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Technical Paper

Low Volume Automation, Challenges and Advantages

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This paper is the third and final in a three paper series discussing cost reduction through process improvement in the wax room. My first two papers focused on two techniques to reduce scrap and rework during injection. Making these improvements and optimizations leads to the next logical step of process improvement which is automation. Historically, automation has been thought of as unachievable for the 'job shop' which runs lots of different jobs and short runs. The prevailing belief has been that only very high volume or very high value parts could be affordably automated. This paper will focus on the processes, advantages, and challenges of automation in the wax room for the Job Shop.

All parts shown are thanks to Lamothermic in Brewster NY.

The challenge that set out by the customer was to automate their parts cost effectively without making costly changes to their process. Being a job shop, Lamothermic is given tools by their customers for short runs with little to no minimum guarantee other than the initial PO. The 'job shop' atmosphere is commonly believed to be a barrier to entry into automation since the prevailing belief is that you cannot automate low volume, high changeover work. We worked with the customer to develop a unique automation solution around some specific design constraints:

- No major die modifications were allowed
- No major runner modifications were acceptable
- Short set up time on new jobs
- Easy job changeover is a must

We chose to focus on a few representative parts to prove out our concept. There were, of course, a number of challenges. Automation requires repeatability, which requires consistency in a process and standards for evaluating a process. The challenges included:

- There is no such thing as a standard runner in a foundry. Runners come in all shapes and sizes. Even small variations in length and geometry can be a real challenge when automating a process.
- Runners are treated with little respect or concern for their full or true cost to the process. Many foundries do not spend any time or money to produce runners with the same quality as a pattern, nor do they accurately measure what it costs in time, money and rework to produce a runner.
- Patterns are often not similar or have no commonality
- Pattern gates and runners are mismatched, resulting in many opportunities for poor welds, undercuts and rework of the weld in both manual and automated processes.
- Dies are not built to produce defect free parts, meaning no flash, etc.
- Typical Die, injection runners and gating runners tend to be pretty non-standard. Rather, they are ideas an engineer tried one time before coming up with a new unique solution
- Injection feeds are secondary to pattern shape having dramatic impacts on fill and quality.

First steps first, *Automating the Assembly*

Although this may sound a bit counterintuitive, starting the automation project with the whole assembly is often the simplest and most clear cut automation project for a job shop. Automating assemblies are where we often see the biggest return on investment since most manual assemblies contain lots of variation. Reducing variation in the assembly can create gains both in the wax room as well as unforeseen gains and savings in all downstream processes. The part we focused on first is reference part #1 (See Figure 5 through 7) and a baseline was recorded for injection, inspection, assembly, metal scrap and metal yield. For information on injection improvements you may reference our second paper in this series "Overcoming Common Wax Injection Problems: The First Step Toward Automation".

