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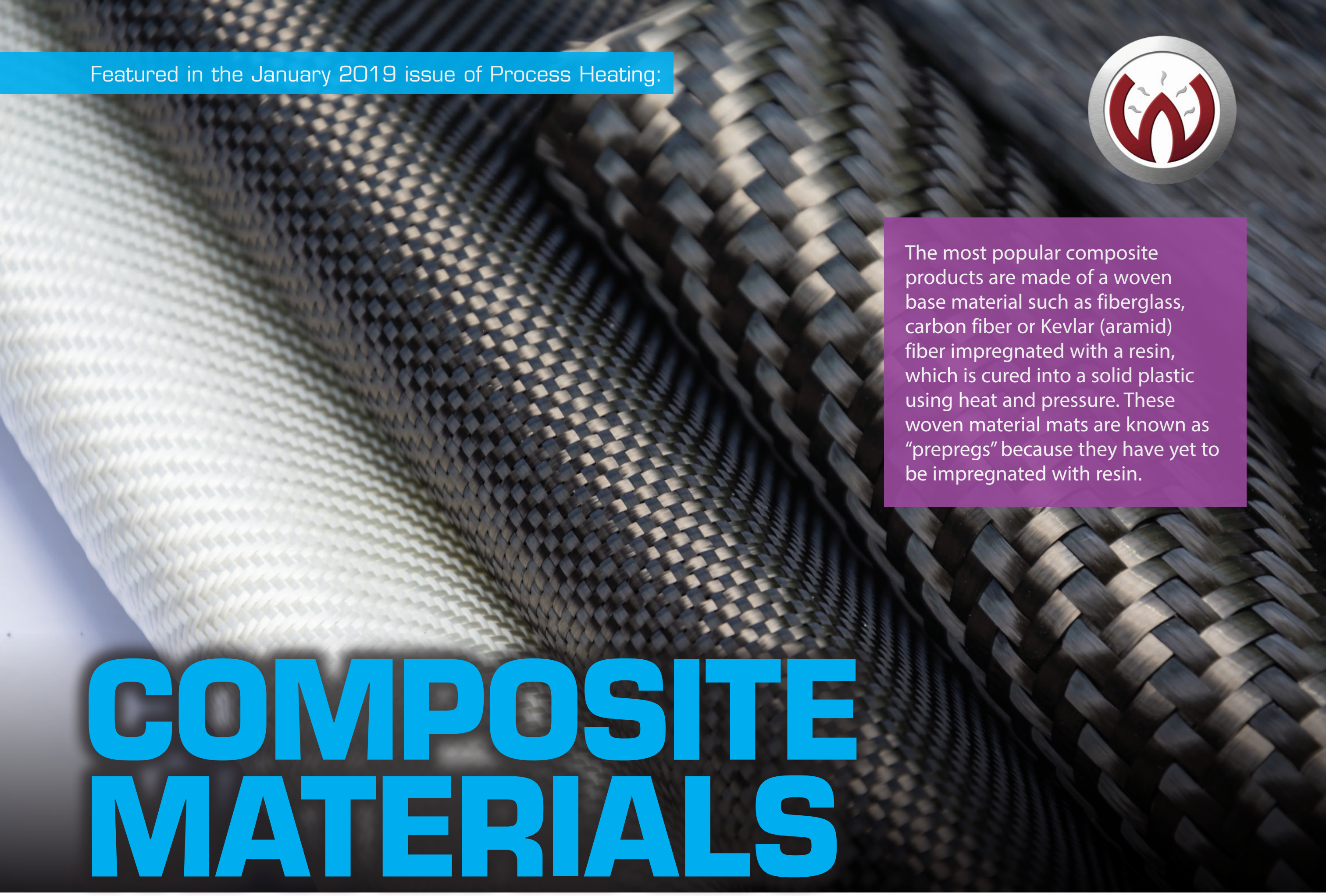

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COMPOSITE MATERIALS Require Specialized Processing

Composite curing ovens are specially designed for this process. Specific features can help optimize composite curing oven performance.

By Mike Grande,
Wisconsin Oven Corp.

Emerging developments in modern technologies — space exploration, high efficiency vehicles, aircraft manufacturing and wind power — are driving the demand for stronger and lighter materials. Composite materials are one of the best candidates to meet these "light weighting" needs.

Originally used primarily in the aerospace industry, composite materials currently are employed anywhere a premium is placed on reduced weight. Valued for their high strength-to-weight ratio, the most popular composite products are made of a woven base material — fiberglass, carbon fiber or Kevlar (aramid) fiber, for instance — impregnated with a resin. The mats made of woven material are known as "prepregs" because they have yet to be impregnated with resin. The resin paired with prepregs to produce composite products is an epoxy, polyester, polyurethane or other plastic in a liquid state. During composite manufacturing, the fiber mat and resin are cured into a solid plastic using heat and pressure.

