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Automation

The Why and How

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Good afternoon! I would like to thank all the members of the EICF for allowing me to present today. Thank You!

My paper today, Automation, The Why and How, is focused in the wax room.

Many people look at automation as a way of reducing costs through labor reduction. And this is a reasonable approach. After all, it is a sure way to get a capital package through upper management if you can provide a guaranteed ROI, return on investment, and labor reduction is often times a guaranteed approach.

The problem all foundries face today is variability; Pattern to Pattern Variation and Assembly to Assembly Variation. And those all to familiar inclusions in your castings that are attributed to poor quality wax welds; poor quality wax assemblies.

What can we do to put consistency into your wax room?

What can we do to insure repeatability of assemblies that are going into your down stream operations?

Why Automate

Automation = Repeatability!
- Pattern to Pattern Repeatability
- Assembly to Assembly Repeatability
- Casting to Casting Repeatability

Think about this. If you could reduce all your process variables, for your entire foundry operation, to be within the tolerance limit you have set for each step of your process, your casting yield would be 100%. Your scrap begins in the wax room, making it very logical to automate your foundry by starting in the wax room and automating as much of the process as possible.

Our customers have seen huge productivity gains from the automated cells as compared to an operator controlled process.

How to Automate

Now this is easier said than done. It is common for foundries to want to automate what they are presently doing, but if they do not take a closer look at their entire foundry operation, they may not achieve the maximum results or the highest casting yield gains. So what is the correct way to go about getting closer to, or achieving the goal of 100% casting yield?

When considering automation you should take a holistic approach. That is to say that you should consider the entire process. To analyze your system we recommend starting at the end of your process, part cut off and finishing and work your way backward to the wax room. Include an analysis of each step of your entire foundry process. Include key personal from each department and understand the problems that they are encountering every day. It is our experience that when this analysis is completed thoroughly, root cause of much of a foundry's scrap is actually found in the wax room with wax pattern and/or wax assembly defects. Many of these defects can be reduced through appropriate application of

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automation in the wax room. Until you are sure that the final wax assembly, its layout or design as it leaves the wax room can in fact produce the highest possible casting yields, you are not ready to automate. You need to optimize the pattern assembly so that you have included the following:

- Design the assembly to have the highest pattern to runner density so you achieve the highest metal pour to part ratio. Remember that automation of the pattern assembly process allows for a pattern density that is tighter than what your operators can do manually, take advantage of this.
- The assembly layout needs to have the optimum metal flow characteristics for your particular parts.
- Design the assembly for the optimum metallurgical properties.
- Create a layout that can have the parts cut off efficiently using automation. Automated pattern assembly creates a common method for holding the runner that can be used in casting cutoff.
- The assembly design facilitates the de-wax process.
- The assembly can be shelled using automation.

Now you are ready to look seriously at what can be done in the wax room, and remember, the wax room affects every downstream operation. Automation requires a new discipline, standardization. In order to have an effective implementation of automation standardization is required. Use a future oriented vantage point. Do not let the past, or what you are presently doing today, contaminate your vision for the future. You need to see clearly where you want be in the future, and work out how you are going to get there. Change is always painful but making money is fun.

Where do you start?

You should work closely together with your automation integrator from the start of the project so all the possibilities for gains are achieved. In order for your automation project to be successful there needs to be a well-defined plan for its implementation. Automation requires standardization so we will be looking to define and reduce the amount of variables. You need to clearly define the following:

1. What do you want to automate?
    a. The injection of wax patterns
    b. The injection of wax runners
    c. The assembly of wax patterns to your runners
    d. Transportation of the various components
    e. All the above

If the answer is "All of the above" you do not need to do it all at once. Automation if done correctly, can be done in stages. But it is more efficient if you start by including your ultimate automation goal.

2. Why do you want to automate? What are your automation objectives?
    a. Reduce labor
    b. Reduce pattern to pattern variability
    c. Reduce pattern warpage
    d. Reduce assembly failures in the shelling operation
    e. Reduce metal inclusions due to inconsistent welds

Wax Injection Automation

Now lets talk about the automation of wax injection. Note: This applies to both wax patterns and wax runners. A wax runner is a critical wax pattern and needs to be treated like one.