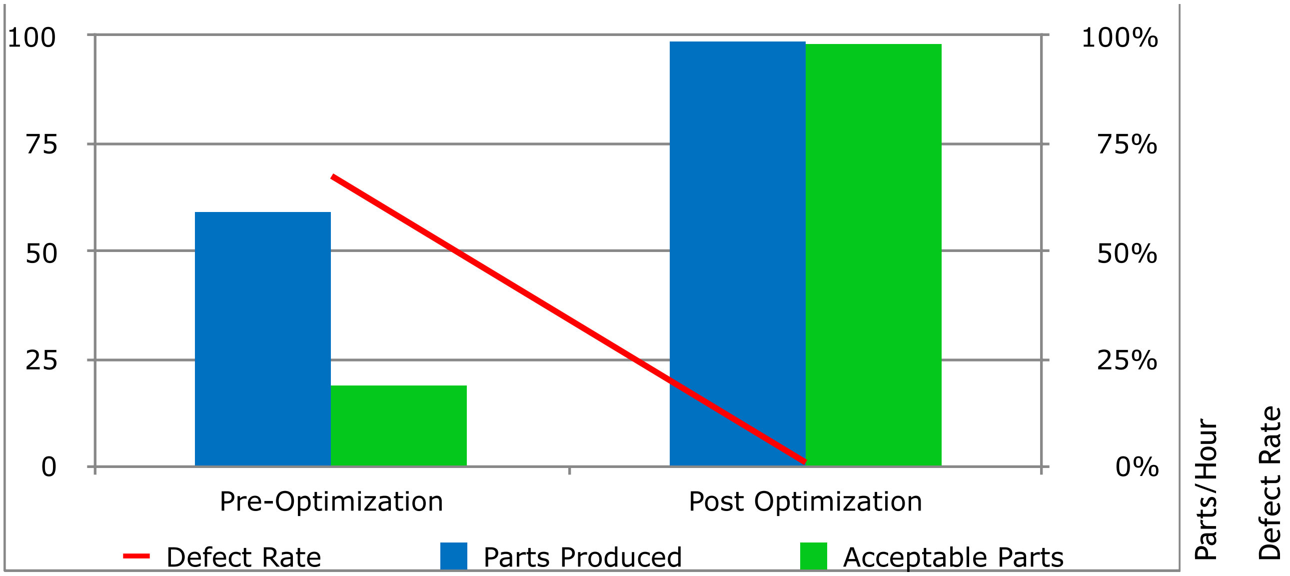

Figure 01: Parts injection optimization taken from paper #2

As you can see from the chart above, making minor modifications to the injection die and optimizing the injection process and parameters resulted in a dramatic reduction in the defect rate. Overall, the defect rate was reduced from 67.5% (pre-optimization) down to 1% with the optimized recipe run on the die after modification. This represents a 98.52% decrease in defect rate. It also resulted in a significant improvement in cycle time per batch of parts. The original recipe provided by the customer produced 19 acceptable parts per hour prior to optimization. After injection modification and a minor die modification, the run rate was increased to 98 parts per hour. This is a total improvement of 516% in acceptable parts per hour. The process changes and die modification combined achieved a throughput gain of more than 5 times on this machine with this part. Consequently, there was a significant reduction in the required pattern inspection requirements. Inspection savings were directly proportional to the defect rate in injection. The reduction in injection defects reduced the manual inspection from 100% inspection of every single part to a rate of only 1 in 50, greatly reducing operator handling time and the need for machine tending.

Assembly of this part historically took between 11 and 20 minutes, and averaged 14 minutes over the range of assembly operators and the life of this product. Much of the variation found in the manual building of this assembly was attributed to operator turnover and the resulting variation in training and proficiency.

As alluded to earlier in order to automate the assembly of a process such as the assembly shown in *figures 4 and 8* some changes where required. Typically this has been done through die and part modification to achieve pattern quality runners and parts with common features. Because of the customer constraints and challenges it was clear development of a new process would be required. Cooling processes for runners were developed to allow them to cool in a manner that guaranteed repeatable runners that provide a consistent working surface. This process varied depending on runner geometry always reducing variation without adding additional cost to the base line process. In addition, given the variety of part and gate geometry a new generation of specialized and easily customized tooling was developed to allow for a wide variety of parts to be manipulated with minimal cost. After the assembly process was successfully automated, the resulting cycle time of the finished automated assembly including loading and unloading the machine is between 8.5 minutes yielding a 41% decrease in overall cycle time. It is important to note that until this point we had not focused on anything more than proving the capability of the automated system by building the assembly with the same spacing and number of parts per row as the proven manual process that resulted in 42 parts per assembly.

Now that the process was proven on this part, the real fun of finding additional process improvements and casting yield increases was ready to begin. Because of the flexibility of the End of Arm tooling, we were able to produce molds for casting trials with 7, 8 and 9 parts per bar or 42, 48 and 54 parts per assembly. These additional parts would represent a potential increase in yield of 14 and 28% respectively over the original part layout of 42 parts per tree. Admittedly there was some skepticism over whether the denser assemblies would be able to be cast reliably. The new automated assemblies were run side by side through the foundry. Initial results looked promising as there were no visual defects after shell removal. As an extra precaution all parts were run through X-Ray to ensure there were no metallurgical defects such as internal porosity or shrink. All parts passed X-Ray with zero defects.

Once the casting trials where completed we ran into our first road block. Despite the positive results it was decided to only take advantage of the 8 parts per row or 48 parts per tree configuration in production. This is due to the fact that there is a weight limit on all downstream operations. The 54 part tree configuration exceeded this weight limit. Because of the unique End Of Arm Tooling (EOAT) design we are able to easily adjusted the number of parts per runner bar. This allowed multiple casting tests to be run optimizing the pattern spacing in the foundry without effecting the cycle time of the welding operation.

