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DEVELOPMENT OF AN IMPROVED
BONDING FIXTURE

PDO 6984797, Topical Report

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Project Team:
N. M. VanDyke

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MASTER

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Prepared by J. D. Sheeley, D/812, under PDO 6984797

A bonding-laminating fixture with self-contained heating, cooling, pressure, and vacuum features has been developed. The fixture has a usable platen area of 24 by 36 inches (609.6 by 914.4 mm) and has a control panel which allows the bonding cycle to be programmed for automatic operation. The fixture is used to laminate adhesive-coated Mylar or Kapton to etched circuits.

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SUMMARY

An improved laminating or bonding fixture with self-contained heating, cooling, pressure, and vacuum features has been developed to laminate adhesive-coated Mylar or Kapton to planar or nonplanar cables and other etched circuitry.

The fixture has a usable platen area of 24 by 36 inches (609.6 by 914.4 mm), a control panel which allows complete programming of the bonding cycle, and automatic sealing which is accomplished by an O-ring seal around the hydraulically lifted door. The fixture was designed with separate heating and cooling platens to minimize power consumption during the heating cycle. Cycle times depend on the set temperature, dwell, and degree of cooling required for the material being laminated. Typical cycle times vary from 40 minutes for most Mylar adhesive applications to approximately 75 minutes for the longer curing, higher temperature Kapton covercoats.

DISCUSSION

SCOPE AND PURPOSE

Longer flat cables and various nonplanar cables require a bond form or platen length of at least 36 inches (915 mm). These items require the lamination of insulating materials over the surfaces of the etched parts. While most flat cables can be press laminated, the nonplanar work is not suitable for a conventional laminating process. The fixture described in this report was designed to provide an automatic autoclave cycle but shorten the time normally required for it.

PRIOR WORK

A smaller, manually operated laminating fixture,¹ previously developed worked successfully but had a platen area of only 14 by 22 inches (356 by 559 mm). The fixture described in this report was based on the smaller fixture, but with a larger platen area and automatic controls to extend its usefulness.

ACTIVITY

The laminating fixture previously described¹ performed well, although all operations including timing of the dwell period and cooling cycle had to be performed by the operator. Air, vacuum, and pressure connections had to be made and regulated by hand. Vacuum sealing against the platen was performed as in autoclave bond forms by wedging a silicone rubber rope under a lip around the platen edge (Figure 1) and evacuating air from under the silicone rubber blanket. This procedure has been in use for many years on autoclave bond forms, and while it works well, it is often time-consuming.

Theory of Operation and Design Considerations

The lamination of adhesive-coated Mylar* or Kapton* to etched circuits is accomplished by suitable heat and pressure. Normal

*Du Pont trade names.

Figure 1. Autoclave Bond Form

adhesives used to laminate Mylar are activated at temperatures of 260 to 300°F (126.7 to 148.9°C) while typical adhesives used to laminate Kapton are cured at approximately 350°F (176.7°C). While most circuit laminations are performed in presses, previous work has shown that autoclave cycles can produce acceptable cables.² Temperature-activated adhesives will generally produce good bonds whenever sufficient pressure is available to maintain intimate contact during the heat cycle. Autoclave bonding provides less pressure than most presses, but because the pressure is applied over a flexible blanket it is uniform over the entire surface and good bonds are obtained. The continuation of autoclave bonding was made necessary by the increasing variety of nonplanar laminations which are readily adaptable to autoclave techniques.

In normal autoclave operation, the materials to be laminated are placed on a bond form, covered with bleeder cloth and silicone rubber, and sealed by evacuating the bond form (Figure 1). The bond form is lowered into an autoclave and heated by convection while the entire autoclave is pressurized. Heating time for the bond form is rather slow even when the autoclave has been preheated; cooling is even slower, especially if the material should be cooled under pressure. A typical autoclave cycle is approximately 4 to 4.5 hours.

Because autoclave bonding is satisfactory, and because a variety of nonplanar parts can be laminated reasonably with an autoclave, it was desirable to develop a specialized fixture to perform the cycle more rapidly. In developing such a fixture,¹ the very basic approach was followed of putting a self-heating platen inside

a box that could be pressurized. This approach was crude but effective, and the original manually-operated fixture is still in daily use with several modifications made to improve its appearance and simplify operation. Success with the original fixture and a requirement for longer laminated cables as well as more nonplanar devices encouraged the development of a larger, more versatile design.

A larger platen requires a larger opening for access to the platen and immediately complicates design of the pressure container: too much clamping force would be required to make it practical to lift and re-clamp the top for each cycle. Any opening besides the top makes it necessary to move the platen in and out to load and unload material. Because the smallest opening would be the easiest to close, the end of the box was chosen as the location for the door. The platen was designed to be carried in and out by slides mounted along the length of the platen. A vacuum line and a thermocouple line follow the platen, but because the cooling platen is separate and does not move back and forth, the water line is stationary.

Sealing of the pressure container is accomplished at the end of the closing stroke by wedging the door against an O-ring around the opening (Figure 2). The door is lifted by two hydraulic cylinders and is interlocked to prevent the door from closing unless the platen is fully inside the container and to prevent cycle start unless the door itself is completely closed. After the internal laminating pressure has been relieved at the end of the cycle, the door can be opened by activating the Door Open switch on the control panel. This relieves the hydraulic pressure and allows the door to open by its own weight.

The laminating fixture requires external vacuum, shop air, power, and water connections. The fixture requires a power input of 5 kW, has a maximum operating temperature of 360°F (182.2°C) and a maximum operating pressure of 100 psi (689.4 kPa).

