T.C.

ALTINBAŞ UNIVERSITY

Graduate School of Science and Engineering

Department of Mechanical Engineering

ANALYSIS OF POLYMERIC COMPOSITE MATERIALS FOR FRICTIONAL WEAR RESISTANCE PURPOSES

Badeea Khudhair Majeed

Master's Thesis

Supervised by Asst. Prof. Dr. Suleyman BASTURK

Istanbul, (2019)

ANALYSIS OF POLYMERIC COMPOSITE MATERIALS FOR FRICTIONAL WEAR RESISTANCE PURPOSES

by

Badeea Khudhair majeed

Mechanical Engineering

Submitted to the Graduate School of Science and Engineering

in partial fulfillment of the requirements for the degree of

Master of Science

ALTINBAŞ UNIVERSITY

2019

This is to certify that we have read this thesis and that in our opinion, it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Asst. Prof. Dr. Suleyman BASTURK

Supervisor

Examining Committee Members (first name belongs to the chairperson of the jury and the second name belongs to supervisor)

Asst. Prof. Suleyman BASTURK	School of Engineering and Natural Sciences, Altinbas University	
Asst. Prof. Haydar UYANIK	Faculty of Engineering and Architecture, Gelisim University	
Asst. Prof. Armin BIJANZAD	School of Engineering and Natural Sciences, Altinbas University	

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Asst. Prof. Dr. Suleyman BASTURK

Head of Mechanical Engineering Department

Approval Date of Graduate School of

Prof. Dr. Oğuz BAYAT

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Badeea Khudhair Majeed

Science and Engineering: ____/____/____

____
Director

DEDICATION

I would like to dedicate this work to my very first teacher, my mother, my first supporter and role model, my wife and my companion throughout the journey and my brothers and my sister. Without you, this dream would never come true.

ACKNOWLEDGEMENTS

I might want to offer my thanks to every one of the individuals who have upheld me all through the regularly extended periods of this voyage. I might want to thank my advisor, Asst. Prof. Dr. Suleyman Basturk for being my compass notwithstanding, when I believed I was lost and being in extraordinary part in charge of the zenith of this work. I might likewise want to thank my supervisor for his supportive exhortation, which incredibly enhanced the nature of this work. Finally, I thank this institution for hosting me during these years, securely earning its place as my home. I am very thankful to my mom and dad, whose values and education motivate me to keep asking questions; to my siblings and family for their infinitely appreciated love and to my country which, although inanimate, keeps me anchored and offers me an example of resiliency.

ÖZET

SÜRTÜNME AŞINMA DAYANIMI AMAÇLI POLİMERİK KOMPOZİT MALZEMELERİN ANALİZİ

MAJEED, Badeea Khudhair Majeed,
M.S., Makine Mühendisliği, Altınbaş Universitesi,
Danışman:Asist.Prof. Suleyman Basturk

Tarih: Haziran/ 2019
Sayfalar: 100

Bu araştırma, piyasada bulunan ve daha ucuz olan ev malzemelerinden oluşan polimerik bir kompozit malzemeden üretilen fren balatataları ile ilgilidir. Doymamış polyester hazırlanan numuneler için temel malzeme olarak kullanılılmiştir. Örnekleri hazırlamak için Stiren Bütadien Kauçuğu (SBR) ve Montmorolonite Kil ve piyasada ucuz ve mevcut olan diğer dolgu maddeleri gibi dolgu maddelerini eklenmiştir. Ayrıca, Kevlar lifleri, naylon ve çelik bu numuneler için takviye malzemesi olarak %10 ile %25 arası mekanik özelliklerin iyileştirilmesi amacı ile takviye malzemesi olarak kullanılmiştir. Numuneler, bu malzemelerden hazırlanmış ve bu numunenin mekanik ve fiziksel özellikleri test edilmiştir. Test sonuclar piyasada mevcut olan ticari fren balatalar ile kerşilaştirilmişter. Shore D'nin sertlik testi, darbe dayanımı, sıkıştırma, aşınma direnci ve ısıl iletkenlik testleri yapılmıştır. Hazırlanan örnekler üzerinde yukarıda belirtilen testleri yaptıktan sonra, hazırlanan ve liflerle takviye edilmiş numunenin özelliklerinin çoğunun, piyasada bulunan ticari kalemlerin özelliklerinden daha iyi olduğu bulunmuştur. 7,9,10 ve 11 numaralı numuneler, mekanik özelliklerin test sonuçları ticari fren balatalarının özelliklerinden çok daha iyi olduğundan, balata yapımı için en uygun olanlardır.

Anahtar kelimeler: Sürtünme, Aşınma, Polimer Kompozitler, Sertlik, Darbe, Sıkıştırma.

ABSTRACT

ANALYSIS OF POLYMERIC COMPOSITE MATERIALS FOR FRICTIONAL WEAR RESISTANCE PURPOSES

MAJEED, Badeea Khudhair Majeed,
M.S., Mechanical Engineering, Altınbaş University,
Supervisor:Asst.Prof. Suleyman Basturk

Date: June/ 2019
Pages: 100

This research is about manufactured brake pads from a polymeric composite material composed of domestic materials available in the market and cheaper. The unsaturated polyester is used as the basic material for the prepared samples. Add the fillers such as the Styrene Butadiene Rubber (SBR) and Montmorolonite Clay and the other filler that is cheap and available in the market to prepare the samples. In additions, the Kevlar fibers, the nylon, and the steel is used as reinforcing materials for these samples for reinforcement percent from 10%-25% in order to improve the mechanical properties. The samples were prepared from these materials and tested the mechanical and physical feature of these sample; and the compared the test result with the commercial pads available in the market. The hardness test of Shore D, resistance of Impact, compression, resistance of Wear and thermal conductivity tests have been carried out. After doing above mentioned tests on the prepared samples, it is found that most of the feature of the prepared sample and that which, reinforced by fibers are better than the feature of commercial pads available in the market. The samples that are numbered 7,9,10 and 11 are the most suitable ones for making pads since the test results of mechanical features were much better than the features of the commercial brake pads.

Keywords: Friction, Wear, Polymer Composites, hardness, impact, compression.

TABLE OF CONTENTS

Pages

LIST OF TABLES

Pages

LIST OF FIGURES

LIST OF ABBREVIATIONS

PMCs : Polymer Matrix Composites

CMCs : Ceramic Matrix Composites

MMCs : Metal Matrix Composites

GF : Glass Fiber

NF : Nylon Fiber

SF : Steel Fiber

PANF : Poly-Acrylo-Nitril-Fiber

CF : Carbon Fiber

CEF : Cellulose Fiber

E : Epoxy resin

SR : Synthetic Rubber

HMT : Hexamethelne Tetramine

SBR : Styrene Butadiene Rubber

T_g : Glass Transition Temperature

ASTM : American Society for Testing Material

I.S : Impact Strength

μ : Coefficient of friction

K : Thermal Conductivity

Wr : Wear rate

v_f : Volume of fiber

v_c : Volume of composite

1. INTRODUCTION

The industrial development and rapid technology that has taken place in the world have stimulated the researchers to find multi-use materials with high engineering and structural specifications according to the requirements of use due to the renewed human tendency towards a luxurious life. Since its appearance on earth, man has been interested in forming and modifying materials in order to obtain useful innovations. By studying the properties of engineering materials (metals, ceramics, polymers) of hardness, durability, thermal and electrical conductivity, corrosion resistance and plasticity, the researchers observed a difference in the properties of these materials [1,2]. For example, polymers are lightweight and resistant to oxidation, transparency and the ability to manufacture complex shapes and non-tolerances, high temperatures and high strength (higher than 400 °C). Ceramic materials are characterized by high temperature, thermal and electrical insulation, high hardness and high compressibility, but also brittleness, spelling, fracture, and non-impact shock and stress [3]. Metals are characterized by their high ability to withstand the loads, resistance, durability and non-resistance to weather conditions being oxidized [4].

Therefore, these materials may be suitable for use in a particular field and unsuitable for use in another field. Many technology and modern industries require materials with a combination of unusual properties (high shock, light weight and resistance to different environmental conditions) so that they are economical and suitable for industrial purposes and their engineering applications, and this was a motive to find the so-called composite materials [5].

Since 1960, there has been an increase in the need for a material that has high resistance, durability and light weight at the same time as in the field of space and transport for such materials. This requires an effort to research extensively in the field of composite materials by studying the properties of materials and knowledge such as their correlation with each other and their ratios, which in turn led to the emergence of types of composite materials [8,9].

Composite polymers are the best types for their high mechanical properties relative to density as well as their ease of manufacture.

The expansion of polymer-based composites is attributed to several reasons, the most important are being [10,11].

1- The possibility of its formation in different shapes and sizes.

2 - Do not rust and corrode.

3. Good resistance to chemicals and moisture.

4. Light weight and high durability.

5. Good electrical insulation.

For reinforcement materials, different forms, including Particles, Fillers, Flakes, or Fibers are taken. The matrix is often reinforced by fiber, because the fibers have better properties than other types.

In this research, the brake pads will be manufactured from polymeric composite materials, where unsaturated polyester is the base material and fibers are added such as Kevlar fibers, nylon fibers and steel fibers for reinforcement, add the fillers such as the Styrene Butadiene Rubber (SBR) and Montmorolonite Clay and the other filler that is cheap and available in the market to prepare the samples. Tests are then carried out on samples produced, such as Shore hardness test, compression test, impact resistance test, wear rate test and thermal conductivity test. The results of the samples are compared with the specifications of the commercial brake pads available in the local market and the selection of the samples most suitable for the manufacture of the brake pads.

1.1 LITERATURE REVIEW

In 2003, W. Gregory Sawyer and Praveen Bhimaraj a studied on the friction and wear behavior of Polytetrafluoroethylene (PTFE) filled with alumina nanoparticles as follows:
1. A compound of solid lubricants was prepared by pressing and casting the PTFE and small alumina particles.

2. In this composite the friction is greater than the composite without fillers.

3. The wear resistance of the composite increases with the increase in the percentage of filler [12].

In 2004, Jang studied the effect of mineral fibers on the friction performance of the composite materials used in the manufacture of braking pads, using three types of mineral fiber (Al fiber, Steel fiber, Cu fiber) and found better wearing resistance in the composite material containing Al fiber followed Composite material containing Cu fiber and then composite material containing Steel Fiber) [13].

In 2004, Chand and Hashmi developed asbestos-free brake pads they concluded that asbestos-free friction materials could be developed by substituting asbestos fibers with appropriate support. There is also a clear effect of wear and tear on the amount of added mineral fillers and fiberglass additives, it has become possible to use material for the manufacture of asbestos-free pads as well as in friction fields [14].

In 2004, Bigwe studied the effect of various organic fibers on the friction specification, using four different types of organic fibers:

1- Aramid fiber (AF).
2- Ploy- Acrylo-Nitrile (PAN).
3- Carbon fiber (CF).
4- Cellulose fiber (SF).

The compound material containing Aramid fiber has higher wear resistance than the rest, and PAN fibers and carbon fiber also help to improve wear resistance while SF did not improve wear resistance [15].

In 2005, Jang studied the effect of brake pads components on friction specifications and concluded the following:

The coefficient of friction at moderate temperatures depends on the hardness of the components of the pad as the coefficient of friction increases with the increase of phenol resin and MgO and decreases in decreases of potassium tetanate, copper, conia and rubber. Resistance to decay depends strongly on the thermal stability of the components of the pad. The wear resistance improves when the Zirconia and phenol ratios increase.

In general, the physical properties of the friction materials affect the friction characteristics, the body and the thermal stability of the pad components strongly affect friction performance [16].

In 2005, Zhang studied the effect of various fillers such as silica oxide on the sliding wear of the composite materials and concluded that reducing the particle size of the filler minutes improves the wear resistance. This was observed in the composite material containing minutes of filler (1-3 Vol%). This effect allows the use of these composite materials in higher wear conditions under higher pressure and higher slippage speed, as well as the distribution of these filler grains affects the wear properties [17].

In 2006, Lino studied the teripological behavior of polymeric materials. Where used Epoxy resin (E) as a base material and aluminum particles were used as fillers. Carbon fiber (CF) and glass fiber (GF) were used as reinforcing materials. Test on four mixtures.

1. E = Epoxy resin only.

2. EA = Epoxy resin + Al filler.

3. EAC = Epoxy resin + Al filler + carbon fiber.

4. EAG = Epoxy resin + Al filler + glass fiber.

After the test, it was concluded that the composite polymeric material containing epoxy resin as a base material and Al particles as a filler and glass fiber as a reinforcing material has the highest wear resistance and the best tripological behavior of the remaining materials [18].

In 2006, the researcher Rakowski studied the friction properties of a compound polymer. Thromosite polymer was used as a base material and used mineral fillers. It was found that increasing the percentage of metal fillers leads to increased electrical conductivity of the material, which increases the wear resistance and the friction properties of the material depends on the particle size for fillers [19].

In 2006, Qiao used powder rubber to manufacture braking pads and test the effect of using powder rubbers on friction properties. SBR was used in the manufacture the pads and in various sizes. The use of powder rubber improved the friction properties for the pads [20].

In 2006, Findik studied the frictional properties of some of the composite material from phenol proposed for car brakes. The researcher used powders for various materials, including perlite, copper and aluminum oxide, in addition to phenol and compared the results with previous fiber-reinforced samples. It was concluded that wear increased when powder particles were larger compared to samples containing small particles so the small particles are better. There is also heard the sound in the non-fiber reinforced pads because of the heterogeneous perlite. Compared with the fiber-reinforced samples, the previous samples reinforced with Kevlar fibers have wear resistance were better compared to the current samples in this study, although some samples had a wear resistance to fiber-reinforced samples and the hardness values of the current samples were lower compared with the fiber-reinforced samples [21].

In 2007, Shojae studied the thermal conductivity of composite friction materials used in the manufacture of brake pads for vehicles, using several types of filler (Al-chips, Al_2O_3). He concluded that thermal conductivity increases by increasing quantity of fillers and reaching higher value when using Al-chips as a filler in frictional composite materials [22].

In 2007, Mimaroglu studied the friction performance and wear of pure polymer materials and fiberglass reinforced polymers. Polyamide and polyetherimide PEI were used as base materials and glass fiber (GFR) as a reinforcing and three mixtures were tested:

1- PEI
2- PEI + 20% GFR.
3- PA + 30% GFR

It was found that the material resulting from (PEI + 20% GFR) has a friction coefficient (0.13-0.74) and a wear rate of (10-5 - 10-5) and that (PEI + 20% GFR) has high wear resistance when friction with steel disc and disc friction made of (CFR% 30 + PA) [23].

In 2008, Jang studied the effect of phenol on the tropology properties of brake friction material. It was found that the hardness, compressibility and porosity change with the change in the amount of added phenol and that the hardness decreases linearly with compressibility and porosity. The friction coefficient at moderate temperatures (at 100 ° C) increases with increased phenol, while wear resistance increases with the increase in the amount of phenol added, while the noise produced during the braking process decreases with the increase of phenol [24].

In 2012, Ayman A. Aly studied on the composite materials with polymers basic material with low friction and low wear resistance by adding small filler particles. Improved mechanical properties such as fatigue resistance, increased friction coefficient, hardness, tensile strength and corrosion resistance. Different types of polymer are used such as PEEK, PMMA, PTEE and epoxy. The fillers are used such as Si_3N_4, ZrO_2, CuO, SiO_2, Sic, ZnO, Al_2O_3 and TiO_2 [25].

In 2015, Juliana R Souza, Ruthilene CL Silva and Lai´s V Silva studied the tribological behavior of the P/GF composite using the P/GF wastes as a filler and then fill them with calcium carbonate as a filler. Where it was found that the integration of the composite with P/GF wastes is more useful from calcium carbonate in relation to friction and corrosion resistance [26].

In 2016, Adeyemi, I. Olabisi, Nuhu, A. Ademoh studied the use of a mixture of mixed agricultural wastes (cocoa bean husks, corn husks, palm kernel shells) as a filler with epoxy resins and after the production of the samples and testing them to determine their physical and mechanical properties were obtained positive results compared with the commercial braking pads where it was found that decreased corrosion resistance and friction While tensile strength and compressive strength are increasing[27].

In 2017, Wisdom and Abraham have developed asbestos-free brake pads where he used corn husks as a filler alternative of asbestos because the asbestos was a carcinogen. Corn husks were grinded into very small particles ranging from 100-200 micrometers. Then mixing in the different ratio of corn husks, silicon carbide and fixed percentages of graphite, steel dust and resin were mixed. The results showed that the braking pads produced using corn husk were of high compressive strength, high hardness, high porosity and low corrosion. The results obtained were compared with commercial braking pads and found that corn husk can be used to produce asbestos-free braking pads [28].

In 2017, K Ramanathan, P. Saravanakumar, S. Ramkumar, P. Pravin Kumar and S.R. Surender studied use lemon peel powder in asbestos-free braking pads. Lemon peel is dried by sunlight at 32 °C for 240 hours and then grind softy. Two samples were produced with different percentages of lemon peel, aluminum oxide and iron oxide using hand molding technique. Epoxy resins were used as a base material and mixed with epoxy resin in the rate of 1:4. A 30 mm and 25 mm steel mold was used. After testing on both samples, it was found that lemon peel powder can be used in the manufacture of braking pads effectively [29].

In 2017, Dinesh Shinde and K. N. Mistry studied on asbestos and asbestos-free braking pads and studying its mechanical properties. Some testing of organic waste from farms such as banana husks to replace asbestos was tested. After the test, it was found that all other non-asbestos materials have more friction coefficient which is desirable in braking pads. So these materials can replace asbestos in the manufacture of braking pads [30].

In this research, the brake pads will be manufactured from polymeric composite materials, where unsaturated polyester is the base material and fibers are added such as Kevlar fibers, nylon fibers and steel fibers for reinforcement, add the fillers such as the Styrene Butadiene Rubber (SBR) and Montmorolonite Clay and the other filler that is cheap and available in the market to prepare the samples. Tests are then carried out on samples produced, such as Shore hardness test, compression test, impact resistance test, wear rate test and thermal conductivity test. The results of the samples are compared with the specifications of the commercial brake pads available in the local market and the selection of the samples most suitable for the manufacture of the brake pads.

2. THEORETICAL ASPECTS

2.1 INTRODUCTION

The composite materials have emerged as a result of industrial and technical development and to meet the increasing need for new materials with special specifications and alternative interference to other engineering materials. Thus, composite materials of various kinds have occupied an advanced position in industrial applications since their first appearance. As a major member of the composite materials group, the polymer basis is particularly important in many applications depending on the properties of the base polymer as well as the properties of the reinforcement material.

Polymer composite materials have been widely used in the manufacture of friction braking systems for many vehicles because they have good properties such as good friction performance, long life, low braking noise and light weight [31].

2.2 POLYMER

It is sometimes called the macromolecule, as a molecule of a chemical compound that is represented by a high molecular weight (10 million). The molecule in the form of a series of rings is a molecule of a simple compound that is interconnected with Covalent bonds. The monomer is a simple chemical compound with a small molecular weight. The part of this compound is characterized by a special structure that can interact with another part of the same type or with another part of another compound and under conditions suitable for polymer chain formation [32, 33].

The repetitive structural unit is the one that is repeated along the polymer part chain and is placed in parentheses. Note the following equation (2.1).

$$n\,(CH_2 = CH_2) \qquad\qquad [-CH_2 - CH_2-]n$$

$$\text{Polyethylene} \qquad\qquad \text{Ethylene} \qquad\qquad (2.1)$$

$$\text{(Polymer)} \qquad\qquad \text{(monomer)}$$

Polymerization grade represents the number of repeating structural units in the polymer fraction series and is expressed by the number (n), which is placed under the arc that contains the repeated structural unit. The higher the polymerization of a polymer, the greater its molecular weight [4,34].

2.2.1 Classification of Polymers

Polymers are classified according to their technological properties and scientific uses into the following categories:

2.2.1.1 Thermoplastic

These polymers are the result of the interaction of monomers, which have two active groups on the ends of their molecules, such as ethylene. Polymers belonging to this class have longitudinal growth (in only one dimension). Sometimes, some side branches of the chain occur. These polymers remain mainly extended in two dimensions rather than in a third dimension, because the branches are not intertwined with other branches of the chain (Figure 2.1).

