Experimental Study Of a New Composite Materials Firewall For Aircraft By Using Honeycomb Aluminum

دراسة عملية لمواد مركبة جديدة لجدار ناري في الطائرات بأستخدام خلية نحل مصنوعة من الالمنيوم

Luay Hashem Abbud
Department of Air conditioning and Refrigeration Engineering, Mustaqbal University College, Babylon, Iraq

Abstract :
This article presents the experimental study of a new composite materials firewall for light aircraft. Currently, the firewall is made from conventional metallic materials which are used to isolate or protect the cockpit from any flame penetration from the engine compartment. For this reason, additional protection of machinery, wiring and plumbing are required. This protection is accomplished with the use of insulation blankets or other insulating materials at a cost and weight penalty. The use of composite firewall will eventually reduces the need for any additional protection, give a good weight saving and reduces the backside temperature. The composite firewall panel has been tested using the hair dryer with Agilent Bench Link Data Logger for 15 minutes. The temperature distributions across the back of the panel were presented.

Keyword: Composite firewall, aircraft, honeycomb, laminates

الملخص :
قدم في هذا البحث دراسة عملية لمواد مركبة جديدة ليكن جدار ناري في الطائرات الرياضية الخفيفة حالياً ان الجدران النارية مصنوعة من المواد المعدنية المستخدمة في العازل لحماية القيادة من أي اختراق لهب من مقصورة المحرك لهذا السبب أضفنا حماية اكثر من صناعة عوازل مواد مركبة بأقل كلفة واخف وزن وأنها جيده وخفيفة وكذلك تقلل من ارجاع درجات الحرارة باستخدام مصدر واطئ الحرارة وكانت النتيجة جيدة وان فترة استخدام المصدر الحراري 15 دقيقة.

1. INTRODUCTION

Light sport category aircraft commonly use the traditional metallic firewall materials to insulate or protect the aircraft from flame penetration but it will have an effect on background temperature. So adding a protection to the machines for wires and plumbing needed this protection and usually it accomplished by using insulating materials to reduce the cost and weight. The composite firewall will eliminate the need for the additional protection, give a good weight saving and reduce the backside temperature. Guard 1990 [1], reported that the fabrication and testing of a simple uninsulated sandwich composite structure designed from low cost composite materials which can resist a 2000°F for 15 minutes FAA fire test. Misciagna 2005 [2], reported that the integrated ceramic composite firewall is an improvement over the existing metallic firewall technology. This technology reduces cost, part count, weight and manufacturing complexity of composites, which require fire protection. The inventor Misciagna 2006 [3], work under Boeing Co. issued US Patent on March 8, 2005 for "Monolithic composite firewall". In 2006 US Patent no. 6 863 980 by Boeing Co. disclosed a monolithic composite firewall which it claims is particularly suited for use in the canted deck of an aircraft. The firewall consist of a ceramic fabric that offers protection and which is bonded by resin that is co-cured into the laminate to form the structure. This construction can resist maximum temperature of 1204°C (2200°F). Abu Talib 2004 [4] reported that the International

Organization for Standardization (ISO) 2685 propane – air burner is widely used in the United Kingdom to certify critical engine components exposed to the danger of fire in aircraft engines. Stringer 1989 [5] reported that it is widely studied that wet put carbon fiber epoxy composites designed by vacuum air purge from an inherently high void content compared to autoclaved prepared systems, and realy can reach 10% or more in some time. The large propane-air burner consists of a plenum chamber, burner head and burner face.The 373 copper tubes will supply mixed propane-air to the burner head and cooling air is discharged via 332 smaller holes interspersed with the copper tubes in the burner face [6].
The composite firewall was developed using composite materials with high resistance resin to counter this problem. So, the main objective first, the design and fabricate a composite firewall for light sport category aircraft and second, conduct a low temperature test on the composite firewall panel.

