Assessment of sandwich panels in construction Industries

Melod M. Unis [1], Mohamed M.Alghiryani [2]

1,2- Higher Institute of Sciences And Technology,
Gharyan. Libya.

الخلاصة :

الألواح المركبة أصبحت تحظى بشعبية متزايدة في الأعمال والتطبيقات الهندسية نتيجة لقوتها ولصلابتها العالية وخفتها ووزنها النسبي. المواد الطويلة العمر دائما ما تكون مرغوبة من مهندسي الإنشاءات .

مواد الألواح ذات المنشأ البلاستيكي الحراري يتم مزجها مع الألياف الزجاجية أو مع الألياف الكربونية لإنتاج نوع من الحشو المركب يستعمل في الألواح المركبة والذي أصبح الآن يمثل مواد إنشاءات في العلوم الهندسية وفي قطع غيار المركبات في السنوات الأخيرة وهذا أيضاً بسب خفة وزنها وخاصية مقاومة التآكل.

وبرغم إن الألياف الكربونية المقواة بالبوليمير تلبي المطالب إلا أن تباينها يجعل توصيلات العناصر الإنشائية ضعيفة إلى حد كبير وهو السبب الرئيسي من وراء عدم استعمال قوته العالية بالكامل.

ولكن الوجه السفلي للصفيحة مصنوع من البولي بروبليين بنسبة 30 % ألياف زجاجية و1% ألياف كربونية بينما الصفائح المركبة مصنوعة من قشرة خارجية رقيقة من ألياف البوليمير المقواة والذي يربط باللصق بقالب رغوة أكثر سمكاً.

المواد المركبة في الألواح المحشوة تطلب معرفة السلوك الميكانيكي للمواد المستخدمة للواجهات والقالب.

في هذا العمل سوف يتم استعمال نماذج رياضية مختلفة لتقييم التحليل الإنشائي للألواح المحشوة .

نتائج الدراسة التجريبية بينت إن المركبات البلاستيكية الحرارية المقواة سوف تكون لها فوائد كبيرة للإنشاءات في المستقبل.

Abstract:

Composite sandwich plates are gaining increasing popularity in engineering practice, due to their – strength, high – stiffness – to – light – weight ratio. Durable materials are always desired by structure engineer. Composite materials of thermoplastics origin are blended with fiber glass or carbon fiber to produce a sandwich type composite, used in sandwich panels is now becoming the structural material in engineering sciences and automobile parts in recent years also due to its light – weight and anti – corrosion properties. Although carbon fiber reinforced-polymer meets the demands, but its anisotropy makes the connection of structural elements considerably weak which is the main cause that make its high strength not be utilized fully. However, the lower face lamina, the top face are made of polypropylene with (30%) fiber glass or (1%)carbon fiber composite, sandwich laminates are made of thin outer skin of fiber reinforced polymer adhesively bonded to a thicker core of foam. Composite materials in sandwich panels require knowledge of the mechanical behavior of the materials used for the facings and the core. In this work, different mathematical models will be used to evaluate structural analysis of the sandwich panels. The results of the experimental study have showed that reinforced thermoplastics composite will have potential benefits for the structures in future.

1. Introduction :

Sandwich panels are composite structural elements, consisting of two thin, stiff, strong faces separated by a relatively thick layer of low-density and stiff material. The faces are commonly made of steel, aluminum, hardboard or gypsum and the core material may be polyurethane, polyisocyanate, expanded polystyrene, extruded polystyrene, phenolic resin, or mineral wool. In Australia, sandwich panels are commonly made of expanded polystyrene. Sandwich construction has been widely used in aircraft and many structural applications for a long time. In recent years, sandwich panels are increasingly used in building structures particularly as roof . They are also being used as internal walls and ceilings. However, research and development of sandwich panels with profiled faces began only in late 1960s . Due to the increasing interest in the use of structural sandwich panels ,a good deal of research has continued in recent years .

