

CREEP CHARACTERISTICS OF POLYESTER COMPOSITES WITH NATURAL FIBER REINFORCEMENT (HORSE HAIR/SHEEP WOOL)

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ABSTRACT: In this paper, experimental, theoretical, and numerical simulations were used to investigate the effect of adding natural fiber (Horsehair/Sheep wool) with varied weight ratios to polyester composite material on creep behavior at room temperature and constant load. A hand-layup technique was used to create polyester resin, and the test specimens were produced following the standards (ASTM). The results showed an improvement in creep behavior of polyester composites reinforced with natural fibers when compare with non-reinforced polyester, hence the amount of maximum strain was reduced to 74.64% when sheep wool was added at a weight ratio of 0.8%, and 71.114% when horsehair was added at the same weight ratio. The experimental results were verified theoretically and numerically using ANSYS Mechanical APDL software 15, the results demonstrate that they are in good agreement.

KEY WORDS: polyester composite, hand-layup, horsehair, sheep wool, ANSYS APDL, creep behavior.

1 INTRODUCTION

Recently, people are increasingly relying on composite materials and employing them in a variety of ways. Natural fiber composite materials are environmentally benign, lightweight, robust, renewable, affordable, biodegradable, and long-lasting. When compared to synthetic fiber, natural fiber offers better qualities. Natural fibers have recently attracted interest as an alternative reinforcement in polymer composites due to their benefits over standard synthetic materials [1]. The economic and bio-degradable benefits of natural fibers along with similar mechanical properties and chemical resistant are tested and defined by natural fibers to make them suitable for traditional fibers such as carbon, glass, and Kevlar fibers [2–7]. Fibers extracted from natural resources, such as minerals, animals and plants, are natural fibers. Animal fiber contains proteins, for example, wool, mohair, alpaca and silk. The hair of

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animals is collected in the form of fibers. Animals such as sheep's fur, goat's hair, horse hair, alpaca hair, etc. [8] their accessibility, inexpensiveness, low density, and renewability as well as adequate mechanical capacity make them an eye-catching ecological replacement for coal, glass and man-made fibers traditionally used for composite manufacturing.

Somashekar et al. [9] combined the advantages of natural and synthetic fibers by the creation of hybrid composites with varying quantities of fibers and thorough performance analysis by means of various mechanical tests. As per ASTM standards, such as tensile, compression and flexural, by varying proportions of fibers. The findings obtained suggest that natural fiber composites were equal to or greater than synthetic fibers such as glass fibers.

Choudhry et al. [10] researched of the mechanical behavior of polypropylene composites Reinforced with human hair fibers at (3, 5, 10, and 15 percent wt), reinforced polypropylene and hair fiber polymer composites shows higher flexural and Izod impact strength than polypropylene and lower tensile strength.

Oladele et al. [11] investigated the effect of chemical treatment on the mechanical behavior of animal fiber reinforced with polyethylene composites. Used chicken feathers and cow hair were used as animal fibers. Both segments were then using to reinforce the polyethylene polymer at (2, 4, 6, 8, and 10 %) fiber loading , chemically treated cow hair and chicken feathers reinforced polyethylene composites have been shown to have the better flexural properties compared to their untreated animal fiber reinforced polyethylene composites for most fiber loading percentages. Naik et al. [12] investigated the effect of horse hair on cement concrete in terms of its compressive, flexural strength, crushing, , crack and heat resistant to save concrete and to minimize environmental issues. Experiments were carried out on concrete beams and cubes with different percentages of horse hair fiber, namely (0%, 1%, and 2%) by weight of cement. The mechanical properties of one beam and three cubes are checked for each combination of concrete proportions. We discovered that adding horse hair as fiber reinforcement to concrete enhances its various properties and strength, as well as its heat resistance, through testing of cubes and beams. Abed and Battawi [13] investigated the creep behavior of polystyrene composites reinforced with natural fiber at various weight fractions, constant loads, and temperatures. Hand layup was used to establish the fabrication setup for composite materials. Maxwell techniques were utilized to derive the stress and modulus of elasticity from the strain-time curve using curve-fitting methods. Abed et al. [14] evaluated the creep behavior of an epoxy composite material filled with Y_2O_3 powder at various weight ratios while maintaining the temperature constant. Each volume ratio was subjected to five loads ranging from 1 N to 5 N. Creep behavior, stress, and elasticity modulus were studied using both experimental and computational methods.

1.1 SHEEP WOOL CHARACTERIZATION

Wool is a natural protein fiber derived from sheep's fleece. A single wool fiber consists of a cortex and a surrounding cuticle layer, making it one of the most complex structures among textile fibers (Fig. 1) [15].

