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Effect of Immersion Media for Polyester Composite Reinforced with Chicken Feathers on Creep Behaviour

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The use of composite materials has expanded in industrial applications around the world, reinforcing composites with waste materials like chicken feather is one of the effective ways to solve environmental concerns compared to traditional methods, as it is considered one of the renewable and inexpensive methods, in addition to its presence in abundance. The main added feature of composite materials over classic materials are the light weight. This paper investigates the effect of immersion media for a polyester composite reinforced with chicken feather fillers to enhance the creep characteristic. The composite was manufactured using a hand-layup process. The samples were produced by varying the weight ratios of fibre loading (0 %, 0.2 %, 0.4 %, 0.6 %, and 0.8 %) and immersed in three different media (KCl (salt media), NaOH (alkali media) and HNO_3 (acid media)). The creep samples were tested according to ASTM standards. The results show that chicken feather-reinforced composites immersed in various media have probable applications because of their superior mechanical properties over non-reinforced composites.

Keywords: immersed, chicken feather, polyester composite, creep behaviour, reinforcement

Highlights

- *In this study, three different media were used to immerse polyester composites*
- *When compared to standard methods, reinforcing composites with waste materials such as chicken feathers is one of the most effective approaches to address environmental concerns.*
- *This study looked at the effect of creep behaviour on a polyester composite reinforced with chicken feather; there are few investigations on this type of test exist in comparison to when compared to the other mechanical properties.*

0 INTRODUCTION

Due to disposal and pollution, chicken feather fibres have a prevalent concern. This has a severe influence on the environment; however, current study reveals that chicken feather waste may be used as reinforcement instead of being burned [1]. However, industries are primarily concentrating on the notion of sustainable manufacturing, which involves limiting the use of non-renewable resources and implementing environmentally friendly material processes, such as waste recycling and reuse. Composite materials are manufactured for this purpose, and substantial study is being out by researchers in many regions of the world. [2] and [3]. Chicken feathers comprise 91 % protein (keratin), 8 % water and 1 % lipids [4].

Several attempts had been made throughout the past decades to evaluate the potential of chicken feathers as reinforcements in applications of composite materials. Abed et al. [5] investigate the creep behaviour of an epoxy composite reinforced with Yttrium Oxide Powder at different weight ratios. Each volume ratio was subjected to five loads at a steady temperature. The creep behaviour of epoxy composite was studied using both experimental and computational methods.

Šafarič et al. [6] evaluated the use of wood waste with poultry feather waste to produce natural insulating fibreboard composite. The fibreboard composite was set using various amounts of poultry feather waste (20 % to 70 %) and wood waste, resembling mixed wood remains or wood shavings. The thermal and mechanical properties were studied, along with their biodegrading abilities. Oladele et al. [7] utilized brown chicken feather fibres to reinforce polyethylene as a substitution for synthetic fibres to improve mechanical properties of polyethylene, using varying ratios of fibre (2 wt.%, 4 wt.%, 6 wt.%, 8 wt.% and 10 wt.%) with the polyethylene matrix. The flexural modulus and tensile properties for each ratio were studied. In addition, scanning electron microscopy (SEM) and X-ray diffraction (XRD) were performed.

Abed and Battawi [8] investigated the creep behaviour of polystyrene composites reinforced with natural fibre at various weight fractions, constant loads, and temperatures. Hand layup technique was used to build the manufacturing 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.

Reddy et al. [9] showed that chicken feathers could be used as a matrix to build total biodegradable

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composites with properties comparable to those of polypropylene composites, even using jute fibre reinforcements. Using feathers as a matrix allows for 100 % biodegradable composites containing feathers or other bio-polymers as reinforcement at a low cost.

Amieva et al. [10] explored extrusion-processed chicken feathers for making recycled polypropylene compounds. The specimen density and thermal, morphological, and thermo-mechanical properties were assessed. The density of the composite material was lower than that of the non-recycled material. When compared to polypropylene compounds, the transition temperature of the composite materials remained unchanged.

The influence of creep behaviour on polyester composite reinforced with chicken feather was the subject of this research. In comparison to the rest of the mechanical properties, there are few studies on this type of test.