2. The origins Of Sandwich Technology :

The first successful landing of a space ship on the moon on 20th. July 1969 was the result of the successful application of a number of new technologies including rocketry , computers and sandwich construction .Although public interest catered on rocketry and computer technology , it was only with the help of sandwich technology that a shell of the spacecraft could be constructed that was light in weight and yet strong enough to sustain the stresses of acceleration and landing . figure 1 shows the wall construction of the Apollo capsule which consisted of two interconnected sandwich shells. Figure 2 shows details of the outer shell, which comprised two thin steel facings and a honeycomb core. The inherent advantage of sandwich construction is immediately apparent, namely, high strength and rigidity at low weight.

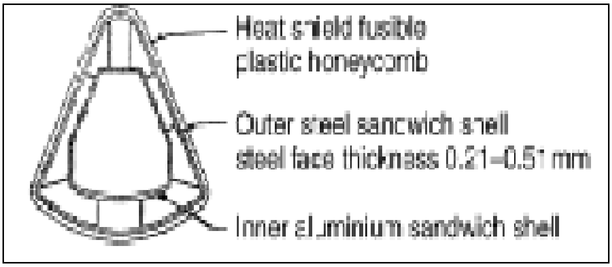


Figure1 Sandwich construction of the Apollo capsule.

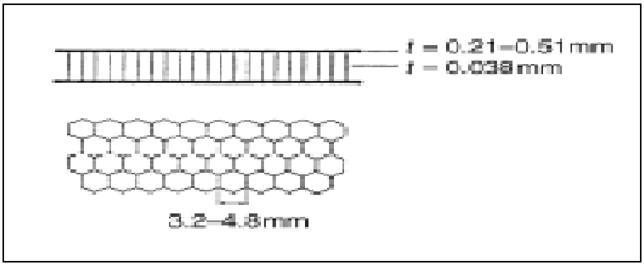
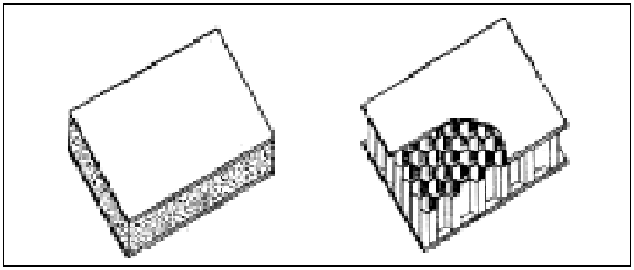


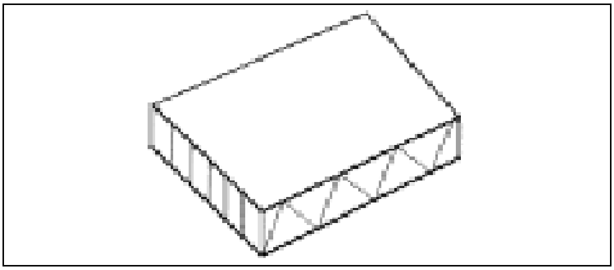
Figure 2 Cellular sandwich forming the outer shell of the Apollo capsule.

3. Principles of Sandwich Construction :

The structure of sandwich panels always follows the same basic pattern. Two facings, which are relatively thin and of high strength, enclose a core which is relatively light and which has adequate stiffness in a direction normal to the faces of the panel. A great many alternative forms of sandwich construction may be obtained by combining different facing and core materials. as shown in figure 3.



(a) Expanded plastic core.   (b) Honeycomb core.



(c) Mineral wool core.

Figure 3 sandwich construction with different cores.

The resulting composite panel owes its success to the following favorable properties:

- high load-bearing capacity at low weight.
- excellent and durable thermal insulation.
- absolute water and vapor barrier.
- excellent air tightness.

- surface finished facings providing resistance to weather and aggressive environments. Capacity for rapid erection without lifting equipment; easier installation in hostile weather conditions.

Facing Materials :

Relatively thin, high-strength sheets are generally used as facing materials.

