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Compression resilience and impact resistant properties of fibre reinforced sandwich composites

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Abstract. This paper presents an experimental investigation on the compression behaviour of fiber reinforced sandwich composites. In this study, 5 different types of sandwich composites were prepared with spacer as middle layer. Also, 3 different types of woven kevlar fabric structures were used as outer layers. Sandwich composites were fabricated using epoxy resin by wet lay-up method under vacuum bagging technique. Compression behaviour, ball burst and knife penetration was tested and effect of weave type of these composites were studied using the compression stress-strain curves. We know, spacers have excellent compression elasticity and cushioning.

Introduction

Many studies have been carried out to find the contribution of aramid fibers in a hybrid carbon–aramid composite. Effect of type of weave also plays an important role. Twill weave was widely used with epoxy resin for impregnation. To evaluate the influence of the aramid fibers, a comparative study between carbon and carbon–aramid woven–reinforced composites was undertaken. A sandwich layer of 100% polyester nonwoven fabric was used. This was made into a composite by using two types of resins, polyester and epoxy resin. Maximum impact energy absorption was obtained by the blended fabric (polyester/glass) woven with satin structure and treated with polyester resin. In a few cases, carbon and carbon-aramid hybrid woven fabrics were studied. Woven fabric of different kinds such as, plain, twill 2/2, quasi-UD were used [1,2]. Although different types of sandwich composites are being developed with aramid fibres as the outer layer, there is no sandwich with knitted spacer as the middle layer. This study will give the effect of spacer as middle layer [3-6].

Experimental

Different types of sandwich composites were made for this study. They differed with the outer and middle layers. The skin or outer layers are made of Kevlar and basalt woven fabric of different weave structures, such as plain, 2x2 twill and satin. The woven kevlar fabrics were obtained from an industry.

The core or middle layer is of warp knit spacers made up of polyester fibers. Warp knit spacers are produced on double needle bar warp knitting machine. These spacers consist of two ground surfaces, which are bound through a pile of yarns, which are monofilaments with stitches. Both the warp and weft knit spacers were obtained from an industry. The composition of sandwich composites is given in table 1.

Table 1: Composition of sandwich composites

Sample No.	Composition of skin	Weave of skin	Thickness of skin (mm)	Areal Density of Skin (GSM)	Composition of Core	Thickness of Core (mm)	Areal Density of Core (GSM)
1	Kevlar	Plain	0.55	410	Polyester	11.1	517
2	Kevlar	Twill	0.51	438	Polyester	11.1	517
3	Kevlar	Satin	0.6	335	Polyester	11.1	517
4	Kevlar	Plain	0.2	115	Polyester	11.1	517
5	Basalt	Plain	0.45	377	Polyester	11.1	517

Sandwich composite manufacturing. The composites were prepared using epoxy resin L180 from the industry Havels composites. The resin to hardener ratio was 40:16 per 20 cm X 20 cm sample. Vacuum bagging technique was used to improve the quality of sandwich composite produced by wet lay-up method. Initially, the resin and hardener are mixed with the help of a magnetic stirrer. The mixture is then applied onto the surface of the woven kevlar fabric by help of a roller [7,8]. In-laboratory set up of vacuum bagging technique is shown in figure 1. A perforated layer of nonwoven on the glass makes the first layer. The sample is placed on the release film. The whole set up is covered with a flexible vacuum bag. Edge of the bag is sealed with vacuum sealing compounds or sealant. Vacuum pressure of 600bar is applied. When vacuum is applied, the trapped air and excess resin escapes out which further consolidates the laminate and eliminates voids. The vacuum pressure was set for 24 hours. After which the sample is put into oven at 60°C for 15 hours.

