© Applied Science Innovations Pvt. Ltd., India Carbon – Sci. Tech. 6/4(2014)41-48

Carbon – Science and Technology

ISSN 0974 – 0546

http://www.applied-science-innovations.com

ARTICLE Received : 16/12/2014, Accepted :31/12/2014

Performance of Polymer gears reinforced with sisal woven rovings

A. Faizur Rahman (*, A), **A. P. Senthil Kumar** (B), **B. Giriraj** (B), **A. P.Arun** (C), **R. Santhosh** (A)

(A) Department of Mechanical Engineering, CSI College of Engineering, Nilgiris - 643215, Tamil Nadu, India.
(B) Department of Mechanical Engineering, PSG College of Technology, Coimbatore - 641004 Tamil Nadu, India.
(C) Department of Mechanical Engineering, Kumaraguru College of Technology, Coimbatore-641006 Tamil Nadu, India.

Polymer gears find a common place in many industries and applications. In general, carbon fibre and glass fibres are used as reinforcement in polymer gears. This current research focuses on developing and testing the temperature and wear performance of Polyester spur gears reinforced with Sisal Woven Rovings (SWRP) . Volume fractions (V_f) such as 5% (SWRP/A), 10% (SWRP/B), 15% (SWRP/C) and 20% (SWRP/D) of gear specimens were prepared and tested for temperature and wear effects. Gears were tested up to 1.4 x 10^6 cycles. Gear tooth damages are recorded through optical photographs. The result reveals that the temperature and wear performance of SWRP/A and SWRP/B gears were low compared to SWRP/D gears.A small amount of wear damages were observed in SWRP/C gears. No damages were occurred in SWRP/D gears upto 1.4 x 10^6 cycles and also it was observed that the temperature and wear rate were found to be 15 % and 36 % lesser in SWRP/D gears when compared to SWRP/A gears.

Keywords: Sisal woven rovings,natural fibers gear,polyester.

---

1 Introduction: The interest in using natural fibres as reinforcement in plastics has increased dramatically during last few years. Natural fiber composites such as sisal and jute polymer composites became more attractive due to their high specific strength, lightweight and biodegradability. The incorporation of sisal–jute fiber with glass fibers improved the mechanical properties and used as an alternate material for glass fiber reinforced polymer composites [1]. Mechanical and thermal stability properties were improved by modifying sisal fibers through chemical treatments [2]. Sisal fiber with glass fibers exhibited superior properties than the jute fiber reinforced glass fibers composites [3]. The increase of fiber content and interfacial compatibilization with maleic anhydride grafted HDPE (MAPE) were found to improve the mechanical properties of the composites [4]. When the treated fibers with epoxy matrix improves adhesion between fiber bundles and fiber ultimate cells [5]. Abrasive wear and mechanical properties of sisal fibre reinforced polypropylene composites were determined [6]. High moisture absorption is the major drawback in the natural fiber composites and chemical treatment is necessary to overcome the solution. Acetylation, benzoylation, silane and triton are the chemical treatments available for fiber surface modification. Alkaline treatment is the common technique used to modify the cellulosic molecular structure. It gives rough surface to fibers thus increase in fiber surface area to better bonding with matrix material [7-8]. Flexural and impact test results improved with modified sisal fibers compared to pure Polyethylene sisal composites [9]. Sisal, hemp and kenaf based on polypropylene composites were comparatively evaluated for tensile strength [10]. Woven sisal fabric composites were manufactured by compression moulding and tensile strength of 25 MPa and flexural strength of 11 MPa were observed [11]. This paper aims to study the fibre chemical treatments, manufacturing techniques and wear testing of sisal woven rovings reinforced with polyester gears

2. Gear materials and processing: Commercially available sisal fibres were purchased from local dealer. Sisal woven rovings were made from these fibres through hand weaving machine and the properties of sisal woven rovings are given in Table 1. Isothalic polyester resin is used as the matrix material while Methyl Ethyl Ketone Peroxide (MEKP) as accelerator and Cobalt Naphthalene as catalyst, were purchased from Kovai Seenu fabrics, Coimbatore.

