Effects of SGF and SCF on Physical and Mechanical Properties of PA66/PP Blend composites

Darshan R[1], B V Lingesh[2], Dr. H N Reddappa[3], Dr. B N Ravi Kumar[4]

[1] PG student, Department of Mechanical Engineering, Bangalore Institute of Technology, Bengaluru-560004, Karnataka, India

[2,3and4]Department of Mechanical Engineering, Bangalore Institute of Technology, Bengaluru-560004, Karnataka, India

Abstract: This article depicts the mechanical and physical characterization of short glass fiber and short carbon fibers reinforced polyamide66 and polypropylene blend composites. Test were done on four different composites with 0wt%, 10wt% SGF, 10wt% SCF and Hybrid (10wt% SGF+10wt%SCF).Physical and mechanical properties were evaluated. It is found that fiber reinforcement improves both physical and mechanical properties. The density and void concentration greatly influenced by the content of the fibers. Water absorption decreased on reinforcement with glass fibers. Tensile flexural hardness, impact properties were also improved on reinforcement with fibers.

Keywords- Short glass fiber, Short carbon fiber, Polyamide 66, Polypropylene, Polymer blend

I. INTRODUCTION

The usage of polymer is continuously increasing due to the special characteristic such as light weight, complex shape forming .polymer replaces the materials in automobile industry such as iron, steel and replacement is continuously increasing. Main feature of polymer components are easy assembly, weight reduction. [1] Polymers are mainly classified into thermoset and thermoplastic on the basis of thermal processing. Compare to thermoplastic, thermoset is harder and sustain high temperature but, it is non recycling polymer and thin film formation on interfacing with metal is very less, [2].

When polymers are reinforced with the fibers, load carrying capacity, strength to weight ratio,high stiffness, corrosion resistance and mechanical properties increases.[3]Long fiber makes fiber attrition ,this can be minimized by decreasing the residence time means shorter screw ,short fibers help to form complex shape and also improves the design flexibility.[4]Polyamide is a tough , ductile and cheap relatively low cost compared to all thermoplastic that are presently founded, it is using in automobile industry , cost may be the limiting factor that made constrained the use of polyamide in so many fields but ,this could be achieve by using reinforcement and polymer blend .bring down the cost to be minimize.[5]Polyamide 66 is the dominating because of its rapid crystallization rate, excellent mechanical properties, process ability ,high melting point, corrosion and wear resistance propertyand also it's melt strength makes it suitable for all processing method ,that also for injection molding.Thus polyamide 66 is mostly using in Automotive industries, Electrical and electronics industries, switches,Glass filled Polyamide 6,6 using in nuts,bolts,washers,trolleys ,bicycle wheels and tires [6]

Unmodified PA66 couldn't satisfy both typological and mechanical properties which required. These properties could be improved by copolymer, polymerblend and fiber reinforcement among these polymer blend is thefascinating method. Due to low cost it is very demand in industry and scientific research [7].Polypropylene is a one of the most using thermoplastic polymer in industry it is the most versatile polymer, its stiffness is increases as crystalline level increases .PP shows less compatibility with fibers and other polymer due to its less interphase adhesion between the phases. Maleic anhydride (MA) is acoupling agent using to increase the compatibility between the phases. [8]

Polymer blend of PA/PP is more interesting from the industry point of view because these are relatively cheap and easily processing.Maleic anhydride is used with PP/PA to improve the interfacial interaction as well as mechanical properties.MA compatibilizers ensure the both good dispersion of minor polymer in major one and also stability of their interaction. Compatibilisation for better dispersion a homogeneous structure, crystallization and thermal behavior, process such as processes ability, draw ability, dye ability and mechanical properties.[9] 80wt% of PA and PP 20wt% gives the better result introduction of PP into the PA matrix, increase in the ductility and resilience's were reported in both the cases of virgin and recycled blend.PA increases the mechanical properties of blend [10less work carried on PA66/PP blend hence this work is carried to study the effects of SGF and SCF.