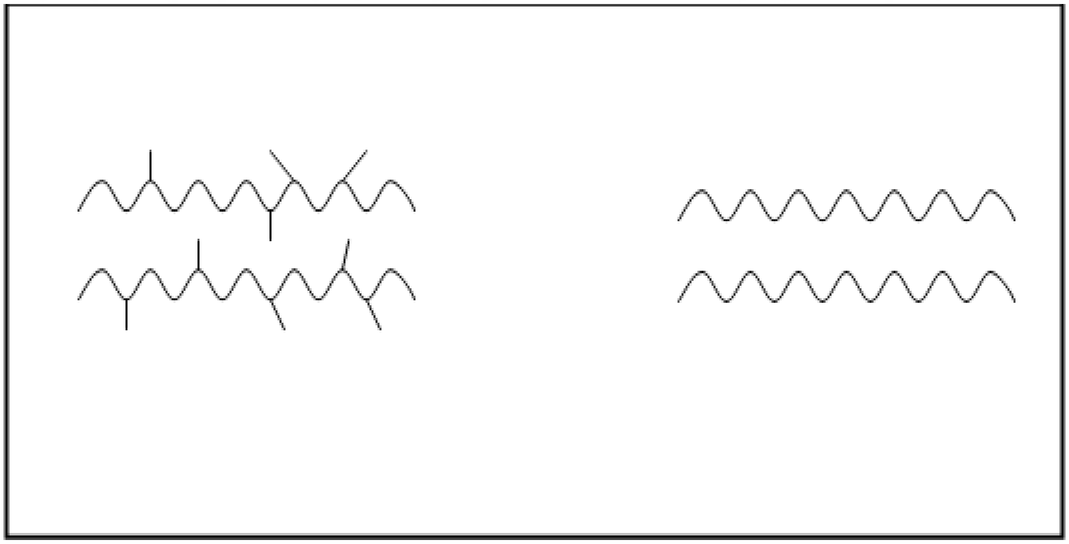


Figure 2.1: The growth of polymer chains.

Because of the polymer's longitudinal extension only, the adjacent chains are associated with natural secondary attractions (not covalent). Therefore, when heating these polymers, thermal energy overcomes the weak natural forces of attraction at a low temperature that does not cause damage to the polymer. As a result of the loss of the force of attraction, the polymer chains slip on each other. These linear polymers are then melted and liquefied, so these long polymers are classified as thermoplastic polymers or thermoplastic. They are the basis of all polymers used in the plastics and fiber industries figure 2.2 shows the effect of temperature on the mechanical properties of the thermoplastic, whose sequences are randomly or semi-crystalline [37, 34].

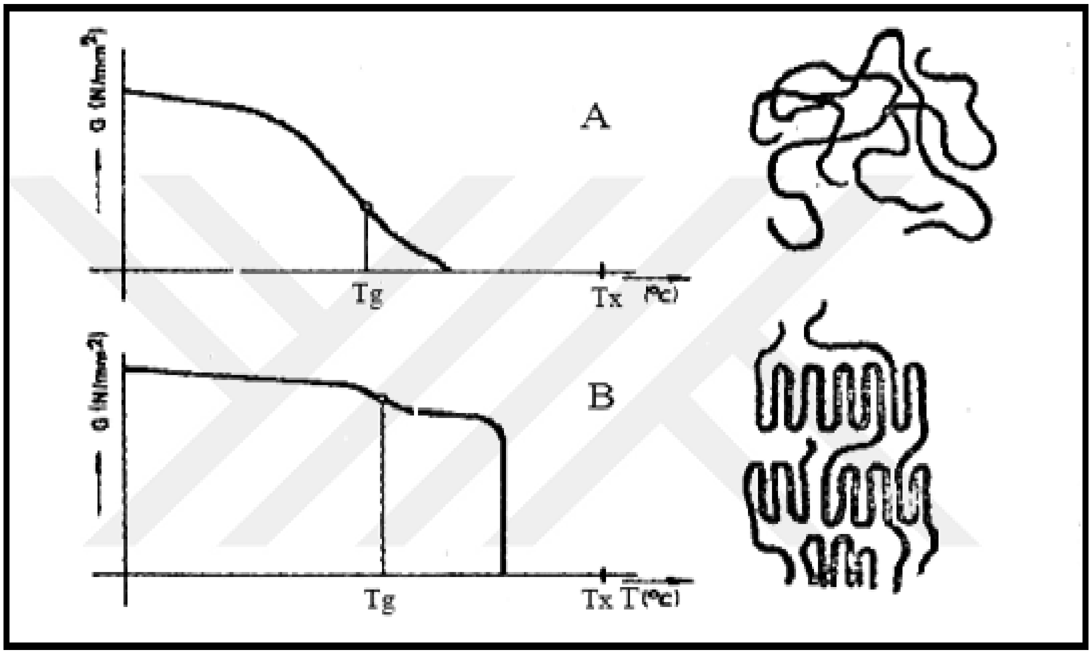


Figure 2.2: Effect of temperature on the mechanical properties of thermoplastic.

2.2.1.2 Thermosets

These polymers undergo chemical changes when heated. These polymers become heat-treated, insoluble, non-fusion, and a poor conductor of heat and electricity. The chains are bonded together by strong chemical bonds that cannot be easily broken. Therefore, these materials cannot be remodeled when exposed to a certain temperature. As the temperature increases, they will be bramble and decompose, that is, they are not susceptible to the temperature below the decomposition temperature. It is characterized by low density, high electrical insulation properties, high thermal insulation, high stiffness and stronger. Examples of this type are phenol, formaldehyde, epoxy and unsaturated polyester [38] (Figure 2.3).

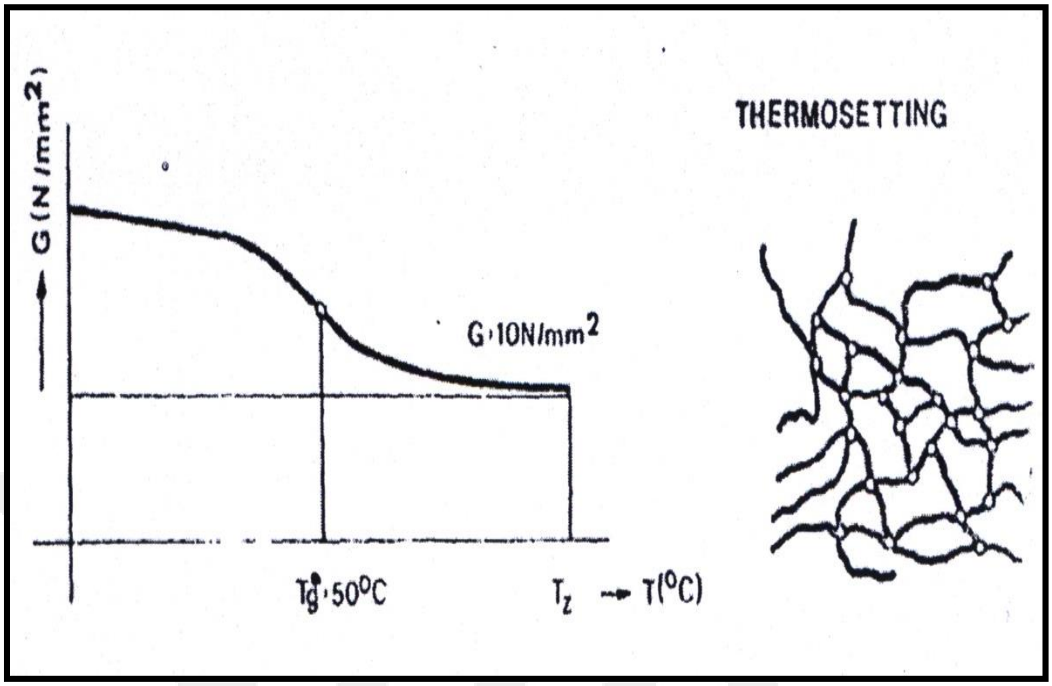


Figure 2.3: The effect of temperature on the mechanical properties of thermoset.

2.2.1.3 Elastomer

They are continuous but they have fewer branches and their chains are movable even at low temperatures (specific flow occurs at low temperature). Therefore, it is clear that these materials have a little modulus of Elasticity, the degree of glass transformation is less than zero and the difference between plastic and elastomer is large in extensibility. [40, 42] (Figure 2.4).

ASTM defines elastomers as polymers that can at room temperature be at least twice as long as their original length (within the elasticity limit) and with the removal of the force, it will return to its original length [32, 36].

Elastomers have two properties:

1. The glass transformation degree (Tg) has a lower temperature than its use.

2. Its molecules are highly interrelated [31].

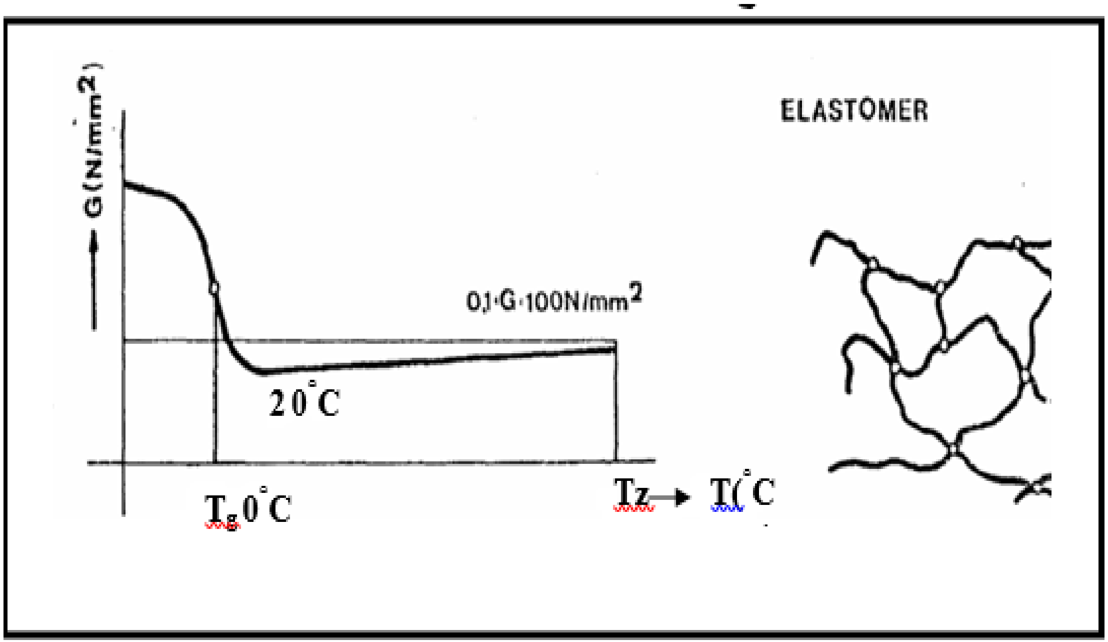
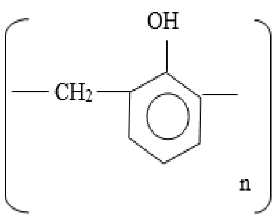
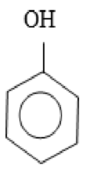


Figure 2.4: The effect of temperature on the mechanical properties of elastomer where G represents mechanical properties [27].

2.3 NOVOLAK

Phenol-Formaldehyde Polymer is one of the oldest resins used historically and is only preceded by cellulose nitrate polymer. It was obtained 30 years before the beginning of the 20th century. The method of preparation is phenolic reaction with formaldehyde to give intensive compounds and the catalyst used is either acid or base. The nature of the resin produced depends on the type of catalyst and the molecular ratios between the reactors (phenol and formaldehyde) [39,40]. The chemical composition of phenol, formaldehyde and novolak is (2.2):





(2.2)

Novolak CH_2O formaldehyde phenol

Interaction is done in several steps:

2.3.1 Methylol Formation

They are additional compounds and this is done in place of ortho and para of the gasoline ring in the phenolic compound. These products are made up under acidic or alkaline conditions and are considered as substitutes for the following polymerization process.

2.3.2 Preparation of Novolak

When adding an auxiliary factor such as acid with a molecular ratio of formaldehyde to phenol, methyllol condenses with phenol first to form daihydroxyl phenyl methane. When condensation continues, methylene bonds are formed between gasoline rings and give polymers known as the novolack. The molecular weight reaches more than 10,000 and expresses about 10 methyl groups. These polymers, then do not react alone to form the grid in three directions. To achieve this, more formaldehyde is added [31].

2.3.3 Characteristics of Novolak

The novolak is a thermostat that has a molecular weight of (500- 3000), which is solid at room temperature. The novolak content of nitrogen is (3.6% - 4.2%). The density of novolak is (1.3 g $/cm^3$) and has solubility in acetone, ethanol and ethyl acetate [23].

2.3.4 Uses of Novolak

1. Used in pressure casting processes to final forms and much. Resin is used in the production of radio vessels and televisions. This resin has excellent properties for heat resistance and electrical insulation.

2. Often used as fillers such as sawdust, short cotton fibers and glass fibers to improve polymer properties. These improved polymers are used in conical missile heads, where the high friction, temperature results in phenol-formaldehyde resin becoming a carbon polymer. This polymer is therefore a coarse insulating layer to protect the front of the missile.

3. Used as lining or covering material on a paper or wood basis. These materials are poured into wood by making Formica sheets.

4. Adhesive in many industrial purposes [40].

2.3.5 Novolak Solidifier (HMT)

The effect of resin (novolak) in mechanical properties is through crosslinking events and the tangles can be induced by adding Hexamethylene tetramine (HMT), is a solid material with a high melting point (3000 ^{o}C) that has a solid composition consisting of formaldehyde and ammonia reaction. The HMT degradation by heat to formaldehyde and ammonia. Ammonia is flying this can be seen through bad smell. Formaldehyde reacts with novolak and giving an increase in hardness, density, viscosity, tensile strength, increased dimensional stability, increased resistance to chemicals, reduce moisture absorption and reduced combustion ability, Figure (2.5) shows HMT installation. The tangent between the resin and HMT is obtained by forming an asymmetric bridge [6,40,41].

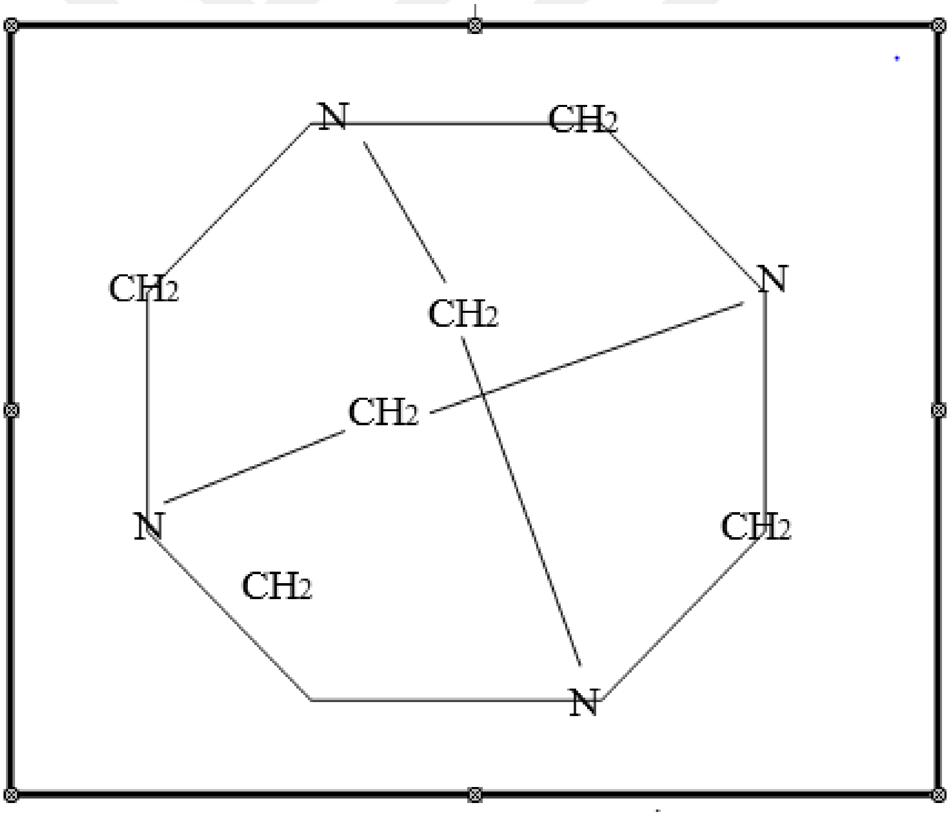


Figure 2.5: Installation HMT.

2.4 TYPES OF RUBBER

There are several types of rubber, but we will mention the most important things we used in our research.

2.4.1 Synthetic Rubber (SBR)

The SBR is produced extensively by polymerization of both solvents and emulsions. Emulsion polymerization occurs at hot temperatures of 50 °C or cold at 5 °C depending on the system of manufacture. Both rubber compounds are considered to be oil compounds, where they contain 50% of the petroleum material. The composition of the oil in this rubber improves some properties, including the ease of mixing with other materials without losing the physical properties of rubber. Synthetic rubber, originally produced by polymerization of emulsifiers by the thermal method, is difficult to mold or knead, such as natural rubber. It is difficult to mix it with other materials and does not maintain all its physical properties. Therefore, the thermal treatment of rubber and the presence of oil improve these properties and support thermal treatments.

The synthetic rubber produced by emulsion polymerization and the cold method has several properties, including higher molecular weight and the narrow distribution of the molecular weight. It is treated as a "high resistance" to friction, wear and high tensile strength compared to hot rubber, but the high molecular weight in cold rubber makes it difficult to treat it with oil compounds. Rubber, made by polymerization solutions, can be manufactured according to the specifications of the existing polymer structure and its properties are better than the rubber produced by polymerization of emulsions, as random copolymers lead to narrow distribution of molecular weight and the chain branches are less brightly colored than emulsified rubber, Rubbers are equal in tensile strength and elongation.

This rubber is characterized by high friction resistance and resistance to the formation of cracks, as well as high thermal resistance compared to natural rubber in addition to it is easy to mold and form compared to natural rubber, is one of the most common rubber used in the manufacture of tires, especially the contact with the ground, Foam Products, Electrical Wire Packaging and Belts Manufacturing [39, 43, 44].

2.4.2 Recycled Rubber (Reclaim)

The use of rubber has been of interest to scientists since the early years of the rubber industry, so in the year (1853) devised a special method of manufacturing Crumb, a term that is called rubber vulcanized and powder into very small and dry pieces. Where the scraper is cooled and grinded to granules of similar sizes, the use of rubber mills helps to reduce the cost, in addition to it helps in the formation and even if the addition of a large amount, it is possible not to change the physical properties and improve the conditions of vulcanization also [44].

2.4.2.1 The process of producing the reclaim

In the past, several methods were used for the production of reclaim, including acid process (Mitchell 1881), which was used in the United States of America and also used the Alkali process using caustic soda (Marks 1899). Where it was used to increase SBR production In 1955, the Heulral process, which used zinc chloride (Cutter 1913) where threads and fibers must be removed in modern processes or at least destroyed. Crumb in the old methods was treated with high pressure steam with a suitable chemical factor [44, 45].

2.4.2.2 Types of reclaim

Whole Tire Reclaim

It is one of the types that is produced in large quantities and the first quality of it is made from the whole tire about 40% hydrocarbon rubber and the remaining 60% contains a quantity of carbon black and a small amount of mineral filler and softeners.

Tire Tread Reclaim

It is produced from scraping the outer layer and touching the ground in the tires. It does not require the removal of the fibers and can be manufactured into car reclaim and tractors reclaim.

Butyl Reclaim

The products manufactured from EPDM, MQ, IR, BR, CR, NBR also have reclaim but one type is economically important. The method of the boiler uses butyl extracts from the internal tubes, Reclaim Butyl has good physiological properties and can be vulcanize by the system of sulfur vulcanization [44].

2.4.2.3 Properties of reclaim rubber

Because the reclaim rubber contains a large amount of mechanical work during manufacturing and contains all the fillers that share the original product, the mixing process containing all the reclaim rubber is generally faster and less thermoplastic and is affected by continuous handling and lower thermoplastic properties as the overall shape changes during handling and the process of vulcanization steam the desired property in products such as hoses and air-resistant products is to reduce swelling in the process of extrusion and shrinkage during cladding to a minimum using reclaim rubber has excellent lifetime properties. On the other side, the tensile strength, elasticity, and abrasion resistance are reduced when the reclaim ratio increases in tires. Rectal rubber can be strengthened by adding carbon blacks in a similar manner to polymers. [44].

2.5 COMPOSITE MATERIALS

The composite material is a mixture consisting of two or more materials of different specifications, combining these materials to produce a composition of desirable specifications, and may be either organic or inorganic, metal (natural or synthetic) [38].

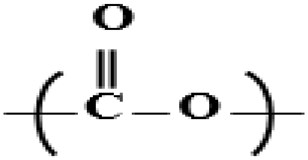
2.6 COMPONENTS OF COMPOSITE MATERIALS

2.6.1 Matrix

It is either polymers, metals or ceramics. It is usually the most important element in composites because many of the properties of these composites are prevalent for this base material [10]. The plastic substrates have the highest tensile strength and more advanced calibration properties in the case of the technical industry, lower raw material and manufacturing costs and allow for more flexible and efficient design as thermal insulators. This can be counted as the bonding material that binds the reinforcement material or primary phase, which strengthens the secondary phase of the reinforcing material [46,47].