Steel facings :

Thin steel sheets are the most frequently used facing material. In general, only sheets with both metallic and organic (plastic) coatings should be used.

Aluminum sheeting :

Sandwich panels with facings made of bare aluminum sheet are sometimes used in applications where there are special requirements for corrosion resistance or hygiene; for example, in the production or storing of foodstuffs.

Composite materials:

Composite materials consist of two or more materials combined in such a way that the individual materials are easily distinguishable. The individual materials that make up a composite are called constituents.

4.1 Constituents of Composite Materials:

Matrix :

Phase that receive the inserts in phase composition is continuous phase and is called as matrix. It is also called as binders .Ex- Polymer, Ceramics, Metals.

Polymers:

Polymers used for auto body applications may be split into thermoplastics and thermosets.

Thermoplastic Polymers :

Thermoplastics can be divided into amorphous and crystalline varieties. In amorphous forms the molecules are orientated randomly.

Thermosetting Polymers :

Thermosets are generally more brittle than thermoplastics so they are often used with fiber reinforcement of some type.

Reinforcement:

Fibers are the principle constituents in fiber reinforcement composite materials.

Glass fiber :

Glass fiber are the oldest form of strength fiber used in composite structure materials.

Carbon fiber:

Nowadays carbon fibers finds its own place in the composite materials where weight reduction are valuable.

Figure 4 and Figure 5 show the main components in the extruder coupled with injection moulding machine .

5. Experimental Work :

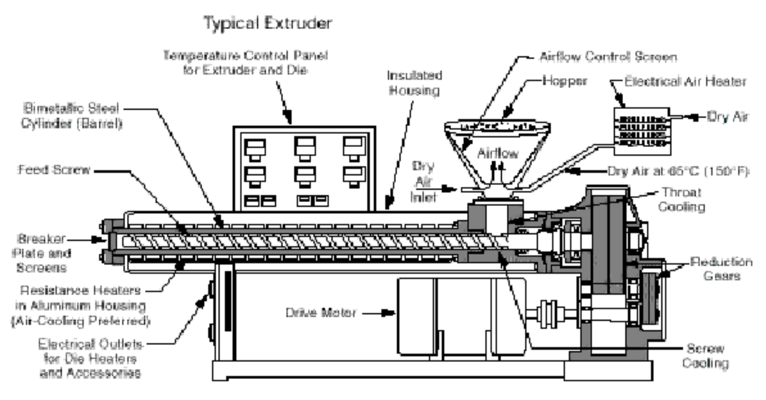


Figure 4 Rabta Extruder.

6. Injection Moulding Process :

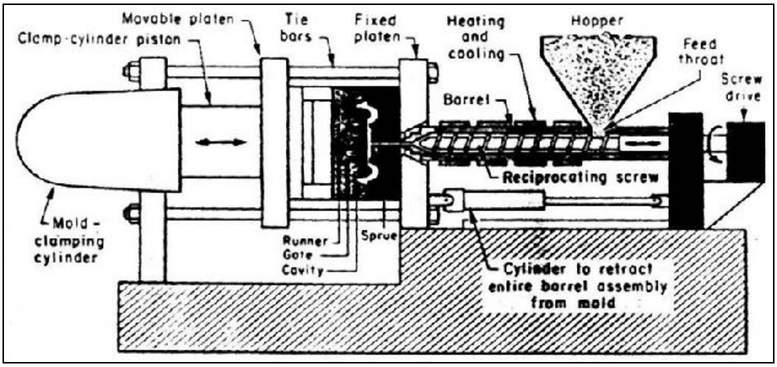


Figure 5 Extruder coupled with injection moulding.

