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Study The Effect Of Particulate Of Some Perennial Plants Waste On The Mechanical And Thermal Characteristics Of Polymer Composites

A Thesis

Submitted to University of Baghdad \College of Education for Pure Science (Ibn-AL-Haitham) in partial Fulfillment of the Requirements for the Degree of Master of Science in Physics

By

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بسم الله الرحمن الرحيم

((ألم تَرَوْا أنَّ اللهَ سَخَّرَ لكم ما في السَّمواتِ وما في الأرضِ وأسْبَغَ عليكم نِعَمَهُ ظاهِرَةً وباطنَةً ومن النَّاسِ من يُجادِلُ في الله بغيرِ علْمٍ ولا هدىً ولا كتابٍ مُنير))

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صدق الله العظيم

(سورة لقمان آية 20)

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I certify that this thesis entitled "**Studying The Effect Of Particulate Of Some Perennial Plants Waste On The Mechanical And Thermal Characteristics Of Polymer Composites**", was prepared by **Huda Razzaq Kttafah** under my supervision at Physics Department, College of Education for Pure Science Ibn - Al- Haitham University of Baghdad as partial requirement for the degree of Master of Science in Physics.

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Committee Certificate

This is to certify that we have read this thesis entitled (Study The Effect Of Particulate Of Some perennial plants Waste On The Mechanical And Thermal Characteristics Of Polymer Composites), and as an examining committee, examined the student (Huda Razzaq kattafah) in its content and in our opinion, it is adequate for partial fulfillment of the requirement for the Degree of Master of Science in Physics.

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Dedication

I give you the Master's thesis and pray Almighty God to be crowned with success and acceptance

To my father and mother..... They were special found in this life and from them learned to withstand whatever difficulties

To my dear husband ..... I have all the respect and appreciation because he had supported me his continuously encouragement, and without him I couldn’t achieve my dream

To my children, I have been preoccupied amidst them some of them have consecrated the letters and learned how to pronounce words and formulate phrases

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Abstract

The first goal of the present study is to improve the mechanical (tensile strength, Young modulus, wear resistance, and hardness), and properties thermal conductivity of the silicon rubber (as a polymer matrix) by using different perennial plant waste particles of three plants wastes as a reinforcement materials, and these plants are Eucalyptus, Date palm and Buckthorn which they widespread in Iraq. The second goals are getting rid of these wastes, to reduce of environmental pollution.

The reinforcement process accomplished by using the wastes particles of three perennial plants widespread in Iraq. The wastes of the plants wastes have been cutting to small pieces, milling, washing, drying at 60°C, re milling, and finally sieving by using three mesh sieves. The final prepared particles used in three aditire ratio: (1, 3, and 5) %, and has been used three particle sizes for each reinforcement rates as (75, 150 and 300). The results of the mechanical, thermal, and water absorption tests features displayed that the composites samples reinforced with Eucalyptus wastes particles at 5% and particle sizes(75) $\mu\mu m$ has the best results among the other samples, where the tensile strength value has been increased by about 150 %, the hardness value has been increased by about 27.18%, the wear resistance has been increased by 115%, Young Modulus(elasticity) has been increased by 115.21%, the thermal conductivity has been increased by 85%, and the minimum water

In addition to that absorption rate which has been increased by 100 %.

reinforcement process decreased the density value of the prepared

samples as a result of the pores and voids created by the reinforcement particles.

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LIST OF ABBREVIATIONS

SYMBOLS	MEANING
F	The applied force
L	The initial length of the specimen
E	Young's modulus
A_Y	Cross sectional area (Young's modulus)
	Change in specimen length
	Ultimate tensile strength
	The maximum (load) applied force
A_T	Cross sectional area (Thermal conductivity)
T_A	The temperature of disk A (Lees disk instrument)
T_B	The temperature of disk B (Lees disk instrument)
T_C	The temperature of disk C (Lees disk instrument)
	The amount of heat transferred through a material
K	The thermal conductivity
	The distance between the two isothermal planes

	The difference in temperature
	The thickness of the sample ((Lees disk instrument)
c	The thickness of the disks (Lees disk instrument)
e	The lost heat per unit time per cubic centimeter
I	The electric current (Lees disk instrument)
V	The applied voltage (Lees disk instrument)
r	The radius of the disk (Lees disk instrument)
	The heat energy passing through the heating coil per unit time (Lees disk instrument)
W	The percentage of water absorption rate
W_f	The weight of the sample after the immersion process
W_i	The weight of the sample before the immersion process
	The density (Archimedes Principle)
m	The mass (Archimedes Principle)
v	The volume (Archimedes Principle)
V	The volume of displaced water (Archimedes Principle)
V	The volume of the sample (Archimedes Principle)

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Composites materials can be defined as the materials physically composed of two or more different materials with resultant material features being superior to the features of individual material that make up the composites [1].

As a result of the following merits: high strength; high Young modulus; low density; high resistance to creep fatigue, corrosion, and wear in composites materials have wide range in industrialization and engineering fields using appropriate material such as metal, polymers and ceramics so as to obtain optimum features, these materials are being used according to the growing need of the society [1, 2].

Composite materials can be classified into two types; the first is based on the type of the matrix material which includes*:*

a. Metal matrix composites that are composed of a metallic matrix (aluminum, magnesium, iron, cobalt, copper).

b. Ceramic matrix composites are composed of a ceramic matrix.

c. Polymer matrix composites are composed of a matrix from thermoset or thermoplastic [2,3].

The second classification is based on the structure of the material (on reinforcing material structure).

a. Particulate composites: particulate composites consist of a matrix reinforced by a dispersed phase in form of particles.

b. Fibrous composites; which include**;** **s**hort-fiber reinforced composites, and, long-fiber reinforced composites**.**

c. Laminate composites, where when the reinforcing by fibers consists of several layers with various fiber directions, it is termed multilayer composite [2, 4]. As shown in Figure.1.

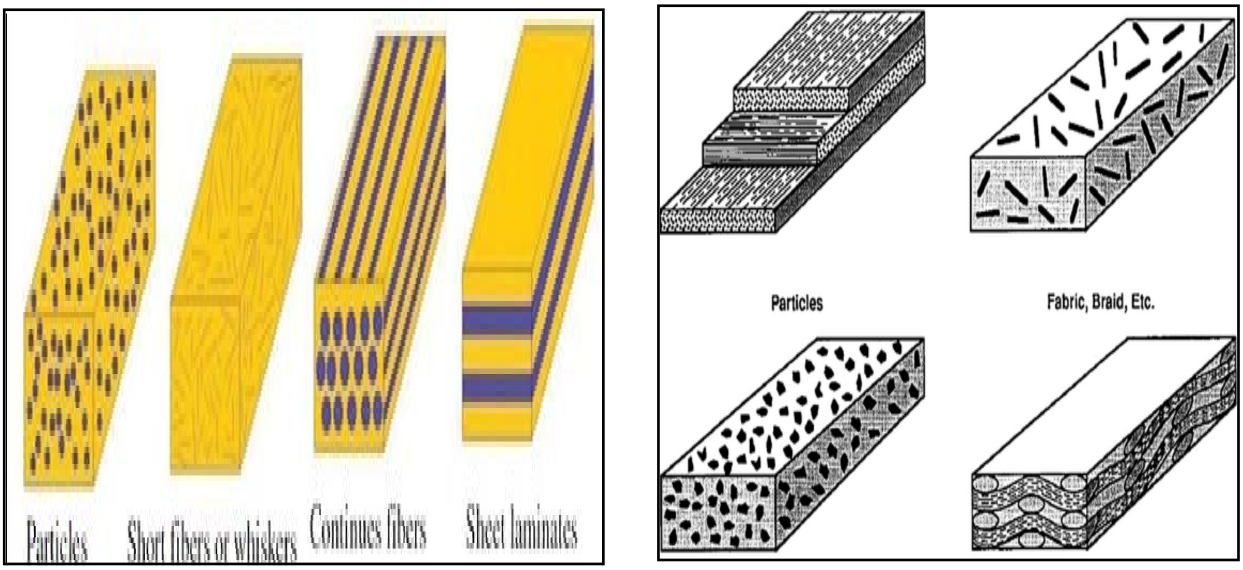


Fig.1. 1. Polymer composite types [2, 4].

Composites are used in many applications around the world such as; vehicles and equipments including, panels, frames, interior components and other parts. Some composite infrastructure applications include buildings, roads, and bridges [2,3].

Polymer composites have very good mechanical strength and stiffness, with a good resistance to corrosion. Polymer materials have advantages over other materials that are used in wide different applications. One of the good features that the light weight and at the same time on condition that provides high strength, by that means diminishing the total weight to fourty percentage. The other features include the potential for rapid process cycles, ability of strict dimensional stability, low thermal expansion features , and very good resistance to fatigue and fracture, in addition of low cost, simple processing rules, and flexibility of designing [4, 5].

1.2. Biocomposites

Biocomposites are mixtures of different materials which are using for various engineering applications and regenerated applications mainly as a result of their biocompatibility, superior mechanical merits, and biodegradability.

Bio-composite have one or more material compounds that derived from natural origin. In terms of the reinforcement, this could include plant particles or particles from recycled plants, waste paper, or even from food crops [6-8].

Biocomposite is a material formed by a matrix (resin) and a reinforcement of natural fibers (usually derived from plants or cellulose), with wide-ranging uses from environment-friendly biodegradable composites to biomedical composites for drug/gene delivery, tissue engineering applications and cosmetic orthodontics. They often mimic the structures of the living materials involved in the process in addition to the strengthening properties of the matrix that was used but still providing biocompatibility . Those markets are significantly rising, mainly because of the increase in oil price, and recycling and environment necessities [9-11],

1.3 Literature Review

2012 Mehmood, investigated flax and polyester with variable fiber volume rates manufactured by a filament-winding process .tensile modulus and ultimate stress are 32 GPa and 350 MPa, . The flax composites show better tensile modulus than the chemical fibers (glass fiber) with values of 23 GPa and 20 GPa, respectively [3].

2012 Al-Mosawi, investigated the mechanical properties of composites reinforced with hybrid Palms - Kevlar fibers, into a single epoxy matrix resin. Impact strength, tensile strength, flexural strength and hardness were studied as a woven roving in different reinforcement percentage (10%, 20%, 30%, 40%, 50%, 60%, 70%, and 80%). The reinforcement has shown an improvement in the mechanical features and increasing with increasing reinforcement percentage [4].

2014 Surata, et al, investigated the effect of rice husks produced with unsaturated polyester resin as the matrix on the mechanical properties of the composite. Composites were made by hand lay-up techniques, with the variation of fiber weight fraction 20, 30, 40 and 50%. Tensile test specimens were made according to the ASTM D3039, and flexural test specimens according to the ASTM D790M. The results showed that the tensile and flexural strength of the composites increased when the fiber weight fraction increased [5].

2015 Bispo et al, investigated the improvement of polypropylene matrix by mixing with curaua fibers . The samples were prepared in the disks form with curaua rates of 5, 10 and 20 percentage (mass rates). The effect of fibers addition increases the modulus of elasticity (from 1.08 GPa to be 2.72 GPa), and increases the strength of tensile (from 25.9 MPa to be 31.2 MPa) [6].

2015 Ameh et al, investigated the reinforcing results of date palm seed particle on the features at the polyester polymer at particles size of 0.5, 2.0 and 2.8mm utilize different force of 5, 10, 15, 20 and 25 percentage. The prepared samples were subjected to different tests. The best tensile strength value of 16.7619N/mm2 and modulus of elasticity of 343.8N/mm^2 at 15 percentage and 10 percentage loading (0.5mm) respectively and the rate of absorption of water at particle size 0.5mm . The best hardness value of 74 HRF (Rockwell) at particle size 2mm at 25 percentage loading. Where the pure polyester tests values were tensile strength 17.5959N/mm^2, modulus of elasticity of 316.7N/mm2 and hardness of 33.5 [7].

2016 Mohammed et al, investigated the effect of sugar palm fiber mixed with polyurethane, after processing with various rates of NaOH from 2 to 6 percentage to increase the compatibility between the mixture.. The tensile modulus of 440 MPa at 2 percentage of Sodium hydroxide, and strain of 41.6 percentage at 6 percentage of Sodium hydroxide. The tensile modulus and strain of the prepared samples are bested than the unprocessed samples. On the contrary, the tensile strength was still not still as the same and not changed [8].

2016 Benyahia et al, investigated the composite materials based on plant woven and unsaturated polyester resins were manufactured by hand layup technique. The treated samples with permanganate, acetylating and dichromate showed better mechanical results compared to their untreated counterparts. Actually, the treated fiber-reinforced composites showed 43.02 % of increase in tensile strength and 31.59 % in Young’s modulus, while the acetylated fiber-reinforced composites showed maximum improvement in flexural strength of about 23.80 %, and the flexural modulus was also improved by 35.7% compared to the untreated Alfa fiber composites [9].

2016 Oguche, studied reducing and recycling waste paper and rice husk and improvement physical properties of composite ceiling board materials, and to determine the suitability for use in low-cost construction work. where the flexural strength ranged between 0.03N/mm2 and 0.1N/mm2; modulus of elasticity of 1250N/mm2 to 1320N/mm2; water absorption values of between 7.5% and 14.5%; thermal conductivity values of between 0.07kW/MK and 0.082kW/MK as well as density values of 103kg/m3 and 201kg/m^3 [10].

[2017] Al-Mosawi, investigated the effect of Plant waste of sunflower seeds has been grinding to (0.5µ) and used as a natural reinforcement for polyester resin with different weight fraction (1-3) wt.% to produce green composite material. The results showed that the green composite samples were had the highest tensile strength than samples without reinforcement and this increase the tensile strength with increments of recycled sunflower seeds waste [11].

[**2018**] **Al-Mosawi** et al Studied the date seeds as a natural **reinforcement** particles of the polyester resin and reinforcing percentages (1, 2, 3) wt%. Results showed the samples that contain date seeds have a high resistance strain compared to models that contain calcium carbonate and this increase in tensile strength increases with the amount of particles date seeds, plus a big improvement in impact resistance and increases with increasing reinforcement ratio compared with sample have calcium carbonate reinforced particles industrial [12].

2019 Raghavendra, et al, investigated the composite materials were prepared using epoxy resin as the matrix and date palm fibers, polyester, and carbon fiber mats as the reinforcement. The date palm fibers were pre-treated in a 10% alkali solution before use. Composites laminates were prepared using vacuum molding technique. The tensile strength reach 43.41 MPa, the highest Young's modulus of 26.37 MPa, an ultimate tensile strength of 32.92 MPa, and flexural strength of 28.55 MPa [13].

1.4 The aim of the work

Preparation samples of polymeric composites using natural materials residues and study their effects on the mechanical and thermal properties of these composites.
The particles of palm, eucalyptus and buckthorn plants waste were used as a reinforcement of polymeric matrix (silicone rubber), and then for using as coating and painting.
This study aims too many achieve several goals simultaneously.
The first goal is improving of the mechanical and thermal merits of the of silicone rubber, the second is getting rid of these plants wastes, and reducing of the environmental pollution.

1.5 Application fields of silicon rubber

Silicone rubber can be applied to several fields as follows.

1-Used for floors in buildings and houses.

2- Used for wall covering.

3-Used as paint for walls, especially in regions with zigzags.

4- Used as an insulator to reduce energy waste in the summer and winter.

CHAPTER TWO
THEORY

2.1. Introduction

Two approaches can be used to engineer to improve the mechanical properties of materials. One involves the modification of the internal structure of a given material system (intrinsic modification) by minor alloying, processing, and/ or heat treatment variations. However, after a number of iterations, an asymptotic limit will soon be reached by this approach, as the properties come close to the intrinsic limits for any given system. In contrast, an almost infinite array of properties may be engineered by the second approach that involves extrinsic modification by the introduction of additional (external) phases [2, 4, 23].

For example, the strength of a system may be improved by reinforcement with a second phase that has higher strength than the intrinsic limit of the ‘‘host’’ material which is commonly known as the ‘‘matrix.’’ The resulting system that is produced by the mixture of two or more phases is known as a composite material [1, 5, 24].

2.2. Composite

Composites generally consist of two or more different materials or phases, which are combined exhibit a combination of both properties making them better than each of its individual constituents. Reinforcement will be in the form of short or continuous fibers or particulates composite material is a combination of ingredients from a macro to a composite material can be defined as a material system composed of a mixture or combination of two or more of the elements that are different in the macro or the shape and material composition basically inseparable. Composite formed from two different compilers components namely amplifier (reinforcement) that have formed confidential nature but more rigid, stronger, and generally malleable matrix but has the strength and stiffness of the lower [1, 3, 25].

However, the demand for the new material in the global composite industry is increasing from time to time and steady supply are becoming highly crucial. Current research finding shows that the performances of natural fibers over synthetic fibers like glass and carbon include biodegradability, reduced greenhouse gas emissions, low energy consumption, low cost, low density, and acceptable specific strength properties [1, 2].

2.3. Benefits and drawbacks of composite

2.3.1. Benefits

Brief statement of the advantages exhibited by composite materials, which are of considerable use in the different branches of technology and industry applications are as follows:

1- A higher performance for a given weight leads to fuel savings. Excellent strength-to weight and stiffness-to-weight ratios can be achieved by composite materials. This is usually expressed as strength divided by density and stiffness (modulus) divided by density. These are so-called "specific" strength and "specific" modulus characteristics.

2- Laminate patterns and ply buildup in a part can be tailored to give the required mechanical properties in various directions.

3- It is easier to achieve smooth aerodynamic profiles for drag reduction. Complex double-curvature parts with a smooth surface finish can be made in one manufacturing operation.

4- Part counts are reduced.

5- Production cost is reduced. Composites may be made by a wide range of processes.
6- Composites offer excellent resistance to corrosion, chemical attack, and outdoor weathering; however, some chemicals are damaging to composites (e.g., paint stripper), and new types of paint and stripper are being developed to deal with this. Some thermoplastics are not very resistant to some solvents [1, 2, 4].

2.3.2. Drawbacks

Drawbacks of composites some of the associated disadvantages of advanced composites are as follows:

1- Composites are more brittle than wrought metals and thus are more easily damaged.
2- Rehabilitation introduces new problems, for the following reasons:
a- Materials require refrigerated transport and storage and have limited shelf lives.
a. Hot curing is necessary in many cases, requiring special equipment.
b. Curing either hot or cold takes time. The job is not finished when the last rivet has been installed.
3- If rivets have been used and must be removed, this presents problems of removal without causing further damage.
4- Repair at the original cure temperature requires tooling and pressure.
5- Composites must be thoroughly cleaned of all contamination before repair.
6- Composites must be dried before repair because all resin matrices and some fibers absorb moisture [1, 2, 4].

However, suitable designing and material selection can dodge many of the disadvantages which mentioned above.

New technology has provided a variety of reinforcements materials and matrices, which can be combined to configure (compose) composites having a wide range of exceptional features [12].

Since the advanced composites are capable of providing structural efficiency at lower weights as compared to equivalent metallic structures, they have emerged as the essential materials for future applications. In aircraft application, advanced fiber reinforced composites are now being used in many structural applications, engine cowlings, flight control surfaces, landing gear doors, wing-to-body fairings, etc., and also major load carrying structures including the vertical and horizontal stabilizer main torque boxes [4, 7].

Composites are also being considered for use in improvements to civil infrastructures, earthquake proof highway supports, power generating wind mills, long span bridges, etc [4, 26, 27].

2.4. The Matrix

It can be defined as the essentially homogeneous material in which the fiber system of a composite is embedded [1, 5].

The matrix is an important part of the composite that provides a protection against the adverse environment conditions. It also protects the surface of the fibers from mechanical degradation and transfers the load to the fibers. The most common used matrices in the natural fiber reinforcement composites are polymeric [28, 29].

The matrix combines the individual particles of reinforcement, protecting them against external influences and prevents their violation. The basic function of the matrix is to transmit the external load onto the reinforced phase. For the matrix, a good bond strength with the reinforcing phase material (i.e. perfect wettability without chemical interaction at the interface of the matrix and reinforcement) is required.

Among other requirements for the matrix, a low weight is commonly included. In comparison with the reinforcement phase, a matrix has generally lower strength and greater plasticity [5, 30].

The primary functions of the matrix are to transfer stresses between the reinforcing fibers (hold fibers together) and protect the fibers from mechanical and/or environmental damages. A basic requirement for a matrix material is that its strain at break must be larger than the fibers it is holding [4, 31].

The functions of a matrix

1. Holds the reinforcement phase together.
2. Protects the reinforcement phase from environment.
3. Protects the reinforcement phase from abrasion (with each other).
4. Helps to maintain the distribution of reinforcement phase.
5. Distributes the loads evenly between reinforcement phases.
6. Enhances some of the properties of the resulting material and structural component (that fiber alone is not able to impart). These properties are such as, transverse strength of a lamina impact resistance.
7. Provides better finish to final product [4, 28, 32].

2.5. Types of Composites

Depending on the composites matrix material, the composites can be divided to three groups. They are [2, 33, 34]:

a. Metal Matrix Composites (MMC)
b. Ceramic Matrix Composites (CMC)
c. Polymer Matrix Composites (PMC).

2.5.1. Metal Matrix Composites

Metal matrix composites (MMCs) generally consist of lightweight metal alloys of aluminum magnesium, or titanium, reinforced with ceramic particulate, whiskers, or fibers, the reinforcement is very important because it determines the mechanical properties, cost, and performance of a given composite [2, 35].

Metal matrix composites reinforced with particulate (discontinuous types of reinforcement) and continuous reinforcement (long fiber or wire reinforcement) can result in dramatic improvements in MMC features, but have high costs comparable to unreinforced metals, but with significantly better hardness, and somewhat better stiffness and strength [4, 36].

Processing ability is a key advantage of all types of composites, but is particularly so in the case of MMCs. MMCs can be designed to fulfill requirements that no other materials, including other advanced materials, can achieve. There are numbers of many applications in aerospace structures and electronics that capitalize on this advantage [1, 4, 34].

Metal matrix composites, at present though producing a wide interest in research fields, are not as widely in use as their polymeric counterparts. High strength, fracture toughness and stiffness are offered by metal matrices than those offered by their polymer counterparts. They can withstand elevated temperature in corrosive environment than polymer composites. Most metals and alloys could be used as matrices and they require reinforcement materials, which need to be stable over a range of temperature and non-reactive too. However, the guiding aspect for the choice depends essentially on the matrix [26, 37].

2.5.2. Ceramic Matrix Composites:

The word ceramic is derived from the Greek word keramikos. Keramikos term is used to refer to pottery. In general, ceramics may be defined as solid materials which exhibit very strong ionic bonding and in few cases covalent bonding. Ceramic materials are typically crystalline in nature [2, 34].

Ceramics are inorganic and non-metallic solids that are typically available in the form of powder materials. Monolithic ceramic materials possess several desirable properties, such as high moduli, high compressive strength, high temperature capability, high hardness, wear resistance, low thermal conductivity and low chemical inertness. The high temperature proficiency of ceramics makes these materials very attractive for extremely high temperature applications [4, 34].

However, because of their very low fracture toughness, ceramics are not appropriate for structural applications.

One of the main objectives in producing ceramic matrix composites is to increase the toughness. Naturally, it is hoped and indeed often found that there is a concomitant improvement in strength and stiffness of ceramic matrix composites [37, 38].

2.5.3. Polymer Matrix Composites:

Most commonly used matrix materials are polymeric. There two reasons. Firstly, in general, the mechanical properties of polymers are inadequate for many structural purposes. In particular, their strength and stiffness are low compared to metals and ceramics [38] . These obstacles are overcome by reinforcing polymers with other materials. Secondly, the preparation of polymer matrix composites require neither high pressure nor high temperature [2].

In addition, needs simpler instruments for preparation polymer matrix composites. For this reason, polymer composites developed and after a short time be common for structural applications. Polymer composites are used because their features are superior to those of the individual polymers. They have a greater elastic modulus than the individual polymer and in the same time are not brittle like ceramics [38] .

Polymer matrix composite provides strength and stiffness that are lacking in the matrix. The composites are designed so that the mechanical loads to which the structure is subjected in service are supported by the reinforcement [31].

The function of the relatively weak matrix is to bond the fibers together and to transfer loads between them, the reinforcement may consist of particles, whiskers, fibers, or fabrics [5].

When discontinuous particles are used for reinforcement, the properties tend to be more isotropic because these reinforcements tend to be randomly oriented, Such PMCs lack the outstanding strength of continuous-fiber PMCs, but they can be produced more cheaply, using the technologies developed for unreinforced plastics, such as extrusion, injection molding, and compression molding. Sheet molding compound (SMC) is such a material, widely used in the automotive industry [4, 34].

Polymeric matrices are the most common type in production. In comparison with metals, they have low weight, high strength, are corrosion resistant, do not require surface treatment, absorb vibrations and have low thermal and electrical conductivity [2].

The mechanical properties vary according to the type of polymer, whether it is a thermoplastic, thermoset or elastomer. For the production of composites, all three types of polymers are used. Thermoplastics are mostly chemically resistant and tougher than thermosets, while for elastomers, the dominant feature is its elongation [22, 25].

Due to their low density, they are most widely used in aircraft design. The disadvantage is the low thermal stability of polymers [14].

2.6. The Reinforcement

The reinforcement phase transmits the bulk of the external loads. It is expected to have high strength and a modulus of elasticity E (E is about one order higher than that of the matrix), as well as a small deformation at a fracture with a high proportion of elastic deformation. Regarding the tensile behavior of the composite, it is given by the shape, concentration and orientation of reinforcement [4, 39]

The strength, stiffness, and density of the composite material is very dependent on the reinforcing material. The ultimate tensile strength of a composite is a result of the synergy between the reinforcement and the matrix (the interaction of elements that when combined produce a total effect that is greater than the sum of the individual elements). The matrix forces load sharing among all the fibers, strengthening the material. The main types of reinforcements are continuous fibers, discontinuous (short fibers), whiskers, and particulates [2, 39].

The orientation of the reinforcing phase affects the isotropy of the system. If the reinforcing particles have the shape and dimensions in all directions about the same (for example powders), the composite behaves (basically) as an isotropic material, and therefore its features are the same in all directions. On the contrary, systems reinforced with cylindrical reinforcement (fibers) show an anisotropy of features [40].

As mentioned above the reinforcing phases are mostly divided according to the geometry of their individual particles into:

- Particulate
- Fiber [4, 38].

2.6.1. Fiber Reinforced Polymer

Fiber-reinforced polymer (FRP) is a composite material made of a polymer matrix reinforced with fibers. The fibers are usually glass, carbon, or aramid, although other fibers such as paper or wood or asbestos have been sometimes used. FRPs are commonly used in the aerospace, automotive, marine, and construction industries [2, 25].

