Effect of graphite content on the dynamic behavior of sandwich panel under low velocity impact

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Abstract:

Experimental investigations had been done in this work to demonstrate the effect of graphite filler contents on the dynamic behavior of (30%) weight fraction glass-polyester sandwich panel under low velocity impact. The composite sandwich panels are manufactured using the honeycomb core and laminated composite face sheets. The wet hand layup technique is used. The mechanical properties were tested based on ASTM D-638. The panel is fixed from three sides and the other is free. The impact load is applied. The dynamic response of the plate is measured using vibration data collector (TVC 200). The panel is supported also on a rigid foundation. The steel impactor of 15 kg weight dropped from 2 m height. The deformation is measured using vernier caliper. The results showed that the mechanical properties are improved when the graphite filler content increased up to 7.5% and then decreased after that. The same dynamic behaviors were obtained but differ in magnitude. The minimum deflection and deformation takes at 7.5% filler content for both face and core. At 7.5% filler content the deflection and deformation decreased by 28% and 60% respectively less than the unfilled panel. The effects of using different faces with the same core have a little variation.

Keywords: dynamic behavior, sandwich panel, composite material.

تأثير كمية دقائق الكرافايت على السلوك الديناميكي لشطيره خلية النحل عند سرعة الصدم الواطئة

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الخلاصة:

في هذا البحث تم اجراء الاختبار التجريبي لدراسه تأثير كمية دقائق الكرافايت على السلوك الديناميكي لشطيرة خلية النحل المصنعة من راتنجات البولي استر المدعم بالياف الزجاج وبكسر وزني 30% عند سرعه الصدم الواطئة. تم الحصول على شطيره خلية النحل بتصنيع قالب خليه النحل و تصنيع اوجه متعددة الطبقات باستخدام طريقه التشكيل اليدوي في التصنيع. تم دراسة الخواص الميكانيكية وفقا للمواصفه ASTM-D638. تم تثبيت شطيرة خلية النحل من ثلاث جهات وتركها حره من جهه واحده. وتم اسقاط الحمل الصادم. تمت دراسة الاستجابة الديناميكية للعينات باستخدام جهاز قراءة الاهتزازات TVC 200 بحيث يقوم الجهاز بتحسس الانفعال. تم اجراء فحص اتلافي على العينات باسقاط جسم يزن 15 كغم من الحديد الصلب من ارتفاع 2م. بحيث تم تثبيت عينات شطيرة خلية النحل على ارضية صلبه. تم قياس النقصان بالطول باستخدام الفيرنية. أظهرت النتائج تحسن في الخواص الميكانيكية حتى نسبة اضافة 7,5% من الكرافايت. وان شطائر خلايا النحل لها نفس سلوك الارتداد ولكن باختلاف القيمة. وأن اقل ارتداد يحصل عند اضافة 7,5% كرافايت. عند استخدام 7,5% كرافايت فان مقدار الارتداد والتشوه يقلان بمقدار 28% و 60% على التوالي عند المقارنة مع العينات بدون اضافات. وان تغير الاوجة كان لة تأثير بسيط على النتائج.

الكلمات المرشدة: السلوك الديناميكي, شطيرة خلايا النحل, المواد المركبة

Symbols

D	Diameter (m).	α	Coefficient of thermal expansion (C°)
E	Modulus of Elasticity (GPa).	Δ	Deformation (mm).
F_T	Fracture toughness (MPa-m$^{0.5}$).	ɣ	Thermal conductivity (w/m.K).
R	Electrical resistance (Ω).	λ	Specific heat (J/kg.K).
T_S	Tensile strength (MPa).	ρ	Density (gm/cm^3).
e	Elongation at maximum tensile strength (%).	σ_{ut}	Ultimate tensile strength (MPa).
h	Height (cm).	σ_y	Yield stress (MPa).
m	Mass (gm).		

