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LOW COST RESIN TRANSFER MOLDING MANUFACTURING CELL

Frank Roundy, D. DeWayne Howell
Storage Technology Corporation, Composites Group
One StorageTek Dr. , MS-0091
Louisville, Colorado 80028

ABSTRACT

In an effort to reduce the cost of composite structures Resin Transfer Molding (RTM) is widely used. In turn to reduce the cost of RTM this paper has been written to describe a method of obtaining a low cost RTM production cell. There are systems available to the Resin Transfer Molder that can be purchased, this paper analyzes a method of establishing an RTM manufacturing cell in house. The methods to build a press, provide pressure, move the molds in and out of the press, and heat and cool the molds are discussed in this paper. The advantages and disadvantages of this system are discussed. Finally, the cost of putting this system together is outlined.

KEY WORDS: Resin Transfer Molding (RTM), presses, equipment and machinery

1. INTRODUCTION

The purpose of this paper is to provide the information on how to obtain a low cost Resin Transfer Molding (RTM) manufacturing cell (Figure 1) and avoid common pitfalls. The benefits of RTM have been well documented in many excellent articles and books. The basics of RTM is a mold, a preform and a method to introduce resin. This paper will examine the steps taken to establish a RTM manufacturing cell. It will outline the type of press used, how to move the molds in and out of the press, lifting devices for the mold tops, and a method to heat and cool the molds,. Problems encountered in bringing the manufacturing cell into production and modifications that were made to address those problems are also addressed.

Figure 1
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The RTM manufacturing cell can be broken into four areas, mold prep and preform loading / part unloading, mold clamping, resin injection, and heating and cooling. The mold prep area is where the mold is cleaned, release agent applied, and injection tubing installed. In this application it is also the same area where the preform is loaded into the mold and where the part is removed after it is cured. The mold clamping area is where the mold is secured so resin can be injected. There are many methods to ensure the mold does not open. A press, actuated by filling a fire-hose with water, is the method used for this application. Once the mold is clamped, resin can be injected into the mold and preform. Some type of resin injection machine must be used for this purpose. There are several systems that can be used and the relative merits of each of these systems is beyond the scope of this paper. For those resin systems that require heat to cure, a heating method is required. A hot water system is used to provide the necessary heat to cure the resin in this example.

The manufacturing cell discussed in this paper makes 101.6 mm square tubes 2,032 mm long (4 inch square by 80 inch long). The final part must be flat within 0.508 mm (0.010 in) and the outside dimension must be within plus or minus 0.254 mm (.010 inch) of nominal. The surface finish must be 16 RMS or better. This cell has four molds that are made out of P20 steel and weigh 1,134 kg (2500 pounds) each . The molds are split in half along the length and the bottom half is supported by four wheels. The presses are capable of creating 13,794 kilopascals (200 psi). Each presses has the capacity for two molds. When both molds are in the press and pressurized, there is approximately 272,155 kilograms (300 tons) of force keeping the molds shut. The resin system used is a two part epoxy system that has a pot life of 20 minutes at room temperature. It cures at 65.5 degrees Celsius (150 deg. Fahrenheit).

This paper will discuss the four basic areas of the RTM cell and how they were fabricated.

2. MOLD PREP / PREFORM LOADING AREA

The mold prep area consists of a station where the mold can be cleaned, a part release applied, the preform loaded, injection and vacuum tubes attached and the mold top lifted on and off. The most expensive item in this area is the lifting apparatus, if the mold is heavy. In this operation a jib crane is employed to do the lifting. (See Figure 1) The crane has a variable speed motor to move the hoist along the length of the jib. The ability to move the hoist very accurately is extremely important when it comes to positioning the mold lid. The mold lid has lifting eye bolts that allow the lid to rotate. By rotating the lid 180° (Figure 2) and placing it on a surface, the cleaning and releasing of the molding surface is much easier. The use of the jib crane has been satisfactory, however if given the chance to do the job again a gantry crane would be used. The jib crane requires an extensive foundation. This 907.2 kg (2000 pound) crane required the concrete floor to be cut and a hole that was 5 ft x 5 ft x 4 ft deep filled with steel reinforced concrete. The likelihood of moving this manufacturing cell becomes non-existant when a hole like this is

Figure 2
Mold Cleaning

poured. The jib crane is also not very stable. When there is no weight on the crane the jib doesn't move, but when the mold half is lifted, the weight of the mold makes the jib want to drift. This makes accurate positioning the hoist very difficult. A gantry crane does not have this problem. A gantry crane does not need the extensive cement work required for the jib. The gantry crane does require at least 4 support posts, which may make placement and movement around the area more difficult. The positive placement of the hoist in relationship to the items being lifted would be the main reason to use a gantry crane.