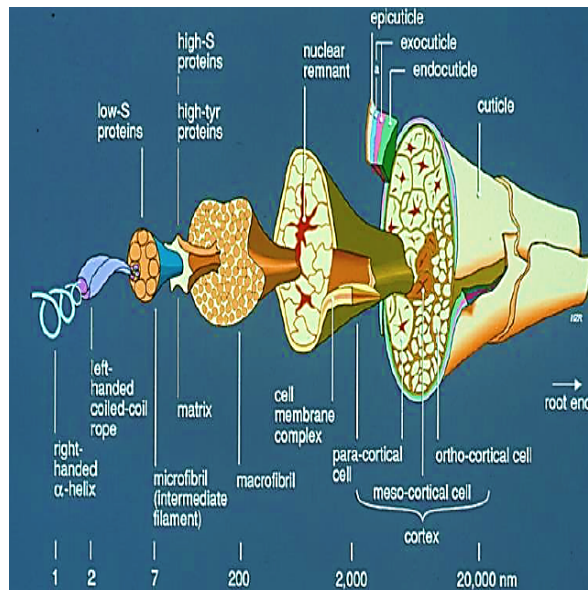


Fig. 1: Schematic illustration of wool fibers structure [15].

The use of wool in composite material manufacture is both ecological and environmentally benign, as it encourages recycling [15]. Wool might be a promising marketing tool as well as a reliable raw source if used creatively. Furthermore, alternate uses for wool may result in a new product entering the market, transforming it into a worthy and successful competitor. Compared to insulating materials used in industry [16].

1.2 HORSE HAIR CHARACTERIZATION

Horse hair is long, coarse hair that grows on horses' manes and tails (Fig. 2). Upholstery, brushes, musical instrument bows, and a hard-wearing fabric known as hair cloth are only some of the applications. The hair of a horse is rigid, fine, and flexible. It's a protein fiber that takes a long time to absorb water. The use of horse hair as a reinforcement material is a novel attempt because it requires a creative waste disposal process. Because of its resistance to stretching, compression, and high strength, it can be used as a reinforcement material.



Fig. 2: Horse hair.

The objective of this work is investigate the effect of natural fiber (sheep wool and horse hair) as a reinforced filler on polyester composite to analysis the creep behavior through experimental, theoretical and numerical simulation.

2 THEORETICAL PART

In order to calculate the theoretical composite materials properties, several equations were applied:

$$(1) \quad \sigma_0 = 1 \text{ Mpa}, \quad \varepsilon_0 = \frac{\sigma_0}{E}, \quad \varepsilon(t) = \varepsilon_0 + C_1 \sigma^{C_2} t^{C_3}.$$

Total strain is given by

$$(2) \quad \varepsilon = \varepsilon_0 + \varepsilon^C = \varepsilon_0 + C_1 \sigma^{C_2} t^{C_3},$$

where ε_0 is the initial strain, E – Young modulus, σ_0 – the initial stress, ε^C – strain at any time, t – time in second, C_1 , C_2 , and C_3 – creep constants.

The creep constants, initial strain, Young modulus for each composite material weight ratio are summarized in Tables 1 and 2 for sheep wool and horse hair, respectively.

Table 1: Characteristic of sheep wool/polyester composite

Add. %	E_0 (MPa)	ϵ_0	C_1	C_2	C_3
0	34.592	0.043	1.7	0.6	0.32
0.2	90.558	0.064	0.9	0.6	0.315
0.4	62.195	0.024	0.85	0.6	0.3
0.6	135.428	0.011	0.48	0.6	0.34
0.8	60.685	0.023	1.4	0.6	0.218

Table 2: Characteristic of horse hair/polyester composite

Add. %	E_0 (MPa)	ϵ_0	C_1	C_2	C_3
0	34.592	0.043	2	0.6	0.301
0.2	76.178	0.0196	0.98	0.6	0.27
0.4	66.822	0.0224	1	0.6	0.27
0.6	114.129	0.013	0.728	0.6	0.278
0.8	67.658	0.0221	1.5	0.6	0.182

3 EXPERIMENTAL WORK

3.1 PREPARATION OF HORSE HAIR AND SHEEP WOOL

Sheep wool and horse hair are gathered from local sources. It is a fiber that is readily available and inexpensive in Iraq.

To eliminate impurities and dirt, the wool was washed in a Steel basin for 15 minutes with warm water 40°C and cleaner. The clean wool was rinsed for 5 minutes to remove any cleaner residue before exposure to the sun for at least 24 hrs. The washed and dried sheep wool is shown in Fig. 3. To ensure a uniform distribution of wool fibers in the matrix of the composite materials, the dried wool was trimmed to 8 cm long. In the other hand horsehair (tail) (Fig. 4) is not subjected to any treatments other than cleaning and set its size also to 8 cm long.