II. EXPERIMENTAL DETAILS

2.1 COMPOSITE PREPARATION

The composition of the composite materials of the present work is given in the Table1. These compositions were mixed and extruded with twin screw co-rotating extruder. It has three mixing zones made up of kneading blocks set, five heating and one cooling zone along the barrel. It includes adapter and die; it has sensors to control the parameter. Temperatures of these five zones were maintained by heating coils. Temperatures maintained in experiment are zone 1 (220^{0}C), zone 2 (235 ^{0}C), zone 3 (240^{0}C), zone 4 (265^{0}C) and zone 5(270^{0}C) and die temperature is set to 75^{0}C.the speed of the extruder screw is set to 100 rpm and feed rate is 5 kg/hr. After the extrusion process the extrudates were quenched by cold water. By using injection molding produced the test specimens according to the ASTM standards but before going injection molding we need to palletize the extrudates by using chopper.

Table 1 Composition of fiber filledPA66/PP polymer blend composite in Wt. % used in present work

Composites	Composite material Code	PA66 (Wt %)	PP (Wt %)	SGF (Wt %)	SCF (Wt %)	MA (Wt %)
PA66/PP (Blend)	Blend	80	20	-	-	0.5
Blend (PA 66/PP)+SGF	1G	80	20	10	-	0.5
Blend (PA 66/PP)+SCF	1C	80	20	-	10	0.5
Blend (PA 66/PP)+SGF+SCF	2CG	80	20	10	10	0.5

2.2 PHYSICAL CHARACTERIZATION TEST DETAILS

2.2.1 Density

Displacement method was used to find out density of the material with the help of Mettler electronic balance with an accuracy of ±0.0001g. Initially weigh the specimen in air and then weighed when immersed in distilled water. And then by using formula we found specific gravity from specific gravity found density.

Specific gravity =mass of the specimen in air/ (mass of the specimen and sinker-mass of the sinker)

Density kg/m3= (specific gravity)*(997.6)

2.2.2 Void concentration

Void concentration measure the percentage of void in polymer composite, here void concentration were measured with the help of theoretical and measured density. Measured density $\rho_{ce}$is practically measured density and theoretical density ρ_{ct} was calculated in terms of weight fraction by using this relation. Experimental density was determined by displacement method. The volume fraction of voids was calculated by this equation.

Theoretical density $(\rho_{ct}) = 1/(W_s/\rho_s) + (W_m/\rho_m)$, $V_v = (\rho_{ct} - \rho_{ce})/\rho_{ct}$

Where, W represent the weight fraction and ρ represents the density. The suffix s, m, n are stands for constitution matrix, fibers and coupling agents that are used in composite material. Vv is volume fraction of voids, ρ_{ct} the theoretical density, ρ_{ce} is measured density.

2.2.3 Water absorption

Initially note down the weight of the dry specimens and then samples were immersed in water as shown Figure 1and allowed the specimen in water for 96 hours. After that, weigh the swollen material and note down wet weight. The percentage of water uptake was calculated by using this relation.

Percentage water absorption=[(Wet weight - Dry weight)/ Dry weight] x 100

Figure 1 Composites immersed in water

Figure 2(a) Rockwell hardness tester (b) Specimens after indentation

2.3 Mechanical properties test

2.3.1 Hardness test

Method used to study the surface hardness is Rockwell hardness test. Here we applied 100 kg load on to the material surface by using the ball indenter for 30 seconds duration. Three trials were done; note the reading shown in dial gauge. Hardness test carried on M scale.

