A REVIEW OF: THE ROLE OF POLYMER COMPOSITES IN THE FABRICATION OF ARTIFICIAL HUMAN ARMS.

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ABSTRACT

Polymer composites have been found useful in the fabrication of artificial prostheses limb, most importantly in the field of medical science which cannot be over emphasize, especially in the manufacturing and production of artificial human arms such as amputed hand and legs. Polymer composite which are of various types of different degree of strength are being employed in the production of prosthesis limb which includes; polyethylene, polyester, vinyl ester, epoxy, poly imide, poly propylene, hydroxyapatite, and poly ethyl ether ketone, with their respective reinforce material[fibres] such as glass fibre, carbon fibre, and bone fibre. these provides devices that are strong and light weight than earlier limb made of iron and wood. The aim of this paper is to highlight the role of polymer composites in the fabrication of artificial human arm, with the use of Nano Composites as which would prevent the casino genic of some synthetic composite.

***Keywords**: Polymer Composites, Artificial human arms, Application and manufacturing.*

INTRODUCTION

An artificial or prosthesis is an artificial device that replaces a missing body part, which maybe through trauma, diseases [through diabetes], accident or congenital condition prosthesis amputee. The idea of using composite in bone implant come since 1980 (1). Considering the observed problem and failure from the previous materials, using composite materials with high strength and stiffness and more similar natural bone had since started to develop in medical composites, one of the constituent materials is bioactive [metal polymer or ceramic]. The composite type is based on their matrix phase [metal-ceramic] or polymer (2). Human beings are naturally and structurally composites materials made from collagen fibre and nano crystal of hydroxyapatite which are sediment in collagen fibre (3). The collagen fibres have low elastic modulus and hydroxyapatites are with high elastic modulus and contain almost 70percent of bone-dry weight and support the stiffness of the bone (4).

HISTORICAL DEVELOPMENT

Artificial arms and legs or prosthesis are intended to restore a degree of normal function of amputees. Mechanical device that allows amputee to walk again or continue to rise two hands have probably been in used since ancient time and was not largely successful until around 600.b.c. Armorers at the middle ages created the first sophisticated prosthesis, using a sting, heavy flexible iron to make limbs that the amputee could scarcely control. Human born naturally composite material made of collagen fibres and nano crystal of hydroxyapatite which are sediment in collagen fibres (3) hydroxyapetite is made with is made with elastic modulus and contains almost 70percent of born dry weight and support the stiffness of bone.

COMPOSITES

Composites are naturally or synthetic occurring substance made from two or more constituents' materials, with significant different physical or chemical properties, that when combine, produce a material with characteristics different from the individual component (5). The individual components remain separates and distinct with the finished structured. the individual components remain separate and distinct with the finished structured. Composite materials are becoming an essential part of today's material due to advantage such as low weight, corrosion resistance, high strength, high flexible, and elastic properties, faster assembly. They are extensively used as materials in making air craft. Structure, electronic packaging, medical equipment, interior ear part, structural building materials, security equipment such as ballistic bullet proof and armored cars etc. The basic difference between blonds and composites is that two main constituents in the composites remain recognizable while they may not be recognized in blends. Composite's material is made up of distinct phases [matrix-phase and dispersed phased] and bulk properties significantly different from those of any of the constituent. Matrix phase is the primary phase having a centenary character, matrix is usually more ductile and less hard phase. It holds the dispersed [rem forcing] phase is embedded in the matrix in a disinsertions' form. The secondary phase is usually stronger than the matrix, therefore it is sometimes called reinforcing phase.

CLASSIFACATION OF COMPOSITE

On the basis of matrix phase, composite can be classified into metal matrix composite [MMs], ceramic matrix composite [CMCs] and polymer matrix composite [PMCs]as in figure 1 below (6) The classification according to the type of reinforcement is particulate composite [composite of particle], fibre composite [composite of fibre]and laminate composites [composites of laminates]. Fibrous composite can be can be divided on the basis of natural /bio fibres or synthetic fibre. Bio fibre encompassing composite are referred to as bio fibres composite. They can be again be divided on the basis of matrix, that is non-bio degradable matrix and bio depreble matrix (7). Bio-based composites are made natural /bio fibre and bio deprables polymer are referred to as green composite. These composites can be further sub divided as hybrid composite and textile composite. hybribe divided as hybrid composite and textile composite. hybribe composite compose of a combination of two or more fibres.