One of the most common ways composite materials are manufactured is the vacuum-bagging method. Vacuum bagging is a technique that tightly holds the composite material in the mold using atmospheric pressure, squeezing the resin-impregnated layers (the laminate) together and conforming them to the shape of the mold. This involves starting with a fabric prepreg made of carbon or other fiber, placing it in a mold (also referred to as a tool) and manually forcing epoxy resin into the weave with a roller or other tools. Multiple mats of the fabric are layered onto the first, with the epoxy imbedded into and between each layer. Then, the mold is bagged and a vacuum is drawn under the bag before the materials and mold are placed in the oven. The materials are cured in the oven while vacuum is maintained.

Composite Cure Oven Design

Ovens used for curing composite materials are specifically designed for this purpose. They have several special features necessary for performing the composite cure process.

The first of these is a carefully engineered air supply system. The most common air duct arrangement is referred to as combination airflow. The composite parts are loaded on top of a traveling load car rolled into the oven, or on a fixed table placed in the oven by forklift. Alternatively, personnel sometimes perform the composite layup in place on a load table inside the oven prior to the cure process. After loading, the doors are closed and the heating/recirculation system is turned on. The heated air is delivered from supply ducts located on both sides of the heating chamber, passed through and around the bagged composite materials in the molds, and then returned to the heating/recirculation system at the top. A high volume of air is necessary to provide the temperature uniformity required for composite curing. The ductwork that delivers the air must run the entire length of the heating chamber so there are no dead spots that remain unheated. It is important that the proper calculations be performed to determine the necessary heat input and air circulation volume. An oven designed for paint or powder curing, for example, may not be have sufficient capability to properly cure composite materials.

The second important feature of a composite cure oven is the control and data acquisition system. This system not only must perform closed-loop control of the heating and cooling processes; it also must gather and record inputs. Thermocouples are positioned throughout the oven chamber to sense the oven air temperature and part temperature. Also, transducers sense the vacuum level at each vacuum port.

When required, the vacuum level can be individually controlled at each vacuum port. In this scenario, each vacuum port can be set at a different vacuum level to provide accurate processing of a range of parts in the same heating cycle.

Control systems for composite curing often are designed with a thermal overdrive feature — also known as a controlled heat head. With thermal overdrive, the oven air temperature is temporarily set higher than the part cure temperature in order to accelerate the heating rate. The control system does this automatically. It avoids overheating the composite parts by monitoring them using thermocouples buried inside the composite material during layup. As the part temperature approaches its required cure temperature, the control system automatically reduces the oven heat output — and, correspondingly, the oven air temperature — to avoid overheating the parts.

In addition to controlling the oven

A vertical lift door allows the space directly in front of the oven to be used for loading and unloading, reducing floor space requirements.

temperature and vacuum level, the system must record all the part temperatures and the vacuum at each port. That data set is associated with a discrete batch identification number. After each heating cycle, the data should be automatically sent to a designated location on a network for storage. This provides traceability of the temperature and vacuum for all parts being processed. The approach also documents any alarms and other anomalies for each batch to help with problem diagnosis and continuous improvement. It is common for each batch to be identified using a bar code scanner, reducing the chance of operator error.