2.3.2 Tensile test

Tensile properties were determined by conducted test according to ASTM 638 by using microprocessor controlled UTM.The tests were performed under constant strain rate of 5 mm/min.The standard size of the specimen is show in Figure 3 Area 40.64 (mm^2). Load applied at the rate of 5mm/min. The stress and stain were calculated by measuring specimen elongation and applied load and from that curve we found out elastic modulus and yield strength .the ultimate strength σ is determined by using the equation, where σ is theultimate tensile strength N/mm^2.P is the Maximum load in N, b is width of the specimen in mm and d is the thickness of the specimen in mm.

$$\sigma = \frac{P}{b \times d} [N/mm^2]$$

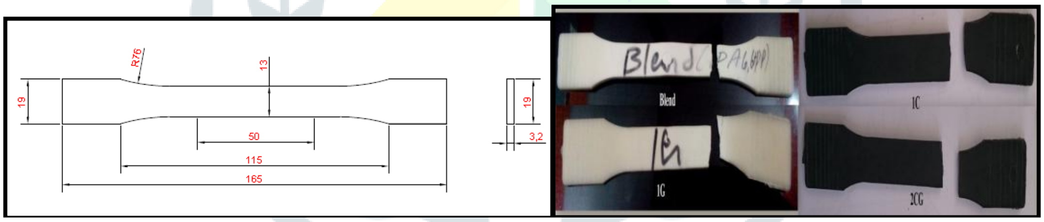

Figure 3 Tensile specimen ASTM 638 and fractured specimens of different percentage of fiber reinforced composites

2.3.3 Impact test

The standard specimen size according to the ASTM D 256 is given in Figure 4.It acts as cantilever beam when it is clamped in to the pendulum impact fixture with notch and this notch has to be face toward the pendulum. The pendulum is released and allowed to strike the specimen at rate of 3.2 mm/min. Pendulum is connected to the dial mechanism it indicates excess energy remained in pendulum after breaking the specimen.

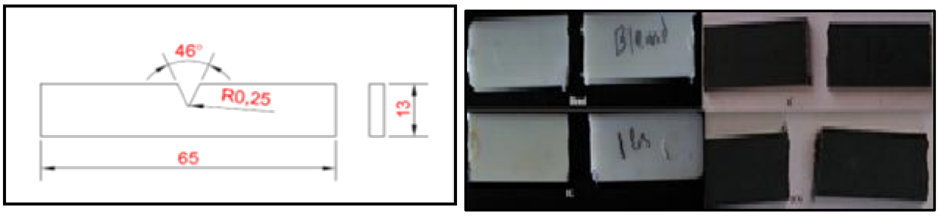

Figure 4 Specimen dimension for impact test as per ASTM 256 and fractured specimens composites

2.3.4 Flexural test

According to the ASTM 790, the dimensions of the specimen are shown in the figure 5. Specimen were supported by support span and it acts as a simple supported beam, the load is applied at the center by point load at the rate of 2mm/min the load and deflection were noted, loading stopped when the specimen breaks before 5% deflect. Flexural strength by using the equation where, p is the maximum load, b is the width of the specimen, L is length of the specimen, t is thickness of the specimen

$$\Sigma f = \frac{3PL}{2bt^2} \qquad [N/mm^2]$$

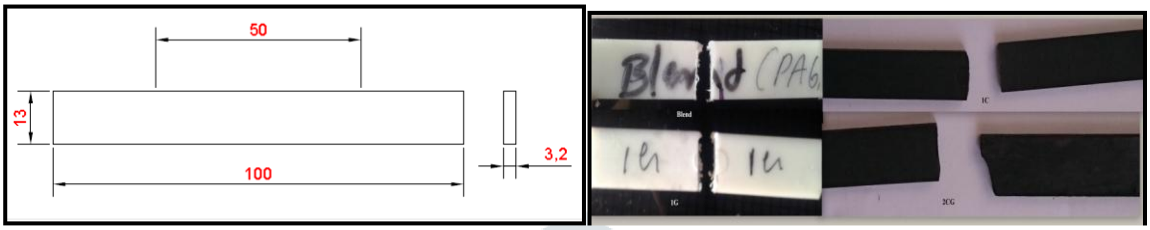

Figure 5 Specimen dimension for flexural test as per ASTM D790, Fractured specimens of different fibers reinforced

III. RESULTS AND DISCUSSION

3.1 Density

The Density mainly depends on the composition. Figure 6 represents the plots of Density as a function of different fiber reinforcements. Compared to the pure polymer blend, glass fiber reinforced composite has high density, this is due to the glass fiber reinforcement. It increases the mass of the composite. Compared to glass fiber, carbon fibers are less dense. Hence, it has less density compared to glass reinforced polymer. Finally Hybrid composite has got high density compare to all the other composites, because of the amount of reinforced fiber.

