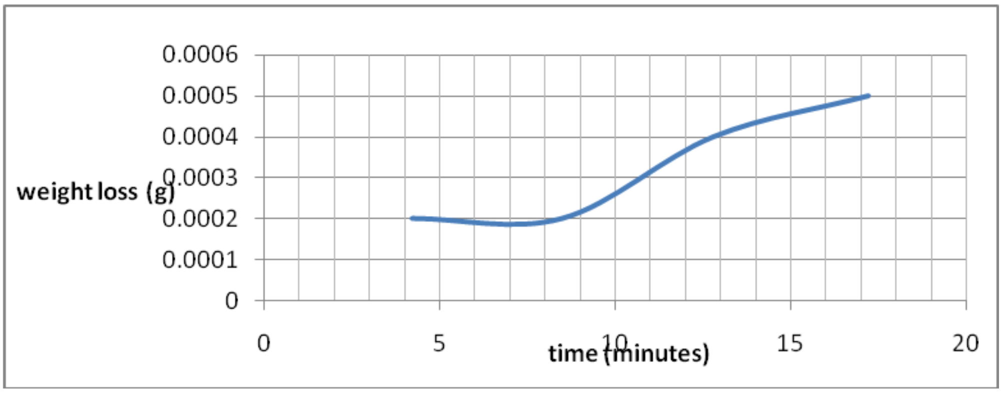


Figure (8) the relation between the weight lost and time for the sample (3-c) under load (4) KN and speed 20 m

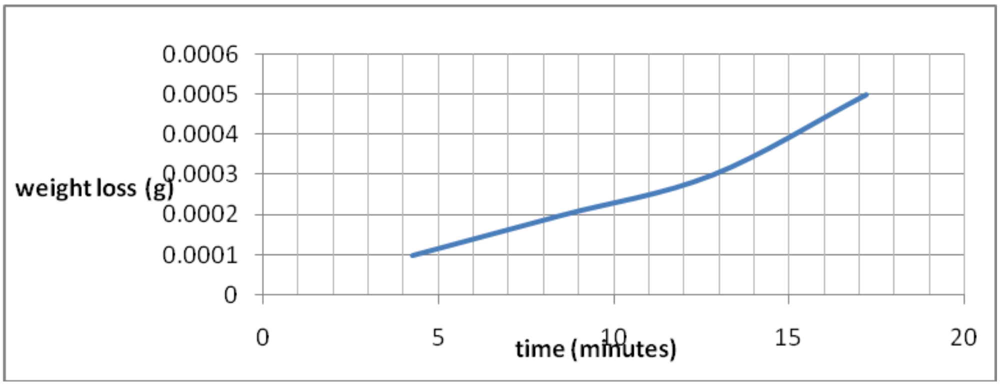


Figure (9) the relation between the weight lost and time for the sample (4-c) Under load (4) KN and speed 20 m

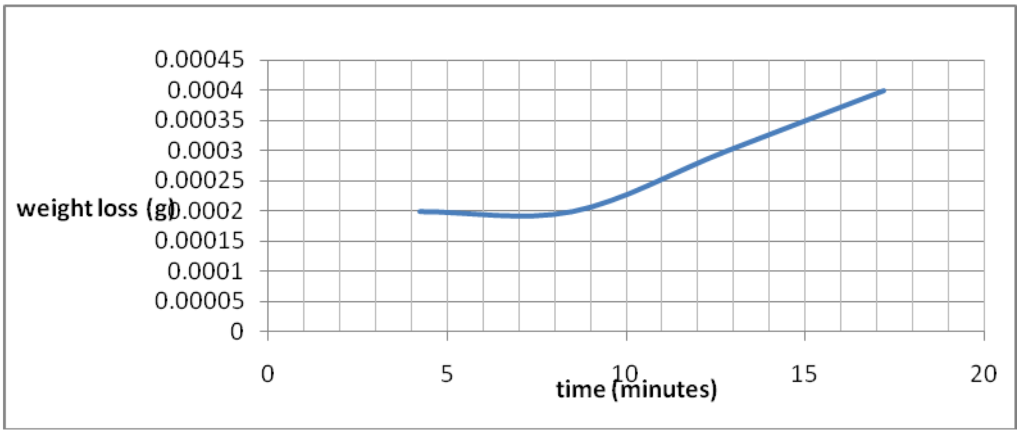


Figure (10) the relation between the weight lost and time for the sample (1-m) under load (4) KN and speed 20 m