1 EXPERIMENTAL

1.1 Preparation of Fillers

The chicken feathers were gathered from poultry production units. They were first cleaned with ethanol, then washed five times with tap water and exposed to the sun for two days until they dried entirely. The dried chicken feathers were trimmed with scissors to separate the avian fibres (barbs) from the quill (rachis) portion of the feathers, as shown in Fig. 1. The average size of 1 cm was considered for chicken feather samples.

Fig. 1. *Dried feathers*

1.2 Sample Fabrication

Polystyrene (Ps) granules were dissolved by adding chloroform and mixing with a magnetic stirrer. Liquid polyester (Up) was prepared separately and added to the Ps mixture at a 92:8 ratio of polyester to polystyrene and stirred for 3 h [8]. Thereafter, an appropriate hardener (K-6) was added to the solution in the recommended proportion (10:1) and stirred for 15 min. A rubber mould was initially gently washed, and liberated from moisture and dust. A thin layer of wax was then added along with its base plate to the inner walls of the rubber mould for quick removal of the cast after drying. Previously prepared avian fibres (dried chicken feathers) were laid longitudinally inside the mould with weight ratios (0 %, 0.2 %, 0.4 %, 0.6 %, and 0.8 %). The Up-Ps resin mixture was then poured over them using a hand lay-up method. Care was taken to prevent air bubble formation. Samples were kept in the mould for 18 h and subsequently placed in an oven at 55 °C for 3 h to rid the moisture.

1.3 Immersion Media

In the present work, samples were immersed in different media, as salt media (KCl), alkali media (NaOH), and acid media (HNO_3), as shown in Fig. 2, at a rate of 5 % for 4 h. The samples were then washed with tap water and left to dry. Fig. 3 illustrates a creep sample of Up-Ps reinforced with different weight ratios of chicken feathers and immersed in the three media.

Fig. 2. *Samples immersed in different media*

1.4 Testing

The creep characteristics of the Up-Ps composites were estimated by creep testing. The tests were conducted according to ASTM D2990 [8] at a constant temperature of 21 °C using the creep testing machine model WP600, as shown in Fig. 4. A total of 45 creep tests were performed for all volume ratios (0 %, 0.2

%, 0.4 %, 0.6 %, and 0.8 %). Each ratio was tested three times to obtain an average. The load was applied for 1 hour, then removed, and readings were taken continuously for another hour.

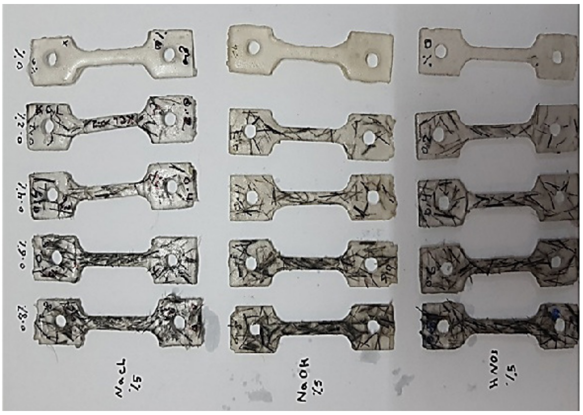

Fig. 3. *Creep sample of Ps-Up reinforced*

Fig. 4. *Creep testing machine (WP600) with chicken feathers*

2 RESULTS AND DISCUSSION

A creep test was used to determine the mechanical properties (strain, stress, and modulus of elasticity) of the polyester composites reinforced with chicken feathers at 0.2 wt.%, 0.4 wt.%, 0.6 wt.%, and 0.8 wt.% and immersed in the three different media (salt, alkali, acid) at 26 °C atmospheric temperature. All the samples successfully carried the equivalent load for 1 hour. For the estimation, three samples were examined for mechanical properties, and the values were averaged.