Table 2 Physical properties of the composites

Materials	Measured density	Theoretical density	Void concentration	Percentage of water absorption
Blend	1.08	1.09	0.9	1.55
1G	1.14	1.16	1.72	.8478
1C	1.13	1.14	1.007	1.33
2CG	1.17	1.20	3.02	1.1565

3.2 Void concentration

Difference in the measured and theoretical densities gives the amount of pores present in the composites. Figure 7 represents the plot of void concentration as a function of different fibre reinforcements. Fibers are higher denser materials, composite materials density increases with the fibre reinforcement; this is due to the great difference in surface energies and also the difference in polarities with polymer blend matrix and fibers. This is also due to the entrapment of air bubbles during mechanical melt mixing.

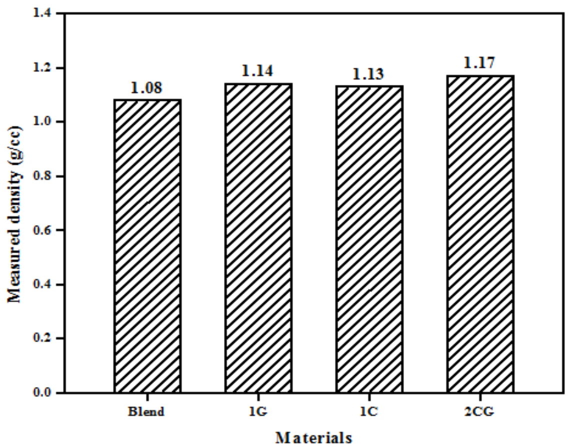

Figure 6 Plots of Density of composites

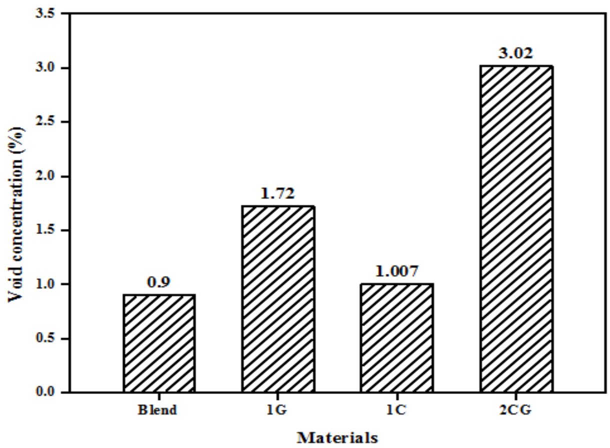

Figure 7 Plot of void concentration of composites

3.3 Water absorption

From the Figure 8 we could see that, the water absorption property of the polymer blend is more compared to the other composites, this is due to polyamide. Pure polyamide is hydrophilic in nature and Glass is hydrophobic in nature. Hence, it has got less water absorption property.