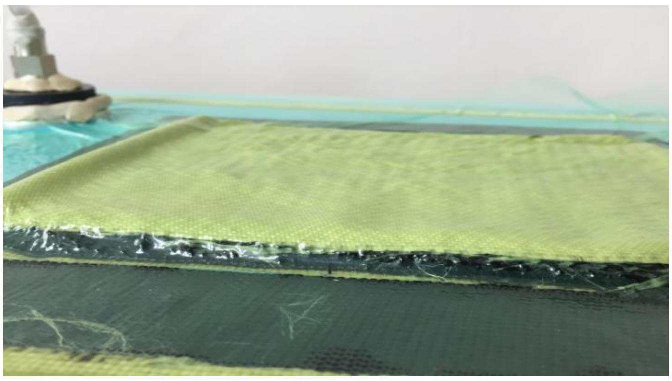


Fig. 1: Vacuum bagging for composite preparation

Measurement of compression. The measurement of compression for the prepared sandwich composites was done as shown in figure 2. The sandwich composite samples were tested according to the Standard ASTM D 575 on a TIRA Tester device set up with two compression circular plates. The size of all the specimens was 10cmX10cm. The compression tests were conducted at a speed of 10 mm/min up to a deformation 40% of the initial thickness for each composite sample in an environment of 20 0C and 65% relative humidity [9].

Fig. 2: Compression testing set-up for sandwich composites

Knife penetration test. Knife penetration test was carried out on Testometric as show in in figure 3. The sandwich composite was placed between the jaws. The traverse rate of the knife was set to 10mm/min. the size of the specimen was 10x10 cm. The environment was maintained at 20 0C and 65% relative humidity [10,11].

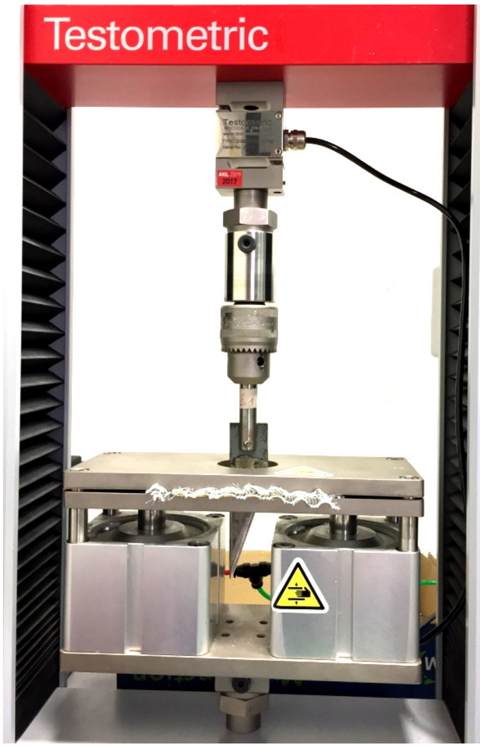


Fig. 3: Knife penetration test

Ball burst test. The ball burst test was carried out in the same testometric tester with the knife replaced with a ball head. ASTMD 3787 standard was followed for testing of the sandwich composite. The traverse rate of the ball head was set to 100mm/min. The diameter of the ball is 44.45mm [12-15]. The set up is shown in the figure 4 below.

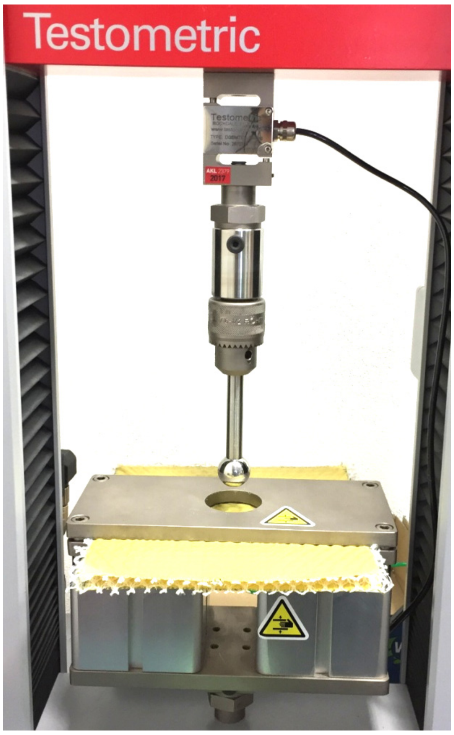


Fig. 4: Ball burst test

Results and Discussion

The first and foremost parameter taken into consideration is the effect of spacer as core material used in the study. Generally a spacer fabric has good cushioning effect. The typical stress-strain curve of a spacer can be divided into four regions [16-18]. The initial stage, elastic stage, plateau or energy absorbing stage and the densification stage as shown in figure 5.

