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Development of Lightweight Composite Pallets for Assembly Line of LCDs and PDPs

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Abstract

Aluminum pallets are used in assembly lines for LCDs (Liquid Crystal Displays) and PDPs (Plasma Display Panels). When used for high quality and large-sized LCDs and PDPs, these pallets have many problems, including heavy weight, and permanent deformation due to their own weight. To solve these problems, it is required that the pallets have light weight, high precision and multiple functions. In this study, stiff, flat, stable and lightweight composite pallets were developed to eliminate the problems associated with the current aluminum pallets. To withstand conditions of concentrated and distributed loads, the designed composite pallets consist of a honeycomb sandwich structure and patterned stiffeners. The composite pallets were made using a hot press under vacuum in a high temperature and high pressure environment. To achieve optimal weight, strength and utility of the composite pallet, the thicknesses of the skin and honeycomb core were determined, and mechanical experiments were conducted. Consequently, we developed highly durable and functional composite pallets with a weight reduction of about 60%.

Keywords

LCDs, PDPs, composite pallets, honeycomb sandwich structure

1. Introduction

1.1. Background

Aluminum pallets are used to transfer LCDs (Liquid Crystal Displays) and PDPs (Plasma Display Panels) in the post-assembling manufacturing process. As LCDs and PDPs become larger in size to meet market demands, the pallets also increase in size, and require greater stiffness and flatness. The pallets have become thicker,

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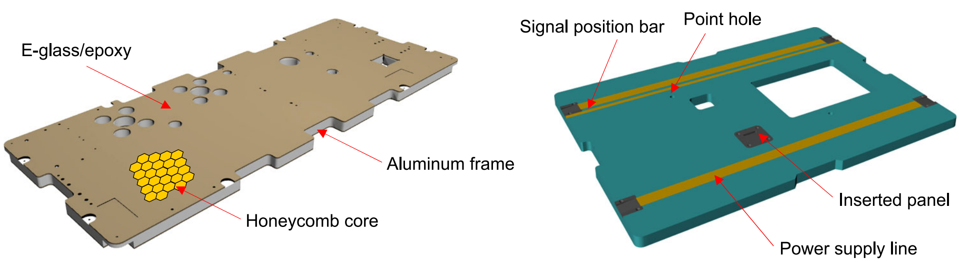
heavier, and have permanent deformation due to their own weight and the weight of the LCDs and PDPs. Increasing the weight of the pallets not only increases management and maintenance costs, but also decreases manufacturing efficiency. Accordingly, reducing the weight of pallets can have many advantages, such as maximizing manufacturing efficiency and saving management and maintenance costs and energy. In order to reduce permanent deformation and decrease manufacturing costs and weight, it is essential that fiber-reinforced composite materials be employed as the main structural materials of the pallets due to their high stiffness and specific strength. In this study, a honeycomb sandwich structure [1–3] was employed to develop composite pallets that are light and have more acceptable properties than aluminum pallets. In order to achieve an optimal pallet design, the thicknesses of the skin and core were calculated. E-glass fiber/epoxy prepreg, adhesive film and manufacturing methods were developed. The composite pallets were manufactured under vacuum, high temperature, and high pressure environments using a hot press. Mechanical properties, thermal properties, and flatness were evaluated to ensure the reliability and dimensional stability [4] of the composite pallets.

1.2. Apparatus of Composite Pallets

The composite pallets consist of E-glass/epoxy prepreg, honeycomb core, aluminum frames (see Fig. 1(a)), and other parts. For the skin material, E-glass/epoxy prepreg was employed to minimize electrification and electrostatic effects due to its superior electric insulation. A honeycomb core was used for the core material to increase bending stiffness, resulting in a lightweight pallet. The skin was treated with non-reflective finish to avoid damaging the LCD and PDP panels with light. In order to replace aluminum pallets with composite pallets, the various electrically functional parts were added to the skin of the composite pallets to have the same function as aluminum pallets, as shown in Fig. 1(b). An aluminum frame was inserted at the honeycomb sandwich structure to shape geometrical forms and to protect the pallets from external impact. The sizes of the composite pallets depend



(a) (b)

Figure 1. Schematic of composite pallet. (a) Classification based on materials; (b) classification based on each part. This figure is published in color on http://www.ingentaconnect.com/content/vsp/acm

on the LCD and PDP panels and their shapes; these can be varied according to the models of each maker.

