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Improved the Tensile Properties of UHMWPE Reinforced by Short Fiber of PAN for Meniscus Knee Joint Replacement

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Abstract:

Ultra high molecular weight polyethylene (UHMWPE) was usually used in cartridge of KJR due to possess excellent mechanical properties such as self-lubricant, impact strength and biocompatibility but with the time is failed therefore the present study would improve the tensile properties: tensile strength, elastic modulus and elongation at the break to increased service life of joint by addition different weight fraction (1,3,5,7and 9) w.t % short fibers of PAN. The tensile properties were increased spatial at 5% PAN. The FE-SEM test was be done to confirm the interface bonding between matrix and PAN fibers which allow to transfer loud from matrix to fiberthus enhanced the properties of UHMWPE.

Keywords: *UHMWPE; PAN; Tensile Properties; Elastic Modulus and FE-SEM.*

I. Introduction

Osteoarthritis is a progressive joint disease which caused not only articular miscuesdegeneration but had also harmful effects in the adjacent bone and another tissues [1,2].in the last 40 years, Total knee replacement (TKR) procedures improved toundertaking theimplants life improvement and asuperior functionality for the patient and reduction of the cost [3]. In the 21st century, the engineering of medical is theevaluated field of technological development. The development, design and processing of medical implants that replace failed organ functions are of the major importance for an aging people. It is estimated that 250,000 knee replacements wereaccomplished per year [4,5]. It was predictable that the number would be became double unto 2025 due tooldpeople worldwide and increasedrequirement for a higher life quality [4-6]. Due to increase continuously in procedures of the orthopedic surgical and thefurther young people weresufferance OA, the widening of thelifespan of artificial joints wasessentially and had become the farthest defy issue in artificial joint performance refinement [7,8].The implant must be biocompatible since the patient is alive thus,the implantdid not included toxicity and did not had adverse effects in a biological system [9,10].Therefore, Biomaterials must be non-pyrogenic, non- carcinogenic, non- allergenic, non- toxic, non-inflammatory and blood compatible[11,12]. UHMWPE is anunparalleled polymer hadsuperior chemical, physical and mechanical properties [13].Furthestoutstanding were its chemical inertness, lubricity, impact resistance and abrasion resistance ,therefor it waswidely used in medical fields, such as, orthopedic implants [14].The various forms of polyacrylonitrilesuch asfilms, fibers and Nanofibers had been used in verydifferent applications of composites, protective outfit, water

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handling, the technology of gas segregation, Nano sensors, hemodialysis, enzyme immobilization, biochemical product refining and anther biomedical fields.The publicity of polyacrylonitrileis due to their superior thermal and mechanical properties, abrasion resistance, chemical stability, high tensile strength and forgivenessto utmost solvents, photo-irradiation and bacteria [15].

In the current study, the different weight fraction of short fiber of polyacrylonitrile (PAN) (1,3,5,7 and 9)w.t% were added to UHMWPE to prepared composite materials with good tensile properties and tested by FE-SEM to prove the good distribution and bonded with the matrix to use as a meniscus of knee joint replacement

II. Experimental Procedure

UHMWPE polymer was gained as a powder from LUOYANG MAX PIPE INDUSTRY with Molecular weight600-700(10^4g/mol.),density (0.093-0.94) (g/cm^3) and Granularity (≥99%)20-40 Mesh Polyacrylonitraile (PAN) is a short fiber was obtained from TENGZHOU TUOLDUO INDUSTRIAL &TRADE CO.,LTD, with length 3mm, diameter (15 ± 2) μm and density 1.18±0.01 g/cm^3.

The materials were weighted according to weight fraction and then the PAN fiber are dispersion in ethanol by ultrasonic device at 40°C for 15 min and then the UHMWPE are added to fiber simultaneously with mixing by mechanical mixing for 30 min. To eliminate the ethanol, the composite material was put in oven at 60°C with vacuum until the weight is fixed. After that the mixture was put in mold and press in hydraulic press at temperature 180 °C and pressure 12 MPa for one hour. Then the mold left to cool in air up to room temperature to get the sheet of composite material whichwas cut by CNC laser machine according to ASTM standard of each test in present study

Tensile test was carry out to dedicated the tensile properties such as tensile test, elastic modulus and elongation. In this study, the test was carry out according to ASTM D 638-03 at strain rate 5mm/min and the loud gradually applied until the sample was fracture. The data of stress-strain are obtained and each tensile properties are the average of the data of five samples. The test was done at room temperature(25±2°C)[16,17]

The technique of SEM hademployed in current research to study the surface of fracture. Thus, to get good conductivity of electric, composites materials were spluttered with gold. An electronically pictures were recorded, the working voltage was hold at (15 kV).