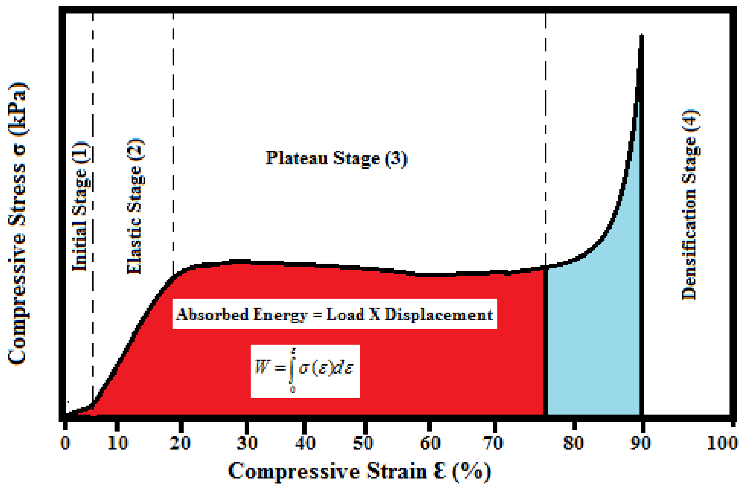


Fig. 5: Stages of compression for 3D spacer fabrics

A similar trend of stages in observed in the sandwich composites in figure 6.

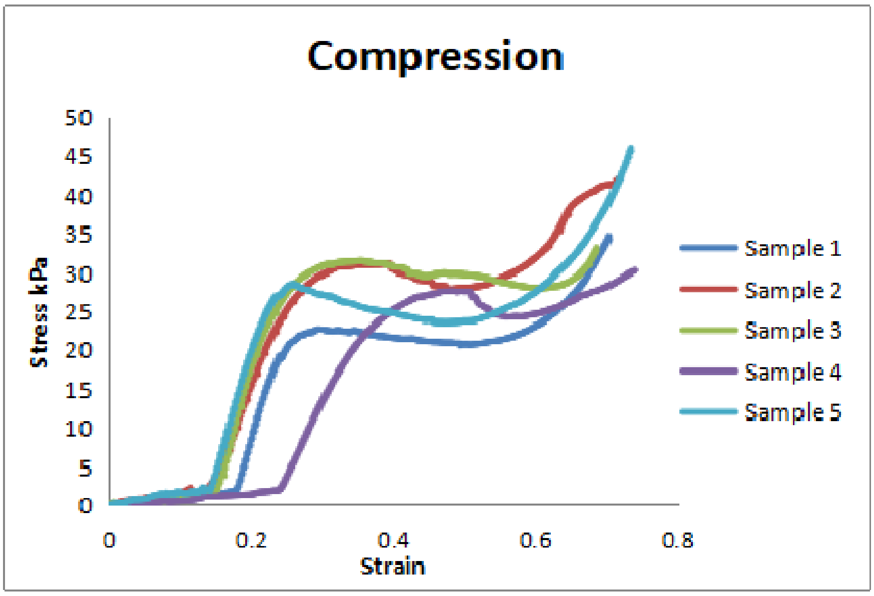


Fig. 6: Compression result for sandwich composite

Compression depends on mostly the core material. There is a minor difference due to structure of outer layer. Better adhesion of surface layer leads to more uniform compression cycle. Compression resilience is very high in all samples.

Maximum compression energy with minimum thickness of the surface fabric. Thus the overall compression is mostly dominated by the spacer fabric layer. Compression resilience maximum with thinnest surface layer. With similar middle layer, there is similar compression and recovery behavior.

The results of knife penetration resistance are shown in figures 7 and 8. Mostly dependent on cover of surface layer. Twill weave based sandwich composite shows maximum resistance due to better adhesion of yarn floats, impregnation of resin and adhesion with core layer.

