EGTRIB Journal
JOURNAL OF
THE EGYPTIAN SOCIETY OF TRIBOLOGY
VOLUME 13, No. 1, January 2016, pp. 43 - 53 ISSN 2090 - 5882

INFLUENCE OF NATURAL FILLERS ON TRIBOLOGICAL AND MECHANICAL PERFORMANCE OF POLYESTER COMPOSITES

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ABSTRACT

Polymer composites reinforced by natural fibers/fillers provide good tribological properties as nontraditional materials for industrial applications that require proper friction coefficient and wear resistance such as bearing materials, brake pad materials and flooring materials. In the present work, polyester composites filled with Corn Straw Powder (CSP) or Jasmine Leaves Powder (JLP) proposed as new engineering materials with improved mechanical and frictional behavior. Cylindrical pins with 10 mm diameter and 30 mm height were prepared as test specimens. Two factors are considered when designing the experiment; first the size of filling particles, second the weight ratio of the added particles. A Pin-on-disk tribometer designed and constructed to perform measurements of the friction coefficient and wear rate for proposed composites was used. WP300.20 universal testing device used to investigate the mechanical properties of polyester composite. Results show that corn straw particles and jasmine leaves powder have a significant effect on the mechanical and tribological behavior of polyester composites.

KEYWORDS

Corn Straw Powder (CSP), Jasmine Leaves Powder (JLP), Polyester Composite, friction, wear, stress-strain curve.

INTRODUCTION

Agricultural wastes (A. W.) added as reinforcement materials for polyester resin. Tribological properties investigated for the proposed composites. The results show that agricultural wastes have a significant effect on the friction coefficient and wear rates of polyester composites [1]. Short fiber reinforced polymer composites used nowadays in numerous tribological applications. In spite of this fact, new developments are still under way to explore other fields of application for these materials and to tailor their properties for more extreme loading conditions, [2]. Polyester composites commonly used in industrial applications such as bearing materials, brake pads materials and flooring materials, [3]. Fiber Reinforced Plastics (FRP) are widely used as structural materials in the manufacture of, for example, marine boats, automobiles and bathtubs due to their light weight, high degree of rigidity and superior moldability, [4]. There are the two main characteristics which make these materials attractive compared to conventional metallic designs. They are of relatively low density and they can be tailored

to have stacking sequences to provide high strength and stiffness in directions of high loading, [5].Composite materials consist of a resin and reinforcement chosen according to desired mechanical properties and the application, [6]. Polyesters also commonly used as matrix materials, particularly with glass-fibre-reinforcement. Polyester is an economic material that has high chemical resistance and is resistant to environmental effects. It has high dimensional stability and low moisture absorption. The production technologies for thermoset glass/polyester composites are easier and cheaper than those for other glass/resin materials. Glass-fibre-reinforced polymer with thermosetting polyester resin is an attractive material that is economically desirable. Its application at low temperatures and under service terms is easy when this material is compared to advanced polymer composites with a complex molecule structure, high strength and working under terms of difficult service, [7]. Fibre-Reinforced-Polymer composites are used particularly in the automotive and aircraft industries and the manufacture of spaceships and sea vehicles [8]. In industrial applications, the increase in the use of composite materials means that it is necessary to know their behaviour under working conditions. Wear and friction are an important parameters and their experimental behaviour must be known, [9]. Polymers frequently used in tribological applications because of their self-lubricating ability and loadability. However, most research on their friction and wear mechanisms is performed on small-scale test samples under relatively low normal loads, [10]. Polymers have been favorably introduced as sliding materials in offshore structures for over ten years because of good wear resistance. Mainly under high loads, surface plasticity contributes to low friction, which is favorable for a reduction in dissipated sliding energy, [11].

In the present work, polyester composites reinforced with Corn Straw Powder (CSP) proposed as new engineering materials with improved mechanical and frictional behavior.

EXPERIMENTAL

The investigation was carried out to detect the effect of adding corn straws or jasmine leaves on the mechanical and tribological properties of polyester.

Raw Materials are polyester risen (commercial name SIR RESIN from SABIC KSA) as a polymeric matrix and natural filler in form of powder of corn straws and jasmine dry leaves were supplied as agricultural waste from the plants. These wastes were cleaned from any other contaminants and ground into two scales of particle size, soft particles with 0.5 mm particle size and coarse type with 3 mm particle size.