Table(1): Properties of sisal woven rovings

Properties	**Sisal woven rovings**
Areal Density A_f (g/m^2)	150
Tensile modulus of elasticity (Mpa)	404
Maximum tensile load (N)	520
Lamina thickness (mm)	0.19

Figure (1): Prepartaion of SWRP gears through hand layup process.

The woven rovings were dried under sunlight for a week. Then the woven rovings are subjected to alkali treatment, to remove the moisture content in the fibers. Using laminate equation (1), the required number of layers was made for the different volume fractions of SWRP/A, SWRP/B, SWRP/C and SWRP/D gear samples and are shown in Table 2. In the laminate equation V_f is Volume fraction of fibre, n is number of layers, A_f is Areal density of fibre, ρ_f is density of fibre and t is laminate thickness.

Hand layup technique is used to prepare the composite specimens. Figure (1) explains the preparation of SWRP gears. During hobbing process, plywood's are placed at top and bottom of the gear blank to avoid sudden impact of gear cutter.

$$\mathbf{V_f = (n\ A_f) / (\rho_f\ t)} \quad \text{-------} \ (1)$$

Table (2) : Number of layers required for volume fractions

Specimen	Volume fraction	Number of layers 'N'
SWRP/A	5%	8
SWRP/B	10%	17
SWRP/C	15%	25
SWRP/D	20%	34

3 Testing of SWRP gears: The schematic diagram of the gear test rig used for conducting the performance tests are shown in Figure (2). In this test rig, the test gear (SWRP) is driven using a three phase induction motor, which runs at 1440rpm. Test gear runs against nylon gear. The required test torque is induced through a load cell attached to the eddy current dynamometer. Gear specifications and test conditions are given in Table 3and Table 4 respectively. All tests were conducted under unlubricated conditions. Four gears (SWRP/A, SWRP/B, SWRP/C and SWRP/D) were tested by subjecting it to 1.40 x 10^6 revolutions.