Introduction

Liquid resins exhibit a good mixture and processing ability with reinforced materials in granular or fiber form. The results of these mixtures are composite materials with intermediate properties depending on the combined action of the components. Fiber and/or filler reinforced epoxy matrix composites are known for their high specific mechanical properties and are therefore used in numerous light weight engineering applications ranging from sports goods to automobiles and aircraft[1]**.** The sandwich structures are widely used in aerospace. However, these structures are usually weak in the thickness direction. Particularly, the impact loads may cause delamination of these structures. However, the impact loads of external objects are still a major concern for such laminates in comparison to similar metallic structure that can cause internal material damage. Typical impact scenarios in a design range from a tool dropped on the surface, over object thrown up by force. In the literature there are many studies concern with the impact load on the composite structure, N. K. Alpaydin and H. S. Turkmen[2], were investigated the dynamic behavior of sandwich panels subjected to the impact load experimentally and numerically, they investigated the dynamic response of the panel by measuring strain on a particular location on the panel. T.J. Vogler, et al[3]**,** reported that the dynamic behavior of a tungsten carbide filled epoxy composite under planner loading condition. Planar impact experiments were conducted to determine the shock and wave propagation characteristics of the material. H. J. Jaafer[4], studied the effects of fiber on damping behaviors of composite materials with volume fraction (Vf=1%, 2% and 3%). It was concluded that the stiffness, natural frequency, vibration damping and damped period increased with the increases of volume fraction of reinforcement material. Heimbs, et al[5], were studying (experimentally and numerically) the influence of a compressive preload on the low velocity impact behavior of a carbon fiber – reinforced composite plate. They were developed modeling strategies for low velocity impact simulation of plate under compressive preload with LS – DYNA with emphasis on the laminate delimitation and preload modeling. Farag M. and Drai A.[6]**,** demonstrate the effect of graphite filler contents on the mechanical and tribological behavior of glass-polyester composite system. They showed that the mechanical and tribological properties behavior was improved when the graphite filler content increased.

The main objective of this study is to investigate, experimentally, the effect of the graphite filler content on the dynamic behavior of composite sandwich panel subjected to low velocity impact.

Experimental work

Materials

The material used in this investigation was woven roving glass fiber made of 360 gsm, containing E-glass of 8-14μm diameter. The matrix system used was unsaturated polyester resin known commercial by TOPAZ -1110 TP medium reactive based on Phthalic Anhydride and a room temperature hardener (Methyl Ethyl Kenton Peroxide (MEKP)). The filler used was graphite powders (no. 7782-42-5 Merck index 10, 4410 Swiss). The technical and mechanical characteristics of the raw materials are presented in **Tables (1, 2** and **3).**

Table .(1) Mechanical and physical properties of E-glass fiber [9].

E (GPa)	gm/cm^3	D m	T_S MPa	e %	10^{-6}/C	w/m.K	J/kg.k
72.5	2.58	8-14	3450	4.3	5	1.3	810

Table .(2) Mechanical and physical properties of unsaturated polyester resin [10]

E (GPa)	gm/cm^3	F_T $MPa\text{-}m^{0.5}$	T_S MPa	e %	10^{-6}/C	w/m.K	J/kg.k
2.06-4.41	1.2	0.6	41.4-89.7	<2.6	100-180	0.17	710-920

Table .(3) Mechanical and physical properties of graphite powders [11] .

E (GPa)	gm/cm^3	T_S MPa	R Ω	10^{-6}/C	w/m.K	J/kg.k
11.7	1.78	31-69	$(10\text{-}18)10^{-6}$	2.2-6	130-104	830

Specimens Preparation

All the composite honey comb sandwich panel specimens were manufactured using dry hand layup procedure. E-glass woven roving fibers, compatible to unsaturated polyester resin, was used as the reinforcement. The filler material adds to matrix material with (0, 2.5%, 5%, 7.5% and 10%) and blended with it. The hardener adds in the ratio 100:2 by weight. The stacking procedure of glass-polyester composites was constructed by placing the E-glass fiber ply one above the other with the resin mixed well to spread between the plies using (300x300) glass mold for the face sheet and (160x85) mm steel mold for the core as shown in **Figure.(1)**. This process was repeated till all the 2 ply were completed with a fixed weight fraction of (30%). The second Half of the mold fixed on the top to give the shape of the honey comb. In order to compact and to consolidate the surface of the honey comb, applied an equal pressure on the fiber impregnated by the resin. The Honey comb was cured at room temperature for (24) hours, then removed from the mold and left for seven days. Each two half cells of the honey comb connected together by using Unsaturated polyester. The upper and lower plates (faces) jointed with the honey comb by unsaturated polyester. The final shape is (80×40×40) mm honey comb sandwich panel as shown in **Figure.(2).** According to the filler content, there are 25 types of honey comb sandwich panel presents.