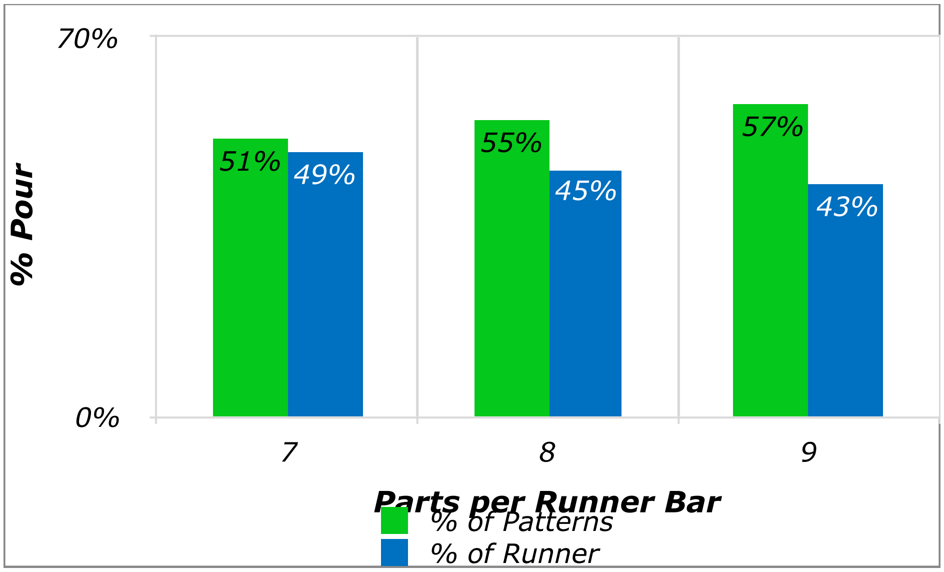

Figure 1: Pour Ratio Gains

Conclusion:

Automation reduces variability. When automation starts in the wax room the following benefits are achieved:

- Reduced shell material- the more parts you can put on an assembly the fewer assemblies you will need to dip resulting in reduced shell usage.
- Further shell reductions are produced based on reduced part spacing and bridging.
- Uniform part coverage due to presentation of the part in to the slurry
- Increased accuracy of solidification models
- More accurate part cut resulting in reduced gate grind
- Reduced cut off scrap
- Reduced scrap due to inclusions

These process gains allow your engineers to focus on corrective actions that focus on problems at the root of their origin.

Figure 2: Part #3, Patterns to be automated

Figure 3: Part #2, Patterns to be automated

Figure 4: Part # 2 Example of automated assembly using common tooling

Figure 5: part # 1, 54 part tree showing bridging and shell reduction

Figure 6: Part #1, Consistent shell build and bridging resulting from closer automated part spacing

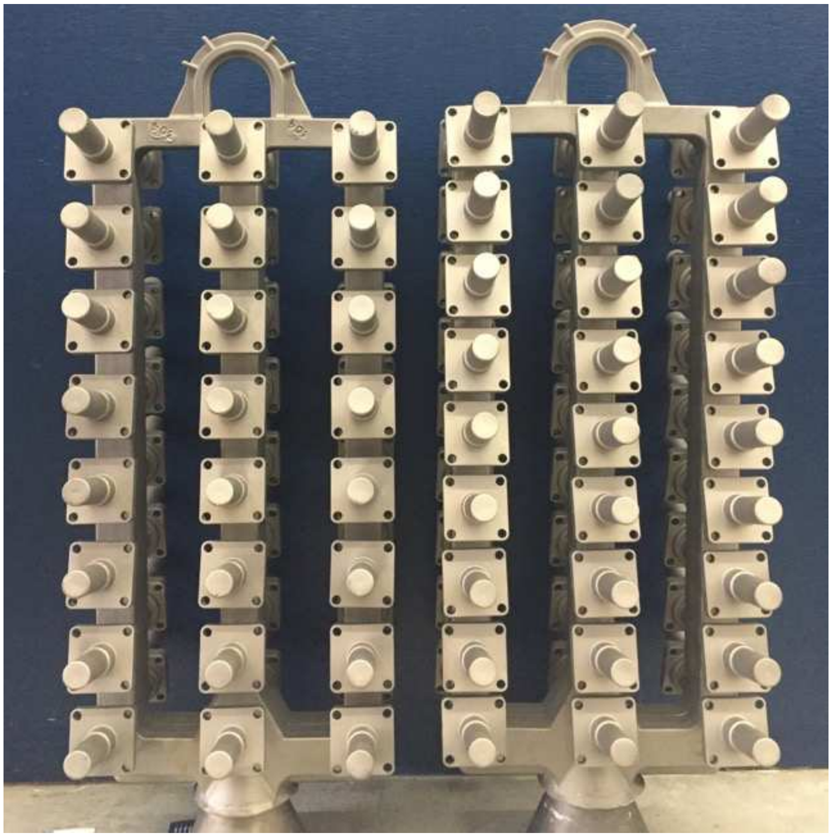

Figure 7: Part #1, 8 and 9 parts per weld casting examples