Controls and Operation

The laminating fixture was provided with a control panel which allows the cycle to be programmed and automatically controlled. The control system was modeled after the forming station³ but is not as elaborate because fewer controls are needed. Platen vacuum is applied continuously throughout the laminating cycle and is separate from the automatic part of the cycle.

Platen temperature is regulated by a Fenwall Model 540 temperature controller. A Type J thermocouple is mounted in the edge of the platen to report platen temperature. When the platen reaches

Figure 2. End View with Door Open

the temperature set on the controller, the dwell timer is activated and the platen remains at its set temperature throughout this period. The end of the dwell period activates the cooling timer and water circulates through the cooling platen for the length of the cooling period. Four small air cylinders lift the cooling platen against the bottom of the heating platen during the cooling cycle (Figure 2). Two timers, one of 30 minutes and one of 60 minutes, are used in the dwell and cooling functions. These interchangeable timers are easily exchanged to satisfy special heating or cooling requirements. When the cooling timer reaches the end of its set time, the cycle is complete and the controls are inactive except for the independent platen vacuum. Laminating pressure is automatically relieved through a pneumatic muffler, and the door can be opened as soon as the internal pressure returns to normal.

Laminating pressure is set by the regulator in the control panel. The laminating fixture is pressurized when the Cycle Start button is activated.

These steps would form a typical operation: first the Power On switch would be activated; the platen would be pulled out and material placed on it; the Vacuum On switch would be activated; the platen would be pushed in and the door closed; the pressure regulator, dwell timer, and cooling timer would be set; the Cycle Start switch would be activated; and the platen temperature would be set. The fixture would complete the cycle automatically. At the conclusion of the cooling cycle, internal pressure would be relieved. The Door Open switch would then be activated; the platen drawer would be pulled out; the Vacuum Off switch would be activated; the vacuum blanket would be lifted; and the material would be removed.

Platen Sealing

The improved laminating fixture eliminates the rope sealing process shown in Figure 1 and makes it considerably easier to evacuate the platen. A silicone rubber blanket is held on a hinged frame which lifts up to expose the platen (Figure 3). The material to be laminated is placed on the platen and covered with vacuum cloth. The sealing blanket is lowered over the material and the air evacuated by activating the vacuum button on the control panel (Figures 4 and 5).

Several frames were fabricated so that nonplanar laminations could be performed by changing to a frame with a suitable formed blanket. While flat sealing blankets can be stretched over nonplanar mandrels, the stretching often disturbs or disarranges the materials to be laminated. This can be avoided by using formed blankets instead of flat ones. Formed blankets are made

Figure 3. Platen Extended, Sealing Blanket Up

by flowing successive coats of Dow Corning 92-009 dispersion material over a metal mandrel. Each coat is allowed to dry before the next coat is applied. The formed material is trimmed to a circle on the flange area and bonded into a hole in a flat blanket with a lap joint. RTV 140 makes an excellent bond between the flat silicone blanket and the flange of the formed blanket. Normal practice is to make a separate frame for each different nonplanar configuration to be laminated. Frames are mounted with only seven screws and are easily changed in a few minutes.

Heating and Cooling

The heating platen is a 0.5 inch (12.7 mm) aluminum plate with an electromesh heater bonded on the reverse side. This type of heater was chosen because of its reasonably short rise time compared to power consumed and uniform heat distribution. The 24 by 36 inch (609.6 by 914.4 mm) platen draws only 4.5 kW. The platen is mounted on slides and is thermally isolated from the walls and floor of the pressure vessel.

The separate cooling platen rests on four small air cylinders (Figure 2) and is in contact with the underside of the heating platen only during the cooling cycle. A separate cooling platen

Figure 4. Platen Extended, Vacuum Frame Sealed

Figure 5. Improved Sealing Method

was used for two reasons: first, less mass means less power consumed and shorter rise time; second, the water line does not have to travel back and forth with the heating platen.

Typical temperature rise and fall are plotted in Figures 6 and 7. The cooling cycle is longer than anticipated primarily because of inefficient heat transfer between the rear of the heating platen and the cooling platen. Very little real cooling help is realized by circulating water through the cooling platen as shown in Figure 7. One of the cooling curves in Figure 7 was plotted by turning off the heat but not circulating water, which showed that the lower the temperature desired, the more effect the water has. For instance, to cool from 300 to 200°F (148.9 to 93.3°C) is 3 minutes faster using water; however, to cool to 180°F (82.2°C) is nearly 5 minutes faster using water.

It is possible to design a platen with nearly any desired combination of rise time and cooling rate. Practical considerations, however, usually dictate some compromise based on size of platen, power available, and mechanical constraints. In the case of the present fixture, cooling time could probably be reduced by up to 15 minutes per cycle by use of a platen with integral cooling, but the increased mass of such a platen would at least double the power requirements. An integral platen would require a traveling water line, but this is not a serious drawback and could be designed with a suitable hose retraction mechanism. Each laminating fixture should be considered with respect to what its use will be. High production requires high power consumption. But for development applications, a slower rate with less power consumption would probably be acceptable.

ACCOMPLISHMENTS

A successful fixture has been fabricated and is in steady use for lamination of a variety of planar and nonplanar configurations. The control panel allows complete programming and automatic control of the laminating cycle. Because of the wide variety of parts expected to be fabricated on this equipment for future paid orders, the fixture has been added to the capital equipment list and titled "Laminator 24" x 36".

FUTURE WORK

At LASL request, a similar fixture has been designed and is currently being fabricated for installation at LASL. The LASL fixture will have a platen area of 14 by 48 inches (0.35 by 1.22 m) but otherwise will retain all the features of the Bendix laminator.

Figure 6. Heating and Cooling Cycle, 350°F (176.7°C)

Figure 7. Heating and Cooling Cycle, 300°F (148.9°C)

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