III. Result and Discussion

Fig 1 exhibited the relationship between stress – strain as a function of addition different weight fraction of PAN Fibers. in current study, the mechanical behaviorof the prepared composites materials depended on the natural and properties of reinforced additives and also on the mechanism and the strength of bond between the matrix and short Fiber PAN.

It showed from figure the initial part of the curves is linear which indicated the behavior of composites material is elastic behavior at this position of the curve and the elastic modulus can be detected. after that the behavior of composites is nonlinear because of the plastic deformation which increased continuously until the composite fractured at this point the tensile strength can be detected.

Generally, the stress was increased with increased the weight fraction of PAN fibers until 5%PAN due to uniform distribution of the fibers and good bonding between matrix(UHMWPE) and PAN fibers which can allowed to transferred the loud from polymer to fibers. the stress was decreased at weight fraction 7% and 9% PAN fibers due to flock of the fibers within polymer which effect on the bonding between them thus, effect on transfer of the loud from matrix to fibers [15]

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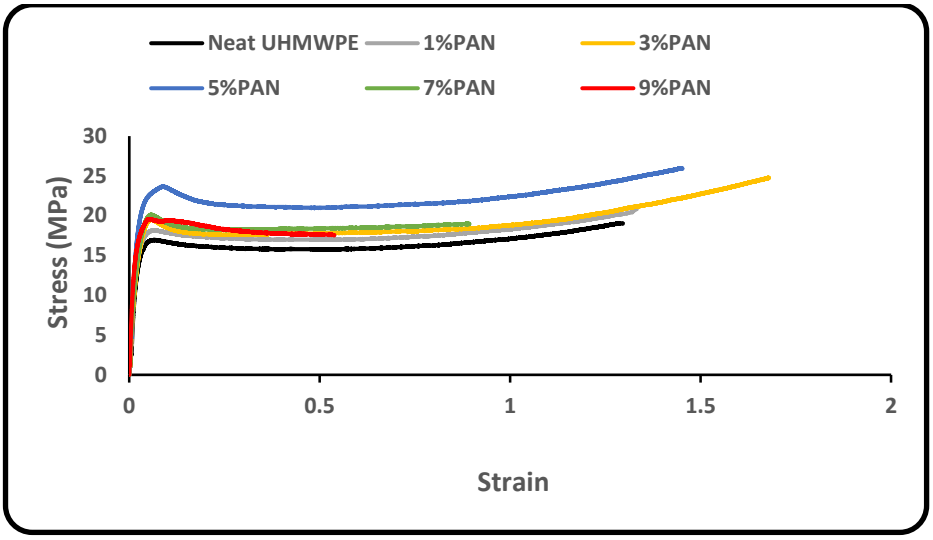

Fig 2: Stress -Strain of composite material as function of PAN wt.% content in composite

With the increase weight fraction of PAN fibers,the tensile strength and elastic modulus had a similar tendency as illustrated infig 2 and 3 whichhad been increased with the increased the percent of the fibers to reach the highest value of 25.952 MPa and 0.93 GPa, respectively at 5%PAN. It is nearly 1.3 times as high as that of neat UHMWPE due to increase the crystallinity which had enhanced by PAN fibers. Moreover, the PAN fibers can be presented as nucleating agent and then the degree of crystallinity of composites improved and the intermolecular forces become higher. this increment of tensile strength and elastic modulus can be assigned to the good interface bonding between the matrix(UHMWPE) and PAN fiber which lead to transfer effectively the load from matrix to the fiber, in another word, the fibers were deformed by strong friction during pulled out from the matrix which permitted the loud and strain transferred from matrix to fibers [15,18 and 19]. after over 5% of PAN fiber, the tensile strength and elastic modulus decrease due to crowded of the PAN fibers leading to decrease adhesion between fiber and UHMWPE and the fibers were pulled out with a little deformed byfriction which lead to decrease the load transfer from matrix to fiber. in spite of decrease of tensile strength and elastic modulus but still higher than neat polymer[15,18]

