Effect of Surface Scratch on the Impulse Impact Energy of Recycled Natural Jute Fiber Mat Reinforced Polymer Matrix Composites

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Abstract

This research work intended to study the effect of the scratch with different scratch loads (20, 40, and 60 N) on the drop weight (impulse) impact energy of recycled needle punched natural jute fiber mats reinforced unsaturated polyester composites with 25 Vol.% fiber volume content. The fracture behavior of the above-mentioned composites was also investigated for each case. The results showed that the impact energy of scratched composites was decreased 40% by scratch load 20 N compared to that of virgin specimen and by increasing the scratch load to 40 N the loss in the total impact energy of the composites was decreased to 2% compared to that of the virgin specimen. On the other hand, the total impact energy of the composite was improved to around 10% by increasing the scratch load to 60 N compared to that of the virgin specimen. Moreover, the fracture behavior showed that the radial matrix cracks and more extensive delamination was observed in scratched specimen at a scratch load of 60 N compared to those of the virgin specimen and this leads to dissipate most of the impact energy and so the impact energy of the composites was improved at a scratch load of 60 N compared to that of the virgin specimen.

Keywords: Jute mat; Scratch depth; Impulse impact energy; Fracture surface; Delamination.
1. Introduction

The considerable advantages of using natural fibers over synthetic fibers are biodegradability, abundance, renewability, low cost, low specific gravity, and high specific strength, etc. However, the incompatibility of natural fiber with the hydrophobic polymer matrices reduces significantly the mechanical properties of the natural fibers reinforced composite materials [1, 2]. During the service age of the composite structure, they may be exposed to different impact loading under different loading conditions. For instance, a composite may be subjected to scratch by a tool during the operation life or maintenance. Moreover, a flying particle resulting during manufacturing or operation with low or high velocity can impact the composite structure. In the aerospace as another example, the aerospace debris or the flying birds may impact the air plane while flying. Regular minor impacts on the rivers and sea boats or ships as another example results from the striking of floating objects in the water to the boats and ships bodies. Therefore, the evaluation of the impact properties is critical issues in the aerospace and marine industry due to the possibility of sustained damage. Scratch represents another problem which appears during the friction of the composites with a hard object and this will have an effect on the impact properties of the composites. Scratch damages are undesirable in many field applications that demand high surface durability and quality for long-term service. The scratch behavior of polymers is very complex and depends on various parameters such as scratch load, scratch speed, and scratch tip geometry/size, material properties including elastic modulus, yield stress, tensile strength and surface characteristics including surface roughness and surface texture [3]. Most of the previous research focused on the investigation and understanding of the surface mechanical properties, such as wear, friction and scratch resistance [4-6]. The low velocity impact response of the composites has been studied extensively. In most studies, the composites were impacted using different shape of impactors at various velocities and energy levels and the resulting damage was evaluated as reported in [7-10]. Moreover, Atas et al. [11] studied the effect of weaving angles between interlacing yarns on the drop weight impact responses of the composites and Zhang et al. [12] investigated the effect of water immersion aging on the drop weight impact responses of the composites. However, understanding the effect of the scratch on the impact properties of natural fiber reinforced polymer composites especially the drop weight impact properties is lacking. It is therefore, in this work, the effect of the scratch in terms of scratch loads in terms of the scratch load on the drop weight impact (impulse) energy and the fracture behavior of jute mat composites with 25 Vol.% fiber volume content was investigated.

Experimental procedures

Materials

Jute fiber mats consisting of 50% jute slivers and 50% recycled jute were prepared by Yano Co.LTD, Japan with 25 Vol.% fiber volume content. Unsaturated polyester, Rigorac™ was obtained from Showa Denko K.K., Japan and the curing agent is Methyl ethyl ketone peroxide (PERMEK® N) obtained from NOF Corporation, Japan.

Preparation of the composites

Jute mats were dried for 6 h at 100°C and were completely submerged in unsaturated polyester resin. The next step which differentiates the modified technique over the conventional technique is that the jute mats were degassed in a vacuum for 20 minutes at room temperature to remove the entrapped air
bubbles and the details were mentioned in [13]. Sheets were prepared with 25 Vol% fiber volume content and the specimens of required dimensions were cut from the sheets and used for testing.