7. Result And Discussion :-

Fiber Mass Fraction :

Fiber mass fraction is defined as:

$$Mf = \text{Mass of fibers} / \text{Total mass}$$

In consequence, the mass of matrix is:

$$Mm = \text{Mass of matrix} / \text{Total mass}$$

With : $Mm = 1 - Mf$

Fiber Volume Fraction :

Fiber volume fraction is defined as:

$$Vf = \text{Volume of fiber} / \text{Total volume}$$

As a result, the volume of matrix is given as:

$$Vm = \text{Volume of matrix} / \text{Total volume}$$

With : $Vm = 1- Vf$

Mass Density of a Ply :

The mass density of a ply can be calculated as :

$$\rho = \text{total mass} / \text{Total volume}$$

The above equation can also be expanded as:

$$\begin{aligned} \rho &= \frac{\text{mass of fiber}}{\text{total volume}} + \frac{\text{mass of matrix}}{\text{total volume}} \\ &= \frac{\text{volume of fiber}}{\text{total volume}} \rho_f + \frac{\text{volume of matrix}}{\text{total volume}} \rho_m \end{aligned}$$

Theoretical calculations for strength, modulus, and other properties of a fiber reinforced composite are based on the fiber volume fraction in the material.

Experimentally, it is easier to determine the fiber weight fraction Mf, from which the fiber volume fraction vf and composite density ρc can be calculated :

$$\rho c = vf \times \rho f + vm \times \rho m$$

Mechanics of fiber-reinforced composites :

The mechanics of materials deal with stresses, strains, and deformations in engineering structures subjected to mechanical and thermal loads.

As a result, the mechanics of fiber-reinforced composites are far more complex than that of conventional materials. The mechanics of fiber-reinforced composite materials are studied at two levels:

1. The micromechanics level, in which the interaction of the constituent materials is examined on a microscopic scale. Equations describing the elastic and thermal characteristics of a lamina are, in general, based on micromechanics formulations. An understanding of the interaction between various constituents is also useful in delineating the failure modes in a fiber-reinforced composite material.

2. The macro mechanics level, in which the response of a fiber-reinforced composite material to mechanical and thermal loads is examined on a macroscopic scale. The material is assumed to be homogeneous. Equations of orthotropic elasticity are used to calculate stresses, strains, and deflections .

8. Compliance And Stiffness Matrices :

Specially Orthotropic Lamina (θ = 0° or 90°) :

$$\begin{bmatrix} \varepsilon_{xx} \\ \varepsilon_{xy} \\ \gamma_{xy} \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & 0 \\ S_{21}(=s_{12}) & S_{22} & 0 \\ 0 & 0 & S_{66} \end{bmatrix} \begin{bmatrix} \sigma_{xx} \\ \sigma_{xy} \\ \tau_{xy} \end{bmatrix} = \left[S\right] \begin{bmatrix} \sigma_{xx} \\ \sigma_{xy} \\ \tau_{xy} \end{bmatrix}$$

where :

$$S_{11} = \frac{1}{E_{11}}$$

$$S_{12} = S_{21} = -\frac{V_{12}}{E_{11}} = -\frac{V_{21}}{E_{22}}$$

$$S_{22} = \frac{1}{E_{22}}$$

$$S_{66} = \frac{1}{G_{12}}$$

$$\begin{bmatrix}\sigma_{xx}\\ \sigma_{yy}\\ \tau_{xy}\end{bmatrix}=\begin{bmatrix}Q_{11} & Q_{12} & 0\\ Q_{21}(=Q_{12}) & Q_{22} & 0\\ 0 & 0 & Q_{66}\end{bmatrix}\begin{bmatrix}\varepsilon_{xx}\\ \varepsilon_{yy}\\ \gamma_{xy}\end{bmatrix}=\left[Q\right]\begin{bmatrix}\varepsilon_{xx}\\ \varepsilon_{yy}\\ \gamma_{xy}\end{bmatrix}$$