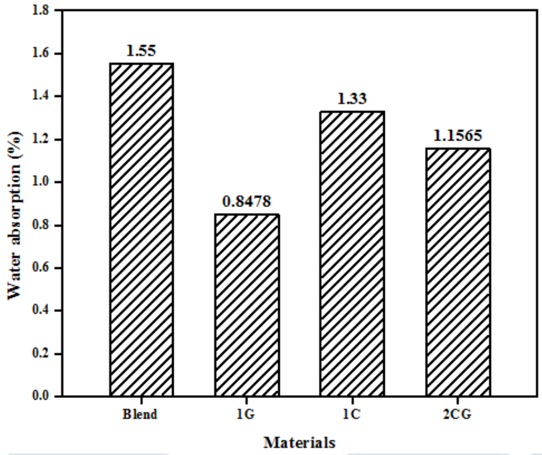

Figure 8 Plots of Water absorption of composites

3.4 Hardness

Pure blend has got least hardness compared to others; this is due to fiber reinforcement. The glass fiber reinforced composite has got more hardness compared to carbon fiber reinforced composites. Hybrid fiber reinforced composite has got more hardness compared to others.

Table 3 Mechanical properties of the composites

Materials	Hardness	Impact strength	Tensile strength(Mpa)	Tensile modulus(Mpa)	Flexural strength 1.33 mm/min	Flexural modulus(Mpa)
Blend	83.33	119	40	104.065	40	1137
1G	96.66	65	42	34.688	61.4	1899
1C	92.33	39	61.5	208.132	100.5	5500
2CG	97.33	42	69.5	208.132	110	5200

3.5 Impact properties

The Low toughness is high brittle. On fiber reinforcement, the composite becomes brittle in nature. Hence carbon fibre reinforced composite has high brittleness compared to other composites. Pure blend has got less brittleness, it absorb the high energy before it breaks. Compared to carbon fiber reinforced composite, the glass fiber reinforced composite has high impact strength.

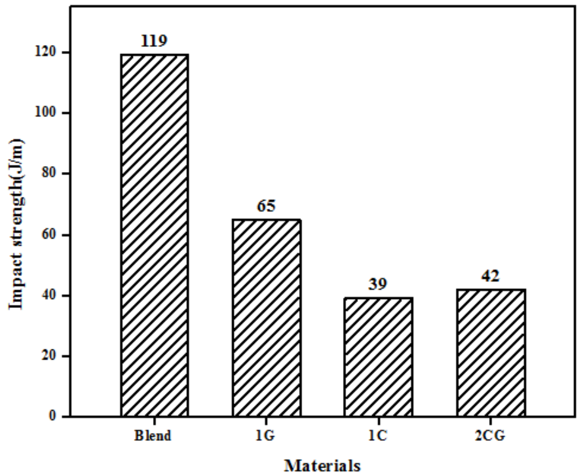

Figure 9 Plots of impact strength of composites

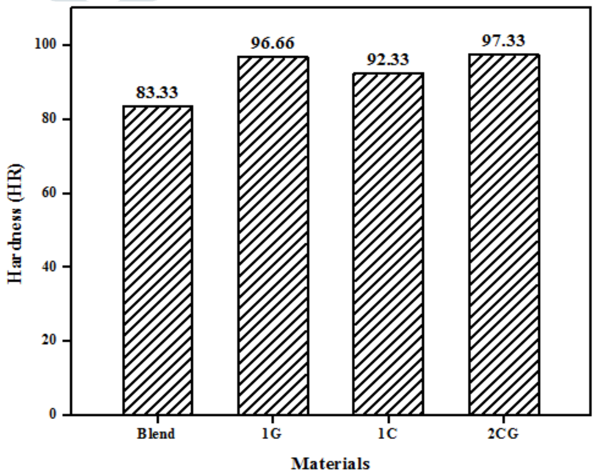

Figure 10 Plots of Hardness of composites

3.6 Tensile properties

Tensile strength of the thermoplastic composite with different compositions increases when compared to the pure polymer blend shown in Figure 11 Fibers in composites resist to tensile stretching force. Hence, tensile strength increases when reinforced with fibers. Carbon fibers having more compatibility with the polymer blend matrix compared to the glass fibers.

Figure 12 shows the plots of young's modulus as a function of fibers contents in PA66/PP polymer blend. It can be seen that it increases on reinforcement with fibers. Carbon fiber reinforced in hybrid contributes more since it shows high tensile modulus compared to glass fiber reinforced composites. Reinforced fibers are harder and also having good bonding between the matrixes, which leads to higher stiffness of the material.