The mold prep area is the station for the cleaning and releasing of the mold. Because of the flash that is inherent in a molding operation, keeping the area clean can be difficult. Any type of surface will be a great area for the flash to accumulate. When designing an area, cover up areas to prevent the accumulation of garbage and make it easier to clean. Anyplace a shelf is located is an area for junk. Locate the required tools for cleaning and mold release in a convenient spot, but make sure that that area is used only for those tools. Some manufacturing procedures require applying release agent in a separate area from where the preforms are loaded. Special provisions need to be used if this is the process one is working under. The cost of providing the correct tools for the job is much less expensive than reworking a tool because some gorilla used his air hatchet to clean the mold. Tools required in this area are: soft scrappers to remove resin residue and flashing, an air hose to blow off dust, a wrench to tighten the hose fittings, a mallet to assist in removing parts, probes to clean injection ports, and a marker to identify parts.

3. Press

After the preform is loaded into the mold, the part and mold are ready to be moved into the press. An rodless air cylinder is used to move the mold back and forth from the press to the preform loading / part unloading area. The rodless air cylinder is compact and provides a long length of travel. Provisions must be made to keep any stray resin off the critical seal area of the cylinder. This can usually be accomplished with a plastic curtain. To keep the speed of the mold down, flow regulators can be attached to the cylinder. The attach mechanism that connects the cylinder to the mold must be able to positively control the mold in both directions plus be able to move up and down as the mold is clamped in the press. With the mold in the press it is now ready to be clamped together. There are many methods to secure the mold, from bolting the mold together, to placing it in a hydraulic press. The method used in this manufacturing cell is a fire hose press. It has the advantage of being able to generate fairly high clamping pressure at a reasonable cost. The disadvantage of this type of press is that the opening must be standardized for all the parts being used. The fire hose press gets its clamping pressure by inflating a hose. The more contact the hose has against the part the more pressure is exerted. (Figure 3)

Flatter hose = more contact area (more pressure)

Inflated hose = more travel (less pressure)

Figure 3

For this reason it is important to keep the hose as flat as possible, by doing this the amount of travel is greatly reduced. The travel on a fire hose press is usually less that one inch.

The fire hose press consists of a pump, valves, hoses, accumulator tank and a robust structure. Our first approach was to use compressed air to inflate the hoses. As good as our technicians were at assembling the hoses we constantly had problems with air leaks. In addition the large hoses filled with air became a safety concern. To alleviate these concerns a water pump was installed. The pump is capable of generating 250 psi. The pressure is controlled with pressure regulating valves. The plumbing schematic is shown in Figure 4 .