2. METHODOLOGY

Laminated composite materials are used to develop material proprieties of woven fiber composite. The required characteristics of composites depended on the nature of the matrix, the nature of the reinforcement, the ratio of risen to reinforcement, and the mode of fabrication. The replacement of metallic materials by composite materials in structural applications suitable as light-weight, while the analysis and design of these materials is more complicated than those of metal structures. The Composites material has a layer properties such as strength, stiffness, thermal and moisture conductivity, wear and environmental resistance which strongly depend on the form of the reinforcement in the laminate. So, the choice of composite materials to make a light weight firewall for small aircraft are the Kevlar, carbon fiber, Honeycomb and carbon veil the epoxy mix called Heat Resistance Resin (HRR) has been used for this project.

2.1 Kitting Process

The kitting size for firewall test panel is 12 by 10 inches following the minimum requirement from the Federal Aviation Administration (FAA) [7]. The composite materials were cut in needed size using a sharp knife and a special scissor at a top of a clean table. The orientation for carbon fiber is ±45° and the Kevlar is 90° as shown in **Table 1**. During the kitting process the safety precaution need to be aware which wear a glove and face mask.
The kitting materials are packed in the plastic bag for storage purposes before the lay-up process. It is to prevent from the contamination of dust and control the orientation of the carbon and Kevlar cloth.

2.2 Mould Preparation

Three feet long and two feet glass mould is used for the lay-up process. The glass surfaces must be cleaned using the Acetone or Isopropyl Alcohol with a clean cloth. The bagging tape or sealant tape was sticked along the edge of the glass to prevent any air leak during vacuum bagging process. After that, the glass surface has been waxed using the carnauba wax with a clean cloth and leave it for 5 minutes for the haze look a like and then wiped it off with another clean cloth. For safety it needs to be aware when performing the preparation process.
The wax needs to be applied for three times for getting a very good layer of wax. This process is important to prevent the panel from stuck to the mould, by mean, an easy demoulds after the panel cured. The glove must be worn when perform this preparation for safety purposes.

2.3 Vacuum Process

Pressure is applied to the composite materials once laid to improve its fabrication. This is achieved by sealing a plastic film over the wet put composite onto the tool. The air affect the bag is pulled by a vacuum pump and thus up to one atmosphere of pressure can be applied to the composite materials to consolidate it **Figure 1**. Fiber content can be increased by up to 50 percent by curing the part in a vacuum bag, using 2 psi to 14 psi vacuum pressure and cure temperatures under 350°F Hahn 2006 [8]. The applied vacuum will compact the preform and helps the resin to penetrate and wet-out the fiber perform **Figure 2**. Waited for the part cured before demould and trim the size needed.

The cured firewall panel has been trimmed to the needed size 12 x 10 inches using the proper cutter and cleaned using the isopropyl alcohol. From the observation, a dried area at the panel showed that the error during lay-up process which the resin distribution are not done properly. This problem can be solved if using the pre-prep material with the heat resistance resin. The test panel has 0.45 inches of thickness.

2.4 Thermal conductivity

The thermal conductivity (k) of the composite material (Honeycomb Aluminum) used for manufacturing heat sinks was measured by apparatus shown in **Figure 3**. The apparatus was manufactured by Cussons Technology Ltd. (England). The heat conducted was measured from the equation:

$$q = \dot{m} C_p \Delta T \qquad \text{............} \qquad (3\text{-}1)$$

Where:

$\dot{m}$: Weight of collected water per time, kg/sec.

C_p : Specific heat capacity, J /kg.K.

ΔT: Temperature difference between inlet water temperature and outlet water temperature, (K). Fourier Law is used to measure thermal conductivity (k) as shown below:

$$q = -kA\frac{\Delta T}{\Delta x} \qquad \text{............} \qquad (3\text{-}2)$$

Where:

q; Heat flow (W) [measured from eq. (3-1)].

A; Area perpendicular to heat flow

(m2).ΔT/ΔX : Temperature gradient, and

k : Thermal conductivity.

By taking the average value of measured thermal conductivity, the resulting value of k was 192 Watt /m.C°.

