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Improving Tensile Strength of Polymer Blends as Prosthetic Foot Material Reinforcement by Carbon Fiber

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Abstract

Prosthetic Foots or artificial limbs, are fabricated devices that provide amputees with a replacement for their missing limb, restoring some function, The development of polymer blend materials has, in recent years, led to technological advances across a wide range of applications in modern orthopedic medicine and prosthetic devices. The basic of this research new polymer blend self-cure PMMA/SR which can be used in manufacturing the prosthetic foot with a reasonable cost and satisfying mechanical properties accepted. Improvement tensile strength of this polymer blends for this application, one of the simple improve tensile strength of PMMA/SR polymer blend reinforcement by carbon fiber CF.

Polymer blends (PMMA:SR) 90:10; 80:20; 70:30; 60:40; 50:50 were prepared reinforcements each one by carbon fibers from 5-15% (CF), then tensile strength test was carried out for prepared specimens, and effect of reinforcement by carbon fibers on tensile strength of polymer blends were determined as one improvement for prosthetic foot material.

Keywords: Poly methyl mehta acrylate; Silicon rubber; Carbon fibers

Introduction

Prosthetic foot Options which attempt to restore their natural gait patterns and Ankle range of motion. Such foot options are chosen based on their daily activities, occupational demands and personal parameters such as age and weight Popular prosthetic feet on the market include dynamic response feet, such as Flex Foot, which currently allow for the most natural gait and multi-axis feet which have six degrees of rotation at the ankle joint. However, such prosthetic foot designs lack the flexibility necessary for amputees to perform activities such as kneeling and putting on shoes, which imparts limitations on the user. This problem is the basis for the development of a more functional prosthetic foot. The proposed design must have increased flexibility to facilitate kneeling, while maintaining or enhancing the normal gait patterns that are created by current, top of the line prosthetics. The foot must also provide stability and balance to the amputee [1,2].

Initial material made of wood and metals for artificial legs had major drawbacks, since they were limited by their weight, and had poor durability to corrosion and moisture induced swelling. These limitations resulted in restricting the user to slow and non-strenuous activities due to poor elastic response during stance. Due to these limitations, polymer composites were introduced for material of choice for limb systems, because of their "lightweight, corrosion resistance, fatigue resistance, aesthetics, and ease of fabrication", Polymer composites can be either thermosetting or thermoplastics composites that are reinforced with glass, carbon, or Kevlar fibers [3].

During the past 10 years the most notable reinforcing materials for orthopedic use have been carbon fibers. Especially for lower limb prosthesis carbon composite lay-ups are very popular. These composites are chosen or their flexibility and energy storage and release properties. The fibers can be fabricated in different ways such as being braided, woven, knitted, or laminated. According to a lower limb design by Strike and Hillery, the lamination would allow them to have specific tensile strength and stiffness "by changing the resin and controlling the angles between successive layers [4,5].

Applications of polymer are being developed in such diverse areas as conducting and storage of electricity, heat and light. Indeed, polymers have played and will continue to play an increasingly important role in all aspects of life. In recent years mixed systems or blends of different polymers have been developed which are of increasing importance in the plastic industry [6].

A polymer blend or polymer mixture is a member of a class of materials in which two or more polymers are blended together to create a new material with different physical properties. They combine in an advantageous manner the properties of the alloying components and in some cases the properties of the blend are superior to those of the individual components, Blending of polymer is a technological way for providing materials with full set of desired specific properties at the lowest cost, e.g. a combination of strength and toughness, strength and solvent resistance, etc. Blending also benefits the manufacturer by offering improved process ability, product uniformity, quick formulation changes, plant flexibility and high productivity, i.e. polymer blending is one of the most common techniques employed for developing new polymeric materials [7,8].

