

# Japan Foundry Society, Inc.

### Profit though Innovation

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Paper:

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### **Profit Through Innovation**

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We all know how automation has changed the world. The question becomes; can we see the same results in our Investment Casting world? Why have we automated some processes in investment casting, but not all? This paper will discuss the benefits of automating the wax room and will highlight how different companies have used automation to their competitive advantage.

#### Why Automate?

We know the trend of our industry is for high cost, lower production run castings. Some people believe that automation is reserved for a world of high volume long production runs. They question the value in automating short runs. Will the automated equipment will be flexible enough to respond to their changing needs? I believe that the question is: Can we afford not to automate our processes? By using automation equipment that adapts to your needs and can do so with minimal down time, low volume castings can be automated and generate the same type of ROI that high volume castings produce. Many successful organizations are demonstrating that in order to be competitive and maximize your human capital you must take advantage of automation.

#### Direct Benefits of Wax Room Automation

The benefits of automation in the wax room are many and can be summed up as higher casting yields at reduced operating expense, which net a significantly greater profit per casting.

The increased yields come from three main areas: (1) increased patterns per assembly, (2) fewer defects and (3) less variation in both patterns and assemblies.

More and more investment casting customers are sharing data that reveals a high percentage of casting-to-casting variation is coming from the handling of the wax patterns by the operator. By replacing the operator with a robot, the defects and variations are reduced and the number of patterns per assembly can be optimized. How can this be achieved effectively?

#### Automation Experience:

A number of investment casters have experienced successful automation projects covering:

1) Automated injection.

2) Automated assembly of directionally solidified (DS) and single crystal assemblies.

3) Automated pattern assembly.

Interestingly, (and understandably) the benefits of this technology are not eagerly shared.

While the Investment Casting Industry tries very hard to find speakers who will share foundry success stories and supply real, hard facts of what they did and the gains they achieved, caster's are reluctant to come forward.

From the caster's point of view, divulging tools that give him a competitive edge, would not be a smart business move. The last thing he wants is to give his competition the "secrets" behind his real gains in productivity and profitability.

Thus we offer the following success stories with the names of the companies omitted.

#### Example #1: Automating a Wax Injection Machine

MPI is currently working on projects that integrate a robot with an injection machine, creating a fully automated injection cell. (Due to the sensitivity of these projects, there is presently little data that can shared.) This being said, a number of investment casters have reported that manual handling of the wax pattern creates pattern-to-pattern variation. Depending on the pattern geometry, this variation can account for as much as 50% of the metal scrap.



Fig.1 Marrying a semiautomatic injection machine to a 6-axis robot creates a fully automated cell.

By automating the injection process, including secondary operations to the patterns, much of this variation can be eliminated.

Marrying a semi-automatic injection machine to a 6 axis robot and creating a fully automated cell provides the ability to perform the following tasks:

- The robot picks up a combination air knife/die lubrication nozzle assembly and precisely manipulates the nozzle assembly to (a) clean the die of any foreign material, flash etc., using the air knife; and (b) lubricate the die with mold release with more accuracy and repeatability than is possible by a human. (c) The robot picks up a ceramic core and manipulates the core for inspection; (d) the bar code is automatically read and recorded to a particular injection; and (e) the robot accurately places the core into the die.
- 2) The injection press closes the die and starts an injection cycle.
- 3) While the pattern is being injected, the robot (a) removes the previous pattern from the setter and trims the injection runner from the pattern; and (b) places the pattern into a tray on a conveyor.
- 4) The injection press opens.

- 5) 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.
- 6) The entire cycle repeats until the tray is full.
- 7) Once the tray is full, the conveyor transports the tray out of the cell.
- 8) An empty tray is moved into the load position.
- 9) Enough trays are loaded into the cell so that there is no need for human intervention for several hours of production.
- 10) The cycle repeats until it is programmed to stop.

Investment casters have seen huge productivity gains from the automated cells as compared to an operator-controlled injection machine. Twice as many patterns can be produced from an injector when run automatically as the same machine run with an operator. The patterns produced automatically also have yields 10-50% higher than the same die run with an operator. This is because of (a) reduced pattern defects from improved die spray coverage; (b) reduced pattern distortion from improper manual handling of the patterns; (c) uniform pattern trimming, minimal variation; (d) the ability of the cell to run more hours with no coffee breaks; and (e) higher casting yields because of reduced pattern defects.

#### Example #2

Several aerospace blade manufacturers automate the assembly of turbine blades into circular assemblies for equiax, DS and single crystal applications. Their goal is to retain or regain their leadership position by reducing costs and improving profits. These innovators are investing in their future.