Wool yarns and horse hair are weighed with a sensitive scale to obtain the weight ratios used in this research, and they are as follows: (0.2, 0.4, 0.6, and 0.8%).

3.2 PREPARATION OF MOLD AND MANUFACTURING OF CREEP TEST SPECIMENS

Hand layout method was used to fabricate models and specimens of horse hair and sheep wool reinforced composites, since it is the simplest procedure to use and the most efficient way to produce specimens in various shapes and sizes. This procedure



Fig. 3: Sheep wool.

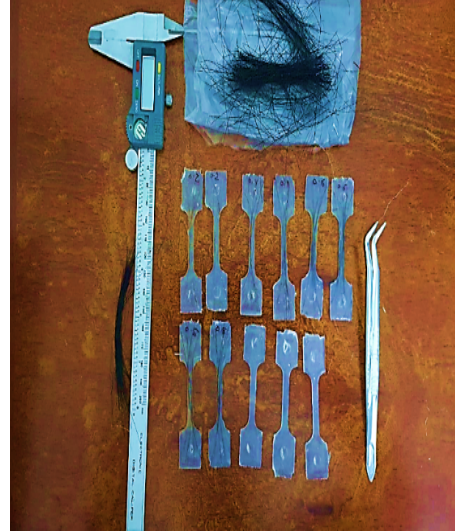


Fig. 4: Horse hair.

includes the steps listed below:

1. Clean both the interior surfaces of a prepared rubber mold of dimension $21 \times 30 \times 1.5 \text{ cm}^3$ with a brush to eliminate dirt and other contaminants.
2. For easy removal and a fine surface finish on the product, a mold release agent (silicon spray) was sprayed all over the mold surface.
3. The granules of polystyrene (PS) are dissolved in chloroform and then mixed with magnetic stirring. After it had been made separately, liquid polyester (up) was added and agitated for 3 hrs. The up/ps ratio is (92:8) [13].
4. Un-saturated polyester is used as a matrix, which is a viscous liquid, that's turned into a solid state by mixing with the hardener (K-6) (according to the supplier's specified percentage (10:1)) added to the solution and agitated for 15 minutes.
5. The fibers (horse hair/ wool) are placed inside the mold as a first layer based on the weighed amount.
6. Next, a sufficient amount of mixing resin and hardener was poured into the mold, and a brush was used to blend the material throughout all of the mold's surfaces.

7. Fibers and matrix were distributed uniformly throughout the specimen, which was carefully monitored.
8. Then specimens were allowed to cure for 48 hrs. At room temperature, there-after carefully removed from the mold (Fig. 5). Same procedure are repeated for other percentage ratios of fibers.

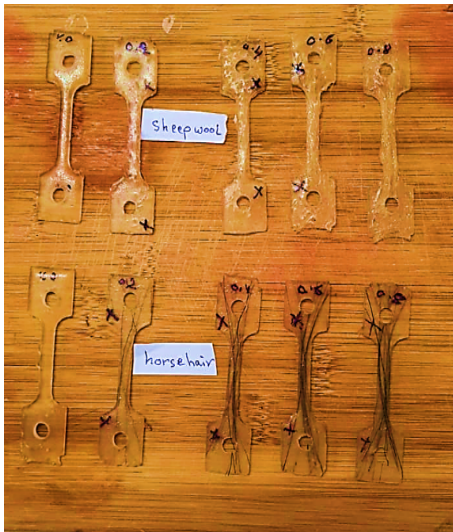


Fig. 5: Creep specimens.



Fig. 6: Creep testing machine.

3.3 CREEP TEST

Creep tests were carried out according to ASTM (D2990) using the creep testing machine type (WP600) as shown in Fig. 6. These tests were mainly carried out at a constant temperature of 18°C controlled with the assist of temperature controlling system, with a static load of 1 N. Steel wire and turnbuckle arrangements are mainly used to apply loads. The strain rate of specimens is recorded using a digital strain meter.

4 FINITE ELEMENT ANALYSIS

The ANSYS Mechanical APDL software 15 package has a well-deserved reputation for technology, quality, and dependability, and it offers a powerful and comprehensive solution for both regular and complicated linear and non-linear engineering issues. ANSYS provides a unified FEA environment that is an appealing alternative to