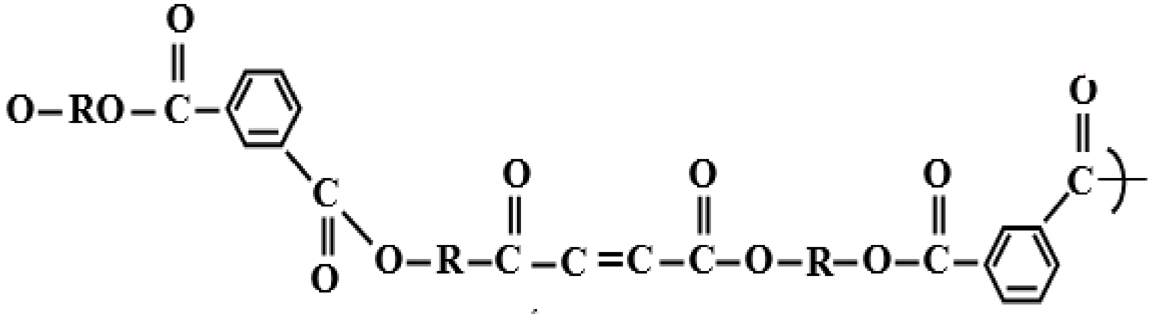
2.6.1.1 Unsaturated polyester resin

These are materials that are intertwined with additional independent polymerization through the effective double bonds found in the main structure of polyester. This type is known as unsaturated polyesters. Unsaturated polyester resins consist of polymer chains. These chains dissolve in active organic solvents and appropriate accelerators and adjuvants are added to the polyester when in the liquid state so that a chemical reaction occurs in the cold state without pressure then a solid installation is made. Furthermore, polyester resins can be defined as industrial polymers in which the repetitive units that make up the molecular chain are of the type ester and its chemical formula are (2.3) [48]:



$$-\!\left(\overset{\overset{O}{\|}}{C}-O\right)\!- \qquad (2.3)$$

The polystyrene resin is produced from the reaction of its raw materials (saturated and unsaturated alkaline acid) with dihydroxyl alcohol (claycol) and the displacement of the water between the acid and the claycol. The ester will be linked to a ring shape and the result will consist of a long chain of molecules containing alternating units of acid and claycol as in the following chemical equation (2.4):



(2.4)

After completion of the reaction and adding the monomer or solvent that represent the tangle factor such as styrene with the inhibitor, the mixture is cooled to room temperature and the content of the styrene is added up to (40-30%) [4, 49].

2.6.1.2 General applications of unsaturated polystyrene resins

Unsaturated polyesters are used in many general areas such as construction, marine industries, electrical, industrial, transportation, and health. In the field of construction, it is used to obtain roofs, air-conditioning corridors, partitions, window and door frames, swimming pools, industrial marble panels and water-resistant coatings. In the furniture they are used for the manufacture the decor and decoration panels, furniture parts, frames, school desks, blackboards, interior parts of semi-transparent windows, and is used in the manufacture of recreational boats, fish storage boxes, fishing boats, containers, car bodies, interior lining of subway cars, caravans, Radar screens, racing car helmets, parts of aircraft and helicopters, electrical insulators, industrial tanks, fishing hooks and various tools [38, 48, 51].

2.6.2 Reinforcements

These materials are added to the matrix to improve most properties and maintain desired qualities in it [5]. If the reinforcement material improves the strength of the matrix, it must be stronger and more solid than the matrix and must modify the mechanical failure sufficiently and in an improved manner. The requirement of high strength and high rigidity involves little or no ductility, relative brittle behavior. The reinforcement materials may be ceramic, metal or plastic, characterized by high hardness and resistance and vary in different forms. They may be fibers, minutes, scraps, sheets or fillings [38, 51].

2.6.2.1 Fibers

Fibers are regular filament structures with distinct properties that reinforce the matrix in the composite material. Fibers bear the bulk of the load on the composite material. The properties of composite material reinforced by the fibers are closely related to fiber properties (fiber diameter, volumetric fracture, fiber length, fibrous composition) and fibers can be metallic, ceramic, or plastic, whether natural or synthetic [5, 36].

2.7 SYNTHETIC FIBERS

Synthetic fibers are the most common types of fiber used for their good and desirable specifications. The origin of synthetic fibers is due to the natural materials. They are treated and manufactured to improve their properties and their formation according to demand and includes:

2.7.1 Glass Fiber

Fiberglass is one of the most common materials used for reinforced resins in general, since these fibers are relatively easy to manufacture and form, and have "good" properties with relatively low economic cost. Glass fibers are made by mixing the glass and dry components of silica, limestone, Boric Acid, and some materials such as clay, coal and Feldspar. And then smelted in special tanks in an oven whose temperature-depends on the type of mixture and usually at a rate of (1260 °C). The molten glass is then passed into a container made from platinum and circular with a perforated end to allow the molten to pass through and then pulled and treated. Therefore, long, thin glass fibers are obtained on a fast-moving roller, Rotation pulley whenever the diameter of the fiber glass product is less, so that a fiber can be produced with a diameter of about 2 microns using a rotation speed of 500-300 m / s [52]. It is then cooled and spun to obtain the final forms of glass fibers. Chemical surfaces of these fibers are usually chemically treated to be bonded with resinous materials. They are treated with chemicals called linking coefficients [5].

2.7.1.1 Glass fiber properties

1 - Glass fiber characterized a relatively high durability and when added to the middle of the plastic will produce a composite material with very high quality resistance.

2 - It does not burn and does not help combustion due to its chemical nature and has a high melting point.

3 - Do not absorb moisture and therefore not exposed to swelling or expansion.

4 - Glass fibers are characterized by a low linear expansion coefficient and thermal conductivity and are low relative to the matrix.

5 - Glass fibers are not electrically conductive and therefore are ideal insulators [53].

2.7.1.2 Glass fiber types

Glass fiber is produced in different types, each of them has distinctive properties. This is done depending on the nature of the oxides involved in the industry and that the basic oxide of all types is silica SiO_2. Other oxides are added according to the specifications required for glass fiber and the most important types of glass fiber [58]:

Glass Fiber Type E

It is a symbol of electrical properties, which is the most common form due to its ease and smooth pulling during manufacturing, its high durability, stiffness and properties in electrical insulation and resistance to weather conditions.

Glass Fiber Type C

It is a symbol of corrosion resistance. It has more chemical resistance than type E, but it is less durable and more expensive.

Glass Fiber Type S

It is a symbol of the properties of resistance, which is the most expensive among other types, but it is characterized by having a high elasticity coefficient, and great resistance to high temperatures. This type of use is limited, especially as it is used in the aircraft industry, as its high performance justifies its additional cost. In addition, glass fiber has an efficiency of visible light and has a softness of about 850 °C, as well as having the property of symmetry (equal properties in all directions). For example, the coefficient of thermal expansion in the axial direction is similar in value to the diameter direction [10, 54].

Table 2.1: The most important types of glass fibers and their chemical composition [54].

	E glass (%)	C glass (%)	S glass (%)
SiO_2	52.4	64.4	64.4
$Al_2O_3.Fe_2O_3$	14.4	4.1	25.0
CaO	17.2	13	-
MgO	4.6	3.3	10.3
$Na_2O.K_2O$	0.8	9.6	0.3
Ba_2O_3	10.6	4.7	-
BaO	-	0.9	-

2.7.2 Nylon Fibers

Nylon Fibers are made from Polyamides that are heat-compliance polymers made from amino acids or lactams or from the intensification of binary acids with binary amines. They were first produced by the Dupont company in 1930 and by Carothers. These polymers are commonly known as Nylon, which was launched by Dupont and later developed the distinctive numbers of different nylon types such as Nylon 6 and Nylon 66. These numbers have special significance. If the number is as single as 4 or 8, this indicates the preparation of nylon from one raw material is the amino acid containing four or eight carbon atoms as shown in the following reaction (2.5) and (2.6) [2]:

$$H_2N-(CH_2)_3-COOH \rightarrow (-NH-(CH_2)_3-CO-) + H_2O \tag{2.5}$$

Nylon 4

$$H_2N-(CH_2)_7-COOH \rightarrow (-NH-(CH_2)_7-CO-) + H_2O \tag{2.6}$$

Nylon 8

If the number is double, such as 88 or triple such as 106, this indicates the preparation of nylon from two materials where the left number indicates the number of carbon atoms in the binary acid and the right on the number of carbon atoms in the binary amino and as shown in the following reactions (2.7) and (2.8) [2]:

$$H_2N-(CH_2)_8-NH_2 + HOOC-(CH_2)_6-COOH \rightarrow (-CO-(CH_2)_6-CONH-(CH_2)_8-NH-) + H_2O \tag{2.7}$$

$$H_2N-(CH_2)_6-NH_2 + HOOC-(CH_2)_8-COOH \rightarrow (-CO-(CH_2)_8-CONH-(CH_2)_6-NH-) + H_2O \tag{2.8}$$

Polyamide fibers are characterized by their ability to form hydrogen bonds through the amide aggregates, which helps in the regularization and stacking of molecules, giving them high crystallization ability and thus obtaining good properties of polymer fibers. Nylon fibers have good mechanical properties and their thermal resistance is also good, ranging from (200 °C to 250 °C) and has suitable glass transition grades ranging from (40 °C to 70 °C). Polyamides have a humidity ratio of between (2-4%) at External relative humidity (65%) [2].

2.7.3 Kevlar Fiber

It is a polymer (p-phenyleneterephthalamide) which is produced by the condensation polymerization of the composites:

- Terephthaloyl Chloride

- P-phenylene diamine

These fibers are in the form of an intermittent linear polymer chain due to the bonding of the benzene rings [55]. This is what then explains in Figure (2-6).

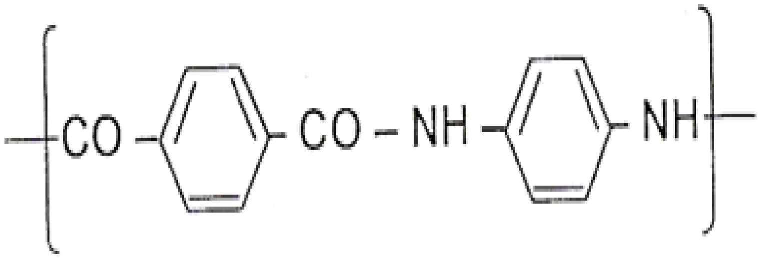


Figure 2.6: The chemical composition of Kevlar fibers [10].

2.7.4 Steel Fiber

Many metals are used in wires and high resistance levels and include beryllium wires, tungsten wires and iron wires which are characterized by high strength and low density. Iron wire is a reinforcing material and is the most commonly used for concrete than polymers and metals. It is also used for tire reinforcement. Iron wire is very fine with a diameter (0.1µm) with high resistance, 5 Gpa [56], and its components are described in the Table 2.2:

Table 2.2: The components of steel fibers [56].

C %	Mn %	Si %	S %	(S + P) %	P %	Ni %	Cr %
0.72	0.6	0.2	0.05	0.08 Combined	0.05	0.1	0.05

Because these fibers are used for tires as they do not adhesion to the frame until they are coated with brass and are composed of copper (67-61%) and zinc is (33-39%).This is because the strength of Cu adhesion with rubber is very high as well as the brass while the strength of adhesion to the iron fibers with the rubber is very weak Note that the strength of Cu adhesion with iron fibers is very high so the brass will have a very high adhesion strength with iron fibers [40].

2.8 CLASSIFICATION OF COMPOSITE MATERIAL

Most composite materials developed to date have been specifically designed to improve mechanical properties such as strength, stiffness and high temperature performance, and the ownership of composite materials for a specific property is due to the nature of the material or the type of reinforcement and therefore the composite materials can be classified according to the nature of the base material or the type of reinforcement used [57].

2.8.1 Nature of The Base Material

According to the base material, composite materials can be classified into three types:

2.8.1.1 Metal matrix composites (MMCs)

Metallic composite materials are made in several ways, including plasma spraying of the base material on the appropriate fiber layers [58] and through the fusion of the base material, mixing it with the reinforcement phase, using the metallic base in a powdered form and mixing it with the reinforcement phase and then compressing and coating them together [59]. It is characterized by being efficient at high temperatures and has high cutting resistance and high compressive resulting from the strength and durability of the base material and the bonding of the good interface. Examples of these compositions include the use of boron fibers in a base of aluminum and carbon fiber in a base of magnesium, copper and aluminum. Although applications of composite material with a metallic basis are not widespread compared to supported plastics, there are cases where these composites are more appropriate than others [59]. Its applications are used in piston heads in automatics motors blades for gas turbine fans.

2.8.1.2 Ceramic matrix composites (CMCs)

These composites were used for a long time in the form of reinforced concrete and by the low tensile strength of these composites, their applications were limited to compressive structures and the ceramic was very resistant to oxidation at high temperatures and resistance to creep. These materials would be well suited for use in heat-exposed parts of aircraft turbines. Examples of this type of compound are silicon (Si_3Ni_4) reinforced by carbide silicon (SiC) and glass composite reinforced by carbon fiber [56, 58].

2.8.1.3 Polymer matrix composites (PMCs)

One of the common composite materials where polymer is a base material containing fiber (the reinforced material) that can be made of glass or carbon. Either the base material can be thermostat, thromboplastic, elastomer. These materials are the best species because of its high mechanical properties in proportion to the density and easy to manufacture [5, 51, 57].

Polymer composite materials are one of the most common types of materials. The interest in these materials has increased significantly in recent years. It has been used in many applications for the manufacture of molds and aircraft parts because of the light weight and durability that led to on low-cost ideal materials and low energy consumption. As a result, resins have gained widespread fame as a modern material entering the industry and several alternatives to traditional materials and their alloys in many uses [56, 60].

Polymer composites contain excellent properties at room temperature and at low cost. The base material contains various thermally rigid polymers, and later thermoplastic polymers reinforced by fiberglass, carbon, boron, organic fiber and polymeric base material are often reinforced by fibers due to its properties and features different from other reinforcing materials [4, 58].

Because polymers are characterized by low density, but lack strength and durability, so some other components are added to the homogeneous polymer and the formation of polymers composite in order to change some of its properties and the introduction of new qualities, including [57]:

1 – Increase polymer stiffness, strength and dimensional stability.

2 - Increase the shock resistance of the polymer.

3 - Improved tensile and elasticity.

4 - Increase the Distortion Temperature.

5 - Reduce polymer permeability to gases and liquids.

6 - Reduce the cost of polymer.

Finally, the expansion of polymer-based composites is attributed to several reasons, the most important of which are [5,10]:

1 - The possibility of forming in different shapes and sizes.

2 - Do not rust and corrode.

3 - Good resistance to chemicals and moisture.

4 - Light weight and high durability.

5 - Good electrical insulation.

The characteristics of the polymer-based composites are determined by the characteristics of polymer additives, the nature of their minutes, the nature of the overlap between the polymer and the additives, and the weighted proportion of additives that play a large role in determining the mechanical properties of polymeric composite materials (Table 2.3).

Table 2.3: The types of composite material and by type of base material [56].

Matrix Type	Common Designation	Matrix Properties			Most Effective Reinforcement
		Stiffness	Strength	Ductility	
Polymer	PMC	Low (0.2 to 0.5) Msi	Low (0.2to 5) Ksi	low(<2%)	Continuous Fiber
Metal	MMC	Moderate (6to16) Msi	High (10to150) Ksi	High (20%)	Continuous and Discontinuous fiber
Ceramic	CMC	High (20to80) Ksi	High (20to80) Ksi	Low (<١%)	Discontinuous fiber Or Whisker and particulate

2.8.2 The nature of The Reinforcement Phase

The classification on the basis of the reinforcement phase, it depends primarily on the geometry of reinforcement and is divided into four groups:

2.8.2.1 Composite materials reinforced by dispersion

This type of composite material is produced by the distribution of very small particles of materials that may be metallic, nonmetal or oxides of materials such as aluminum oxide (Al_2O_3) in the base material. The distribution of these particles is random, so the material resistance and other properties are identical in all directions. The size of the particles between (0.1 - 0.01μm), where these particles block or resist the movement of dislocations at high temperatures, where these particles are distributed in the base material and works to increase the flexibility because it reduces the stresses placed on the base material [4]. Reinforcement in this way is where the base material is which gives strength to the composite material [10, 61].

2.8.2.2 Composite materials reinforced by particles

These are composite, particles materials, but they are different from the dispersive material reinforced by dispersion in terms of the size of the particles, which is greater than (1 μm) and the percentage of the fractional fractions may reach 90% in the composite material high addition [48, 62]. The reinforcement occurs when the granules act as a barrier to deformation of the base material because of its high strength and non-distortion during the loading and be on several types and forms, including spherical, cortical, needle and thread where the particles increase the stiffness and increase resistance to shock and improve the coefficient of thermal expansion of the base material [63]. That the final properties of the composite material, reinforced by particles are affected by several factors, some of which are related to the properties of the base material and other to the properties of the reinforcing material, such as the type, size and shape of the particles and their distribution within the base material. The strength of the bond between the base material and the particles is a great effect in determining the properties of the final composite material [60, 62]. The use of this type of reinforcement is in the manufacture of heads of cutting pens [63] particles prevent distortions in the base material in addition to the bear of the stresses placed on the composite material due to its large size as shown in the figure 2.7 below [40].

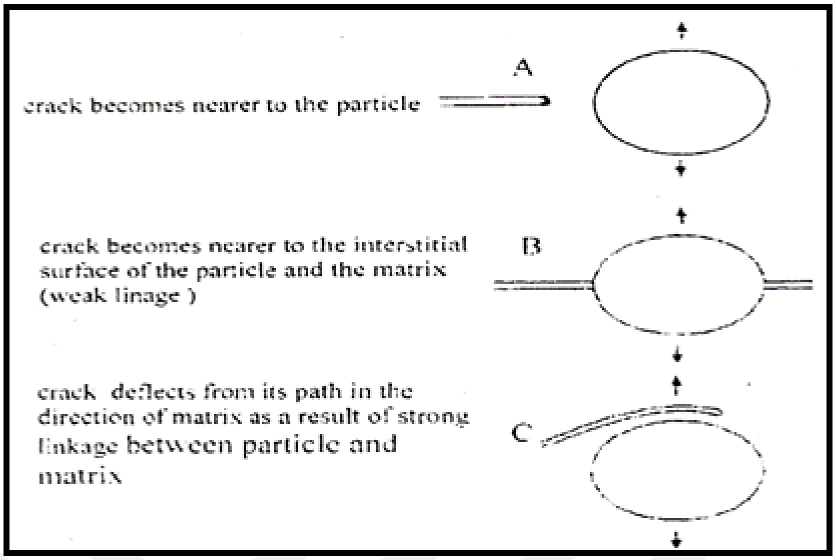


Figure 2.7: The path of the crack in the reinforced composite material in particles under tensile strength [40].

2.8.2.3 Composite materials reinforced by fibers

In this type of composite material, the base material shall be reinforced by fiber in the form of long fibers or short fibers, and the fibers shall be in the same direction or randomly in base material [7, 64]. The fibers shall have mechanical resistance and high elasticity coefficient while the base material is metallic and does not affect in the fiber. The importance of fiber reinforcement is to increase the resistance of the shock and improve the mechanical properties in general. There are many types of fiber, such as polymeric fibers such as Kevlar fibers and nylon or metal fibers such as copper wire or ceramic fibers such as glass fiber [10, 65]. In this type of composite material, the fibers are immersed in the floor that is either continuous or non-continuous and its volume fraction is not more than 70% [66], and is called fiber reinforced materials (FRM) [63]. Fiber must have high resistance and elasticity to produce materials with high resistance relative to weight. The important difference between composite materials reinforced with fiber and those reinforced by dispersion is that fibers with high elasticity factor bear almost all loaded. The base material of most composite materials that are reinforced by fibers can be a ceramic, polymer or alloy material that can represent fiber at the same time. Fibers are largely responsible for revolutionizing composite materials to improve their properties according to use (Figure 2.8) [48, 66].

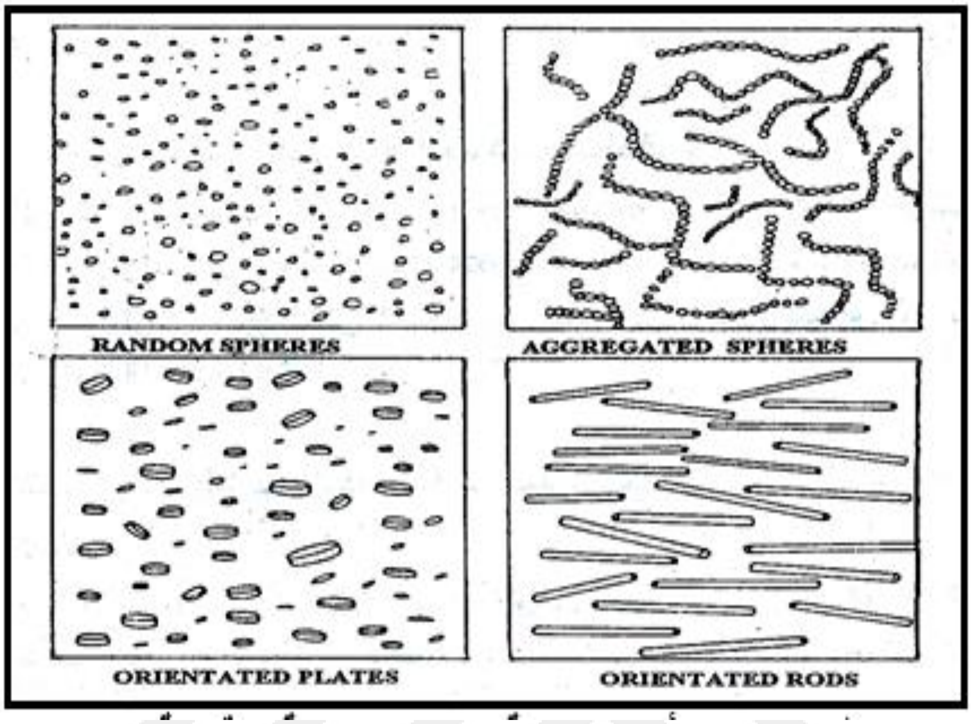


Figure 2.8: Different types of reinforcing particulate materials [48].