Where [Q] represents the stiffness matrix for the specially orthotropic lamina.
Various elements in the [Q] matrix are :

$$Q_{11}=\frac{E_{11}}{1-V_{12}V_{21}}$$

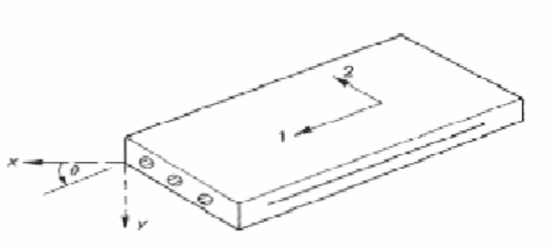
$$Q_{22}=\frac{E_{22}}{1-V_{12}V_{21}}$$

$$Q_{12}=Q_{21}=\frac{V_{12}E_{22}}{1-V_{12}V_{21}}=\frac{V_{21}E_{11}}{1-V_{12}V_{21}}$$

$$Q_{66}=G_{12}$$

The strain–stress relations for a general orthotropic lamina, can be expressed in matrix notation as:

$$\begin{bmatrix}\varepsilon_{xx}\\ \varepsilon_{yy}\\ \gamma_{xy}\end{bmatrix}=\begin{bmatrix}\bar{S}_{11} & \bar{S}_{12} & \bar{S}_{16}\\ \bar{S}_{12} & \bar{S}_{22} & \bar{S}_{26}\\ \bar{S}_{16} & \bar{S}_{26} & \bar{S}_{66}\end{bmatrix}\begin{bmatrix}\sigma_{xx}\\ \sigma_{yy}\\ \tau_{xy}\end{bmatrix}=\left[\bar{S}\right]\begin{bmatrix}\sigma_{xx}\\ \sigma_{yy}\\ \tau_{xy}\end{bmatrix}$$



Expressing stress in the x ,y coordinate system in terms of stresses in the 1,2 coordinate system in the following way , shear strain must be used in the transformation:

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \sigma_{xy} \end{Bmatrix} = \begin{bmatrix} m^2 & n^2 & -2mn \\ n^2 & m^2 & 2mn \\ mn & -mn & m^2-n^2 \end{bmatrix} \begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{Bmatrix}$$

where : m = cos(θ) , and n = sin(θ).

$$\{\sigma_{xy}\} = [T]\{\sigma_{12}\}$$

$$\{\sigma_{xy}\} = [T]\{\varepsilon_{12}\} = [T][Q][T]^{-1}\{\varepsilon_{xy}\} = [\bar{Q}]\{\varepsilon_{xy}\}$$

$$\begin{bmatrix} \sigma_{xx} \\ \sigma_{yy} \\ \tau_{xy} \end{bmatrix} = \begin{bmatrix} \bar{Q}_{11} & \bar{Q}_{12} & \bar{Q}_{16} \\ \bar{Q}_{12} & \bar{Q}_{22} & \bar{Q}_{26} \\ \bar{Q}_{16} & \bar{Q}_{26} & \bar{Q}_{66} \end{bmatrix} \begin{bmatrix} \varepsilon_{xx} \\ \varepsilon_{yy} \\ \gamma_{xy} \end{bmatrix}$$

where [Q] represents the stiffness matrix for the lamina. Various elements in the [Q] matrix are expressed in terms of the elements in the [Q] matrix as :

$$\begin{aligned}
\bar{Q}_{11} &= Q_{11}\cos^4\theta + 2(Q_{12}+2Q_{66})\sin^2\theta\cos^2\theta + Q_{22}\sin^4\theta, \\
\bar{Q}_{12} &= Q_{12}(\sin^4\theta\cos^4\theta) + (Q_{11}+Q_{22}-4Q_{66})\sin^2\theta\cos^2\theta, \\
\bar{Q}_{22} &= Q_{11}\cos^4\theta + 2(Q_{12}+2Q_{66})\sin^2\theta\cos^2\theta + Q_{22}\sin^4\theta, \\
\bar{Q}_{16} &= (Q_{11}-Q_{12}-2Q_{66})\sin\theta\cos^3\theta + (Q_{12}-Q_{22}+2Q_{66})\sin^3\theta\cos\theta, \\
\bar{Q}_{26} &= (Q_{11}-Q_{12}-2Q_{66})\sin^3\theta\cos\theta + (Q_{12}-Q_{22}+2Q_{66})\sin\theta\cos^3\theta, \\
\bar{Q}_{66} &= (Q_{11}+Q_{22}-2Q_{12}-2Q_{66})\sin^2\theta\cos^2\theta + Q_{66}(\sin^4\theta\cos^4\theta).
\end{aligned}$$