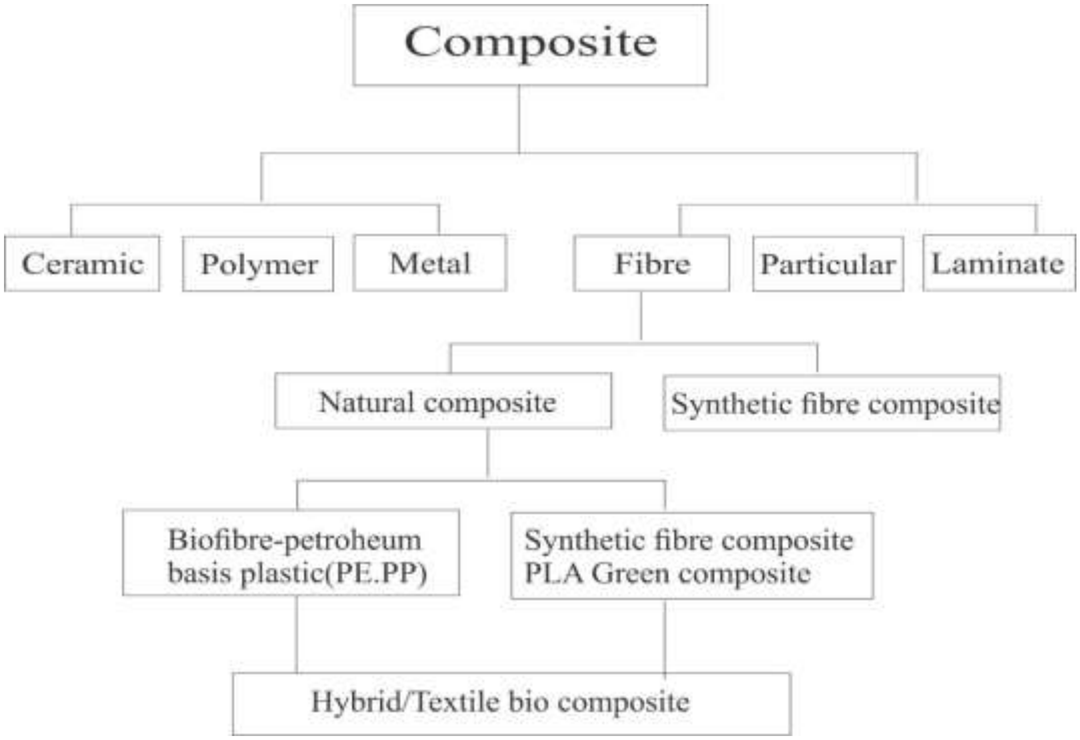


FIGURE 1: CLASSIFACATION OF COMPOSITE

NATURAL COMPOSITES

Natural fiber brings in several disadvantages as they are incompatible with polymers when used in raw state such as high water absorption, dead cells, wax, and oil. To overcome this, their surface needs to be modified. The main purpose of surface modification is to increase the properties of natural fibers for it to impart better strength in composites system. Surface modification is done either by chemical treatment, enzymatic treatment, corona or plasma treatment, or by addition of coupling agents. These treatments mostly target the amorphous part of cellulose region hence improve compatibility between fiber and polymer matrix. The amorphous part of cellulose consist of multiple hydroxyl groups which impart a polar nature to the fiber which lead to a poor bonding with polymer matrix. Therefore, surface modification was subjected with the purpose of reducing the polar nature of the fiber by reducing/removing the hydroxyl groups and help to increase the fiber-matrix adhesion and enhance its mechanical properties (8).