Preparation of Test Specimens

Polyester resin as matrix material was hand mixed by means of a long wooden stirrer with proposed filler powder in volumetric ratio up to 50 wt. % and mixed with its corresponding hardener by ratio of 3:1. After well mixing of the composite contents for 3 to 5 minutes it were poured into cylindrical mold (30 mm height and 10 mm diameter) under ambient conditions of temperature, humidity and pressure. After 24 hours, test specimens became completely solid and ready for measurements. All test specimens subjected to soft sandpaper for cleaning the surfaces and remove irregular layers for performing the tribological measurements. It was observed that there is a symmetrical distribution of the filling powder on the projected area of polyester composites, which

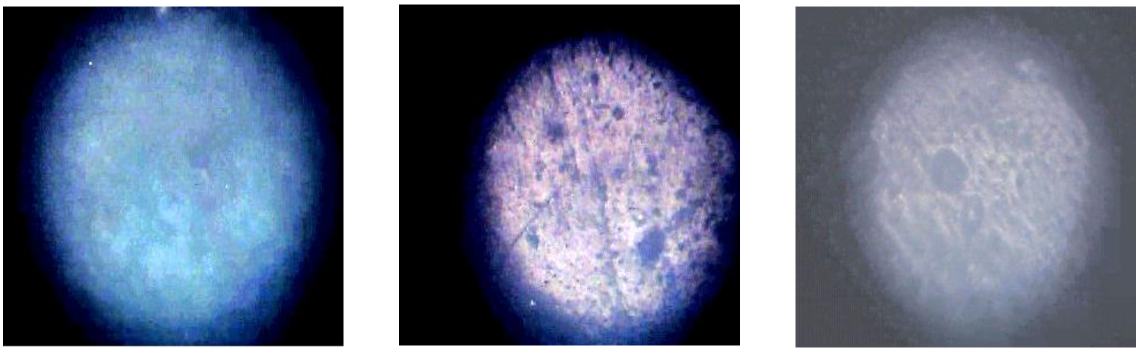
means that there are different amount of fillers on the surface of composite which varies from 0 to 50 wt. % of the contact surface.

Description of test rig

Experiments were carried out by means of pin-on-disk tribodevice for tribological measurements in form of coefficient of friction and rate of wear for the proposed composites. This device was designed and constructed to perform the experiment. Pin-on-disc consists of variable speed motor 170 rpm, steel counterface with 0.13 µm Ra and wear track of 90 mm diameter, pins holder with load cell for friction force detection connected with digital screen. Tests carried out at ambient conditions of temperature and humidity at 0.8 ms^{-1} sliding speed. Friction coefficient of polyester composites in dry contact with rotating steel disc was measured under different applied loads from 2 to 6 N. Polyester composites were held in specimen holder and loaded against the rotating steel counterface. The friction force was monitored by the digital screen attached to the load cell. Figure 1 shows the surface of worn specimens. Friction coefficient was calculated by dividing the friction force by the applied load, eq. (1).

$$\mu = F_f / F_n \qquad (1)$$

Where,
μ = friction coefficient
F_f = Friction force N, and
F_n = Normal force N.



a b c

Fig. 1 a) Unfilled polyester, b) Polyester reinforced by soft particles and c) Polyester reinforced by coarse particles.

Mechanical measurements

A compression test was carried out to indicate the effect of corn straw or jasmine leaves content on the stress-strain behaviour of the proposed composites. Mechanical investigations performed by means of WP 300.20 universal testing machine under load range of 0 to 5 KN. A stress-strain curve plotted directly by the testing device for each test sample.

RESULTS AND DISCUSSION

Effect of corn straw particles

Figure 2 shows that the increase of coarse particles of corn straw contents decreases slightly the friction coefficient of polyester composites from 0.75 for unfilled specimens under 6 N applied load to 0.51 for composites reinforced by 15 wt. % coarse particle corn straw, then the friction coefficient increases to 0.58 with increasing corn straw contents to 50 wt. %. The friction reduction may be explained as a result of the contact between the counterface material and corn straw particles, which come to the contact zone. However, the friction coefficient increases for composite with high corn straw contents, which may be a result of the contact between the composite surface and transferred layer from the composite surface to the counterface. Figure 3 shows that the increase of soft particles of corn straw content slightly decreases the friction coefficient of polyester composites from 1.02, 0.79 and 0.75 for unfilled specimens to 0.9, 0.58 and 0.48 under 2, 4 and 6 N applied load respectively for composites reinforced by 15 wt. % soft particles corn straw. Then the friction coefficient increases under all loads with the increase of corn straw contents to 45 wt. %.