1. Customer needs to define what is critical on the patterns e.g.:
    a. Where the pattern can be gripped without doing damage
    b. The amount of witness that is allowed on the pattern after the injection runner is removed
    c. Are there secondary operations required, if so what are they:
        i. X-ray
        ii. Pinning cores
        iii. Inspection
        iv. Pattern cleaning and trimming
2. An automated injection cell must include automated wax injection tools (dies/molds) with the following features:
    a. Successful automation requires high quality automated tools with no flash on the pattern.
    b. Tools need to have standardized mounting and accurate location features
    c. Core pulls need to be automated
    d. Automated pattern ejection. The wax pattern needs to stay on the die half with the pattern ejectors every time. Note: a sticking wax pattern cannot be automated
    e. Water cooling passages in the tool
    f. This applies to runner injection as well **SEE THE NEXT VIDEO**

Here is an example of an automated runner die.

- Pattern ejection form both die halves, upper and lower
- Water cooling
- Quick Change Die Clamping into the press

3. An automated injection cell needs to have the following operations clearly defined:
    a. Tool clean off: Blow off of any residue wax and die lubrication
    b. Tool lubrication: The correct amount of mold release with the correct frequency. A programmable robotic movement is ideal for this operation.
    c. Pattern removal: The pattern and injection runner comes out of the tool as a unit; the injection runner cannot break off.
    d. Injection runner removal
        i. cut off with a defined witness on the pattern
        ii. deposit the injection runner into a receptacle
    e. Pattern setter, does your pattern need to be cooled in a supporting fixture to prevent warpage? If so:
        i. All setters need to have common mounting and location features
        ii. If the setter clamps the pattern it will need to be automated
    f. Pattern transport out of the cell needs to be defined
        i. What is the next operation and where?
        ii. How is it transported to the next operation?
            1. Tray
            2. Conveyor
            3. Tray on a Conveyor
4. Wax Pattern Specifications: You will need to provide solid model files and pictures of the wax patterns including the gate. The pattern gate is a critical dimension of the pattern and must be clearly defined for automation.

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5. Wax Runner Specifications: You will need to provide solid models of the wax runners including any special requirements or tolerances of the runner. Include any steel inserts, pouring cups, and any special requirements or secondary operations
6. Wax Properties:
    a. Wax Manufacturer's Part #
    b. Viscosity Curve

Automated Injection, 6 Axis Robot

The automated cell consists of a vertical clamping wax injection machine married to a 6 axis robot performing the injection of a single crystal cored turbine blade. The cell performs all of the operations required to make the pattern automatically.

- The robot picks up a combination air knife/die lubrication nozzle assembly and precisely manipulates the nozzle assembly to clean the die of any foreign material, flash etc., using an air knife
- Lubricates the die with mold release with more accuracy and repeatability than is possible by a human
- The robot picks up a ceramic core and manipulates the core for inspection
- Reads the bar code on the core and records the core to a particular injection
- The robot accurately places the core into the die
- The injection press closes the die and starts an injection cycle
- While the pattern is being injected the robot
- Removes the pattern from the setter and trims the injection runner from the pattern
- Places the pattern into a tray on a conveyor
- The injection press opens
- The robot removes the pattern from the die and places the pattern in a setter for cooling; the setter maintains the patterns critical dimensions while reducing the injection cycle time.
- The entire cycle repeats until the tray is full
- Once the tray is full the conveyor transports the tray out of the cell
- An empty tray is moved into the load position
- Enough trays are loaded into the cell so that there is no need for human intervention for several hours of production.
- The cycle repeats until you tell it to stop.

Our customers have seen huge productivity gains from automated injection cells as compared to an operator controlled injection machine.