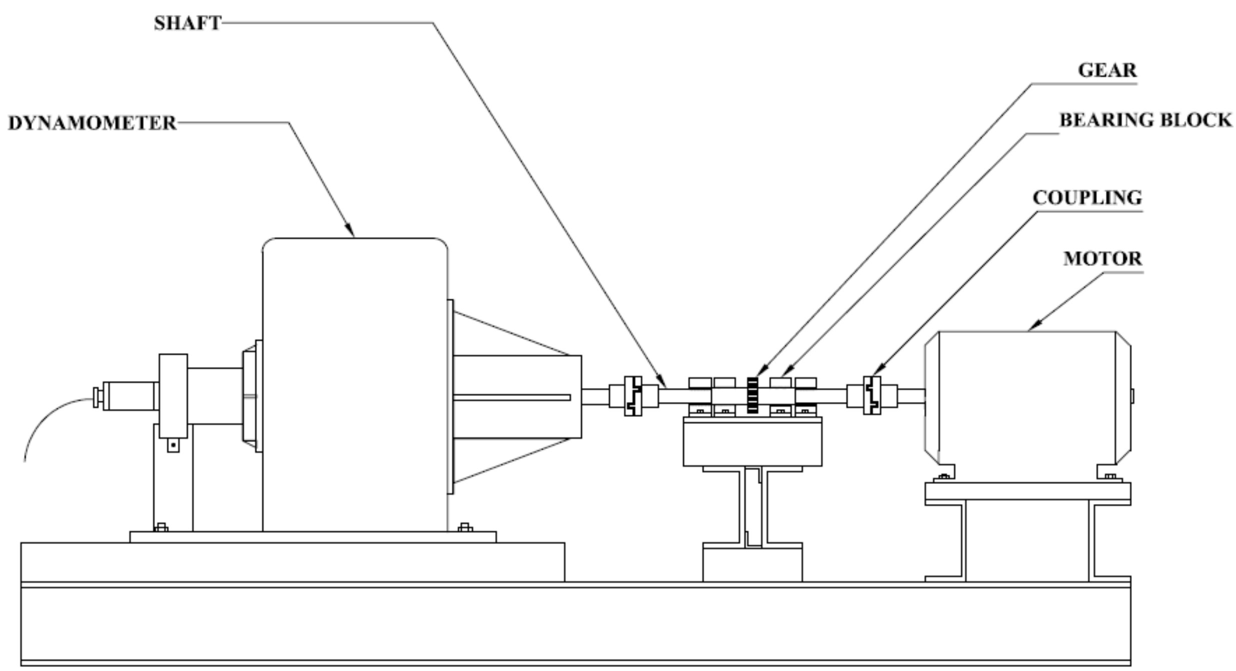

Figure (2): Schematic diagram of the gear test rig.

For each torque, fresh gear is chosen. The tooth thickness (chordal thickness) was measured by gear tooth vernier at PCD. Three teeth for each gear chosen for measuring tooth thickness and average value is taken. Tooth thickness was measured at every 0.20 x 10^6 revolutions. During the tests, gear damages were investigated and photographs were also taken. Gears under test are shown in Figure (3).

Table (3): Specifications of SWRP gears

Description	**Pinion gears**	**Driver gears**
Material	SWRP gear	Nylon
Module	2	2
Number of teeth	30	30
Center distance(mm)	60	60
Pitch circle diameter ,PCD(mm)	60	60
Pressure angle(degree)	20	20
Tooth thickness on PCD (mm)	3.14	3.14
Face width (mm)	18	18

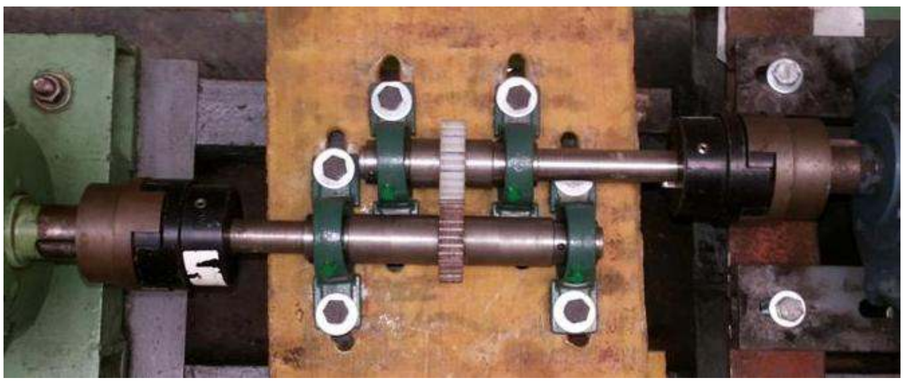

Figure (3): SWRP gears under test against nylon gear at 1440rpm

Table (4): Gear test conditions

Torque (Nm)	4,8,12 and 16
Rotational Speed (rpm)	1440
Pitch line velocity (m/s)	4.52
Lubricant	Dry

4 Results and Discussion

4.1 Influence of temperature on gears: A non-contact temperature sensor were mounted near the gear tooth to measure the tooth surface of SWRP gears. Temperature were measured at every 0.20 x 10^6 cycles and also damages, cracks and wear are investigated and photographs were also taken. Variation of temperature on the gear tooth surface with different volume fractions are shown in Figure (4**).** From the graph, it was observed that certain amount of heat was accumulated in the gear tooth. The heat generated in the gears due to friction between the mating gear teeth. The gear tooth surface temperatures measured during test at SWRP/A and SWRP/B shows rise in temperature when compared to SWRP/C and SWRP/D. Addition of sisal fabric layers increases the gear tooth stiffness and hence less gear tooth temperature occurs in SWRP/C and SWRP/D gears, for the same loading conditions. Finally SWRP/B,SWRP/C,SWRP/D gears shows 4 %, 8 % and 15 % less in temperature when compared to SWRP/A.

