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EVALUATION OF RESINS AND FIBERS CONTENT FOR FRICTION MATERIALS INDUSTRY

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Abstract:

In the present study the rubber was added to novolac resin as a binder to improve the mechanical properties. Glass fibers and steel fibers were used at different ratios as a reinforcing fibers, molybdenum trioxide and calesuim carbonate as filler, zirconium oxide as abrasive material and copper sulfides as a lubricant. The current work investigates the characteristics of three resins: (i) SIR with novolac resin (ii) NBR with novolac resin (iii) SBR with novolac resin. The addition of SIR or NBR was used because it undertakes the high temperature and has good chemical resistance. The SIR was used with deferent weight ratio of fibers to compare its effect on the mechanical properties. The samples were prepared by using cold pressing at (250MPa) .The samples were cured at (80^{o}C). Wear test was carried out by using pin on disc test system. Results from the present study showed that the friction coefficient and wear rate varied with the change of the resin and fibers ratio. The result showed that NBR and SIR addition proved best in terms of impact strength, hardness, wear rate and friction coefficient result but SBR showed poor result. The NBR addition had better wear results than SIR. The high ratio of fibers decreases the wear rate and increases the impact strength and friction.

الخلاصـــة

في هذه الدراسة تم تحسين الخواص الميكانيكية للمادة الرابطة بإضافة المطاط. تم استخدام ألياف الزجاج بنسب مختلفة كألياف تقوية, اوكسيد المولبدنيوم الثلاثي وكربونات الكالسيوم استخدمت كمادة مالئة, اوكسيد الزركونيوم استخدم كمادة حاكه و كبريتات النحاس كمادة مزيته. الدراسة الحالية حسنت مواصفات ثلاث راتنجات هي (1) المطاط السليكوني (SIR) للنوفلاك (2) مطاط (SBR) للنوفولاك (3) مطاط (NBR) للنوفولاك. استخدم المطاط السليكوني و (NBR) لأنه يتحمل درجات الحرارة العالية وقد تم استخدامه مع عدة نسب للألياف لمقارنة تأثيرها على الخواص الميكانيكية. حضرت النماذج باستخدام تقنية الكبس على البارد تحت

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 [1].
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. 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 [2, 3].
Brake pads typically comprise the following subcomponents [4]:

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 as shown in table (1) .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 [1].
Binder is the heart of a system which binds the ingredients formally so that can perform the desired function in the friction materials. Phenolic resins are invariably used as binder in friction materials due to low cost along with a good combination of

Table (1) Classification of brake pads [1]

Classification	Ingredients
Metallic	Predominantly metallic, such as steel fibers, copper fibers, etc.
Semi-metallic	Mixture of metallic and organic ingredients
Non-asbestos organic.	Predominantly organic, such as mineral fibers, rubber, graphite, etc.

2.Experimental Analysis:

2.1Preparation of samples:

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 10mm diameter, and 20mm height according to ASTM (G65) [9] .The wear test system (pin on disc) was used in the present study, where the disc was connected through an interchangeable flange rotation rate to a shaft which was connected by two pulleys to the motor. The disc rotation rate was fixed at 660 rpm to conform that test .The load on the pin was (15.225 kg) which was adopted from the literature study.

Table (2) represents the components of the batch samples which have NBR or SIR rubber as a binder. Sulfur was added at weight ratio of (1.5%) to the samples batch which contain NBR and SBR because the sulfur was the responsible of crosslinking during vulcanization.

The preparing processes of the samples are:

1. Weighting of the components of the batch.
2. The fibers were cut to (5-10) mm length.
3. Novolac powder particle size must be larger than (45) µm so it shacked using a sieve size (50 µm) to determine the size of novolac powder.
4. The rubber was added as a liquid by dissolving in heptanes solvent. Each 1gram of rubber added to 10 ml of heptanes.

5. The components were mixed by intensive mixture.
6. After mixing the rubber with the other components the solvent must be evaporated by naturally for 48 hours.
7. The samples were prepared by pressing the components in the die under a pressure of 250 MPa at room temperature.
8. The curing must be occurred in the clamped die at 80 ^{o}C depend on die thickness (1 hour for each 1mm of die thickness).