PMMA and SR were used as polymer blends for this research as suitable material for prosthetic foot, PMMA is a linear thermoplastic polymer. PMA has a lack of methyl groups on the backbone carbon chain its long polymer chains are thinner and smoother and can slide past each other more easily, PMMA has high mechanical strength, high Young's modulus and low elongation at break. Table 1 some of mechanical characteristics of PMMA, SR are general Category of synesthetic polymers whose backbone is made of repeating silicon

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Material	Specific Gravity	Tensile Modulus GPa	Tensile Strength MPa	Yield Strength MPa	Elongation at break %
Polyethylene (low density)	0.917-0.932	0.17-0.28	8.3-31.4	9.0-14.5	100-650
Polyethylene (high density)	0.952-0.965	1.06-1.09	22.1-31.0	26.2-33.1	10-1200
Poly(vinyl chloride)	1.30-1.58	2.4-4.1	40.7-51.7	40.7-44.8	40-80
Polytetrafluoroethylene	2.14-2.20	0.40-0.55	20.7-34.5	------	200-400
Polypropylene	0.90-0.91	1.14-1.55	31-41.4	31.0-37.2	100-600
Polystyrene	1.04-1.05	2.28-3.28	35.9-51.7	------	1.2-2.5
Poly(methyl methacrylate)	1.17-1.20	2.24-3.24	48.3-72.4	53.8-73.1	2.0-5.5
Phenol-formaldehyde	1.24-1.32	2.76-4.83	34.5-62.1	------	1.5-2.0
Nylon 6,6	1.13-1.15	1.58-3.80	75.9-94.5	44.8-82.8	15-300
Polyester (PET)	1.29-1.40	2.8-4.1	48.3-72.4	59.3	30-300
Polycarbonate	1.20	2.38	62.8-72.4	62.1	110-150

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Table 1: Mechanical characteristics of Polymers [9].

Mechanical Properties	Value
Appearance	white
Hardness, Shore A	30 ± 2
Tensile Strength, Ultimate	5.8 MPa
Elongation at Break%	420
Tear Strength (kgf /cm²)	30
Curing time/mentis	2-6
Mixing proportion of curing agent (%)	2-4
Density (g/cm³)	1.08

Table 2: Properties of silicon rubber [6].

Figure 1: Failure of prosthetic Foot [11].

Sample No.	PMMA	SR	CF %
1	90	10	0
			5
			10
			15
2	80	20	0
			5
			10
			15
3	70	30	0
			5
			10
			15
4	60	40	0
			5
			10
			15
5	50	50	0
			5
			10
			15

Table 3: Number and ratios of mixture for the prepared samples.

to oxygen bonds. In addition to their links to oxygen to form the polymeric chain, the silicon atoms are also bonded to organic groups, typically methyl groups, SR is generally no reactive, stable, and resistant to extreme environments as show from Table 2 properties of silicon rubber cold cure [9,10].

The aim of this work majority of prosthetic foot failure as show from Figure 1 (specialized in the fore foot region), As show from Figure 1 the mostly failure in prosthetic foot, Five polymer blends PMMA:SR reinforcement by CF were used as improvement polymer materials tensile properties for this application.

Experimental

PMMA polymer was supply from Italian BMS Company for dental Materials as polymer and hardener self-curing, silicone rubber (silicon) and silicon are generally named as two-part room temperature sulfurated silicone rubber, which features an exceptional fluidity and good operability When mixed with 2%-4% curing agent, they can still be operable within 35 minutes, but it will be formed after 3-5 hours supply from Shenzhen Hong Ye Jie Technology Co., LTD. Carbon Fiber CF is used as reinforcement material, short carbon fiber with length 3mm reinforcement polymer blends from 5-15% CF.

As show from Table 3, Five polymer blends prepared by PMMA:SR all five polymer blends reinforcement by CF from 5-15% and the step for preparation this polymer blends:

Firstly PMMA polymer which is still in a liquid state to SR which in a liquid state and mixed well by using mechanical mixer to form a binary blend then reinforcement by Carbon Fiber (CF) added to the binary blend to form a composite polymer sheet**.** Secondly pouring the blend into the mould, Casting sheet was left inside the mould at room temperature about (15-20 min) for both blends. Finally solidification the testing samples were obtained by cutting the cast sheets according to the relevant ASTM standard. All properties were measured at room temperature (25-30)°C [11].