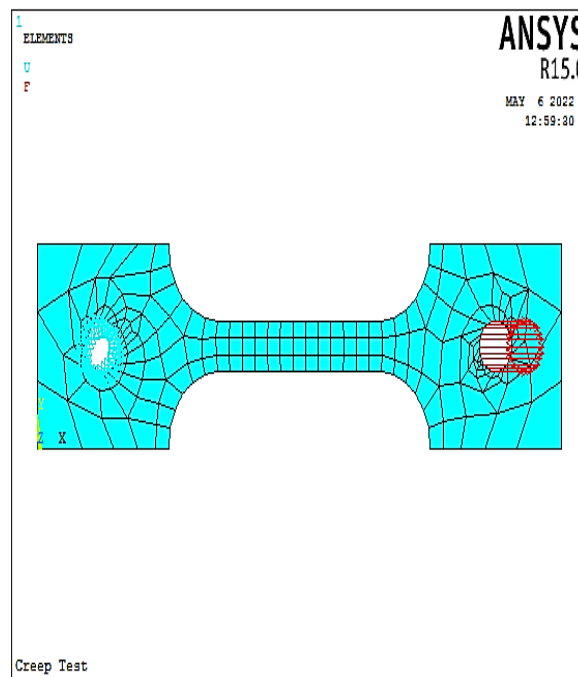


Fig. 7: Creep specimen with an appropriate mesh.

multi-product, multi-vendor solutions. The material was assumed to be isotropic in nature when performing finite element analysis. In this work, finite element analysis is utilized to investigate the creep behavior of polyester composite reinforced with sheep wool and horse hair with different volume ratio at constant condition the element type that was employed in this study is PLANE182 adequate for predicting creep behavior. Experimental data were used to determine the values of young modulus and poisson ratio. Specimen model was meshed with an appropriate mesh figure. Figure 7 shows a FEA model, and the boundary and load conditions used were similar to those used in the experiment. The model is solved, and finally the strain versus time for each volume ratio model is plotted.

5 RESULTS AND DISCUSSION

The creep behavior (strain vs. time curve) was investigate in this study for two materials groups, initially, for polyester composite reinforced with Horse hair. Secondly, polyester composite reinforced with sheep wool. Using different weight ratios (0, 0.2, 0.4, 0.6, 0.8%) with ambient temperature of 18°C and constant load (1 N), to understand the processes of deformation that occur. Creep is dependent on the time

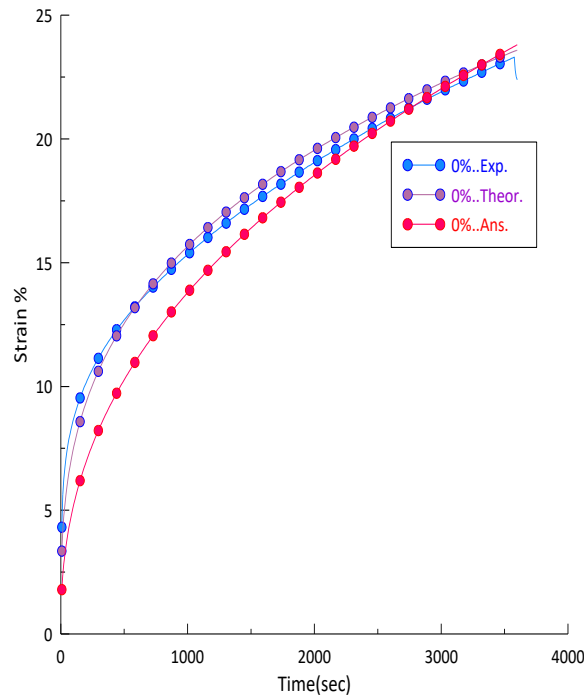
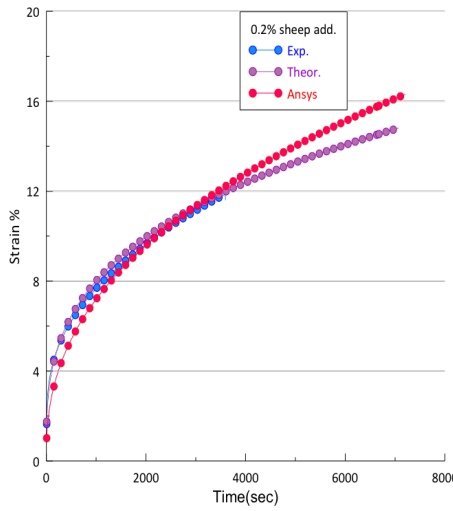


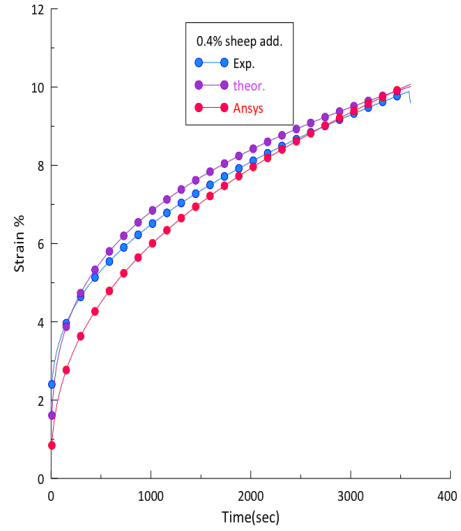
Fig. 8: A comparative between experimental, numerical and theoretical results of creep behavior with 0% weight ratio of natural fiber.

that the applied stress is applied as well as the value of the applied stress. Figures 8 to 10 explain the effect of adding natural fiber weight ratios (horse hair and sheep wool) to polyester composites on creep behavior (strain-time) based on experimental, numerical and theoretical results. It was observed that adding natural fiber to a polyester composite material improved its creep behavior, this is evidenced by the lower values of strain of polyester resin reinforced with natural fibers in contrast to that of non-reinforced polyester resins.