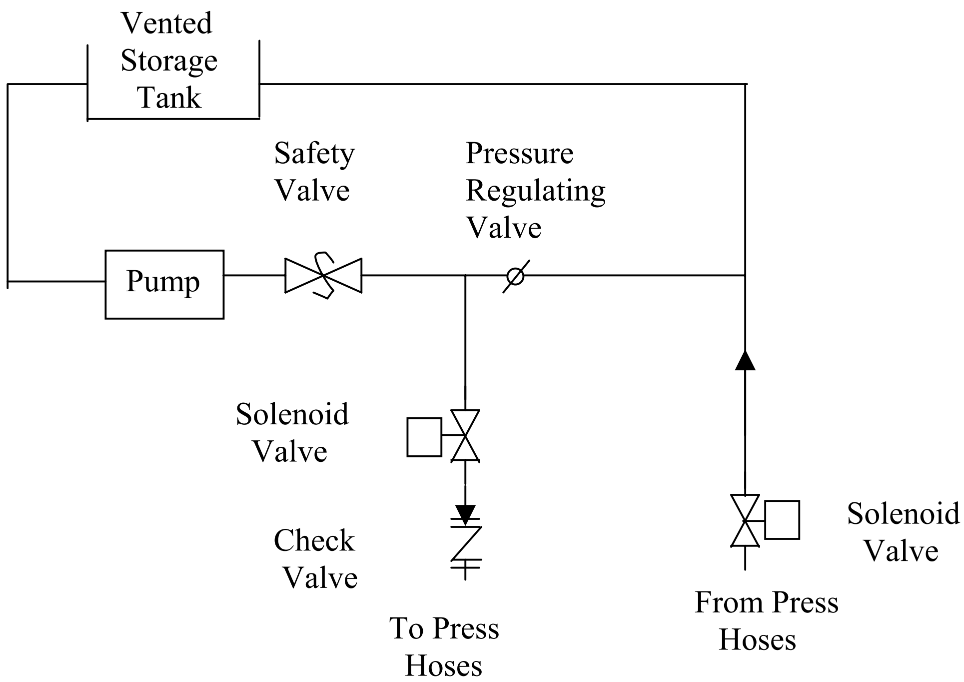

Figure 4
Plumbing Schematic for Press

To service more than one press a manifold can be used. Each press would require its own set of solenoid valves if they are to operate independently. Check valves are installed to prevent the loss of pressure when another press is pressurized. The best hose to use in an RTM environment is one that has a rubber coating and lays flat when not pressurized. A 50.8 mm (2 inch) inner diameter lay flat high-pressure Buna-N rubber hose works very well. In every RTM operation, sooner or later, the mold is going to leak. A covered hose is easier to clean up when the leak occurs. Another item that helps in case of spills is a pan under the mold. The pan can be as simple as a piece of sheet metal with a couple of sides bent up. The metal should be cleaned and coated with a release agent, to assist with clean up. It is also a good manufacturing policy to stop injecting resin if a leak is discovered.

The robust structure that is the frame is made out of steel. The bottom, where the fire-hose rests, and the top, where the mold is pushed against, is made of one inch steel. To keep the steel plates from bending C-channels are welded to the bottom and top of the respective plates. To maintain the proper height and provide the ability to adjust the height of the press, one inch all-thread is used. When bolting the unit together it is important to use lock washer on all the nuts. A typical view of this arrangement is shown in Figure 5. Although time consuming, the opening of the press can be adjusted to be flat within 0.020. If one does not have the facilities to fabricate this type of structure it is recommended to go to a place that does heavy fabrication as part of their business, as opposed to a machine shop. For example we went to a crane fabrication company. This type of job was outside what they normally do, but a change was welcomed and the work was excellent. When building this type of press, provide a generous radius around the hose.

Figure 5
Press, Side View

If the molds used are different heights it is not economical to raise and lower this press. Different size spacers (Figure 6) can be used to compensate for the mold height difference. Depending on the cure temperature, the mold shims can be made of all most anything. If heating the mold is required then fiberglass shims can be used to help insulate the mold from the press.

Figure 6
Mold Shims

The press has the advantage of producing good clamping pressure for the cost of a pump and some hose. The pressure is applied evenly over the entire surface and the pressure of the system is relatively low. The problem with this type of press is the limited amount of travel one achieves on the platens. Shims must be provided if different size molds are to be used in the press.

4. HEATING AND COOLING

Most epoxy resin systems require some additional heat to accelerate the cure. The best possible resin system would have an unlimited pot life when it was mixed, have the right viscosity to wet out the fibers and when the last fiber was coated with resin the material would then cure at room temperature and have a glass transition temperature above 5000 degrees. Unfortunately this resin system does not exist and most systems require heat to cure. In addition, in order to cycle the tool quickly, one must also be able to cool the mold. For this RTM cell a Delta Therm water heater was used. The molds were manufactured to be integrally heated and cooled. Because of the mass of the tool, and a small heating unit, heated platens were not an option. The molds were plumbed and hoses attached to both halves. (Figure 7)

Figure 7
Heating / Cooling Hoses

The attachment of the hoses creates a problem with moving the molds in and out of the press. If at all possible heated platens are preferred. This system required a cure temp under 100° Celsius, so a water heating system was used. For temperatures above 100° Celsius hot oil or electric systems can be used. When using hoses attached to moving systems it is necessary to provide a method for the hose to swivel around. A hose generally has great flex bending but twisting the hose can severely damage it.

Most heating systems are self contained on the heating side and require an external source of cold water to assist with the cooling side. Typically the cold water goes through a heat exchanger on the hot water system to remove heat. To conserve water this system should also be a closed system. The cooling system has a water source, pump, valves, and a cooling tower. A schematic of this system is shown in Figure 8.