Fiber reinforced polymer material is very complex. For instance, the variabilities in the polymer include its manufacturing techniques and whether additives or modifiers have been incorporated. The fibers stabilize the polymer with the effect that the composite material has elastic characteristics compared with the viscoelastic properties of the polymer. In addition, the composite material is less affected by changes in temperature and load duration. However, the composite material is a complex one, due to the large variation in the two constituent properties and the various different fibers and their orientation in the composite. All these factors are required to be embraced in the limit state design method [2, 4].

Fiber-reinforced polymers are multipurpose materials widely employed in advanced applications because of their high stiffness and high-strength properties. Conversely, their brittleness, which is primarily induced by low stiffness and fracture toughness, leads to low matrix-dominated properties such as fracture toughness [32, 38].

Common fiber reinforced composites are composed of fibers and a matrix. Fibers are the reinforcement and the main source of strength while matrix glues all the fibers together in shape and transfers stresses among the reinforcing fibers. The fibers carry the loads along their longitudinal directions. Sometimes, filler might be added to smooth the manufacturing process, impact special properties to the composites or to reduce the product cost. Fiber reinforced composites systems reinforced with cylindrical reinforcement (fibers) show an anisotropy of properties [4, 41].

2.6.2. Particle Reinforced Polymer

Polymeric matrices have low strength (themselves) and have low heat resistance, in particular. Adding a mixture of dispersion particles to a polymeric matrix increases the modulus of elasticity, thermal (dimensional) stability, reduces shrinkage and improves other properties [2, 39].

A composite with particles as reinforcement is called particulate composite [1, 4].

Particles as a reinforcing phase are dispersed in a matrix and do not own an aggregate structure. They may have a spherical, lamellar, rod or irregular shape where one dimension of such a reinforcement unit does not significantly exceed the dimensions of others. A metal, polymeric, or ceramic matrix is used. The most often used particles are oxides, nitrides, carbides and borides [38, 42].

Particles in the composite limit the development of the plastic deformation in the matrix material, and participate in the transmission of stress, but to a much lesser extent than the fibers in the fibrous composites [39].

Particle reinforcement is used to improve the properties of matrix materials, for example to modify thermal and electrical conductivity and the behavior at high temperatures, to reduce friction, increase wear resistance, improve machinability, increase hardness, and reduce contraction [22].

Generally speaking, from the mechanical point of view, the particles in the matrix of the composite cause strengthening [18].

Particulate composites contain larger particles of regular shapes (spheres, platelets) or irregular shapes [1, 14].

Particles used for reinforcing include ceramics, small mineral particles, metal powders such as aluminum and amorphous materials including polymers and carbon black. Particles are used to increase the modulus and to decrease the ductility of the matrix. Particles are also used to reduce the cost of the composites. Reinforcements and matrices can be common, inexpensive materials and are easily processed. Some of the useful properties of ceramics and glasses include high melting temperature, low density, high strength, stiffness, high wear and high corrosion resistance [39, 43].

An example of particle reinforced composites is an automobile tire, which has carbon black particles in a matrix of poly-isobutylene elastomeric polymer [37].

Particulate composites consist of particles immersed in matrices such as alloys and ceramics. They are usually isotropic because the particles are added randomly. Particulate composites have advantages such as improved strength, increased operating temperature, oxidation resistance, etc. Typical examples include use of aluminum particles in rubber; silicon carbide particles in aluminum; and gravel, sand, and cement to make concrete [19].

Particles in composites are typically used not only to improve the mechanical properties, but often to improve or modify properties such as heat resistance, electrical conductivity, damping of vibrations, wear resistance, hardness, resistance to high temperatures, etc. As the particulate reinforcement, respectively dispersion, there can be used practically anything, but most frequently the dispersion of ceramic particles is used [4, 32].

According to their size, we distinguish the particles as follows:

1- Particles of(2 mm – $10^{-3)}$ mm
2- Dispersions (10^{-3} – $10^{-5)}$ mm (1 to 0.01 μm), recognizable by a scanning electron microscope.
3- Nanoparticles under 10^{-5} mm (below 10 nm), recognizable by a transmission electron microscope [39, 44].

The particles in the matrix should be distributed (completely) evenly. Clustering of the particles at the grain boundaries of the matrix (a risk especially within a metal) during the solidification of the matrix is very undesirable. It is therefore necessary when producing the composite by adding dispersion particles to the melt to (often) use intensive mixing [39, 45].

Granular strengthening is based on separate particles of different sizes and their different volume share in the matrix. Optimum strengthening occurs at approximately the same particle size and their even distribution. Such composites are used particularly to obtain specific combinations of performance and not only to increase their strength [1, 19].

Superstructure evaluation according to the reinforcement condition segregated reinforcement - reinforcement particles are not in direct contact, they do not create their own infrastructure, reinforcement is a discontinuous phase aggregated reinforcement- the individual particles are in direct contact, they can create their own infrastructure - they are somehow arranged, reinforcement is a continuous phase [39, 41].

Production of particulate composites is considerably simpler, grains are not as sensitive and therefore intensive manual mixing can be used. It is necessary to ensure complete coating of all grains by a matrix, force out the air and ensure maximum homogeneity of a mixture, and further to prevent particle sedimentation, while the viscosity of the matrix is important (as well). In some cases, sedimentation is used especially when we want to obtain a material with a graduated percentage of filler [1, 39].

Elastomers are generally very homogeneous; therefore, we can use very small particles to depressively solidify the elastomers [32].

The distribution of particles in the composite matrix is random, and therefore strength and other properties of the composite material are usually isotropic [22, 25].

2.7. General Features of Particle Reinforce Composites

1- Advantages of particle reinforced composite materials

a. Low cost
b. High stiffness and strength (inorganic particles)
c. Wear resistance
d. Simpler manufacturing process

2- Mechanical properties depend on the reinforcement, manufacturing and subsequent treatments

3- Polymeric matrixes are reinforced to improve their mechanical strength and abrasion resistance [1,15].

2.8. Particles in Elastomers

Elastomers are generally very homogeneous; therefore, very small particles can be used to depressively solidify the elastomers.

A specific example are conveyor belts, tires, where 10 to 20 % of silica powder can be used, talc, or carbon black for the base rubber. It often also combines several kinds of dispersion [45].

The reinforcing phase provides the strength and stiffness. In most cases, the reinforcement is harder, stronger, and stiffer than the matrix. The reinforcement is usually a fiber or a particulate [2].

Particulate composites have dimensions that are approximately equal in all directions. They may be spherical or any other regular or irregular shape. Particulate composites tend to be much weaker and less stiff than continuous fiber composites, but they are usually much less expensive. Particulate reinforced composites usually contain less reinforcement (up to 40 to 50 volume percent) due to processing difficulties and brittleness [14, 39].

2.9. Polymer

The term "polymer" is a Latin origin, where it consists of two parts (poly) of the first section and means (multi), and (mer) the second section which means (unit), therefore the word polymer means multi-units [37]. Polymers are known as giant chemical compounds composed of simple structural units called monomers. These “monomers” are repeated several times, and they are connected to each other by chemical bonds that form long molecular chains [46].

These chains may take different forms (linear, branched, or cross linked). The process of connecting the monomer units together is called polymerization as shown in Figure 2-1 [37, 47].

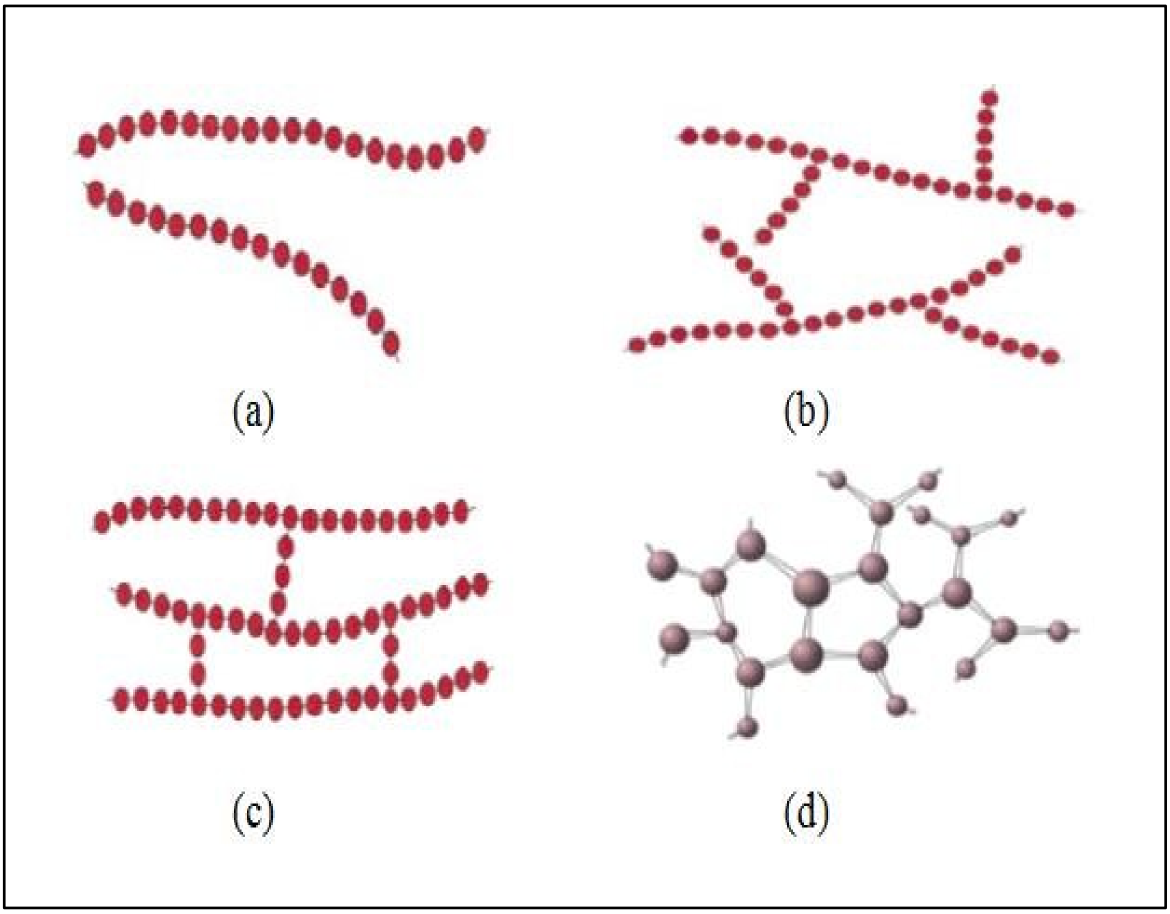


Fig .2-1. Schematic representations of (a) linear, (b) branched, (c) cross linked, and (d) network molecular structures. Circles specify individual repeating units [20].

2.10. Classification of Polymer:

Polymers are classified according to their thermal behavior (thermal Response) to the following types [48]:

2.10.1. Thermoplastic Polymers:

Polymers with long molecular chains that have little branching or have single or double bond chains, where long chains of similar molecules are connected together by weak secondary forces called "Van der Waals forces" [37]. These types of polymers are highly affected by the temperature, where their properties easily change. When the temperature reaches the glass transition, these polymers become flexible [48, 49]. At high temperatures, the breakdown of the secondary bonds between the chains will be more easily; therefore the material fused and returns to its solid state again when the temperature decreased below the glass transition point, this property is used in the plastics manufacturing and industrial of fiber, as shown in Figure 2-2 [37, 48].

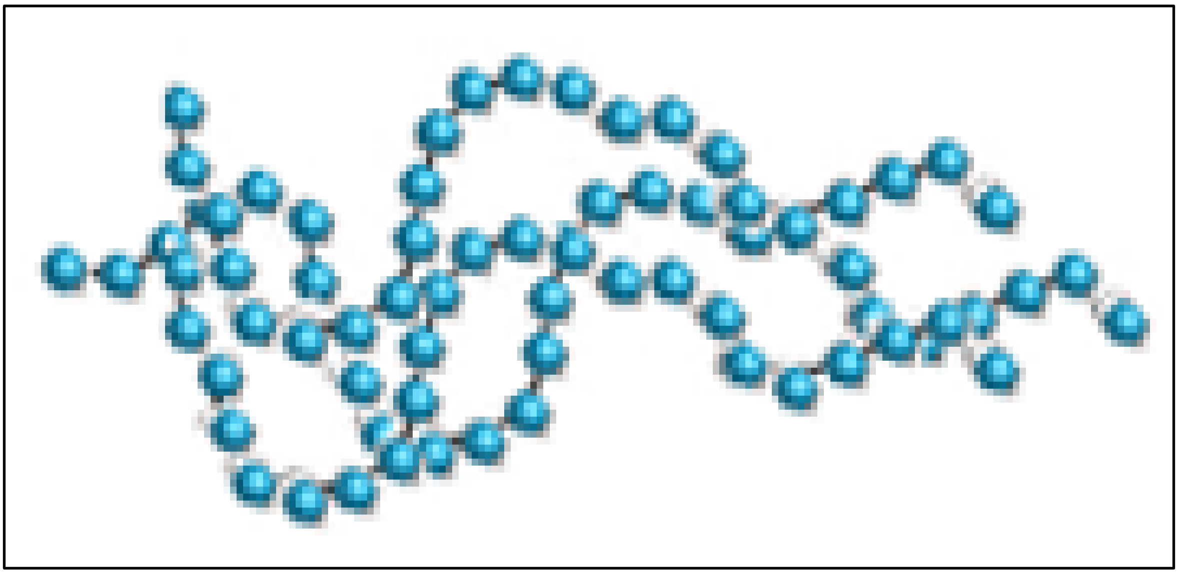


Fig. 2-2. Schematic representations of thermoplastic polymers [20].

Thermoplastic materials possess the following characteristics:

A. High hardness.
B. High resistance to fracture stresses.
C. High expansion and elongation.
D. They are usually non-uniform (Anisotropic), depending on the conditions of manufacturing, during the casting and cooling process (Solidification) [37, 47].

2.10.2. Thermoset Polymers:

Polymers that be in the form of liquid resins. They subjected to chemical changes when heated [37]. The polymer chains are intertwined. These polymers become infusible after processing, and poor thermal and conductivity.

They are transformed from heat tolerant polymers to brittle solids by chemical bonding [37]. This transformation creates a three-dimensional bonded network of polymeric chains; the chains together have strong chemical bonds that cannot be easily broken. These polymers cannot be reconstituted after the initial reaction process, as the temperature increases, it will be charred and decomposition occurs, as shown in Figure 2-3 [47, 48].

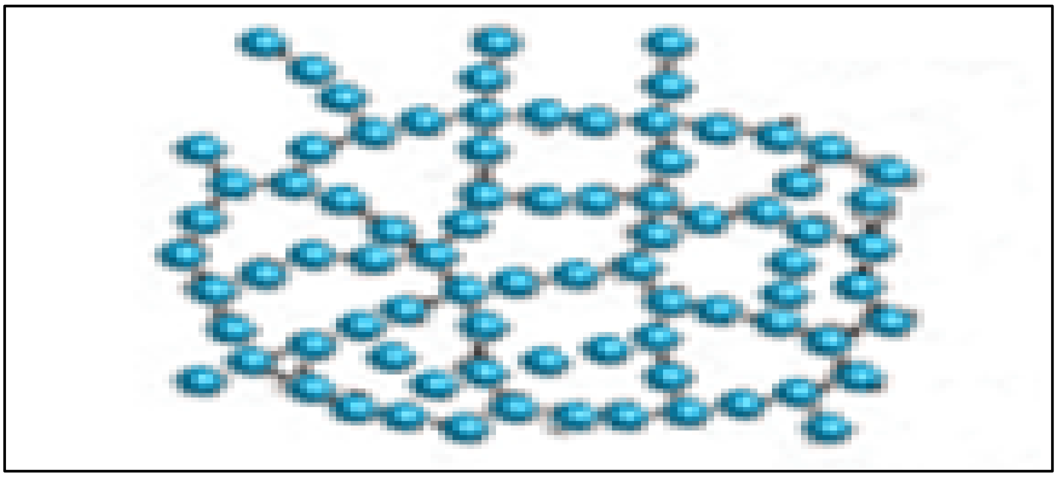


Fig 2-3. Schematic representations of thermoset polymers [36].

Thermoset materials possess the following characteristics:

A. High thermal stability, this is because the molecules have a strong three-dimensional bonded network.
B. They are non-crystalline (amorphous) and have high glass transition temperature.
C. Characterized by stiffness and strength.
D. Good resistance to creep.
E. They have high electrical and thermal insulation.
F. Do not dissolve in all solvents but tend to bulge in strong solvents [43, 48].

2.10.3. Elastomer polymer:

These polymers are composed of linear molecular chains with little tangles in the chains. They show very intense strain when they are being under an external stress, but they can return to their original dimensions when the applied stress removed [50, 51].

The elastic properties for this type of polymer are based on the elasticity of the long chains states, where they intertwined (wrapped up) randomly, therefore ((in this state of intertwining the distance between the ends of the polymer (bulk)) molecule is much less than the distance when the molecule is in the extended position [37, 52].

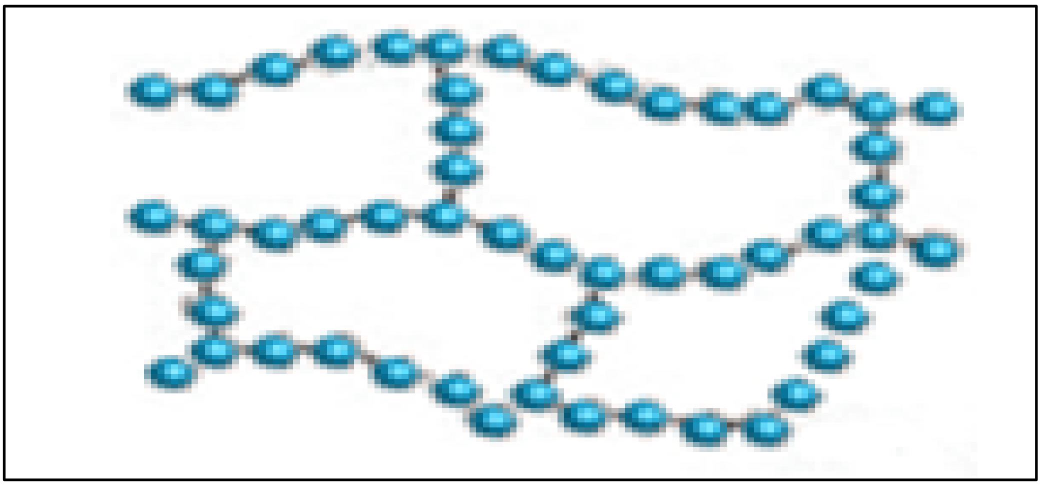


Fig. 2-4. Schematic representations of elstomer polymers [37].

This type of polymer has important features:

A. It has a low glass transition temperature.
B. The particles of these materials are highly twisted.
C. High ability of elongation and contraction [37].

2.11. Silicone Rubber

Silicone rubber (SIR) is a type of elastomer polymer, a semi-organic compound composed of sand and aryl halides [26].

Silicon rubber consists of a chain of silicon atoms and oxygen instead of carbon atoms and hydrogen as found in other types of rubber. This structure gives the silicon a high flexible chain, as shown in Figure 2-6 [25, 26].

Silicone rubber characterized by a high temperature stability, and it has a high characteristics of resistance to chemicals, oil, high temperatures, ozone, oxygen, ultraviolet light, fungi and water. It is characterized by the characteristics of electrical insulation, that make it useful for use in various industrial applications, which include household materials, food, medical applications, electrical and mechanical parts [26, 43, 53].

The silicone rubber used as an insulator in high voltage equipment because it has excellent merits with regard to corrosion resistance [54, 55]. It's stability features against heat and ultraviolet rays are due to the fact that silicone rubber chains are the strongest among other bonds such as Ethylene propylene rubber (EP rubber) or epoxy [54]. It able to restore the water repellent property even if the pollution layer is establish on the surface which inhibits increases of rapid leakage currents [55]. Silicone rubber is hydrophobicity, where the hydrophobicity (the property of repelling water rather than absorbing it or dissolving in it) [1, 54].

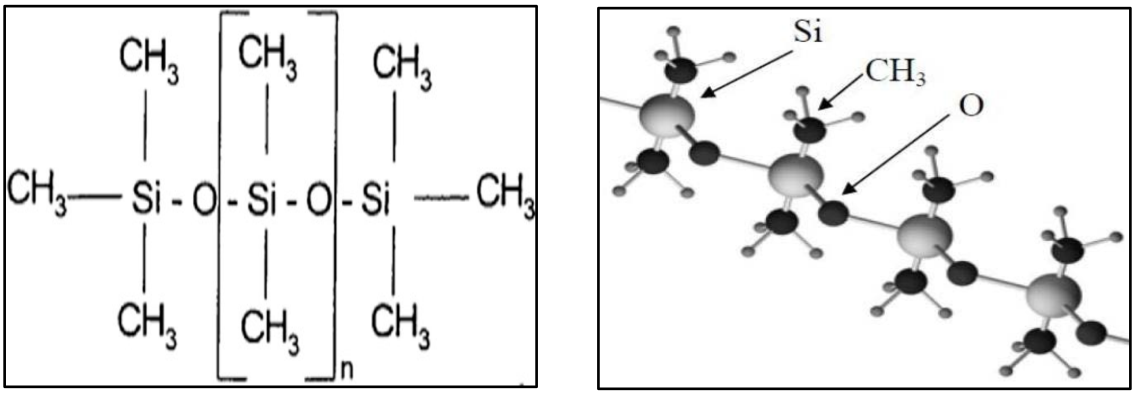


Fig. 2-5. Schematic of the structure of silicone rubber [54].

2.12. Characteristics of Silicone Rubber

Silicone rubber has the following features.

1. High flexibility at high and low temperatures.

2. Excellent resistance to aging.

3. Weather resistant.

4. Electrically insulating.

5. permeable to gas.

6. Low flammability [36, 51].

2. 13. Materials Selection

One of the most challenging task of materials engineer is the proper selection of the material for a particular job, *e.g.*, a particular component of a machine or structure. An engineer must be in a position to choose the optimum combination of properties in a material at the lowest possible cost without compromising the quality [27].

Factors affecting the selection of materials.

(i) Component Shape:

The shape and size of a component has great effect on the choice of the processing unit which ultimately effects the choice of the material [28].

(ii) Dimensional Tolerance:

Some materials can be finished to close tolerance while others cannot. Obviously, the required dimensional tolerance for finished components will, influence the choice of materials [6, 8].

(iii) Mechanical Properties:

To select a suitable material for specific conditions, all mechanical properties, e.g., toughness, hardness, strength, etc. guide us [6, 8].

(iv) Fabrication (Manufacturing) Requirements

Method of processing of the material also affects the properties of a component, e.g., forged components can be stronger than the casted components. Different types of working processes may also give different types of product structure. However, casting process can provide precise dimensions at low cost in comparison to machine operations [6, 8].

2.14. Mechanical Properties

Mechanical properties can be defined as Characteristics that indicate the elastic or inelastic behavior of a material under pressure (force), such as bending, brittleness, elongation, hardness, and tensile strength [24]**.**

(physical properties that a material exhibits upon the application of forces. Examples of mechanical properties are the modulus of elasticity, tensile strength, elongation, hardness and fatigue limit) [24]**.**

Mechanical properties describe the behavior of material in terms of deformation and resistance to deformation under specific mechanical loading condition. These properties are significant as they describe the load bearing capacity of structure. Elastic modulus, strength, hardness, toughness, ductility, malleability, and wear are some of the common mechanical properties of engineering materials [4, 27].

The standard mechanical properties were determined by the procedures found in ASTM standards for plastics. The mechanical properties studied were tensile strength, hardness [56].

2.14.1. Tensile Testing

Tensile testing is a way of determining how something will react when it is pulled apart - when a force is applied to it in tension [5].

Tensile testing is one of the simplest and most widely used mechanical tests. By measuring the force required to elongate a specimen to breaking point, material properties can be determined that will allow designers and quality managers to predict how materials and products will behave in their intended applications [25].

Many performance parameters can be measured by well executed tensile testing. The resulting data - a curve of force vs extension - shows the tensile profile of the test up to the point where the specimen breaks. Along this tensile profile there are many points of interest, chief among them the elastic limit and force to break or failure point [5, 24]. The following Figure shows the ideal stress-strain behavior of the material.

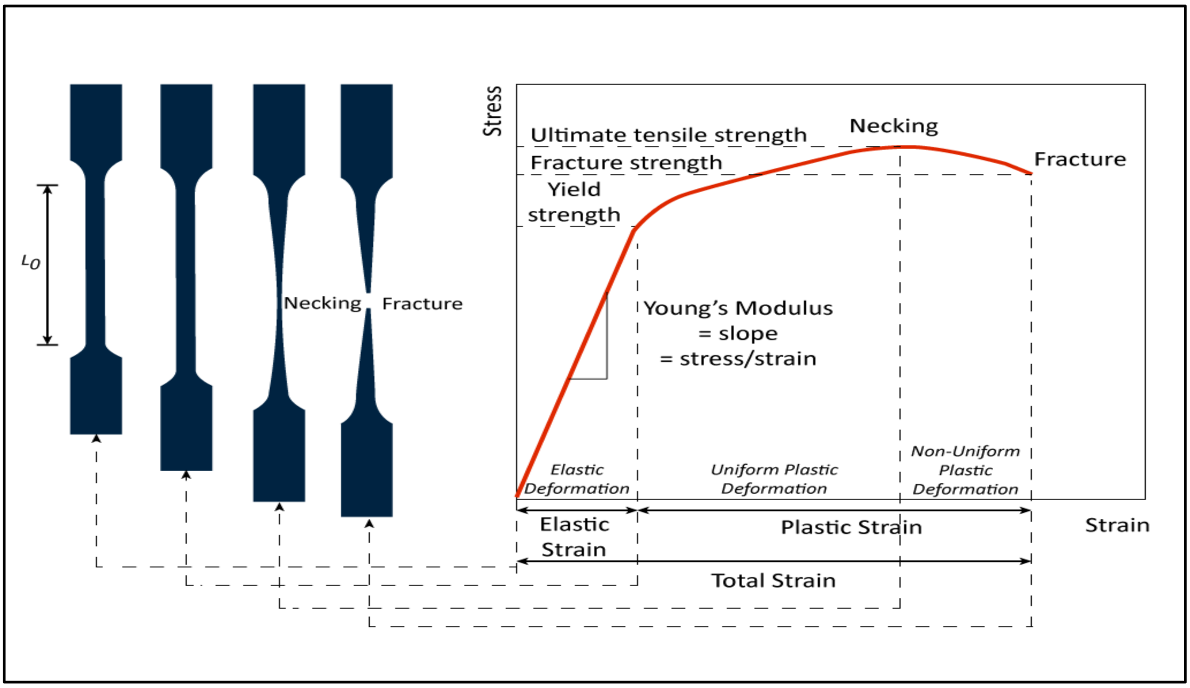


Fig .2-6. The ideal stress-strain behavior of the material [24].