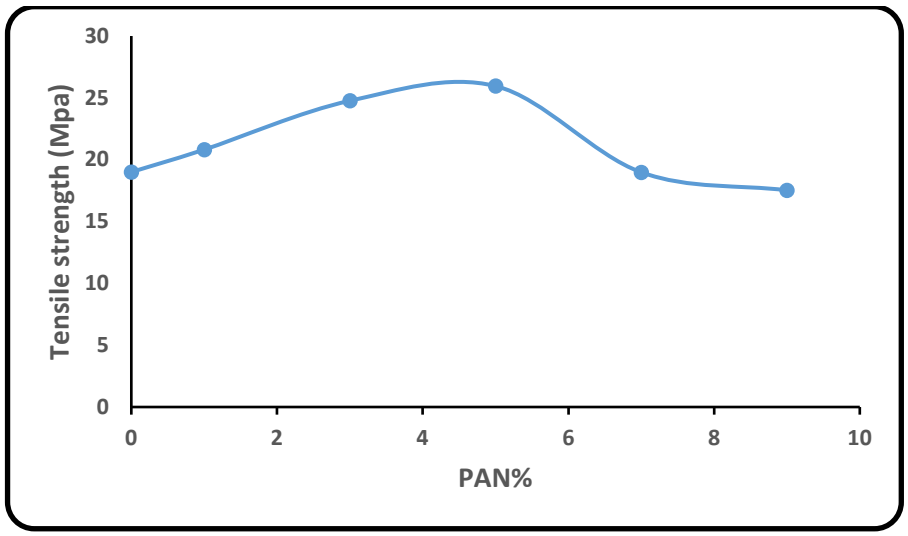

Fig 2: Tensile Strength of composite material as function of PAN wt.% content in composite

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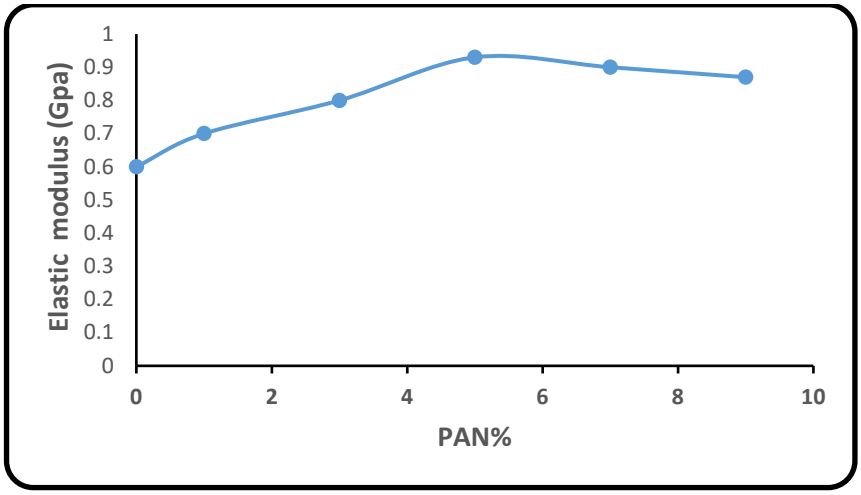

Fig 3: Elastic Modulus of composite material as function of PAN wt.% content in composite

Fig 4 shows the elongation was increased with increased weight fraction of PAN fiber to reach maximum value (167.902%) at 3% of PAN because the small percent of fiber don't hind the movement of molecular chain,but the elongation was decreased after 3% because the PAN fiber was hind the movement of molecular chain and also the increased crystallinity made the molecular chain movement are difficult or restricted [15, 19]

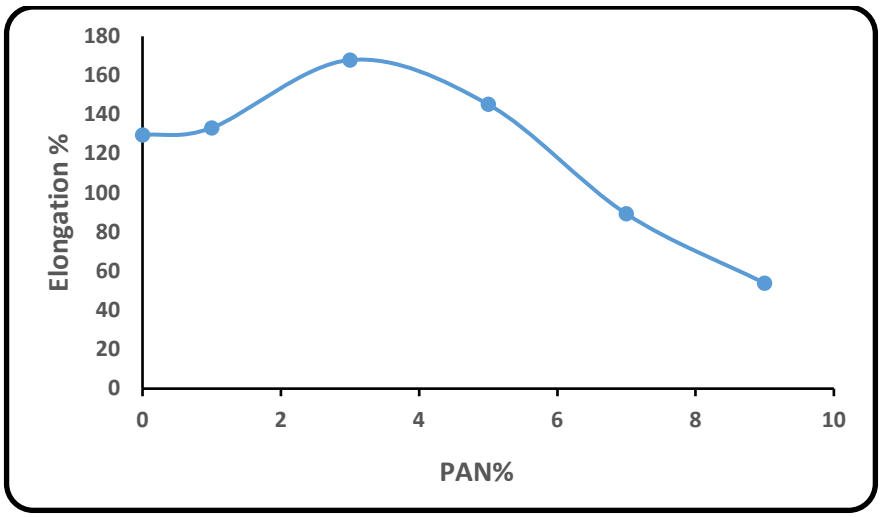

Fig 4: Elongation of composite material as function of PAN wt.% content in composite

The properties of composite material depend on morphology of its contents in another word, depend on the shape, size, distribution and wettability of reinforced phase. The cross section of fracture surface of all composite materials were examined by FE-SEM technique which showed in fig 5. The photos of FE-SEM had taken at two magnifications (500x) and (2kx) which demonstrated that there were two phase and also indicated to uniform distribution of the fibers within UHMWPE. Moreover, there was a good adhesion between fiber and matrix, the matrix encapsulated the fibers lead to transfer the loud from matrix to fibers,thus enhance the tensile strength and elastic modulus. The best incorporation can be seen at UHMWPE reinforced by 5% short fibers of PAN.