2.8.2.4 Composite laminated materials

In this type, a reinforcement material is used in layers of different materials and consists of two or more layers placed one above the other. The laminate compositions consist of several layers of the same material, such as fibrous plastic laminate, but with different orientation of fibers in the alternate layers or consisting of layers of different materials linked together as polymer and metal [56, 58, 59]. The use of this type of composite material allows designers to use the best properties of each layer to obtain composite materials with good qualities, including corrosion resistance, wear resistance, durability, light weight, stiffness and many qualities that can be controlled by reinforcement of various materials [7, 37].

2.9 HYBRID COMPOSITE MATERIALS

They represent new systems of composite that connect two or more different types of fiber in the same middle material, or one fiber type in two different bases linked to one system, and the definition extends to multiple reinforcement materials. The objective is to collect different types of base materials or reinforcement materials or both to obtain a good balance of properties in general and the possibility of collecting in a single material [10], and to build a new material that preserves the benefits of its base materials and makes them suitable for the requirements that are designed for them. Cost, weight and behavior after failure and avoid the production of composite materials hybrid weaker than its basic materials (Figure 2.9) [4, 48, 65].

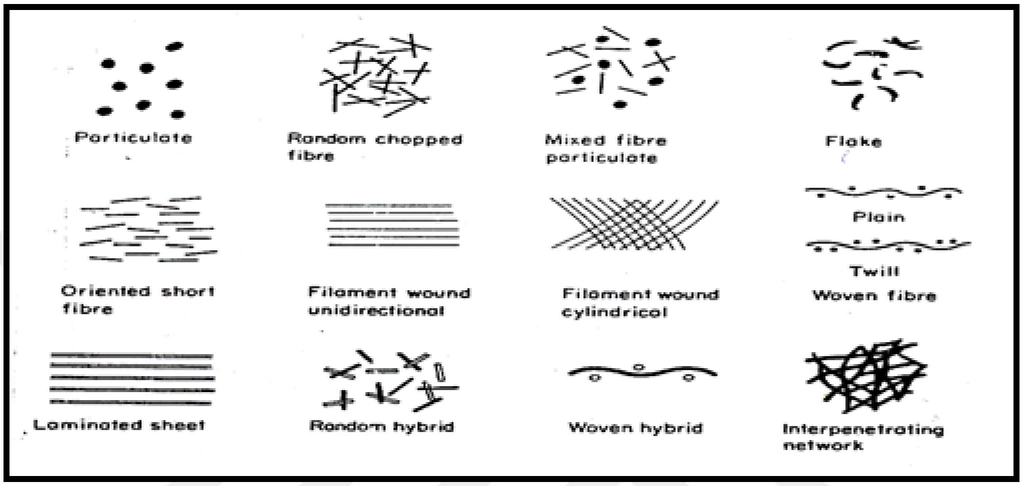


Figure 2.9: Different forms of unilateralism and hybrid reinforcement materials [48].

2.9.1 Types of Hybrid Composite Materials

There are many types of hybrid composites that are described according to the method of mixing their components into:

1. Sandwich Hybrids: represent one material is placed between two layers of another material.

2. Laminate Hybrids: It consists of layers of two or more composites. Unidirectional compositions, in which the layers are exchanged for two or more materials and are regularly collected.

3. Intimately Mixed Hybrids: The fibers are mixed randomly by ensuring that there is no specific concentration of any type of material, which is used in our research.

4. Interplay Hybrids: Includes a strand of two or more fibers mixed regularly or randomly [10].

2.9.2 The Importance of Hybrid Fiber Composite Materials

Their importance lies in the possibility of obtaining a wide range of physical and mechanical properties by optimizing the testing of fiber used and appropriate volume fraction [10]. The ease of manufacturing some hybrid composite materials using two types from reinforcement material such as the use of fillings with fibers to achieve the required properties [60]. It is good to control the cost of composite materials, since cost is an important factor in heavy and large industries. Hybrid composite materials give designers a greater chance of obtaining lightweight, low-cost materials and good mechanical properties [67].

2.10 FACTORS INFLUENCING THE BEHAVIOR OF FIBER COMPOSITE

2.10.1 Direction of Fiber

Shows the importance of this effect for the symmetry of composite materials and affects their mechanical and physical properties [66]. The following figure shows the effect of fiber orientation on tensile strength, where different tensile strength values are observed with the angle difference between fibers (tensile direction) [66, 68].

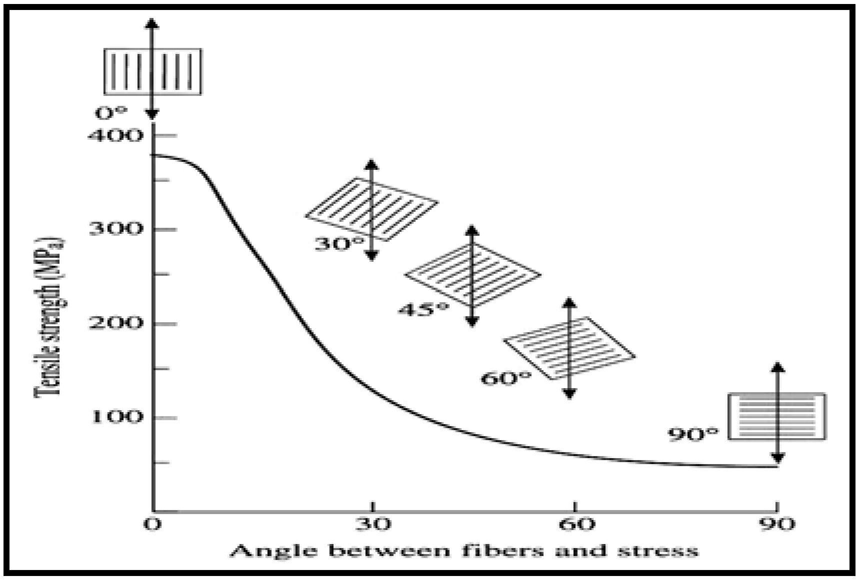


Figure 2.10: The effect of fiber orientation on the tensile strength of a composite polymer-reinforced material with continuous fibers [68].

2.10.2 Length of the Fiber

The mechanical properties of fiber reinforced materials also depend on the degree to which the load is transferred from the base material to the fibers [69]. When the composite material, reinforced with non-continuous fibers are subjected to tensile stress, the short fibers in the base material will suffer tension due to shear stress at the interface Which operate on the fiber surfaces and these shear stresses are of great value at the ends of the fibers that are experiencing greater tension. The value of the shear stresses begins to decline as we approach the center of the fiber. The tensile stresses in the fibers are zero at the ends and begin to increase with decreasing shear stress as shown in Figure 2.11 [56].

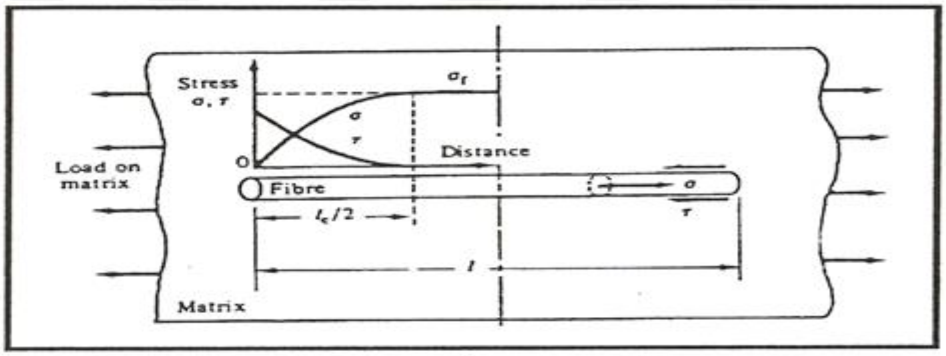


Figure 2.11: The distribution of tensile stress and shear stress to the surface along the short fibrous surface in the base material [56].

2.10.3 Geometric Shape and Cross Sectional Area

The properties of the geometric shape of the fiber are related to the shape and area of the cross section, where they can be circular, pyramidal, flat or square, as in Figure 12.2 which shows different shapes of the cross-sectional area of the fibers, where they can be circular, square or triangular. The ring or cylindrical fiber called Dumbbell is the shape of the preferred cross-sectional area. The stresses are not concentrated on the end of the fiber and thus help to distribute the stresses [70].

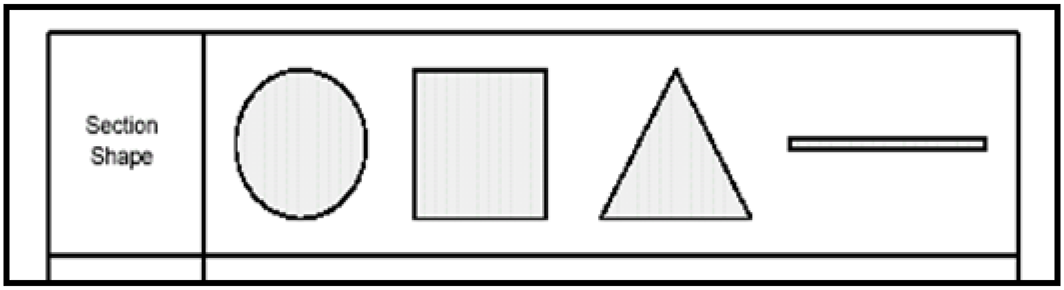


Figure 2.12: The different shapes of cross-sectional area of fibers [70].

2.10.4 Volume Fraction (VF)

Volume fraction affects the mechanical properties of composite materials [42]. When the volume fraction is increased, the tensile strength increases and continues to increase to a reach to a Peak value and then begins to decrease as a result of the low resin efficiency to absorb the fiber. The amount of fiber in the composite material is known as volume fraction (V_F), where the ratio between the volume of fibers (V_F) and the volume of composite material (Vc) [68]:

$$V_F = \frac{Vf}{Vc} \tag{2.9}$$

Where (V_F) is the volume fraction of fiber and (V_f) the volume of fiber (V_c) the size of composite material.

2.10.5 The Link Between Fiber and the Base Material

The ideal conditions for applications of composite materials reinforced with continuous fibers are that the bond is strong between the fiber and the base material. This is necessary for the transfer of pregnancy from the base material to the fiber. Without this interconnection, the composite material system does not function [66].

2.10.6 Properties of the Base Material

Base material should be strong, durable and ductile, to transfer the load to the fibers and prevent the growth of the cracking during the composite material [68].

2.11 BRAKE PADS

Since 1970, asbestos fibers have gained sufficient knowledge in the manufacture of braking pads, and although the prevention of asbestos fibers was recognized in the United States until 1989, the ban was introduced until 1991. There was a serious demand by companies for the difficulty of finding alternatives to asbestos and the applications available to it. While recent applications of asbestos fibers have been banned, according to the International Occupational Health and Commonwealth Safety Committee of the Commonwealth of Australia, the use of asbestos fibers has been banned from 31 January 2002 in Australia. According to the United States Air and Pure Water Association of the United States of America, asbestos fibers were banned in 1985 in European countries. However, asbestos fibers have been banned only since 1 January 2005 [71].

Consumer demand and the warning of health organizations prompted intensive research and continuous development of brake pads at an early stage in 1990 to find suitable substitutes for asbestos fibers. In the past decade of development, friction material manufacturers have changed their opinion of asbestos. So the market was surprised by different friction pads each of which has an unparalleled combination. When the driver presses on the brake lever, the braking fluid will effectively push the pistons in the brake system, which in turn will press the brake pad opposite the rotor. This act of braking slows down the rotary motion of the disc and thus slows down the rear axle of the vehicle. Thus, the kinetic energy of the vehicle becomes almost thermal energy, which is generated mainly between the pads and the rotor. The specifications for which brake pads are manufactured shall apply to the following [72].

1. Maintain high and sufficient friction coefficient with brake disk.

2. The absence of fractions due to breakage and disintegration by selecting suitable friction coefficient with the brake disk at high temperature.

3. Select a stable friction coefficient compatible with the brake disk.

2.11.1 Types of Brake Pads

There are three types of braking pads according to the materials used in manufacturing:

2.11.1.1 Organic brake pads

It is a composite material consisting of one or more bonding resins, rock silk fibers and a combination of additives to improve friction, improve wear resistance, reduce cost, facilitate material handling, color change, and so on. Currently, there are three sub-categories of resin-bonded friction materials:

* Asbestos, also called organic brake lining.

* Non-Rocky Organic Materials (NAO), using a variety of fibers.

* Semi-metallic materials, any metal materials bonded resinous.

The semi-metallic lining consists of about 65% iron and 10-25% rock wool and the rest is a powdered iron (porous) as weight ratios. The graphite is usually "synthetic" about 15%, while the heat resistant bond is about 10%. It should be noted that non-asbestos organic materials have evolved steadily and expanded into several groups. These compositions now indicate that they contain no metal, not rock. Over 1200 different fiber types and reinforcement materials have been selected up to this moment. Due to the possibility of mixing different fibers and other reinforcing materials within a single compound, it is possible to produce structures with remarkable properties. The most commonly used fibers are glass fibers (including intermittent glass fibers, mineral wool and many associated species), metal, ceramic, cellulose, and other organic forms reinforce materials. The bonding resins used in organic friction materials are typically polymers and are often phenolic, and their liquid and powder forms are used. Resins and other components of the organic brake liner that are carbonization and lubricating breakdown products, depending on the conditions of use, may give us no suitable behavior for friction and wear. The wear properties of the friction material can be enhanced by the efficient selection of its inorganic components. In general, additives for lining can improve their resistance, thermal expansion and absorption of heat, friction and other properties. The impact of additives on friction cannot be accurately predicted due to the limited understanding of the fundamentals of this relationship. The successful combination of brake lining is obtained by trial and error in conjunction with the prior experience and the designer's intelligence as the composition consists of countless materials [73].

2.11.1.2 Metallic brake pads

It can be mainly copper or iron. Which is treated with solid state mechanics (formation, thermal treatment, etc.) with organic additives improve performance. For example, solid-state reinforced bronze and padding used in race cars and high-speed train brakes. The graphite reinforced iron is used in some heavy duty brakes for both cylindrical and dislike types as well as for cylindrical brakes found in transport vehicles [73].

2.11.1.3 Carbonic brake pads

Such as the carbon-carbon pads used for commercial and military aircraft, and some of which are used in modern racing cars where critical weight, good performance and cost requirements are secondary. Carbon-carbon pads constituents from carbon fibers (graphite fibers), which are well bonded to the carbon base, organic resins that are either designed at high temperatures or where steam is deposited thermally, are used to form good bonding of these compounds. After lengthy treatment, it is necessary to obtain pure carbonate as a friction material with very poor permeability. Carbon-carbon compounds can be replaced with steel, iron for suitable applications at 2000 ° C temperatures with high quality heat to obtain a weight reduction of 85% [73].

2.11.2 Friction Materials Used in Manufacturing Brake Pads

The friction material used in the brake industry plays an important role in influencing brake performance. Friction materials have evolved for more than 100 years. The first generation of friction materials ensures asbestos materials that contain large proportions of asbestos. The second generation of friction materials is asbestos-free materials containing organic materials. Asbestos was replaced with organic materials. The last generation of Friction materials include the introduction of ceramic friction materials with organic materials in the manufacture of braking pads, which contains several ceramic materials, which must achieve several demands, including stability in the coefficient of friction and low wear rate and thermal resistance [74] and brake pad usually consists of several components developed between the duration and the other in order to obtain better friction performance for these materials in general, there are more than ten components consisted of which braking pads included:

1. The binder, which includes phenolic resins, is often added to rubber and has a thermal stability and phenolic resins from heat-resistant polymers.

2. Materials reinforcement, which includes metal fibers, glass, carbon, Kevlar and ceramic fibers designed to achieve good mechanical resistance.

3. Fillers are added to reduce cost and facilitate the formation process and include several materials, including Mica as well as barium sulfide used as a filler.

4. Friction additives, it adds to control the friction properties and the rate of wear. Include solid lubricants such as graphite and other metal sulfate, which gives stability in the coefficient of friction where the graphite is considered a good lubricant, however, it is not used with phenol because the strength of the phenol and graphite bond is very weak, resulting in reduced mechanical properties. And also include abrasive these include metal oxides, which increase the coefficient of friction and reduce the rate of wear [15, 75].

2.12 Mechanical Properties and Tests

General and engineering uses of polymers depend largely on their good mechanical properties, especially their high strength and their ability to be distorted by the influence of different forces. This duplication of polymorphic properties arises from the nature of its composition. The presence of two types of forces, namely strong chemical bonds and secondary bonds between molecules, affect in one way or another their mechanical properties [56]. Mechanical properties generally describe the behavior of polymers and their compositions under influence forces. There are many methods by which these properties can be classified into three groups and as follows [76]:

1. Methods for examining the mechanical properties that describe the behavior of materials under the influence of static forces such as tensile, bending, compression, shear.

2. Methods for examining mechanical properties that describe the behavior of materials under the influence of moving forces such as impact, torsion and fatigue.

3. Methods for examining the mechanical properties that describe the behavior of materials under the influence of constant forces over time such as the creep.

2.12.1 Hardness Test

Hardness is one of the important surface mechanical properties that can be defined as the material's resistance for the stitches or plastic deformation. Surface hardness can be measured by measuring the friction resistance of the material, but the most common measurement of hardness is measuring the diameter of the impact on the surface of the material due to the penetration of a steel ball or object Pyramidal under the influence of a given pregnancy [76].

As the degree or depth of the stitches within the material is a measure of the material's ability to resist plastic deformation. Hardness testing is characterized by the fact that it does not require samples of standard dimensions, so it is a relatively low-cost test, and some important properties such as maximum tensile strength, wear resistance and other properties which can be predicted through the results of the hardness test [58]. The hardness is directly proportional to the tensile strength of a specific material, since high hardness materials have high tensile strength and are related to the following relationship [39]:

$$\text{Tensile Strength} = K^{o} * \text{Hardness} \tag{2.10}$$

Where K° is a constant for a particular material. There are several methods for measuring hardness, the most important of which is Brinell, Rockwell s test and Vickers' test.

2.12.2 Impact Test

When the material is exposed to a sudden load, it will behave differently from its behavior when exposed to a static load. The material may behave in the same way as when it is subjected to a static load (stress test, bending test). But when subjected to dynamic load may behave fragile behavior. Shock resistance can be obtained from the following relationship [1,48]:

$$I.S = \frac{Uc}{A} \tag{2.11}$$

Whereas:

I.S: Shock resistance to material (J / m^2).

Uc: Shock Power (J).

A: Area of the cross section of the sample (m^2).

2.12.3 Compression Test

The compression is defined as the maximum stress borne by rigid material under vertical pressure [61]. Compression strength is an important design factor in the manufacture of composite materials, since these materials are repeatedly subjected to bending curves and can then fail as a result of compression in compressive strength [38]. The compression strength depends heavily on the properties of the base material, the volume fractions of the composites and the method of testing. The properties of the base material are usually controlled by the pattern of failure, while the test method leads to inconsistencies and dispersion of recorded information. Most studies have shown that failure to resist compression depends on the way in which the load is applied. [66] Compression resistance can be calculated using the following equation:

$$\sigma = \frac{P}{A} \tag{2.12}$$

Where σ is the compression resistance (MPa), (P) is the maximum carrying loads (N) and (A) is the loading area (mm^2).

2.12.4 Wear Test

The simplest definition of wear is the loss of the material of one surface or both of the two surfaces when they are under relative movement. According to this mechanism, it is generally divided into: scrape, surface fatigue wear and tribochemical processes such as corrosive wear [77].