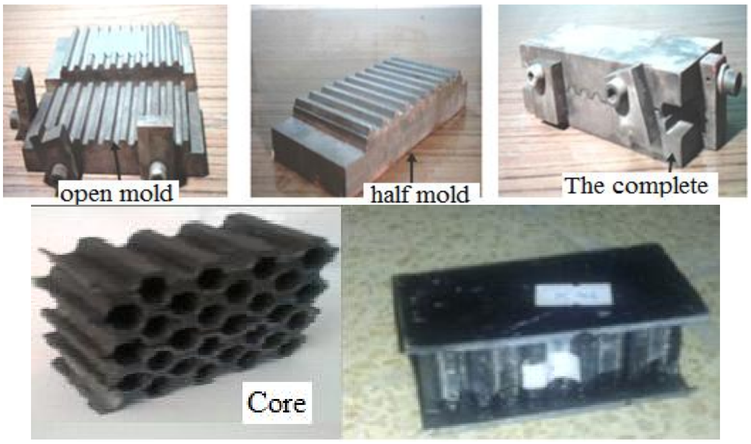

Fig .(1) The Honey comb mold and sandwich panel.

Fig .(2) The Tensile test specimens according to (ASTM D-638) [7].

Experimental program

In order to characterize effect of graphite filler contents on the dynamic behavior of (30%) weight fraction glass-polyester sandwich panel under low velocity impact, the following experimental tests were performed:

- **Tensile test:** The plate was machining using CNC vertical milling machine to produce the tensile test samples according to ASTM-D 638 [7] .The results of the tensile test are listed in **Table(4).**

Table .(4) Effect of graphite filler content on the mechanical properties.

Graphite %	E(Gpa)	σ_y (Mpa)	σ_{ut} (Mpa)
0%	2.590	55.5	129
2.5%	2.895	76	133
5%	2.950	80	151
7.5%	3.610	89	169
10%	3.090	77	158

- **Dynamic behavior test:** The composite honey comb sandwich panel of (80×40×40) mm has been fixed from three sides and free from the other. The accelerometer has been glued at the center of the lower sheet. A metal pipe is fixed by a suitable structure over the sheet. This structure shown in **Figure.(3),** was used as a guide to drop the steel ball of 45g and 80g on the panel center from the height of (90 and 120) cm. Each ball dropped three times for each height. The strain is digitized and transferred to the vibration data collector (TVC 200) device. The data transferred to a computer by connect the (TVC 200) to it. The data was analyzed by utilizing MCM3 software program to represent the dynamic response of the tested panel.

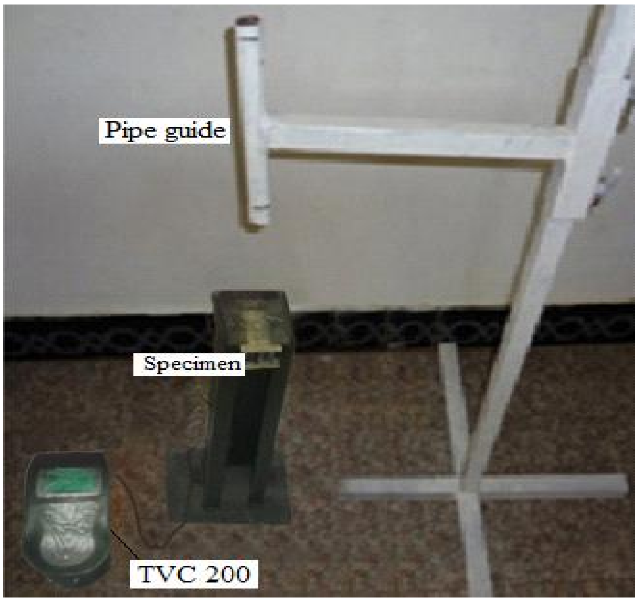

Fig .(3) The dynamic response test rig.