Curve-fitting techniques, as shown in Fig. 5, were used for the extraction of stress and modulus of elasticity)from the strain-time curve using the Maxwell method (spring and dashpot in series) **[11]**.

$$\sigma(t) = \sigma_0 e \frac{-\delta_1 \cdot t}{\eta_1}, \qquad (1)$$

$$\delta_1 = \frac{\sigma_0}{\varepsilon_1}, \qquad (2)$$

$$\eta_1 = \frac{\sigma_0}{\tan\beta}, \qquad (3)$$

$$\varepsilon^- = \tan\beta = \frac{\Delta\varepsilon}{\Delta t} \cdot \frac{1}{S}, \quad \text{where } \varepsilon = \frac{\Delta L}{L}, \qquad (4)$$

$$E(t) = \frac{\sigma(t)}{\varepsilon(t)} = \frac{\delta_1 \cdot \eta_1}{\eta_1 + \delta t}, \qquad (5)$$

$$\varepsilon(t) = \frac{\sigma}{\varepsilon_1} + \frac{\sigma}{\eta_1} t. \qquad (6)$$

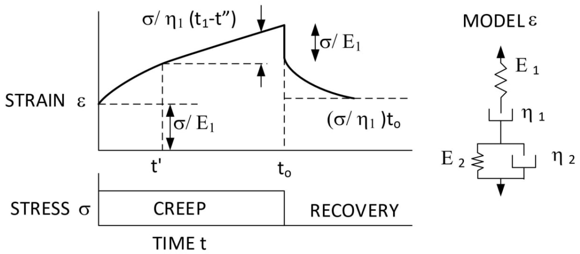

Fig. 5. *Maxwell method (spring and dashpot in series)*

2.1 Immersion in Salt Medium

Fig. 6 demonstrates creep behaviour (strain vs time) in KCl. The composite with 0.6 wt.% chicken feathers performed better than the other weight fractions in the salt medium, which yielded an 86.2 % enhancement in strain compared with pure polyester. All the reinforced composites showed a decrease in strain compared to the non-reinforced composite. The 0.4 wt.% chicken feather composite had the least strain among the reinforced composites, resulting in 47.6 % when compared to pure polyester. The deformation was seen to develop in three distinct stages: elastic, yielding, and a plastic deformation zone.

The stress vs time graphs for all reinforcements in salt media are shown in Fig. 7. The composite with 0.2 wt.% of chicken feathers achieved the highest percentage of stress (100.05 % stress improvement over pure polyester) in the salt media compared with other weight fractions. The composite with 0.4 wt.% achieved only 99.998 %, the lowest percentage of the weight fractions, which indicates that immersing in KCl enhance the creep behaviour of the composites.

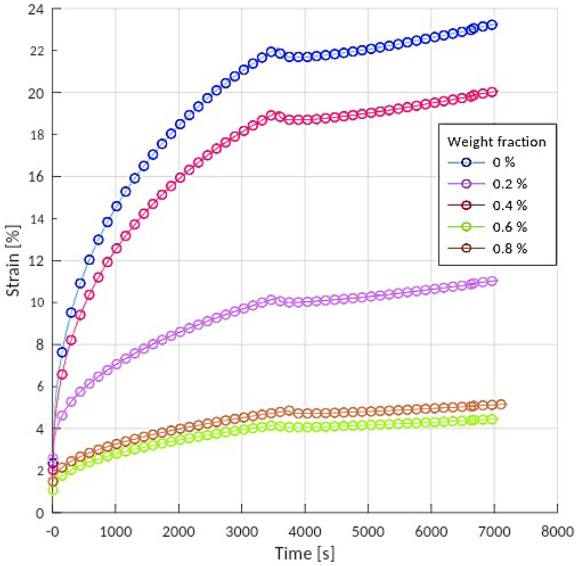

Fig. 6. *Strain behaviour of polyester reinforced with different weight fraction of chicken feather immersed in KCl media*

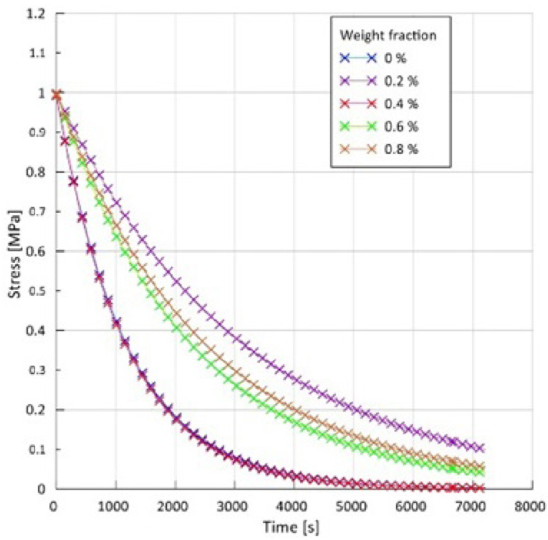

Fig. 7. *Stress vs time for polyester reinforced by different chicken feather weight fraction immersed in KCl media*

