



BEHAVIOUR OF HYBRID POLYMER COMPOSITE REINFORCED WITH SUPERELASTIC SHAPE MEMORY ALLOY AND KEVLAR

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ABSTRACT

The concept of low weight of material for application of impact resistance has turned the research towards composite because it has high strength to thickness and weight ratio when comparing other materials. However the damage is the drastic problem that a composite material faces. Possibility of reducing the impact damage of a composite material will overcome by embedding Smart material along with the composite. In this paper, improvement of impact resistance character of composite laminate by embedding Shape memory Nitinol (NiTi) wire was investigated. Where bi-directionally pre-stressed shape memory alloy (SMA) was used to smart component integrated into the composite structure made of SiC and Kevlar and experimentation was carried out under low velocity impact. Result of the experiment shows that apparent advancement in impact resisting capability and healing effect are appeared on the composite structure after impregnating SMA then the conventional standalone composite. This is because of the martensitic transformation SMA to it's the initial position and the super-elastic property SMA prevents the striking force from of the composite. The super elastic behavior of Nitinol wire dissipates the shock load uniformly throughout its structure hence, SMA can be an appropriate damper for the structural modification of the composite.

Keywords: impact, SMA wire, composite, super elasticity, PMC, kevlar.

INTRODUCTION

The safety of a material against Striking force during accidents and vibration control has been concerned in material design. The idea of low weight of such material has led the researchers towards composite. Because of the concept of high strength to low weight composite has extensively used as safety materials. Ceramic utilization in composite growing extensively in today's armor design. Smart material application in composite has improved the mechanical property of the composite [1]. Severe damage to protection material has made the developers to introduce smart material into it. And the damage is the drastic issue that a composite material faces. Possibility of lowering the effect damage of a composite laminate could be overcome by means of embedding shape memory alloy (SMA) into its structure. Due to some properties like high reversible strain, high damping limit, extensive reversible change to its original region, SMA is more advantageous than other materials [2]. SMA reinforced protection material gives enhanced performance over vibration control and shape recovery [3]. Because of its super elastic property it will reduce the effect under low velocity [4]. However impact damage of composite can't be resisted completely but it can be decreased by integrating SMA into its layer. This super behavior of SMA wire dissipates the impact velocity of projectile uniformly throughout its design; this mechanism is due to the martensitic transformation of shape memory alloy to its initial position after dissipating the impact load [3]. This reversible property does not happened in other metal wires. The ability of SMA wire to recover stress and high tensile load will lower the deformation under low velocity impact. Since strain energy absorption rate is higher for SMA considering other materials and fibers, SMA wire diminishes the danger of delimitation of structure during

impact effect [4]. In this paper, pre-stressed Nitinol SMA Wire of 0.409 mm is meshed bi-directionally to improve the low velocity damage in the laminate [3].

EXPERIMENTAL PROCEDURE

Figure-1(a) shows the specimen 1 made by single material of PVC foam board with 10 mm thickness and 150 mm×150 mm in cross section. The Silicon carbide (SiC) ceramic of 2 mm in thickness and 150 mm×150 mm in area was inserted between PVC foam boards epoxy resin and hardener of ratio 10:8 was used the bind these SiC and PVC foam board shown in Figure-1(b). A unique combination of high strength, high stiffness and high toughness Kevlar-29 fiber fabric was fused with PVC foam board with the help of epoxy resin and positioned as the supporting back layer to PVC foam and SiC sequence as third lamination where PVC/SiC as front face and Kevlar/PVC as the next face. For this purpose a single layer of Kevlar fabric of 1 mm thickness and 150 mm×150 mm in cross section was uni-directionally laid on the PVC foam board and bonding. These composite laminates were prepared using hand layup technique shown in Figure-1(c). Then straight annealed oxide free surfaced superelastic shape memory alloy wire of 0.409 mm was meshed. SMA used for reinforcing the composite was mechanical shape memory Nitinol Nickel-Titanium alloy (Ni =55.8% and rest Ti) of type SE508 was weaved bi-directionally at a distance 10 mm. The Weaving was performed using hand loom technique and Pre-stressing was done at 115N and located such that single layer of SiC is the first and front face against impact load, SMA wire mesh as the second, PVC foam board of 10 mm thick as third and Kevlar laminate as the last as well as blackening of all the layer. All these four layers are bonded by epoxy resin and hardener of above mentioned ratio to foam



sandwich and clamped together by bolts to hold firmly during impact load analysis shown in Figure-2(d).