- **Destructive test:** To demonstrate withstand (deformation resistance) of honey comb sandwich panel under the impact load. The low velocity impact tests (destructive test) were conducted by drop a steel impactor of 15 kg weight from a tower of 2 m height, 6.2 m/s impact velocity, and 300 J impact energy, on the honey comb sandwich panel of (80×40×40) mm. The panel is supported on a rigid foundation and the impactor object release. The shortness in length of the panel was measured using vernier caliper. The results are shown in **Table (5)**.

Table .(5) Low velocity impact test results of honey comb sandwich panel with graphite filler content.

Honey comb core	Face sheet	Δ mm
0% C	Unfilled	17.5
	2.5% C	17
	5% C	17
	7.5% C	16
	10% C	16.5
2.5% C	Unfilled	15
	2.5% C	14.7
	5% C	14
	7.5% C	13.6
	10% C	14
5% C	Unfilled	13.3
	2.5% C	12.8
	5% C	12
	7.5% C	11.7
	10% C	12.3
7.5% C	Unfilled	8
	2.5% C	7.6
	5% C	7.3
	7.5% C	7
	10% C	7.4
10% C	Unfilled	10.6
	2.5% C	10.5
	5% C	10
	7.5% C	10
	10% C	11

Results and discussion

The mechanical properties study includes the stress-strain relation, modulus of elasticity, yield stress and ultimate tensile strength. **Figure.(4)** illustrates the stress-strain behavior of the tensile test with graphite filler content. The behaviors of stress strain relation in the five conditions have the same behavior but differ in magnitude. As the filler content was increased the mechanical properties of the composite generally increased as shown in **Table(4)**. The modulus of elasticity increased by (11%, 13%, 39% and 19%). The yield stress was increased by (36%, 44%, 60%, and 38%). The ultimate tensile strength was increased by (3%, 17%, 31% and 22%), when using (2.5%, 5%, 7.5% and 10%) graphite filler content respectively as compared with the unfilled composite system, and these results identical with results of [6,8]. Because the filler acts with the fiber and resin in resisting the load and the graphite has a greater strength than the fiber and resin. There is also compatibility between the filler and fiber and between filler and resin. The maximum values of mechanical properties at 30% weight fraction of glass-polyester composite system were found at 7.5% graphite filler contents. But the mechanical properties decreased when the filler content was increased more than 7.5%. Because the resin becomes more viscose with increasing filler which leads to a problem in the resin flows, and gets lower adhesion force with more defects.

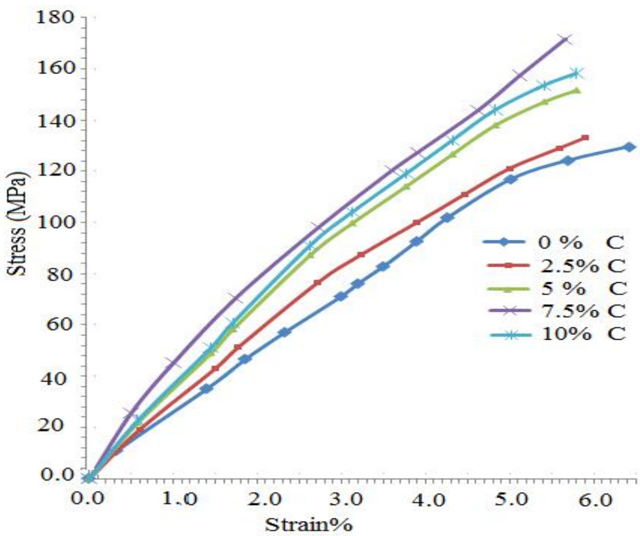

Fig .(4) Effect of graphite filler content on the Stress-strain behavior of tensile test.