Plants that generate natural fibers are classified as primary and secondary, depending on their use. Primary plants are those which are grown specifically for their fibers, such as cotton, jute, kapok, hemp, kenaf, sisal and secondary plants, which are produced as by-products such as banana, coconut coir, pineapple and oil palm (9). Near about 30 million tons of natural fibers are produced every year and used as component of many manufacturing processes like clothing, packaging, paper making, automobiles, building materials, and sports equipment. Other than plant fibers, various animal fibers also have different types such as products from the wool, silk, feathers, avian fiber, and animal's hairs which are prime resource. Natural fibers have been used for a long time in many developing countries (10). Low cellulose causes weak bonding between adjacent moisture content and fiber causing better interfacial adhesion between the components. Hence, improving the overall suitability to high-end ballistic applications. Table 3 tabulated types of hybrid natural fiber/synthetic fiber reinforced polymer matrix use in ballistic application.

APPLICATION OF POLYMER COMPOSITE

Polymer composite are used for the following applications.

- Aerospace Structures: the military aircraft industries have mainly led the use of polymer composite. In commercial airlines, the use composite is generally increasing space shuttle and satellite systems use graphite/epoxy for many structural parts 11(29-37).
- Marine: boat bodies, canoes, swimming jacket. Etc.
- Automotive: body panels, leaf springs, shaft drive, bumpers, doors, racing car bodies. Etc
- Sports goods: golf clubs skis, finishing rods, tennis rockets, sport wears etc
- Chemical storage tank: pressure vessels, pipping, pump body, valves.
- Bullet proof vest, and other armor part.
- Construction: Bridges made of polymer are gaining wide acceptance due to their lower weight, corrosion resistance, longer life cycle, and limited earthquake damage.
- Electrical and telecommunication: cable wires, housing switch, telecommunication wires
- Biomedical applications: medical implant, x-ray tables, orthopedic devices, prostheses limbs, medical equipment such as ventilators, disposable medical gown, and hand gloves etc.

APPLICATIONS OF POLYMER COMPOSITES IN MEDICAL FIELD

- Bone fractures

  The bone fractures are fractures that are possible to repair in some different ways, external fixation and internal fixation. In internal fixation there is need to open the tissue, the bone fracture is kept in some device and material such as cost-splint. The casting materials consist of composite materials made of woven cotton and calcium sulphate ($CaS0_4$) matrix and reinforcement by using surgery techniques and implant of the bone fracture is repaired (4).

- Bone plates

  In non- resorbable plate material is stable in the body an in vivo condition without any change in strength and stiffness. It can be made of thermoset or thermoplastic composites materials (PLA) or polylactic acid, polygelicolic acid (PGA) can be degraded in the body. The material gets weaker after a certain period, fully resorbabe materials. Example are: polylactic acid (PLA) fibre and calcium phosphates base glas fibres. In partially resorbable to improve their mechanical properties, the resorbable polymer are reinforced by some materials (non- resorbable) such as carbon fibre, polymeric fibre, thus they called partially resorbable materials like CF/PLA composites (4).

- Bone cement

  The main function of bone cement is to stabilize prostheses by filling the gap between it and the bone to transmit loads from the prostheses to the bone. Polymethylmethacrylates (PMMA) has been used in born cement for nearly 40 years with little change in its composition and structure. PMMA is prepared in the operating from powder polymer containing an initiator/ catalyst and liquid monomer containing an activator polymerization is limited on mixing those component or zirconium sulphate is usually added to the polymer powder to render the cement opaque and antibiotic is commonly added to reduce the risk of infection (4).

- Intermedullary nails

  They are used in long bone fractures and can be inserted inside the bone to fill it. The nails must be strong to support the weight of the body. Intermedullary nails are mostly made of steel or glass fibre/

polyethyletherketone (GF/PEEK) composites, which was suggested by (Linetal, 2007) the reason for this is that composite materials show more biocompatibility and also better mechanical properties in contact with bone. The used of carbon fibre reinforced liquid crystalline polymer continued in the application of intramedullary nails, they have high flexural strength and closer elastic modulus to the bone (4).

- Bone Replacement
  There are many polymers composite that are made or are still under investigation. Hydroxyl apetite/ High density polyethylene (HA/HDPE) the first bioactive composite, it is very biocompatible and used in orthopedic and HDPE is linear polymer. Hydroxyapatite reinforced polysulphone (HA/PSU) is a new composite for bone replacement with almost40% HA/PSU is a polymer with high modulus and strength. It is applied in load bearing prostheses (1). It has a better mechanical property than high density polyethylene and is resistance to oxidation and hydrolysis (9).