The friction coefficient is calculated by divided the friction force by the normal force as shown in equation (1). The friction force find by the multiplying of the strain by the coefficient *k* [10]. In the present study the strain gauge was connected with pin on disc test unit under (5 kg) load. The readings of the strain gage are as shown in Table (3). Figure (1) shows the strain gage device.

$$\mu = \frac{F}{N} \qquad (1)$$

$$F = k * \varepsilon \, ; k = 0.33$$

Table (3) Strain Results

Samples number	Strain (ε)
1	45
2	42
3	58
4	60
5	62
X-1	63

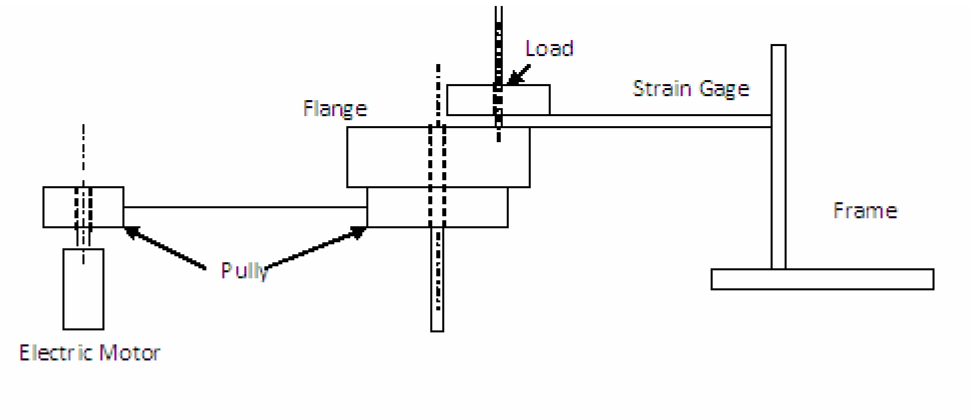

Figure (1) :strain gage device

3. Result and discussions:

Also, figure (2) shows the relation between the wear lost and the time for the sample (1) under (7.725 and 15.225) kg load. The ratio of the fibers is 10 percent which represent the minimum weight ratio of fibers. 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. Phenolic 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 [11].

The sample (1) was tested under (7.725) kg load and (15.225) kg. As the load increase the wear lost increased. The reason behind that are the surfaces of some composites worn under 1.2 kg load. The increasing in the load led to increase the wear lost of the sample. The reason behind that is the shear strains which were results by the pressure stress when the load applied and these strains caused the material transfer from the sample surface to the disk surface, therefore the coefficient of friction increased with the increase of friction force and that's led to increase the contact area. The wear lost increased as the contact area increase as in equation (1).

$$\Delta w = wear\ \mathrm{rate} * \rho * \mathrm{L} * \mathrm{A} \qquad (1)$$

$\Delta w =$ wear lost (kg)

L= sliding distance (m)

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

A= real contact area (m^2)

Figure (3) shows the wear lost as a function of the time with (7.725 and 15.225 kg) load of specimen (4). The increasing in wear behavior due to the increasing in the load led to worn the surface of the sample as it was discussed above. It's clearly shown that the wear lost under 15.225 kg is less than the wear loss of specimen (1), the reason behind that is the higher fiber ratio (27%) compared with fiber ratio of specimen (1) that has a fiber ratio of (10%).

Figure (4) shows the relation between the wear lost and time for specimen (5) under (7.725 and 15.225kg) load. The wear loss of specimen (5) is less than the wear loss of specimen (4) and specimen (1) under the same load. That's due to the high ratio of fiber content in specimen (5).

Figure (5) gives the wear loss of specimen (2) as a function of time and (7.725kg) load. It is clearly that the wear loss of this specimen is very high compared with the other specimens. The reason behind that is the high ratio of SBR (20%) and the tension strength increase to the maximum with the strain increase when the ratio of rubber addition to the thermoset reach 10% while the strength decrease with the strain increase at 20% of rubber [12, 13].

Figure (6) gives the wear lost of specimen (3) as a function of time. Specimen (3) has NBR instead of SIR with fiber ratio of (27%). This led to decrease the wear lost with time comparing with specimen (4) which has the same fiber ratio. Thus NBR addition had better wear results than SIR.