2.12.4.1 Types of wear

Surface Fatigue Wear

As is known of the mechanical behavior of materials under the influence of repeated mechanical stresses, changes may occur in the micro-structure of the materials due to the occurrence of mechanical failure, the same thing happens frequent friction loads, the phenomenon of fatigue surfaces that lead to the final generation of wear particles and these effects is a basic base for movement of stresses in or below surfaces without the need for direct physical contact of surfaces. The effects of wear are associated with repeated cyclic stress in the tangent rolling

[77,78]. As for wear the resulting from the fatigue, compared to other types of wear, it is necessary to break down due to fatigue, which is the loading of the surface metal, while other wears need physiologic contact. In addition to the load, even if the surfaces are separated by the oil membrane.

Abrasive Wear

The effect of abrasive occurs at the tangent site in the direction of physical contact between two surfaces where one of these surfaces is hard and the other is harder. It is the hard surface that causes roughness in the soft surface with plastic deformation of the soft surface occurring around the roughness sites generated by the hard surface. When the tangent moving is arranged or regularized, the harder surface will transport or remove the soft material. The size of the wear is related to the roughness or severity of the abrasive particles and the hardness of the abrasives. The following are the observed phenomena affecting the properties of materials in the case of abrasive wear [78]:

1. The pure metals in the non-plasticized state and the non-plasticized steels show a direct relationship between the relative wear resistance and the hardness of the diamond pyramid.

2. Nonmetallic materials and raw materials have a similar linear relationship between wear resistance and hardness.

3. For metal materials and raw materials - Hardened by plastic deformation, it was found that the relative wear resistance does not depend on the hardness resulting in cold forming. But depends on the amount of emotional solidification.

4. Thermal treatment for the installation of natural and hardened steel proves its resistance to abrasive wear.

An example of this type of wear is when loose particles are confined between sliding surfaces and particles of this type may be external such as sand grains or corrosion particles generated in the primary corrosion process. This type of wear can be reduced with high quality of the tangent surfaces, especially for the hard surface [79].

Adhesive Wear

The contact between two surfaces occurs between the values of the extrusions that are distorted by the effect of pregnancy. The nature of the adhesion between the extrusions changes with surface membranes, but after the start of the movement these membranes are relatively torn and the adhesion appears on a part of the contact surface. The size of this wear is proportional to the load as it is directly proportional to the sliding distance and vice versa with the hardness of the metal, especially pure metals. Adhesion alone does not result in the separation of the corrosive particles because the shear as a result of slipping, usually appears in the contact zone, and the wear particles are generated if the contact zone is stronger than the layers of the material beneath it so that a part of the surface material is separated when the slide continues [61, 77, 78].

Tribe Chemical Wear

This type depends on the impact of the environment or the surrounding circumstances and includes the following types:

Corrosive wear

A clean metal surface reacts to the environment. The membranes are contaminated and the rate of formation of such membranes is rapid at first and slows down when the thickness of the rust membranes increases, as in steel, and the adhesion of these membranes to the surfaces is weak. The itch removes these membranes, leaving a clean metal that once exposed to the environment again has new surface membranes removed again during the itching, so the material is constantly removed which wears off [73].

Oxidative wear

It appears when two objects slide and the slide is exposed to air movement in the atmosphere or oxygen contained in the cooling, as the oxide is formed on the surface and it is the one who suffers or bears wear. This case was first studied in 1942 by German scientist Dies on steel [51].

In most metals, the oxide is more solid than the metals themselves, so when oxidation of wear waste is hardness increases and the wear is increased, such as relatively soft aluminum metal while its oxide is very hard, it is used in the manufacture of grinding stones. The surface finish of the metal is very effective in changing the effective barriers that affect the oxidation ratio as well as the chemical compound of the oxidation. In addition, the time of the rupture of the oxide membrane depends on the strength of the adhesion and the effective stresses [77].

Erosion wear

Which is the most wear types distribution, and that the modern theories of erosion wear are based on the movement of particles cutting into the surface of wear. The material properties have an important effect on the relationship between the wear ratio and the collision or attack angle. In plastic materials, the deformation compounds for wear are very low and the highest wearable percentage can be seen in the area where the collision angle is low, while the fragile materials are stable, highest value is at angle 90°. This type of wear can occur if the shock between objects and materials involves a "flexible" interaction, and for minerals, these areas are not familiar [80].

2.12.4.2 Methods for wear measurement

Weighting Method

One of the simplest methods for measuring wear and summarizing this method is to calculate the rate of wear [80].

Mechanical Gauging Method

A typical micrometer with a design limit of 10^{-3} and a surface area of 10^{-2} is used. This method is used to measure wear in large volumes such as vehicle engine cylinders [73].

Measurement of Wear Using Radiotracers

It is a sophisticated method for measuring the wear and has more accuracy than the previous methods and is used for two types of studies, the first when the required wear is too small and less than what is measured in the previous methods the second is used when there is a need to know the properties and characteristics of the impact [73] and include:

Method of measurement of nuclear radiations

Where the radioactive material is placed on the surface of the non-radioactive material and then the process of sliding between them and then a quantity of radioactive material will be transferred to the non-radioactive material where the fixed surface is represented, then the quantity of the transferred material is measured by a counter and the counter is used when the minimum value of the quantity transferred to the limits of 10^{-9}grams [73].

Method of measurement, wear debris is non-adherent

In which the percentage of wear is determined by the lubrication, where one of the sliding parts is made radioactive and then controlled those radiations by a counter.

2.12.5 Coefficient of Friction

The friction coefficient can be defined by the first law of friction:

$$F = \mu.N \tag{2.13}$$

Where μ is the friction coefficient and is a constant fit between two different metals sliding relative into each other under the weather conditions. For example, the value of the friction coefficient for two similar hard steel surfaces is 0.5, and if he carries two surfaces of the graphite with a vertical force under standard conditions, the value of the friction coefficient is 0.1 and this value rises to 0.5 if the weather conditions are very dry [81]. The friction coefficient is calculated from the following equation:

$$\mu = F / N \tag{2.14}$$

The friction force is calculated by fixed the Loading System with the sample holder on the cantilever at its free end. This arm is a 20x20 mm² square section made of a CuZn alloy fixed near its end the strain gauge. The system and the holder are fixed in a way that affects the arm at maximum deviation at its free end (the contact area between the sample and the disc). This leads to maximum curvature in the place where the strain gauge is located. The friction force is calculated from the strain on the arm multiplied by a constant called the calibration constant of the arm as in the following equation:

$$F=K.\ \zeta \tag{2.15}$$

Where F friction force, K constant calibration and equal to 0.33 as in the following Figure 2.13, ζ the strain on the arm.

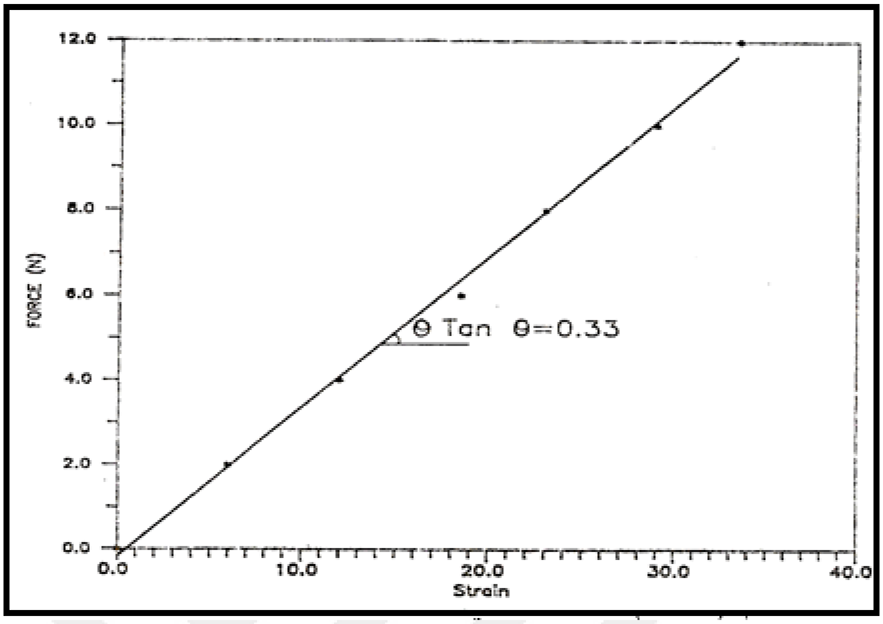


Figure 2.13: The relationship between force and strain to extract the constant calibration [81].

After calculating the friction force, the vertical force (N) is calculated through the weights defined by multiplying the weight by the acceleration of the ground, and then the coefficient of friction is calculated. The following are the steps to calculate the friction coefficient:

1. The meter is operated and left for half an hour after operation to reach stability.

2. We make the strain gauge zero at the starting moment.

3. The sample is placed inside the sample holder.

4. At the moment the test begins, static strain is recorded.

5. Strain is recorded at different intervals.

6. The friction force is then calculated by multiplying the calculated strain by the calibration constant [81].

2.12.6 Thermal Conductivity

The heat energy is transferred through the material in different ways depending on the state. In the solids, the conductivity is transferred as the energy moves due to the irritation of molecules from one location to another accompanied by a change in temperature. The mechanism varies depending on whether the solid is conductive or insulating, in conductive materials the heat travels through the material through the free electrons in the structure. In the case of insulating materials, free electrons are not present. Therefore, the heat is transmitted by different ways of elastic waves, resulting from the oscillation of molecules that transmit this oscillation to the molecules that are adjacent to it Together by bonds, thus the oscillation moves from the hot party to the cold party by forming elastic waves called photons [7,82]. Polymer materials are of poor heat conductivity and have a conductivity of (0.3 W.m^{-1} . K) or less while the thermal conductivity (K) of the copper is (400 W.m^{-1} . K). The thermal conductivity is a measure of the material's ability to conduct thermal conductivity known as the amount of heat transferred in a second divided by the temperature gradient [83]. In general, the methods of measuring thermal conductivity (K) vary depending on the type of materials and as follows:

1. Thermal conductivity of good thermal conductivity materials such as copper is measured using the Searls Method.

2. The thermal conductivity of low-conductivity materials is measured in the form of a disk such as plastic materials using the Lees Method. The model (S) is shown between two copper disks (A, B), the disc (B) touches the electric heater (H) as shown in the figure 2.14 [82, 84].

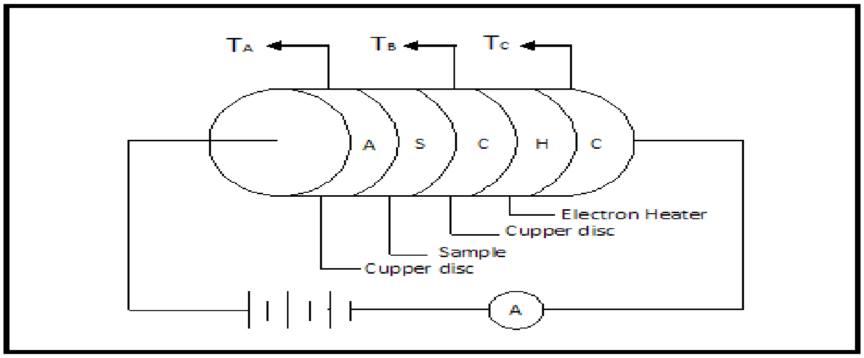


Figure 2.14: Thermal conductivity measurement scheme.

Depending on the calculation of the amount of heat passing through a sample of the material represented by the disk (S), the value of (k) is calculated from the following equation:

$$K[\frac{T_B - T_A}{d_S}] = e[T_A + \frac{2}{r}(d_A + \frac{1}{4}\ d_S)\ T_A + \frac{1}{2r}\, d_S\ T_B] \qquad (2.16)$$

Whereas: (e) represents the amount of heat energy passing through the unit of disk space per second ($w / m^2 . k$) Calculated from the following relationship:

$$I.V = \pi r^2 e(T_A + T_B) + 2\pi.r\, e[d_A . T_A + ds \frac{1}{2} (T_A + T_B) + dB.\, T_B + dc.\, T_C] \qquad (2.17)$$

Whereas:

(T_A, T_B, T_C) represents the temperature of the disk (ºC) (A, B, C) respectively.

d_A: Disk thickness A mm.

d_B: Disk thickness B mm.

d_C: Disk thickness C mm.

ds: thickness of sample mm.

r: radius of disk mm.

I: The current passes (Ampere).

V: processed voltages (Volt).

3. EXPERIMENTS

3.1 INTRODUCTION

This chapter covers the practical coverage of the research and includes the following:

The definition of the raw materials used in the preparation of the polymeric composite material, its main characteristics, general characteristics, how to prepare the samples, as well as the presentation of the drawings and pictures of the shapes and dimensions of these samples, with a comprehensive explanation of the devices used in conducting the tests conducted on the samples, namely hardness testing, shock testing, compression test, Wear, friction coefficient test, thermal conductivity test, and technical methods for conducting such tests.

3.2 MATERIALS USED

The materials used in the research are divided into:

1- Matrix material

2- Reinforcement materials

3- Fillers

4- Friction materials

3.2.1 Matrix Material

3.2.1.1 Unsaturated polystyrene resin

Unsaturated Polyester resin (UP) was used as a matrix material in the form of a viscous liquid at room temperature, a type of density thermosets is(1200Kg / m^3). Transform to the solid state when added the hardener (MEKP- Methyl- Ethyl Ketone Peroxide) in the form of a transparent liquid and added to the polystyrene resin unsaturated by 2 g from the hardener for each (100 g) of polystyrene resin Unsaturated at room temperature.

Unsaturated polystyrene resin is widely used in the industry for possessing many physical and mechanical properties. It is characterized by its dimensional stability, good interconnectivity with other materials as well as its ease of formation and low cost.

The duration of hardening of the resin used is 3 hours at room temperature, but this period varies depending on the amount of added crucifixion and laboratory conditions surrounding the experiment.

3.2.2 Reinforcement Materials

Three different types of reinforcing materials were used as fibers. These fibers were cut into short fibers with a length of about 5 mm and diameter is 0.96 mm.

3.2.2.1 Nylon66 fiber

In this research used nylon fibers 66, called polyamide fibers, were used to reinforce the base polymer materials. These fibers have good mechanical properties. These fibers are cut and homogenized with the base material.

3.2.2.2 Kevlar fiber

Also used in this research is the Kevlar fiber and its yellow color known to support polymeric materials. These fibers have good properties, especially when added with hard fibers such as steel fibers. These properties have good wear resistance and impact resistance at high temperatures.

3.2.2.3 Steel fiber

These fibers have been used in the Reinforcement with Kevlar fibers mainly for the latter to provide good properties of the resulting composite polymeric material as these fibers are characterized by solid fibers and good mechanical properties. The components of these fibers are mentioned in Chapter 2 and are the cheapest in addition to the good mechanical properties such as resistance and high durability with a 0.96 mm fiber diameter.

3.2.3 Fillers

A range of fillers was used to reduce the cost and to provide a "good" frictional performance and thermal stability as described in Chapter 2:

1- Rubber

2- Montmorolonite

3- Aluminum

3.2.3.1 Rubber

It is the SBR rubber, SBR is a synthetic rubber used in the form of very fine powder.

3.2.3.2 Montmorolonite

A kind of locally available and low cost clay, as it is grinded and added to a very fine powder.

3.2.3.3 Aluminum particle

Aluminum is used as the powder in the research. The aluminum is characterized by its ability to resist wear, and is characterized by light weight, so used in the manufacture of aircraft, and also has a high melting temperature.

3.2.4 Friction Materials

In this research friction materials are include:

1- Lubricants

2- Abrasive

3.2.4.1 Lubricants

The graphite is in the form of small particles and the graphite is considered a good lubricant so we used it in the research.

3.2.4.2Abrasive

It includes iron oxide (Fe_2O_3), aluminum oxide (Al_2O_3), silica oxide (SiO_2) and Magnesium oxide

(MgO). These materials are available locally and also powders and added to compound polymer dough to improve the frictional performance.

3.3 STANDARD SPECIFICATION FOR COMMERCIAL BRAKES

Samples of commercial braking pads available in the local market were taken and mechanical and physical tests were carried out. The results of the tests are shown in the Table 3.1.

Table 3.1: The specifications of the commercial braking pad.

Shore D Hardness	Impact resistance kJ/m^2	Wear rate* 10^{-6} (g/m)	Comprising strength MPa	Thermal conductive K W/m °C
70.8	6.26	2.12	48.38	0.293

The specifications required for brake pads should be as follows:

1 - Have high wear resistance and high friction coefficient when friction with braking disk.

2. It has good impact resistance as well as other mechanical properties such as high hardness and compressive strength.

3.4 PREPARATION OF SAMPLES

The samples are prepared according to the weight percentages shown in Table 3.2. The polyester resin is mixed with other powders such as rubber, aluminum, graphite, Montmorolonit clay, kevlar fiber, nylon fibber and other constituents of the samples to be prepared and mixed well and added the hardener for the polyester resin and cast in special molds by hand molding and leave for a full day until hardening of the sample.

To find the most hardness sample, we prepare samples 1, 2, 3 and 4 by changing the polyester ratio as shown in Table 3.2.

Table 3.2: The proportions of sample components 1, 2, 3 and 4.

	Components	Sample1 Weight %	Sample 2 Weight %	Sample 3 Weight %	Sample 4 Weight %
Filler	SBR Rubber	8	8	8	7
	Montmorolonit clay	5	4	3	2
	Aluminum particle	3	2	1	1
Matrix	Polyester Resin	60	65	70	75
Lubricants	Graphite	10	7	6	5
Abrasive	Fe_2O_3	2	2	1	1
	Al_2O_3	2	2	1	1
	SiO_2	1	1	1	1
	MgO	1	1	1	1
Reinforcements	Kevlar fiber	4	4	4	3
	Nylon66 Fiber	4	4	4	3

The hardness is tested for the samples prepared in the above table for the selection of a main sample that is characterized by good properties compared to the other samples and can be developed to improve it is the properties by fiber reinforcement. Based on the hardness test results of the samples prepared above, Sample 2 was selected as the main sample, they can be developed to improve their mechanical properties. These samples have been selected because they have high hardness compared to the rest of the samples as shown in the Table 3.3.

For the purpose of improving the mechanical properties of the selected sample, we add kevlar fibers and nylon fibers at different ratios in the first case. Then we add kevlar fibers and steel fibers in different ratios in the second case. Then we add kevlar fibers, nylon fibers and steel fiper in the third case.

Table 3.3: The hardness test result for the first four samples.

Samples	Hardness test results
Sample 1	75.4
Sample 2	77.2
Sample 3	76.1
Sample 4	72.3

The way this sample was developed is to consider this sample as one component and 100% to be added to different ratios of fibers ranging from 10%- 25% to improve their properties.

After considering the selected sample as one component 100% we add the kevlar fibers and nylon fibers with different ratio to the component for the purpose of improving the other mechanical properties and prepare the samples 5, 6 and 7 as shown in Table 3.4.

Table 3.4: The proportions of the components of the samples 5, 6 and 7.

Components%	Sample 5	Sample 6	Sample 7
Components	90	80	75
Kevlar fiber	5	10	12.5
Nylon fiber	5	10	12.5

Then added in the same way the kevlar fibers and the steel fibers to the component for the purpose of improving the mechanical properties with different ratio and prepare the samples 8, 9 and 10 as shown in Table 3.5.

Table 3.5: The proportions of the components of the samples 8, 9 and 10.

Component%	Sample 8	Sample 9	Sample 10
Component	90	80	75
Kevlar Fiber	5	10	12.5
Steel Fiber	5	10	12.5

Then add the three types of fibers the Kevlar fibers, nylon fibers and steel fibers to the component to prepare the sample 11 as shown in Table 3.6.

Table 3.6: The proportions of the components of the sample 11.

Component %	Sample 11
Component	85
Nylon Fiber	5
Kevlar Fiber	5
Steel Fiber	5

Using special molds, we prepare samples for each test. We prepare samples for hardness test, thermal conductivity test, impact test, wear rate test and compressibility test as shown in Figure 3.1.

Figure 3.1: The samples.

3.5 TESTS

we will carry out the test on the samples according to ASTM (American Society for testing materials). An American society for the testing of materials and the study of the mechanical and physical properties of materials according to the special criteria of the Society, and work on developing these properties of materials.

3.5.1 Compressive Test

The hydraulic press is shown in Figure 3.1 used to calculate the maximum compressive resistance of the samples. The standard sample is installed between the piston discs. When pressed the upper disc moves and the lower disc remains fixed. This causes the sample to compress until the fracture. For the purpose of calculating the shortest of the sample length during the test, a digital Vernier with a sensitivity of 0.01 mm was used so that it could move with the upper disc. It was possible to draw a stress-strain curve for the samples. The load was gradually raised on the sample with the standard dimensions until the sample failed. Maximum load is the value of maximum compressive strength.

Figure 3.2: Compression measurement device.

3.5.2 Hardness Test

The Shore (D) instrument used to measure the hardness of polymeric materials was used as shown in Figure 3.3. The sample is placed on the machine's table and pressed until the surface of the material touches the flat surface and then wait for three seconds after taking the value of hardness from the device gauge.

Figure 3.3: Hardness Measurement Device (Shore D).