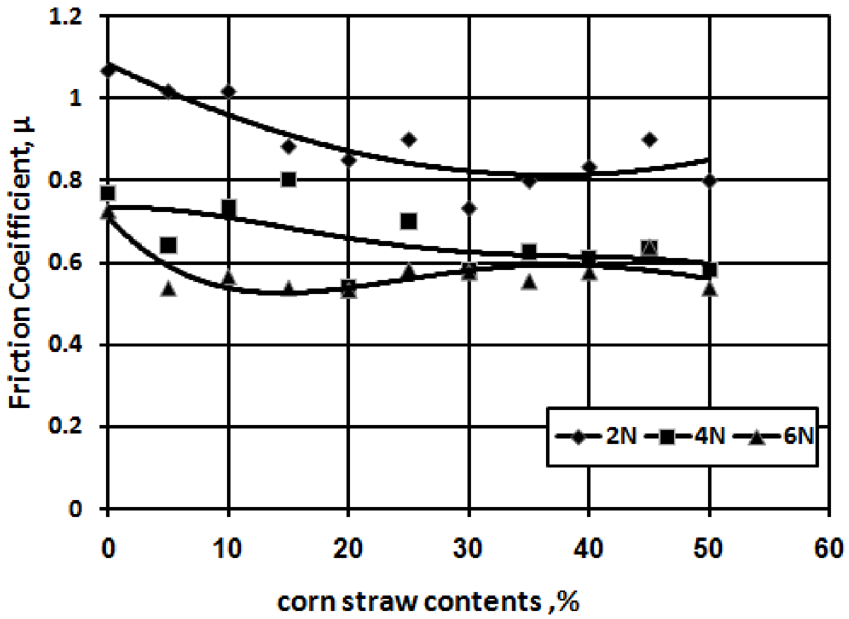


Fig. 2 Effect of coarse corn straw particles on the friction coefficient of polyester composites.

It seems that there is an elastic deformation occurred on the composite surface under high loads, which may be responsible for the friction reduction. It can be concluded that the transferred layer is responsible for the increase of friction for composite with high corn straw contents. These results show that there is insignificant effect for the particle size on the friction coefficient of the proposed composite. Figure 4 shows the rate of wear in grams per minute for polyester composites filled with coarse or soft corn straw. As shown, both coarse and soft particles of corn straw decrease the rate of wear for polyester composites, where wear rate decreases from 0.03 g/min. for polyester free of corn straw to 0.01 g/min. with increase of soft corn straw to 25 wt. %. However, increase of coarse particles in polyester composites to 40 wt. % decreases the rate of wear to minimum value 0.005 g/min. It seems that increase of soft and coarse corn straw powder to 25 wt. % and 40 wt. % in polyester respectively strengthens the bonds between composite phases and decreases the amount of material losses.

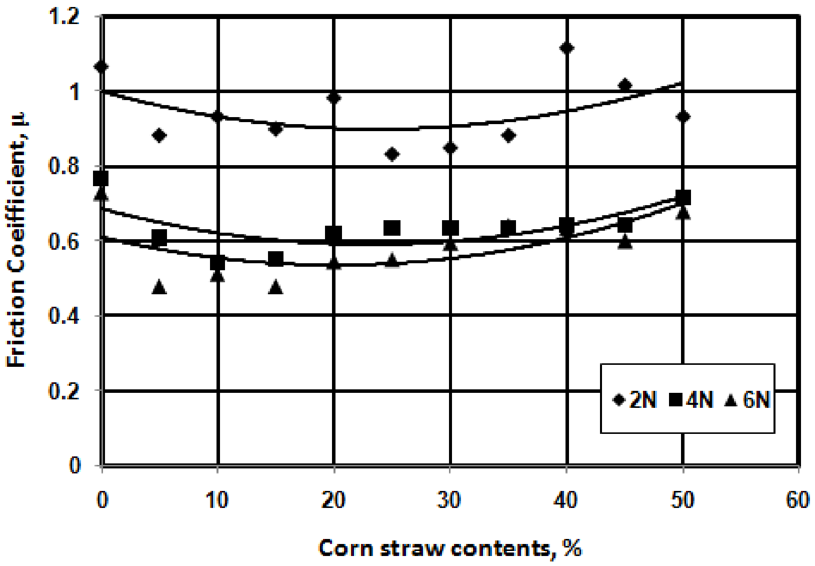


Fig. 3 Effect of soft corn straw particles on the friction coefficient of polyester composites.