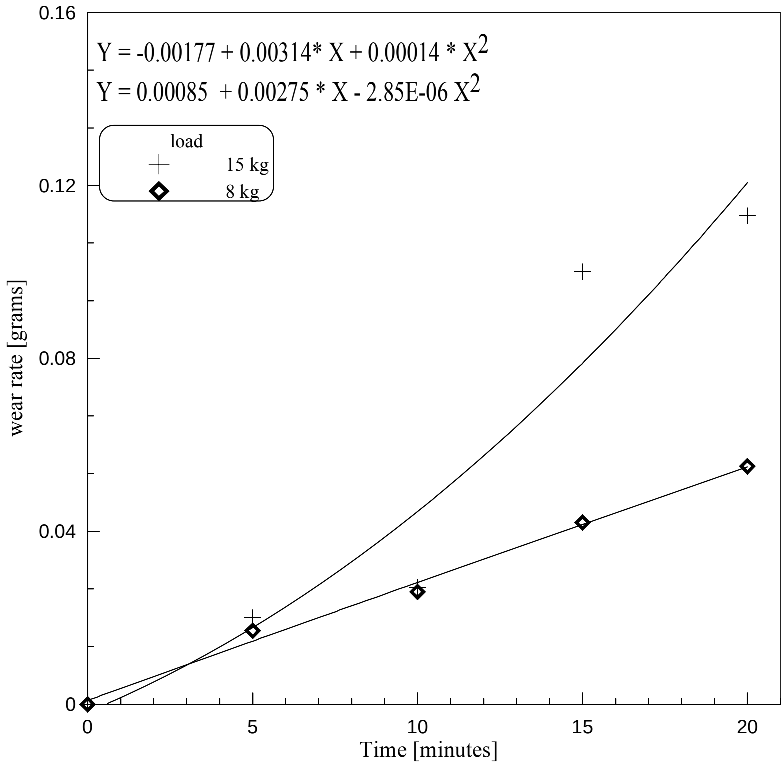

Figure (2) The relation between the wear lost and time for the sample (1) under (7.725 and 15.225) kg load

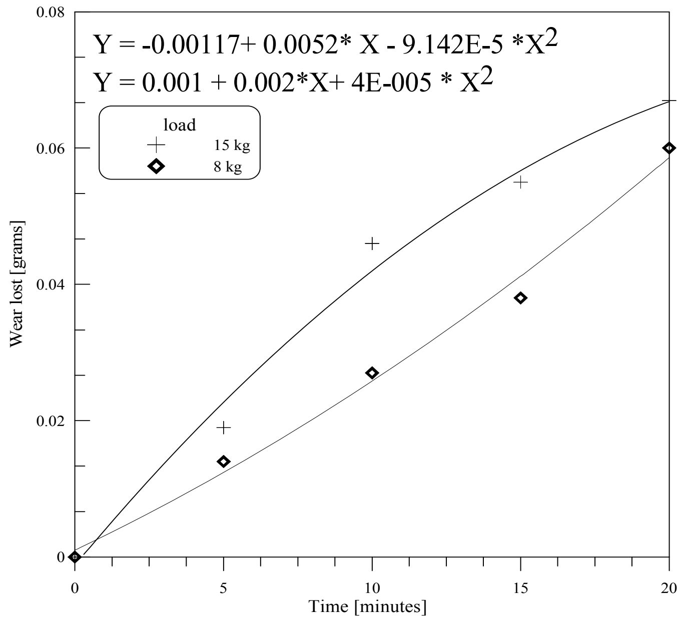

Figure (3) The relation between the wear lost and time for the sample (4) under (7.725 and 15.225) kg load.