3.5.3 Impact Test

The Impact test device shown in Fig 3.4 and using the Charpy Impact Test, the energy required for the breakage, has been calculated for the impact resistance of the material.

The machine consists of a pendulum with a hammer to break the samples, and the machine contains hammers of different sizes and capacities 2 J, 5 J, 30 J and 45 J respectively, so that the hammer can be replaced by another and according to the power required to break but the speed of the test is fixed 3.42 m / sec, the value of the cross section area of each sample is 50 mm^2.

The pendulum touches the other end of the pointer that moves on the scales of the broken power account installed on the instrument panel. At the start of the test, the pendulum is raised with the hammer to the maximum height so that it is installed properly by an installer located on the machine. The sample shall be placed on the place assigned to it, the energy meter is first zeroed, then the pendulum is released using the lever mounted on the scale and by a swing motion, the potential energy becomes kinetic energy when it hits the sample. Part of the sample is lost. The meter index reads the energy of the sample break. Impact resistance is calculated from the following relationship:

$$I.S=\frac{Uc}{A} \tag{3.1}$$

Where: - I.S: shock resistance to the material (J /m^2).

U_c : Shock energy (J).

A: The area of the cross section of the sample (m^2).

Figure 3.4: Measuring device of impact resistance.

3.5.4 Wear Test

A wear measuring device is used and is designed according to ASTM for the purpose of obtaining contact between the sample and the rotor disc under a vertical load bearing as shown in Fig.3.5. The machine consists of a constant speed drive of 950 RPM. The two-phase engine is the first stage in which the motor is moved by the pulley on which it is installed and the V-Belt conveyor belt to the center column with two rollers on it to receiving the movement and the other to transport it. The second stage involves moving from the center column to the stabilized column The disc, in addition, the device has a rectangular arm to the end of the holder to install the sample in which the diameter of the catcher 11 mm, where the use of a load of 6 kg with a distance of installation of 53 mm and for 10 minutes, number of turn per minute of the disc is 950 RPM.

The following law explains how to calculate the rate of wear [80]:

$$\mathrm{Wr} = \frac{\Delta w}{\mathrm{SD}} \tag{3.2}$$

$$\mathrm{SD} = 2\,\pi\,r\,n\,t \tag{3.3}$$

Wr: Rate of wear (g/m).

Δw : The difference in the weight of the sample before and after the test (g).

SD: Sliding distance (m).

t: Time per minute (min).

n: Number of turn per minute (RPM).

r: sliding distance (m).

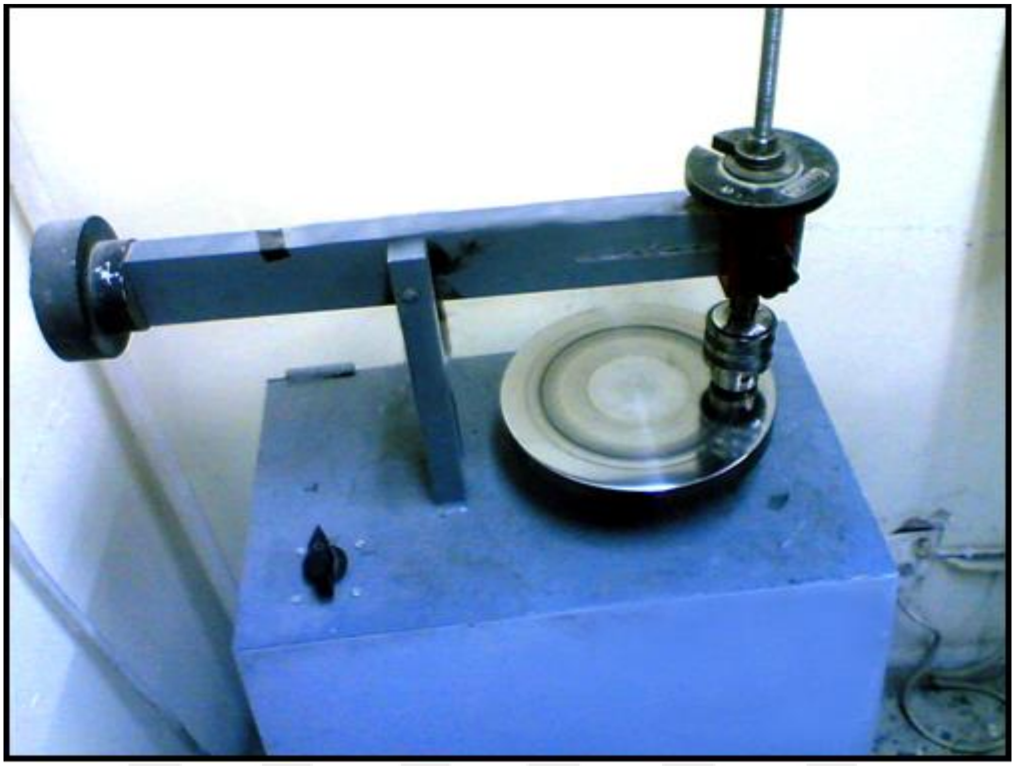


Figure 3.5: Measurement of wear.

3.5.5 Thermal conductivity test

The thermal conductivity of the test specimens can be calculated using a Lee`s Disc device manufactured by Griffen & George. As shown in Fig. 3.6, heat is transferred from the heater to the disc that follows it until it reaches the final disc.

It is possible to determine the temperature of the three discs T_A, T_B, T_C is using the thermometers placed inside. It is very important to ensure that the surfaces of the copper plates are clean and that they are well contacted to get the best heat transfer through them.

The value of thermal conductivity K is calculated from the equations 2.16 and 2.17 [82, 84]. The value of the current is 0.2 Amp, the voltage is 6 V, the value of the thickness of disk A, B and C is 13 mm, radius of disk is 21 mm and the sample thickness is 5 mm.

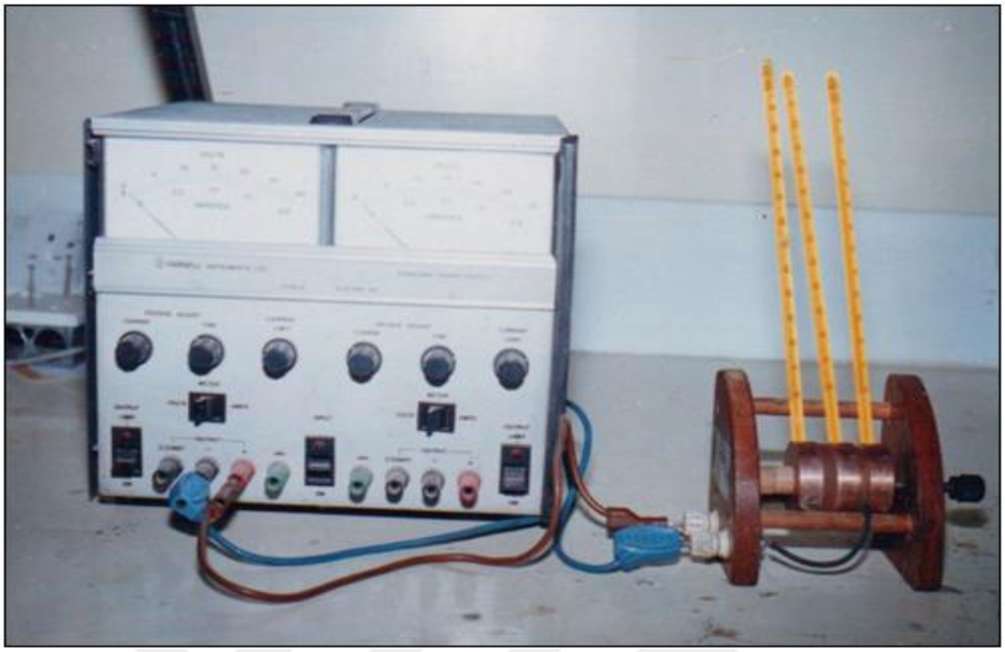


Figure 3.6: Thermal conductivity measuring device.

4. RESULTS AND DISCUSSION

This chapter discusses all the results obtained and examines the effect of Reinforcement materials on the mechanical and physical properties of the samples designed in the manufacture of brake pads.

4.1 MECHANICAL PROPERTIES

4.1.1 Hardness Test Results

Hardness gives a good idea of the strength and consistency of the material mass, which is used to measure the material resistance of the plastic malformations in the surface areas. Hardness was measured for the samples designed in the manufacture of braking pads using the Shore D device. In Figure 4.1, it shows the relationship between the hardness of the shore and the ratio of the base material in samples 1, 2, 3 and 4, the hardness of the shore increases with the increase of the percentage of the base material in the samples up to 65%, after which the hardness of the shore starts to decrease when the base material ratio increases more than 65%.

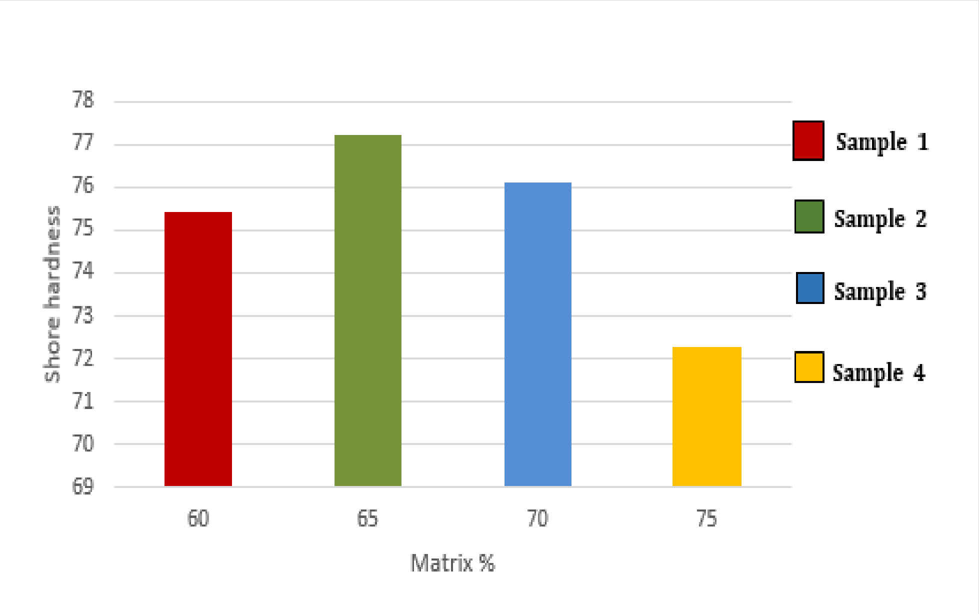


Figure 4.1: The relationship between the Shore D hardness and matrix ratio.

The sample 2 was then selected for the development of mechanical properties, including hardness to be suitable for the design of braking pads. This sample was reinforced once with

Kevlar fibers and nylon fibers and again with Kevlar fiber and steel fibers. The hardness was increased by increasing the reinforcement ratio of Kevlar and Nylon fibers in samples 5, 6 and 7, This is due to the improvement of mechanical properties through fiber reinforcement and fibers carry the bulk of the stresses placed on the samples [55] and in Figure 4.2 which shows the relationship between the hardness of the shore and the reinforcement ratio of the Kevlar fibers and the nylon fibers. Either in the case of reinforcement by Kevlar fibers and Steel fibers, we found that the hardness values increased in the samples 8, 9 and 10 because the Kevlar fiber reinforcement increases the mechanical properties of the material. Kevlar fibers take on a greater role by increasing the mechanical properties of the material when there are solid fibers such as steel fibers [55, 71, 85] as in Figure 4.3 showing the relationship between the hardness of the shore and the ratio of the reinforcement by the Kevlar fibers and steel fibers.

Shore hardness was found in sample 11, equal to 86.1, which was reinforced with Kevlar fibers, nylon fibers and steel fibers.

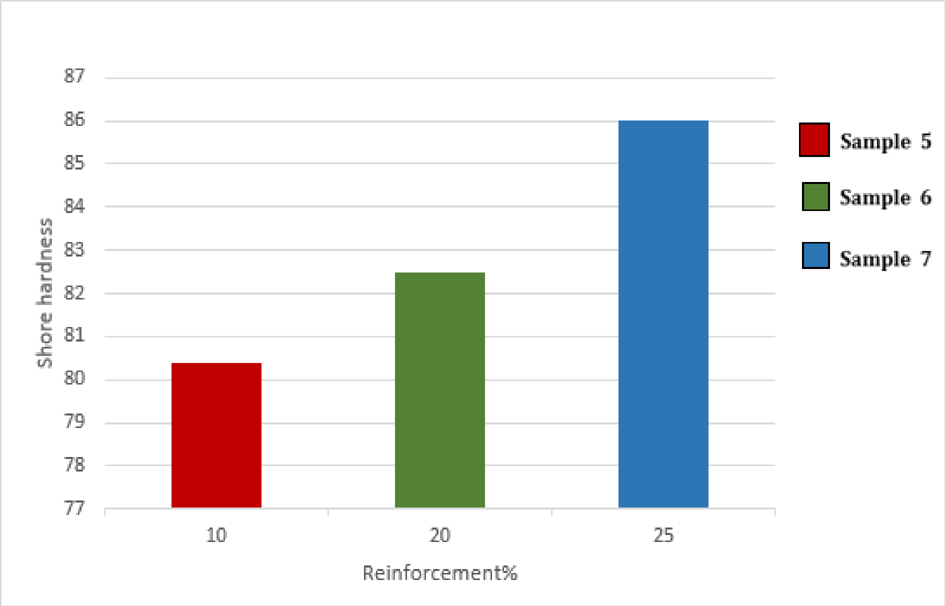


Figure 4.2: The relationship between the shore hardness and the ratio of reinforcement in samples 5, 6 and7.

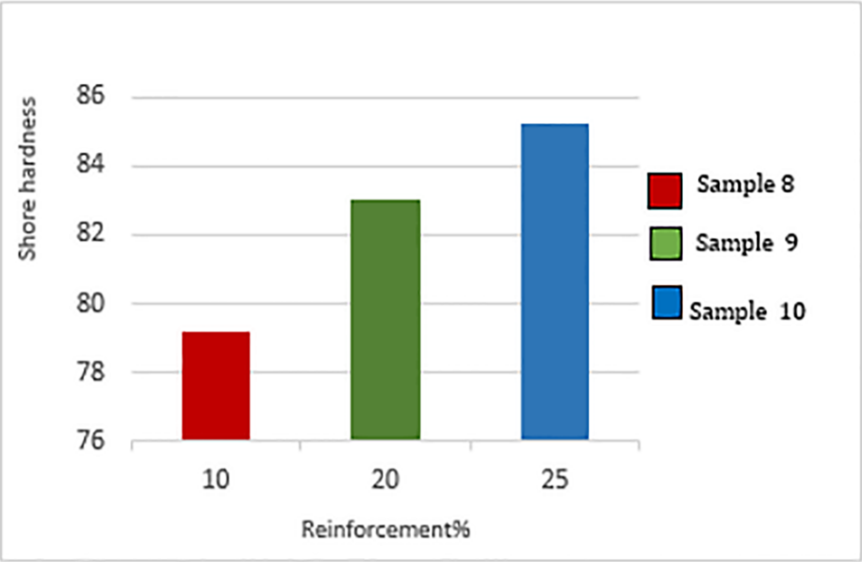


Figure 4.3: The relationship between the shore hardness and the ratio of reinforcement in samples 8, 9 and 10.

4.1.2 Impact Test Results

The impact resistance test was carried out using a jarby method for all samples designed for this purpose, this test is an important test to study the behavior of materials under effect of fast force. This test is used to determine the extent of composite material bearing strength of impact through the energy absorbed by these materials to resist this type of the forces.

The sample 2 selected to strengthen them with fibers in order to develop its properties to be suitable for use in the manufacture of braking pads. It was observed that the resistance of the impact increases in the samples 5,6 and 7 by increasing the reinforcement ratio of the Kevlar fibers and nylon fibers, as in the Figure 4.4 that shows the relationship between impact resistance and the ratio of fibers reinforced by Kevlar fibers and Nylon fibers. The reason for the increased resistance of the impact with increased reinforcement ratio is that the fibers work to bear the most of the stress exerted on the composite material. Therefore, the fibers distribute the stress on a larger area and reduce the possibility of concentration of stress on a more area and reduces the probability of concentration of stress on a particular area, the Nylon fibers are characterized by high durability and impact resistance [5], as fiber working to block the spread of cracks.

The reinforcement by Kevlar fibers and steel fibers increases with mechanical properties such as resistance to impact as shown in Figure 4.5, which shows the relationship between impact resistance and reinforcement ratio by Kevlar fiber's strength and steel fibers. And the Impact resistance for sample 11 is 12.4 kJ/m².

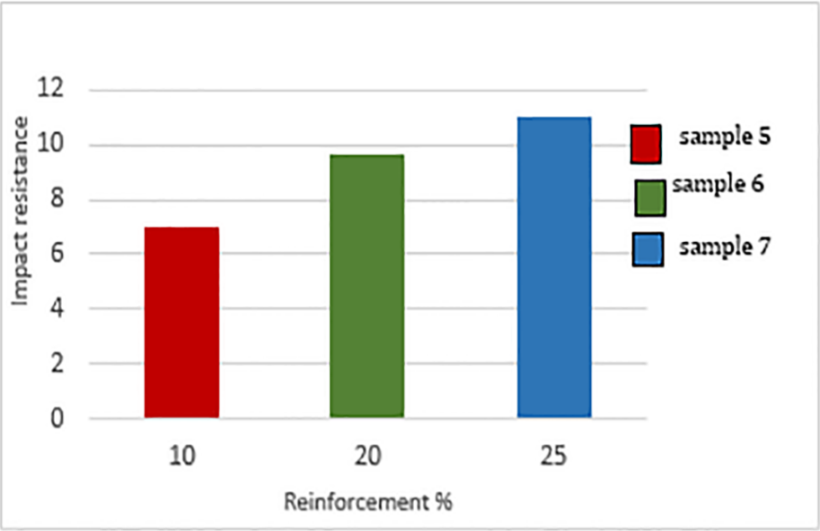


Figure 4.4: The relationship between impact resistance and reinforcement ratio in samples 5, 6 and7.

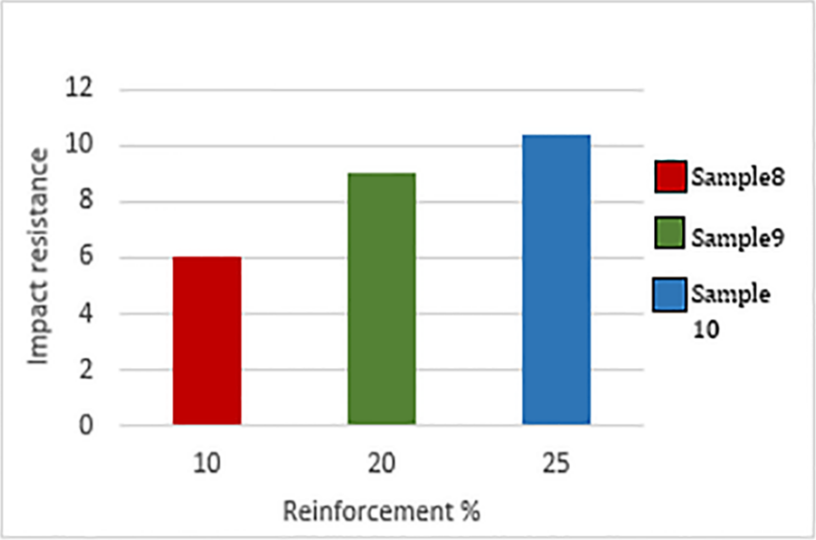


Figure 4.5: The relationship between impact resistance and reinforcement ratio in samples 8, 9 and 10.

4.1.3 Wear Test Results

The wear test is one of the most important tests for braking pads. These pads should have a high wear resistance to be suitable for this application. The wear test of the selected sample was performed to improve its properties by reinforcement of the Kevlar fibers and Nylon fibers once and reinforcement by Kevlar fibers and steel fibers again. The rate of wear is decreased when increasing the ratio of Kevlar fibers and nylon fibers in the samples 5, 6 and 7. The reinforcement of the Kevlar fibers increases the wear resistance of the composite material. The nylon fibers have a capillary surface which has a high adhesion to the base material, which increases the resistance of composite material to wear, as in Figure 4.6 which shows the relationship between wear rate and reinforcement ratio by Kevlar fibers and nylon fibers. In the case of reinforcement by Kevlar fibers and steel fibers, the wear rate decreases because the Kevlar fibers have high wear resistance [71, 15] as shown in Figure 4.7 showing the relationship between wear rate and reinforcement by Kevlar fibers and steel fibers. The wear rate of the sample 11 was 0.16 g / m.