PROTHESES LIMB

A prostheses limb is a functional replacement for an amputated or congenitally malformed or missing limb, patient receive a prescription for their particular prosthetic solution from a physician, most often physiatrist or vascular surgeon, which is then custom fitted by a prosthetist. Prostheses specialize in the design and fabrication of these individually tailored upper and low limb custom prosthetics.

In most cases, the prostheses being by making a plaster of the patient affected limb, high weight, high- strength thermoplastics are custom-formed to this model of the patient. Cutting-edge material such as carbon fibre, titanium and Kevlar provide strength and durability while making the new prosthesis lighter. More sophisticated prostheses are equipped with advance electronic, providing additional stability and central (11).

TYPES OF PROSTHESES LIMB

Limb’s prostheses include both upper and lower extremely prostheses: upper extremity prostheses and lower extremity prostheses.

Upper extremity prosthesis: are used at varying levels of amputation, shoulder disarticulation, transhumeral prostheses wrist disarticulation, full hand partial hand, finger and partial finger.

LOWER EXTREMITY PROSTHESES

Provide replacement at varying levels of amputation these include: Hip Disarticulation, transtibial prosthesis, partial foot and toe.

BASIC COMPONENT OF PROSTHETIC LIMBS

The basic components of prosthetic limbs are:

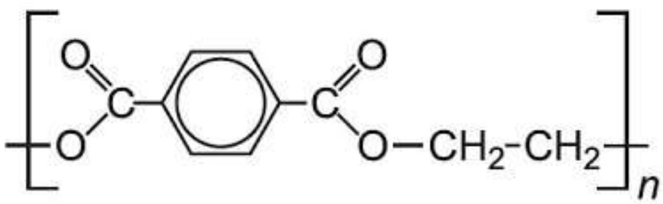
a. The Pylon: This is the internal frame or skeleton of the prosthetic limb. The pylon must provide structural support and hard traditionally been formed of metal rods. In more recent times, higher carbon-fibre composites have been used to form the pylons. The Pylon are sometimes enclosed by a cover, typically and from foam. The Material of the cover can be shaped and colored to match the recipient skin tone to give the prosthetic limb a more lifelike appearance (12).
b. The Sucket: this is the portion of the prosthetic device that interface with the patient limb stump or residual limb stump or residual limb to the patient body, it must be meticulously fitted to the residual limb to ensure that it doesn't causes irritation or damage to skin or underlying tissues a soft line is typically situated within the interior of the socket, and a patient input also wear a layer of one or more prosthetic socks to activities a smugger fit.
c. Belt and harnesses: Sometimes the prosthetic is attached by a belt or harness. These devices may be used by people who have different keeping the prosthesis on with a section value or leaking pin or who cannot tolerate the pin. However, the harness is relatively rigid and thus can be uncomfortable (13).
d. The suspension system: This is what keeps the prosthetic limb attached to the body. The suspension mechanism can come in different form. For example, in the case of harness system straps, belts, sleeves are used to attach this prosthetics devices for some types of amputations, the prostheties is able to stay attached just by fitting around the shape of the

residual limbs. One of the most common types of suspension mechanism relies on suction.

RAW MATERIALS FOR PROSTHESES LIMB

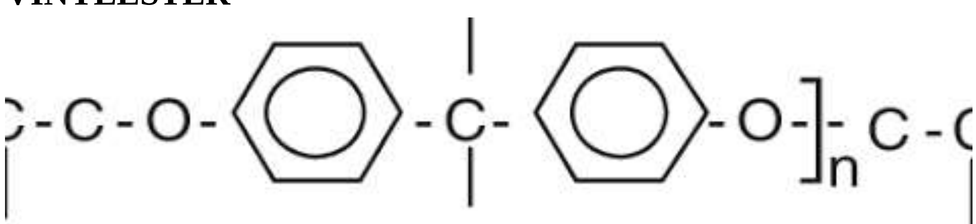
There are relatively a number of polymer types that can be used in the fabrication of a composite's artificial limb. However, it must be remembered that within each class, many grade variations exist. The section of any polymer system will be a function of the design criteria including operation environment, cost, fibre type, and manufacturing method. The most common polymer resin includes (14).