Fig. 8 represents the modulus of elasticity with time in the salt medium. The results revealed that the 0.2 wt.% chicken feather composite performed better than the other weight fractions in the salt medium, which yielded a 2.422 % enhancement in elasticity as compared with pure polyester. The 0.4 wt.% sample achieved the smallest improvement of 1.138 %. These findings imply that a fibre content of 0.2 wt.% is the ideal weight fraction for improving the property.

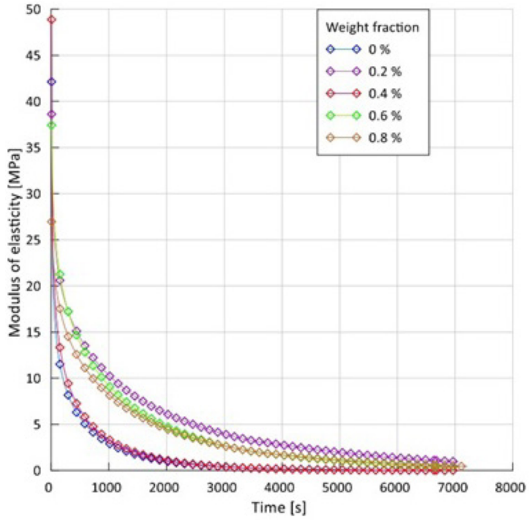

Fig. 8. *Modulus of elasticity for polyester reinforced by different weight fraction of chicken feather immersed in KCl media*

2.2 Immersion in Alkali Medium (NaOH)

The strain vs time graphs for all reinforcements in the alkali medium are shown in Fig. 9. The composite with 0.4 wt.% of chicken feathers exhibited a higher percentage of strain in the alkali medium compared with other weight fractions and yielded a 75 % enhancement in the strain as compared with pure polyester. The composite with 0.8 wt.% achieved only 43.12 %, which was the smallest percentage.

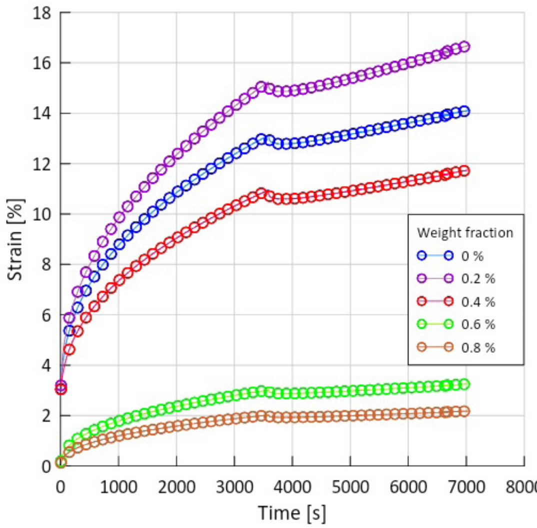

Fig. 9. *Strain vs time for polyester reinforced by different weight fraction of chicken feather immersed in NaOH media*

Fig. 10 demonstrates stress vs time graphs for all reinforcements in the alkali medium. The results revealed that the 0.4 wt.% chicken feather composite had a better result than the other weight fractions, achieving 100.06 % stress improvement compared with pure polyester. The 0.2 wt.% sample achieved only 100.30 %, the lowest percentage of the weight fractions.