2. Development

2.1. Theoretical Background of Composite Pallets

The design of the pallet was focused on determining the thicknesses of the skin and core. It was determined that the thickness and size should be the same as the aluminum pallets which are used on the assembly lines today. In this study, the intended size of the composite pallet was 950 mm × 550 mm × 16 mm, and the thickness of skin was 2.5 mm, the thickness of core was 20 mm, the weight of panel 50 kg. The stiffness calculation used to determine the optimal thicknesses of the skin and core is given in (1) and calculation of the maximum deflection of the panel used (2).

$$D = \frac{E t_S (t + t_c)^2}{8\lambda}, \tag{1}$$

$$\delta = \alpha_1 \frac{q a^4}{D} + \alpha_1 \alpha_2 \frac{q a^2 \pi^2}{t_c G_c}, \tag{2}$$

where D is the stiffness of the honeycomb sandwich panel; δ is the maximum deflection at distributed load, and t — thickness of pallet (mm); t_S — thickness of skin (mm); t_c — thickness of core (mm); E — elastic modulus of skin (N/mm^2); a — width of pallet (mm) G_c — shear modulus of core (N/mm^2); b — length of pallet (mm); λ — 1-(Poisson's ratio)^2; q — distributed load (N/cm^2); α_1, α_2 — coefficients;

$$\frac{a}{b} = 0.57895, \qquad \alpha_1 = 0.0089, \qquad \alpha_2 = 0.004.$$

From (1) and (2), the stiffness was obtained 7 363 636.3 N/mm and the maximum deflection was obtained 0.9 mm. The maximum deflection is better to 0.9 mm of composite pallet than 3–4 mm of aluminum pallet. Figure 2 shows schematic diagrams of composite pallets under distributed load.

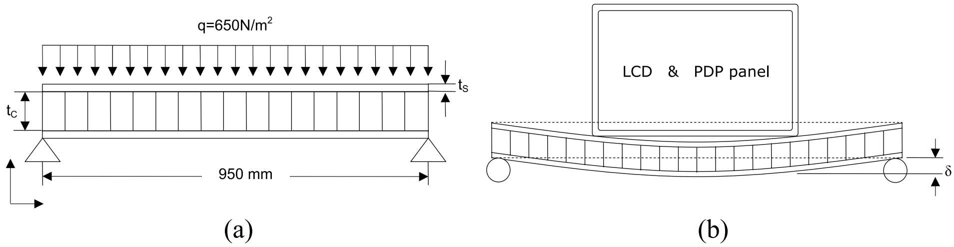


Figure 2. Schematic diagrams of composite pallets under distributed load. (a) Distributed loading condition; (b) deflection due to LCD and PDP panel.

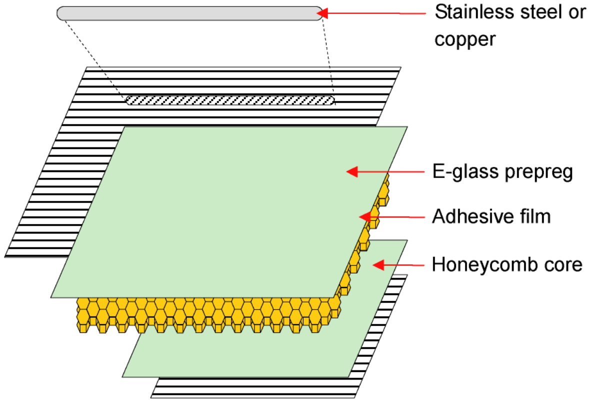


Figure 3. Fabrication method for composite pallet. This figure is published in color on http://www.ingentaconnect.com/content/vsp/acm

2.2. *Development of Fabricating Method*

The autoclave process is intended to manufacture high quality pallets composed of a honeycomb sandwich structure. However, the autoclave process has various problems such as a long work time, low productivity rate, subsidiary materials, maintenance, and repair [5–7]. In addition, high flatness could not be achieved using the autoclave process because of weak pressure during curing. To solve these problems, a multistage hot pressing process was introduced to improve the productivity and flatness of the composite pallets. As shown in Fig. 1(b), stainless steel or copper plates were added at the top of the composite pallet to give electrical functions. In order to provide a smooth surface, these plates, which have same thickness as the prepreg, were embedded in a trimming area at the top ply of the prepregs with the integral molding, as shown in Fig. 3. First, a laid-up stack of prepreg and the pallet assembly were cured under the curing cycle and vacuum environment in the hot press. Next, the cured laminates and the honeycomb core were bonded with adhesive film under a pressure of approximately 5 kgf/cm^2 in the hot press. Figure 4 shows the curing cycle for the skin and the honeycomb sandwich structure of the composite pallet.

