DIE CASTING AUTOMATION – AN INTEGRATED ENGINEERING APPROACH
Die Casting Automation: An Integrated Engineering Approach

Abstract

This paper identifies key reasons for automating die casting operations, the impact of robots on the automation, and the advantages of using Product Life Cycle Management (PLM) tools to generate and validate the automation process.

Introduction

Die casting is a process that has been around for several decades. It is a flexible process for producing metal parts by forcing molten metal under pressure into reusable steel molds or dies. The dies can be designed to produce highly accurate and repeatable complex shaped parts.

Die cast products are the bulk of mass-produced items manufactured by the metalworking industry, with applications in a variety of consumer, commercial and industrial products. Various products ranging from alloy-based toys to automotive engine parts are manufactured using this process. Based on the size of the end product and the volume requirements, automation of die casting operations can be critical for a successful manufacturing process.

Business Drivers for Die Casting Automation

In the last 25 years, there has been a steady increase in the role of industrial robots in manufacturing. With over 15,000 industrial robots sold every year, robots have become a mainstay in the manufacturing industry. Their flexibility, reliability and repeatability, to name a few advantages, have made them a vital component in the automation process for die casting applications.

Some of the business drivers for automation of die casting operations are:

- Low cost of robots leading to cost effective automation with quick return on investment (ROI).
- Increased requirements for system flexibility to produce multiple parts.
- Ever increasing focus on the human factor/ workcell safety.
- Variety of production rate requirements based on market for cast products.
- Cycle time requirements by station or operation.
- Life cycle of manufactured product to ensure acceptable ROI.
- Product handling requirements.
- Maintenance requirements.
- Safety standards related to heat and gas exposure in casting operations.
Designing a Robotic Cell for Die Casting

If business requirements drive the die casting cell to be automated, there are many factors that need to be considered during the design of the cell.

Product and Die Design

The size and shape of the cast product essentially drives the design of the dies used for casting the product. Shape, size and stroke of the die have a strong impact on the automation in terms of robot reach and accessibility. In today’s technologically advanced climate, almost all manufacturers have their product and dies designed in 3D CAD packages. This 3D data is critical for accurate end-effector design as well as design of storage racks or conveyor pallets. Ensure that this data is at the latest revision and the product used for equipment design is displayed in the form and shape that it is expected to be in after exiting the die cast machine.

Environmental Factors

Safety is a major issue in die casting operations due to the extreme heat and emissions that are generated during the casting process. Robots are used primarily to avoid humans from being exposed to this dangerous environment. Most robot OEM’s have a “foundry” series of robots that are designed and manufactured using strong heat resistant materials which could be used if applicable. End-effector component materials should be selected based on heat resistance since these parts interact with the high temperature product as it exits the die.

End-effector Design

While the size and shape of the die cast product is the major factor in the design of the robotic end-effector, other factors like temperature, payload, and force requirements should be taken into account. 3D product, fixtures and die models should be used to design the end-effector to ensure that the design has appropriate clearances to surrounding parts within the die. Clamping surfaces are generally based on quality and finish requirements and should be carefully chosen with the customer. End-effector design should be developed in conjunction with robotic simulation to ensure that the design is suitable for all robot tasks and associated equipment. In cases where removal of gates, risers and “biscuits” on the product is required, the end-effector may need to be designed with the appropriate force compensation or compliance devices.
Floor Space

The amount of floor space required to automate a die casting operation depends largely on part processing requirements as well as peripheral equipment design and sizes. The most effective way to ensure that appropriate space is earmarked for the robotic automation process is by performing a simulation of all the robotic operations. This will ensure that equipment is placed in locations that will suit all process requirements and sequence of operations. A significant benefit of using robotic simulation is the ability to test multiple product styles and dies to arrive at a common layout configuration which reduces changeover time and associated costs. The simulation done in conjunction with mechanical design and layout development will act as a virtual three dimensional integrated cell.

Payload and Robot Selection

Robot selection is driven not only by environmental conditions but also based on payload, reach and part access within the die. The mass, center of gravity and moments of inertia about the mounting face of the robot determines the robot model based on payload capacity. The mass data for the payload analysis can be generated from the mechanical design CAD package as long as the data entered into the system for material properties is accurate. The mass data that is generated can then be entered into a payload calculation program to determine the robot model that can withstand the payload requirements. Apart from payload, other factors that help drive robot selection are – die travel (horizontal vs. vertical), gantry vs. floor mounted robots based on equipment size and access and cycle time requirements.