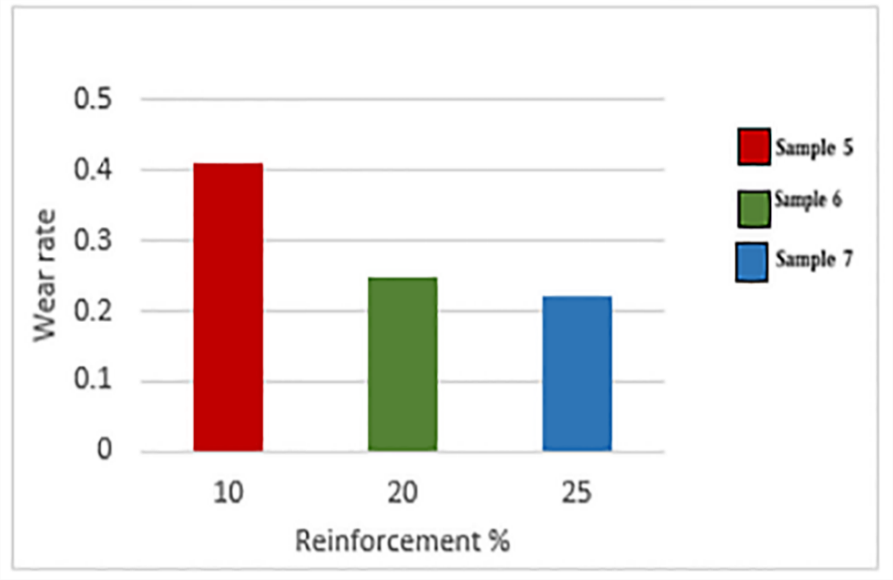


Figure 4.6: The relationship between wear rate and ratio of reinforcement in samples 5, 6 and7.

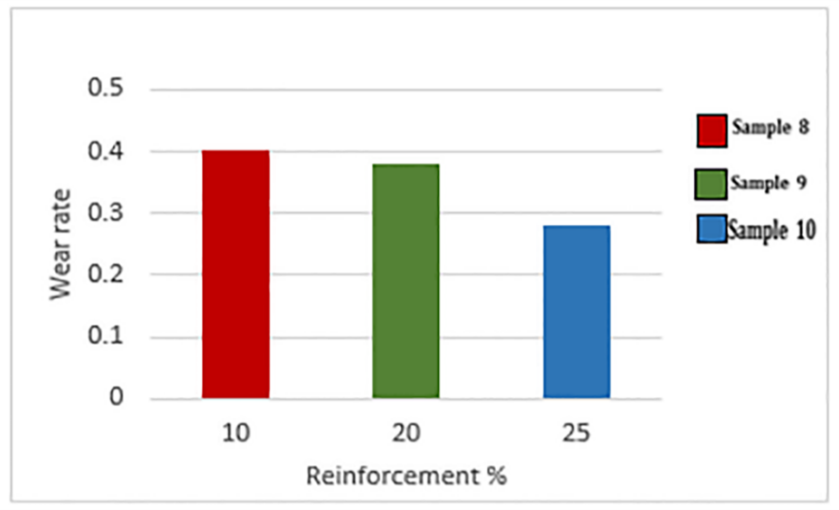


Figure 4.7: The relationship between wear rate and ratio of reinforcement in samples 8, 9 and10.

4.1.4 Compression Test Results

Compression test is one of the most important mechanical tests for composite materials used for brake pads. The tests were done on the samples prepared for this test of the selected sample 2 whose mechanical properties were improved and reinforced by adding Kevlar fibers and nylon fibers once and adding Kevlar fibers and steel fibers. Although the compressive strength depends on the direction of the fiber, it is shown that by strengthening the fibers of the Kevlar and nylon fibers, compressive resistance is increased by strengthening these types of fibers as shown in Figure 4.9. The explanation of this increase resistance to compression bears due to the strengthening of the base material by fibers and the role played by these fibers the bulk of the stress on the sample as well as the increasing strength of the cohesion of fiber surface and base material, and the formation of a strong link between Fiber and base material, which contributes to the improvement of mechanical properties [55]. The reinforcement of both the Kevlar fibers and the steel fibers leads to a marked increase in compressive resistance as shown in Figure 4.10, the cause of this increase resistance to compression is that the great role played by Kevlar fibers and steel fibers to strengthen the base material and improve the mechanical properties. The sample 11 when testing resistance compressibility found that the value is 65 MPa.

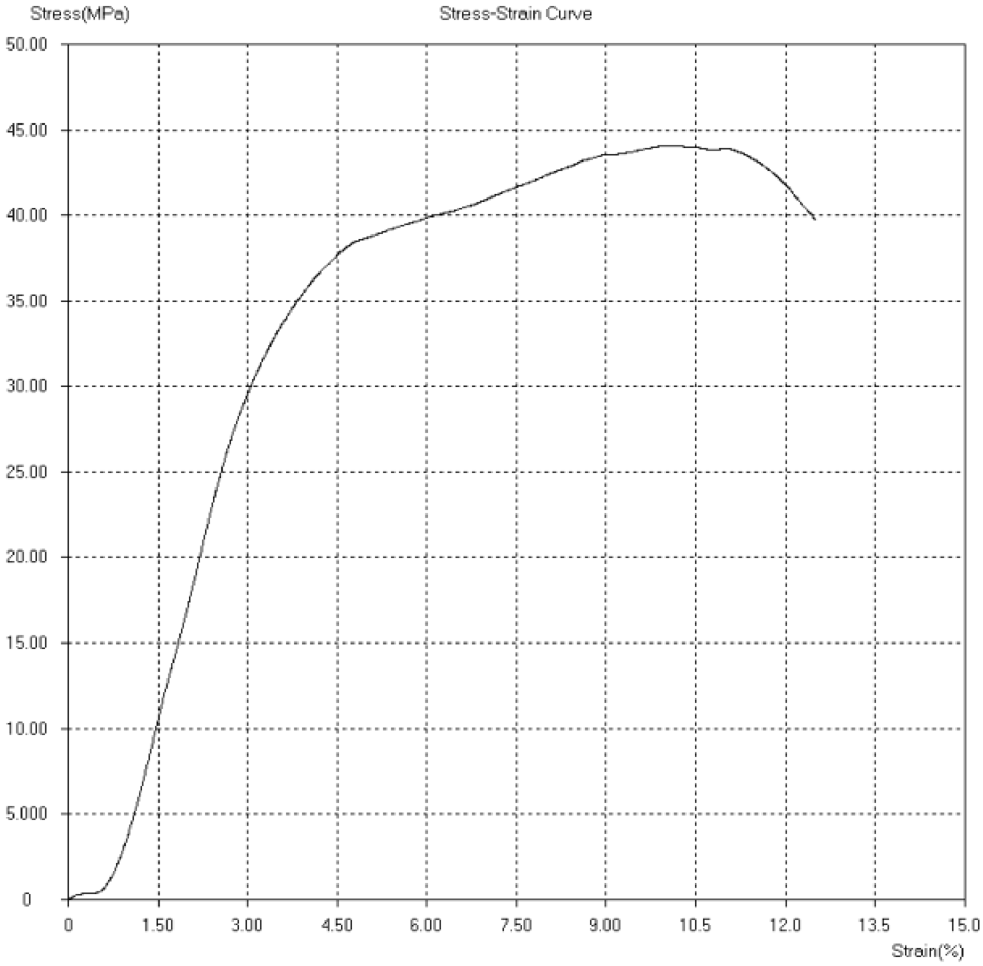


Figure 4.8: The relationship between stress and strain in the compression test for sample 5.

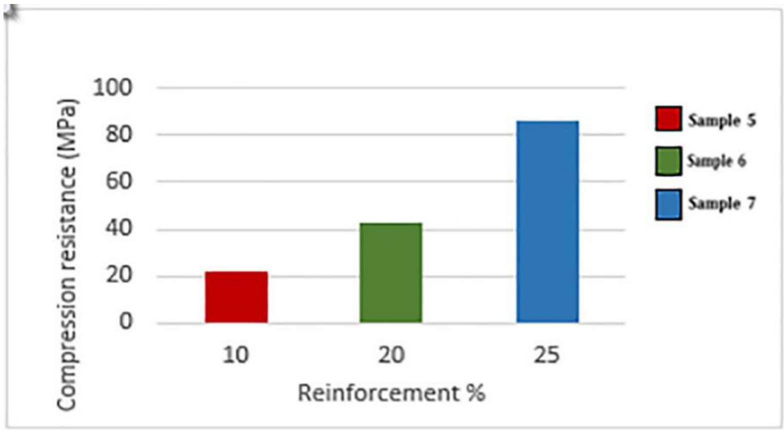


Figure 4.9: The relationship between the compression resistance and reinforcement ratio in samples 5, 6 and7.

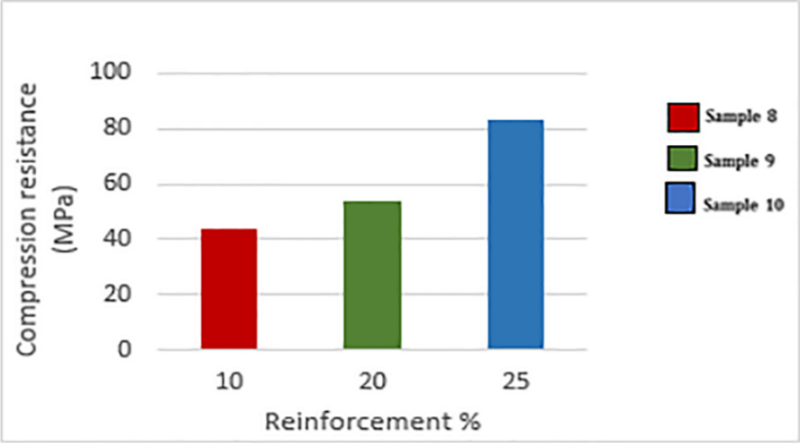


Figure 4.10: The relationship between the compression resistance and reinforcement ratio in samples 8, 9 and 10.

4.1.5 Thermal Conductivity Test Results

The thermal conductivity calculated of the prepared samples for this purpose from sample 2, which was once reinforced by both Kevlar and nylon fibers, and again by both Kevlar fibers and steel fibers. It was noted that the thermal conductivity after strengthening was reduced by increasing the process of strengthening with both Kevlar fibers and nylon fibers, is shown in Figure 4.11. The reason for the decrease in conductivity values is due to nylon fibers, which are characterized by insulation [67], Isolation depends on the presence of fine filaments, which leads to heat transfer in two ways (conduction and convection). When the reinforcement of the Kevlar fibers and steel fibers, the conductivity value was increased with the increase of the fiber reinforcement ratio. As shown in Figure 4.12 that shows the relationship between the constant coefficient of thermal conductivity K and the reinforcement ratio of the Kevlar fibers and steel fibers. The steel wire is characterized by high thermal conductivity it also the Kevlar fibers have thermal conductivity, contributing to increased thermal conductivity [56,55].

The value of thermal conductivity constant K for sample 11 was 0.222 W / m °C.

Table 4.1: The values in the thermal conductivity test.

Samples	T_A	T_B	T_C	Thermal conductivity K
5	29	34	34	0.266
6	32	37	37	0.22
7	32	38	38	0.162
8	27	31	31	0.235
9	30	36	36	0.296
10	30	39	39	0.325
11	33	40	40	0.222

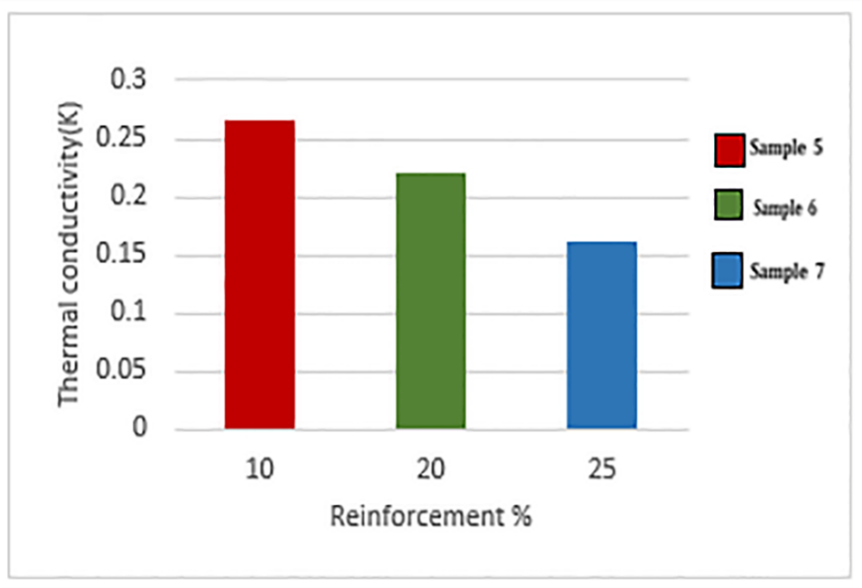


Figure 4.11: The relationship between the thermal conductivity constant K and the ratio of reinforcement in samples 5, 6 and7.

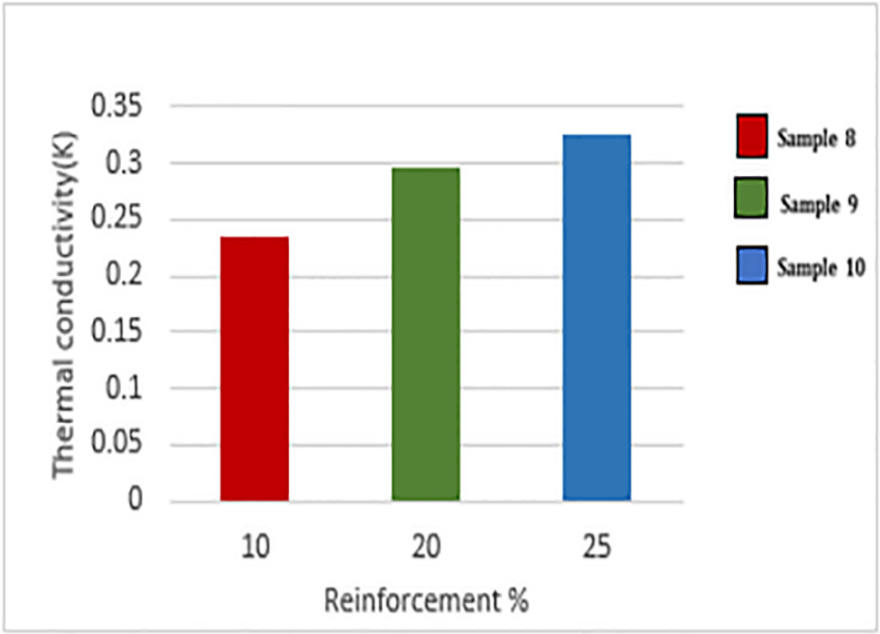


Figure 4.12: The relationship between the thermal conductivity constant K and the ratio of reinforcement in samples 8, 9 and 10.

4.2 COMPARISON OF THE RESULTS WITH THE STANDARDS FOR BRAKE PADS

Comparing the results of the mechanical tests of the samples designed to the specifications of the brake pads of the commercial vehicles available in the local markets. As shown in Table 4.1, shows the comparison the specifications of the samples prepared with the specifications of the brake pads. In Figure 4.13, Figure 4.14, Figure 4.15, Figure 4.16 and Figure 4.17 we can comparison between the samples 5, 6, 7, 8, 9, 10 and 11, and choose the most suitable sample for the production of brake pads.

Table 4.2: The properties of the samples designed and compared with the standard specifications of the commercial pads.

	hardness Shore	**Impact resistance** (kJ/m²)	**Wear rate** (g / m)	**Compression** (MPa)	**Thermal conductivity** (W / m °C)
Sample 5	80.4	7	0.41	22	0.266
Sample 6	82.5	9.6	0.25	43	0.22
Sample 7	86	11	0.22	86	0.162
Sample 8	79.2	6	0.4	44	0.235
Sample 9	83	9	0.38	54	0.296
Sample10	85.2	10.4	0.28	83	0.325
Sample11	86.1	12.4	0.16	65	0.222
Commercial Brake pads	70.8	6.26	2.12	48.38	0.293

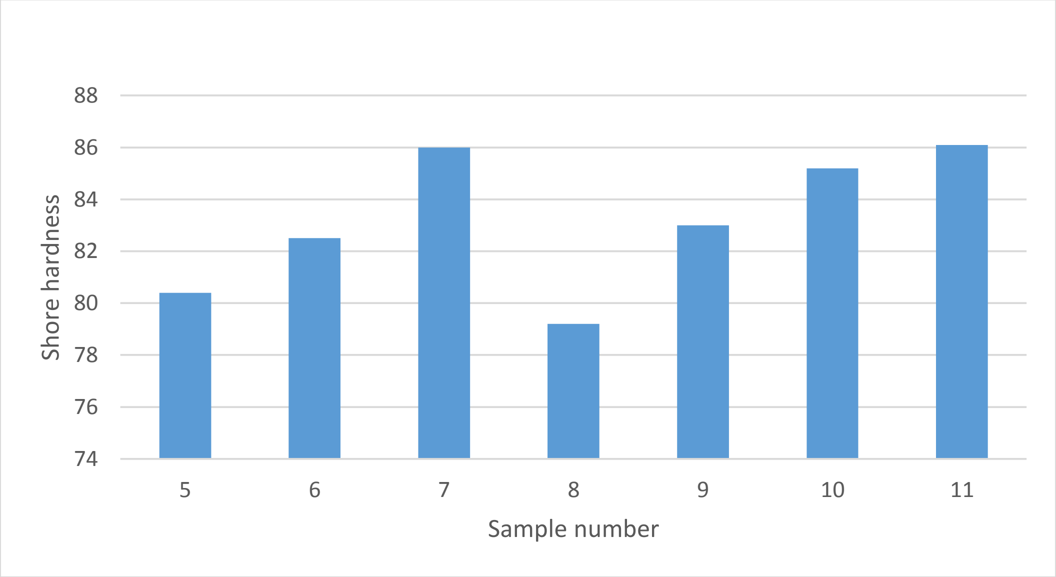


Figure 4.13: The relationship between the hardness shore and the sample.

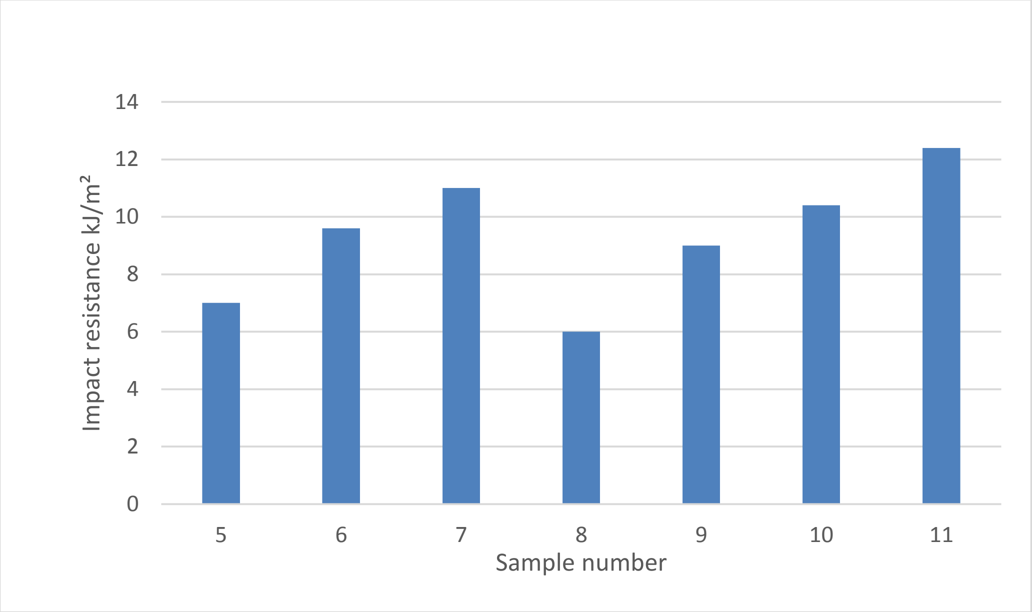


Figure 4.14: The relationship between the impact resistance and the sample.