Young's modulus is defined as the ratio of stress below the proportional limit to the corresponding strain. It is a measure of the rigidity or stiffness of a material. Young's modulus is also known as elastic modulus [24, 25, 57].

Young's modulus measures the resistance of a material to elastic (recoverable) deformation under load. A stiff material has a high Young's modulus and changes its shape only slightly under elastic loads (e.g. diamond). A flexible material has a low Young's modulus and changes its shape considerably (e.g. rubbers) [1, 25, 30].

Young's modulus equation is

E = tensile stress/tensile strain

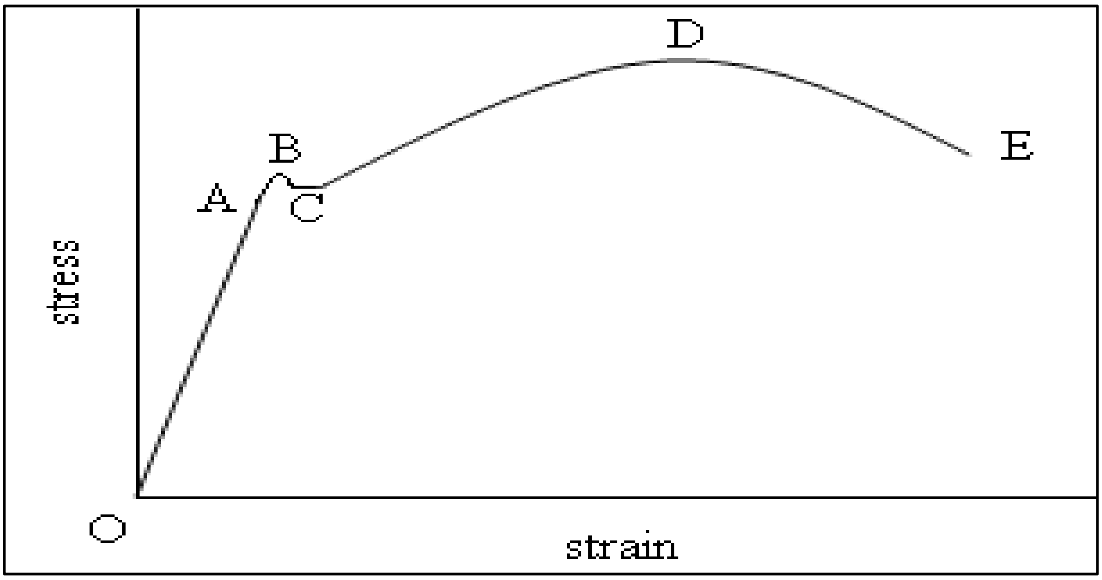
$$E = \frac{F\,L}{A\,\Delta L} \quad \text{……………………………………(2-1)}$$

Where F is the applied force, L is the initial length of the specimen; A is the area, and E is Young's modulus in Pascal (Pa), but the practical units are megapascal (MPa) or gigapascal [24, 25, 57].

Ultimate tensile strength (UTS), often shortened to tensile strength (TS), ultimate strength, within equations, is the capacity of a material or structure to withstand loads tending to elongate, **or it is the** maximum load that a material can support without fracture when being stretched, divided by the original cross-sectional area of the material [1, 8].

$$E_{UTS} = \frac{F_{max}}{A} \quad \text{……………………………………..(2-2)}$$

Where E_{UTS} Ultimate tensile strength, F_{max} is the maximum (load) applied force, and A is the area, as shown in the following figure [1, 25].



-Fig 2.7. The ultimate tensile strength of the material, where, (A) Elastic Limit, (B) Upper Yield Stress, (C) Lower Yield Stress, (D) Ultimate Stress, and € Breaking Stress [24].

2.14.1.1. Advantages of Tensile Testing

Tensile testing provides data on the integrity and safety of materials, components and products, helping manufacturers ensure that their finished products are fit-for-purpose and manufactured to the highest quality.

The data produced in a tensile test can be used in many ways including:

1. determine batch (The quantity of product at one time) quality.
2. determine consistency in manufacture.

3. aid in the design process.
4. reduce material costs and achieve difficult manufacturing goals.
5. ensure compliance with industry standards [24, 25].

Tensile tests are performed for several reasons. The results of tensile tests are used in selecting materials for engineering applications. Tensile properties frequently are included in material specifications to ensure quality. Tensile properties often are measured during development of new materials and processes, so that different materials and processes can be compared. Finally, tensile properties often are used to predict the behavior of a material under forms of loading other than uniaxial tension [1, 2, 25].

While the tensile strength indicates the maximum axial pull, it can withstand without failure. Or the ability of a material to withstand tensile (stretching) loads without rupture occurring. The material is in tension [24, 25].

The strength of a material often is the primary concern. The strength may be measured in terms of either the stress necessary to cause appreciable plastic deformation or the maximum stress that the material can withstand. These measures of strength are used, with appropriate caution (in the form of safety factors), in engineering design. Also of interest is the materials ductility, which is a measure of how much it can be deformed before it fractures [24, 45].

2.14.2. Hardness Testing

Hardness is the resistance of a material to localized deformation. Or, it is the ability of a material to resist to permanent shape change due to external stress, **or** is the resistance to plastic deformation (malformations) [24].

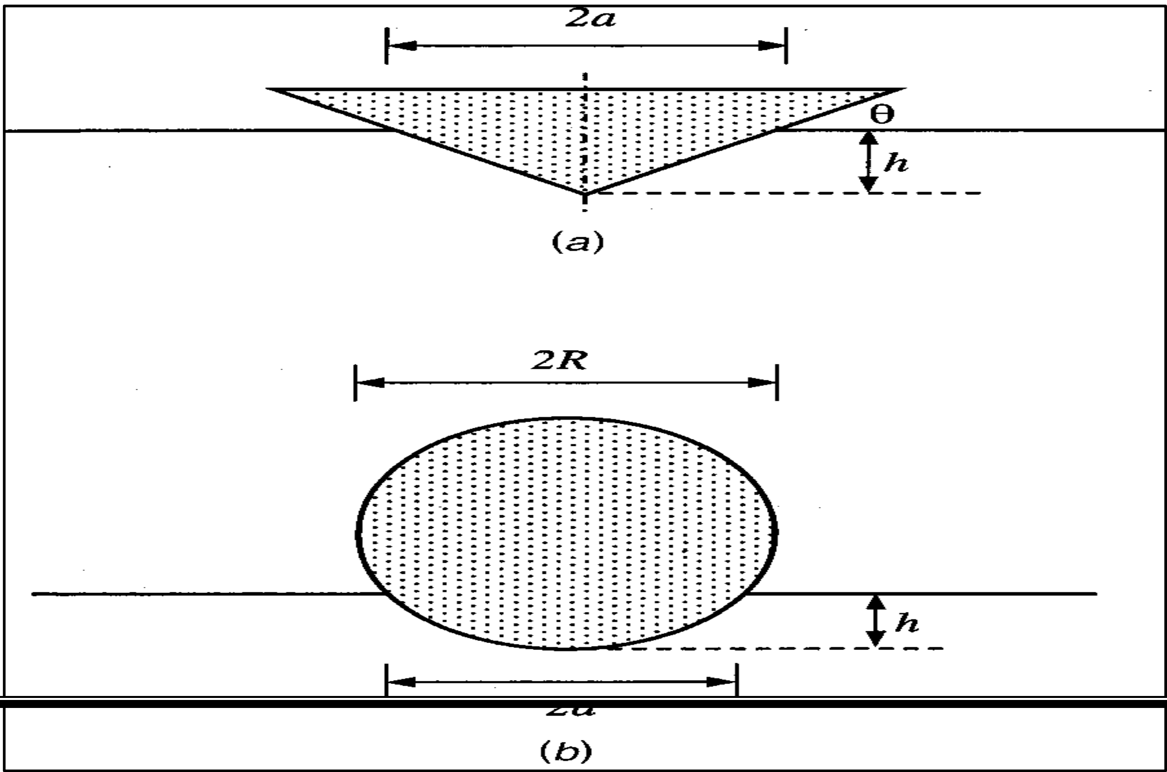
The term can apply to deformation from indentation, scratching, cutting or bending, so it is an indication of the wear resistance of a material. In metals, ceramics and most polymers, the deformation considered is plastic deformation of the surface [25].

For elastomers and some polymers, hardness is defined as the resistance to elastic deformation of the surface. The lack of a fundamental definition indicates that hardness is not be a basic property of a material, but rather a composite one with contributions from the yield strength, work hardening, true tensile strength, modulus, and others factors [57].

Hardness measurements are widely used for the quality control of materials because they are quick and considered as nondestructive tests when the marks or indentations produced by the test are in low stress areas [57].

Thus, it is a measure of plastic deformation, as is the tensile strength, so they are well correlated [1].

The hardness of the materials depends on the type of strength that binds the molecules and the atoms. This bonding will increase the



attachment (interconnection between the molecules) and adhesion, which reduces the movement of the particles of the material, which increases the material's resistance to scratching and cutting, as shown in Figure 2-9 [57].

Fig. 2-8. Schematic diagrams of indenters, (a) a sharp conical indenter; and (b) a spherical indenter [24].

Historically, it was measured on an empirically scale, determined by the ability of a material to scratch another, diamond being the hardest and talc the softer. Now standard tests are used, where a ball or point is pressed into a material and the size of the dent is measured. There are a few different hardness tests: Rockwell, Brinell, Vickers, etc. They are popular because they are easy and non-destructive (except for the small dent) [57].

In the other hand, there are various measure of hardness – scratch, indentation and rebound hardness.

1. **Scratch Hardness**

   Scratch Hardness is the ability of materials to resist the scratches to o

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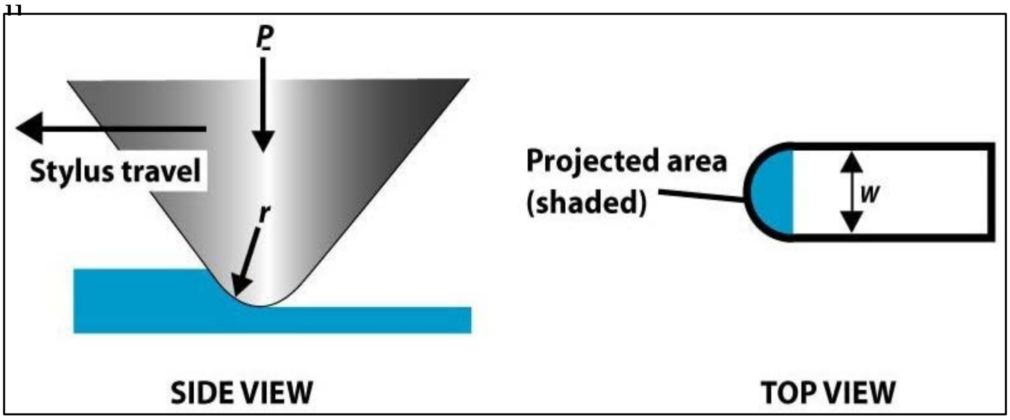


   rface layer due to external force, as shown in Figure 2-9 [1].

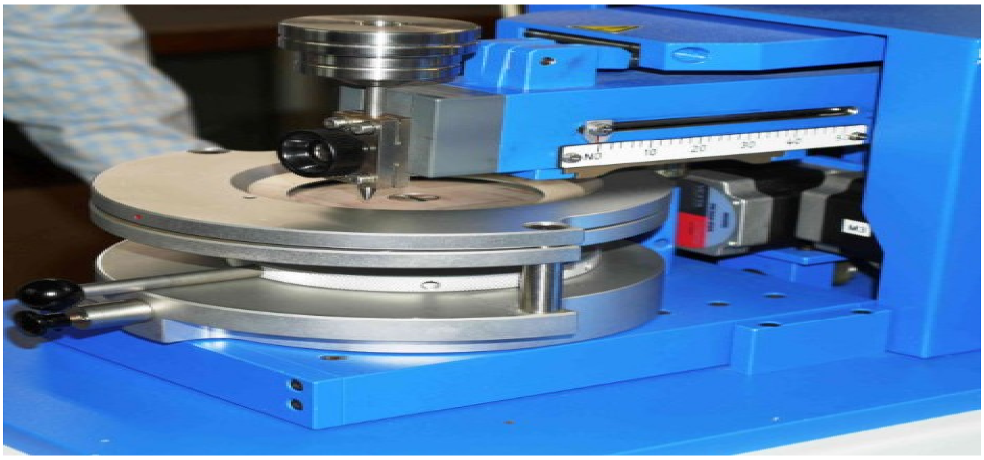


Fig. 2-10. Scratch Hardness [1].

2. **Indentation Hardness**

   It is the ability of materials to resist the dent due to punch of external hard and sharp objects, as shown in Figure 2-11, [24].

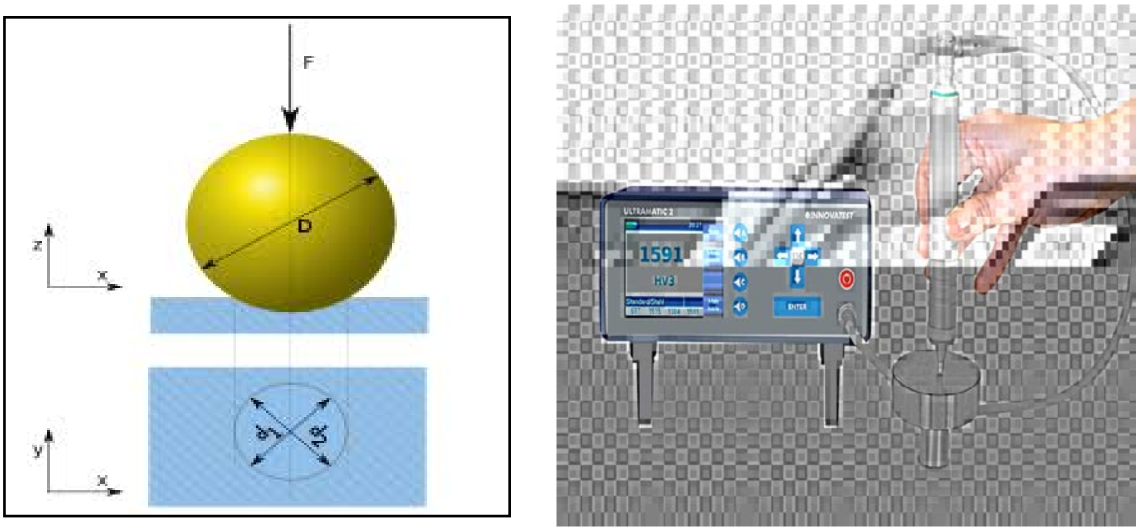


Fig .2-11. Indentation Hardness [24]

3. **Rebound Hardness**

Rebound hardness is also called as dynamic hardness. It is determined by the height of “bounce” of a diamond tipped hammer dropped from a fixed height on the material [24].

This test is easy because it does not need complex, expensive, fast and non-adaptive devices, because the samples do not undergo damage, as they are not broken when tested and are not severely deformed. It is used for quality control at production. It is a measure of the mechanical properties that affect the chemical composition as well as the conditions manufacturing and homogeneity of molded model [25].

Processes that increase the hardness of materials also increase their tensile strength. At the same time, the toughness of the material is reduced as it becomes more brittle, as shown in Figure 2-12 [24].

Fig .2-12. Rebound Hardness [24].

2.14.3. Wear Testing

Is the progressive loss of material from surfaces as a result of contact with other surfaces. It can occur as a result of sliding or rolling contact between surfaces or from the movement of fluids containing particles over surfaces [1].

Because wear is a surface effect, surface treatments and coatings play an important role in improving wear resistance. Lubrication can be considered to be a way of keeping surfaces apart and so reducing wear [1,45].

2.14.3.1. Properties Of Wear Materials

1. A wear material may be used to reduce dimensional changes due to unwanted material removal, reduce frictional losses, to tailor the physical performance of a component, and/or to provide a physically stable working surface.
2. The proper selection of a material for a wear application will strongly depend on both the type of wear to be countered and on the wear environment. The wear environment can be dry, wet, warm, cold, and so on. Wear taking place in a corrosive marine environment will be more damaging than the marine environment or the wear alone.
3. Wear phenomenon is a factor in applications where it might not be readily apparent. Optical windows that are exposed to the natural elements have a need for wear protection where dust, sand, and ice can impact and roughen soft optical surfaces. Fan and propeller blades in water can experience wear by cavitation erosion in water and bug and dust impact erosion in air [1, 58, 59].

2.14.3.2. Mechanisms for wear

A number of different mechanisms for wear have been identified:

1- **Adhesive wear**

On an atomic scale, even smooth surfaces appear rough and thus when two surfaces are brought together; contact is made at only a few points, Figure 2.9. The forces holding the surfaces together can result in very high stresses at the few very small area of contact. Surface projections become plastically deformed by the pressure and can weld together. Sliding involves breaking these welded bonds, the breaks resulting in cavities being produced on one surface, projections on the other and frequently tiny abrasive particles [32, 59].

Adhesive wear or galling is used for this type of wear when two solid surfaces slide over one another under pressure.

How to reduce wear rate for this type:

a. If the harnesses of the two surfaces are high, the wear rate can be reduced.
b. Also, high strength, high toughness and ductility all contribute to reducing such wear, preventing the tearing of material from the surfaces, as shown in Figure 2-13 [15, 45].

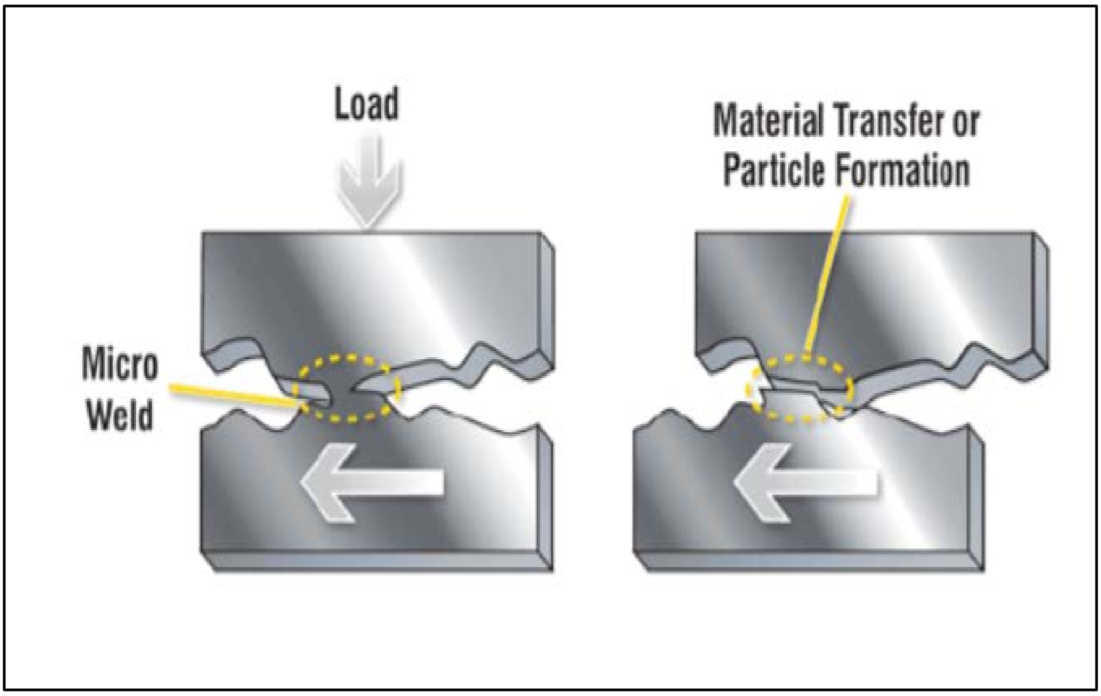


Fig .2-13. Adhesive wear [20]**.**

2- Abrasive wear

The term abrasive wear is used when material is removed from a surface by contact with hard particles; sliding resulting in the pushing out of the softer material by the harder material (Figure 2-14**)**. Such wear is common in machinery used to handle abrasive materials. Materials with a high hardness, high toughness and high strength are most resistant to such wear [45, 59].

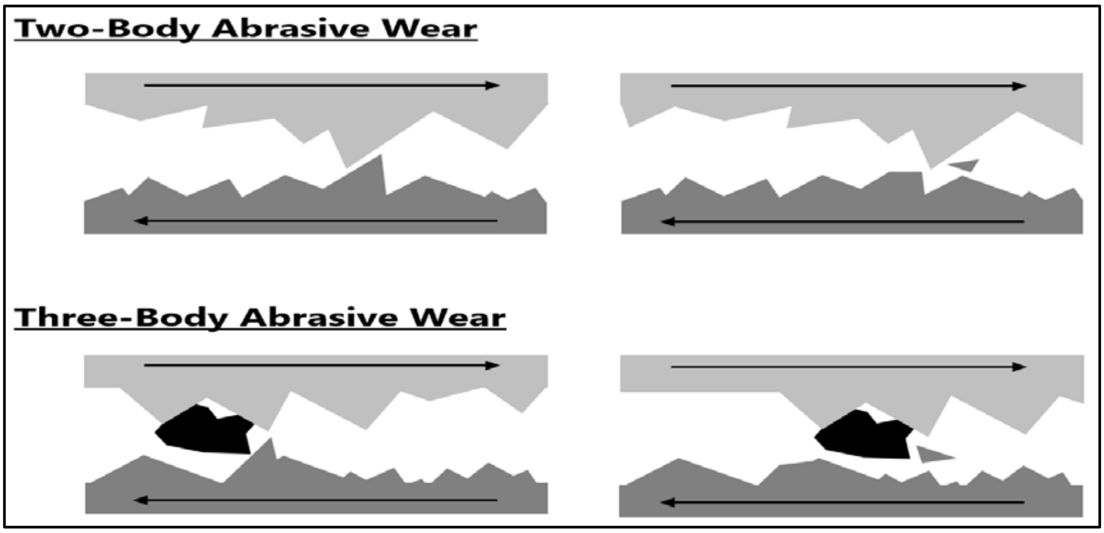


Fig. 2-14. Abrasive wear [32].

3- Corrosive wear

When rubbing between surfaces takes place in a corrosive environment, surface reactions can take place and reaction products formed on the surfaces. These generally poorly adhere to the surfaces and the rubbing removes them. The process thus involves the repeated forming of reaction products and their removal by the rubbing. Lubricants can be used to separate surfaces and protect the surfaces from the corrosive environment, as shown in Figure 2-15 [1, 45].

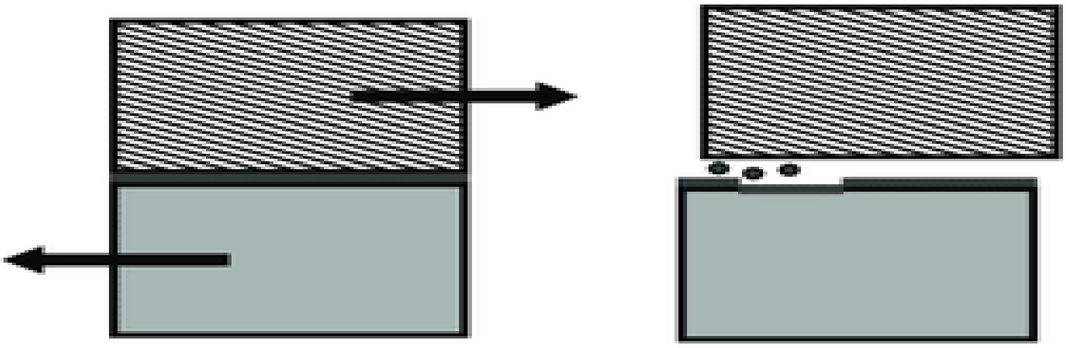


Fig. 2-15. Mechanisms for wear [45].

2.15. Thermal conductivity

The quantity of heat transmitted through a unit thickness in a direction normal to a surface of unit area due to a unit temperature gradient under steady state conditions and when the heat transfer is dependent only on the temperature gradient [60].

The exchange of energy between adjacent molecules and electrons in a conducting medium, is a material property that describes heat flow within a body for a given temperature difference per unit area [61].

Or it is a measure of the ability of a material to transfer heat. Given two surfaces on either side of the material with a temperature difference between them, the thermal conductivity is the heat energy transferred per unit time and per unit surface area, divided by the temperature difference [60, 61].

Fourier's Law expresses conductive heat transfer as explained in the following equation:

$$Q = kA\frac{dT}{dX} \quad \text{………………………………………………………….(2-3)}$$

Where, Q is the amount of heat transferred through the material in Joules/second or Watts, K is the thermal conductivity coefficient in W/m.K, dX is the distance between the two isothermal planes, A is the area of the surface in square meters, dT is the difference in temperature in Kelvin [60, 61].

Thermal conductivity coefficient refers to the intrinsic ability of a material to transfer or conduct heat. Heat moves along a temperature gradient, from an area of high temperature and high molecular energy to an area with a lower temperature and lower molecular energy, and it is measured in watts per square meter [60, 61].

Thermal properties that are generally of interest in the selection of materials include how much a material will expand for a particular change in temperature; how much the temperature of a piece of material will change when there is a heat input into it, and how good a conductor of , 60heat it is. Figure 2-16 explains the thermal conductivity coefficient [62].

Factors that affect rate of heat flow include the conductivity of the material, temperature difference across the material, thickness of the material, and area of the material. Different materials have greater or lesser resistance to heat transfer, making them better insulators or better conductors [60].

The ability of a thermal insulation material to transmit heat in the presence of a temperature gradient is determined by its thermal conductivity coefficient. [48, 60].

Conduction takes place when a temperature gradient exists in a solid (or stationary fluid) medium. Conductive heat flow occurs in the direction of decreasing temperature because higher temperature equates to higher molecular energy or more molecular movement. Energy is transferred from the more energetic to the less energetic molecules when neighboring molecules collide [63].