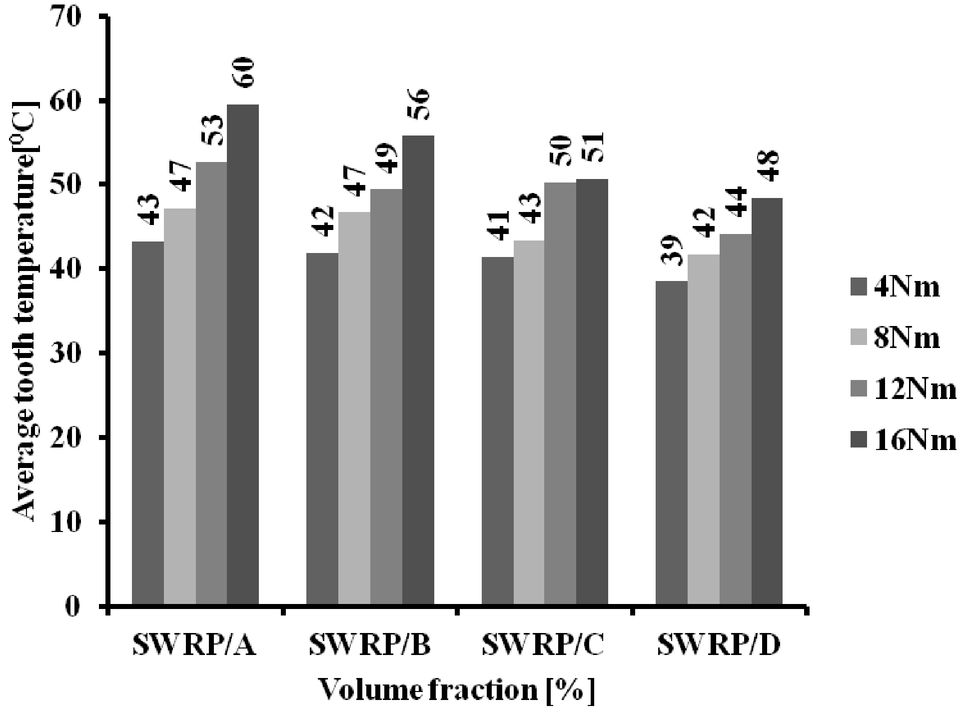

Figure (4): Average tooth temperature of SWRP gears

4.2 Wear and performance of gears: In this experimental study, SWRP gears of different volume fractions were used. Torques of 4, 8, 12 and 16 Nm were applied at 1440 rpm, and the damaged zones as well as the performance of gears were investigated. Figure (5) shows the wear depth of SWRP/A, SWRP/B, SWRP/C and SWRP/D gears at different torque levels. All gears were run up to 1.4 x 10^6 cycles at 4 Nm torque without major damages. However small wear debris occurred after 1 x 10^6 cycles. For SWRP/A, tooth breakage occurred after $0.8x10^6$ and $0.4x10^6$ cycles at 8 Nm and 12 Nm respectively. Little wear debris was occurred at 8 Nm torque for all gears. For torques 12 and 16Nm, there was a rapid wear were occurred and the size of the worn particles is larger. Tooth breakage for SWRP/A, SWRP/B and SWRP/C occurred after $0.4x10^6$, $0.4x10^6$ and $0.8x10^6$ cycles respectively. However SWRP/D gears shows comparatively less wear rate at all torque levels. This is due to higher number of sisal fabric layers were stacked in the gear. Figure (6) shows the average wear depth of gears and it demonstrates that wear depth were increased at higher torque levels. Figure (7) shows the optical photographs of SWRP gears at $0.6x10^6$ cycles. It was observed that at high stress levels, wear debris of SWRP/A,SWRP/B and SWRP/C gears were high due to meshing.It leads to weakening of gear material and reduces the performance. The thermal damages on the tooth surface did not occur at SWRP/D, but small wear occurred around pitch line. Finally, SWRP/D gears shows 36 % less wear rate compared to SWRP/A gears.