Vacuum Pumps for Composite Manufacturing

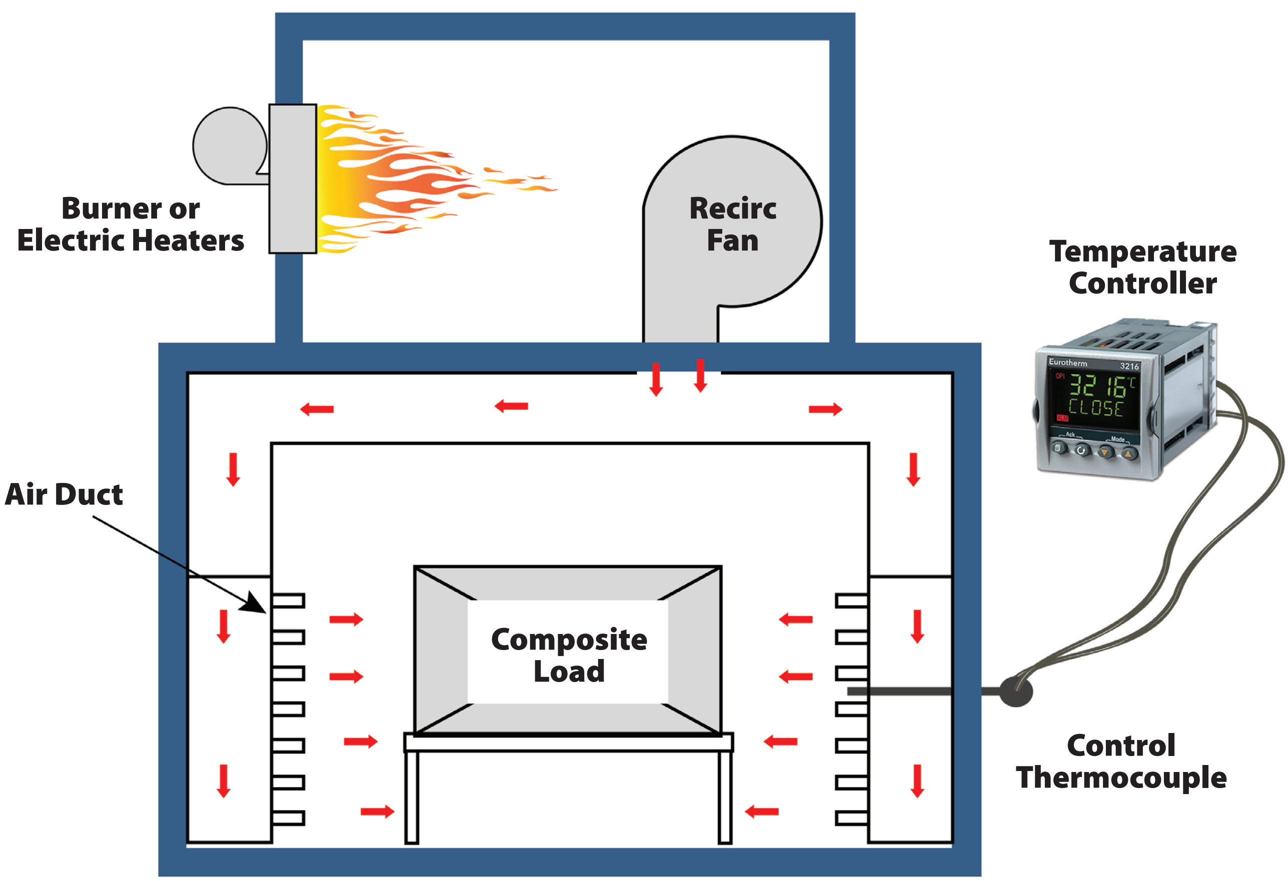
The central element of the composite cure vacuum system is the vacuum pump. The pump must be capable of drawing the necessary vacuum, and it must also be able to provide sufficient displacement. The level of vacuum necessary depends on the shape and complexity of the part being molded. For example, a part with many contours and complex features will require a higher vacuum to squeeze the part via atmospheric pressure on the outside of the bag. This forces the laminate into the concave mold cavities without creating voids. A flat, panel-shaped laminate does not have these cavities and therefore may need a lower vacuum to be drawn on the bag.

The maximum pump flow rate (referred to as the "pumping speed") must be considered as well as the flow rate at full vacuum, which will be lower than the maximum pump flow rate. Pump manufacturers provide pump curves illustrating the flow rate at both conditions. If one of these ratings is ignored during pump selection, the system can either take too long to draw down (while under minimal vacuum) or fail to maintain the required vacuum level after draw down (at maximum vacuum) due to system leakage.