POLYESTER



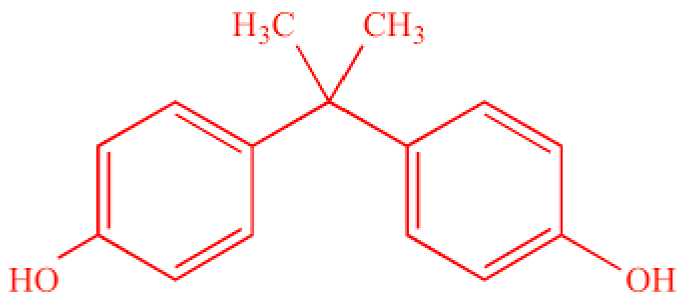
Polyester usually dissolves in system to reduce its viscosity for ease of fabrication. A cold such as organic provided is added to produce. Polymerization (Solidification). With the application of heat around 160^{0}C. The material exhibits significant mould shrinkage, which can be educe by the addition of thermoplastic additive. Polyester is widely used matrix, generally in conjunction with reinforcement. It is primarily for low performance application and has limited high temperature performance. Strong bounding **between** the matrix and the glass fibre can be achieve by providing silane coupling agent is used. Other type of reinforcement fibre is generally is not used because of inadequate bounding to the resin.

VINYLESTER



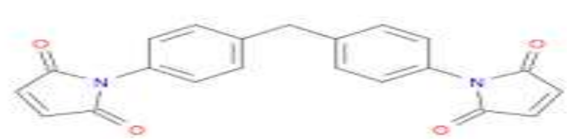
Vinyl ester are dissolve in styrene in order to reduce the viscosity and facilitate to fabrication in to a composite structure. Catalyst is required to cure the method. No addition agents are used in order to produce high adhesion to glass fibre. The product has more flexibility and greater fracture toughness than a polyester resin. Heat deflection temperature up to 200°C can be obtained.

EPOXY



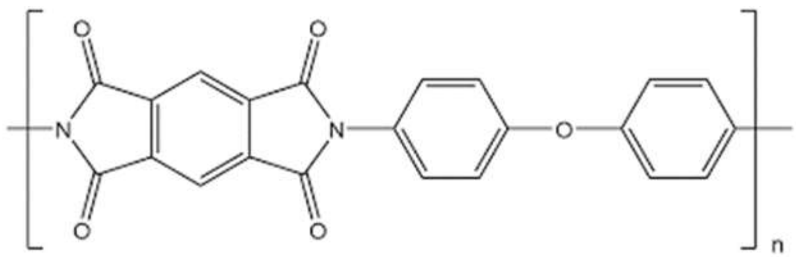
A liquid resin which is cured by the addition of a curing agent at room or high temperature condition. Epoxy resin has a wide range of properties. These can be rigid or flexible with different temperature resistance, with some able to withstand continuous use up to 250°C. advantage of epoxy resist over polyester and vinyl ester includes: lower mould shrinkage, low vehasity during curing, good environment friendly, and solution resistance and a very good adhesion to reinforcement materials.

BISMALEIMIDE



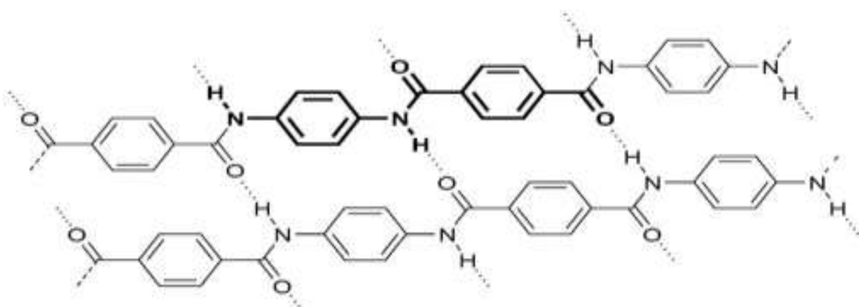
Bismaleimide can exist in solution or hot melt resin, these materials have high temperature resistance and withstand temperature of 300°C when used with carbon fibre reinforcement, they are considered to be advance composite because they have superior performance to epoxies in hot/wet condition, but there are limited limitations, they are normally very brittle and prone to micro-cracking, although as with epoxies, this tendency can be reduced by the incorporation of thermoplastic compound.