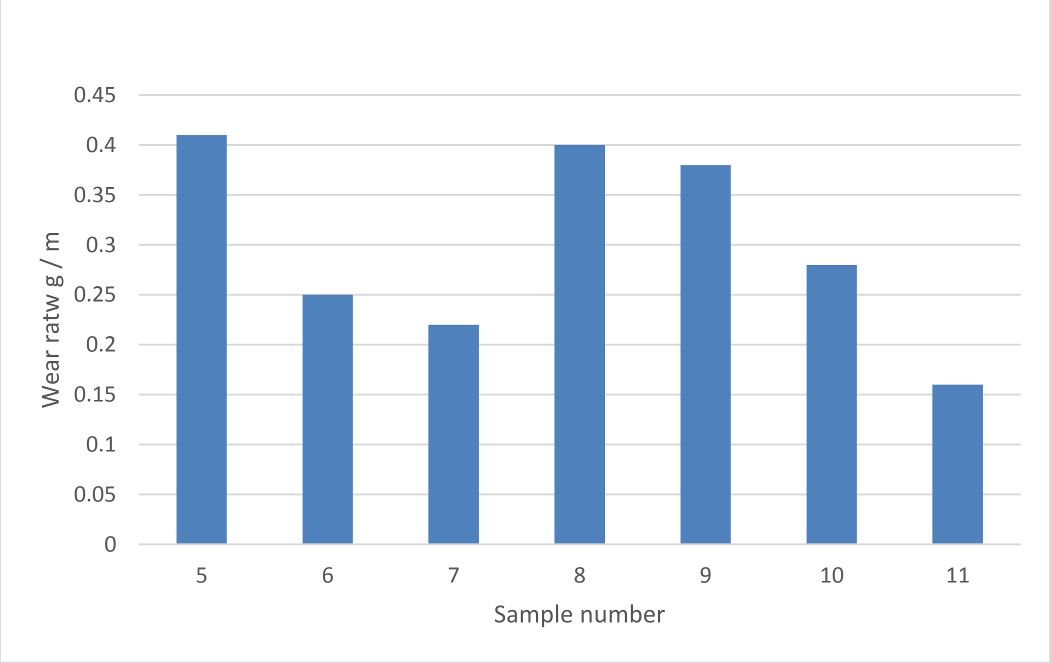


Figure 4.15: The relationship between the wear rate and the sample.

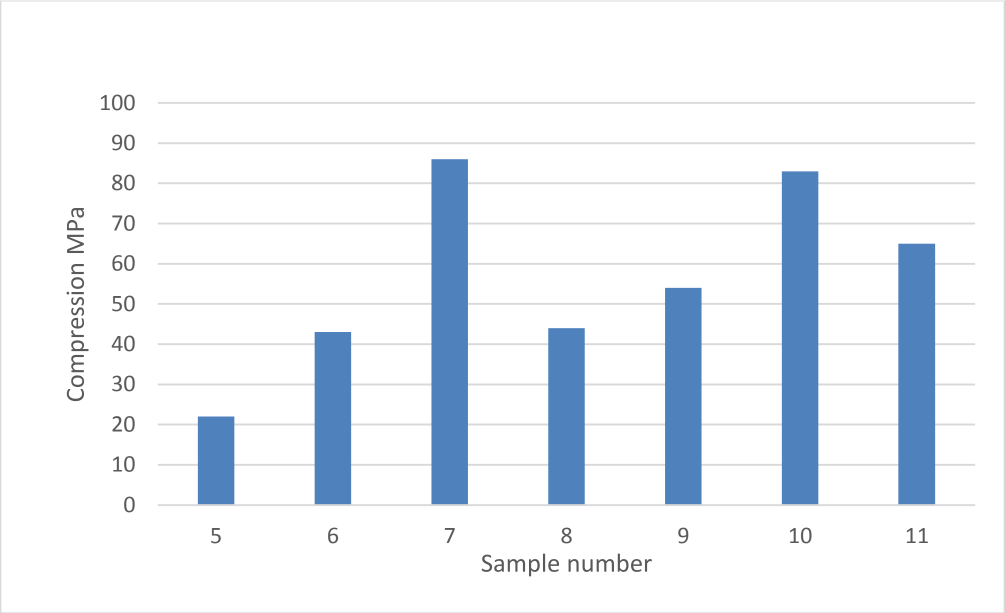


Figure 4.16: The relationship between the compression and the sample.

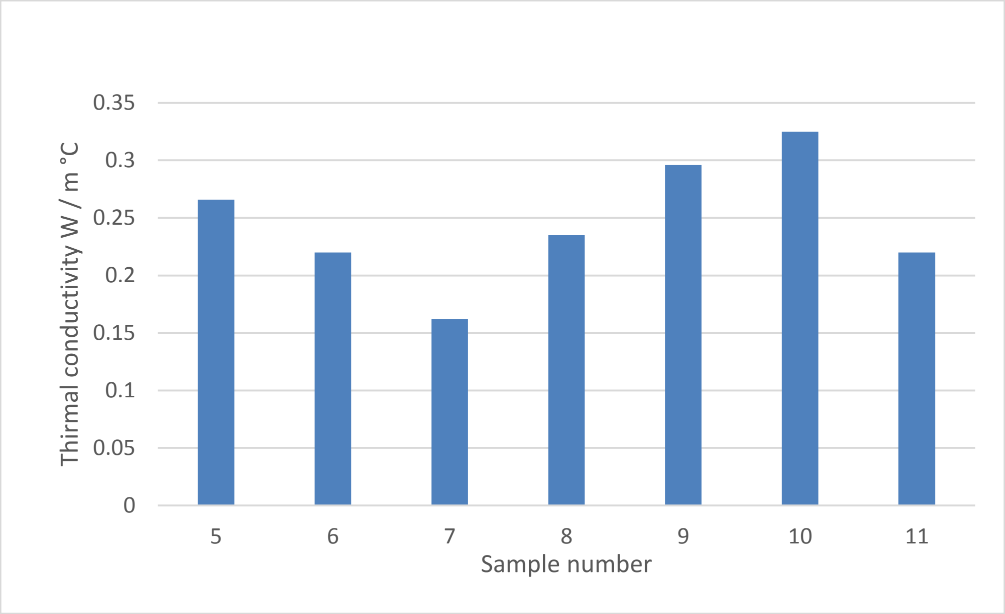


Figure 4.17: The relationship between the thermal conductivity and the sample.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

After conducting this research and through the results of mechanical tests, the most important conclusions were reached:

1. Increasing the matrix composed of the polyester material to 65% increased Shore hardness to 77.2. after which the hardness of the shore starts to decrease when the base material ratio increases more than 65%.
2. The increase in the reinforcement ratio of the samples of the Kevlar fibers and nylon fibers to 25% increases the shore hardness to 86. In the case of increasing the reinforcement ratio by the Kevlar fibers and steel fibers lead to increase the shore hardness to 85.2. In sample 11 the value of the hardness is 86.1.
3. Increase the reinforcement ratio of the samples of Kevlar fibers and Nylon fibers to 25% lead to increase the resistance of the impact from 7 kJ/m² to 11 kJ/m², and from 6 kJ/m² to 10.4 kJ/m² in the case of reinforcement by the Kevlar fibers and steel fibers. In sample 11 the value of the impact is 12.4 kJ/ m².
4. The wear rate decreased from 0.41 g/m to 0.22 g/m with an increase in the reinforcement ratio by Kevlar fibers and nylon fibers, while wear rate decreased from 0.4 m/g to 0.28 m/g with an increase in the reinforcement ratio by Kevlar fibers and steel fibers. In sample 11 the value of the wear rate 0.16 g/m.
5. Increase the compressive strength from 22 MPa to 86 MPa by increasing the reinforcement by Kevlar fibers and Nylon fibers from 10% to 25%, increasing compressive strength from 44 MPa to 83 MPa by increasing the reinforcement ratio by the Kevlar fibers and steel fibers from 10% to 25%. In sample 11 the value of the compressive strength is 65 MPa.
6. The thermal conductivity decreased from 0.266 W/m °C to 0.162 W/m °C with an increase the reinforcement ratio by Kevlar fibers and Nylon fibers to 25%, the thermal conductivity increased from 0.235 W/m °C to 0.325 W/m °C with an increase the reinforcement ratio by Kevlar fibers and steel fibers to 25%. In sample 11 the value of the thermal conductivity is 0.222.

The above results show that the hardness, compression resistance and impact resistance of the samples increases with the increase of reinforcement ratio by Kevlar fibers, Nylon fibers and steel fibers. The rate of wear decreases with the increase of reinforcement ratio. The thermal conductivity decreases with an increase the reinforcement ratio by Kevlar fibers and Nylon fibers, the thermal conductivity increase with an increase in the reinforcement ratio by Kevlar fibers and Steel fibers. The Samples numbered by 7,9,10 and 11 are more suitable for the design of brake pads. These samples are characterized by high wear resistance, high impact resistance, high hardness, high compressive strength and low thermal conductivity compared to commercial brake pads. Table 4.1 shows comparisons the characteristics of samples designed with standard specifications for commercial brake pads. In addition to the specifications of the samples mentioned above, they are made up of materials available in domestic markets with low cost.

5.2 RECOMMENDATIONS

The followings are some advices for the future studies:

1. Study of wear and other mechanical properties under wet environmental conditions.
2. The use of a scanning electron microscope to study the interfaces of composite materials.
3. Study the reinforcement of composite materials by steel particles and compare the results of mechanical tests with the actual results.
4. Study of the effect of changing the ratio of hardener material added to the polyester on the mechanical properties of composite materials.
5. The use of other types of fiber, such as carbon fibers and study its effect on mechanical properties.
6. Study of other mechanical properties such as bending, flammability, oxidation effect, fatigue behavior and tensile resistance.
7. Studying the effect of particle size on the mechanical and physical properties.
8. Studying the glass transformation degree (Tg) of the composite materials.

REFERENCES

[1] R. J. Crawfer, *"Plastic Engineering"*, 2nd ed., Pergamon press, V. K., (1987).

[2] Dr.Akram Azez , “Chemistry of plastics”1993.

[3] Theodore J. R., *"Engineering Materials Hand Book"*, Vol. 1, 1987.

[4] Dr.Gorges , Dr. Huseen Ali, “Polymer Technology and Chemistry”, College of Science, University of Basra, Iraq, 1983.

[5] Lamis Ali Khalaf, "Study of the Mechanical and Physical Properties of Non-Saturated Polystyrene and Reinforced by glass fibers and nylon fibers ", Master Thesis, Materials Engineering Department, University of Technology, Iraq, 2006.

[6] Rola Abdul-Khader Abbas,"Study of the Thermal and Mechanical Properties of Novolack Materials and Their Compositions", Master Thesis, Department of Applied Science, University of Technology, Iraq, 2001.

[7] Hazem Faleh Hassan, "Improving locally produced Novolack and studying some of its thermal and mechanical properties and their resistance to combustion", Master Thesis, Materials Department, University of Technology, Iraq, 2007.

[8] D. Lukhassen and A. Meidell, "A advanced materials and structures and their fabrication process”Third Edition, Narvik university college, HIN (2003).

[9] http ://www. owenscorning. com/owans/composites.

[10] D. Hall, *"Introduction to Composite Materials"*, Cambridge University Press, 1981.

[11] I. M. W. Gaylord, *"Reinforced Plastic Theory and Practice"*, Canners publishing Com, 1974.

[12] W. Gregory Sawyer , Kevin D. Freudenberg , Praveen Bhimaraj , Linda S. Schadler ‘‘A study on the friction and wear behavior of PTFE filled with alumina nanoparticles’’ Wear 254 (2003) 573–580

[13] H .Jang ،" The effect of metal fiber on the friction performance of automotive brake friction materials",J.Wear.256(2004)406-414.

[14] N.Chand,S A R .hashmi,"Development of Asbestos Free Brake Pad",85 (2004).

[15] J.Bigwe."Performance of friction materials based on variation in nature of organic fibers",2004.

[16] Ho.Jang , "Effect of ingredients on tribological characteriststics of a brake lining", J.Wear 258 (2005) 1682-1687.

[17] Z.Zhang," Effect of various on the sliding wear of polymer composites",J.Com.Sci and Trib. 65 (2005) 2329-2343.

[18] F.J.Lino,"Tribological behaviour of epoxy based composites for rapid tooling",J.Wear 260 (2006) 30-39.

[19] W.A.Rakowski,"Polyesterimide composite as a sensor material for sliding bearings", J.Composites :part B 37 (2006) 81-88.

[20] J.Qiao," Application of nano powdered rubber in friction materials", J.Wear 261 (2006) 225-229.

[21] F.Findik,"Tribological properties of some phenolic composites suggested for automotive brakes", J. Trib. Int. 39 (2006) 317-325.

[22] A.Shojaei," Thermally conductive rubber-based composite friction matrials for railroad brakes – Thermal conduction characteristics",J.Comp.Scie and Tech. 67 (2007) 2665-2674.

[23] A.Mimaroglu," Friction and wear performance of pure and glass fiber reinforced poly-ether-imide on polymer and steel counterface materials",J. Wear 262 (2007) 1407-1413.

[24] H.Jang ,"The effect of phenolic resin potassium titanate and CNSL on the tribological properties of brake friction materials", J. Wear 264 (2008) 204-210.

[25] Ayman A. Aly, " Friction and Wear of Polymer Composites Filled by Nano-Particles: A Review" 2012, 2, 32-39.

[26] Juliana R Souza, Ruthilene CL Silva , Laı´s V Silva, Joa˜o TN Medeiros, Sandro C Amico and Witold Brostow,'' Tribology of composites produced with recycled GFRP waste'', 2015, Vol. 49(23) 2849–2858.

[27] Adeyemi, I. Olabisi , Nuhu, A. Ademoh , Development of Asbestos- Free Automotive Brake Pad Using Ternary Agro-Waste Fillers, Vol. 3 Issue 7, July - 2016.

[28] Wisdom Astotah , Abraham Adeleke , Development of asbestos free brake pads using corn husks ,2017.

[29] K Ramanathan, P Saravanakumar , S Ramkumar, P Pravin kumar , S.R Surender , Development of Asbestos-Free Brake Pads,Using Lemon Peel Powder, Vol. 6, Issue 3, March 2017.

[30] Dinesh Shinde, K. N. Mistry, Asbestos base and asbestos free brake lining materials: Comparative study, WSN 61(2) (2017) 192-198.

[31] Muhannad Khashan Zulim, "Design and Manufacturing of doughs of Cloth Pulls rolls from Composite Rubber Material", Master Thesis, Materials Engineering Department, Babylon University, Iraq, 2007.

[32] Lawrence H. Van Vlack "Materials For Engineering Concepts And Aplplication" ,1982 .

[33] J.M.Kelvey,“Polymer prosing ”John Wiley and son, New York (1962).

[34] A. Harper, “Plastic Handbook” Technology Seminars, Inc., Lutherville, Maryland, (2000).

[35] M. Richardon “Polymer Engineering composite” Applied Science pub.London.(1987).

[36] N. G. Mccrum, et al “principle of polymer Engineering” Edition John Wiley and son, New York (1992).

[37] A. A. Berlin and , S. A. Volfson” Principle of Polymer Composite ”Springer verlag, New York (1986).

[38] Rafah Alwan Naseef, "Improving the properties of composite material of unsaturated polystyrene by adding a rubber phase", Master Thesis, Department of Applied Science, University of Technology, Iraq, 2006.

[39] R-K Mattham “Rubber Engineering” Tata McGraw -Hill publishing company,Delhi 1998.

[40] Mohammed Hamza Al-Mamouri, Ph.D., University of Technology, 2005 entitled: "Mechanical & Physical Properties of Rubber Composite For Engine Mounting ".

[41] AL Marshedy,“Alternative method to produce steal wires used for reinforcement of Babylon tyre ” M.Sc thesis, College of Engineering Babylon University, Iraq, 2000.

[42] James.E.Mark " The science and technology rubber",Third edition, New york ,2005.

[43] P.A.Ciullo,"The Rubber Formulary", New York, 1999.

[44] Ahmed Nouri Ghani, "Rubber Technology", 1995.

[45] B. de Caumia. A.I. Isayev,"Rubber Recycling", New York, 2005.

[46] Martin Hollman, " Composite Aircraft Design " , (1993).

[47] W. J. Work and K. Horie , " Pure Appl. Chem. " , Vol. 76 , No. 11, PP.(1985-2007), (2004).

[48] Saad Mikhael Elia, "Study of Mechanical Properties and Thermal Conductivity of a composite material with Polymer Base Reinforced in Aluminum particles and Aluminum Oxides", Master Thesis, Materials Engineering Department, University of Technology, Iraq, 2007.

[49] Malcom B.Sevenson. translation Dr Kazem Ghayad , Dr. Qais Abdel- Karim Ibrahim, ”Chemistry of polymerization”, Chemistry department, College of Science, University of Basra, Iraq, 1984.

[50] M. S. Bhantnagar , " A Text Book of Polymers Chemistry and Technology Polymers , Condensation Polymers ", Vol. ll , (2004) .

[51] Martin Grayson , " Encyclopedia of Composite Materials and Component" , (1983) .

[52] Dr. Qahtani Al-Khazraji, “Principles of Non-Metallic Engineering”, Babylon University, Faculty of Engineering, 1994.

[53] Amal Ali Rajab, "Study of Mechanical Properties of Composite Materials and Hybrid Composite Materials", Master Thesis, University of Technology, 1996.

[54] Kirk Othmar, “*Encyclopedia of Chemical Technology*”, Tom Wiley & Sons Inc., Canada, 1982.

[55] Ali Hobe Halim, "Improving properties of hardened plastic materials", Master thesis, Materials Engineering Department, Babylon University, Iraq, 1999.

[56] Zaid Assem Ismail, "Study of Physical Properties of Reinforced Polymers", Master thesis, Mustansiriya University, Iraq, 2004.

[57] F.W.Billmeyer ," Text book of polymer science ", Wiley , Inc.New York,1971.

[58] James P.Schaffer , Ashok Saxena , " The science and Design of engneering materials ", Richard D.Irwin,Inc,1995.

[59] P.A.Tornton , V.J.Colangelo , " Fundamental of engneerin materials ", Hall,Inc,1985.

[60] D.R.Paul and S.Newman ,"Polymer Blends ", Vol.1,Acadimic press , Inc,New York , 1978.

[61] Groover M.P. , "Fundamentals of Modern Manufacturing Material" , Processes , (1996) .

[62] L. Holliday, "Composite Material", Elsevier Publishing, London, (1966).

[63] .D.Callister,JR.,"Materials Science and Engineering An Introduction" 6th ed., John Wiely and Sons,Inc., New York, (2003).

[64] J.G.Morley , "High Performance of Fiber Composites " , University of Nottingham , U.K , (1987).

[65] G.Piatti , " Advances in Composite Materials " , Applied Science Publisher /TD , (1978) .

[66] Aseel Mahmoud Abdulla, "Study of the Effect of Shear Stress on the Mechanical Properties of an composite material with a polymeric basis and Reinforced by Steel Fibers", Master Thesis, Materials Engineering, University of Technology, Iraq, 2006.

[67] M.M.Schwarts," Composite Material Handbok", MC Graw –Hill, Inc.,1984.

[68] E . Paul De Garmo, J. T. Black, Ronald A. Kohser and Barney E. Klamecki, "Materials and Processes in Manufacturing", 9th Edition, John Wiley and Sons, Inc., 2003.

[69] J.Stepek and H.Daust," Additive for Plastic", New York , 1983.

[70] Andrea Prota, Kah Yong Tan, Antonio Nanni, Marisa Pecee and Gaetano Manfreeli, "Performance of Shallow RC Beams with Externally Bonded Steel Reinforced Polymer", 2004.

[71] D. Chan and G.W.Stachowiak ," Review of automotive brake friction materials ", University of western Australia,2004.

[72] Eriksson M., Bergman F. and Jacobson S, " Surface charac- terization of brake pads after running under silent and squealing conditions", J. Wear, 1999, 232, 163–167.

[73] Arnold E. Anderson and Walter K. Arnold," Friction and wear Technology", United States of America, Vol 18,1992.

[74] Y.Lu , "Optimization of Ceramic Friction Materials ", J. Com.Sci.Tech., Vol 66, 2006.

[75] S.Jacobson ,"On the Natural of Tribological Contact in automotive brakes ", J. Wear 252.26-36,2002.

[76] M.D.Baijal , " Plastic Polymer Science and Technology ", Applied Science Publishers" , 1978.

[77] Raghad Hamid Talal, "A Study of Resistance to Crawling, Compression and Dry Adhesive Wear for polymeric composite materials ", Master Thesis, Department of Applied Science, University of Technology, Iraq, 2001.

[78] R.B.Pipes," Friction and Wear of polymer Composite Material " , Elsevier 1986.

[79] John Holank, Translation: Dr. Mohammed Jawad Kazem Al-Turanji and Dr. Mahdi Saeed Haidar, "Introduction to the science of Tropolgy", University of Technology, Baghdad 1985.

[80] J.Halling ,"Principle of Tribology",Published by the Macmillan Press Limited , London,1979.

[81] Najm Abd Al-Amir Saad, "Slippery Wear of Self-Lubricating loading Chairs", Master Thesis, Mechanical Engineering, 1995.

[82] A.M.Collieu and D.J. Powney ,“ The mechanical and thermal properties ” , Butter and Tanner , London , (1973).

[83] W.Bolton , Engineering materials technology , 3ed , edition,1983.

[84] E.Grim Shi , “ Atext Book of Physics ” , Vol.11 , Blackie and Sons , London , (1944) .

[85] N.S.M.El-Tayeb and K.W.Liew," Effect of Water spray friction and wear behaviour of noncommercial and commercial brake pad materials",J. material processing technology,2008.

[86] M. Zemanski and R. E. Rethiman, "The heat and Thermodynamics," Dar Makgroil Publishing, Egypt, 1982.

[87] Askeland D.R. & Phule P.P., “The Science & Engineering of Materials”, Fourth Edition, Thomsom Brook/Cole, 2003.