The deflection in z-direction was measured at the center on the lower face of the panel. **Figures.(5 and 6)** represent the behavior of composite honey comb sandwich panel have the same material of face and core subjected to 45g impact load with (90 and 120) cm height respectively. While **Figures.(7 and 8)** at 80 g impact loads with (90 and 120) cm height respectively. The results showed that honey comb sandwich panel have the same deflection behavior but differ in magnitude. The maximum deflection occurs with using 80 g load dropped from 120 cm height. Due to high impact momentum occurs. The deflection decreased as the impact load or height decreased and the filler content increased. As the filler increased the system becomes more damped up to limit. The maximum deflection of honey comb sandwich panel was decreased by (5%,13%,28% and 11%) when using (2.5%, 5%, 7.5% and 10%) graphite filler content respectively in comparison to unfilled one.

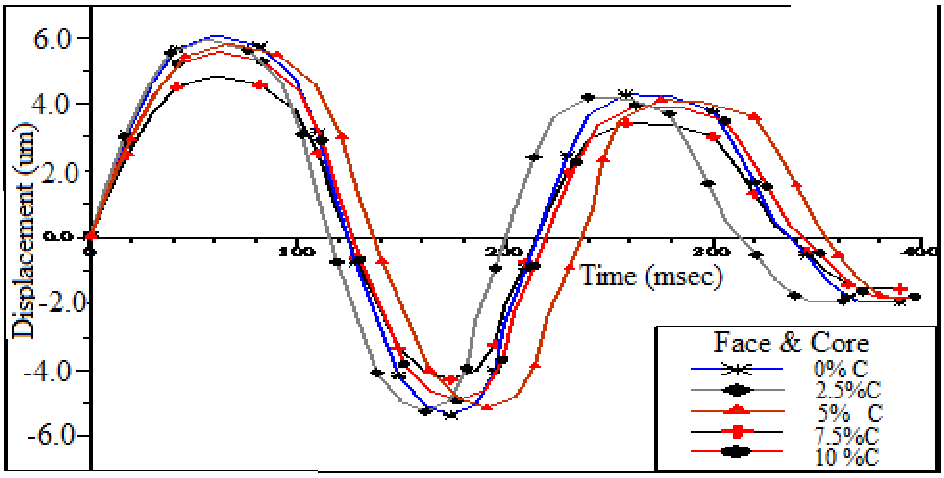

Fig .(5) Effect of graphite filler content on the deflection behavior of honey comb sandwich panel at (m=45g & h=90cm).

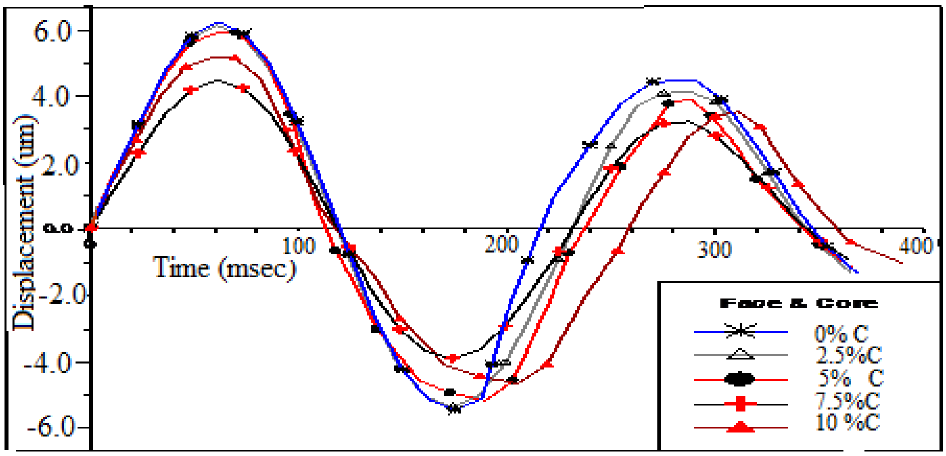

Fig .(6) Effect of graphite filler content on the deflection behavior of honey comb sandwich panel at (m=45g & h=120cm).