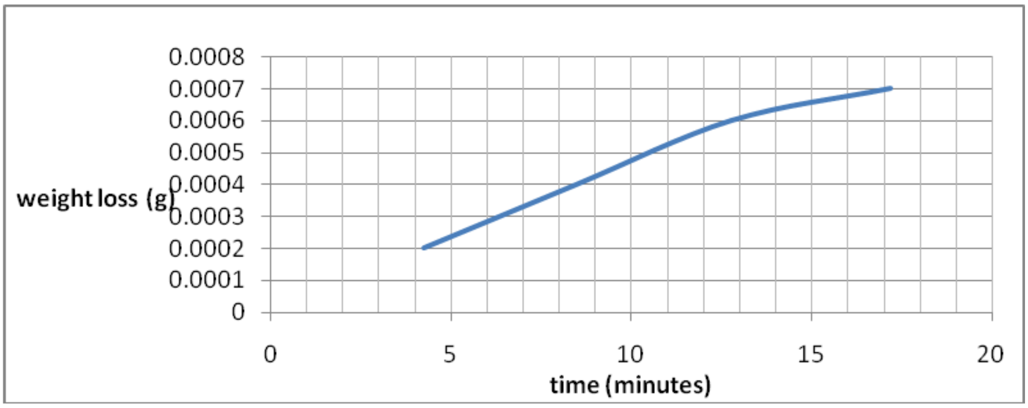


Figure (11) the relation between the weight lost and time for the sample (2-m) under load (4) KNand speed 20 m

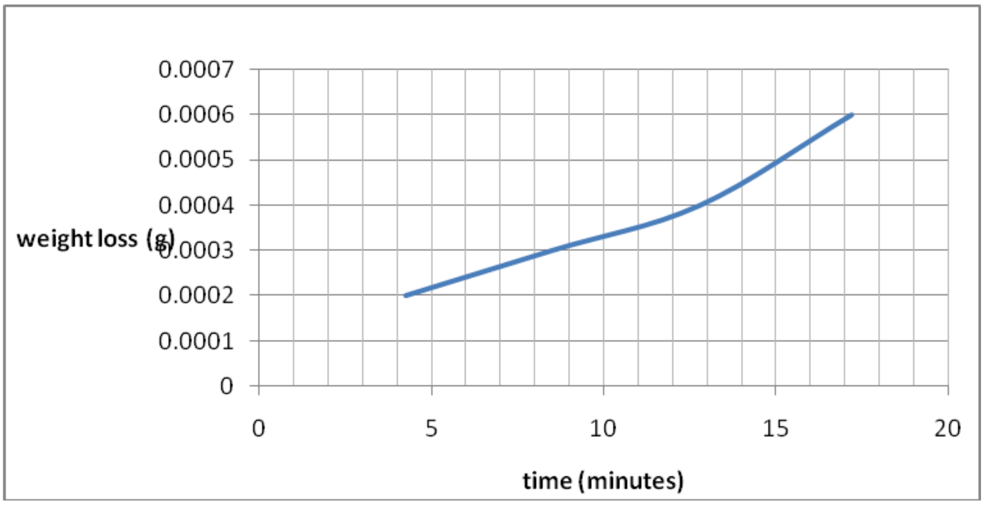


Figure (12) the relation between the weight lost and time for the sample (3-m) under load (4) KN and speed 20 m

