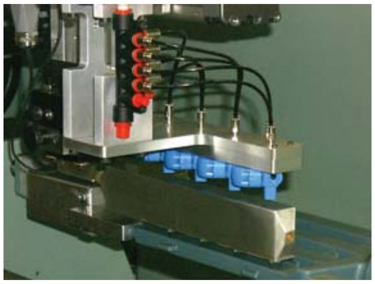
Lost Wax Casting



New Invention, Developed Through Industry-Government-Academia Collaboration, Helps Lost Wax Casting Industry Improve Yield

Background

The use of pre-cast products and components is prevalent in many industries such as: pharmaceutical equipment, heavy machinery, food and dairy process equipment, medical equipment, hardware, industrial pumps and valves, and telecommunications equipment. One of the most popular methods for creating these products and components is a technique known as “Lost Wax” or “Investment” casting. The process involves the use of wax, ceramic, and molten metal to produce a flawless metallic replica of the original wax pattern. The process is unique because it can be used to make components that otherwise could not be manufactured via normal techniques. Some of the materials used in the casting process are: aluminum alloys, bronzes, tool steels, stainless steels, stellite, hastelloys, and precious metals. Currently, the process is used at 700 facilities around the world and is one of the oldest casting methods, dating back almost 5,000 years. It has become the norm in high-precision industries such as medical and military equipment production.

Advantages and Opportunities

The Lost Wax Casting (LWC) process allows for a variety of component features that are not accessible through other manufacturing techniques. Advantages realized through LWC include: the ability to design and manufacture intricate products that are extremely accurate to dimensional tolerances, use of metals that would otherwise be difficult to fabricate, clustering of patterns to yield multiple products during a single metal pour, which allows optimal production, and a high level of product consistency. If done correctly and bolstered with superior controls, the process minimizes waste and decreases material costs.

The key issue that has plagued the process is the need for highly specialized labor. These skilled workers must manually perform a welding step to build the clusters, and this results in a production bottleneck. MPI Incorporated, based in Poughkeepsie, NY, has been a consistent supplier of technically advanced wax room automation equipment. MPI has recently embarked on a program to tackle the major obstacle present in the LWC process. The program included the assistance of the New York State Energy and Research Development Authority (NYSERDA). NYSERDA’s mission is to use innovation and technology to solve New York State’s most difficult energy and environmental problems in ways that

improve the State's economy. The assistance provided to MPI helped to investigate, develop, and demonstrate a solution to enhance the overall efficiency of the LWC process through precision alignment of the patterns during clustering, which can only be achieved via automation of the welding step. This assistance has resulted in a new, patented product, the Automated Pattern Assembly System (APAS), manufactured by MPI for sale to customers worldwide.

Lost Wax Casting Process

The LWC process has multiple steps that occur in sequence. The first step involves forming a pattern using wax to make an exact replica of the desired finished part. Wax is used for this step because it can be melted and extruded into a die to form the pattern at temperatures that enable the use of dies constructed from common metals. Clustering (also called pattern assembly) occurs after several patterns have been formed; they are attached as "branches" to a "tree trunk," which is a central wax core (often called a runner). This attachment, which has heretofore always been done manually, can occur by two methods.

The first method uses hot "sticky wax" to glue the pattern to the runner. The second method is "welding," which begins by heating a section of the pattern and/or a section of the runner with either a flame-heated hot knife or a blowtorch to temporarily melt a small zone of wax. The welding process is completed by holding the pattern to the runner until this zone re-solidifies (the point of attachment is referred to as the gate).

Next, the cluster (consisting of the central core and its branches - often referred to as a tree) is repeatedly dipped into a refractory slurry until a thick skin layer forms over all portions except the "rootbase" of the tree trunk (this process is called shell buildup). The slurry-coated tree is allowed to air dry, then placed (standing upright on its rootbase) in an autoclave and heated. This heating allows the wax to melt and flow out through the rootbase opening, while the dried slurry coating further hardens. This creates a hollow shell (or mold) whose cavity is a perfect mate to the original patterns. The wax patterns, having served their purpose for creating the ceramic mold, are destroyed during the autoclave step.

This remaining shell is next heated in a kiln, inverted, and while the shell is still hot molten metal is poured in through the rootbase opening. The molten metal is allowed to cool and then the ceramic shell is shattered and removed. A saw is used to remove the product from the tree trunk in a process called de-gating, and this rough-cut location on the product is brought to its finished tolerance by grinding. The result is a metal component that is precisely the shape of the original wax pattern.