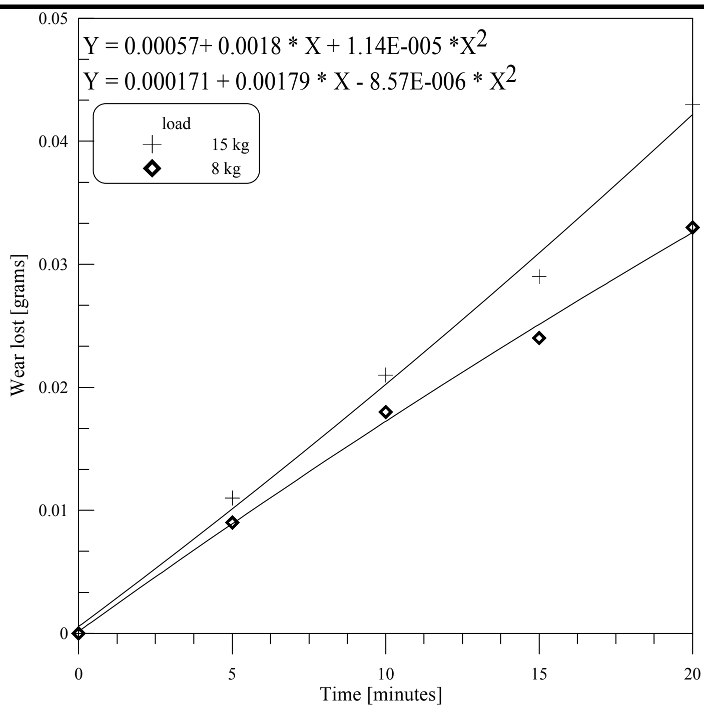

Figure (4) shows the relation between the wear lost and time for the sample (5) under (7.725 and 15.225) kg load

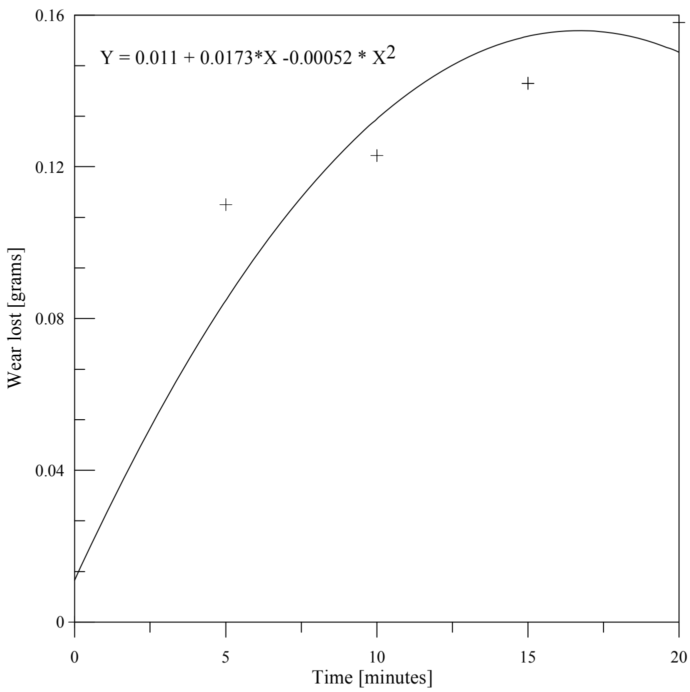

Figure (5) The relation between the wear lost and time for the sample (2) under load (7.725) kg

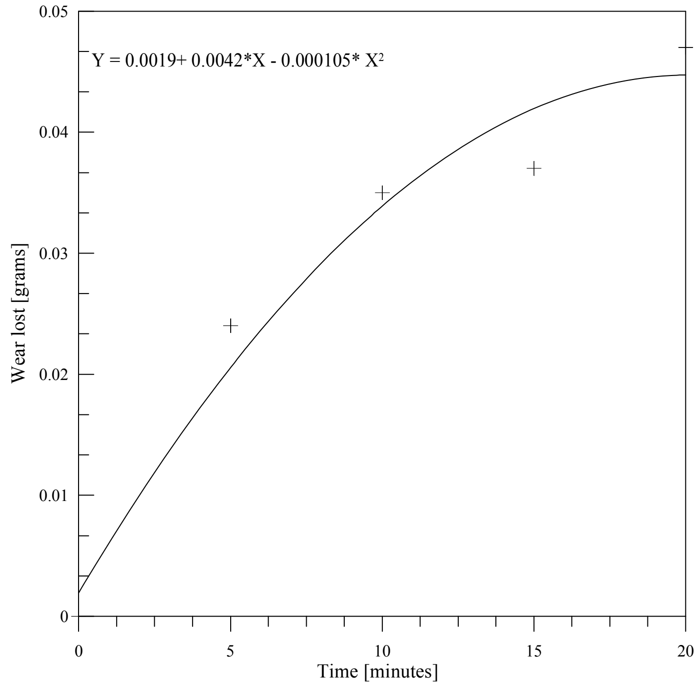

Figure (6) The relation between the wear lost and time for the sample (3) under load (7.725) kg.