2.5 Low Temperature Test

2.6

Initially, fire test has been schedule to be conducted at Forest Research Institute of Malaysia (FRIM). However, FRIM does not have the calorimeter facility that can measure the heat flux density so another alternative is the low temperature test which the heat distribution finding can be done by using the hair dryer with the Agilent Benchlink Data Logger **Figure 4**. The hair dryer has a maximum temperature of 70° Celsius and been used for 15 minutes as per the procedure in FAR fire test requirement. The testing has been done in the lab with the closed environment. The distance between the panel and hair dryer is 2 inches (50.8 mm) in order to achieve the temperature. The placement of the test panel is the same distance during calibration of the calorimeter as per procedure which is used the propane burner. A thermocouple has been placed at the back of the panel with 13 different points and connected to the Agilent Bench Link Data Logger **Figure 5**. The test has been done with 2 panels. The construction for panel 1 has only 1 ply of carbon each side and panel 2 has 2 plies of carbon each side. The test panel 1 has 0.40 inches of thickness and panel 2 has 0.45 inches of thickness. The test are been timing using the time-watch and below is the result of the test in the chart given in **Figure 6** and **Figure 7**.

3. RESULT AND DISCUSSION

The low temperature test result for composite firewall panel using the hair dryer with Agilent data logger started with the room temperature 29.96° Celsius for panel 1 and 31.06° Celsius for panel 2. Average temperature after 902 second for test panel 1 is 58.76° Celsius and 59.10° Celsius for test panel 2. The gradient of the temperature increment by the time can be seen for test panel 1 and panel 2 which the test panel 1 has a greater increment than the test panel 2. This is happen because of the material characteristic such as carbon that can resist the heat at the higher temperature when applied more than 1 plies. The heat flow also can be affect by the thickness of the test panel because test panel 1 only has 0.40 inches and the test panel 2 has 0.45 inches of thickness. After 300 seconds of test the temperature becoming constant because of the limitation of the hair dryer itself in producing the heat.

From the **Figure 8** and **Figure 9**, show that the thermocouple 103(C) is the center of panel which the heat was concentrated. Both panel 1 and panel 2 show at the same point of temperature. The hair dryer was blower the hot air to the center and caused the air distributed to the panel but, the heat increased more at point 102(C), 104(C), 107(C) and 108(C) which have a distance 2 inches from the center. The hot air will go up because it is lighter than a normal air.

4. CONCLUSION

Composites are the best choice to replace the metallic firewall because their use is growing rapidly owing to a significant reduction in the price and increase the availability in aerospace applications, aviation industry, automotive, sporting goods, civil infrastructure, offshore oil and many other consumer applications.

Carbon fiber has in general high strength; high modulus reinforcement used in the design of high performance polymers matrix composites. Its also get through the pyrolysis process which drive out most noncarbon elements in an inert atmosphere up to 1500° Celcius. Then the carbon has the heat treatment process which improves the crystallite structure in inert atmosphere about 1800 - 3000° Celcius. So, the carbon is the best material for making the aircraft firewall because of their low thermal conductivity which makes them ideal for insulating. The combination of the carbon and Kevlar makes them perfect for compression because Kevlar have poor characteristic in compression but has higher tensile strength and modulus.

The wet lay-up process in making the composites firewall have advantages such as, large and complex parts can be produced, required minimum equipment investment, the startup lead time and cost are minimal, the tooling cost is low, semi-skilled workers are easily trained, sandwich constructions are possible and moulded or structural changes are possible. The low temperature test using the hair dryer with the Agilent BenchLink Data Logger gives a good response but still need a further test to be done in the future because of the limitation of producing the heat.