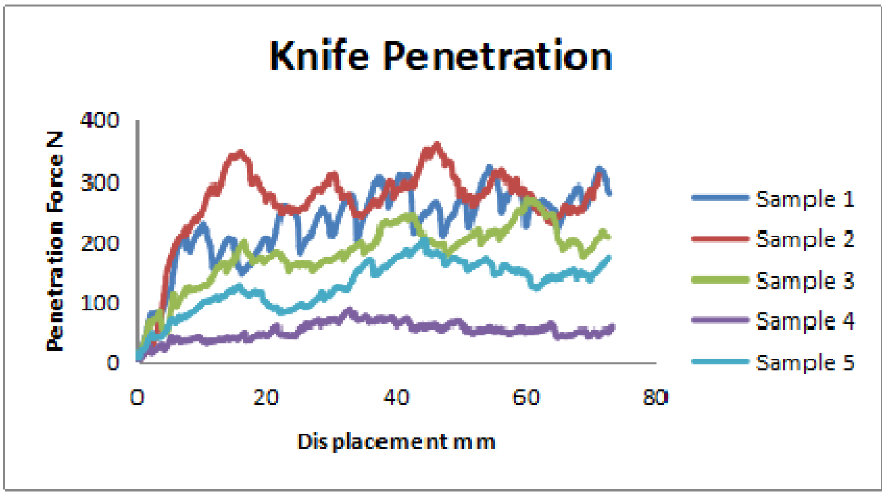


Fig. 7: Knife penetration curve

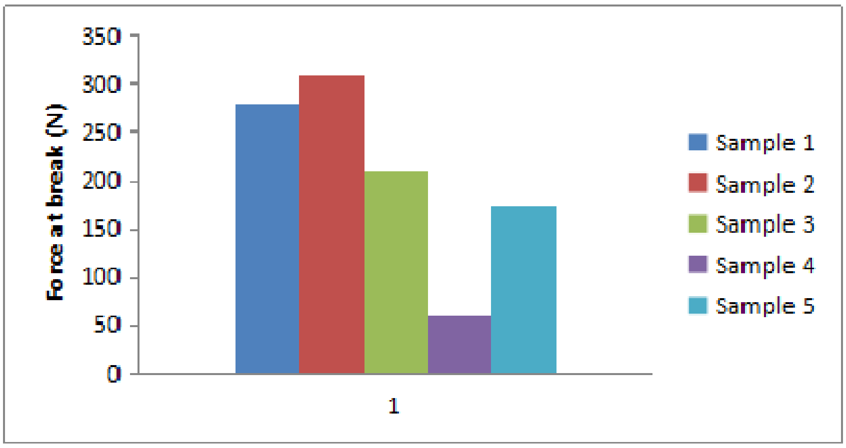


Fig. 8: Knife penetration force

In the knife penetration test, effect of weave structure and density of skin layer plays a significant role. From the graph it is clear that sample 2, with Kevlar twill woven fabric as skin has highest resistance to penetration compared to other weave structures. Sample 1 and 4 have the same plain woven Kevlar as skin but with different densities. Sample 1 with higher density plain weave shows better performance compared to sample 4 with lower density plain weave.

Results of ball bursting test are shown in figure 9.

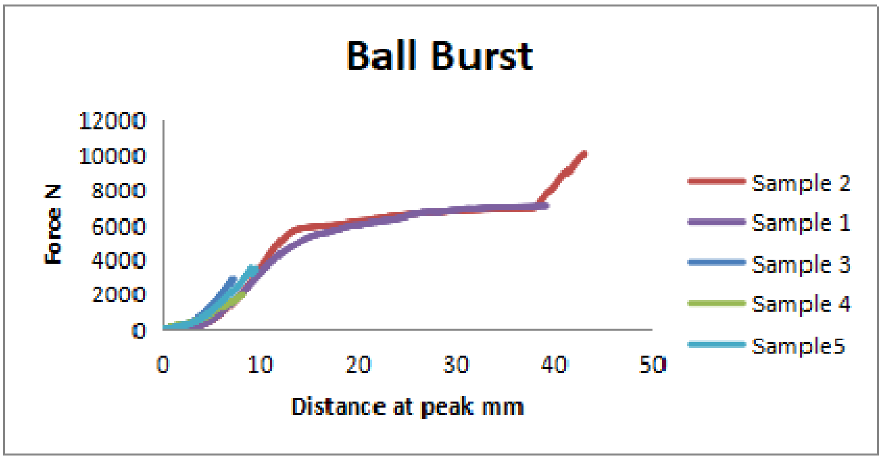
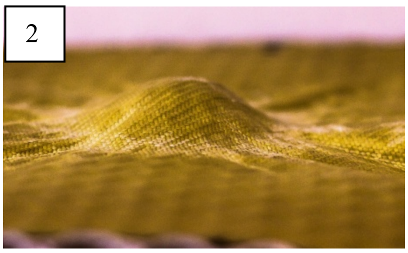