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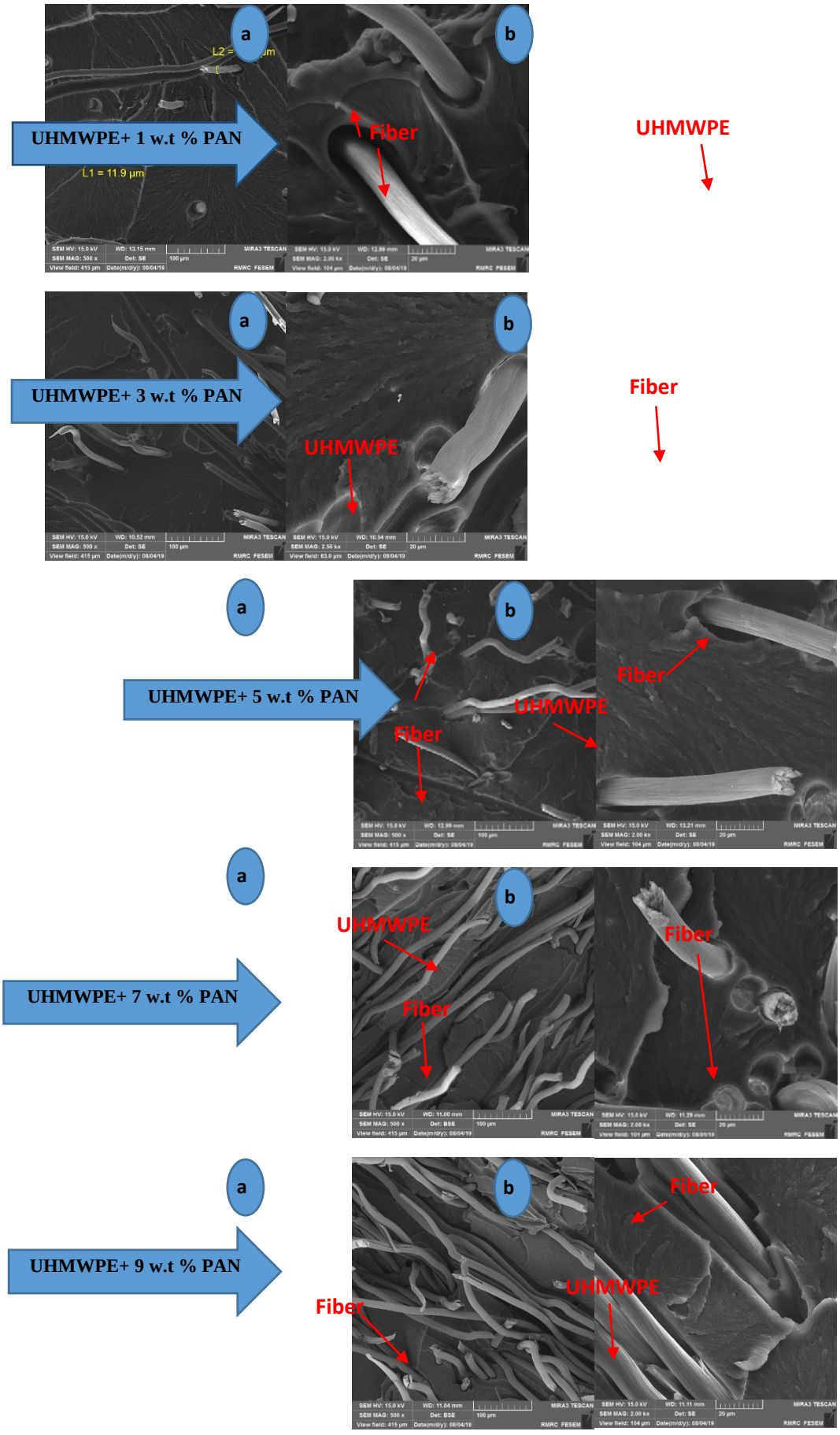

Fig 5: FE-SEM of Cross Section for Fracture Surface of UHMWPE Reinforced by Different weight fraction of PAN Fibers a- image at 500x b- at 2k.

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IV. Conclusions

The tensile properties of UHMWPE were improved when reinforced with different weight fraction of PAN w.t% to reach the best results at reinforced UHMWPE with 5 w.t% of PAN. The pictures of FE-SEM confirm the uniform distribution of the fibers and wrapping with polymer thus, allow to transfer a loud from UHMWPE to fiber and enhance the tensile properties

Ethical clearance

I am studied ten case of patient that proceed surgical operation to replace knee joint in (Medical City Hospital) for knowing the important notes, the defects of joint and the service life of synthetic joint before replacement.

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No conflict interesting

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