The tensile properties were performed according to ASTM D638-Type 1 using Universal testing machine (Lloyds, capacity 1-20 kN). Testing speed was set at 5 mm/min and carried out at room temperature and specimen dimensions are 165 mm × 19 mm × 3.3 mm as shown in Figure 2. Tensile modulus and strength were evaluated from the load-displacement curve.

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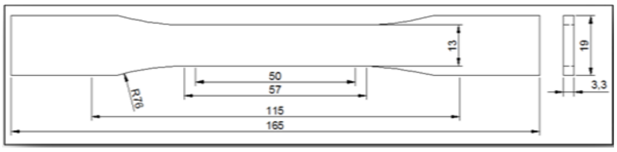

Figure 2: Tensile test specimen dimensions.

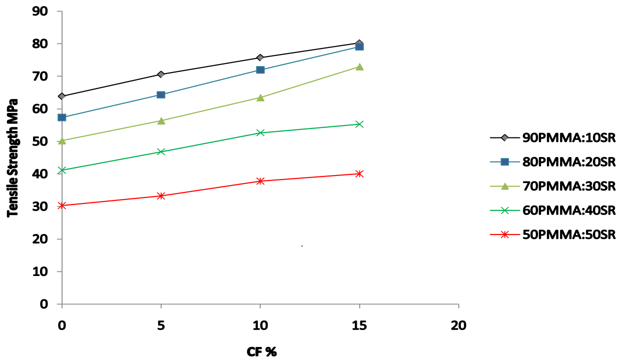

Figure 3: Effect CF on the tensile strength of PMMA:SR polymer blends.

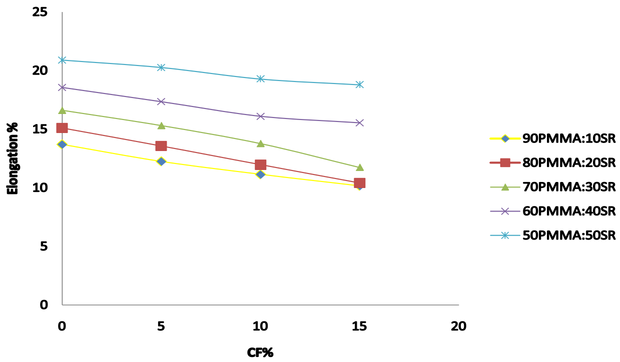

Figure 4: Effect CF on the Elongation of PMMA:SR polymer blends.

Results and Discussion

Tensile properties provide information about the behavior of the material when it is subjected to stretching or pulling force before it fails.

As show from the Figure 3, Effect CF on the tensile strength for polymer blends (PMMA/SR). Tensile strength for PMMA/SR polymer blends increase as content reinforcement increase. This due to reinforced polymer blends with random fibers the load is concentrated at the end of short fibers and the alignment of fibers is randomly distributed in the matrix which make the control of transmission of the load from the matrix to the fibers through the interface region is weak and the tensile strength of CF is high when use as reinforcement material will be produce raise the tensile strength of polymer blends for this reasons tensile strength and modules of elasticity increased as content reinforcements increased [12].

Figure 4 show the effect of CF on the elongation of PMMA:SR polymer blends as showed from the figure that the elongation increase as rubber content increase and decrees as CF increase, this results due to when rubber content increase for the polymer blends the chains of polymer become more free to movement and situation free movement in the increase as rubber material content increase this cause increase in elongation of polymer blends, while during reinforcement by fiber the polymer material become more hard and strength as reinforcement material increase that cause reduction in free movement chain polymer cause decrease in elongation.

Conclusion

Experiments were performed in order to improve the tensile strength properties for polymer blends as prosthetic foot material by reinforcement with short carbon fibers, this improvement as follows:

- Tensile strength, modulus of elasticity, increase as reinforcement material increase.
- Elongation decrease as reinforcement material increase, while increase as rubber content increase for polymer blends
- Tensile strength, elasticity, decreases as rubber content increase.
- Used cold cure polymers blends for simple molding process with improvement the tensile properties by reinforcement is very comparative blends that can be used for prosthetic foot applications, spatially the lower cost for this polymer materials.

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