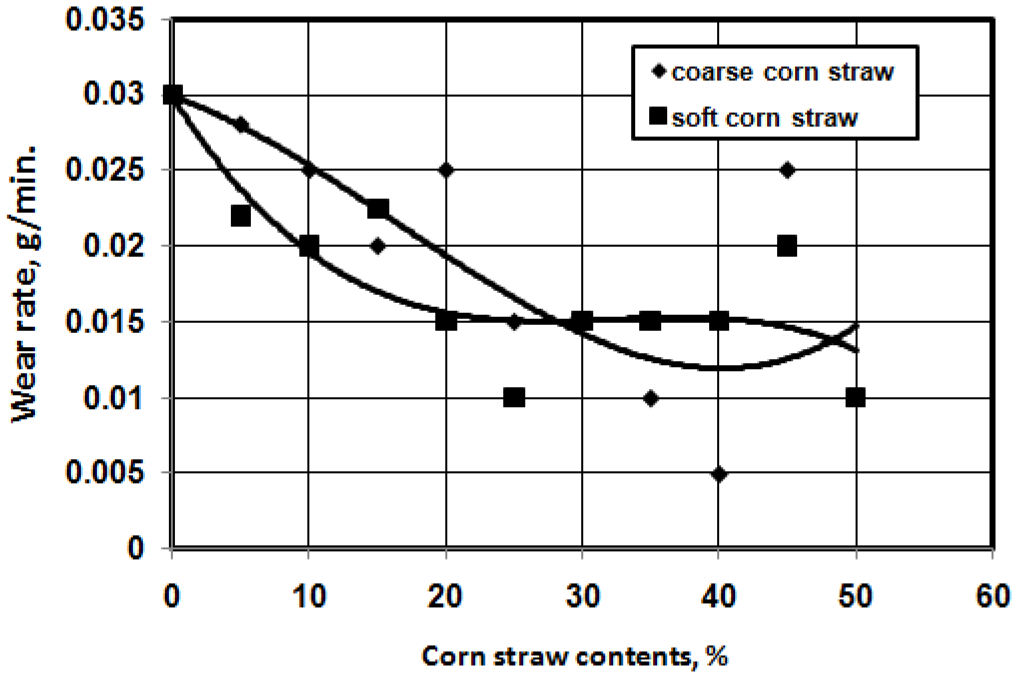


Fig. 4 Effect of corn straw content on the rate of wear of polyester composites.

Figure 5 discusses the relation between stress and strain for polyester composites reinforced by coarse particles of corn straw. As shown, the ultimate strength of polyester composites increases from 48 N/mm^2 for free polyester to 100 N/mm^2 for polyester containing 5 wt. % and 30 wt. % corn straw particles. On the other hand, the fracture strain of polyester increases from 0.8 for free specimen to 1.2 for polyester composites reinforced by 5 wt. % corn straw. Continuous increase of corn straw in polyester composites to 50 wt. % decreases the strength of composites less than 40 N/mm^2 and decreases the fracture strain to less than 0.8, which may be a result of decreasing the

bonding between the composite contents. Figure 6 shows that increase of soft particles of corn straw in polyester composite to 50 wt. % increases the ultimate strength to more than 70 N/mm^2 and increases the fracture strain to 1.2. From these results it can be seen that the optimum composites of polyester reinforced by corn straw contains 5 wt. % coarse particles of corn straw and the composite which have 50 wt. % soft particles of corn straw. These two percentage improved the mechanical behavior of polyester composites.

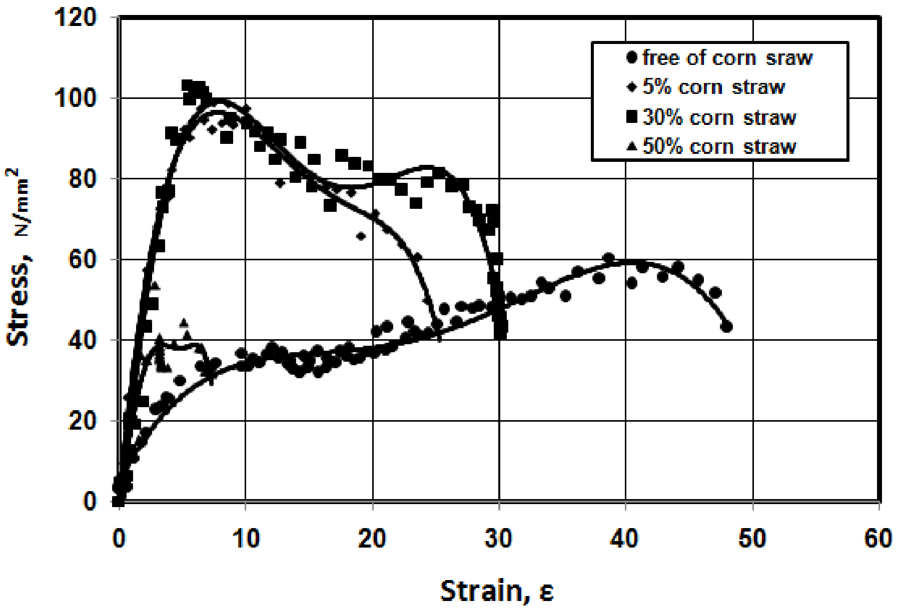


Fig. 5 Effect of coarse corn straw particles on the stress-strain curve of polyester composites.