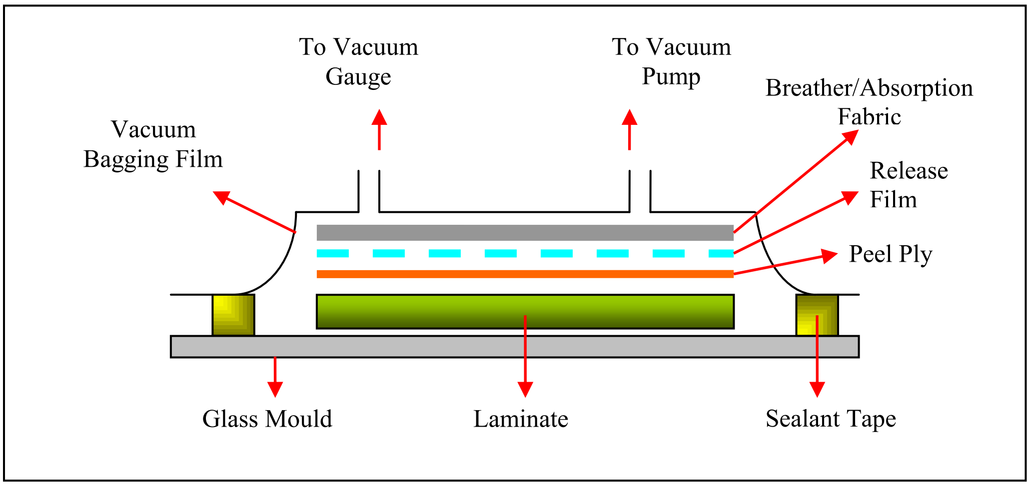


Figure 1 – A schematic drawing of vacuum bagging

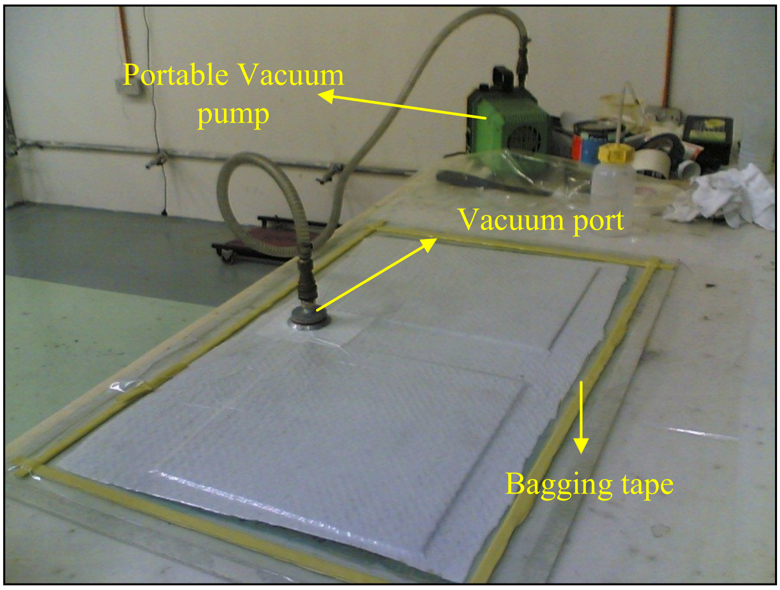


Figure 2 – A vacuum bagging

Figure 3 – Thermal conductivity apparatus

Figure 4 – Agilent BenchLink Data Logger

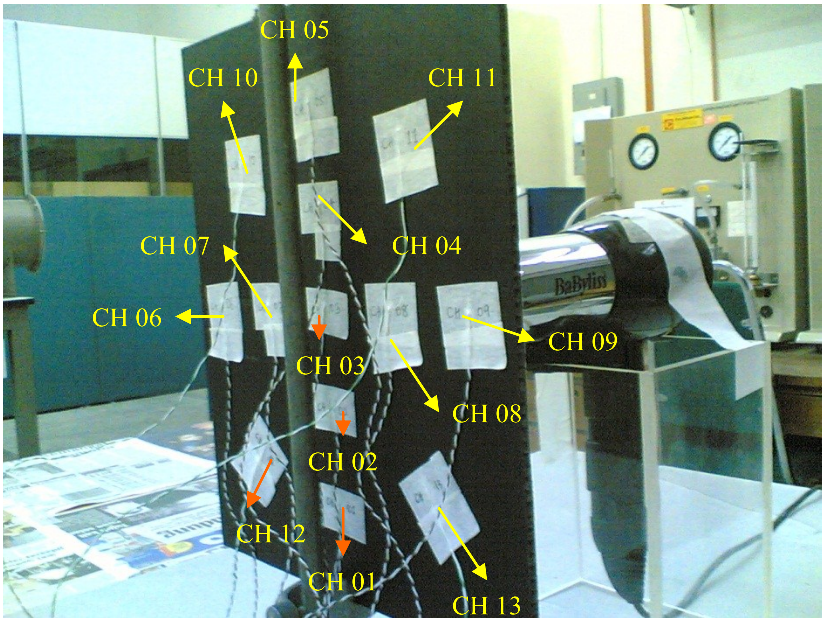


Figure 5– A hair dryer set-up with panel and thermocouple