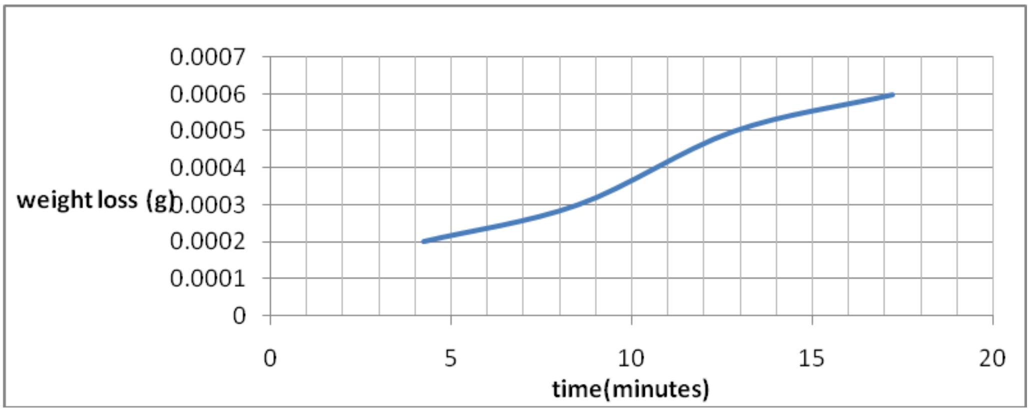


Figure (13) the relation between the weight lost and time for the sample (4-m) under load (4) KN and speed 20 m

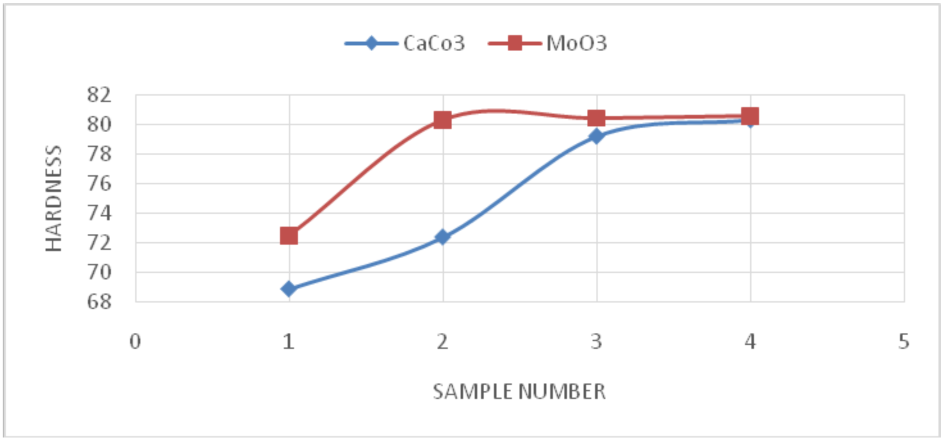


Figure (14) the relation between harness and samples number

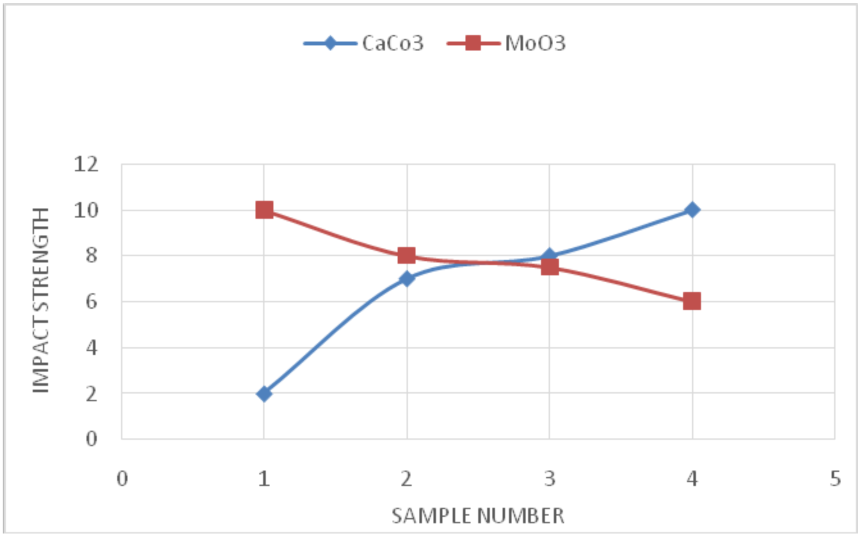


Figure (15) the relation between the impact strength and sample number for the samples