Cycle Time Validation

The main driver for production rate on a die casting system is the time it takes for one cycle of the press and the unload time. Once this data is known, process design must focus on ensuring that the press spends a minimum wait time on other pieces of automation. The time spent by the robot after unloading the part from the dies should not exceed the time required by the press to cycle and generate a new casting. Robotic simulation in conjunction with external robot controller software (RCS) can be used to generate accurate robot motion cycle time. The use of virtual controls replicates real-world conditions and allows for evaluation of both individual processes and coordinated activities of robots within a system.
Part Cooling Requirements

Once the part is extracted from the die, it may need to be cooled prior to further processing or transfer to other equipment. This can be a liquid quenching or air cooled process based on the product and the desired material characteristics. For liquid cooled operations, the equipment could be as simple as a quench tank into which the robot dips the hot part once it is extracted from the die. For air cooled operations, a small fixture or buffer stand may need to be designed so that the robot can unload the parts. Robotic simulation is a great tool to validate buffer stand reach and location.

Degating/ Flash Trimming

In some manufacturing operations like engine parts, the casting may have metal extensions known as gates or runners that are deliberately created in the casting process to eliminate air and porosity in the main casting part. These gates can be removed by several different methods based on the quality and finish requirements of the end product. In most cases, the gates are removed by using a "knock-off" stand. The degating process generally has specific orientation and direction requirements to remove the excess material. Robotic simulation must be used to ensure that the robot can access the desired knock-off position without any reach issues.

An extension of metal is formed on die castings at the parting line of the two die plates and where moving die components operate. This is known as “flash” and is an unwanted by-product of the manufacturing process. This flash is generally removed using a trim press or in some cases a CNC machine. The robot loads the casting into the press or CNC machine, waits for the equipment to cycle before unloading the finished part. Using robotic simulation to validate this load/ unload sequence is important to ensure that there is sufficient opening and clearance to enter the machine.

Part Transfer/ Exit

Die cast parts may be transferred out of the system in several different ways based on customer requirements. Some parts may be transferred out onto conveyors for further processing while others may require robotic palletizing into racks. Robotic simulation is again a valuable tool to ensure that the robot can reach all extremes of all pallets at all heights. The simulation can also be used to analyze cycle time based on stack pattern requirements.
Safety Considerations

All design elements of a robotic/automation workcell should be evaluated for safety issues. Product, process, designed and customized equipment, robot and operator tasks, workcell layout, controls and electrical designs, etc, need to be analyzed and in some cases integrated in a virtual world to ensure safety. The use of 3D virtual manufacturing involving CAD designs, simulated controls and virtual robotic and ergonomic simulations is an ever improving and continuously growing trend that has helped make human machine interactions in the manufacturing sector safer than ever before.

Some of the common analyses and outputs from robotic simulation are robot envelope and hard stop information generation based on the actual motion of the robot incorporating all its tasks. This will help system designers to understand the space requirements and placement of safety equipment like fencing, safety mats and light screens.

Controls Engineering and Robot Programming

While it is important to validate die cast automation in a virtual environment, it is even more important to ensure that controls engineers and robot programmers ensure that safety is an overriding priority. PLC software needs to be capable of ensuring safety checks between software and hardware, proper handshake between the robot, press and safety devices. Safety related items like light screens, perimeter guarding, safe distance calculations, robot base limit switches and hard stops should be carefully designed, programmed and debugged to ensure safe cell operation.

Programming the robot is a task that should be in the hands of an expert. While most of the motion is primarily simple material handling, there are situations where delicately extracting hot the part out of the die or trimming the extracted part requires considerable path teaching skills due to part complexity and surface quality requirements.
Conclusion

The cost savings associated with using 3D CAD based integrated design and simulation tools for die cast system design is negligible compared to problems that could occur on the plant floor if the system is not validated prior to build. Time is at a premium during installation, so spending time up front during the engineering phase of a project to create a quality system is well worth it. The benefit of simulation can be realized even after the end of a product life cycle because it can be reused to validate the next generation of products and dies into the existing system.

Convergence of engineering disciplines in the form of PLM to arrive at system solutions is gaining acceptance in all areas of manufacturing. The benefits gained from creating systems in a virtual environment have resulted in cost savings that far exceed the capital investment and training costs of implementing PLM strategies.

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