POLYIMIDE



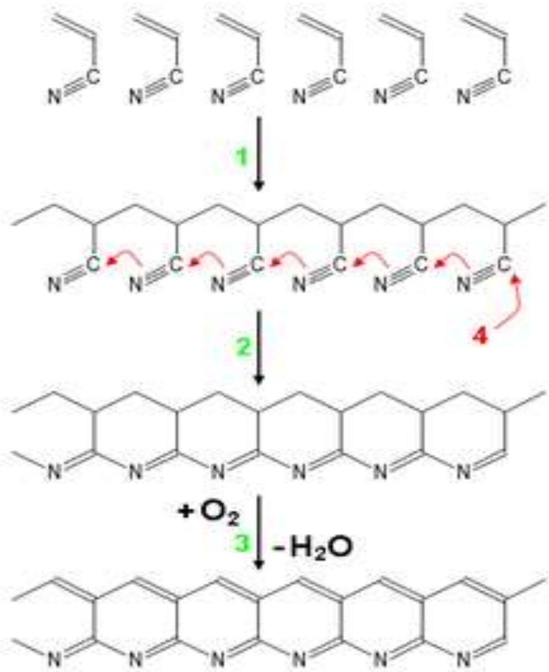
Polyimide exhibit better performance than bismaleimide in high temperature wet condition appear to be the most widely used for high temperature application. It should be noted that service temperature will depend strongly on the nature of the application with some grade capable of sustain period at temperature other is a condensation reaction, this tends to produce valid in cured component, addition reaction can be use instead to reduce or eliminate the problems.

GLASS FIBRE



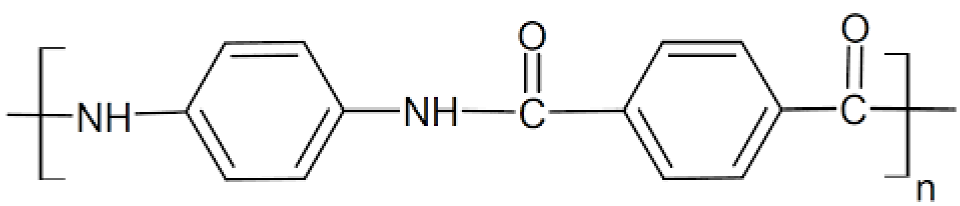
Grass fibre is the commonest reinforcing materials used in polymer matrix composite, these have high tensile strength but low modulus compares to other fibres.

CARBON FIBRE



This is the reinforcement of choice for advance composite, carbon fibre exhibits excellent fatigue resistance which does suffer from stress rapture compare with glass or aramid fibre. Carbon reinforcement composite are often used for low strength application required good electrical properties due to the high conductivity from polyacrylonitrile.

ARAMID FIBRE



This reinforces fibre have the highest strength to weight to other commercially available fibre. Aramid fibre exhibit similar strength to glass fibre. But can modulus at heat two times as great. Aramid is very tough allowing significant energy absorption but compare to carbon, it is lower in compressive strength and has poorer adhesion to the matrix. It is also susceptible to moisture adsorption.

MANUFACTURING PROCESS

Prosthetic limbs are first prescribed by a medical doctor, usually after consultation with the amputees, a prosthetics and physical therapist. The patient then visits the prosthetic to be fitted with a limb although some parts of the sockets first are custom-made, many parts (such as feet, pylons) are manufacture in a factory, send to the prosthetics, and assemble at the prosthetics facility in accordance with the patients need.