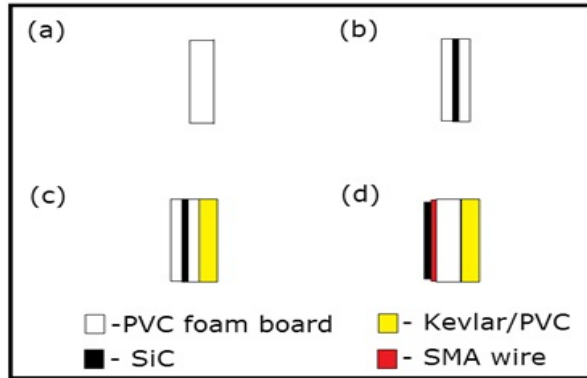


Figure-1. Specimen preparation layout.

TESTING PROCEDURE

To proceed with experimentation, low velocity impact testing is done using gas gun shown Figure-2. Initially gas gun is calibrated for different pressure and observed that at 5 bar pressure in reciprocating compressor the velocity obtained by the projectile is 75 m/s. A conical steel projectile of 7.6mm diameter is used for this purpose of low velocity impact on the laminate. This gas gun is calibrated by ballistic pendulum for finding the striking velocity of the projectile exerted from the barrel mathematically,

$$V = \frac{(M + m)\sqrt{2gh}}{m}$$

Where, m- Mass of projectile, M- Mass of Pendulum, h- Height reached due to pendulum oscillation, V- Velocity of the projectile, g - Gravity of earth

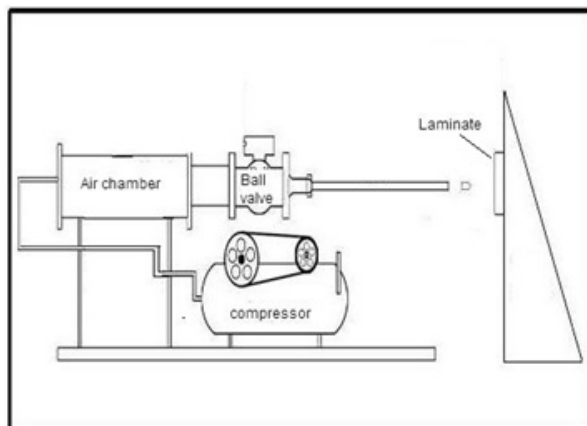


Figure-2. Schematic of impact testing apparatus.

RESULTS AND DISCUSSION

Figures-3(a) and (b) show the impact response on PVC foam board when subjected to low velocity impact load. As a result impact load pierces the foam board and complete damage of the material is appeared. Though the

PVC foam board was rigid in structure, this light weighted was not tough enough to withstand the striking force alone.

Figures-4(a) and (b) show the impact analysis of SiC inserted in between the layer of PVC foam boards. The impact damage was quite less while comparing the previous fabricated PVC foam board. Where bulge appears on the rear layer but the deformation area is relatively low than the above one because the hardness property of silicon carbide resists some amount of impact energy from destroying the composite and PVC foam board absorbs certain quantity of shock load hence, level of destruction of composite is reduced.

Figures-5(a) and (b) show the deformation response of and PVC foam board, SiC, Kevlar/PVC. Though the foam board does not possess greater resistance against impact load, it is inserted to provide to absorb shock load. In this test the bulge formation is very low comparing previous results. A small elevation is formed on the surface of the PVC backing layer as high strength and high stiffness fiber protect the composite laminate form impact load and Kevlar is very less weight comparing its strength and so decreases the overall weight of composite laminate.

Impact response of the SMA embedded composite laminate is shown in Figures-6(a) and (b). Here the rear layer impression towards impact load is null. Therefore neither bulge nor crack is appeared. SMA layer is inserted in between SiC ceramic and PVC foam board. The super elastic behaviour of shape memory Nitinol wire the point load of impinging projectile is dissipated uniformly throughout the structure of SMA wire mesh. As a result no deformation is occurred. The total kinetic energy of the striking force was absorbed by SiC, PVC foam board and SMA, and. Hence final Kevlar/PVC is not affected by impact velocity. This is because of martensitic transformation of shape memory Nitinol wire. Here SMA recovers the deformation due to its super elastic property.