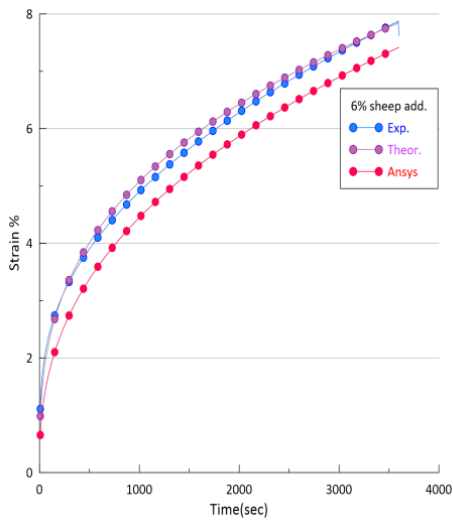
Based on the experimental results, a pure polyester sample has a creep strain of 23.306; however, with the addition of horse hair fiber at weight ratios of 0.2%, 0.4%, 0.6%, 0.8% to the polyester resin, this number reduced gradually to 8.79, 8.9, 7.06, and 6.725. When sheep wool was added to the resin, the creep strain was lowered to 11.86, 9.887, 7.867, and 5.91 by the same weight ratios as compare with pure polyester. The summary of maximum creep strain values in experimental, theoretical and numerical results for different weight ratios of Horse hair/ sheep wool are listed in Table 3.



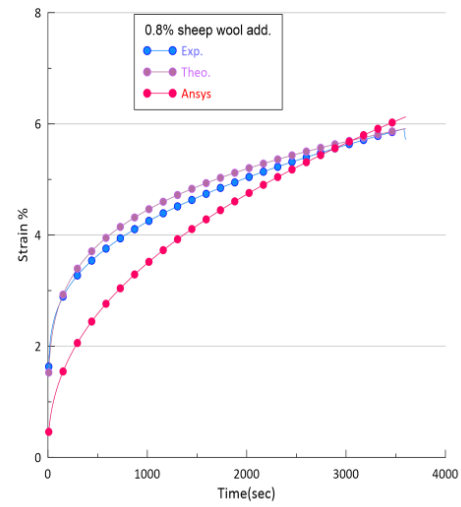
(a)



(b)



(c)



(d)

Fig. 9: A comparative between experimental, numerical and theoretical results of creep behavior with weight ratios of sheep wool: (a) 0.2%; (b) 0.4%; (c) 0.6%; and (d) 0.8%.