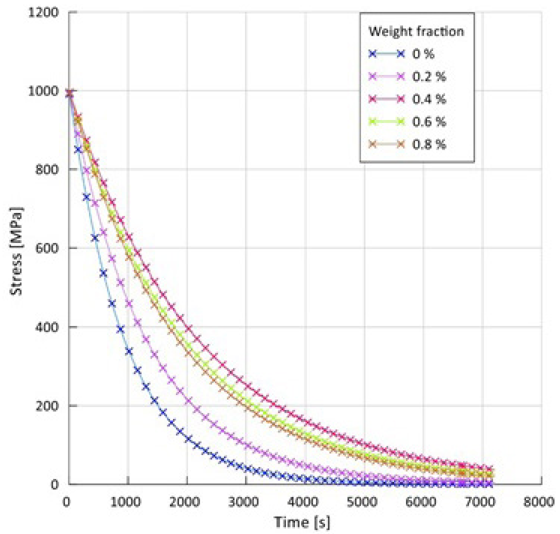

Fig. 10. *Stress vs time for polyester reinforced by different weight fraction of chicken feather immersed in NaOH media*

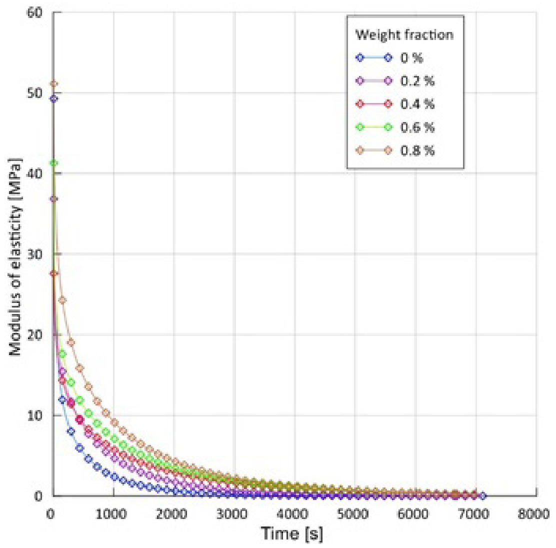

Fig. 11. *Modulus of elasticity vs time for polyester reinforced by different weight fraction of chicken feather immersed in NaOH media*

The modulus of elasticity vs time graphs for all reinforcements in the alkali medium are shown in Fig. (11). The composite with 0.8 wt.% had a higher percentage of modulus of elasticity in the alkali medium compared with other weight fractions, recording a 2.32 % improvement in modulus of elasticity as compared with pure polyester. The 0.2 wt.% chicken feather composite had the lowest modulus of elasticity (1.42 %) as compared to pure polyester.

2.3 Immersion in Acidic Medium (HNO_3)

Fig. 12 shows that strain vs time graphs for all reinforcements in the acidic medium. The results showed 0.2 wt.% chicken feather composite had a better strain than the other weight fractions in the acidic medium, yielding 112.5 % strain improvement compared with pure polyester. The 0.8 wt.% chicken feather composite had the lowest strain enhancement among the other samples, as it improved strain by (36.7 %) when compared to pure polyester. Because delamination increased after being submerged in acidic medium, the effect of acidic media on creep strain is relatively mild.

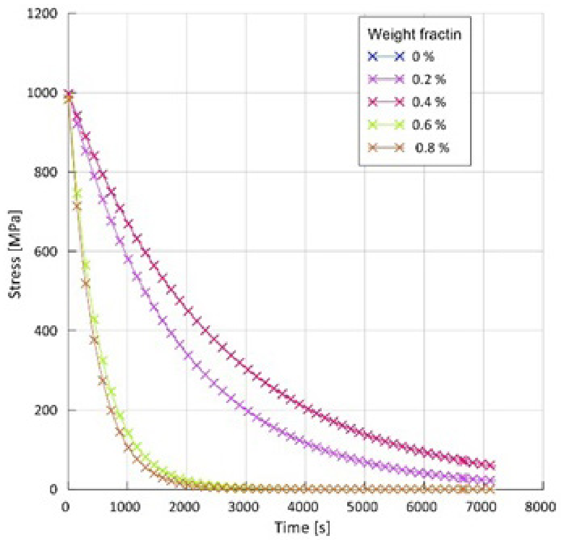

Fig. 12. *Strain vs time for polyester reinforced by different weight fraction of chicken feather immersed in HNO_3 media*

The stress vs time graphs for all reinforcements in the acidic medium are shown in Fig. 13. The results showed that 0.4 wt.% chicken feather composite outperformed the other weight fractions in the acidic medium, resulting in a 100.001 % enhancement in stress compared with pure polyester. The 0.8 wt.% achieved only 99.81 %, with was the smallest percentage among the weight fractions.