3.1 The commercial Samples :

Figure (7) shows the wear lost of the commercial sample (X-1) with respect to time under (7.725 kg) load.

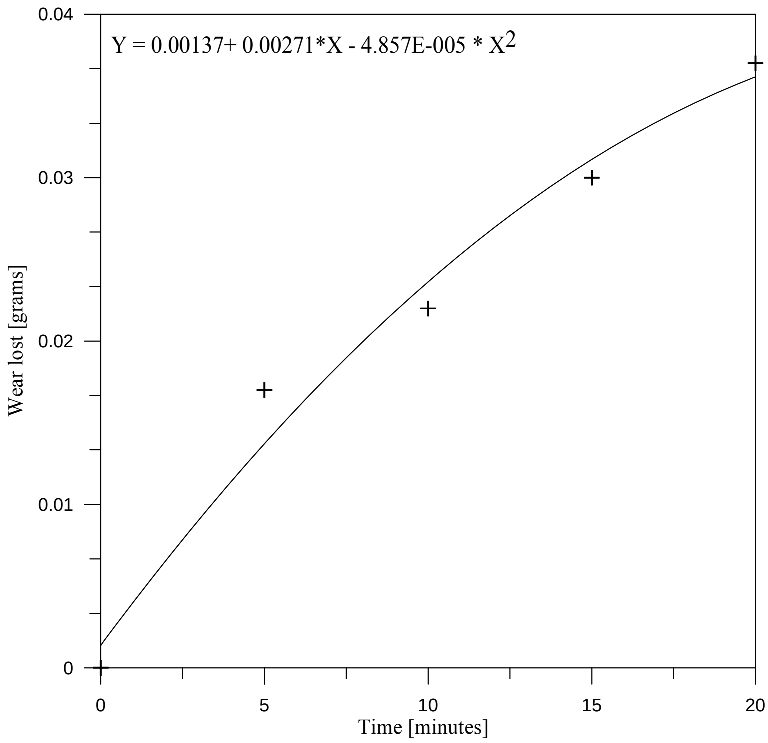

Figure (7) the wear lost versus time for the commercial specimen (X-1) under load (7.725) kg

3.2 Hardness Tests:

The hardness of the samples increases with the decrease of the ratio of the fibers as shown in figure (8). Table (4) shows the hardness of the samples (1-5). The hardness decreases when the fiber ratio increases. The reason behind that is the low weight of the samples as the low density of fibers because the high fiber ratios lead to decrease the penetration of fibers and decrease the filler contents. When the fibers ratio decrease the filler ratio increase and vice versa.

Table (4) Hardness properties of the selected samples

Sample number	Shore Hardness
1	95.2
2	85
3	92.5
4	83.5
5	76.5
X1	89.5

3.3 Impact Strength Test:

Specimens (1, 2, 3, 4, and 5) were tested using Izod impact strength device. Specimen (2) has the lowest impact strength as it has SBR which has low elasticity compared with NBR and SIR [14]. Sample (2) containing 20% SBR has the lower the mechanical properties. By comparing the impact strength of sample (3) which contains (NBR) with sample (4) which contain SIR; there are good accuracy. The impact strength increases as the rate of fibers ratio increase as shown in table (5).

Table (5) The impact strength of selected samples

Sample number	Impact strength
1	97.8
2	112.3
3	86.4
4	115.4
5	146.5
X1	119.3

3.4 Friction Coefficient Results:

The friction coefficient results for selected samples are shown in table (6). It's clearly shown that the friction coefficient increases with the increase of fiber ratio. As the fiber ratio increase the tangential force increase too, so the friction coefficient increase as it proportion to the tangential force that's due to its behavior as an abrasive material.

Table (6) The friction coefficient of selected samples

Sample number	Friction coefficient
1	0.33
2	0.4
3	0.28
4	0.42
5	0.44
X1	0.45

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