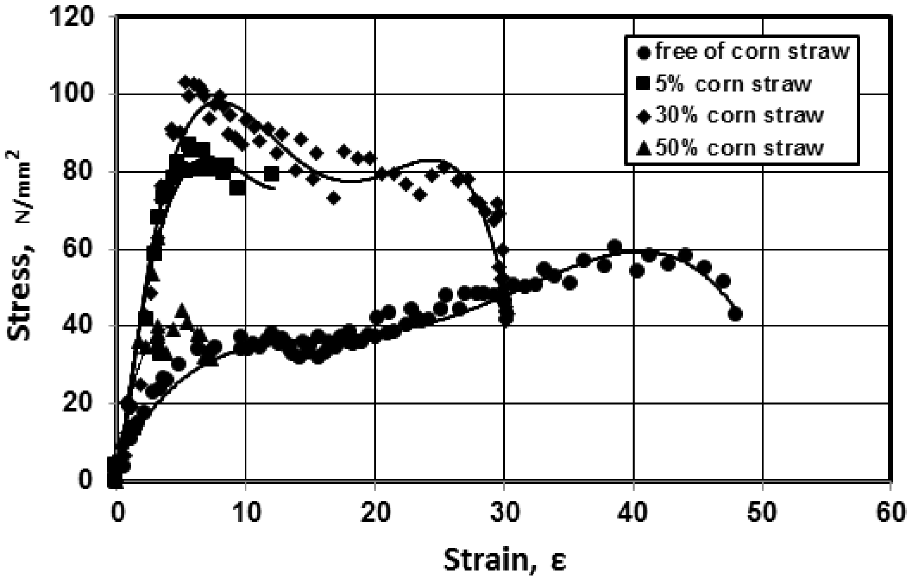


Fig. 6 Effect of soft corn straw particles on the stress-strain curve of polyester composites.

Effect of jasmine dry leaves particles

Figure 7 shows that the increase of soft particles content of jasmine leaves in polyester composite caused an increase in friction coefficient. For instant, friction coefficient increased from 0.7 for polyester free of agricultural wastes to 1.0 for composite containing 30 % jasmine leaves under the load of 4 N. This may be discussed on the basis that the particles of jasmine leaves formed an abrasive layer that increased friction coefficient.

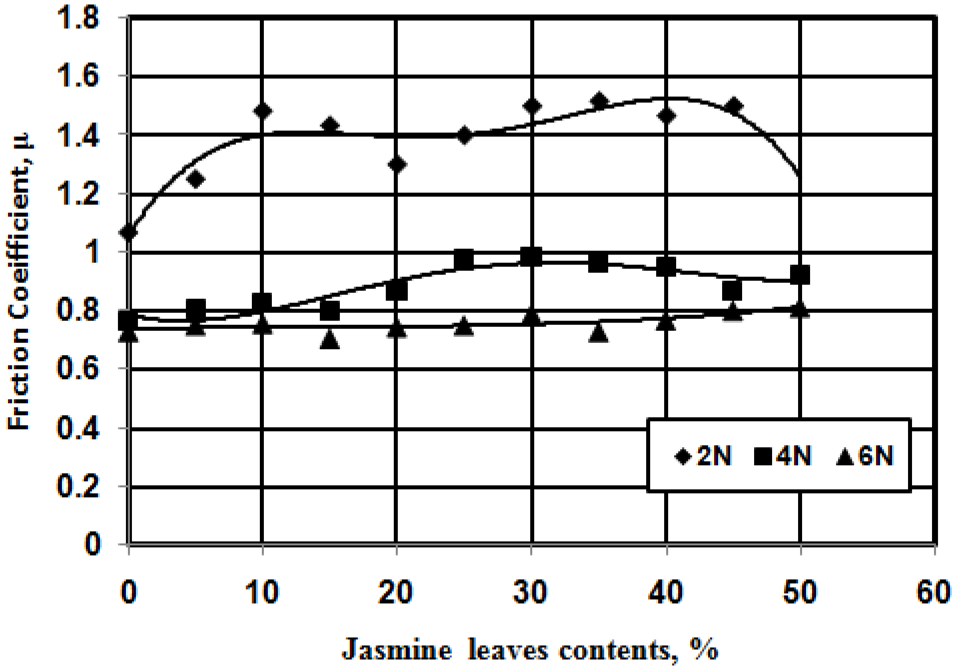


Fig. 7 Effect of soft jasmine leaves particles on the friction coefficient of polyester composites.