2.3. *Development of Fabricating Materials*

Twisting and bending deformations occurred on the skin after curing with the general prepreg because of the different coefficients of thermal expansion between stainless steel or copper plate and the E-glass/epoxy laminate. In order to fabricate flat composite pallets without any deformation after curing at the hot press, multiaxial cloth prepreg and adhesive film were developed. The fabric for the prepreg was woven at angles of $-45/+45/0/+45/-45$ to prevent twisting and bending deformations of the skin laminate after curing. Also, resin consisting of a high cross-linked network was developed. Figures 5 and 6 shows the resin process for prepreg and adhesive film.

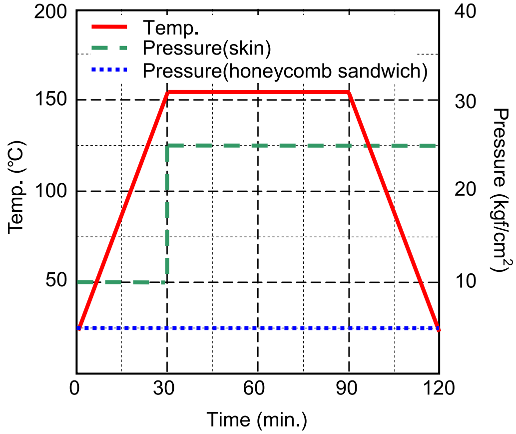


Figure 4. Curing cycle at hot press. This figure is published in color on http://www.ingentaconnect.com/content/vsp/acm

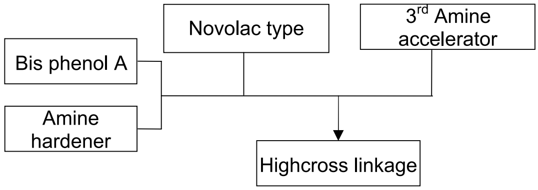


Figure 5. Flow chart of resin development.

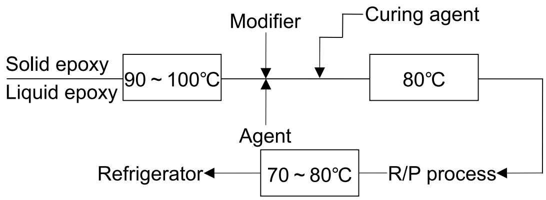


Figure 6. Process flow of adhesive film.

3. Static and Thermal Characteristics of the Composite Pallet

3.1. Mechanical Characteristics

Tensile, compressive and lap bond shear tests were performed on the developed prepreg and adhesive film. Long beam flexural and flatwise tensile tests were conducted to evaluate the properties of the honeycomb sandwich structure consisting of developed prepreg and adhesive film. The specimens were normalized at a fiber volume fraction of 65%. The cross-head speeds were 1.27 mm/min for the tensile and compressive tests, and 7.5 mm/min for the lap bond shear and flatwise tensile tests. Figure 7 shows the results of our mechanical tests.

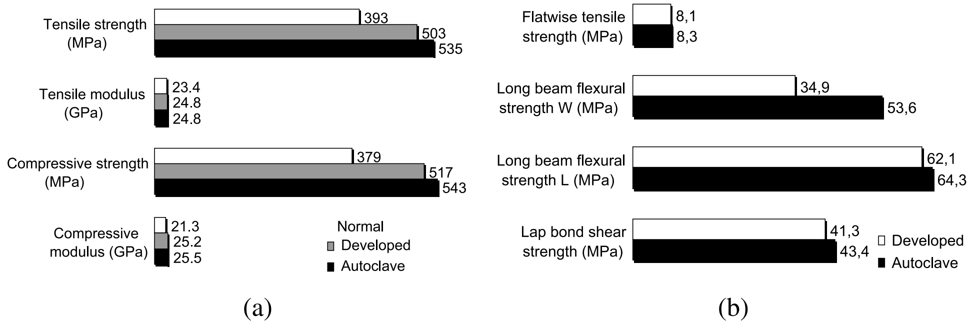


Figure 7. Comparison of mechanical properties. (a) Prepreg, (b) adhesive film and sandwich structure.