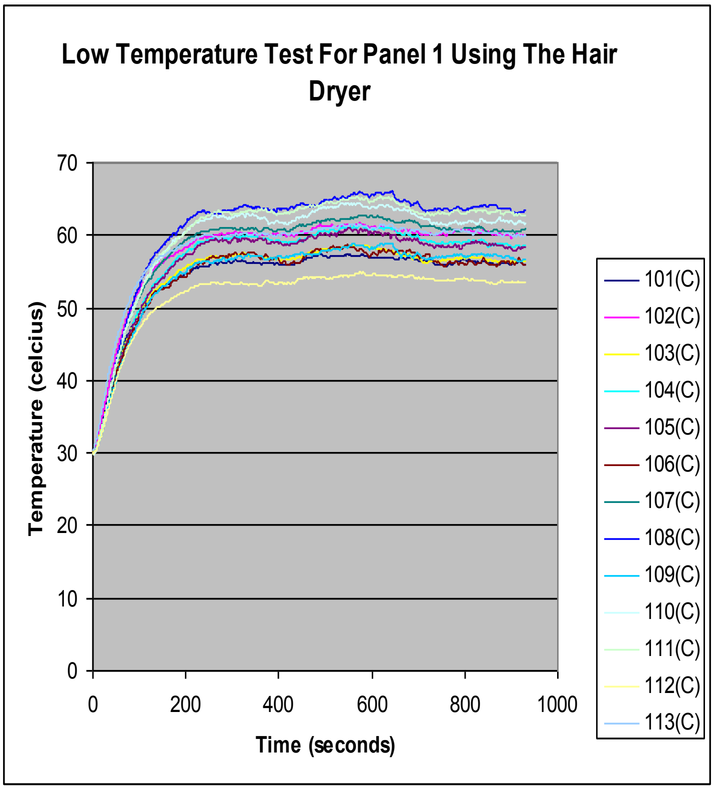


Figure 6 – The result of composite firewall test panel 1

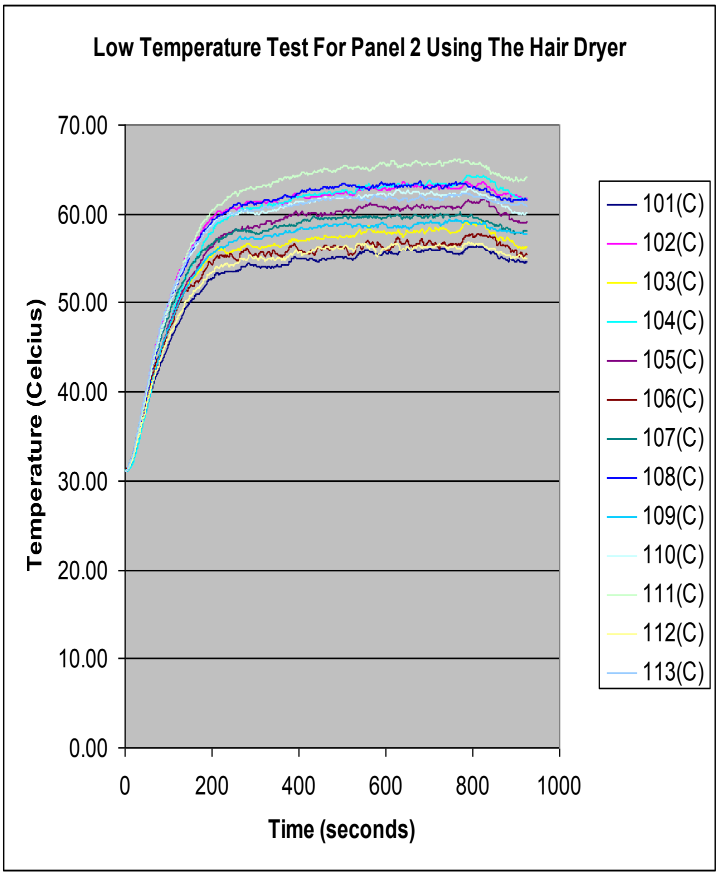
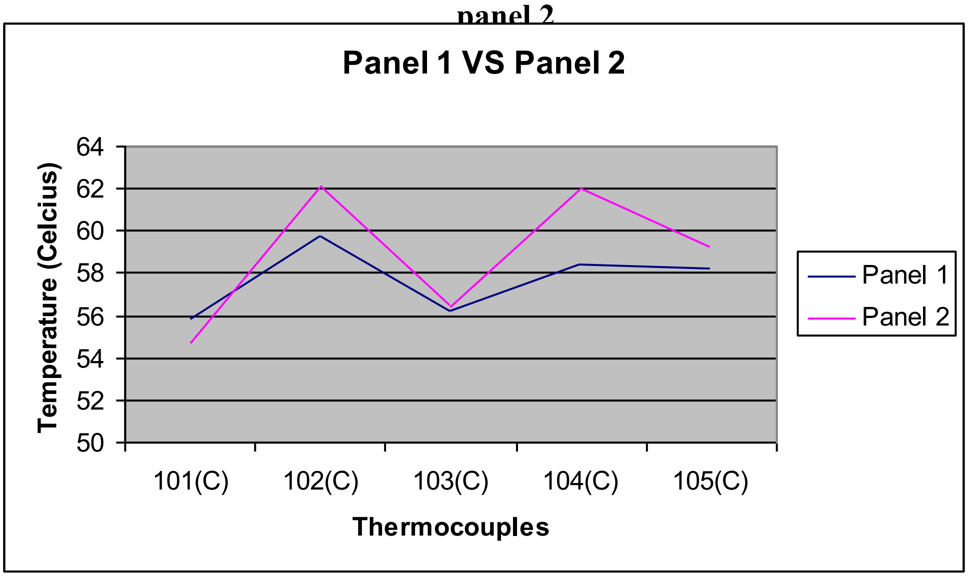
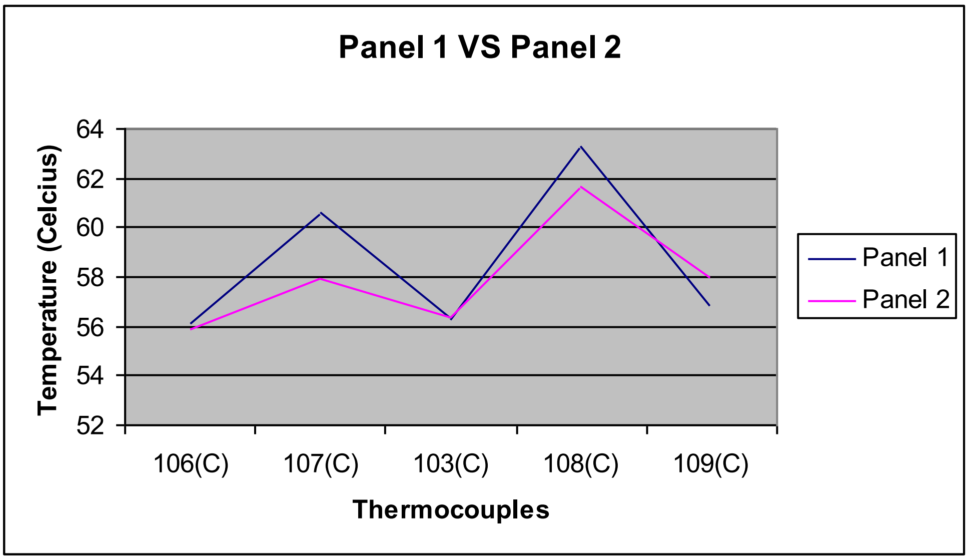


Figure 7 – The result of composite firewall test panel 2



Maximum temperatures for panel 1 and 2 at thermocouples 1,2,3,4 and 5



Maximum temperatures for panel 1 and 2 at thermocouples 6,7,3,8 and 9

Table 1 – The kitting materials size for firewall panel

Material	Size (Inches)	Orientation	Quantity
Kevlar	12.5 x 10.5	90°	2
Carbon	12.5 x 10.5	±45°	4
Carbon Veil	12.5 x 10.5	-	2
Honeycomb 0.3 inch	12.5 x 10.5	-	1

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