**Test methods**

The scratch was carried out using scratch testing machine (Model KK-01, Kato-Tech Co. Ltd, Japan) according to ASTM D 7027-5 and most recently ISO 19252 under different scratch loads of 20, 40 and 60 N with scratch depth of 275, 472, 660 μm for jute mat composites with the scratch speed = 100 mm/s and the scratch length = 80 mm with scratch tip diameter = 0.1 μm at room temperature. Drop weight impact test was carried out using instron dynatup 9250 HV impact tester with hemispherical nose tup with a diameter of 12.7 mm at room temperature and the energy level is 20 J Fig. 1 a with sample dimension 100×100× 6 mm and three specimens were selected for each case.

**Results and discussions**

The configuration of the drop weight impact test of the composites is shown in Fig. 1 b. In this figure, the impact load strikes on the center the on the scratch side (compression side) and the perforation of the impact tup had been occurred on the other side (tension side).

![Fig. 1: (a) Instron dynatup impact tester and (b) Configuration of the impact specimen test with the scratch line.](image)

Load-displacement curves of drop weight (impulse) impact test of the composites for different scratch loads compared to the virgin specimens are shown in Fig. 2. The peak load is the maximum load that the specimen can sustain on fracture, which indicates the beginning of significant damage. The associated energy absorbed up to this point represents the energy to initiate crack (initiation energy). After the maximum load, the dropping off in force indicates crack propagation which represents the energy absorption in this phase (propagation energy) as shown as an example in Fig. 2. The results show that by adding the scratch with different scratch loads to the compression side of the composites, the maximum load was slightly changed compared to the virgin specimen (unscratched).

As the scratch load increased to 20 N, the deflection of the composites was not improved compared to that of the virgin specimen and by increasing the scratch load to 40 N, the deflection is nearly the
same. However, the deflection was enhanced by increasing the scratch load to 60 N compared to that of the virgin specimen. As a result of that the total impact energy was expected to be improved by adding the scratch to the compression side of the composites by carrying out deep scratch with scratch load at 60 N.

Moreover, the initiation energy of the composites at the maximum load for the virgin specimen is nearly the same value as the scratched specimen at different scratch loads as shown in Fig. 2, while the propagation energy of the composites after the maximum load was varied at different scratch loads. The propagation energy was not improved at a scratch load of 20 and 40 N compared to that of the virgin specimen and therefore the total impact energy of scratched composites was not enhanced compared to that of the virgin specimen as shown in Fig. 2. On the other hand, by increasing the scratch load to 60 N, the propagation energy was increased compared to the virgin specimen and so the total impact energy increases.

The effect of the scratch loads on the total impulse impact energy of the composites is shown in Fig. 3. It can be observed that the impact energy of scratched composites was decreased 40% by scratch load of 20 N compared to that of virgin specimen and by increasing the scratch load to 40 N the loss in the total impact energy of the composites was decreased to 2% compared to that of the virgin specimen. On the other hand, the total impact energy of the composite was improved to around 10% by scratch load 60 N compared to that of the virgin specimen.

The fracture surface of the composites under drop weight impact test for the compression (impact) side and the opposite (tension) side for the virgin specimen is shown in Fig. 4. It can be seen that the presence of a perfect circular penetration at the impact side as shown in Fig. 4 a and the tension side exhibit extensive matrix cracking, delamination and fiber breakage at the back side as shown in Fig. 4 b and this fracture behavior is similar in [14].

![Fig. 2: Load-displacement curves of impulse impact test of the composites for different scratch loads compared to the virgin specimens.](image-url)
Moreover, it can also be observed that the virgin specimens without scratch exhibit extensive multiple radial matrix cracks at the back side as shown in Fig. 4 b and these failure mechanisms agree very well the impact damage observed by Dhakal et al. [15].

On the other hand, by adding scratch at scratch load of 20 N to the impact side of the specimen the same behavior as the virgin specimen which a perfect circular penetration at the impact side occurs as shown in Fig. 5 a. However, the other side exhibit less radial matrix cracks as shown in Fig. 5 b.
and this leads to less consumed impact energy and therefore the impact energy decreases compared to that of the virgin specimen.