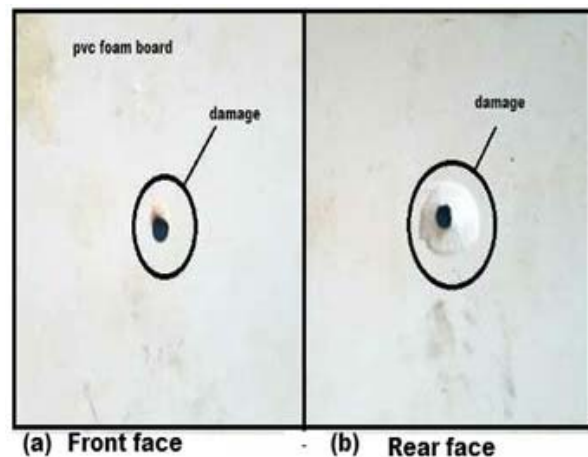


Figure-3. Impact damage PVC foam board under low velocity impact.

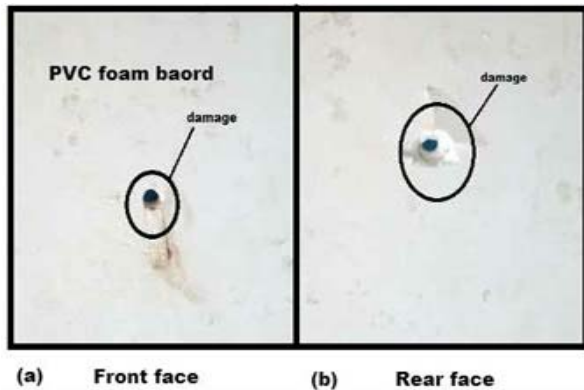


Figure-4. Impact response PVC foam board and SiC in between foam board.

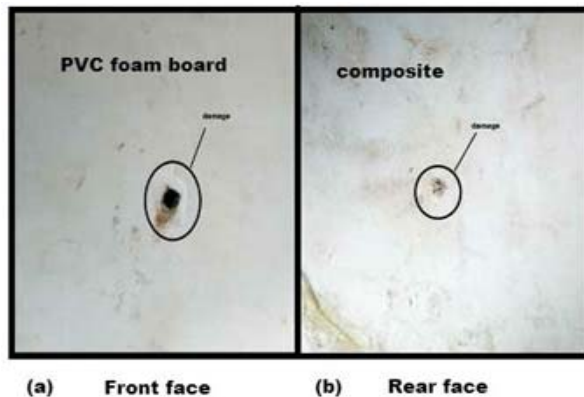


Figure-5. Impact response PVC foam board front, SiC middle and composite back layered laminate.

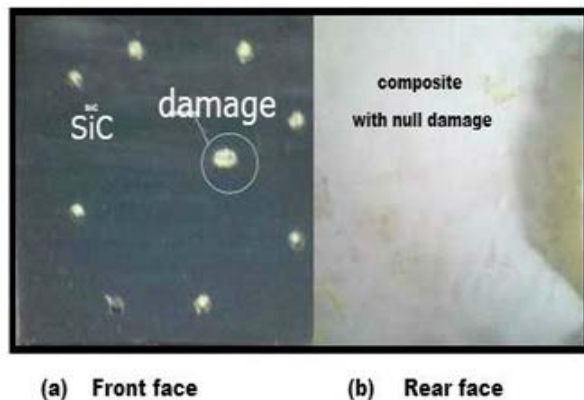


Figure-6. Impact response SMA embedded in between SiC and PVC foam board, composite back layered laminate.

CONCLUSIONS

- The following is the conclusion obtained after analyzing the results of impact response of Kevlar/PVC, SiC, PVC foam board, SMA bonded composite tested at low velocity.

- Large damage is occurred when the PVC foam board alone subjected to impact velocity.
- The further improved performance of resisting capacity is achieved by inserting SiC as a middle layer of PVC foam board.
- A minor damage is appeared when PVC foam board, SiC, Kevlar/PVC are involved in resisting action. Only a punch mark is observed by using these three materials.
- Best result is obtained when SMA layer is embedded between SiC and Kevlar/PVC composite laminate.
- Vibration control and shear deformation is good at the sandwich layer than comparing other material.
- A drastic reduction in shear deformation is obtained by embedding SMA into the composite laminate.

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