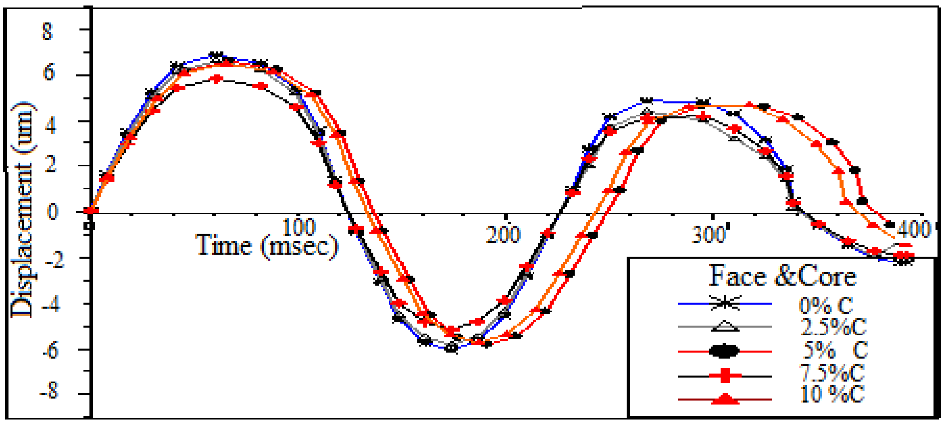

Fig .(7) Effect of graphite filler content on the deflection behavior of honey comb sandwich panel at (m=80g & h= 90cm).

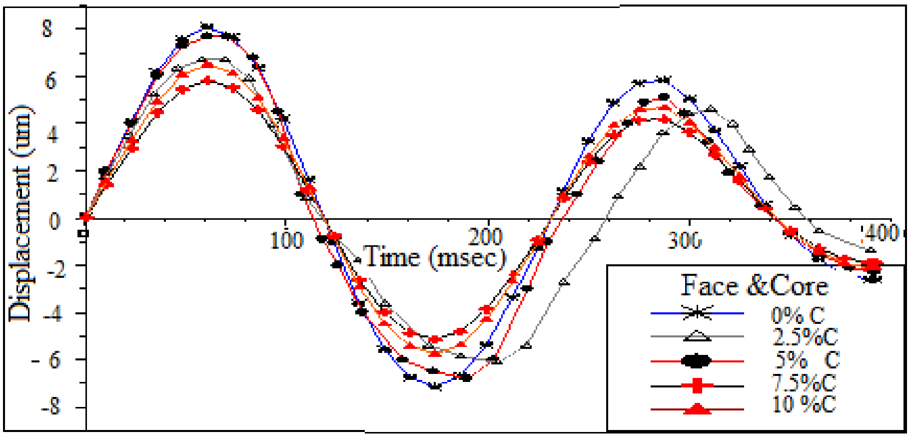

Fig .(8) Effect of graphite filler content on the deflection behavior of honey comb sandwich panel at (m=80g & h=120cm).

The dynamic behavior of the honey comb sandwich panel with differ material of face and core are present in **Figures (9 to 13).** These figures represent the effect of face graphite filler content on the behavior of honey comb sandwich panel have a core with graphite filler content of (0%, 2.5%, 5%, 7.5% and 10%) respectively under 80g impact loads and 120 cm height. The results showed that, the honey comb sandwich panel with different conditions have the same deflection behavior but differ in magnitude. The deflection decreased as the face filler content increased as compared with unfilled one. For a core of 7.5% graphite, the deflection decreased by (1.5%,3%,4% and 2%) when using faces have graphite filler content of (2.5%, 5%, 7.5% and 10%) respectively in comparison with unfilled. So, the faces have a little effect, because the most energy of the impact load absorbed by the core rather than the face.

Table(5) shows the effect of graphite filler content on the deformation of the honey comb sandwich panel subjected to 15 Kg impact load drooped from 2m height. The results show that the deformation decreased as the filler content increased. The panel deformation was decreased by (18%, 28%, 60%, and 37%), when using graphite filler content of (2.5%, 5%, 7.5% and 10%) respectively as compared with unfilled one. This will be conforming the previous discussion that the mechanical properties improved as the filler increased. The system become tougher and damped. When using a core of 7.5% graphite filler content with different face, the deformation was decreased by (5%, 8%, 12.5%, and 7.5%), with the faces of graphite filler content (2.5%, 5%, 7.5% and 10%) respectively as compared with unfilled one. As the most energy absorbed by the core rather than the face; the results showed that the effect of the faces is relatively limited.