Fig. 14 depicts the modulus of elasticity vs time graphs for all reinforcements in acidic media. The 0.8 wt.% sample had a higher percentage increase of modulus of elasticity in the acidic medium than the other weight fractions, which was 2.719 % when compared to pure polyester. The 0.2 wt.% only achieved 0.88 %, the smallest percentage among the weight fractions.

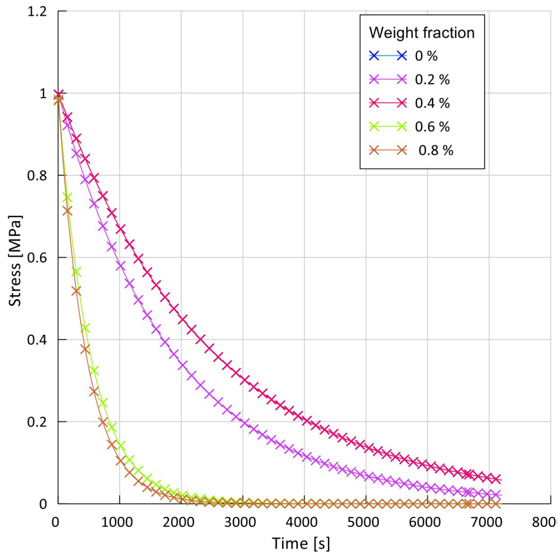

Fig. 13. *Stress vs time for polyester reinforced by different chicken feather weight fraction immersed in HNO_3 media*

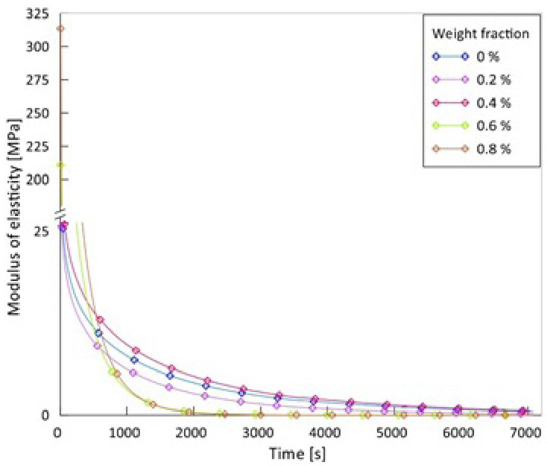

Fig. 14. *Modulus of elasticity for polyester reinforced by different weight fraction of chicken feather immersed in HNO_3 media*

Fig. 15 clearly shows the comparison between the three different media (salt, alkali, and acid) on the percentage rate of creep strain. Of note, the strain decreases with increasing weight fraction of chicken feathers, which indicates the matrix's engagement with the filler was satisfactory. In addition, the percentage rates of creep stress in the three different media are compared in Fig. 16. The stress increased gradually with the increase of weight fractions of chicken feathers. Therefore, using chicken feathers as a reinforcement material might have slowed the crack's progression and allowed the load to be held. Finally, Fig. 17 represents the comparison of the percentage rate of creep modulus of elasticity in the three media (salt, alkali, and acidic), showing that the modulus of elasticity increased with increasing weight fraction of chicken feathers.

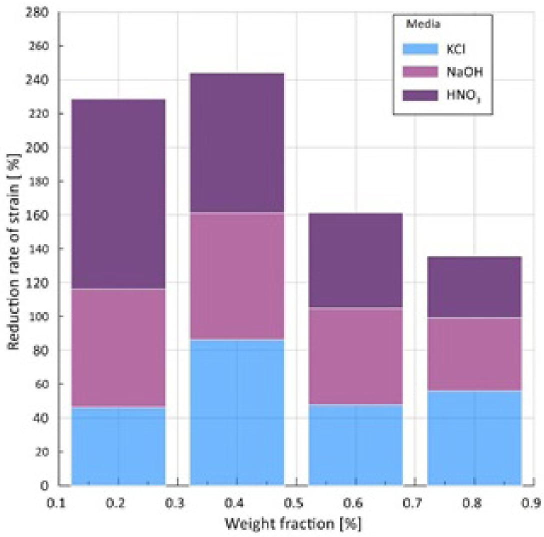

Fig. 15. *A comparative study for the effect of KCl, NaOH, and HNO_3 media on the percentage rate of creep strain*