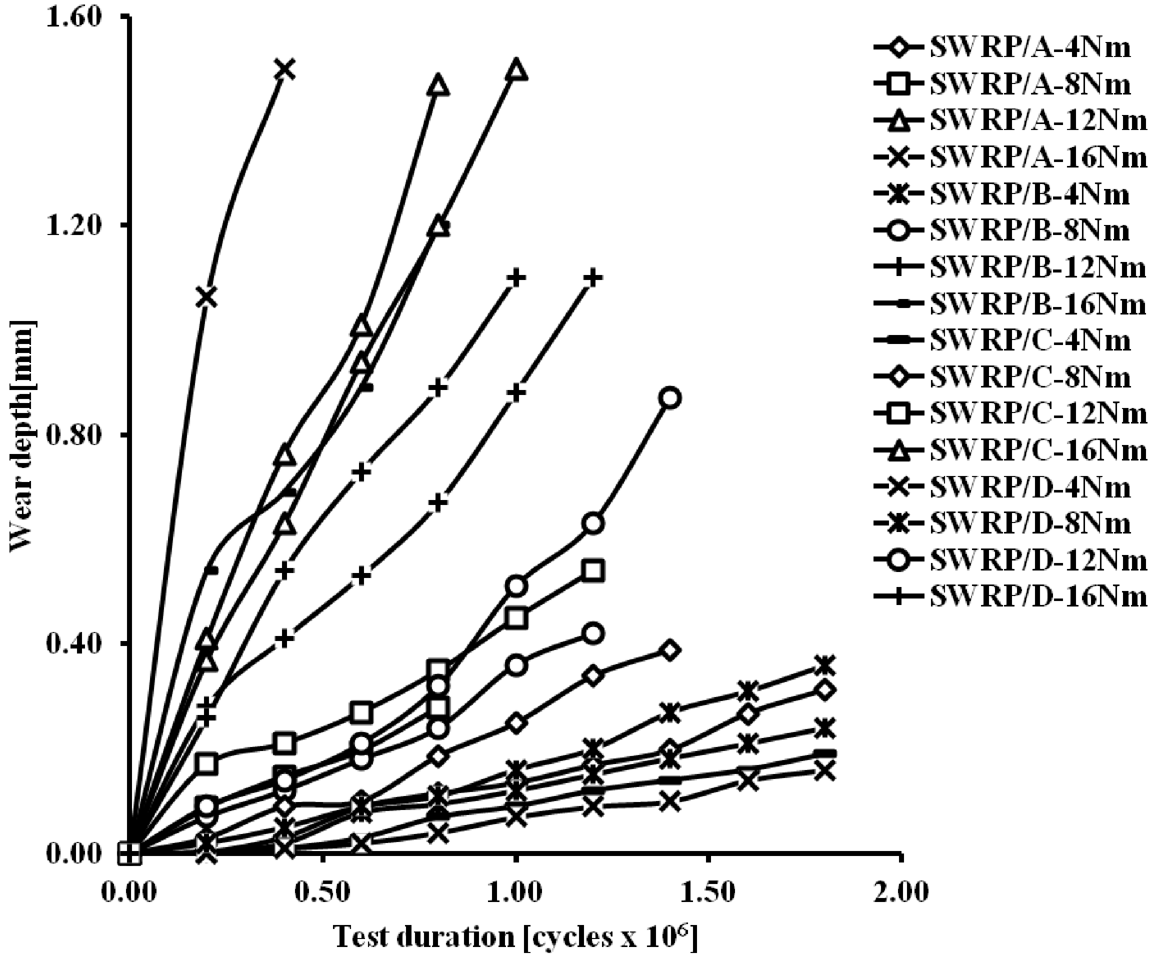

Figure (5): Wear results of SWRP gears.