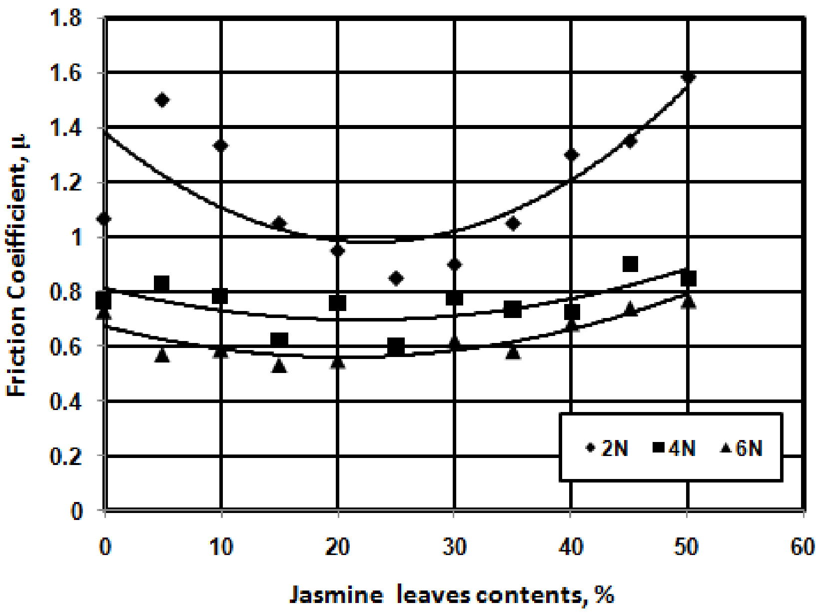


Fig. 8 Effect of coarse jasmine leaves particles on the friction coefficient of polyester composites.

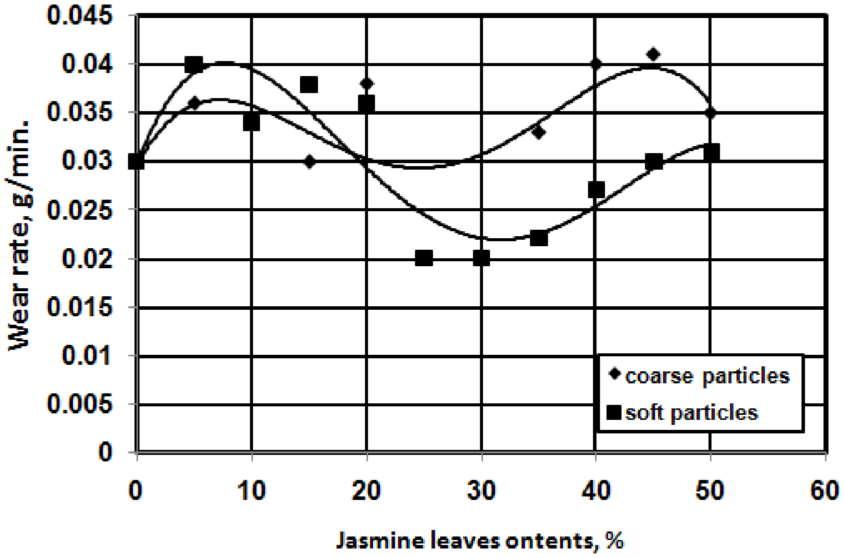


Fig. 9 Effect of jasmine leaves particles on the wear rate of polyester composites.

Figure 10 shows the stress-strain curve for polyester free of agricultural wastes, as shown in this figure, the ultimate stress of polyester is approximately 60 N/mm^2.

