Characterization of Nylon 6 Nano Fiber/E-Glass Fiber Reinforced Epoxy Composites

T Vinod Kumar¹, M Chandrasekaran², V Santhanam³ and N Udayakumar⁴
¹Research Scholar & Assistant professor, Department of Mechanical Engineering, Vels University, Chennai, Tamil Nadu, India.
²Professor, Department of Mechanical Engineering, Vels University, Chennai, Tamil Nadu, India.
³Professor, Department of Mechanical Engineering, Rajalakshmi Engineering College, Chennai, Tamil Nadu, India.
⁴PG Student, Department of Mechanical Engineering, Rajalakshmi Engineering College, Chennai, Tamil Nadu, India.
E-mail: vinodkmmrmech@gmail.com

Abstract. In the paper thermoplastic polymer Nylon-6 is generated in the form of Nanofibers by using an electro spinning method, and concentration of a solution is 4% as a constant then, by varying the process parameters such as flow rate (0.8ml/hr, 1ml/hr and 1.2 ml/hr) of the solution. The results indicated Nanofibers with 4% concentration and 1 ml/hr produced optimum fibers due to continuous fiber formation. Composites Plates are fabricated by using a Hand lay-up method with different volume fraction (0.5, 1, 2 % v/v) of Nanofibers ratio. Then, the optimum Nanofibers volume ratio (2 % v/v) is reinforced with E-glass fibers and epoxy resin as a matrix. In order to find Nanofibers effect, Mechanical properties like (Tensile, Flexural and Impact) is performed and evaluated.

1. Introduction
Fiber Reinforced Polymer (FRP) composites are used in almost every type of advanced engineering structure. E-Glass, Carbon and Aramid Fibers are used glass fibers are most commonly used as reinforcement [1,2]. The idea of using Nanofiber to reduce porous fiber diameter and high stiffness Nanofibers is used as a reinforcement in the form of fibers, tubes, whiskers, platelets, & particles. Nano-fibers are certain increases the mechanical properties, The beneficial of nano-fibers reinforcements is required for reinforcements to be very low [3,4]. Investigation of electro spun fibers for two different polymers Poly (methyl methacrylate) PMMA and Polyacrylonitrile (PAN) polymers is generated by electro spinning. Then three difference combination Nylon-66 fibers are reinforced with PAN, PMMA and PMMA & PAN mixed together fabrication is made and conducted mechanical testing for all plates conducted. Among the three the PMMA and PAN it 5% higher than other two composite plates [5]. The Electro spun fibers as filler materials, Nylon 6 (NY) and polycaprolactone (PCL) used as reinforcements and matrix materials and different weight ratio of filler materials (1wt %, 3wt %, 5%). Compression molding is used in the fabrication process for the three different combination PCL/NY3 was prepared as sandwich of one layer of nylon mat between two PCL films. PCL/ NY5 was obtained from two layers of Nylon 6 mats alternated by PCL films. PCL/ NY8 was prepared interposing all the nylon fiber between two PCL layer (3wt %) is optimum among other the results is better than others [6]. Then, conducted Sixteen ply quasi-isotropic composite laminates interleaved AS4/3501-6 composite laminate clamped all around were the impact test is conducted and the improvement in impact resistance of composite laminates that have been interleaved by electro spun nylon 66 nano-fiber. The interleaved nano-fiber increase the impact force resistance and reduces damage from the impact forces [7]. In this Paper author conducted two different polymers Nylon 6 and Nylon 66 as a solute and Polycaprolactine as Solvent. Three different solution concentration and three
different viscosities for two polymers. Scanning Electron Microscope SEM images is an analysis of all 
samples and found low viscosity and concentrations goat fibers in Nanofibers [8]. Four different 
polymers are Polylactic acid PLA, Nylon 6 PA6, Polyethersulfone PES and TAC used, and kenaf fibers 
used for reinforcement, PA6 polymer tensile properties are increases than other [9]. The use of short 
electro spun fibers for the preparation of homogeneous polymer Nanofibers composites and the 
improvement in mechanical properties is amount of continuing long fibers required for achievement 
almost the same strength was much higher. I.e. 38 weight% in comparison to the 2 weight% required for 
the short fibers [10]. Only Few researcher concentrated on Nylon-6 Nanofibers in different volume 
ration and reinforced with epoxy composites and hybrid E-glass composites. Mechanical properties are 
increased while using Nanofibers in composites.

2. Materials And Methodology

2.1. Concept of Electro- spinning.
An electro- spinning is one of the efficacious technique is used to generate polymers in Nanofibers 
structure. A simple working process behind the electro spinning methods. An Electro spinning 
apparatus is shown in figure 1, and an apparatus used in R&D (Rajalakshmi Engineering College) 
Chennai. A solution is filled in the syringe positive charge is connected and plate collector is placed at 
the bottom.