Fig.2 Aerospace blades are assembled into circular assemblies

The following illustrates how casters and suppliers can partner to achieve their goals. Because of the proprietary nature of the projects and their sensitivity, these casters did not want to be identified, thus we have combined all of these investment casters into one group.

All of these customers have a common approach: to automate an assembly and eliminate the variability that comes from manual assembly. It has been proven over and over again that variation in the wax assembly creates metal scrap.

Today turbine blade assemblies are as unique as the engineers who designed them. The challenge is how to automate such a variety of assemblies. It all starts with a close partnering between the caster and supplier working toward a common goal: automating the assembly and eliminating variability

The following steps are taken to achieve this goal:

1) Problem:

Many of the wax parts that make up the assembly were previously extrusions. These extrusions, due to their very nature, were extremely variable on their own; the addition of the human element of forming the extrusions into a final shape resulted in variation added to variation.

Solution

MPI worked with the customer to eliminate the extrusions and replace them with injected patterns, thus maintaining part-to-part uniformity.

2) Problem:

Many patterns were previously manually assembled into a subassembly from patterns, extrusions or a combination of both, again causing variability.

Solution:

These patterns are now redesigned into a single injected subassembly. This approach eliminates manual assembly while reducing the number of patterns that need to be welded into the final assembly.

3) Problem:

Wax parts were previously welded on vertical planes causing wax dripping.

Solution:

These have been redesigned for horizontal welds allowing for automated drip-free fusion welds with 100% penetration. This horizontal weld can be done two different ways: redesigning the part so the weld is in a horizontal plane or (b) manipulating the entire assembly using two axes of movement so each weld can be positioned for an optimal horizontal drip-free weld.

4) Problem:

The manual assembly of the grain selector to the pattern.

Solution:

The turbine blade wax patterns which require a grain selector are assembled through the injection process as a single pattern.

All of the uniform subassemblies can now be welded automatically and very accurately into the final assembly using two 6 axis robots working in tandem. One robot does the wax melting and the other robot does the pattern manipulation; together they perform a 100% fusion wax weld.

The gains that are able to be achieved by automating the assembly are:

5) Extremely uniform and repeatable assemblies offering improvements in

(a) increased strength of the wax assembly;

- (b) more uniform shell coverage due to accurate spacing;
- (c) improved thermal gradient of the final shell; and

(d) improved metallurgical properties.

- ① Decreased cycle times.
- ② Reduced labor costs.
- ③ Higher casting yields.

Because of the proprietary nature of these projects in the automation of equiax, DS and single crystal assemblies, no specific casting yield improvement numbers are available, but results are significant, and the work is ongoing.

#### Example #3

Avalon, a job-shop foundry specializing in commercial and aerospace hardware components, has agreed to share its name and specifics. Avalon is certified to ISO 9001:2008 ANAB Accredited and is also PED certified to EN764-5, Article 4.2.

Management at Avalon wanted to embrace automated pattern assembly for some time but was reluctant to make the required capital investment. Their biggest concern was a lack of factual data to substantiate the potential ROI. Consequently, they worked with MPI to develop a program where MPI provides complete assemblies. This solution allowed Avalon to get into automation without making the investment in automation equipment.



Fig.3 More patterns per assembly means higher metal yields and increased casting yields.

MPI and Avalon worked closely together to select the correct parts to be automated and establish families of parts that use common tooling.

The results are assemblies with more patterns per assembly, higher metal yields and increased casting yields. Avalon has automated several different assemblies with patterns per mold increasing between 15% and 28% depending on the assembly.

Metal yield has increased between 23% and 31%, again depending on assembly. Overall yield has improved over an already low scrap rate. In addition to these gains there was a welcome and much unexpected surprise. The tighter pattern spacing available with the automated process caused bridging of the shelling material between the parts. This bridging allows for less shelling material per assembly. Another net savings with no impact on the metallurgical properties of the parts.



First Coat

Second Coat

Assemblies are being shipped into Avalon in batch quantity, (contrary to the company's goal of lean). In spite of the change, Avalon was soon able to integrate the groups of molds seamlessly into the daily production flow.

Previously the runners were made by gravity pour into an open-top die; now that they are injected they have a smooth surface finish, virtually eliminating the potential for inclusions in the castings.

#### Conclusion

Automation has and will continue to be a valuable tool in many industries, and particularly in investment casting foundries.

Wax room automation allows casters to gain from:

- 1) Decreased defects.
- 2) Higher casting yields.
- 3) Reduced operating expense.
- 4) Significantly greater profit per casting.