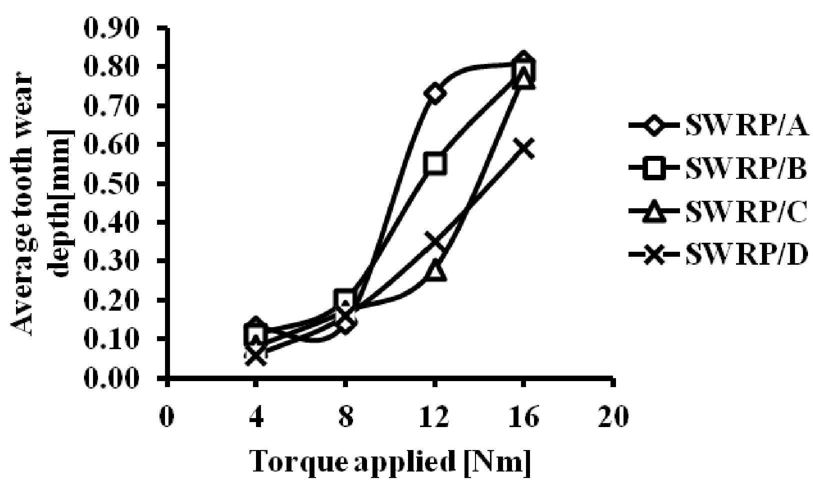

Figure (6): Average wear results of SWRP gears.