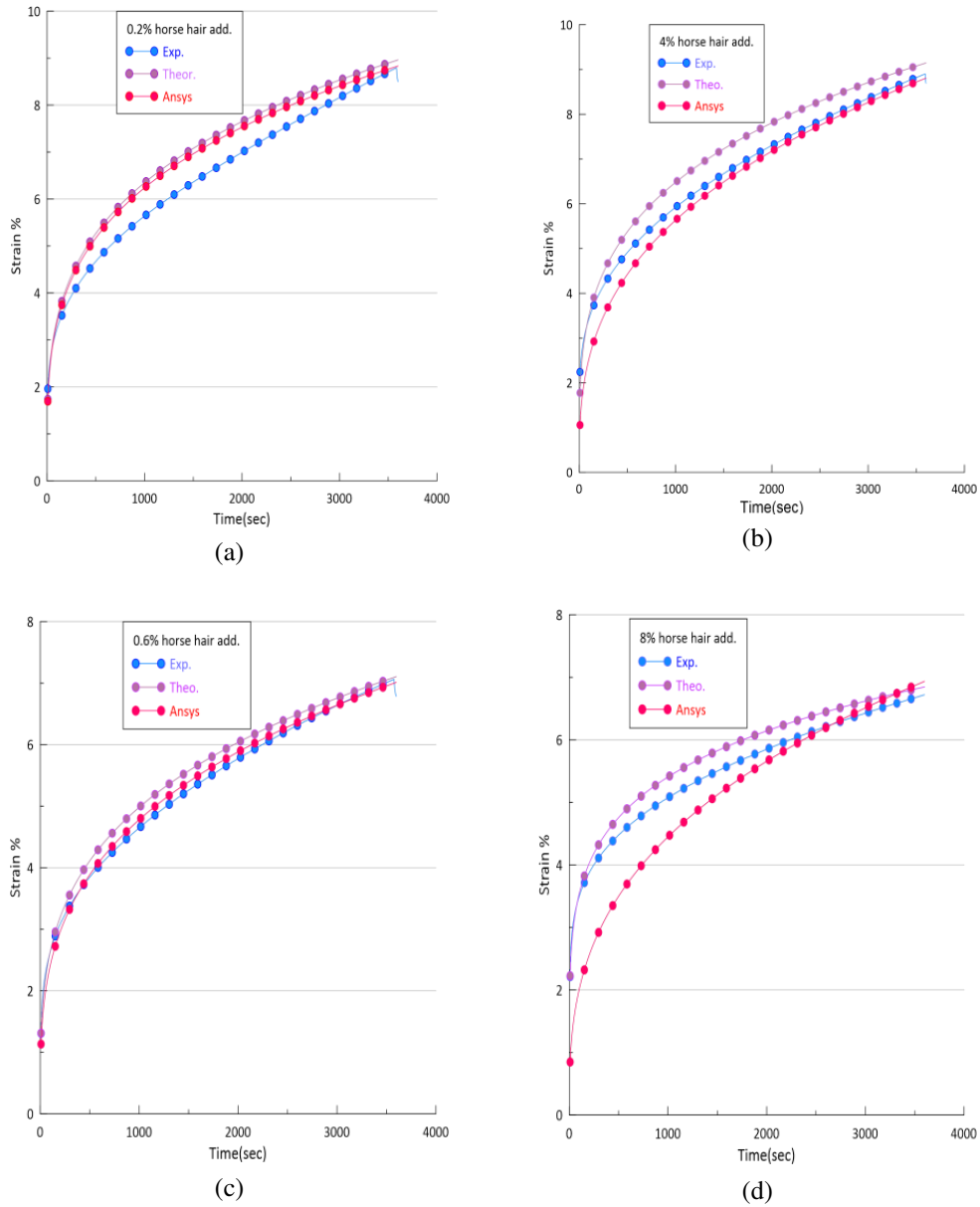


Fig. 10: A comparative between experimental, numerical and theoretical results of creep behavior with weight ratios of horse hair: (a) 0.2%; (b) 0.4%; (c) 0.6%; and (d) 0.8%.

Table 3: Comparison of max. creep strain values in experimental, theoretical and numerical results

W.r. (%)	Experimental		Theoretical		Numerical	
	horse hair	sheep wool	horse hair	sheep wool	horse hair	sheep wool
0	23.306		23.525		23.736	
0.2	8.79	11.86	8.95	11.981	8.82	12.215
0.4	8.9	9.887	9.14	10.001	8.79	10.055
0.6	7.06	7.867	7.09	7.836	6.99	7.405
0.8	6.725	5.91	6.84	5.909	6.93	6.114

According to the above results, it is apparent that when natural fiber is added to polyester resin, the creep strain was restricted since the structure becomes stiffer with a sufficient strength.

Also it is found that numerical simulation of creep strain can be satisfactorily with the experimental results. Figure 11 demonstrates finite element model of creep sample for pure polyester with max strain 23.736. Figure 12 depicts FEM of creep

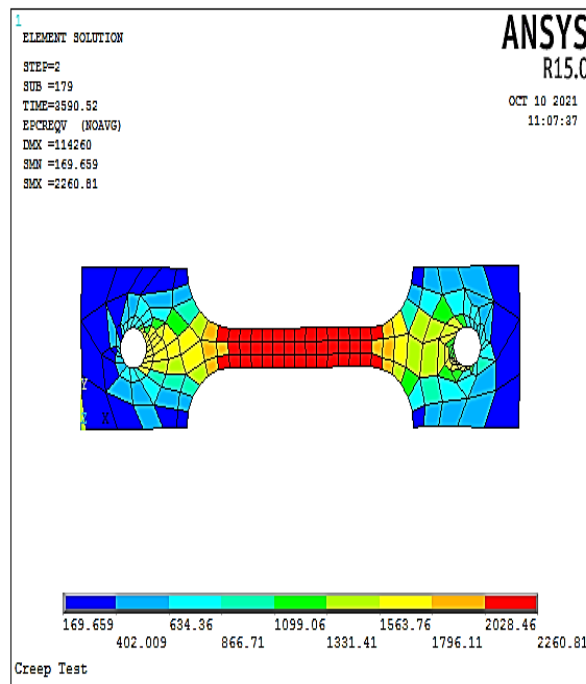


Fig. 11: Numerical results of creep behavior with 0% weight ratio of natural fiber.