Fig. 9: Result of ball burst test

During the ball burst strength, sample 1 and 2 showed different trend compared to other samples. They did not break or crack like the other 3 samples.

From figure 10, it can be seen that sample 1 and 2 bulged out. While sample 3-5 cracked.



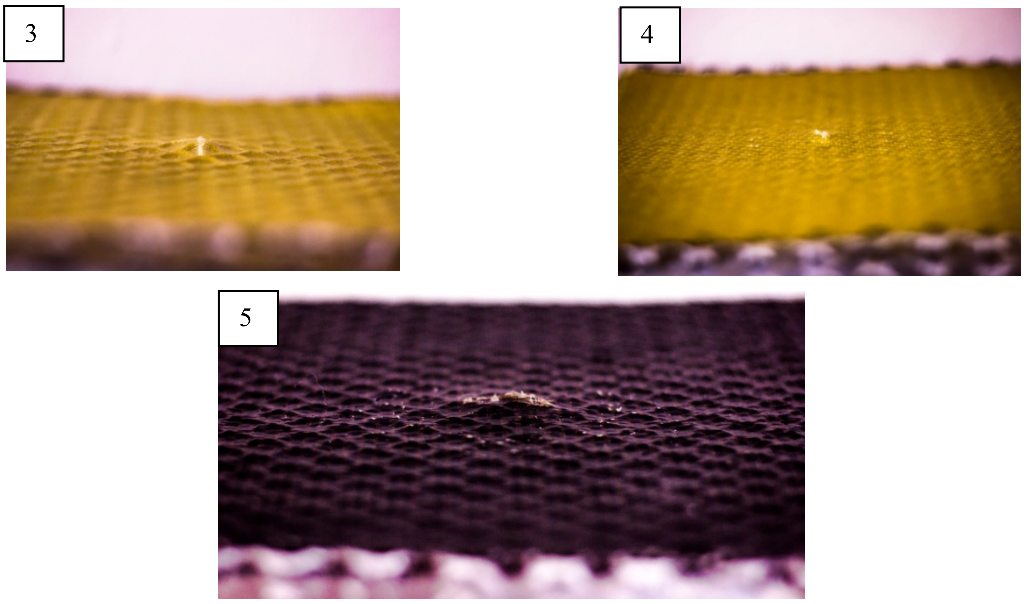


Fig. 10: Samples 1-5 after the ball burst test

The bulging deformations are recoverable after 30 minutes of relaxation. Maximum impact energy with plain woven surface layer Twill and Satin show similar energy level. As it is a high velocity impact test, the integrity of the woven structure or the inter yarn friction is most dominant in deciding the level of resistance

Conclusions

The sandwich composites were developed and evaluated for various mechanical properties. Compression resilience is excellent in sandwich composites with 3D knitted spacer as the core. As the resilience is mainly function of the bulk and middle layer, there is no significant influence of the outer layers of woven fabrics in the sandwich composite system.
Maximum knife penetration resistance is obtained with twill weave on surface due to maximum yarn cohesion and resin impregnation. Higher amount of cohesive friction results in higher resistance against penetration of sharp objects like the knife edge. Plain and twill fabrics offer sufficient resistance again ball burst. The yarn deformation allows formation of dome shape. Maximum impact resistance in ball burst is obtained for plain weave due to inter-yarn binding (friction).

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