- Double the number of patterns injected per day
- Pattern yields increased 10 to 20%
    - Reduced pattern distortion
    - Reduced pattern defects
    - Uniform pattern trimming, minimal variation
- Higher casting yields

Automated Pattern Assembly

When automating pattern assembly select a family of parts that will fit a single runner design. The automated pattern assembly process requires tooling to hold the wax patterns, hold the wax runners,

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and tooling for welding of the pattern to the runner. In order to reduce the tooling cost for automation, the more part numbers that can fit onto a single runner and the more similarity between the patterns will allow for the minimum amount of end of arm tooling. The end of arm tooling cost can be reduced with a family of parts because of commonality.

The range of products or wax patterns needs to be grouped into "families". Each family will have a defined commonality between them. For example they may be grouped by:

1. Patterns of a similar size
2. Patterns of a similar shape
3. Patterns with a common gate
4. Patterns mounted on the same runner
5. Spacing of the patterns on the runner
6. The angle of pattern to the runner bar
7. The type of mechanism that is used to hold the patterns during the assembly process, e.g. grippers or vacuum

The design process requires the following addintional information:

1. Photos of the assembly
2. Internal pattern assembly documentation
3. Solid model file of the complete assembly including:
    a. Steel insert
    b. Pouring cup
    c. Any secondary venting or other unique features or requirements, i.e. minimum spacing requirements for specific alloys

Here is an example of some of the projects we have worked on showing common runners and common parts for different customers

You can talk through the video.

Outsourced Automated Pattern and Assembly

MPI does pattern assembly. MPI injects the pattern and runners and assembles them on the runner using this machine our 20w 10. This close up shows the patterns during the 100% fusion wax welding process. The advantage of automated assembly is closer spacing with more parts per assembly. But the closer pattern spacing created concerns with our customer. They had a concern that the shelling operation would have bridging between the patterns and not shell properly.

There was bridging! But there was no negative impact on shell coverage, on the contrary there was less scrap in shell and metal pour. From the bridging there was a pleasant and very unexpected surprise. This bridging uses less shell material per assembly. Another net savings!

Avalon has seen huge productivity gains from the automated assemblies over the manual assemblies.

Automated Pattern Assembly of Single Crystal Turbine Blades

This is our new 20-14 which uses two 6 axis robots. The 20-14 has the capability to assemble more complex assemblies such as a single crystal assembly and has the capability of changing pattern holding devises automatically.

Robotic Assembly - Automation

This is a representation of products that can be assembled on the 20-14 as well as all the Because we are unable to show you our customers actual wax patterns we have created patterns that are representative of the parts our customers are making. This is a representative assembly of single crystal turbine blades. There will be two video clips which show part of the assembly operation.

Assembly video: This video shows the representative turbine blade being welding at the grain selector end of the blade. A plastic rod represents the grain selector.

The robot on the right picks up the pattern and the robot on the left manipulates the heated welding device. They work together to perform a 100% fusion wax weld.

The completed assembly is extremely strong despite the fragile single crystal patterns.

The red wax pattern on the top of the assembly, we call it a spider assembly, this was injected as a single wax pattern. This single injection eliminates many individual patterns and wax extrusions. This design allows for automated assembly. It creates the venting for the metal pour and it stiffens the assembly making it very ridge.

This video shows the welding of the spider assembly to the individual turbine blades. The two robots work together to make each individual 100% fusion weld. The close up shows the fusion weld. The entire assembly is stronger, more ridged and far more accurate than the manually assembled assembly.

Automated Assembly of DS and Single Crystal Turbine Blades

Results:

- Extremely uniform, repeatable and stronger assemblies
- A more uniform shell coverage due to accurate spacing
- Improved thermal gradient and metallurgical properties
- Decreased cycle times with reduced labor
- Higher casting yields

Our customers have seen huge productivity gains from the automated assembly cells as compared to manual assemblies.

Conclusion

Automation is a clear means to reach many of the critical goals you set for your business. With the correct preparation and mindset, automating your wax room will have a significant positive impact to your bottom line. Once you have made a commitment to automation you will begin to see that every time you receive new orders, possibilities for more automation will become more and more apparent and easier to implement. When you work on new jobs that are presently not in production there is less cost to automate, the conversion cost it gone. You need to tool up anyway why not with automation in mind?