At high voltages is applied to solve. Then, the solution is ejected from the syringe, and collected in the 
top surface of the plate collector. The fiber diameter ranged from 300 to 550 mm. The schematic 
diagram of electro spinning is shown in figure 2. The electro spinning parameters used were: 4% 
Nylon-6 concentration, 20 KV applied voltage, 10 cm distance between the needle and collector, 1 ml/h flow rate. The Nanofibers weight percentage used in between 0.5% and 2 %.

2.2. Materials.
The matrix used as Epoxy resin purchased from (Sakthi glass fiber) Chennai. A thermoplastic polymer 
Nylon 6 pellets used as sample and purchased from Sigma–Aldrich (USA). The solution 4% nylon 6 
solutions in formic acid/acetic acid (80/20, wt/wt %). A fabrication of composites plates in different 
composition in order to find the effect of Nanofibers, in the Composites.

2.3. Fabrication Specimens.
Composites plates are fabricated and mechanical testing (Tensile, Flexural and Impact test ) is 
conducted for all plates, in order to find the effects of Nanofibers in the composites. Fibers are chopped 
and stirred with Epoxy resin. Figure:3 Represents chopped Nylon-6 Nanofibers.
The dimension of the composites plates $200 \times 200 \times 3$ mm and according to the American Society for Testing and Materials (ASTM) Standard Tensile specimen is prepared length 165mm, width 19mm and thickness $3$ mm ASTM D638-03 Standard. Flexural specimen is prepared at length 100mm, width $12.7$ mm and thickness $3$ mm ASTM D790 and Impact specimen is prepared at length 65mm, width $12.7$ mm and thickness $3$ mm ASTM D256. Composites Plates are fabricated by using a Hand lay-up method with different volume fraction ($0.5$, $1$, $2$ % v/v) of Nanofibers ratio. Then, the optimum Nanofibers volume ratio ($2$ % v/v) is reinforced with E-glass fibers and epoxy resin as a matrix.

3. Results and Discussion
In this section effect of Nanofibers in epoxy resin and Mechanical test is conducted. NYLON 6 polymer solution was generated by dissolving the NYLON 6 in formic acid/acetic acid and the PA6 Nanofibers with different Flow rate ($0.8$ ml/hr, $1$ ml/hr, $1.2$ ml/hr) were tested. The temperature in the electro spinning apparatus $25-30 \, (^\circ C)$ respectively. Although Fibers were observed among the NYLON 6 Nanofibers in $4$ % in $1$ ml/hr is observed diameter range from $300 - 550$ nm approximately and $0.8$ ml/hr flow rate of NYLON 6 is observed air bubbles is formed in these fiber due to increasing the flow rate and despite the fact that fiber diameters range from $100 - 200$ NM but more air bubbles is formed. Then, $1.2$ ml/hr is the NYLON 6 Nanofibers could not be formed from the High flow rate. The tensile, Flexural and Impact specimen are prepared based on ASTM standard, average of Five values Mechanical testing (tensile, Flexural and Impact) is evaluated. By increasing ($0.5$, $1$, $2$ % v/v) of Nanofibers Volume ratio in the composites. In the graph samples A is ($100$% v/v) Resin, samples B is ($0.5$%v/v), samples is C ($1$% v/v), samples is D ($2$ % v/v), samples E is ($30$%v/v) E -Glass and samples F is $30$% E- Glass and $2$% Nanofibers. (e) Impact Energy.

3.1. Tensile properties
Tensile strength is comparatively improved in hybrid E-glass composites. A proper bonding between Matrix and E-glass fiber and Nanofibers in the composites that lead to increases in Tensile properties.

   Tensile strength is increased in hybrid E-glass composite samples F is $152.9$ (Mpa). The samples is D ($2$ % v/v) higher compare to A, B and C samples. By increasing the Nanofibers ratio and proper alignment in samples, that lead to tensile strength is increased for samples D $16.6$ (Mpa). Tensile modulus is calculated from the stress - strain relation. Figure:4 Represents average values of Tensile Strength (MPa) and Tensile Modulus (GPA).
3.2. Flexural properties

Flexural strength is comparatively improved in hybrid E-glass composites. A samples D is (2 % v/v) higher comparing to A, B and C Samples. Flexural strength of samples D is 83.33 (MPa), by increasing the Nanofibers ratio and proper alignment in samples, that lead to Flexural strength of hybrid composites is increase samples F is 143.58 (MPa). Flexural modulus is calculated. Figure 5. Represents average values of Flexural Strength (MPa) and Flexural Modulus (GPA).

3.3. Impact Energy (J)

Impact specimen is prepared based on ASTM standard. Then, samples F hybrid composites are higher because of proper alignment in samples F is 1.75 (J) Impact Energy. Samples D is higher compare to A, B and C Samples, the result of sample D is 0.8 Impact Energy. Figure: 6 Represent the average values of Impact Energy (J).
4. Conclusion
Thermoplastic polymer Nylon 6 can generate in the Electro spinning machine. Mechanical properties (Tensile, Flexural and Impact) are calculated for all samples. The Hybrid, E-Glass fiber reinforced with Nanofibers increases the Mechanical properties compared to other samples. Increasing the Nanofibers volume will result Proper Bonding between matrix and fiber.

5. References
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