The term thermal insulation can refer to either materials used to reduce the rate of heat transfer, or the methods or the processes used to reduce heat transfer. Heat energy can be transferred by conduction, convection, radiation. Thermal insulation prevents heat from escaping a container or from entering a container. In other words, thermal insulation can keep an enclosed area such as a building warm, or it can keep the inside of a container cold. Insulators are used to minimize that transfer of heat energy [60, 62].

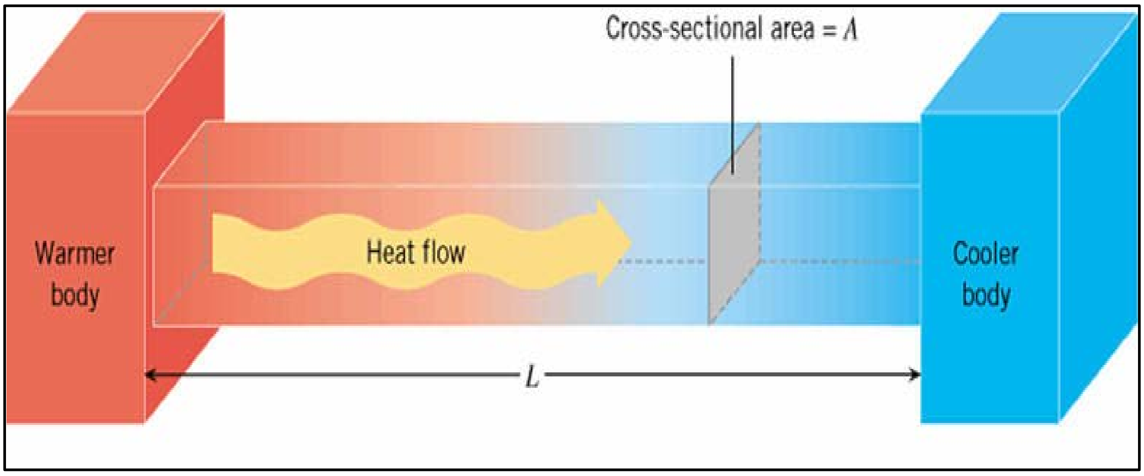


Fig .2-16. Thermal conductivity [62] .

The measurement of thermal conductivity coefficient of the prepared samples based on Lee’s disk method, as explained in equations (2-4) and (2-5) [64]:

$$K\left[\frac{T_B - T_A}{d_S}\right] =$$

$$IV = \pi r^2 e\ (T_A + T_B) + 2\pi r e\ [d_A T_A + \frac{d_S}{2}\ (T_A + T_B) + d_B T_B + d_C T_C] \quad ...(2\text{-}5)$$

Where, T_A, T_B, T_C is the temperature values of the disks A, B, and C, d_S $d_A, d_B, and\ d_C$ the thickness of the sample and the disks *A*, *B*, and *C* respectively, *H* the heat energy passing through the heating coil per unit time, *e* the lost heat in per unit time per cubic centimeter,K is the thermal conductivity coefficient, *I* the electric current passing in the circuit, *V* the applied voltage, and *r* the radius of the disk [64].

Figure 2.17 shows Lee’s disk method parts.

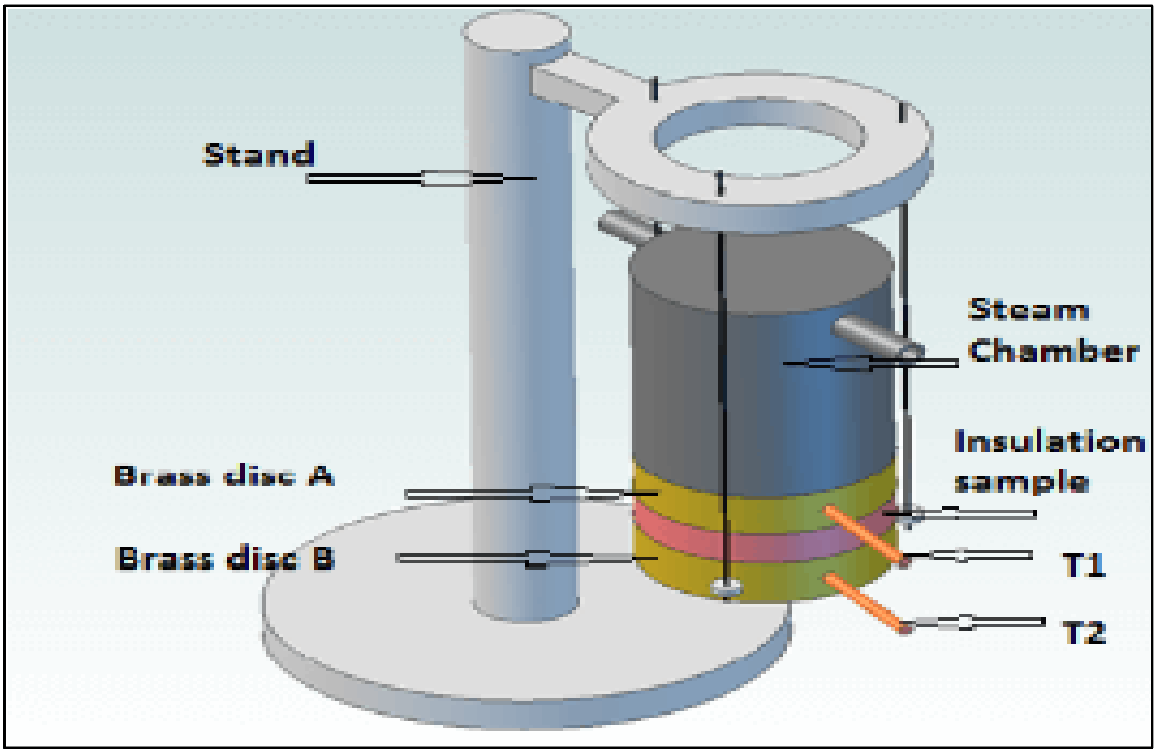


Fig .2-17. Lee’s disk method parts [64].

Factors Influencing Thermal conductivity

1. Free electrons. Metals are having more free electrons compared to that of liquid and gases, so metal are good conductors of heat due to the migration of free electrons.
2. Purity of material.
3. Effect of forming.
4. High temperature.
5. Pressure.

6. Density.
7. Crystalline structure [60, 61].

2.16. Biocomposite Materials

In the last ten years, the natural reinforcement of polymer composites with have received ever-increasing attention, both of the academic field and different manufactories. The attention of polymer composite reinforced by natural materials is increasing day-by-day, where the manufacturing of high performance materials from renewable resources is one of the most important goals at the present time pursued by researchers around the world. In the recent years, natural materials have been more and more used as alternative reinforcements in polymer composites because of their relatively inexpensive (cheap), low density, environmental friendly and biodegradability [2, 8, 65].

Bio-composite have one or more material compounds that derived from natural origin. In terms of the reinforcement, this could include plant particles or particles from recycled plants, waste paper, or even from food crops [4].

Biocomposite can be defined as the materials combine of a polymer matrices and reinforcements, with the feature that both the matrices and the reinforcements, or one of them should at least be of biological origin [65, 66]. In a similar way, efforts are made in the process of developing of polymer composite parts that could be a choice to supply the irregular uses of wood [66].

It is anticipated that the natural materials would not participate to the wear of polymer processing equipments and may not subjected to size decreasing during processing, which both of them occur at using of inorganic materials [10].

The most important merit of natural fiber is biodegradability and noncarcinogenic which get it back into its original form, the other useful merits of natural materials are non-toxicity, The additional benefit (profit gained) of reinforcing natural materials than conventional chemical materials such as carbon or glass, are their specified strength features, are widely available, light weight, ease of separation, enhanced energy recovery, high toughness, non-corrosive nature, low density, low cost, (as well as good thermal and acoustic insulating merits), superior thermal features, reduced tool wear, decreased dermal and respiratory irritation, less abrasion to processing equipment, renewability and biodegradability and absence of the environment pollution [30, 65].

Transition of industries towards production of green composite is taking place due to the increasing request of consumer, to reduce the use of synthetic material, higher sustainability, bio degradability, friendly to environment and recyclability, inexpensive etc [8].

The demand for wood composites from plants waste has been increasing as timber resources in natural forests decline. The use of renewable biomass as a raw material in composites products has been under taken as an alternative source that may result in several environmental benefits [8, 9].

In spite of these affirmative features of natural materials, their applications are still very little [15, 17].

2.17. Plants under study and their wastes

In the present study, we used wastes of three different plants

2.17.1. Eucalyptus Plant

Eucalyptus is a genus of over seven hundred species of flowering trees, they are commonly known as eucalypts. Eucalyptus have bark that is either smooth, fibrous, hard or stringy, leaves with oil glands, Eucalypts have been grown in plantations in many other countries because they are fast growing and have valuable timber, or can be used for pulpwood, for honey production or essential oils. In some countries, however, they have been removed because they are highly flammable [65, 66].

2.17.2. Date Palm Trunk

The date palm (*Phoenix dactylifera* L.) is a mono cotyledon of the family of the Palmate. It is a feather palm, characterized by compound leaves with a series of leaflets on each side of a common petiole, originating from one growing point at the top of the trunk. The date palm may reach an age of over 100 years and reach up to 24 m in height to the growing point normally the age limit is less than this and consequently the height will not be more than 15-20 m maximum before it was cut down due to declining yield and the increasing difficulty (and danger) of reaching the crown during pollination, bunch management and harvesting [66, 67].

All parts of the date palm yield products of economic value. Its trunk furnishes timber; the midribs of the leaves supply material for crates and furniture; the leaflets, for basketry; the leaf bases, for fuel; the fruit stalks, for rope and fuel; the fiber, for cordage and packing material; and the seeds are sometimes ground and used as stock feed [66- 68].

2.18.3. Buckthorn plant

(Sidra), classified from the trees fast growing, the size Buckthorn of medium to large, which is evergreen, has a leg is mostly moderate, cylindrical shape and twigs hanging, aesthetic shape, if we look for the root of it is very deep, And the diffuse, the color of her beard is dark brown or reddish brown, has the grooves of the deep and slightly inclined, but the branches of soft texture, and shows the color white, and the branches spread and dangle, and contain spines sharp and small size [66, 69] .

CHAPTER FOUR

RESULTS AND DISCUTION

RESULTS & DISCUSSIONS

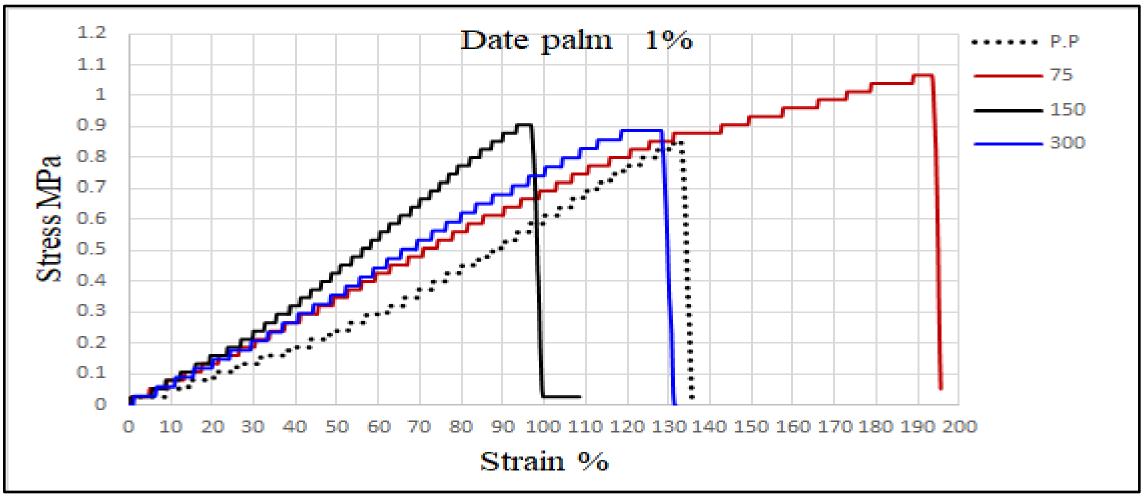
This chapter presents the results, the effect, and the evaluation of particles size and the type of the reinforcement material on the mechanical features (which includes tensile strength, hardness, wear), the thermal conductivity, the water absorption rate, and the density of the samples. The interpretation of the results and the comparison among the variables of the study are also presented.

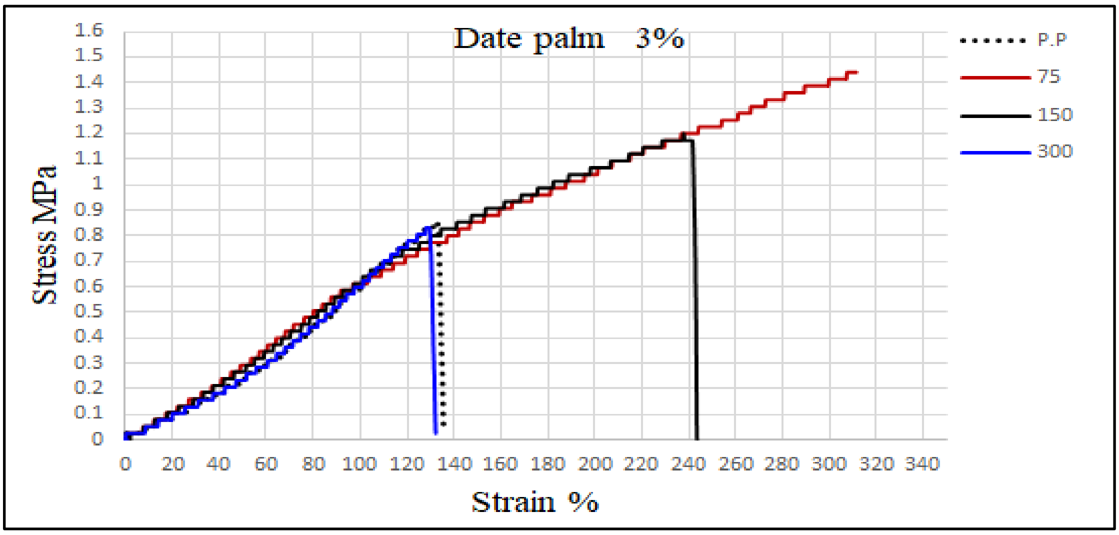
4.1. Mechanical Characteristics of Composites

The characterization of the composites samples proved that the particles size and the reinforcement material type rates have significant effect on the mechanical features of the manufactured composites samples, as explained in the following sections.

4.1.1. Stress-Strain Characteristics

The Figures 4.1, 4.2, 4.3, explain the stress – strain behaviors of the pure and reinforced composites samples (reinforced with date palm, buckthorn, and eucalyptus respectively at different rates), where it can be observed the obvious effect of reinforcement materials particles (type), the particles size, and the reinforcement materials rates on the stress-strain curve which includes elastic and plastic range, ultimate strength (tensile strength), and fracture points. . It is true for all particulate composite material; no material can be fabricated which has more ultimate strength from matrix material if reinforced material is mixed at macro particles. Can be seen in the stress strain diagram due to addition of walnut particles in the epoxy resin matrix for all weight percentages of walnut particles. However, it is seen that of particle the stress strain behavior does increase, therefore there is improvement in load bearing capacity.[67]





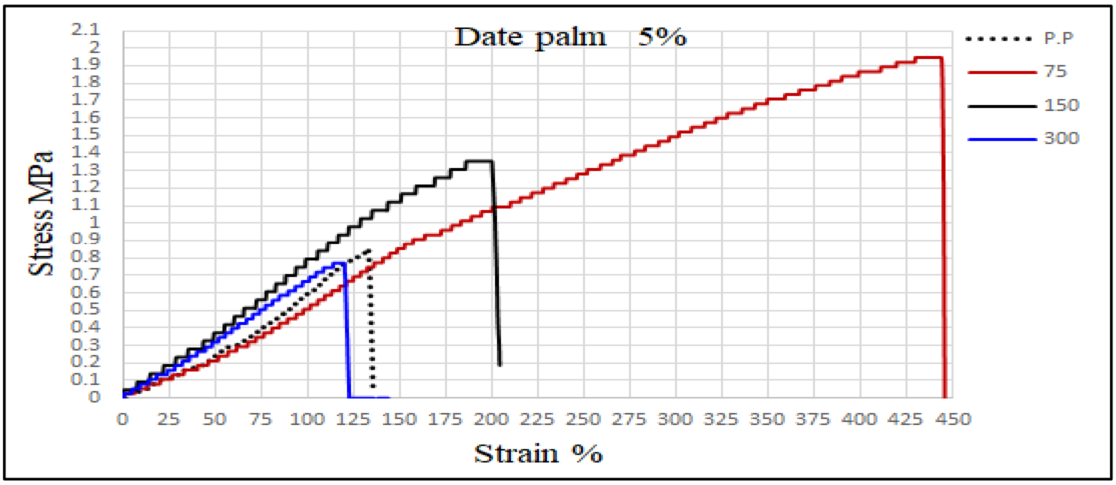
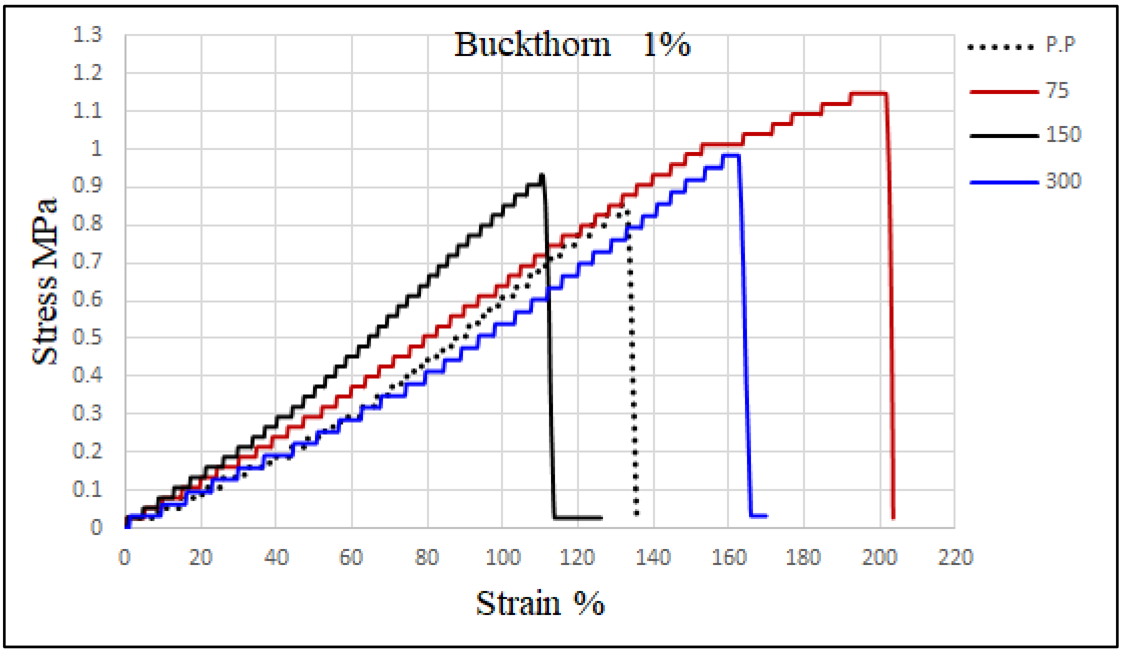


Figure 4.1. The stress-strain curves of the silicon rubber and composites samples reinforced with date palm particles at different particle size and reinforcement rates.



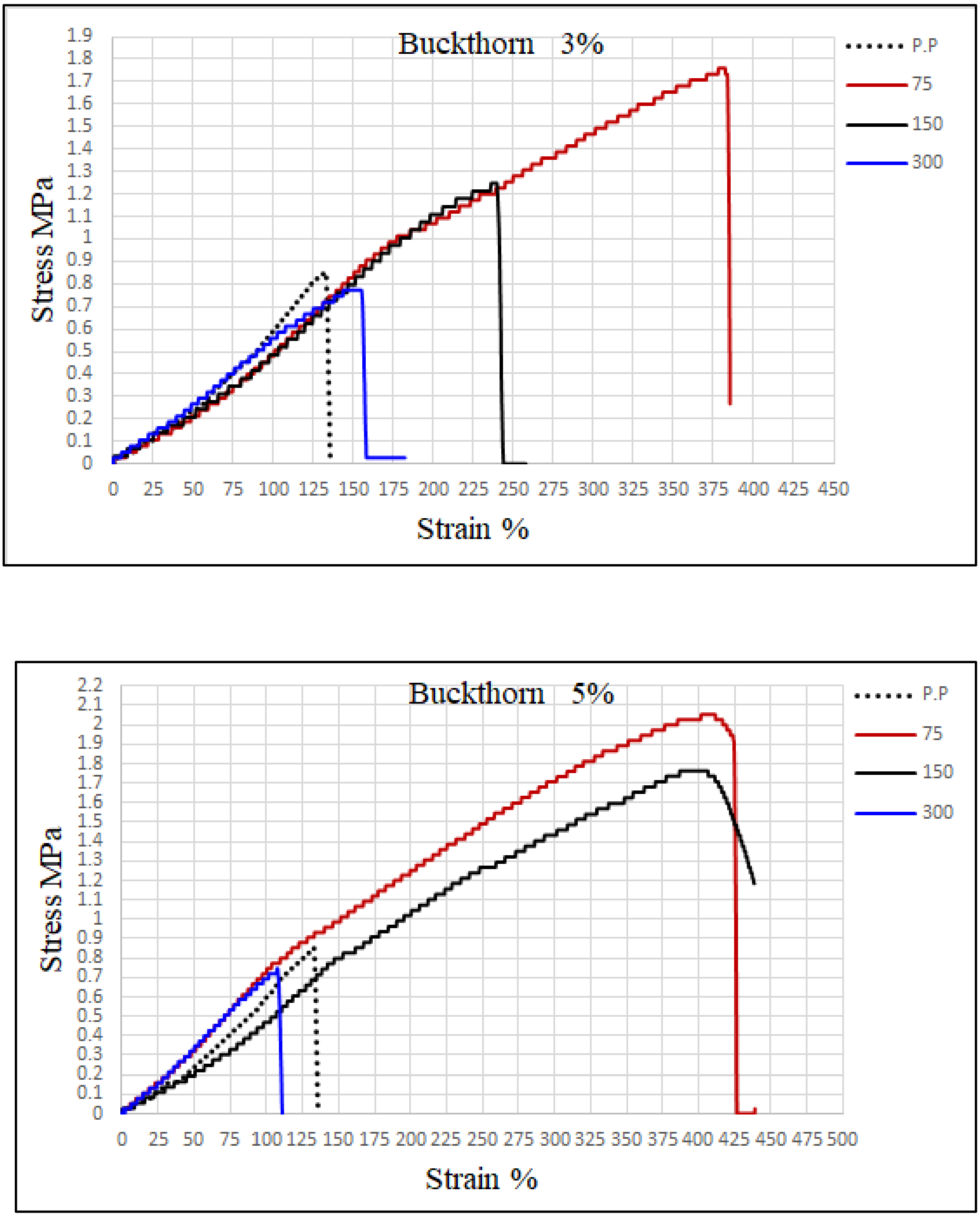
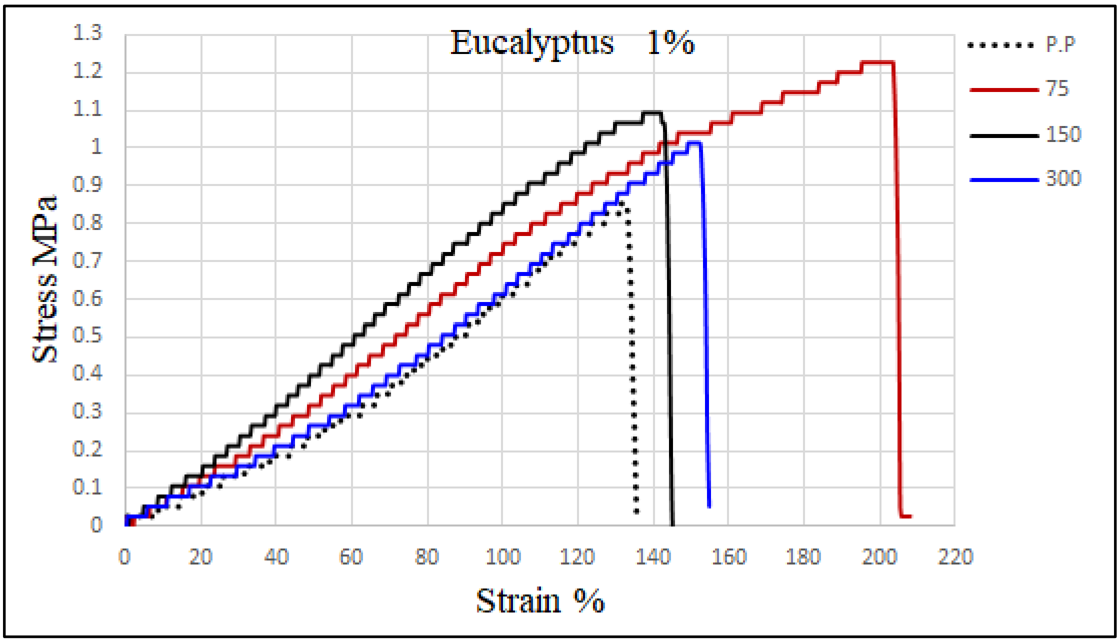
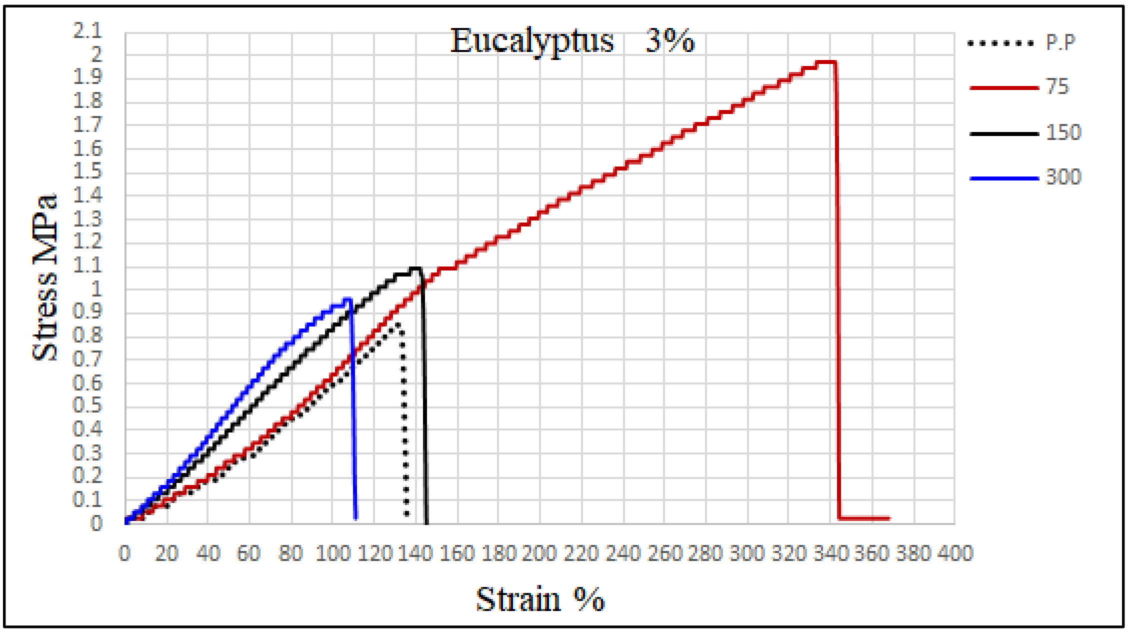