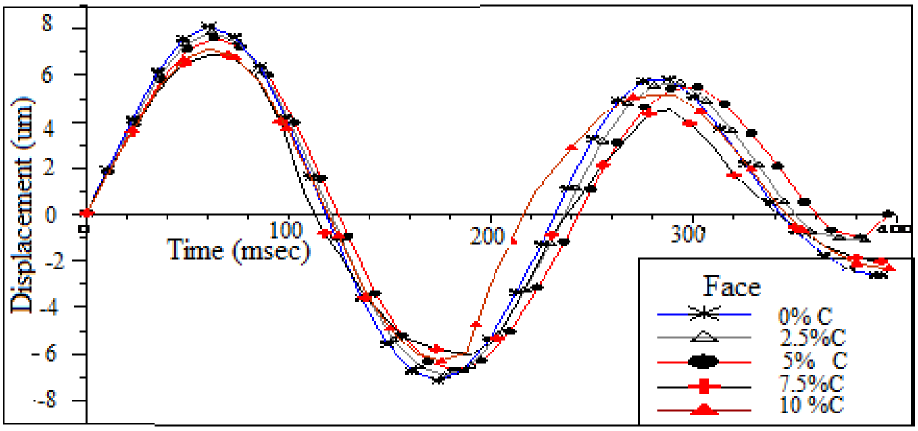

Fig .(9) The defection behavior of honey comb with different faces and 0% C core at (m=80g & h=120cm).

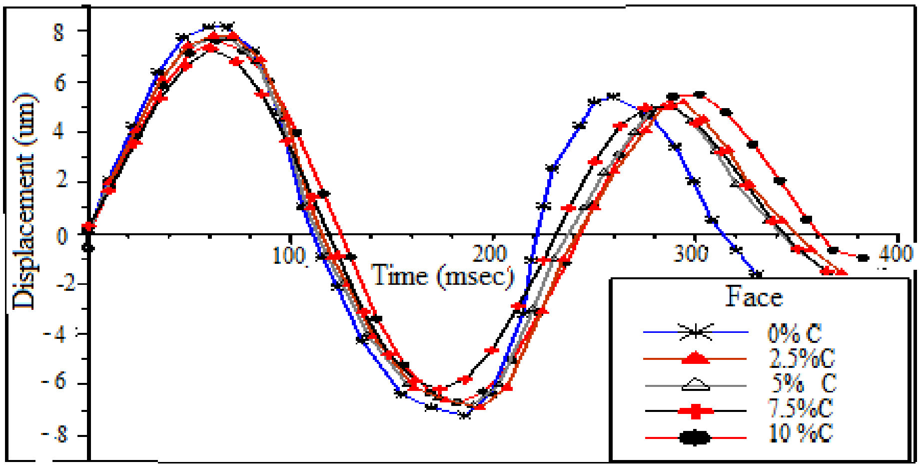

Fig .(10) The defection behavior of honey comb with different faces and 2.5% C core at (m=80g & h=120cm).