![Fig. 5](image1.jpg)  ![Fig. 5](image2.jpg)

**Fig. 5:** Fracture surface of the composites under drop weight impact of scratched specimen at a scratch load of 20 N (a) the impact (scratched side) and (b) opposite side.

Moreover, by adding scratch at a scratch load of 40 N to the impact side of the specimen the same behavior as a scratch load of 20 N which a perfect circular penetration at the impact side occurs as shown in Fig. 6 a. However, the other side exhibit less radial matrix cracks and so suppress any tendency of crack branching out as shown in Fig. 6 b and this leads to less consumed impact energy and therefore the impact energy decreases compared to that of the virgin specimen.

![Fig. 6](image3.jpg)  ![Fig. 6](image4.jpg)

**Fig. 6:** Fracture surface of the composites under drop weight impact of scratched specimen at a scratch load of 40 N (a) the impact (scratched side) and (b) opposite side.

On the other hand, by adding scratch at a scratch load of 60 N to the impact side of the specimen a perfect circular penetration at the impact side occurs and minor crack extend and propagates through the scratch line as shown in Fig. 7 a which consumes more energy. Moreover, the other side exhibit fracture surface with the radial matrix cracks and extensive delamination as shown in Fig. 7 b and this dissipates most of the impact energy and so the impact energy of the composites was improved compared to that of the virgin specimen.
Fig. 7: Fracture surface of the composites under drop weight impact of scratched specimen at a scratch load of 60 N (a) the impact (scratched side) and (b) opposite side.

Conclusions

This study investigated the effect of different micro scratch depths with different scratch loads on the drop weight impact energy of recycled needle punched natural jute fiber mats reinforced unsaturated polyester composites with 25 Vol.% fiber volume content. The results showed that the initiation energy of the composites at the maximum load for the virgin specimen is nearly the same value as the scratched specimen at different scratch loads, while the propagation energy was not improved at a scratch load of 20 and 40 N and by increasing the scratch load to 60 N, the propagation energy was increased compared to the virgin specimen. As a result of that the impact energy of scratched composites was not improved by scratch load 20 and 40 N and it was enhanced by increasing the scratch load to 60 N compared to that of the virgin specimen. The fracture behavior showed that the radial matrix cracks and more extensive delamination was observed in scratched specimen at 60 N compared to those of the virgin specimen and this helped to dissipate most of the impact energy and so the impact energy of the composites was improved at a scratch load of 60 N compared to that of the virgin specimen.

References

الملخص العربي

تأثير خدش السطح على خواص المقاومة للخيبات تحت تأثير الوزن للمتركبة الطبيعية المحتوية على ألياف الجوت الطبيعية المعاد تدويرها كمواد مقوية والبوليمير كمادة حاوية

هذه البحث يتضمن دراسة تأثير الخدش على الخواص المقاومة للخيبات تحت تأثير الوزن للمتركبة الطبيعية الجوت الطبيعية المعاد تدويرها كمواد مقوية والبوليمير كمواد حاوية بنسب حجمية لألياف الطبيعية 25. كما تضمنت الدراسة أيضا سلوك الكسر لهذه المواد المتركبة في كل طاقة الخبط للمتركبة المخدوشة عند حمل خدش يساوي 20 نيوتن تقل 40 نيوتن تقل هذه القيم تي 2. عند زيادة حمل الخدش إلى 60 نيوتن مقارنة بالقاسم المناظرة للمتركبة غير مخدوشة.

بالإضافة إلى ذلك سلوك الكسر لهذه المواد أوضح وجود كسورية قطرية خلال المواد الحاوية أيضا انفصال طبقي كبير مقارنة بالمواد المتركبة غير مخدوشة وهذا يؤدي إلى تبدد معظم طاقة الخبط ويذك طاقة الخبط للمتركبة تحت ضع عند خدشها بحمل 60 نيوتن مقارنة بالقاسم المناظرة للمتركبة غير مخدوشة.