Figure 4.2. The stress-strain curves of the silicon rubber and composites samples reinforced with Buckthorn particles at different particle size and reinforcement rates


Eucalyptus 1%
Stress MPa
Strain %
P.P
75
150
300
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
0
20
40
60
80
100
120
140
160
180
200
220


Eucalyptus 3%
Stress MPa
Strain %
P.P
75
150
300
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2
2.1
0
20
40
60
80
100
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200
220
240
260
280
300
320
340
360
380
400

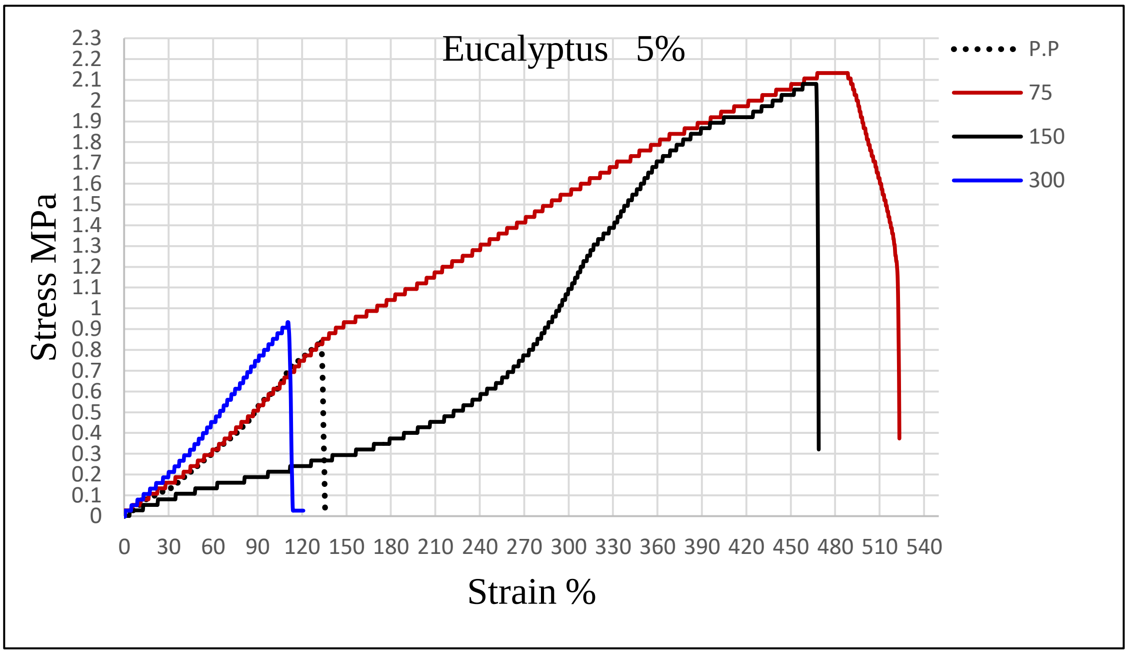


Figure 4.3. The stress-strain curves of the silicon rubber and composites samples reinforced with Eucalyptus particles at different particle size and reinforcement rates

4.1.2. Tensile Strength Characteristics

As the samples have been prepared under the same conditions, therefore, that means the Composition of the reinforcement material and the Molecular Structure have the strongest effect on the mechanical properties of the composite samples.

It can observe that tensile strength values have been increased by reinforcing the pure silicon rubber samples, and in the same time It can notice that the tensile strength values have been increased by increasing the rate of the reinforcement materials particles and for all types at particles size 75μm and 150 μm, which means that these particles have connect the silicon rubber molecules with each other strongly (support), and sustained and withstand the external tensile force which leads to strengthen and support the samples, except for the particle size 300 μm where the tensile strength was increased and decreased with increasing the rate of the reinforcement particles for all types of the reinforcement materials ,and this is due to the voids and vacancies or (pores) caused by the large reinforcement particles size which displace the particles from each other and creates a large voids , which in turn weaken the samples.

The maximum tensile strength value reached of the sample reinforced by Eucalyptus particles at particle size 75 μm (2.133 MPa), while the tensile strength value of the pure sample was (0.853MPa), which means the reinforcement process increases the tensile strength value by about 150 %, it is known that fillers play an important role in mechanical properties of elastomeric materials that the tensile strength Reinforced powders and small size with increasing of filler content. It can be explained by the different nature of a matrix with filler. Characterized by polar while powder nature filler has non- polar array. This gives strength penny the interaction between silicone rubber and the powders thus, leads to composite strength. Dispersion of the powder inside matrix also contributed to the deterioration of power.[68]

As explained in Tables 4.1- 4.3, and Figures 4.4- 4.9.

Table 4.1. The results of tensile strength, at Particle Size 75 μm

Reinforcement Rate %	Tensile Strength MPa		
	Date Palm	Buckthorn	Eucalyptus
0.0	0.853	0.853	0.853
1	1.067	1.147	1.227

3	1.445	1.760	1.973
5	1.947	2.053	2.133

Table 4.2. The results of tensile strength, at Particle Size 150 μm

Reinforcement Rate %	Tensile Strength MPa		
	Date Palm	Buckthorn	Eucalyptus
0.0	0.853	0.853	0.853
1	0.907	0.933	1.093
3	1.200	1.248	1.707
5	1.352	1.763	2.080

Table 4.3. The results of tensile strength (MPa), at particle size 300 μm

Reinforcement Rate %	Tensile Strength MPa		
	Date Palm	Buckthorn	Eucalyptus
0.0	0.853	0.853	0.853
1	0.888	0.984	1.013
3	0.832	0.773	0.960
5	0.771	0.747	0.933

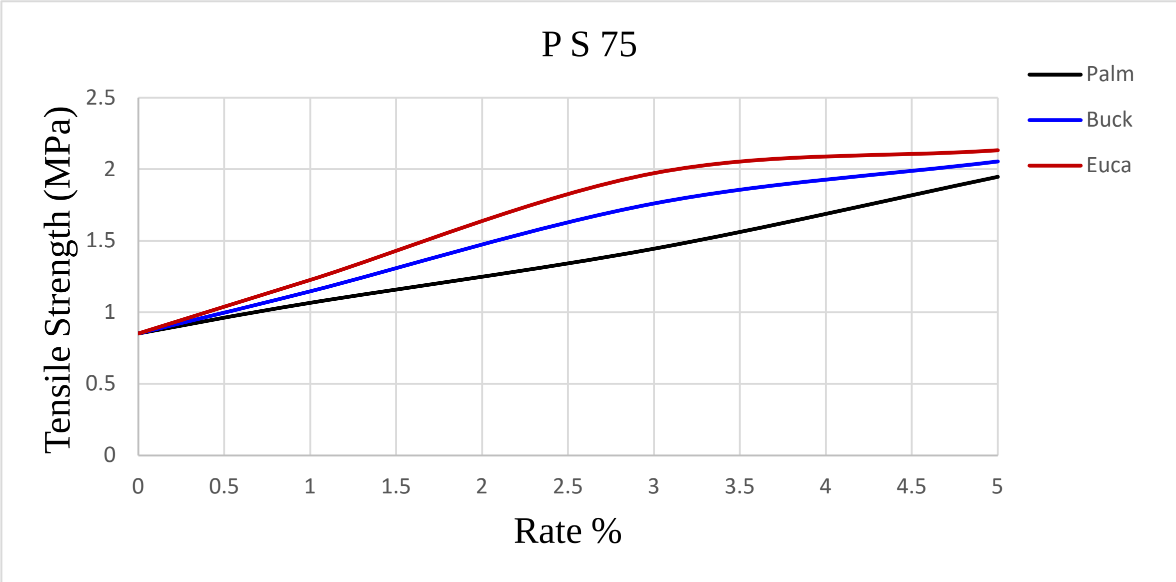


Figure 4.4. The results of tensile strength opposites reinforcement rates, at reinforcement particle size75 μm.

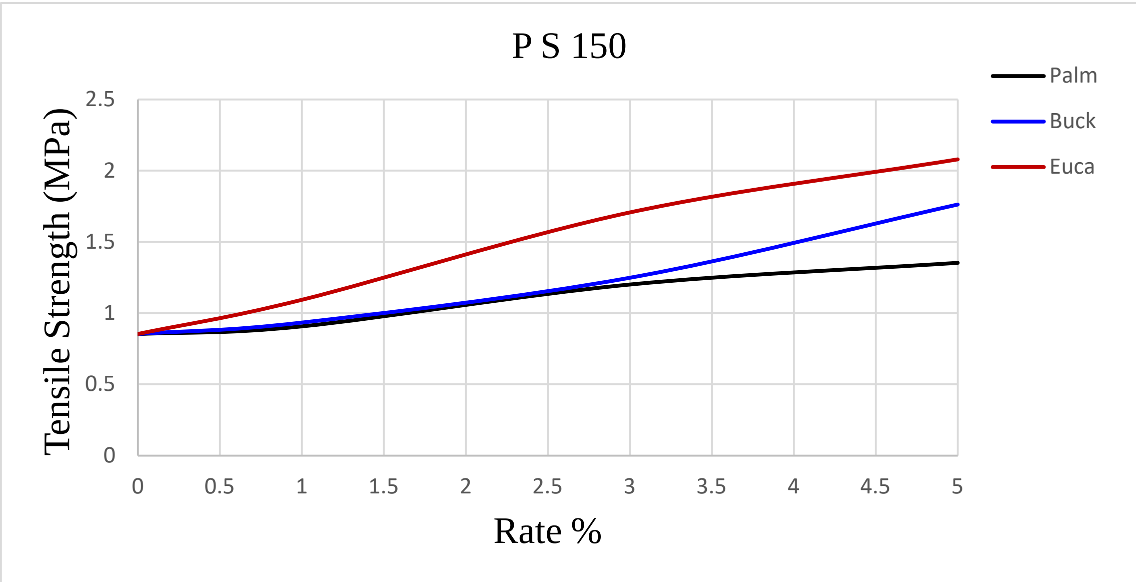


Figure 4.5. The results of tensile strength opposite are reinforcement rates, at reinforcement particle size150 μm.

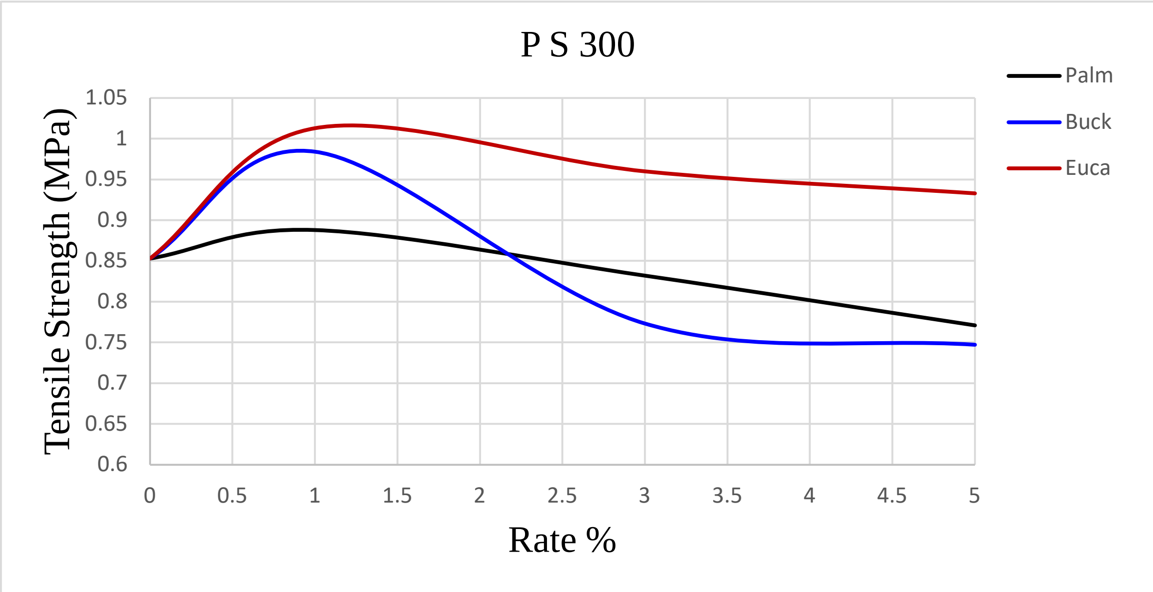


Figure 4.6. The results of tensile strength opposite are reinforcement rates, at reinforcement particle size300 μm.

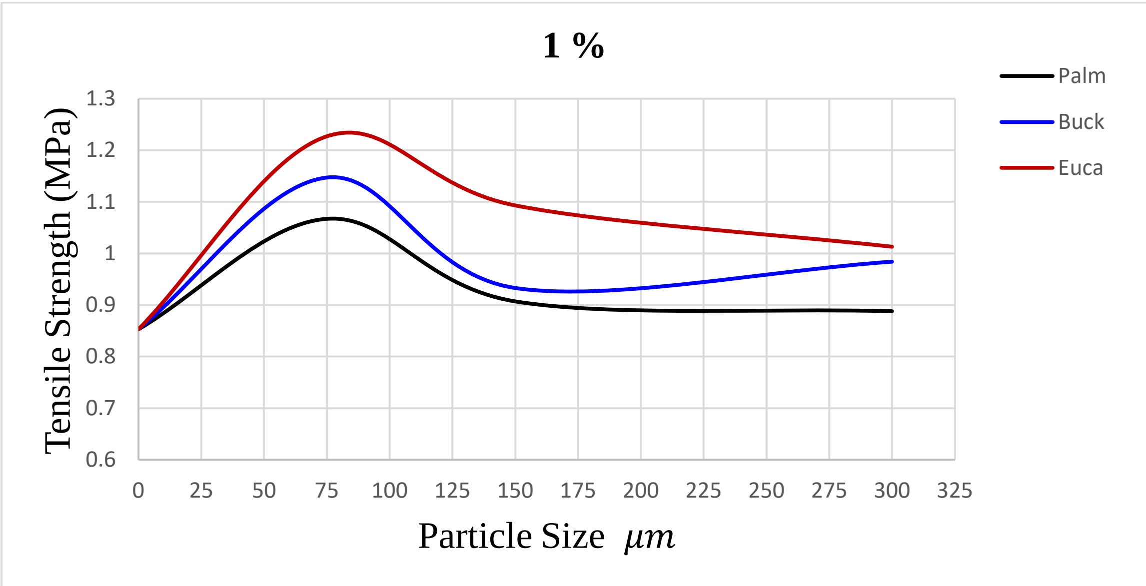


Figure 4.7. The results of tensile strength opposite are reinforcement particle size, at reinforcement rate 1%.

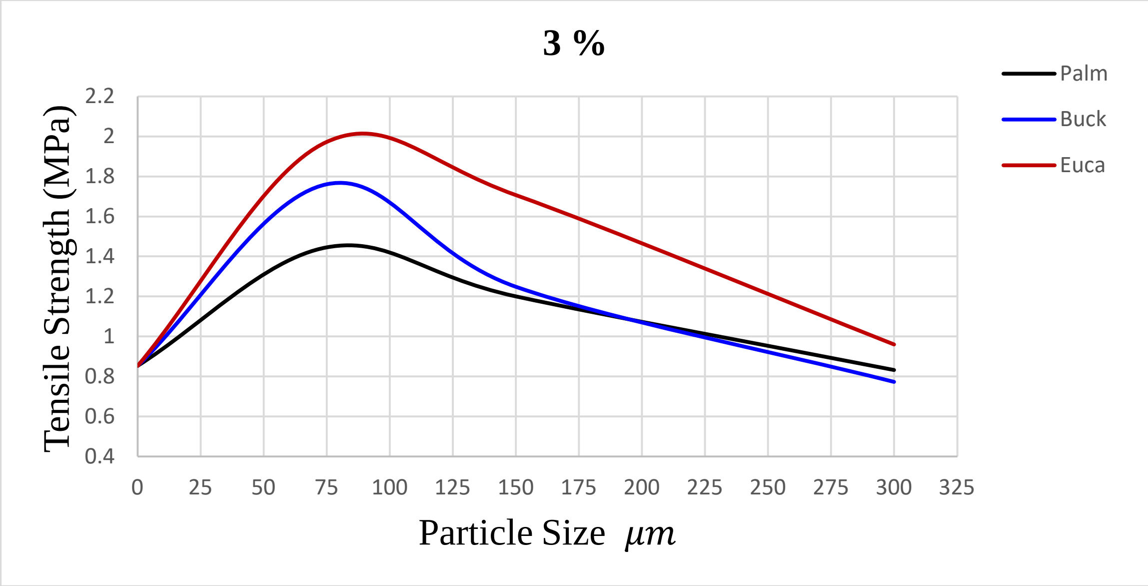


Figure 4.8. The results of tensile strength opposite are reinforcement particle size, at reinforcement rate 3%.

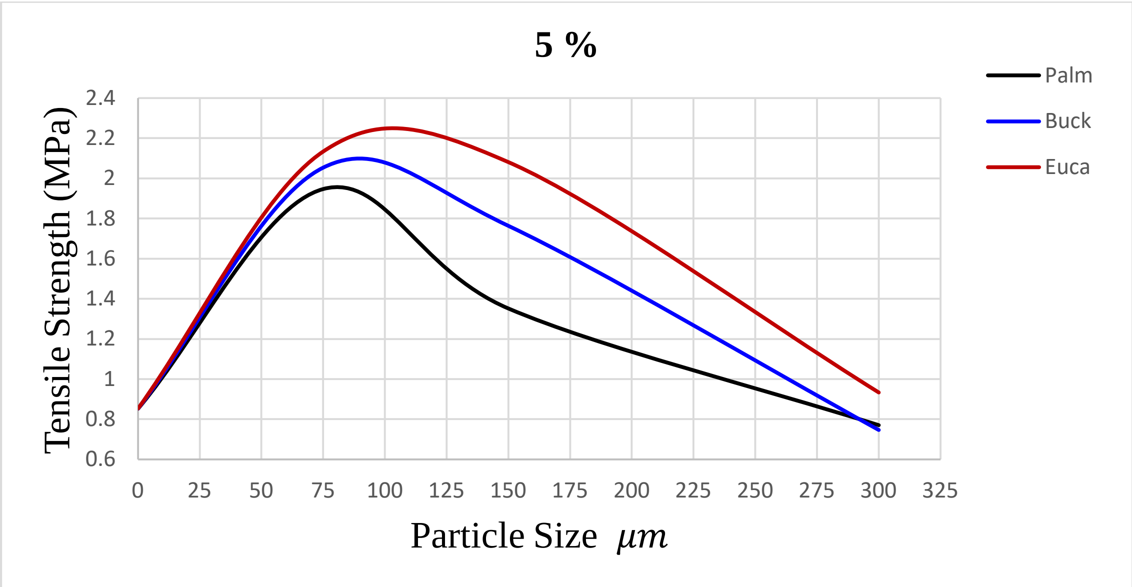


Figure 4.9. The results of tensile strength opposite are reinforcement particle size, at reinforcement rate 5%.

4. 1.3. The Hardness

In addition to the mention above, the results of the effect of the reinforcement particles rate and type on the hardness results of the composite samples, we can notice obviously that the increasing of the reinforcement particles rate increases the hardness values of the samples, which means increases the resistance of the samples to the external effect. The existence of reinforcement particles that led to increased cohesion consistency of the sample structure and this applies to the particles rates 75 and 150 μm, but at the particle size 300 μm, the increasing of particles rates decreased the value of the samples resistance to the external effect e because of that the increasing of the particle increases the voids and pores, which led to decreases the reissuance of the samples and therefore weaken the sample, where the presence of pores has a negative effect on the hardness [56].

The reinforcing of the silicon rubber with the waste particles increases the hardness value from 32 to be 40.7, where the maximum hardness value obtained of the sample reinforced by Eucalyptus particles at particle size 75 μm and rate 5% was (40.7) , which means the reinforcement process increases the hardness value by about 27.18%. The occurrence of improved hardness with corresponding increase in filler loading in particulate-filled polymer composites has been attributed to the fact that most organic fillers exhibit rigidity that is significantly higher than that of the polymer matrix.[67]

As explained in Tables 4.4- 4.6, and Figures 4.10- 4.15.

Table 4.4. The results of the Hardness, at Particle Size 75 μm

Reinforcement Rate %	Hardness (No.)

	Date Palm	Buckthorn	Eucalyptus
0.0	32	32	32
1	35	38	37.2
3	36.2	39.8	37.5
5	39	40	40.7

Table 4.5. The results of the Hardness, at Particle Size 150 μm

Reinforcement Rate %	Hardness (No.)		
	Date Palm	Buckthorn	Eucalyptus
0.0	32	32	32
1	34.2	36.3	35.8
3	34.9	36.8	37.1
5	36.6	37	38

Table 4.6. The results of the Hardness, at Particle Size 300 μm

Reinforcement Rate %	Hardness (No.)		
	Date Palm	Buckthorn	Eucalyptus
0.0	32	32	32
1	34.6	35.8	36

3	33.9	35	35.4
5	33.8	34.9	35.1

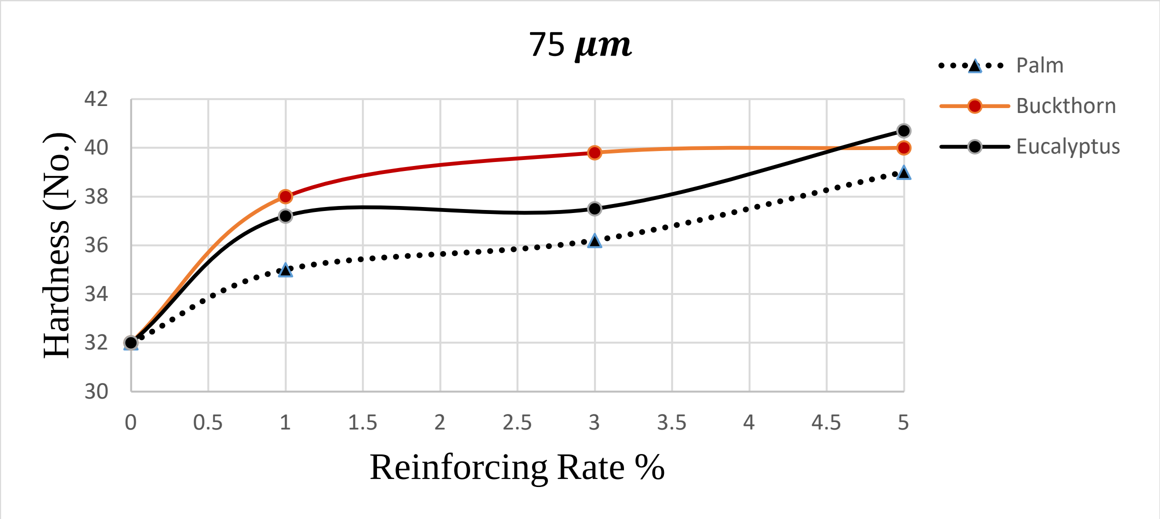


Figure 4.10. The results of the hardness opposite are reinforcement rates, at reinforcement particle size75μm.

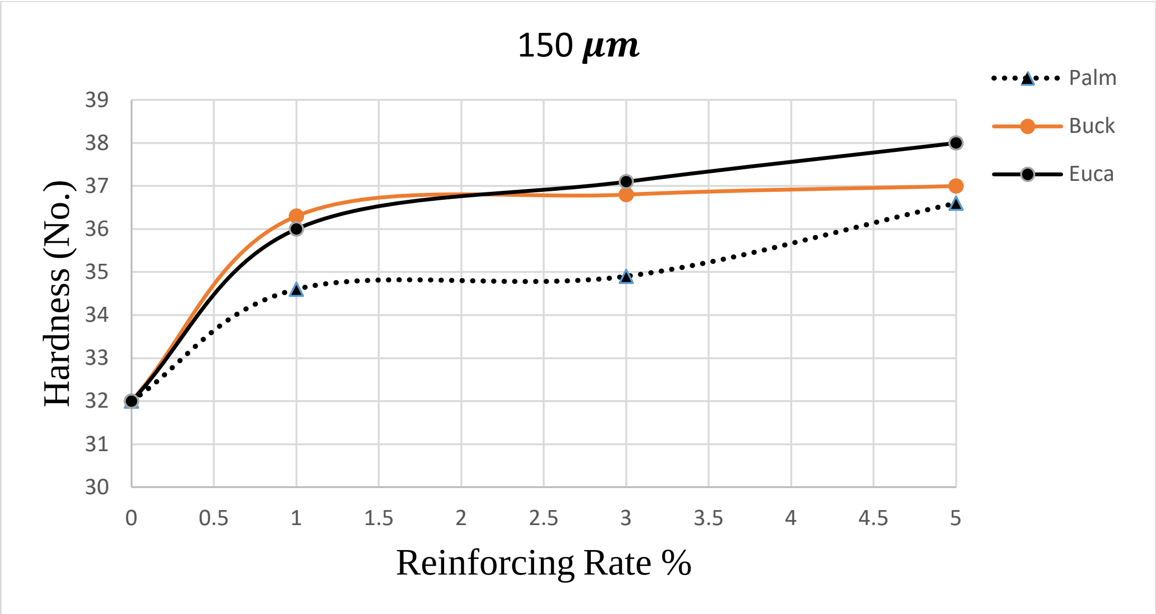


Figure 4.11. The results of the hardness opposite are reinforcement rates, at reinforcement particle size150μm.