Using the same matrix manipulation, the reduced compliance matrix can be generated as follows :

[Ŝ] = [Q] -1

$$\begin{Bmatrix} \in_x \\ \in_y \\ \in_{xy} \end{Bmatrix} = \begin{bmatrix} \bar{S}_{11} & \bar{S}_{12} & \bar{S}_{16} \\ \bar{S}_{12} & \bar{S}_{22} & \bar{S}_{26} \\ \bar{S}_{16} & \bar{S}_{26} & \bar{S}_{66} \end{bmatrix} \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \sigma_{xy} \end{Bmatrix}$$

These expressions are :

$$\bar{S}_{11} = \frac{1}{E_{xy}} = S_{11}\cos^4\theta + (2S_{12} + S_{66})\sin^2\theta\cos^2\theta + S_{22}\sin^4\theta,$$

$$\bar{S}_{12} = -\frac{\nu_{xy}}{E_{xx}} = S_{12}(\sin^4\theta + \cos^4\theta) + (S_{11} + S_{22} - S_{66})\sin^2\theta\cos^2\theta,$$

$$\bar{S}_{22} = \frac{1}{E_{yy}} = S_{11}\sin^4\theta + (2S_{12} + S_{66})\sin^2\theta\cos^2\theta + S_{22}\cos^4\theta,$$

$$\bar{S}_{16} = -m_x = (2S_{11} - 2S_{12} - S_{66})\sin\theta\cos^3\theta - (2S_{22} - 2S_{12} - S_{66})\sin^3\theta\cos\theta,$$

$$\bar{S}_{26} = -m_y = (2S_{11} - 2S_{12} - S_{66})\sin^3\theta\cos\theta - (2S_{22} - 2S_{12} - S_{66})\sin\theta\cos^3\theta,$$

$$\bar{S}_{66} = \frac{1}{G_{xy}} = 2(2S_{11} + 2S_{22} - 4S_{12} - S_{66})\sin^2\theta\cos^2\theta + S_{66}(\sin^4\theta + \cos^4\theta).$$

Figure 6 and Figure 7 show variation of properties in unidirectional composite as a function of fiber angle for a single ply of Polypropylene with (30%) Fiber glass and (1%) Carbon Fiber composite respectively .

Figure 3,6 shows the variation of the moduli and Poission ratio values for all angles between (0 and 90 0). This gives a clear picture of the performance of unidirectional composites when subjected to off-axis loading , Figure 3,6 represents the results for Polypropylene and fiber glass blend .The reinforced mixture of Polypropylene and carbon fiber is shown in figure 3,7 .

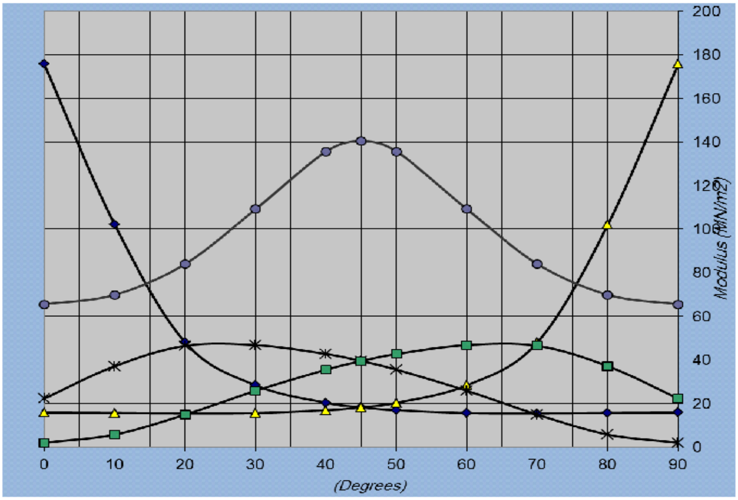


Figure 6 Variation of elastic properties for a single ply of Polypropylene
with (30%) Fiber glass composite.