3.2. Thermal Analysis

The thermal stability of the composite pallet is very important because of its operational environment of approximately 70°C. Accordingly, the prepreg and adhesive film were developed to have a higher glass transition temperature than normal components. The glass transition temperatures T_g were evaluated by DSC (Differential Scanning Calorimeter) according to ASTM D 4065. The temperature was elevated from room temperature to 250°C with a ramping rate of 10°C/min. In the case of the prepreg for the autoclave, the glass transition temperature was 151.6°C. Temperatures of 167.3°C and 162.4°C were used for developed and normal prepreg, respectively. The temperatures of the adhesive film for the autoclave were 150.5°C, the temperature of the developed prepreg and adhesive film were 166.5°C, respectively. The developed prepreg and adhesive film showed stable thermal stability at operational environment of approximately 70°C.

3.3. Flatness Characteristics

A flatness test was performed to determine the deflection of the composite pallet after being used in its environment. The thermal operational environment is shown Fig. 8. The composite pallet was aged in a dry oven for 32 cycles. Both edges were supported by steel pipes, and a steel plate was applied to the composite pallet to add a distributed load of 650 N/m^2. The flatness was measured before and after aging at 10 points on the pallet using a coordinate measuring machine. Figure 9 shows the flatness test. The flatness of the composite pallet was measured to be <85 μm. The flatness was very dimensionally stable before and after aging, with a maximum difference in flatness of 18 μm.

4. Conclusion

In this work, a light weight composite pallet was successfully developed to replace existing aluminum pallets for an assembly line of LCDs and PDPs. To achieve light weight and to restrain permanent deformation due to self-weight, a honeycomb sandwich structure was employed. The optimal thicknesses of the skin laminates

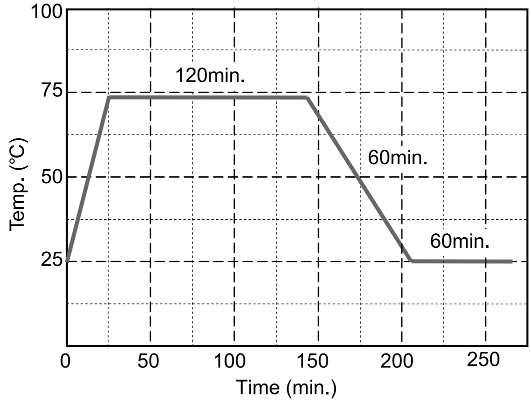


Figure 8. Working environment of composite pallet.

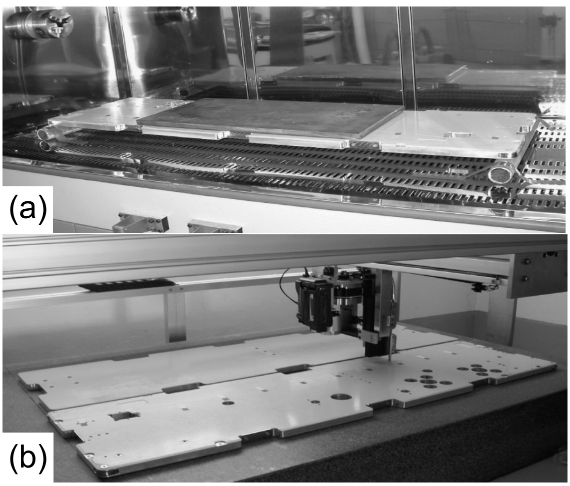


Figure 9. Photographs for flatness. (a) Apparatus for aging the composite pallet; (b) measurement of flatness with the 3-D measuring instrument.

and honeycomb core for the composite pallet were determined. Twisting and bending deformations could be prevented as introducing developed multiaxial cloth prepreg. An integral mould manufacturing method was developed using a multistage hot press under a high pressure and vacuum environment. High strength prepreg and adhesive film were developed to meet the requirements of the composite pallet. The developed prepreg and adhesive film made by multistage hot pressing process had relatively high strength compared with developed prepreg and adhesive film from an autoclave. They also had high glass transition temperatures comparing with their working temperature. The flatness of the developed composite pallet was superior and did not change after aging in the real use environment. The weight of the composite pallet is 88.2 N, whereas the aluminum pallet weighs 215.6 N. Accordingly, the composite pallet achieves weight savings of 60% compared with the aluminum pallet.

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