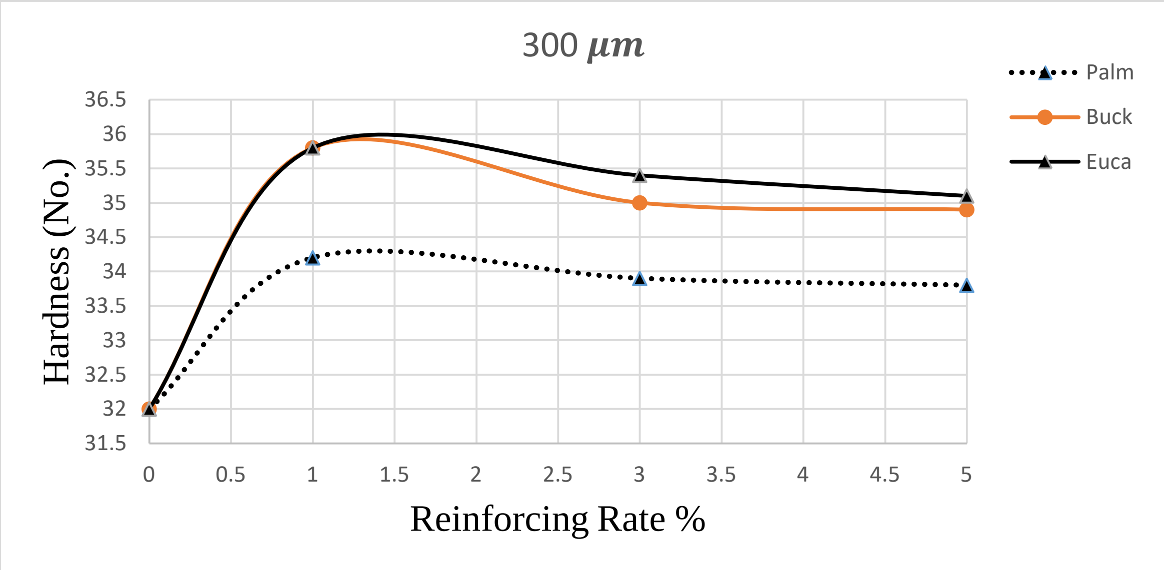


Figure 4.12. The results of the hardness opposite are reinforcement rates, at reinforcement particle size300μm.

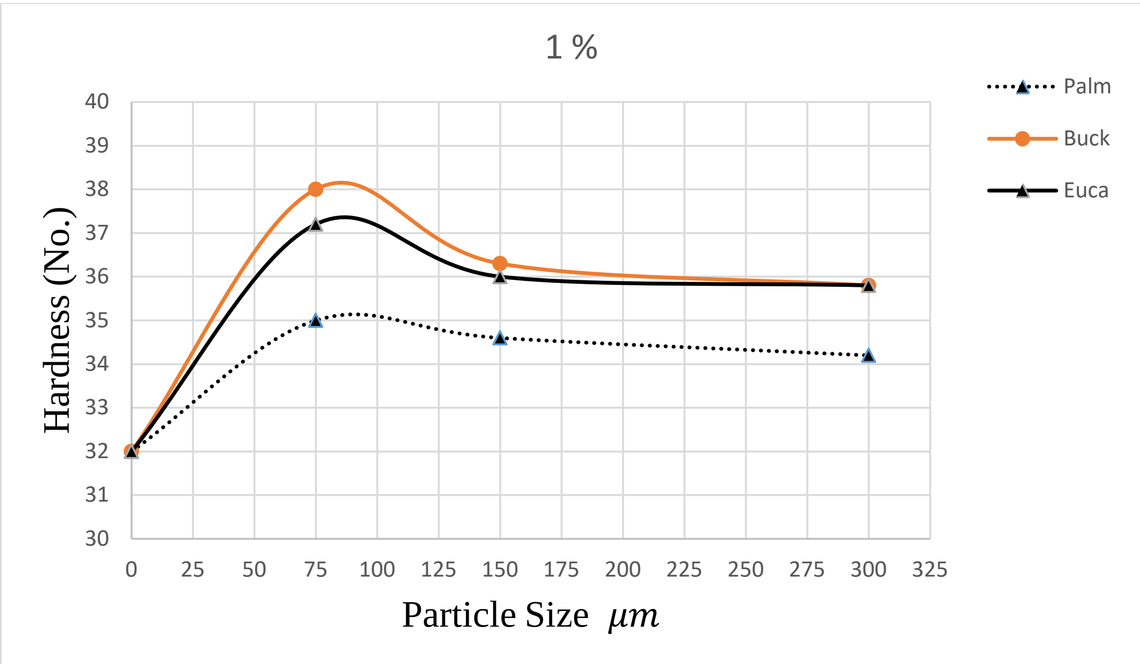


Figure 4.13. The results of the hardness opposite are reinforcement particle size, at reinforcement rate 1%.

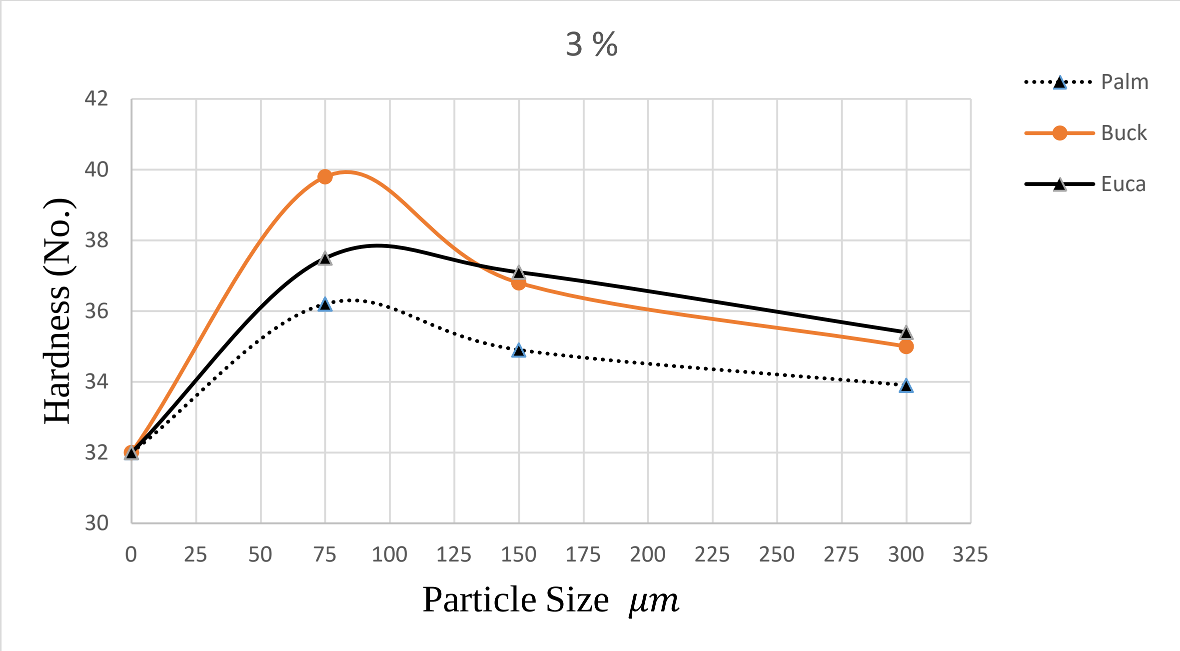


Figure 4.14. The results of the hardness opposite are reinforcement particle size, at reinforcement rate 3%.

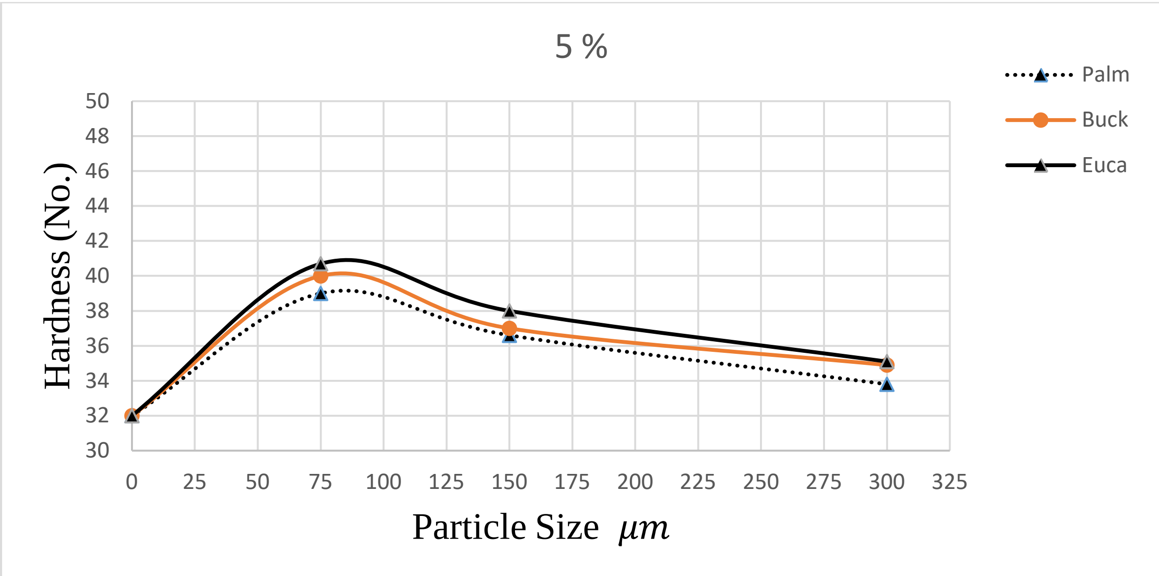


Figure 4.15. The results of the hardness opposite are reinforcement particle size, at reinforcement rate 5%.

4.1.4. Wear Test

As for the results of the wear test, the results were similar to the previous tests at the smallest size of reinforcement particles size 75μm, where the increasing in reinforcing rates increases the resistance of the samples , where the displacement of particles is small, while at reinforcement particles size 150μm and 300μm the effect was different where increasing in reinforcing rates increases the voids and pores between the particles (which have a negative effect) and then decreases the resistance of the samples (weaken the samples).

The reinforcing process increases the wear resistance from, where the best result obtained by reinforcing by Eucalyptus particles, followed by date palm particles, and the maximum wear resistance obtained of the sample reinforced by Eucalyptus particles at particle size 75 μm and rate 5% was (97), which increases the wear resistance by 115%. [8] the wear test results (weight loss and the wear indices) of the silicon rubber and particles, respectively. Observations from these results revealed that, particle size and content of the filler are highly influential in enhancing the wear resistance of the composites. [74]

These results are shown in Tables 4.7- 4.9, and Figures 4.16- 4.18.

Table 4.7. The results of the wear, at particle size 75 μm

Reinforcement Rate %	Wear		
	Date Palm	Buckthorn	Eucalyptus
0.0	45	45	45
1	57	55	71
3	64	57	77
5	91	71	97

Table 4.8. The results of the wear, at particle size $150\ \mu m$

Reinforcement Rate %	Wear		
	Date Palm	Buckthorn	Eucalyptus
0.0	45	45	45
1	90	82	61
3	80	68	59
5	48	46	55

Table 4.9. The results of the wear, at particle size $300\ \mu m$

Reinforcement Rate %	Wear		
	Date Palm	Buckthorn	Eucalyptus
0.0	45	45	45
1	59	65	73

3	46	33	59
5	42	21	55

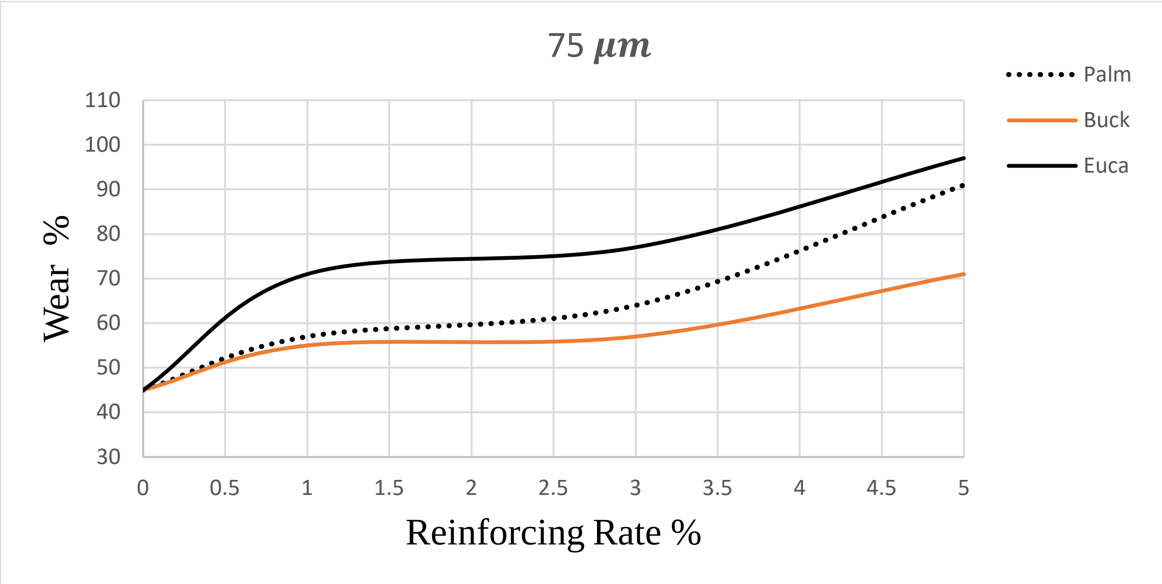


Figure 4.16. The results of the wear opposite are reinforcement rates, at reinforcement particle size75μm.

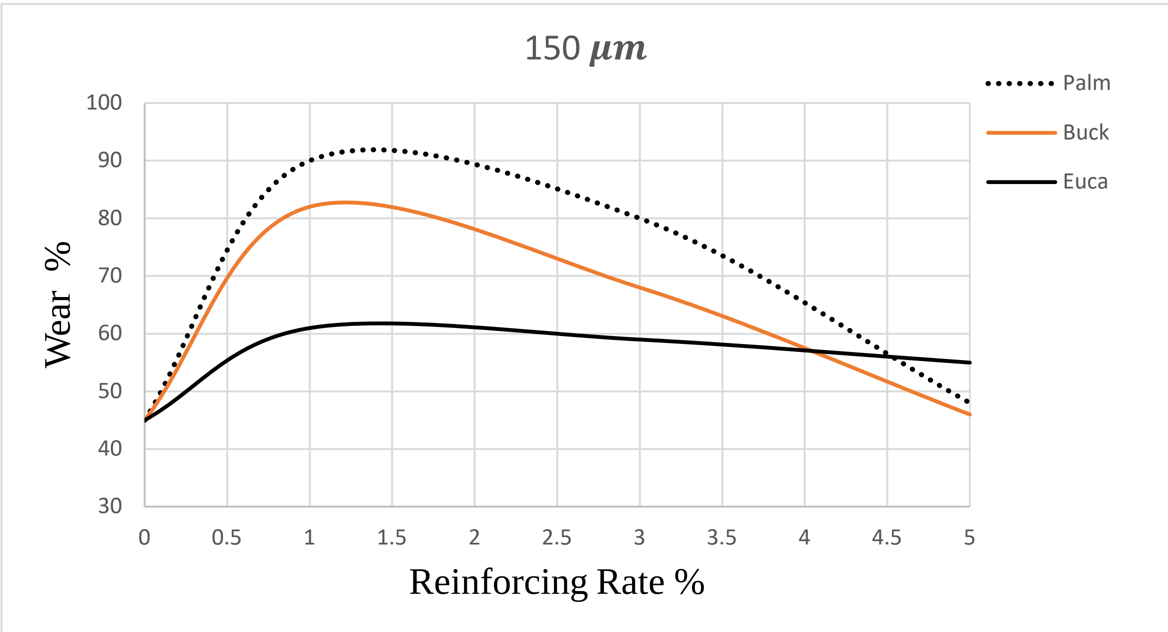


Figure 4.17. The results of the wear opposite are reinforcement rates, at reinforcement particle size150μm.

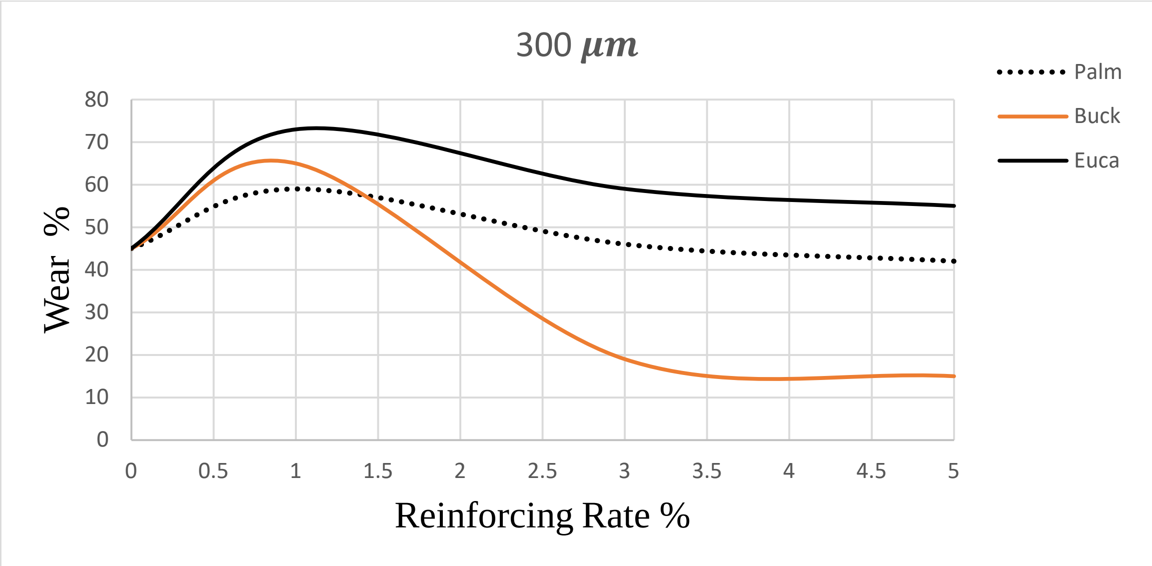


Figure 4.18. The results of the wear opposite are reinforcement rates, at reinforcement particle size300μm.

4 .1.5. Young Modulus

or (Elastic Modulus) values results were The Young Modulus obtained from the digital data of the tensile stress – strain test, and from the elastic region specifically using the Excel program.

The reinforcing process increases the Young Modulus values, where the best result obtained by reinforcing by Eucalyptus particles, , result obtained of the sample and the maximum Young Modulus reinforced by Eucalyptus particles at particle size 75 μm and rate 5%), from 0.0046 MPa to be 0.0099 MPa which increases the Young Modulus by 115.21%. That means the reinforcing increasing the sustain (support) of the sample to elastic deformation before fracturing. The Young's modulus of the silicone rubber reinforced particles biocomposites increases with the increasing amount of filler content, it occurs due to the replacement of polymer matrix by stiffer particulate filler, which improves the overall composites modulus. The increase of the modulus is also due to the fact that the deformation of matrix were restricted by the present of particulate filler that introducing a mechanical restraint.[68,75]

As shown in the tables 4.10- 4.12, and from Figures 4.19- 4.21.

Table 4.10. The results of the Young Modulus at Particle Size 75 μm

Reinforcement Rate %	Young Modulus MPa		
	Date Palm	Buckthorn	Eucalyptus
0.0	0.0046	0.0046	0.0046
1	0.0052	0.0047	0.0051
3	0.0061	0.0049	0.0065
5	0.0065	0.0057	0.0099

Table 4.11. The results of the Young Modulus at Particle Size 150 μm

Reinforcement Rate %	Young Modulus MPa		
	Date Palm	Buckthorn	Eucalyptus

0.0	0.0046	0.0046	0.0046
1	0.0048	0.0051	0.0049
3	0.0067	0.0064	0.0069
5	0.0086	0.0067	0.0095

Table 4.12. The results of the Young Modulus at Particle Size $\mathbf{300\ \mu m}$

Reinforcement Rate %	Young Modulus MPa		
	Date Palm	Buckthorn	Eucalyptus
0.0	0.0046	0.0046	0.0046
1	0.0053	0.0048	0.0064
3	0.0066	0.0073	0.0071
5	0.0071	0.0075	0.0082

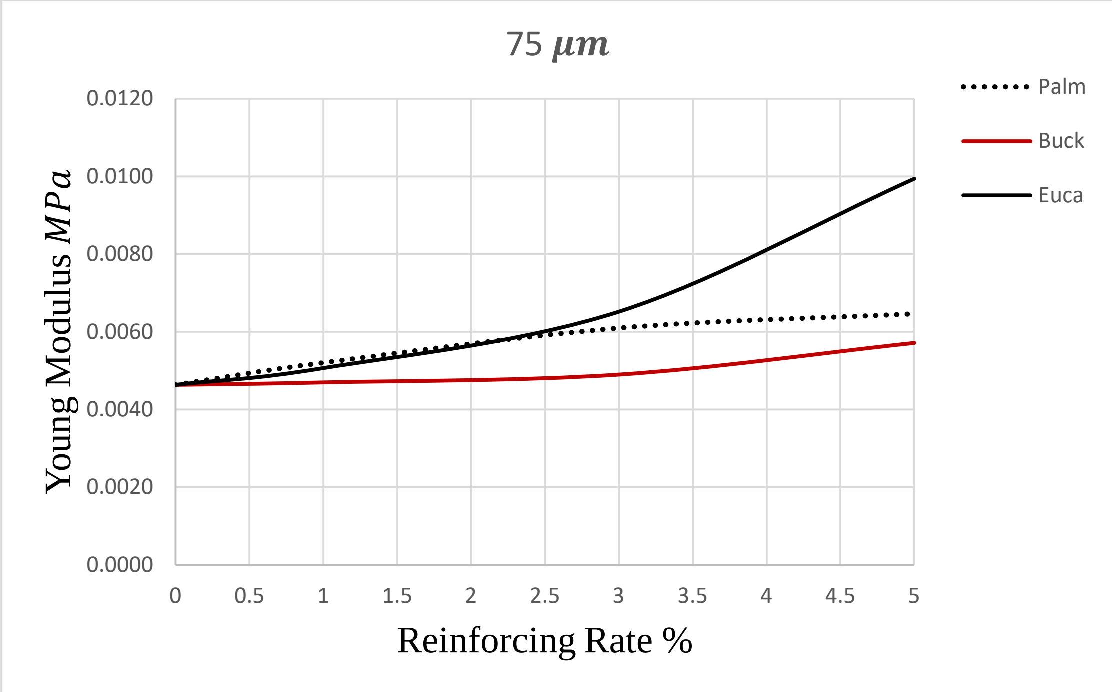


Figure 4.19. The results of the Young Modulus opposite are reinforcement rates, at reinforcement particle size75μm.

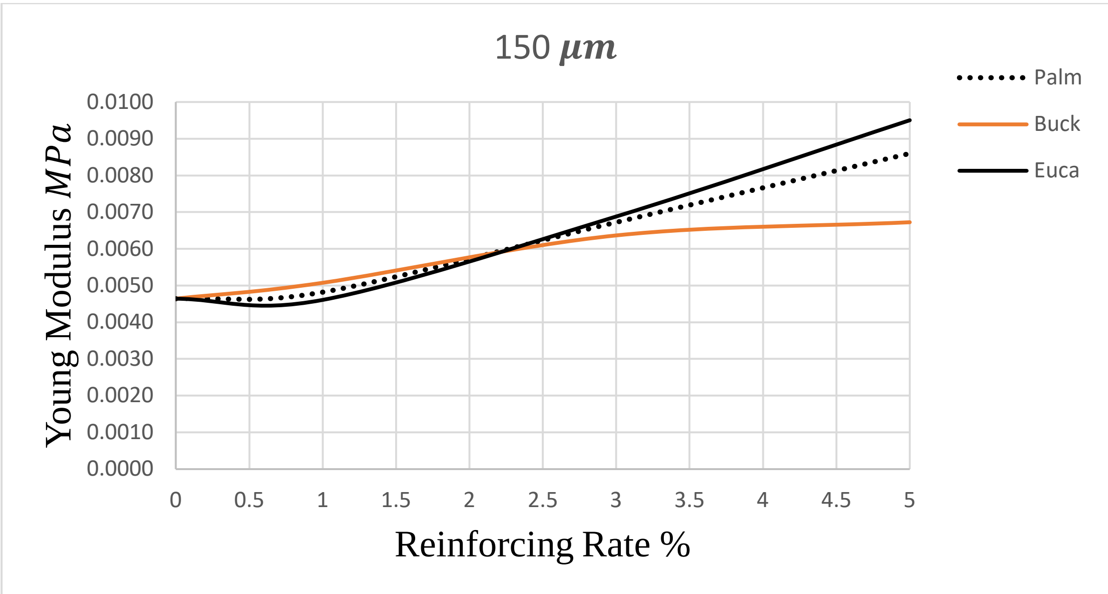


Figure 4.20. The results of the Young Modulus opposite are reinforcement rates, at reinforcement particle size150μm.

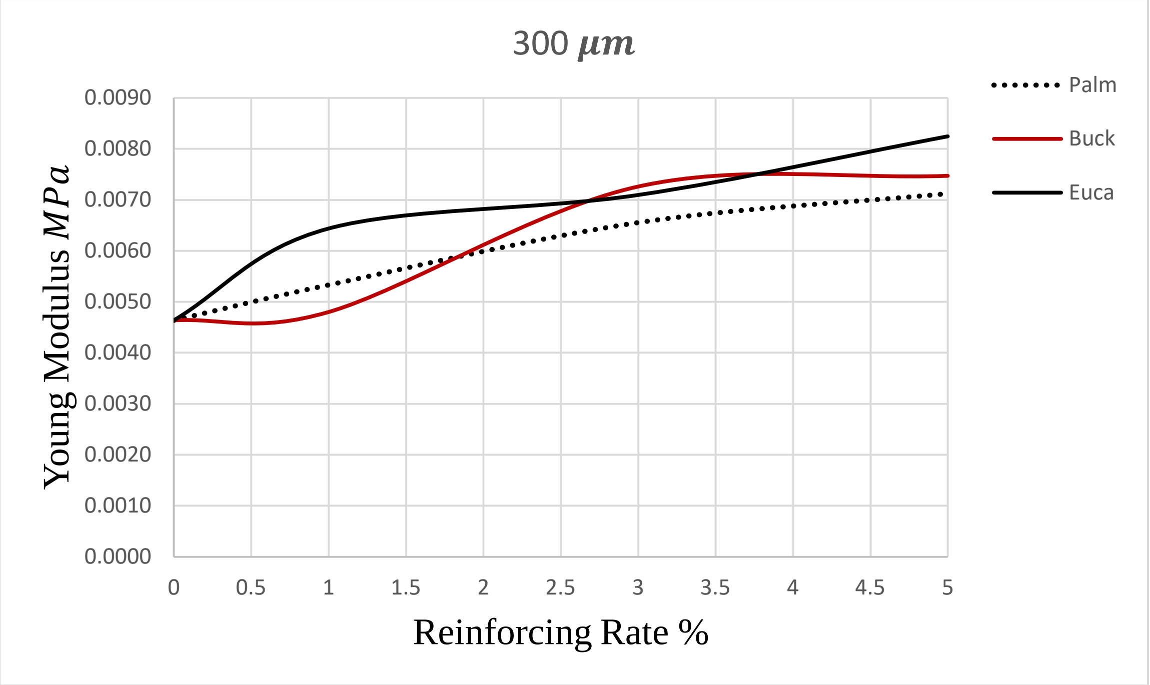


Figure 4.21. The results of the Young Modulus opposite are reinforcement rates, at reinforcement particle size $300\mu m$.