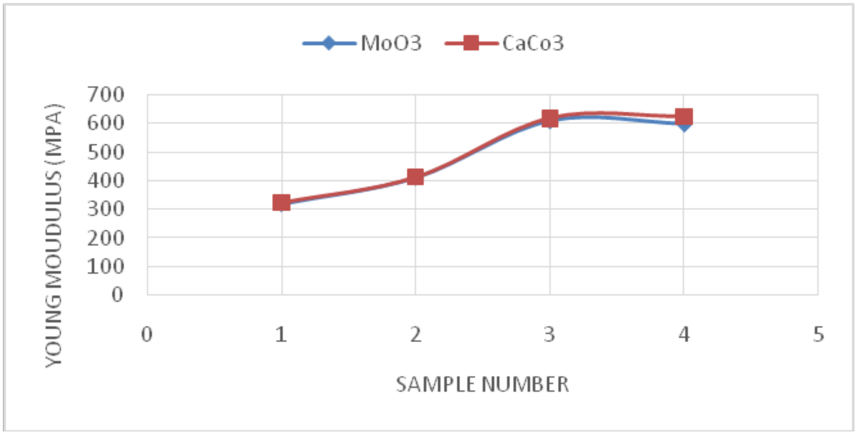


Figure (16) the relation between the young modulus and sample number

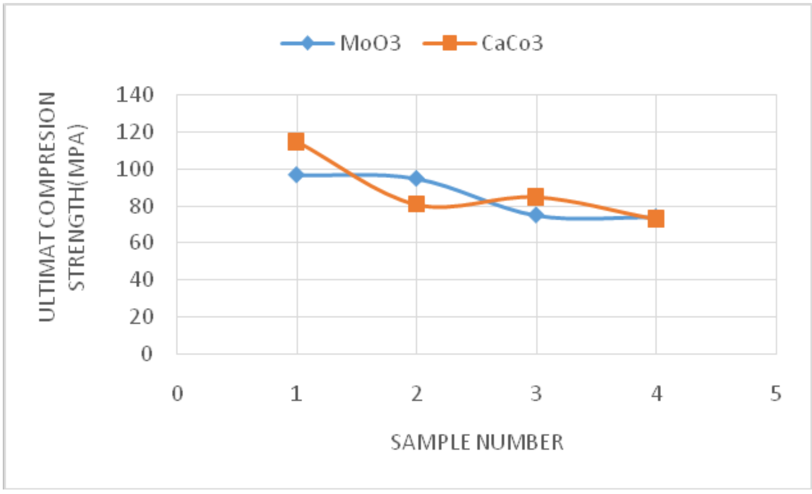


Figure (17) the relation between the impact strength and sample number

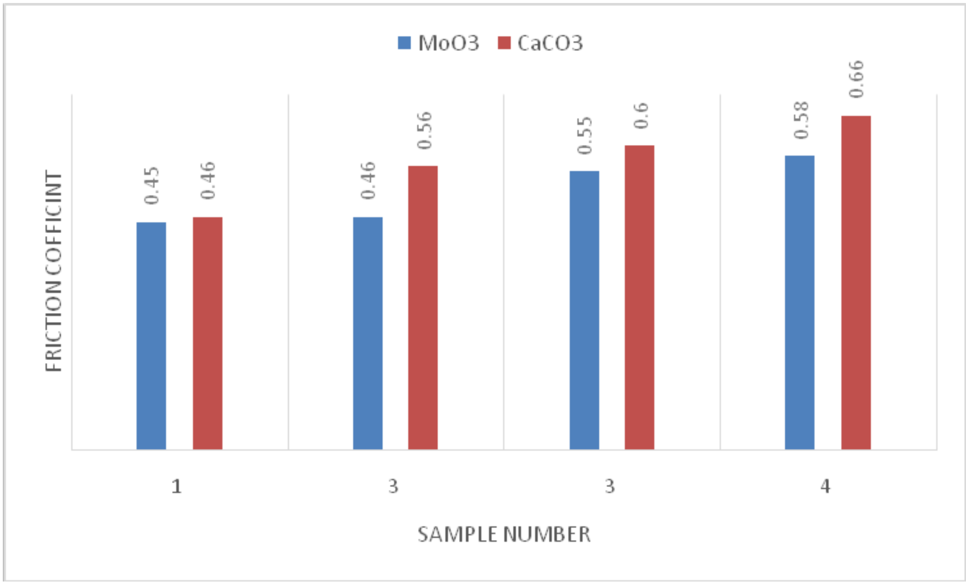


Figure (18) the relation between the friction coefficient and sample number.

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