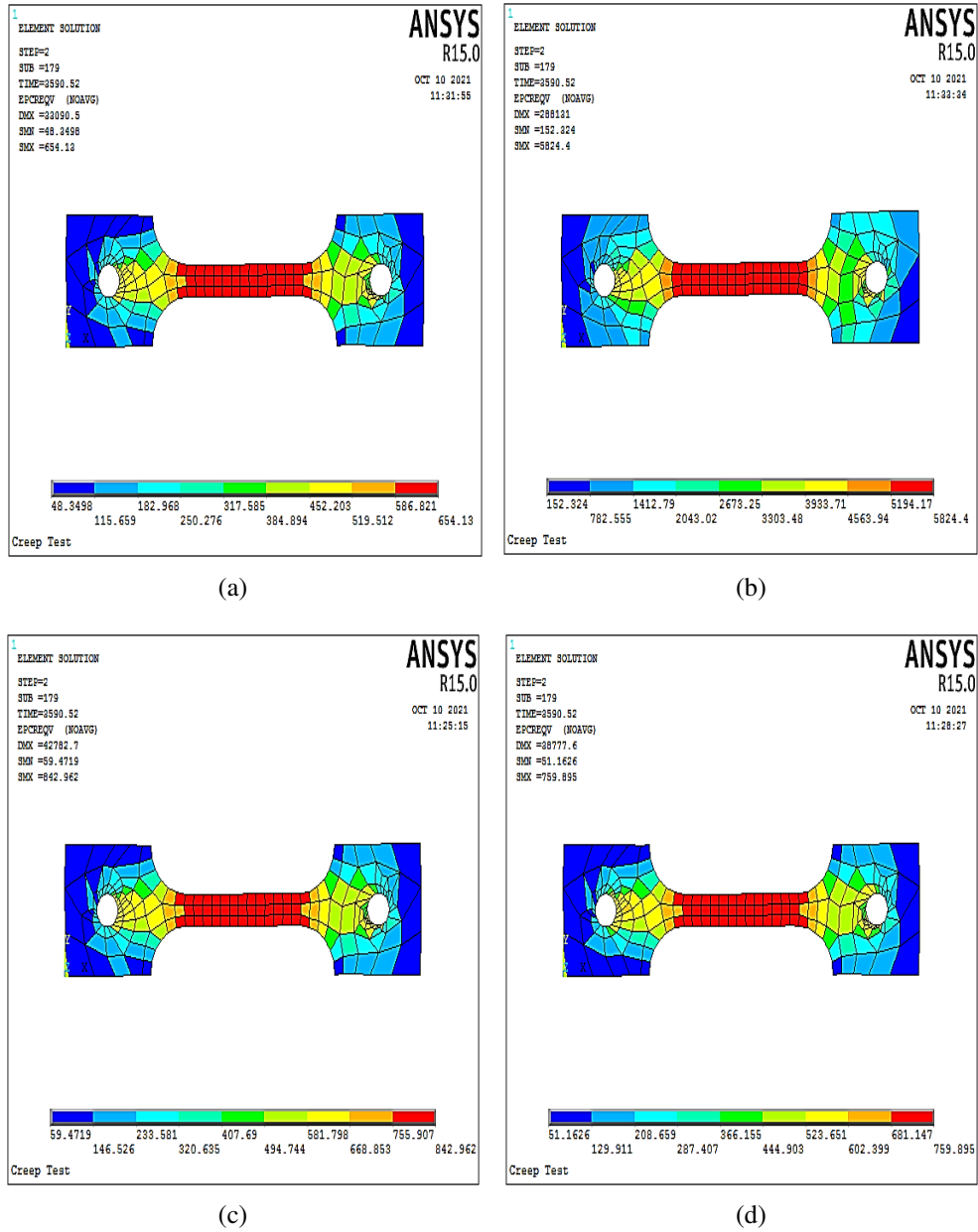
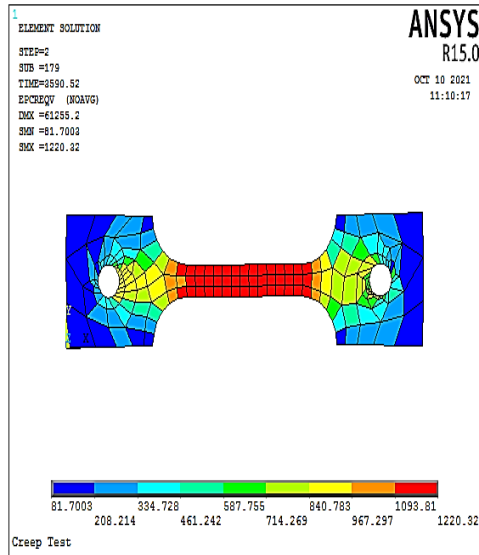
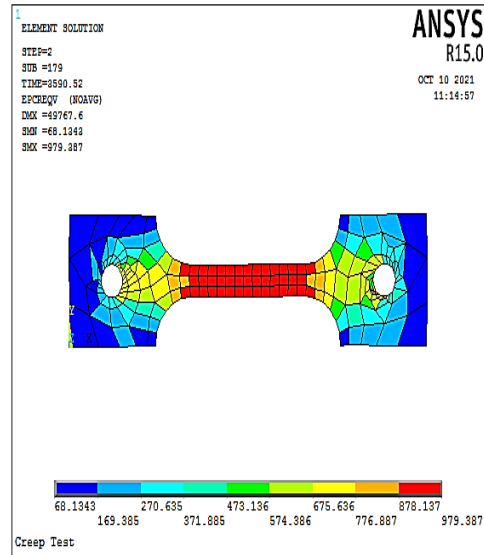