MEASURING AND CASTING

a- Accuracy and attention to details are importance in the manufacturing of prosthetic limbs that comes as close as possible to being as comfortable and useful as natural one. Before work on the fabrication of the limb, the prosthesis evaluates the amputee and takes an impression or digital reading of the residual limb.

b- The prosthetist then measures the length of relevant body segment and determine the location of bone and tendors on the remaining parts of limb using the impression and the measurements, the prosthetist then makes aplaster cast of the stump. This is most commonly made-up plaster of part because it dries fast and yield a detail impression from the plaster cast, a positive model and extract duplicate of the stump is created.

QUALITY CONTROL

Various test is carried out to evaluate the strength and lifetime of a prosthetic device. For instance, static loads strength, a load is applied over a period of 30 seconds, held for 20 second, then removes over a period of 30 seconds, then removed over a period of 30 seconds, the limb suffers no deformation from the test to test for failure, a load is applied to the limb until it breaks, thus determining strength limits. Cycle loads determine the lifetime of the device. A load is applied two million times at one load per second, thus simulating five years of use. Experimental prosthetic limb is usually considered feasible if they service 250,000 cycles.

CONCLUSION

Polymer composites of various types are being employed in the production of prostheses limb that includes: Polyethelene, Polyester, Vinylester, Epoxy Polyamide, Polypropylene, hydroxyapatite and Polyethyletherketone with their respective reinforcement material such as glass fibre, carbon fibre, and bone fibre. These provide devices that are strong and more lightweight than earlier limb made of iron and wood. The selection of any polymer system will be a function of the design criteria including operating environment, cost, fibre type and manufacturing methods.

REFERENCE

Liu Y., Wang M.(2007).'Developing a composite material for bone tissue repair, current applied physics,vol.7,pp 547-554.

Min Wang, 2003' Developing bioactive composite for tissue replacement; Biomaterials, vol 24.pp 2133-2151.

Ramakrishna S., Mayer J. 2001, biomedical applications of polymer composite materials a Review composite Science and Technology, vol 61,pp 1189-1224.

Praveen Kumar A, Jackson Irudhayam S, Navin D,(2012) 'A review on important and recent applications of polymer composite in orthopaedics'. Internal Journal of engineering and development volume (5); issue 2 pp 40-43.

Keith Kedword 2009, ''Composite" Microsoft encerta.

Avila Af, Paullo C.M, Santos D.B, Fani C.A, (2003), Materials Characterization Pg 281.

Nicoleta I., and Hichel H., (2009) Dental materials. Pg 810-819.

George, M.; Mussone, P.G.; Alemaskin, K.; Chae, M.;Wolodko, J.; Bressler, D.C. Enzymatically treated natural fibres as reinforcing agents for biocomposite material: Mechanical, thermal, and moisture absorption characterization. J. Mater. Sci. 2016, 51,2677–2686.

Jawaid, M.; Abdul Khalil, H.P.S.; Noorunnisa Khanam, P.; Abu Bakar, A. Hybrid Composites Made from Oil Palm Empty Fruit Bunches/Jute Fibres: Water Absorption, Thickness Swelling and Density Behaviours. J. Polym. Environ. 2011, 19, 106–109.

Asim, M.; Abdan, K.; Jawaid, M.; Nasir, M.; Dashtizadeh, Z.; Ishak, M.R.; Hoque, M.E.; Deng, Y. A review on pineapple leaves fibre and its composites. Int. J. Polym. Sci. 2015, 2015.

Lekakou,C and Bader, M.G (1999) Composie part a pg 29-37

W.Bonfield, C. Dogle and K.E Tamer M Vivo Evaluation of hydroxy a patite reinforce polyethylene composite "in biological and biomedical performance of biomaterials pp 153-159.

Prosthetics available at http:// www.disaboom.com/amputation- information/the -history-of-prosthetics-artificial-limb-past-and-present. Retrieved on 10/6/2014.

Artificial limb available www. Science lowStuffwork.com/prosthetic-limb2.Retrieved on 10/6/2014.

Prosthetics available at www.slure core.com/health/physical/part-of-prostheties limb. Retrieved 10/6/2014.

http;//www.Sahlgrenskaic.com/wp-content/uploads/2012/treatmentsuccess-digotal-version.pds.