Lost Wax Casting

Challenges

Pattern assembly is the most important and most challenging step in the process because:
(1) there must be sufficient strength at the point of attachment to keep the branches from falling off when the cluster is jostled during subsequent steps;
(2) the angle of attachment is critical for proper flow of wax from the tips of the branches downhill and out the rootbase opening during the autoclave step, and flow of molten metal from the tree trunk into the branches and downhill all the way out to their tips during the metal pouring stage;
(3) a high-quality weld/gluesite (a smooth fillet weld; no glue drips are desired) is necessary to avoid a potential “inclusion” defect in the cast metal part, which can otherwise occur if a jagged lip of ceramic exists at the location where the molten metal flows from the tree trunk into the branch – the flow of metal can snap off a chip of ceramic and engulf it;
(4) a more-densely packed number of branches improves yield of product parts per unit of tree trunk, (which must be re-melted to reclaim the metal);
(5) consistent alignment of branches facilitates precision cutting during de-gating (minimizing the portion of the gate – typically a half-inch long stub, – which remains with the product after cutoff minimizes labor and energy-intensive downstream processing during the grinding step);
(6) uniform spacing between patterns is necessary to ensure each metal part cools at the same rate to prevent premature fracture of the shell; and
(7) the use of a flame-heated hot knife or blowtorch to melt wax creates an unpleasant and potentially dangerous work environment that is only somewhat mitigated by extensive use of energy-intensive mechanical ventilation.

Finding a Solution

MPI addressed this challenge through a progressive approach that began with a feasibility study and proof-of-principle modeling. The project then proceeded to a laboratory prototype machine with a demonstration to several industry stake-holders for feedback, field demonstration of a beta test unit, and culminated in a patented product – APAS, – which has had its first sales.

MPI partnered with an industrial applications-focused research team at Rensselaer Polytechnic Institute (RPI) and NYSERDA for this multi-year effort. The project initially explored techniques for making reliable/repeatable welds, eventually identifying an optimal two-sided electrically-heated hot knife with textured conformal pads. Temperature, positioning, and dwell time of the hot knife can be controlled to create a small pool of molten wax on the top surface of the runner while simultaneously softening the underside of the pattern’s gate. These control

parameters can be adjusted for runners and patterns made from waxes with various thermal properties. Further automation features for queuing-up materials, picking, and placing, were developed with robust characteristics to accommodate the range of most commonly expected sizes and geometries of patterns and runners. In order to achieve repeatable precision welding, a specification for acceptable runner straightness was established.

Outcome

Overcoming some of the major challenges allowed MPI and RPI to establish a new, efficient pattern assembly process. The automated sequence is as follows: (1) wax patterns are loaded onto a positioning pallet on the APAS rotary table, (2) the pallet is indexed on the table to allow access by the robotic picker arm, (3) the picker robot picks up a single row of patterns from the pallet and moves into position above the knife robot, (4) the knife robot moves into position and begins to melt the runner, (5) the picker robot lowers the patterns to begin melting the gates via the top portion of the hot knife, (6) when the heating process is complete the hot knife exits the area and the picker robot lowers the row of patterns so that the gates make contact with the heated areas of the runner, (7) the picker robot holds the patterns in perfect position until the cooling process is finished, (8) the sequence is repeated until the runner is fully populated on one side and then the runner is turned to a new index position and the process is repeated.

The newly-developed APAS has many benefits. The welding temperatures and dwell times are controlled to minimize smoke, and the welding stage occurs within an enclosed chamber, further facilitating control of smoke and minimization of mechanical ventilation. APAS produces precisely-aligned patterns attached to a runner via perfect welds, and the attendant benefits for the LWC process (such as maximization of process yield, reduction of time and labor during the tree assembly stage, elimination of bottlenecks, improvement of throughput, and reduction of defects and scrap).

Pine Tree Castings Division of Sturm Ruger & Company, Inc. was selected to serve as a beta test site. Pine Tree has been involved in investment casting for almost forty years. Use of the MPI 20-10 (APAS) system coupled with another MPI system, the 45-12, a wax injection system for pattern fabrication, enabled Pine Tree to realize some significant achievements early in the testing. Pine Tree saw increased yields of five percent in production, resulting in more output per unit of energy consumed. After evaluating the test results, Pine Tree's management opted to purchase the system, which was offered to them at a discount.

MPI Inc. has developed a product that reinvents the Lost Wax Casting process. MPI has received U.S. patents for the APAS, and has made a commercial sale at full price to an investment casting company that did not participate in the APAS development cycle. This arms-length transaction signifies the marketplace's acceptance of this new product.