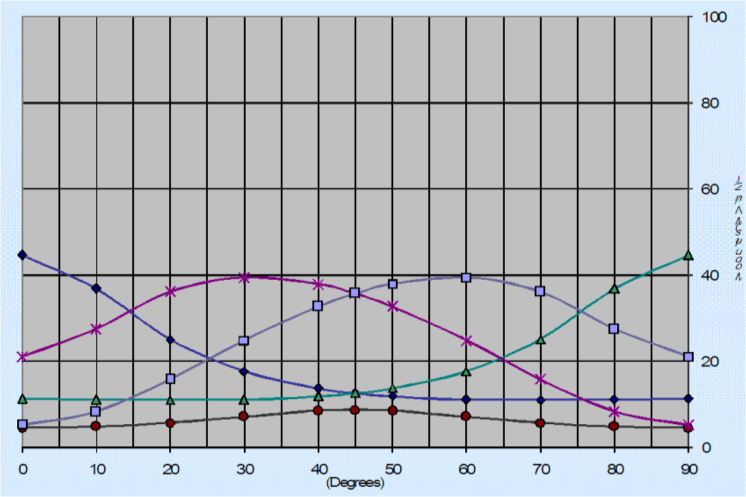


Figure 7 Variation of elastic properties for a single ply of Polypropylene
with (1%) Carbon Fiber composite.

9. Conclusion :

Sandwich panels has future to replace conventional metals in airspace, automobile and building industries due to their light weight and energy saving and carbon dioxide low emissions.

Most structures are not loaded in a single directions. The orientation of sandwich panels are in multiple directions stacking the multiple phase together and enhancing the major mechanical properties.

Stress strain correlations of composite materials made from polypropylene reinforced by fiberglass or carbon fiber are shown superiority and are in the range of applications in the field of airspace, automobile and building industries.

10. References :

[1] Craw Ford R.J, Plastic Engineering , third edition ,Belfast, England. Butter Worth 2002.

[2] S. M. Sapuan, “A computer-aided material selection for design of automotive safety critical components with novel materials”, Malaysian Journal of Computer Science, Vol.12. no.2, December 1999

[3] A.M. Yaacob, M. Ahmad, K.Z.M. Dahlan and S.M. Sapuan, “Experimental studies on fiber orientation of short glass fiber reinforced injection molded thermoplastic composites,” Proceedings of Advanced Materials Conference, Advanced Technology Congress, Putra Jaya, 20-21 May 2003.

[4] Wen S. Chan and Lee Ann Johnson, ”Analysis of Fiber/Matrix Interface in Unidirectional Fiber-Reinforced Composites, Journal of Thermoplastic Composite Materials, Vol. 15, No. 5 2002.

[5] AlaTabiei, and IvelinIvanov, ”Fiber Reorientation in Laminated and Woven Composites for Finite Element Simulations”, Journal of Thermoplastic Composite Materials, Vol. 16, No. 5, 2003.

[6] T. S. Creasy and Y. S. Kang, ”Fiber Orientation during Equal Channel Angular Extrusion of Short Fiber Reinforced Thermoplastics”, Journal of Thermoplastic Composite Materials, Vol. 17, No. 3, 2004.

[7] Powell, P.C. Engineering with Fibre-Polymer Laminates, Chapman and Hall, London (1994).

[8] Mayer, R.M. Design with Reinforced Plastics, HMSO, London (1993).Folkes, M.J. Short Fibre Reinforced Thermoplastics, Research Studies Press, Somerset (1982).

[9] Agarwal, B. and Broutman, L.J. Analysis and Performance of Fibre Composites, Wiley Press (1994).