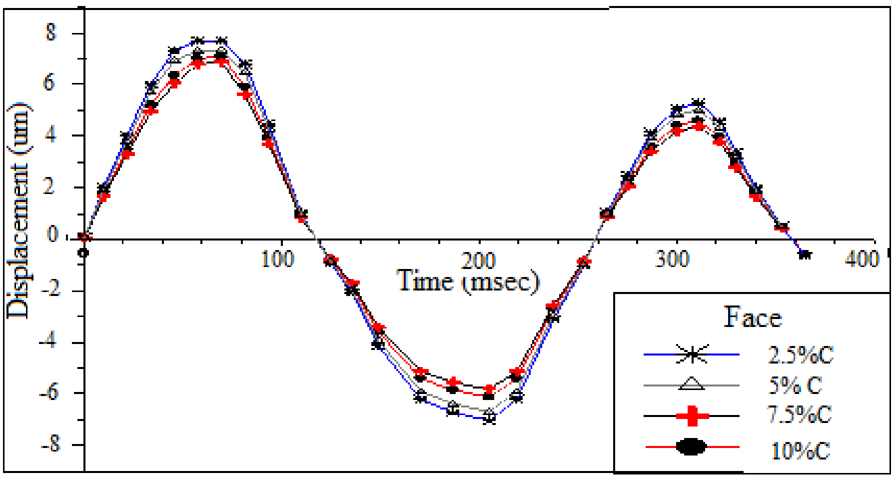

Fig .(11) The defection behavior of honey comb with different faces and 5% C core at (m=80g & h=120cm).

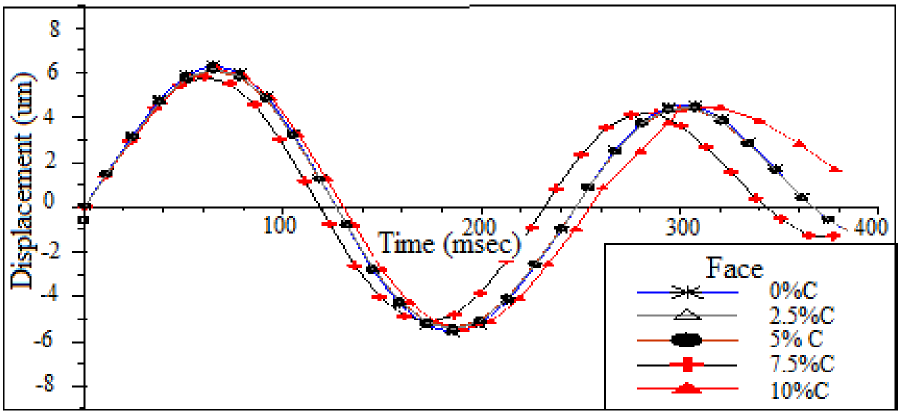

Fig .(12) The defection behavior of honey comb with different faces and 7.5% C core at (m=80g & h=120cm).

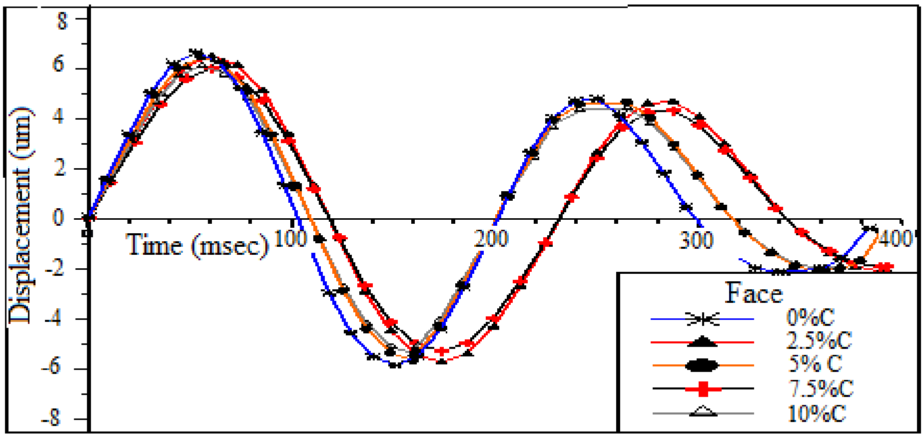

Fig .(13) The defection behavior of honey comb with different faces and 10% C core at (m=80g & h=120cm).

Conclusions

The following conclusions can be drawn:

- At 7.5% graphite filler content the modulus of elasticity, yield stress and ultimate tensile strength increased by (39%, 60% and 31%) greater than unfilled composite.
- The honey comb sandwich panels have the same deflection behavior but differ in magnitude. The deflection and deformation decrease as the graphite filler content increased up to 7.5%.
- The maximum deflection and deformation of the honey comb sandwich panel are decreased by 28% and 60% respectively at 7.5% graphite filler content in comparison to unfilled one. The effects of using different faces with the same core have a little variation.

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