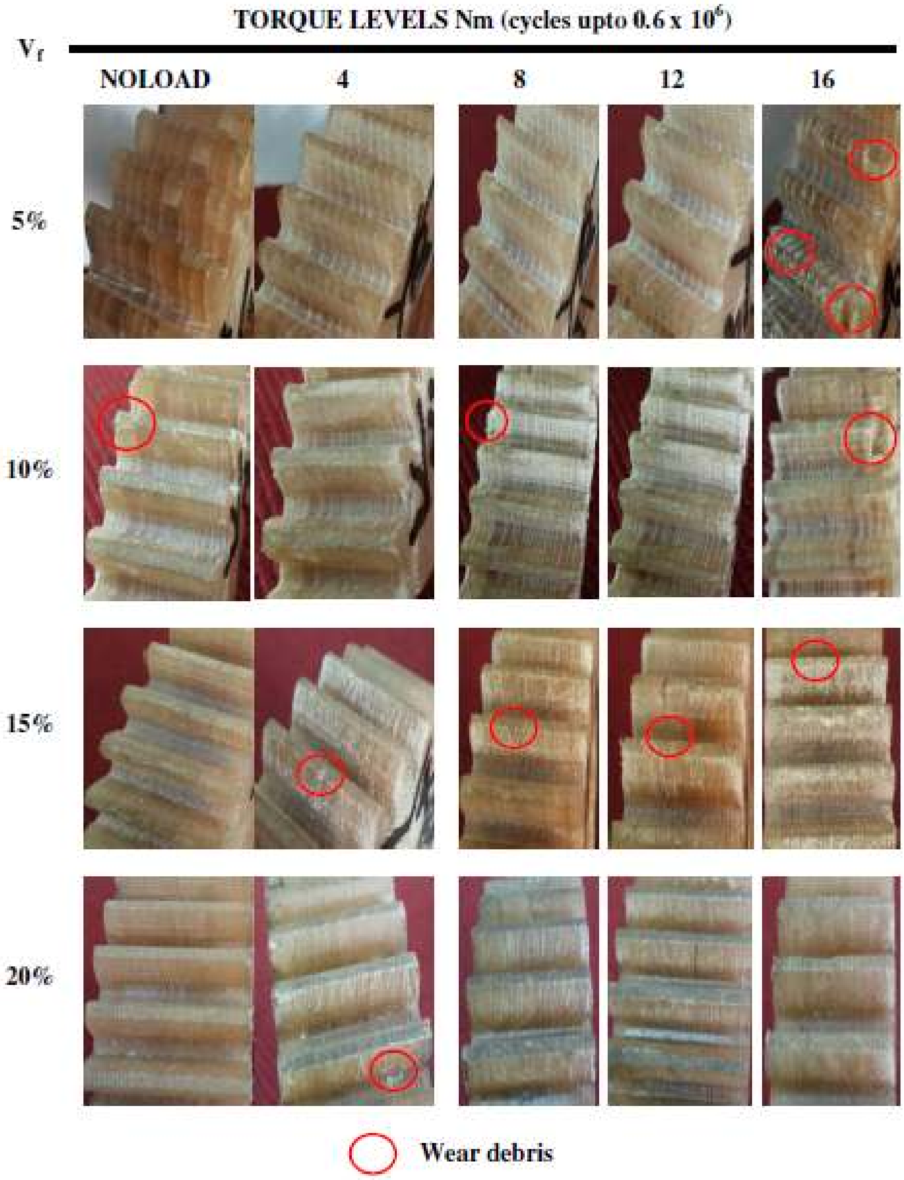

Figure (7): Optical photographs of SWRP gears

5 Conclusions: Sisal woven rovings reinforced polyester spur gears were prepared by hand layup technique.Temeperature and wear performance of SWRP gears were studied and the following conclusions are made.

- SWRP/A ,SWRP/B and SWRP/C shows rise in temperature and thermal damages were recorded.SWRP/D gears shows 15% less in temperature compared to SWRP/A gears.
- SWRP/A ,SWRP/B and SWRP/C gears were worn out quickly.SWRP/D gears shows 36% lesse wear rate compared to SWRP/A gears.

References:

[1] M. Ramesh, K. Palanikumar, K. Hemachandra Reddy, Mechanical property evaluation of sisal–jute–glass fiber reinforcedpolyester composites, Composites: Part B 48 (2013) 1.

[2] Ramzy, D. Beermann, L. Steuernagel, D. Meiners, G. Ziegmann, Developing a new generation of sisal composite fibers for use in industrial applications,Composites:Part B 66 (2014) 287.

[3] M. Ramesh, K. Palanikumar, R. K. Hemachandra, "Comparative Evaluation on Properties of Hybrid Glass Fiber- Sisal/Jute Reinforced Epoxy Composites", "Chemical, Civil and Mechanical Engineering Tracks of 3rd Nirma University International Conference", Ahmadabad, India, 51 (2013) 745.

[4] Xuefeng Zhao, Robert K. Y. Li, Shu-Lin Bai, Mechanical properties of sisal fiber reinforced high density polyethylene composites: Effect of fiber content, interfacial compatibilization, and manufacturing process,Composites: Part A 65 (2014) 169.

[5] Z. R. Min, Q. Z. Ming, L. Yuan, C. Y. Gui, M. Z. Han, The effect of fiber treatment on the mechanical properties of unidirectional sisal-reinforced epoxy composites, Composites Science and Technology 61 (2001) 1437.

[6] U. K. Dwivedi, Navin Chand, Influence of MA-g-PP on abrasive wear behaviour of chopped sisal fibre reinforced polypropylene composites, Journal of Materials Processing Technology 209 (2009) 5371 – 5375.

[7] M. M. Kabir, H. Wang, K. T. Lau, F. Cardona, Chemical treatments on plant- based natural fibre reinforced polymer composites: An overview, Composites: Part B 43 (2012) 2883.

[8] L. Yan, M. Yiu-Wing, Y. Lin, Sisal fibre and its composites: a review of recent developments, Composites Science and Technology 60 (2000) 2037.

[9] S. L. Fávaro1, T. A. Ganzerli1, A. G. V. de Carvalho, O. R. R. F. da Silva, E. Radovanovic, Chemical, morphological and mechanical analysis of sisal fiber-reinforced recycled high-density polyethylene composites, Express Polymer Letters 4 (2010) 465.

[10] W. Paul, I. Jan, V. Ignaas, Natural fibres: can they replace glass in fibre reinforced plastics?, Composites Science and Technology 63 (2003) 1259.

[11] C. M. Andressa, O. H. C. Maria, J. C. V. Herman, Thermal and mechanical behaviour of sisal/phenolic composites, Composites: Part B 43 (2012) 2843.

***