4.2. Thermal conductivity

There are many factors that affect the thermal conductivity coefficient of silicon rubber composites samples, such as the effect of different compositions of the plant wastes particles, the particle size, and the reinforcing rate.

The reinforcing process increases the thermal conductivity values, where the best result obtained of the composites samples reinforcing by Eucalyptus particles, and the maximum thermal conductivity result obtained of the sample reinforced by Eucalyptus particles at particle size 75 μm and rate 5%, which increases the thermal conductivity coefficient from (0.8548 to be 1.5886) w/m.°C by 85%.where the different elements in the waste particles increase the thermal conductivity coefficient of the composites samples in addition of the effect of the voids and pores on created as a results of reinforcing process [73,75] .

As shown in the tables 4.13- 4.15, and from Figures 4.22- 4.27.

Table 4.13. The thermal conductivity coefficient at Particle Size $75\ \mu m$

Reinforcement Rate %	Thermal Conductivity coefficient $w/m.$°C		
	Date Palm	Buckthorn	Eucalyptus
0.0	0.8548	0.8548	0.8548
1	0.9909	0.9548	1.0262
3	1.1629	1.4356	1.2749
5	1.4480	1.6074	1.5886

Table 4.14. The thermal conductivity coefficient at Particle Size $150\ \mu m$

Reinforcement Rate %	Thermal Conductivity coefficient $w/m.$°C		
	Date Palm	Buckthorn	Eucalyptus
0.0	0.8548	0.8548	0.8548
1	0.9613	0.9241	0.8272
3	1.0127	0.9567	1.0209
5	1.1444	1.0490	1.1312

Table 4.15. The thermal conductivity coefficient at Particle Size $300\ \mu m$

Reinforcement Rate %	Thermal Conductivity coefficient $w/m.$℃		
	Date Palm	Buckthorn	Eucalyptus
0.0	0.8548	0.8548	0.8548
1	1.0625	1.1444	1.2508
3	1.0209	1.0718	1.0957
5	1.5191	1.1767	1.1897

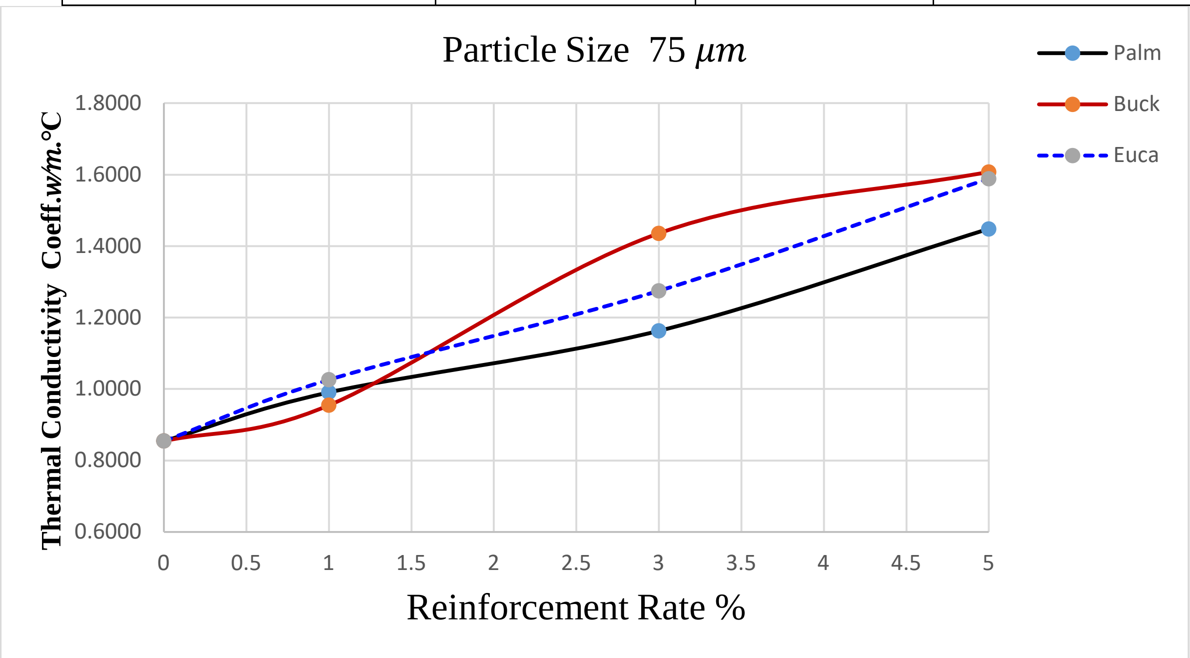


Figure 4.22. The results of the thermal conductivity coefficient opposite are reinforcement rates, at reinforcement particle size$75\mu m$.

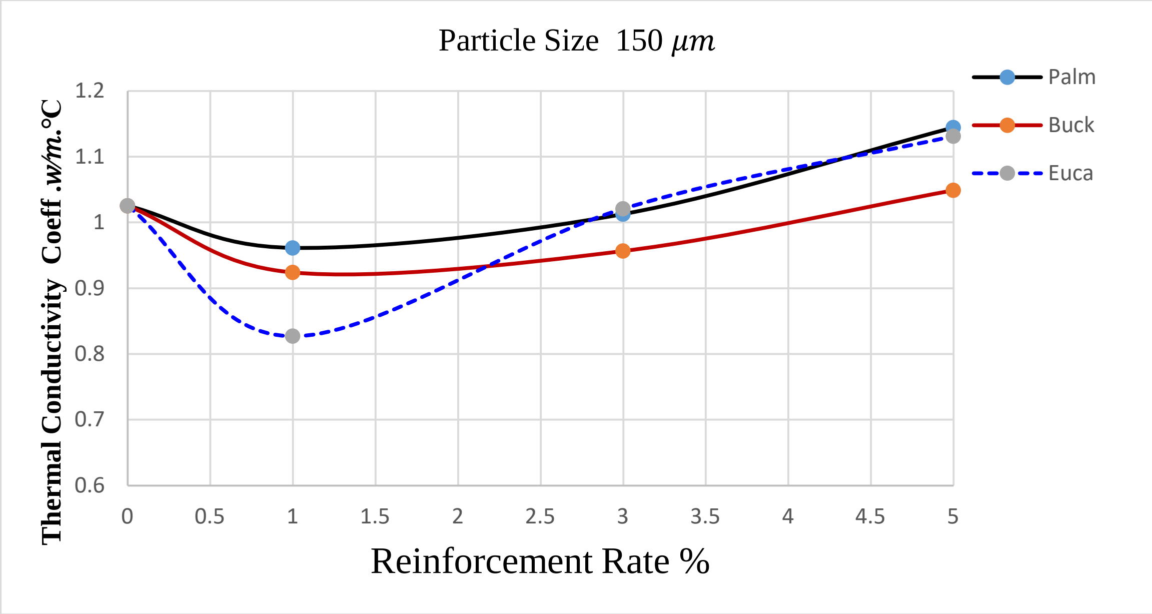


Figure 4.23. The results of the thermal conductivity coefficient opposite are reinforcement rates, at reinforcement particle size$150\mu m$.

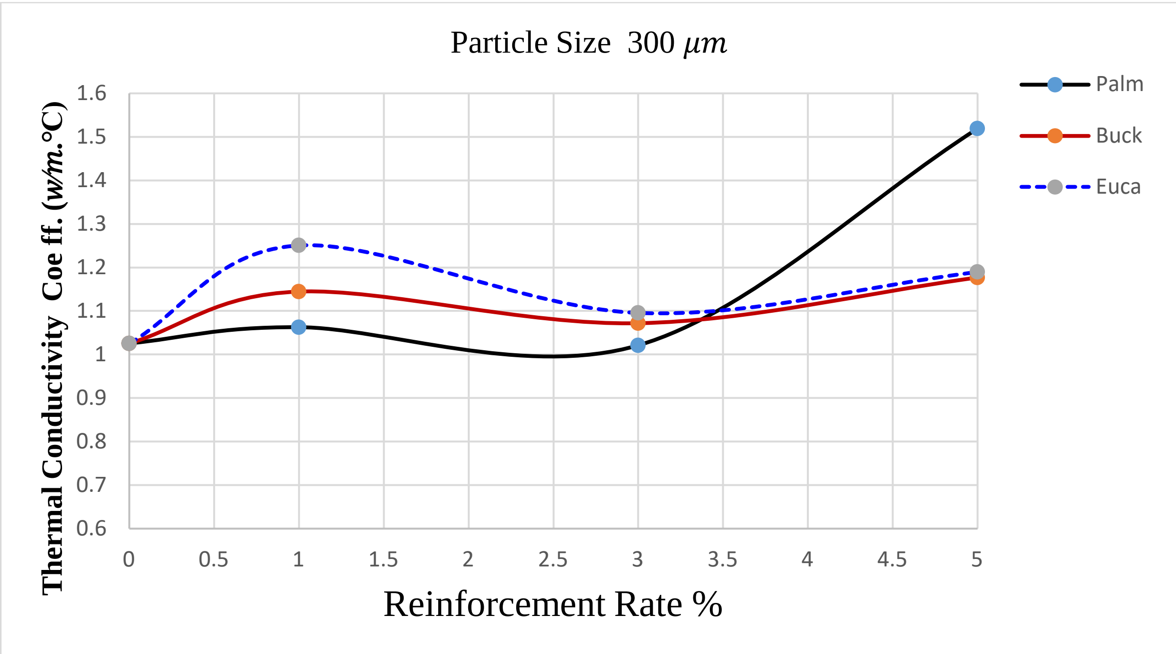


Figure 4.24. The results of the thermal conductivity coefficient opposite are reinforcement rates, at reinforcement particle size$300\mu m$.

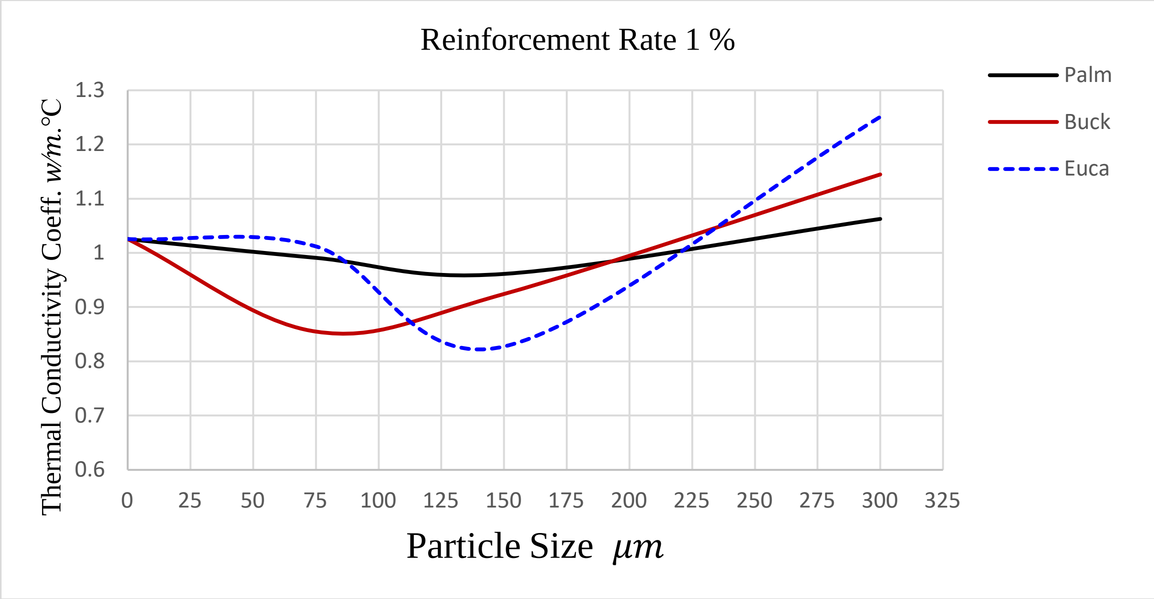


Figure 4.25. The results of the thermal conductivity coefficiont opposite are reinforcement particle size, at reinforcement rate 1%.

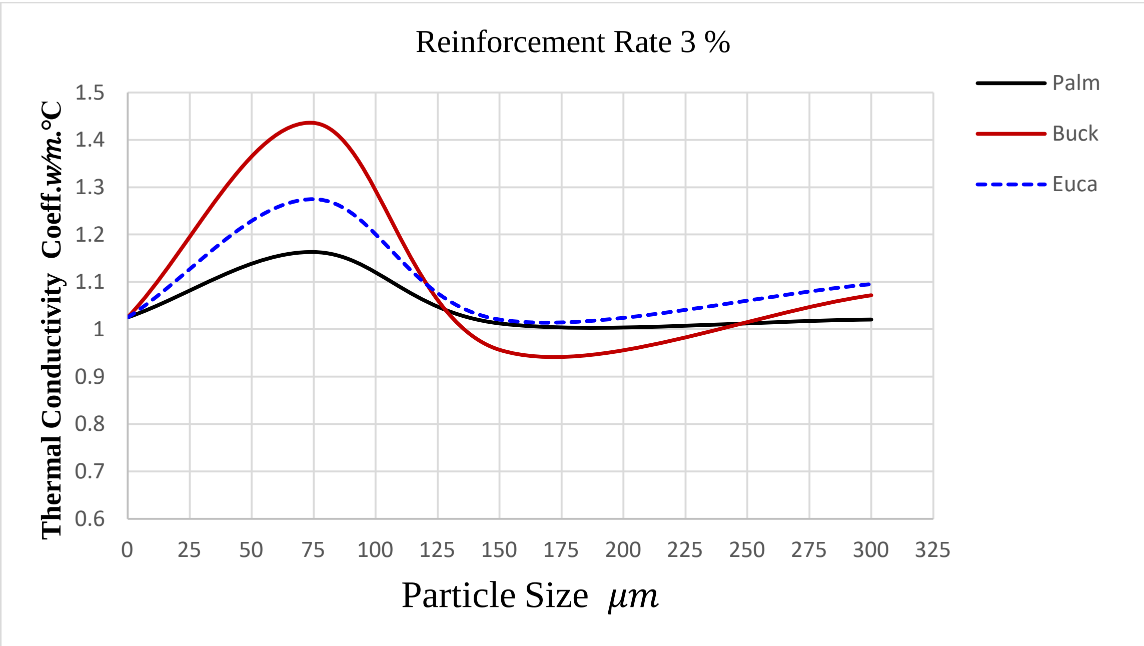


Figure 4.26. The results of the thermal conductivity coefficiont opposite are reinforcement particle size, at reinforcement rate 3%.

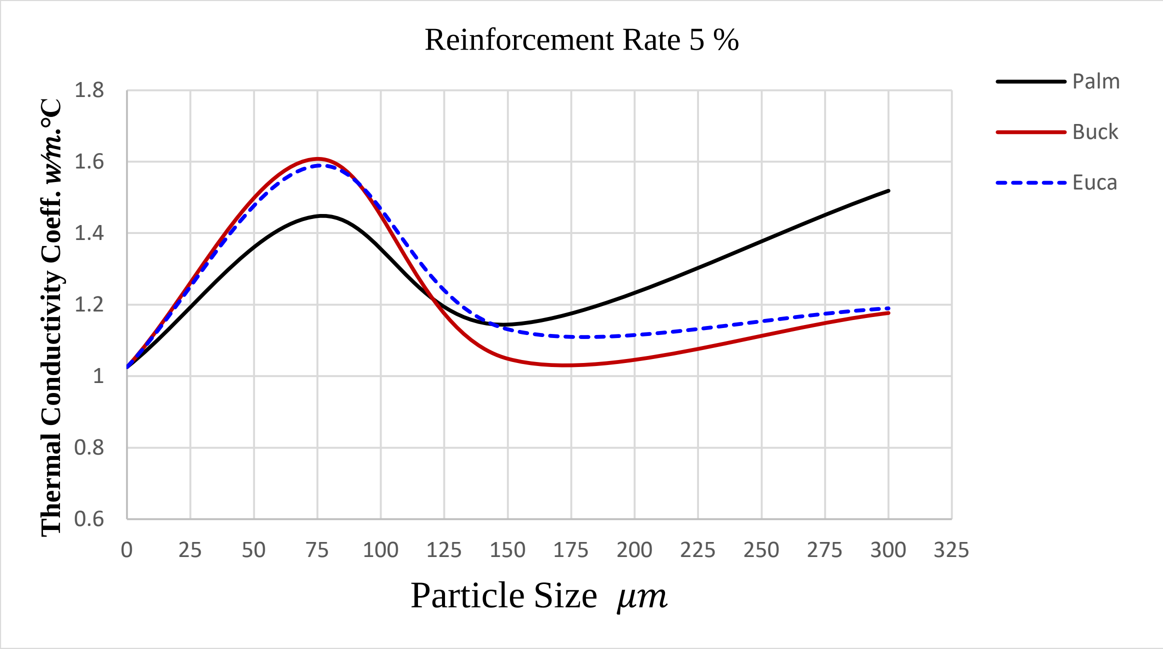


Figure 4.27. The results of the Thermal conductivity coefficient opposite are reinforcement particle size, at reinforcement rate 5%.

4.3. Water Absorption Rate

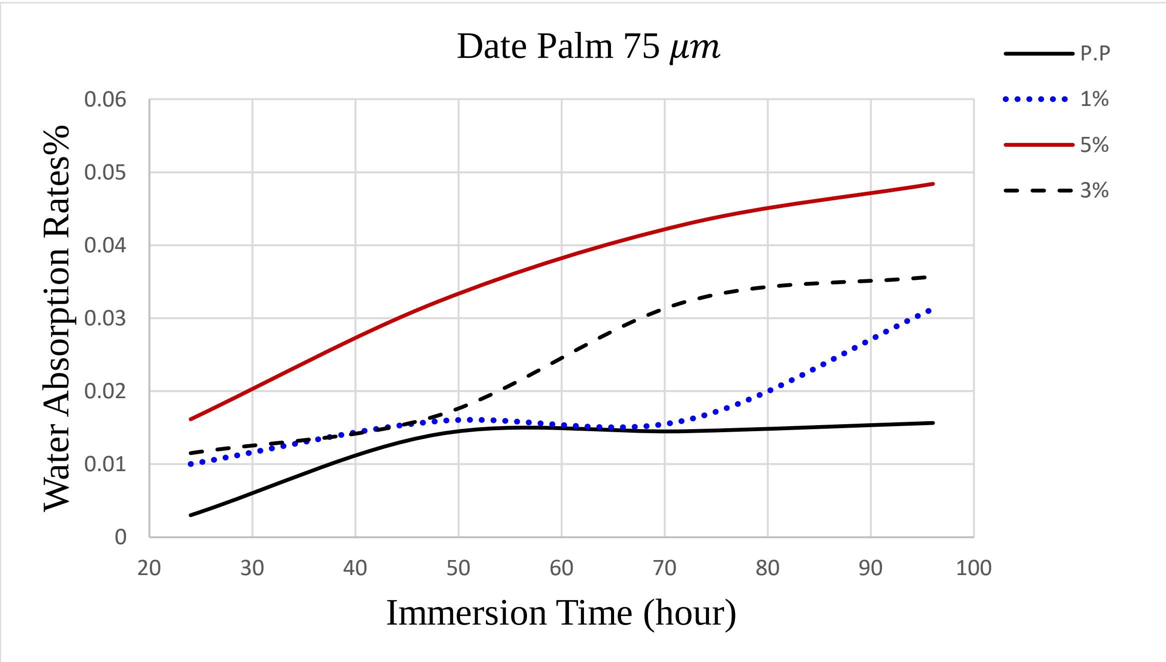
The moisture has negative effect on the mechanical and thermal features of the composite samples, where this section displays the results of water absorption rate (moisture absorption), because of the particles reinforcing process.

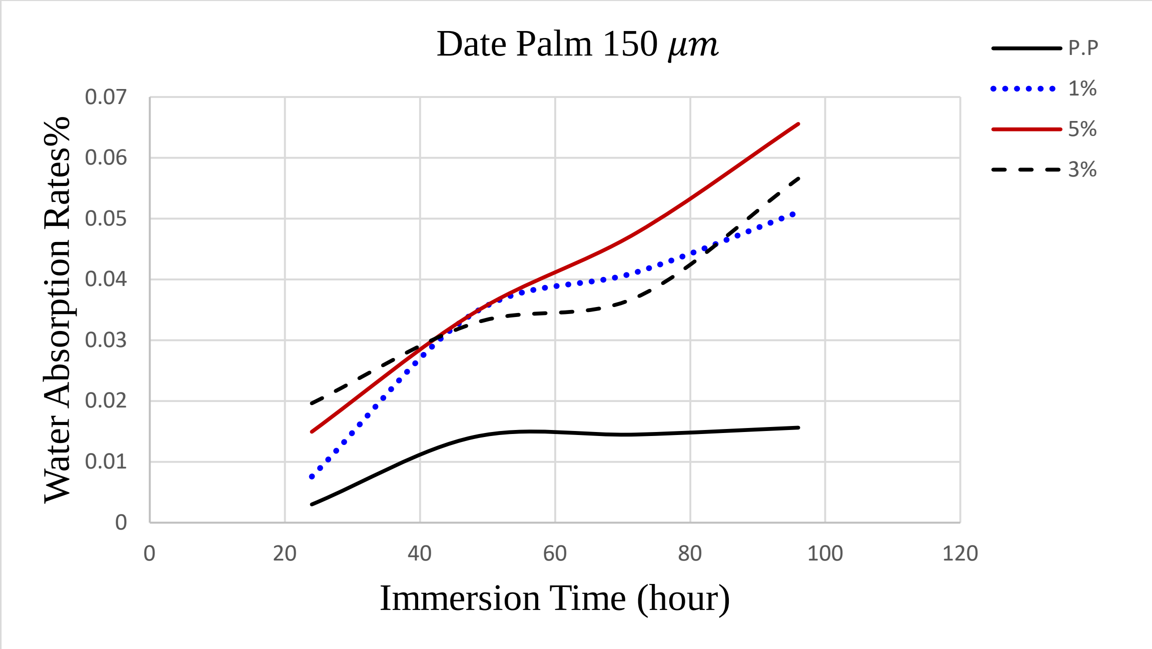
From Figures, we can observe that the reinforcing process creates voids and pores and this leads to increase the water absorption of the samples, in addition of that the nature of the plant waste which tends to absorbs the water from the surrounding, therefore reinforcing process increases the rate of water absorption, and off course increases with the time of immersion in water.

Where the best result obtained of the composites samples reinforcing by Eucalyptus particles, and the minimum water absorption rate result obtained of the sample reinforced by Eucalyptus particles at particle size 75 μm and rate 5%, which increases the water absorption rate from (0.0156% to be 0.0312%) by 100%[70,71].

This substantial increase with regard to the particles could be because the particles here have maximum capacity for water absorption compared to the silicone rubber. [70]

The results of Water Absorption Rate are shown in Figures 4.28- 4.30.