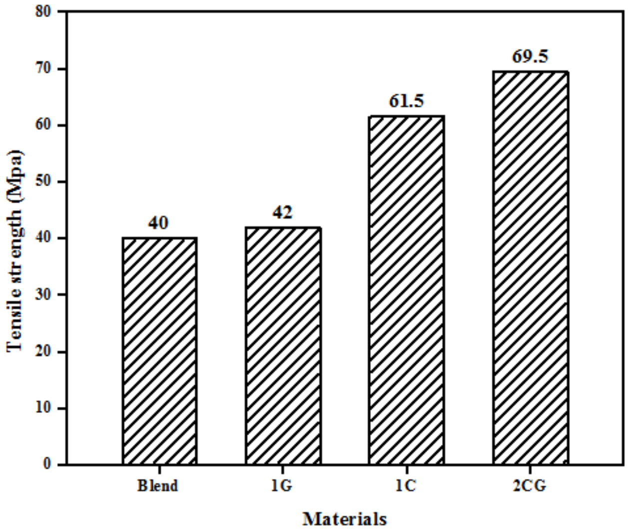

Figure 11 Plots of Tensile strength of composites

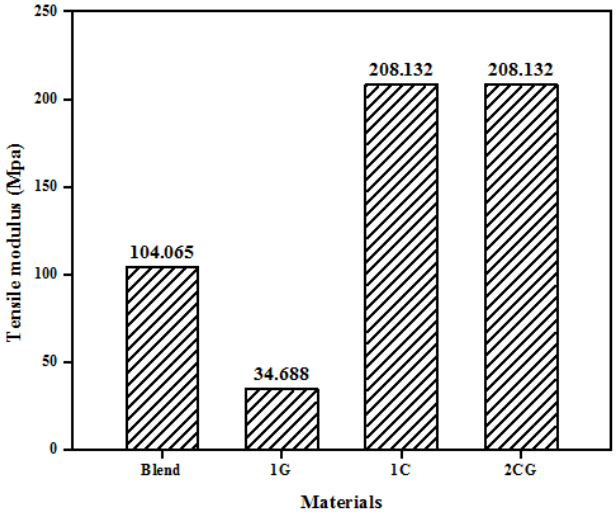

Figure 12 Plots of Tensile modulus of composites

3.7 Flexural properties

On reinforced polymer blend with short glass fibers or short carbon fiberit increases the flexural strength as shown in Figure 13. Compared to all composition 10wt% of carbon gives feasible result, because carbon fiber has got better resistance to deformation under load and also has good compatibility with the polymer matrix. The Variation in flexural modulus in various fiber compositions is shown in Figure 14. Flexural modulus increased in reinforced polymer, compared to pure polymer blend. If we add more fibers to the composites it becomes brittle.