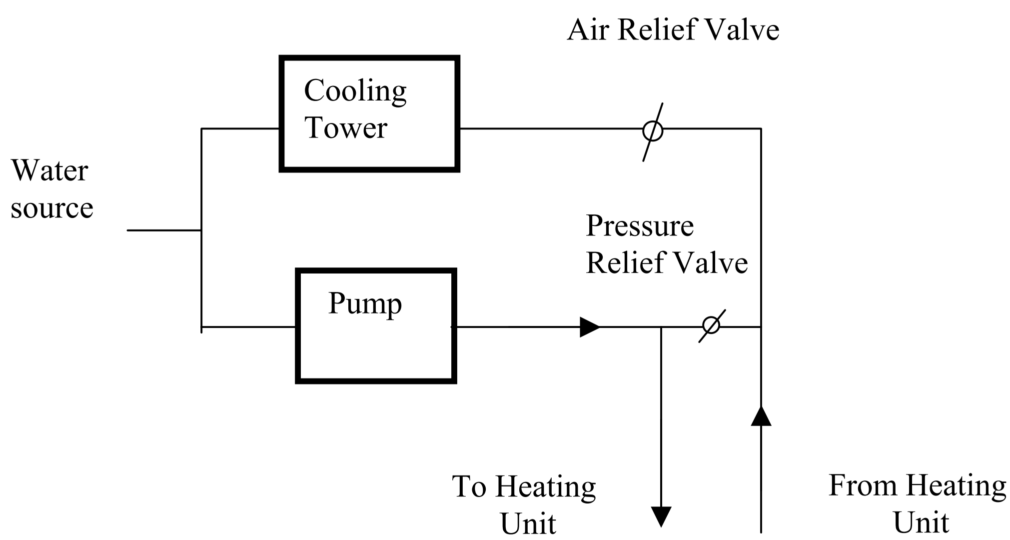

Figure 8
Cooling water Schematic

The cooling tower consists of a large radiator with a squirrel cage fan. The location of the cooling tower will depend on the amount of heat generated. With all the plumbing that is required it is suggested to use copper pipe when possible. The ease of fabrication and the leak free nature of the connections are worth the time.

5. ADVANTAGES / DISADVANTAGES

There are advantages to building a system in house. The system is customized to the exact needs of the organization. Generally all the parts are off the self and readily available in case something breaks. There is also a sense of pride and ownership of the system, the people involved with it make an extra effort to make sure it works. Cost is also a major factor. The savings of building it in house was over $60,000. The advantage of purchasing a system is the expertise the company brings to the system. If the company that is selling the system has been in the business a while, and has built several systems, they should have learned from the process.

The area that resulted in the most rework was switching from a pneumatic press to a water pump press. Along with the switch we changed out the hoses from 3.5 inch ID to the 2 inch ID. This retrofit cost about $3000. The system has been in production for 18 months. The majority of the problems that have been encountered have been related to contaminants in the press water. These contaminants have caused a check valve to remain open and clogged a solenoid valve.

6. COST

The cost of this manufacturing cell is broken out in the following chart:

Press Frame 4 openings 18 x 93	$18000	Heating System	
Jib Crane w installation	$15000	Delta Heater	$5000
Rodless air cylinder Qty 4	$ 8000	Pump	$ 550
Pressure system		Cooling Tower	$ 600
Pump	$ 425	Plumbing	$ 900
Tank	$ 400	Air Vent Valve	$ 10
Plumbing	$ 300	Valves pressure Regulating	$ 150
Check Valves Qty 4	$ 50	Control Valves Qty 8	$6400
Solenoid Valves Qty 8	$ 720	Control Box	$ 120
Pressure relief valve	$ 125	Switches	$ 75
Transformer	$ 115		
Pressure Gages Qty 3	$ 100		
Pressure Hose 120 ft.	$ 400		
Hose Fitting Qty 16	$ 440		
Miscellaneous	$ 1500		

Total Cost	$59,380
Cost per press	$14,845

7. CONCLUSION

In the quest to reduce the cost of composite structures RTM will continue to lead the way. A fire-hose press can be an economical method of clamping a mold for RTM. The simplicity of concept and design, make it easy to build this type of press in house. If nothing more is gathered from this paper, remember this, 1) RTM molds will at some time leak, 2) provide a method to catch the resin before it gets on everything and 3) once the mold starts to leak, quit injecting resin.

8. BIOGRAPHY

Frank Roundy is a graduate of Brigham Young University with a degree in Manufacturing Technology. He has been involved with composites manufacturing since 1984 and has been involved with RTM for over 10 years. He is currently a Senior Development Engineer at StorageTek.

D. DeWayne Howell is a graduate of the University of Cincinnati with a BS in Aerospace Engineering. He has been involved with composite design and analysis for over 15 years. He is currently a Senior Development Engineer at StorageTek , involved with new product design and analysis.