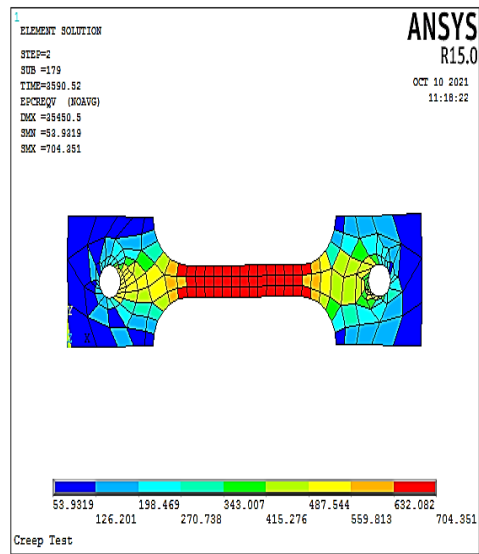
Fig. 12: Numerical results of creep behavior with weight ratios of horse hair: (a) 0.2%; (b) 0.4%; (c) 0.6%; and (d) 0.8%.



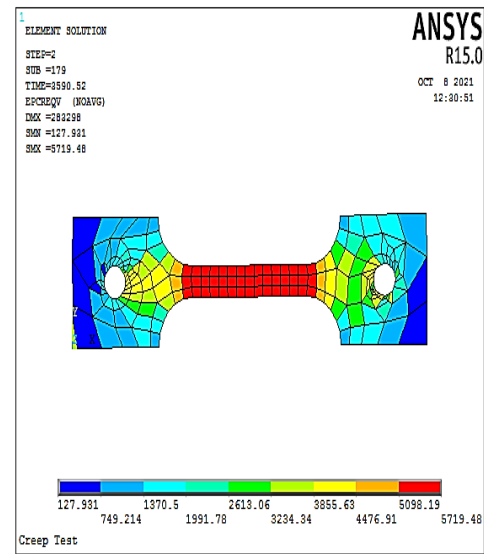
(a)



(b)



(c)



(d)

Fig. 13: Numerical results of creep behavior with weight ratios of sheep wool: (a) 0.2%; (b) 0.4%; (c) 0.6%; and (d) 0.8%.

sample with weight ratio 0.2%, 0.4%, 0.6%, and 0.8% of Horse hair with decreasing the max. Strain to 8.82, 8.79, 6.99, and 6.93. And Figure 13 depicts FEM of creep sample of sheep wool with decreasing the max strain to 12.215, 10.055, 7.405, and 6.114 by the same weight ratios.

Furthermore, it was found that the simulated and experimented creep strain compliance can be approximately fitted by a power-law function.

6 CONCLUSIONS

Experimental, theoretical, and numerical results were used to explore the efficacy of adding natural fibers from two distinct types of horse hair and sheep wool as toughening agents in polyester resin composites in terms of creep behavior. The study's most important conclusions are as follows:

1. The Creep strain decreased with increasing the weight ratios of natural fibers.
2. When compared to pure polyester, the creep strain behavior of horse hair fiber was improved (62.28%), (61.81%), (69.7%), and (71.114%) for weight ratios (0.2, 0.4, 0.6, 0.8%), and sheep wool was reduced to (49.11%), (57.57%), (66.25%), and (74.64%) for the same weight ratios.
3. The best percentage of creeping strain reduction was found at the weight ratios of 0.8% for each of horse hair and sheep's wool compared to pure polyester, and by comparing the same natural fibers, we find that sheep's wool exhibits more decrease than horse hair compared to pure polyester for the same mentioned percentage by 74.64% for sheep's wool and 71.114% for horse hair
4. Numerical simulation using ANSYS Mechanical APDL as well as theoretical studies backed up these findings.
5. A good agreement was found between the results of experimental, theoretical, and numerical investigations.

Horse hair and sheep wool are organic materials that are renewable and have a low negative environmental impact and might be used to replace synthetic materials.

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