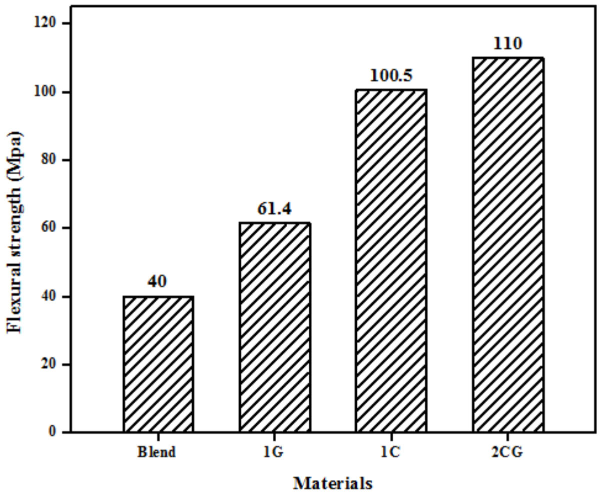

Figure 13 Plots of flexural strength of composites

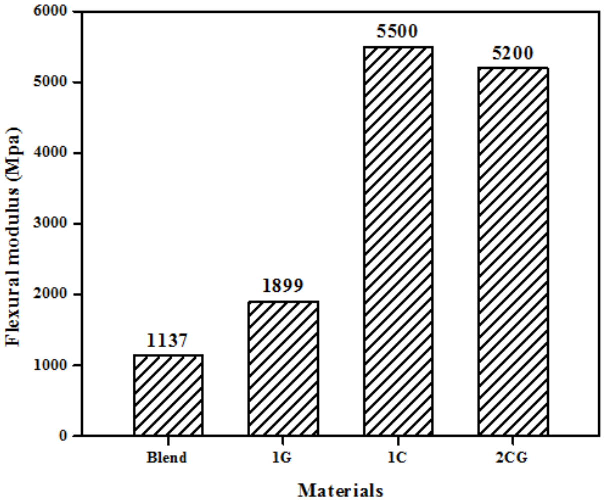

Figure 14 Plots of flexural modulus of composites

IV. CONCLUSION

- On reinforcement with short glass fibers and short carbon fibre, PA66/PP polymer blend shows the increasing in the physical properties such as density increases, water absorption capacity of polymer blend decreases especially in the case of glass filled composites this is due to the hydrophilic nature of the glass fibers. Void concentration increase on fibre incorporation.

- Mechanical properties such as hardness, tensile strength, tensile modulus, flexural strength and flexural modulus increases on reinforcement with Short glass fibers and short carbon fibers. Mechanical properties greatly influenced with reinforcement fibers. Impact strengths of the composites were decreases on reinforcement with the fibers.

References

[1]. Ing.Katarina Szeteiova, Automotive Materials plastics in Automotive markets today, Slovenska Tecnicka Univerzita V Bratislava, Materialovo technologicka fakulta so sidlom v tranve.
[2].B. Aldousiri, A. Shalwan, and C.W Chin "A Review on Tribological Behaviour of Polymeric Composites Future Reinforcements", Hindawi Publishing Corporation, Advances in Materials Science and Engineering Volume 2013, Article ID 645923.
[3]. J.K Lancaster, Polymer-based bearing materials the role of fillers and fiber reinforcement, Tribology, volume 5, Issue 6, December 1972, Elsevier
[4]. Somjate Patcharaphum and Grand Opaskornul, "Characterization of Fiber Length Distribution in Short and Long-Glass-Fiber Reinforced Polypropylene during Injection Moulding Process", Kasetart journal: natural Science 42:392-397(2008).
I.B.Page, Polyamides as Engineering Thermoplastic Materials. Volume 11 2000, Rapra technology LTD
[5]. Vaishali Vaghela R, Prof R. N Desai, Mr. P. K. Patel, Modification of Nylon 6,6, International journal of scientific engineering and technology volume No 1,Issue page No.2 pg 79-82
[6]. S.N. Kukureka, C.J. Hooke, M. Roa, P. Lio, Y. K. Chen , The effects of fibre reinforcement on the friction polyamide 66 under dry rolling-sliding contact, Trilogy International 32(1999) 107-116,Elsevier.
[7]. Michal Kristofic and Anna Ujhelyiova, "Compatibilisation of PP/PA Blends" Fibers and textiles in eastern Europe 2012; 20, 4(93): 30-36.
[8]. Harutun G.Karian. Handbook of Polypropylene and Polypropylene Composites second edition, Revised and Expanded, Taylor and Francis e- Librarary, 2009
[9]. Mariana Etcherry and Silvia E. Barbosa "Glass Fiber Reinforced Polypropylene Mechanical Properties Enhancement by Adhesion Improvement, Materials 2012, 5(6), 1084-1113.
[10]. F. Djeddi, A. Ouibrahim "Elaboration and characterization of blends-Polyamide 6/6 with Polypropylene and evolution of their mechanical properties with recycling", ACMA 2014