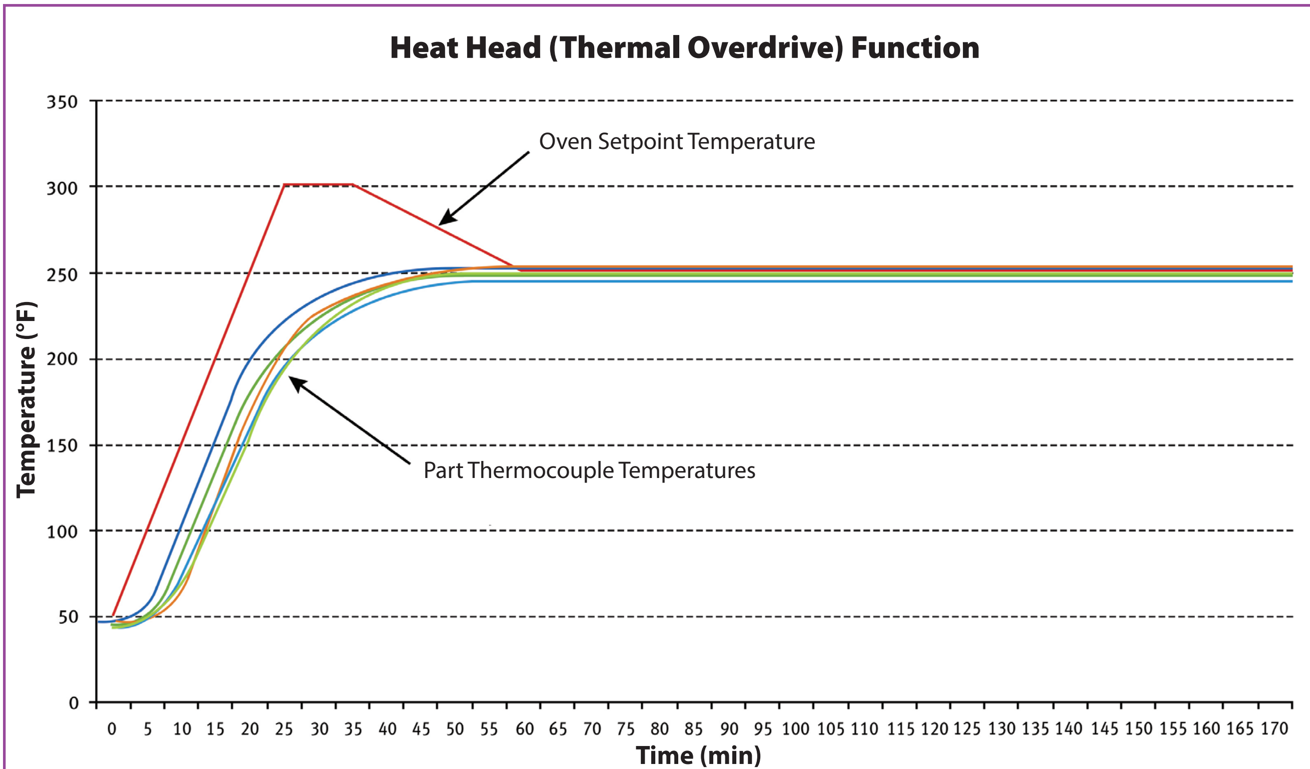
Features to Augment Composite Oven Operation

Several optional features are popular with composite cure ovens. They include vertical lift doors, door safety latches, safety pullcords (trapped personnel), interior lights and windows, and thermocouple jack panels. Compliance with specifications and warranties also must be considered.

Vertical Lift Door. For composite cure ovens with large heating chambers, the typical bi-parting horizontal swing doors take up too much floor space in front of the oven. In this situation, a vertical lift-style door can be advantageous. Because the door opens vertically, it requires no additional space in front to accommodate the



The flow of recirculated air, shown with red arrows, is demonstrated in this section view of a composite cure oven.



Thermal overdrive is used to heat composite parts more quickly.

swing of the doors. This allows the space directly in front of the oven to be used for loading and unloading, resulting in a reduction of floor space requirements. The vertical lift doors can be air operated or powered by an electric motor.

Door Safety Latch. When a vertical lift door is used, it is common to also include an automatic door safety latch as a redundant device to hold the door in the up position while it is open. This device consists of a hook that latches onto a bar located at the top center of the vertical lift door. The hook is spring loaded so that the when the door opens, it is automatically engaged. A pneumatic cylinder retracts the hook prior to lowering the door. The purpose of the door safety latch is enhanced personnel protection to help prevent the door from dropping due to a broken chain or failed air cylinder.

Trapped Personnel Pullcord. A safety pullcord offer an additional layer of protection against trapped personnel. A cable is hung at waist height along the interior oven wall. It is routed through a penetration in the oven wall and wired to a relay to shut down the oven and sound an alarm when the cord is pulled. This cord is used in the event that a person becomes trapped in the oven with the door closed.

Interior Lights and Windows. Composite cure ovens often include windows that allow operators to see inside during processing. The windows are most often located in the doors, but they can be installed in the oven walls. While the windows provide visibility into the oven interior, when the oven doors are closed, it is dark inside. Often, when windows are added, interior lighting also is required.

Thermocouple Jack Panels. When curing composites, it is common for thermocouples to be buried inside the parts for close monitoring of their temperatures during heating. In order to allow convenient connection of these thermocouples to the recording system, thermocouples jack panels are installed inside the oven. They are located on the interior oven wall with the thermocouples wires penetrating through the wall and wired, via conduit, to the recorder in the control panel.

Compliance with AMS2750 MIL Specification. Composite curing ovens can be designed to meet the requirements of AMS2750, a pyrometry specification that governs the temperature uniformity tolerance, the location of test thermocouples, calibration of the thermocouples and similar variables. Most major aerospace users and many other companies require that their composite cure ovens meet this specification. If AMS2750 is required, it is critical that the oven manufacturer perform testing to verify compliance prior to shipment of the oven and provide documentation to the end user.

With an eye on key features, it is possible to specify a composite curing oven that can be used to manufacture stronger and lighter parts.

Mike Grande is VP of Sales and Engineering with Wisconsin Oven Corp., East Troy, Wis. For more information from Wisconsin Oven, call 262-642-3938 or visit www.wisoven.com.