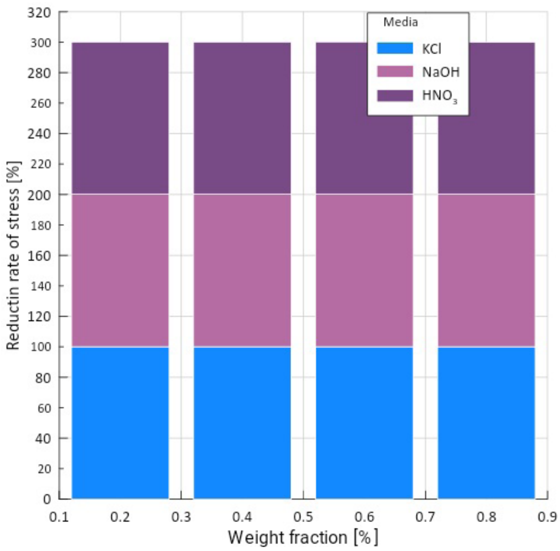

Fig. 16. *A comparative study for the effect of KCl, NaOH, and HNO_3 media on the percentage rate of creep stress*

3 CONCLUSION

The study was conducted to develop materials for engineering applications using poultry wastes that are produced daily around the world. These composites, which are manufactured at a low cost and have superior properties, may be useful in light structural and other engineering applications. In the present study, a polyester composite was reinforced with chicken feathers at different weight fractions using the hand lay-up technique. The results demonstrated that chicken feather-reinforced composites immersed in various media have probable applications because of their superior mechanical properties over immersed for reinforced and non-reinforced composites.

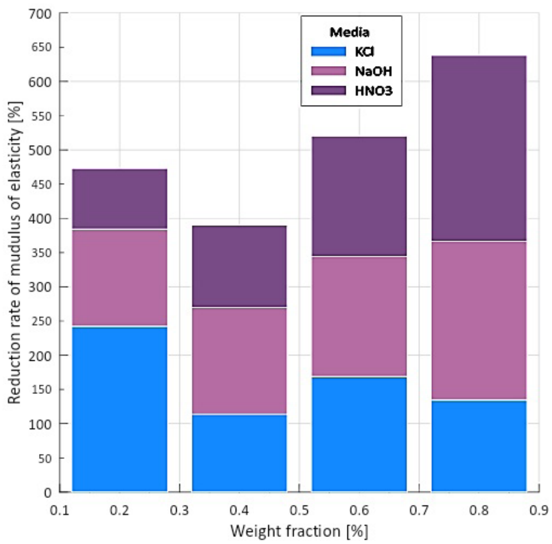

Fig. 17. *A comparative study for the effect of KCl, NaOH, and HNO_3 media on the percentage rate of creep modulus of elasticity*

Polyester composites reinforced with 0.2 wt.% chicken feathers and immersed in the acidic medium had better strain enhancements compared with those immersed in other media and compared with pure polyester and Acidic media have minimal influence on the bonding between the fibres and Up. However, the composite of 0.4 wt.% of chicken feather immersed in the alkali medium showed maximum stress improvement over pure polyester compared with other immersed media. The salt medium improved the modulus of elasticity for the polyester composite at 0.8 wt.% of chicken feathers the most compared with pure polyester and the samples in other immersed media. A literature review revealed that low weight fractions of chicken feather content have resulted in improved mechanical properties of polyester composite in various media. Natural resources have been re-used in a variety of industries as a way of disposal. As a result, the necessity of recycling composites in general and employing them in new applications is emphasized in this study.

4 NOMENCLATURES

σ_0 initial stress [MPa]
$\sigma(t)$ stress at any time [MPa]
δ_1 spring constant [MPa]
ε_1 Maxwell element, [-]
η_1 dashpot constant, [MPa·s]
$E(t)$ creep modulus in function of time, [MPa]
$\varepsilon(t)$ strain in function of time, [-]
t time, [s]
β $\tan^{-1}$ Maxwell element [s]
ε^- the slope of Eq. (4) at ($t=t_1$) [1/s]
L gauge length [mm]
e Euler's number (2.7)

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