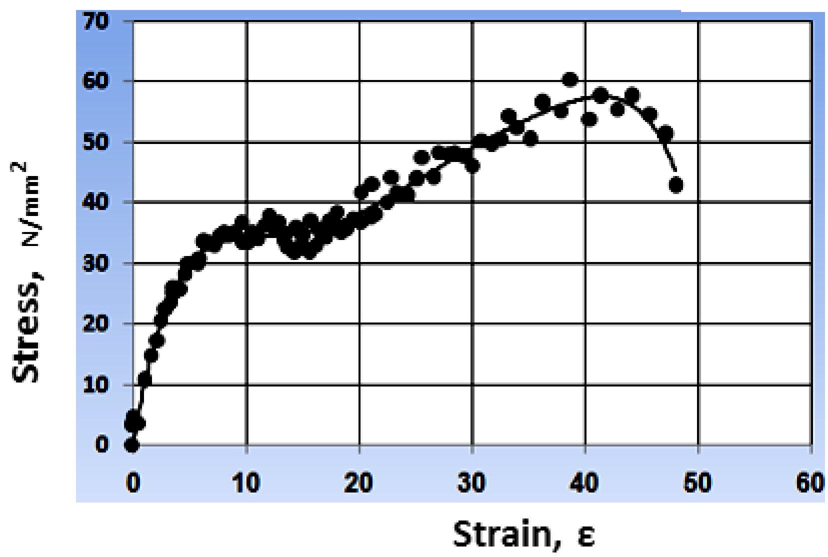


Fig. 10 Stress – strain curve for polyester free of jasmine leaves.

As represented in Fig. 11 increases of jasmine leaves in polyester composite increase the ultimate strength for polyester composite to more than 110 N/mm^2 for composite filled by 5% soft particles of jasmine leaves wastes; beside slightly increases of ultimate strength to 72 N/mm^2 for composite filled by 5 % coarse particles of jasmine leaves.

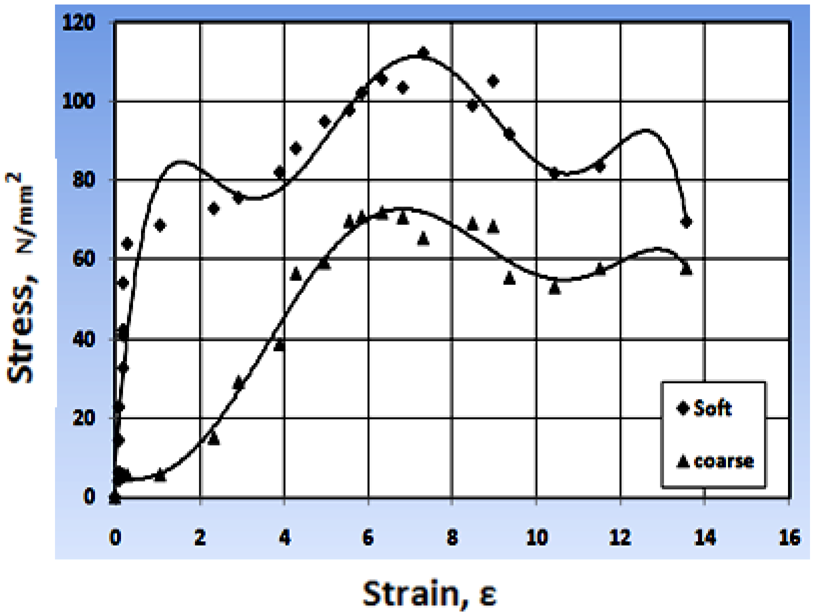


Fig. 11 Stress – strain curve for polyester composite filled with 5 wt. % jasmine leaves.

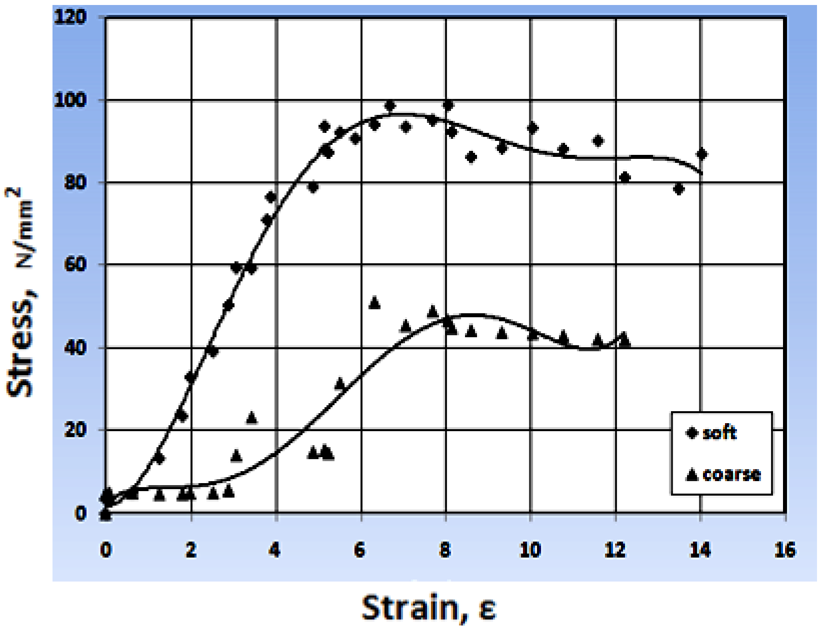


Fig. 12 Stress – strain curve for polyester composite filled with 30 wt. % jasmine leaves.