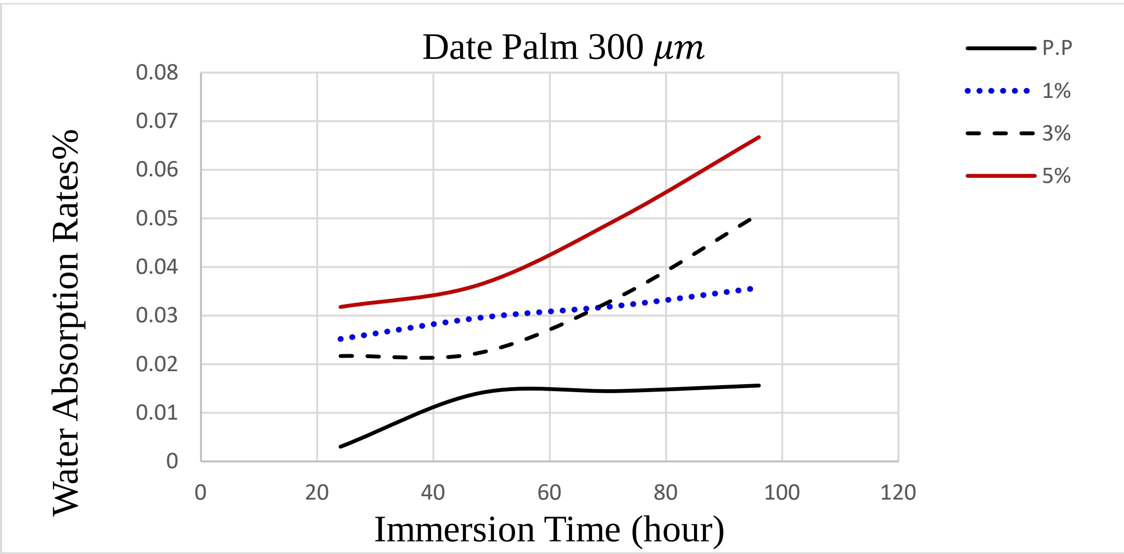
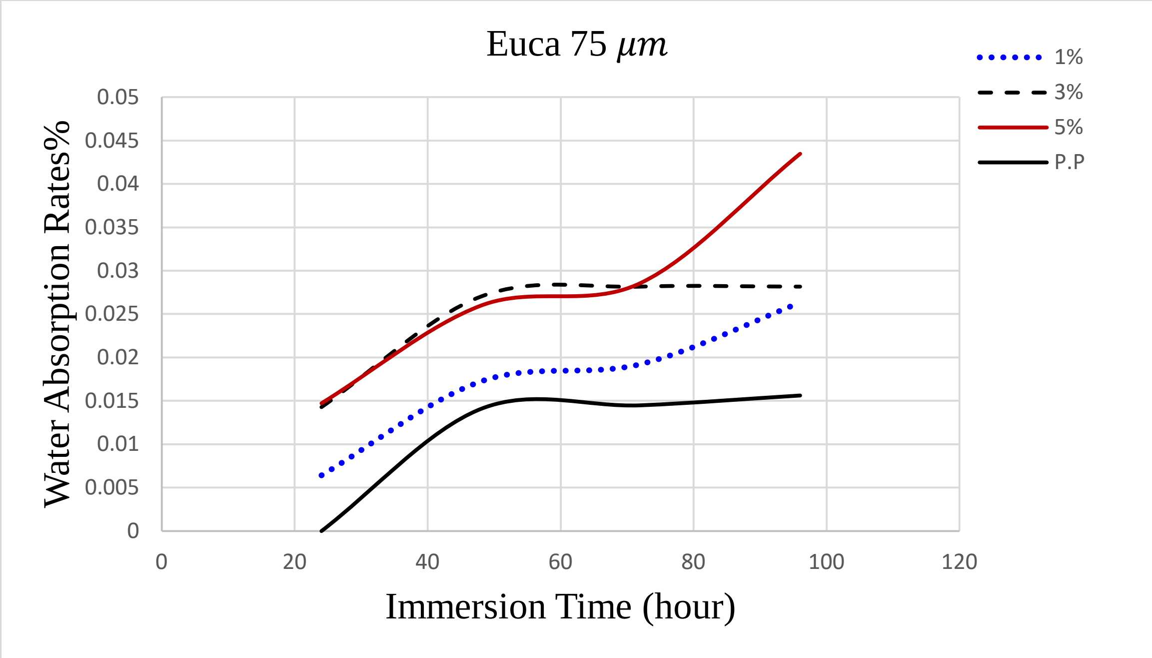
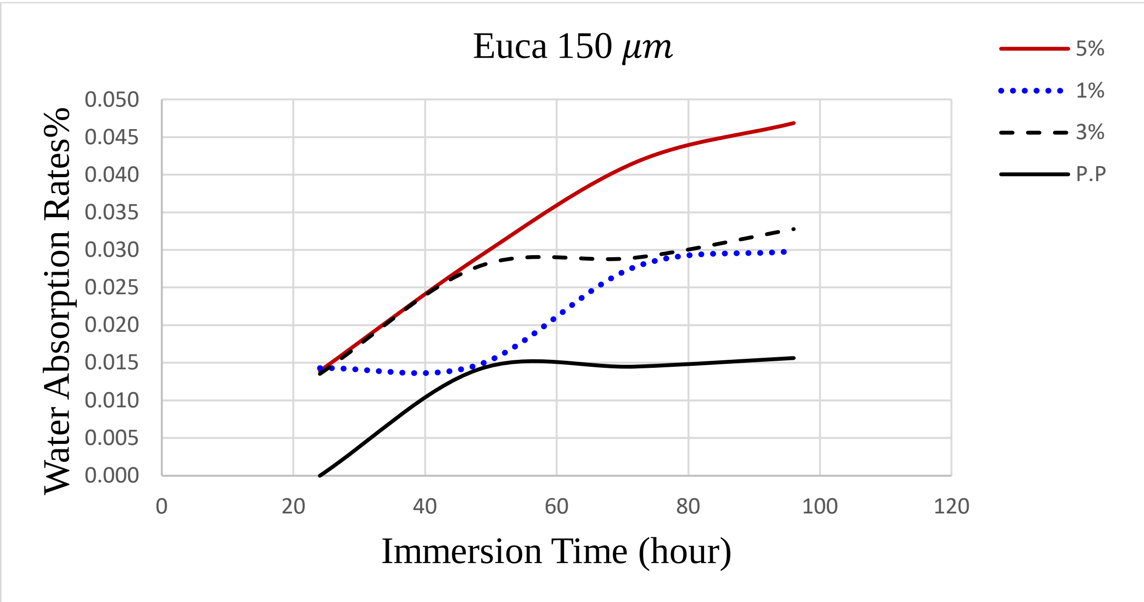


Figure 4.28. The results of water absorption rate opposite are immersion time at different reinforcement rates of the composite samples reinforced with Date palm particles.


Euca 75 μm
1%
3%
5%
P.P
Water Absorption Rates%
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
20
40
60
80
100
120
Immersion Time (hour)


Euca 150 μm
5%
1%
3%
P.P
Water Absorption Rates%
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0
20
40
60
80
100
120
Immersion Time (hour)

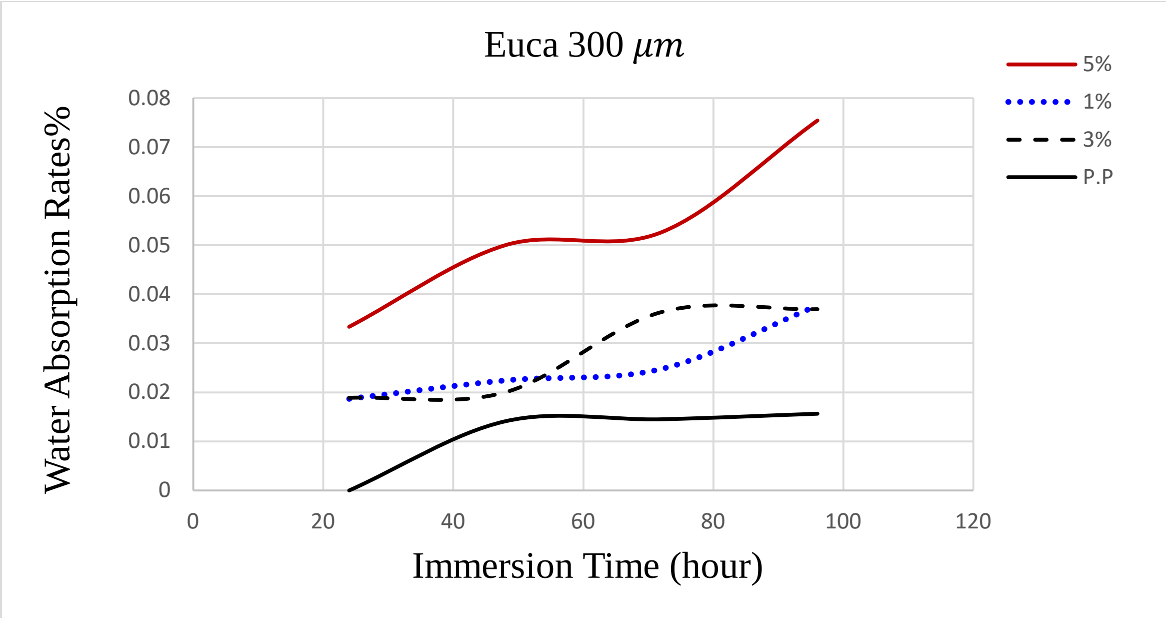
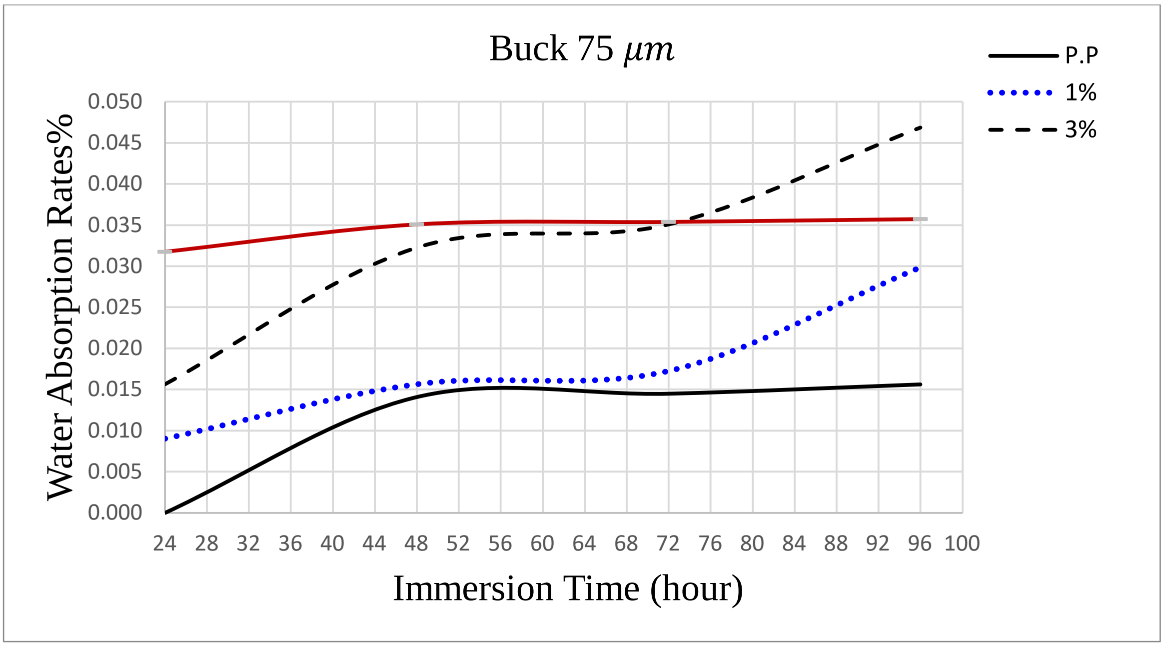
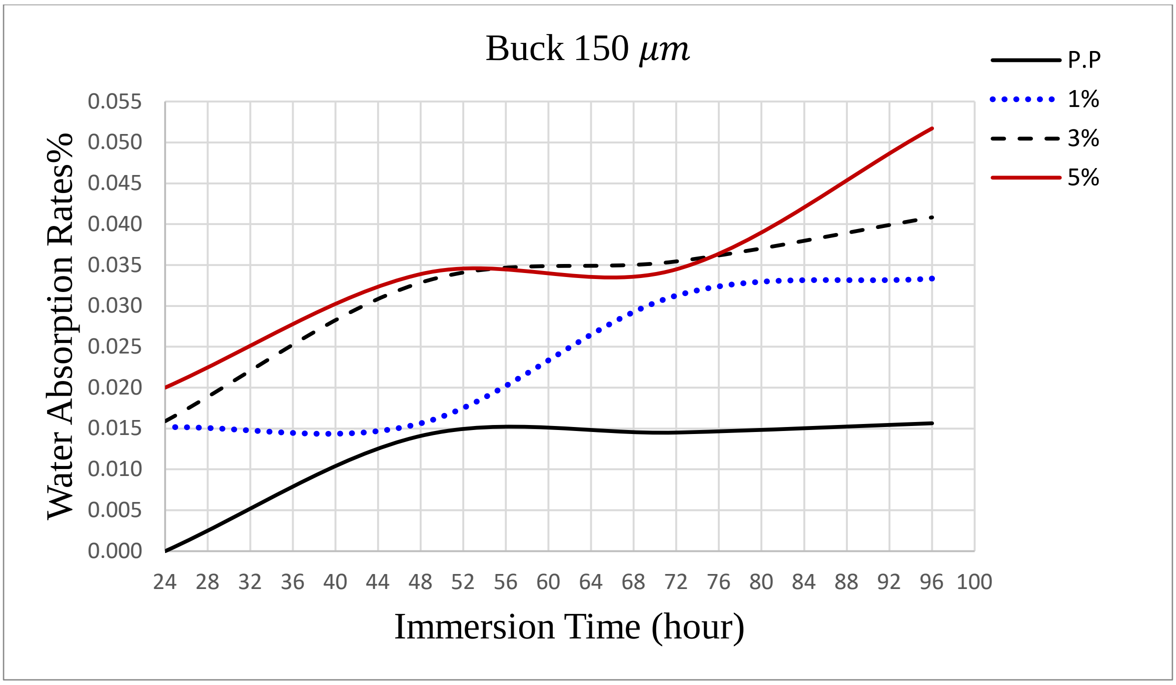


Figure 4.29. The results of water absorption rate opposite are immersion time at different reinforcement rates of the composite samples reinforced with Eucalyptus particles.





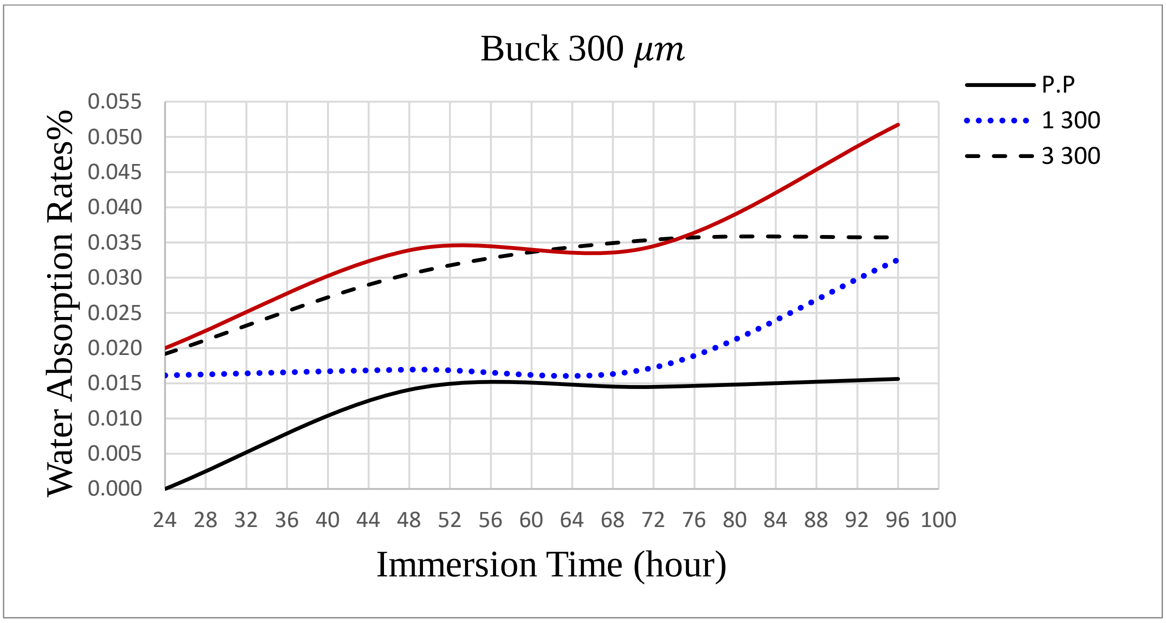


Figure 4.30. The results of water absorption rate opposite are immersion time at different reinforcement rates of the composite samples reinforced with Buckthorn particles.

4.4. Density Testing

As we can notice from tables 4.16- 4.17, 4.18, and Figures 4.31-4.32, and 4-33, the reinforcement process by perennial plant waste particles decreased the density values of prepared composites samples, and that due to two reasons, the first is the voids and pores created by the reinforcing particles during the preparation process. In addition, the second reason is due to the lightweight (low density) of the reinforcement plants, where the density values of the plants are less than the density of the pure silicon rubber. In addition, the density was reduced with increasing reinforcement rates for all particle sizes.

The presence of some oils and gums in the eucalyptus plant reduced the pores voids in the prepared samples, which cause that the density to be more than that of the other samples reinforced with Buckthorn and Date palm particles [72].

Table 4.16. The Density at Particle Size 75 μm

Reinforcement Rate %	Density g/cm^3		
	Eucalyptus	Buckthorn	Date Palm
0.0	3.479684418	3.479684418	3.479684418
1	2.965309209	2.196074445	1.910932124
3	2.639267803	1.877784496	1.860490995
5	2.181250855	1.865899976	1.788638049

Table 4.17. The Density at Particle Size 150 μm

Reinforcement Rate %	**Density g/cm^3**		
	Eucalyptus	Buckthorn	Date Palm
0.0	3.479684418	3.479684418	3.479684418
1	2.865309209	1.651341043	1.521049944
3	2.529860744	1.512450708	1.4777473
5	2.150150932	1.457980563	1.453184973

Table 4.18. The Density at Particle Size 300 μm

Reinforcement Rate %	**Density g/cm^3**		
	Eucalyptus	Buckthorn	Date Palm
0.0	3.479684418	3.479684418	3.479684418
1	1.853589454	1.720589454	1.331159822
3	1.705477529	1.585031988	1.315348913
5	1.62969271	1.533299294	1.295479179

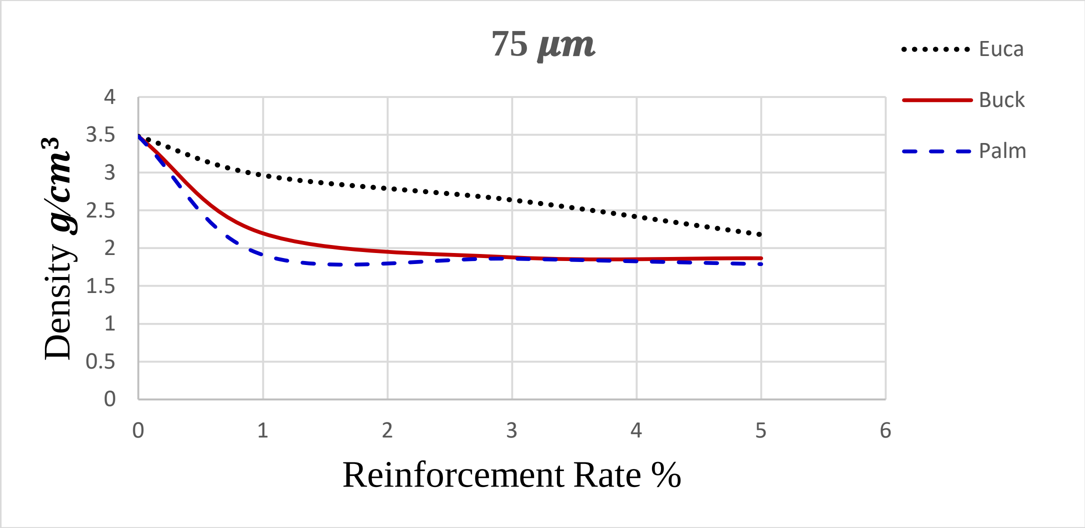


Figure 4.31. The results of the density opposite are reinforcement rates, at particle size75μm.

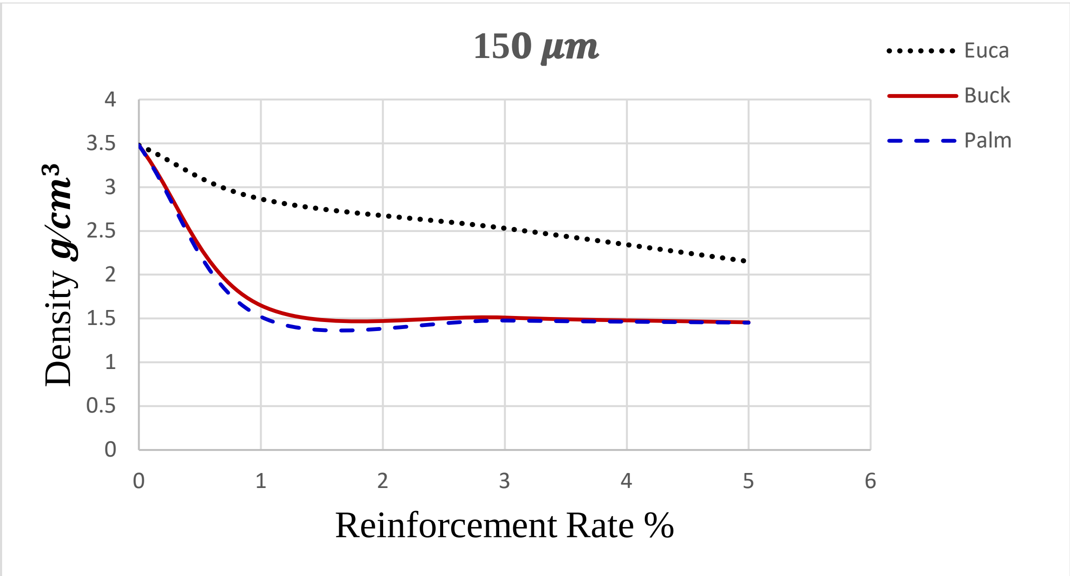


Figure 4.32. The results of the density opposite are reinforcement rates, at particle size150μm.

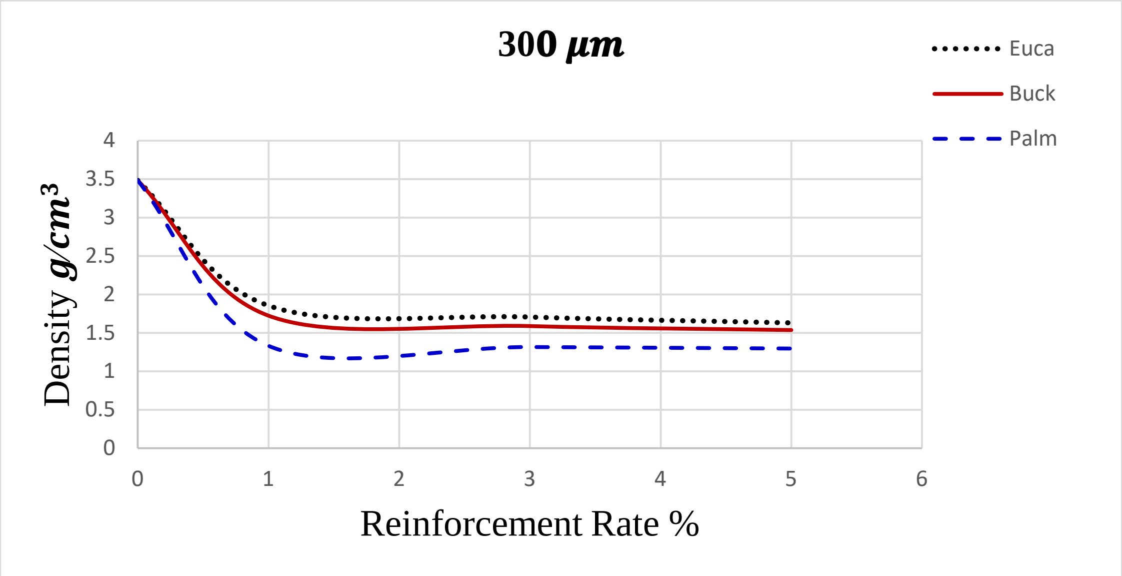


Figure 4.33. The results of the density opposite are reinforcement rates, at particle size $300\mu m$.

CHAPTER FIVE

CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

5.1 Conclusions

Experimental verification of silicon rubber composites leds to the following specific conclusions.

1. The reinforcement process by perennial plant waste particles significantly improved the mechanical and some physical properties of the prepared composites samples.
2. The reinforcement process by eucalyptus plant particles gives the best results among the other plants types.
3. The influence of reinforcement particles was clear and notable on the tensile strength, Young modulus (elastic modulus), and the hardness of the composites samples, where the reinforcement process increased the tensile strength, Young modulus, and hardness values.
4. The reinforcing process has negative effect on the water absorption rate of the samples, where the reinforcing process creates voids and pores so that leads to increase the water absorption rates of the composites samples.
5. The reinforcing process affects on the thermal conductivity coefficients, where it increased by the plants wastes particles.
6. The reinforcing process increased the wear resistance of the composites samples.
7. The reinforcing process decreased the density values of the prepared composites samples because of lightweight (low density) of the reinforcement plants, and the voids and pores were created by the reinforcing particles during the productions process.

5.2 Suggestions and Recommendations

Several recommendations have been identified from this research to improve properties of the prepared composite samples.

1. Increasing the reinforcement particles rates to enhancement the results of the mechanical, physical and thermal effects.
2. Studying the effect of immersion process to the prepared samples in rain water, the water used in the homes, and detergents on the prepared samples, and the sustain ability to environmental conditions.
3. Studying the ability of the samples to the acoustic insulation and the capability of acoustic absorption.
4. Studying the use of the three types of reinforcement's particles with some or two of them in each sample instead of using each type individually separately.

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الخلاصة

إنّ الهدف الرئيس من هذه الدراسة هو تحسين الخصائص الميكانيكية (قوة الشد ومعامل يونك ومقاومة البلى والصلادة)، والتوصيلية الحرارية لمطاط السيليكون بوصفها مادة اساس للمتراكب البوليمري باستعمال جسيمات مختلفة من مخلفات ثلاث انواع من النباتات المعمّرة بوصفها مادة معززة ، وهذه النباتات هي أوكالبتوس ونخيل التمر والنبق وهي نباتات واسعة

الانتشار في العراق. الهدف الثاني لهذا البحث هو التخلص من هذه المخلفات و للحد من التلوث البيئي.

تم إنجاز عملية التعزيز باستعمال مساحيق المخلفات لثلاث نباتات معمّرة في العراق , حيث تم تقطيع مخلفات النباتات إلى قطع صغيرة ثم طحنها وغسلها وتجفيفها عند 60°C ثم إعادة الطحن وأخيرا تم اجراء عملية النخل باستعمال ثلاثة مناخل.

تم استعمال المساحيق النهائية المحضرة بثلاث نسب تعزيز: %(1,3,5) ، واستعملت ثلاثة أحجام حبيبية لكل نسبة تعزيز وهي μm(75, 150 and 300).

أظهرت نتائج الاختبارات الميكانيكية والتوصيلية الحرارية ونسب امتصاص الماء أن عينات المتراكب المعززة بمساحيق مخلفات نبات الأوكالبتوس بنسبة 5٪ وحجم حبيبي 75μm كان لها أفضل النتائج بين العينات الأخرى ، حيث إزادت قيمة مقاومة الشد بنسبة 150% ، كما ازدادت قيمة الصلادة بحوالي 27.18%، وازدادت مقاومة البلى بنسبة 115% ، وازدادت قيمة معامل يونك (المرونة) بنسبة 115.21% ، وازدادت الموصلية الحرارية بنسبة 85% ، كما كان لها الحد الأدنى لمعدل امتصاص الماء والذي ازداد بنسبة 100%.

فضلا عن دلك ،أدت عملية التعزيز الى تقليل قيم كثافة العينات المحضرة نتيجة المسامات و الفراغات الناتجة عن جزيئات التعزيز.

جمهورية العراق

وزارة التعليم العالي والبحث العلمي

جامعة بغداد

كلية التربية للعلوم الصرفة (ابن الهيثم)

دراسة تأثير جسيمات بعض مخلفات النباتات المعمّرة على الخصائص الميكانيكية والحرارية لمتراكبات بوليمرية

رسالة مقدمة إلى

مجلس كلية التربية للعلوم الصرفة (ابن الهيثم)-جامعة بغداد

كجزء من متطلبات نيل درجة الماجستير في علوم الفيزياء

من قبل

هدى رزاق كطافة

بإشراف

م.د. عادل اسماعيل كاظم

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