Figure 12 shows that increase of wastes to 30 wt. % increases the ultimate strength of polyester composites from 60 N/mm^2 to more than 90 N/mm^2 for composites filled by soft particles of wastes. But on the other hand, increase of coarse particles of jasmine leaves in polyester composites to 30 wt. % decreases the ultimate strength to 48 N/mm^2, which mean that the composite become weaker than free polyester. Polyester composites

filled by 50 wt. % soft particles of jasmine wastes have ultimate strength of 85 N/mm^2. Besides, the increase of the content of coarse particles of wastes in composites to 50 wt. % make the composites weaker than free polyester as shown in Fig. 13.

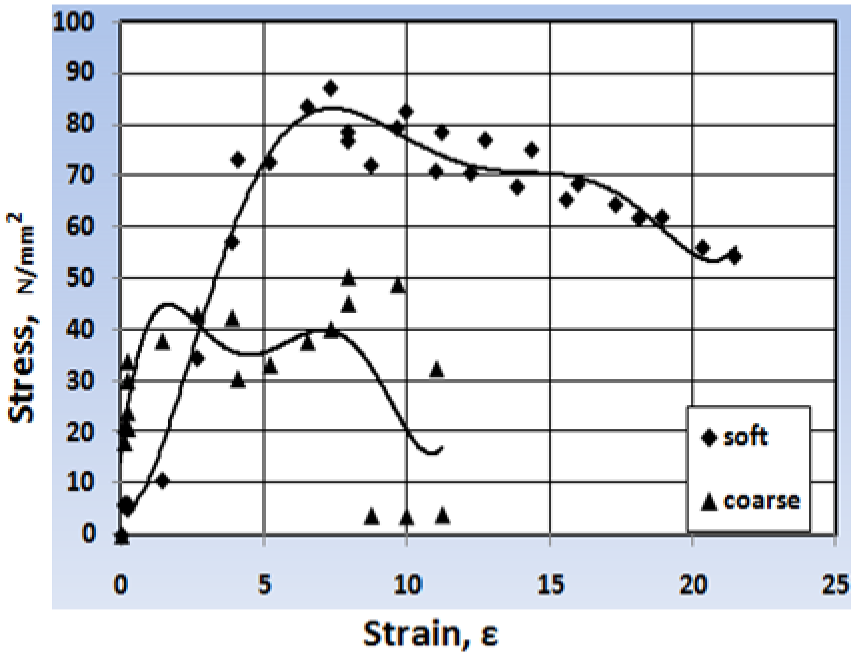


Fig. 13 Stress – strain curve for polyester composite filled with 50 wt. % jasmine leaves.

CONCLUSIONS

From this work, it can be concluded that:

1. **The friction coefficient of polyester decreases with the increase of corn straw content in the polyester composites.**
2. **Wear rate of polyester composites decreases to 0.005 g/min. with increase of corn straw contents to 40 wt. %.**
3. **The mechanical behavior of polyester can be improved by adding corn straw particles to polyester in form of coarse particles by 5 wt. % of the composite weight.**
4. **Use of agricultural wastes (corn straw) can improve the mechanical and tribological behavior of polyester composites that can be used in industrial applications.**
5. **The friction coefficient of polyester composite increases with increasing the content of coarse particles of jasmine leaves in composites under low loads.**
6. **Increase of soft particles of jasmine leaves in polyester composites remarkably decreases the rates of wear for proposed composites.**
7. **Polyester composites filled with jasmine leaves were recommended as high friction and low wear rates material for industrial applications such as brake linings.**
8. **Addition of jasmine leaves improves the mechanical behavior of polyester composites.**

9. Ultimate strength of polyester composites increases remarkably to 110 N/mm^2 and 90 N/mm^2 with increasing the content of soft particles of jasmine leaves in polyester composites to 5 wt. % and 30 wt. % respectively.
10. Increasing the content of coarse particles of jasmine leaves in composites to 50 wt. % makes the composites weaker than free polyester.

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