Innovating wax injection in investment casting: Leveraging collaborative robotics for a manual wax injection

Abstract:

The investment casting industry operates within a field that combines advanced technology with a significant amount of manual labour. Meeting the demands for complex, precise, and reliable parts at a competitive cost is crucial for staying competitive in the global marketplace. This project aims to analyse the current manual processes involved in wax injection. The goal is to explore potential areas for low cost low effort automation and assess how this could affect product quality, productivity, and yield. These factors are crucial performance indicators for the investment casting industry. Through the implementation of a five-step DMAIC technique, it became possible to pinpoint various factors that require attention in order to effectively deploy collaborative automation into investment casting wax injection processes. Through extensive analysis and exploration, the manual process was thoroughly examined and improved. By implementing collaborative automation in the injection process, significant advancements were made. As a result, the overall production time and cost were reduced by an impressive 95%.

Submitted By:	Joel Jeremy Munilal
Company:	Designed Precision Castings
Email:	Joel.munilal@dpcast.com

DESIGNED PRECISION CASTINGS INC.
PARTS OPTIMIZATION

AS 9100:2016 BUREAU VERITAS Certification

Canada
CONTROLLED GOODS PROGRAM (CGP) CERTIFICATE No. 22201

INNOVATOR OF THE YEAR

DESIGNED PRECISION CASTINGS INC.
PARTS OPTIMIZATION

Contents

List of Figure:

List of Tables:

1. How was the innovation uniquely established by the nominee?

1.1. About the company

DP Cast is a manufacturer of specialised steel and aluminium investment castings for various sectors such as aerospace, nuclear, mining, medical, and commercial. DP Cast prides itself through its customer base from all across the North American region. The primary aim of DP Casts' foundry business is to offer products, processes, and personnel that meet the high standards required in the aerospace industry. Our dedication to consistently inventing and enhancing our casting metallurgy and processes has led to the development of cutting-edge techniques and exceptional material quality, setting the standard in the industry. DP Cast acknowledges and values the need of ongoing enhancement in its procedures for sustained achievement and expansion. To ensure the fabrication of aerospace-quality designed components, DP Cast follows a series of processes:

- Tool & Die
- Wax pattern production
- Shell room Wax evacuation
- Metal pouring
- Finishing
- Quality Control (NDT)

1.2. Background to the problem:

The mechanisation of manual procedures in the industrial domain has been and will continue to be a crucial aspect of industrial advancement for many generations. Automation not only enhances manufacturing productivity but also reduces the likelihood of human mistake and lowers labour expenses. An assembly line can be enhanced by including a collaborative robot (Cobot), which has the advantage of possibly replacing a two- or three-shift human workforce with just one robot. A Cobot may be configured once and operate continuously without any interruptions (Lights out manufacturing), resulting in a short return-on-investment time.

In order to minimise labour costs, waste, and other manufacturing inefficiencies, while upholding the stringent standards of Safety, Quality, and Integrity in DP Casts products, the full spectrum of processes was looked at with a mindset of improving the most cost bearing operations.

DP Cast incurs significant costs during the wax injection operation, which is one of our primary cost-bearing procedures. A significant amount of time is dedicated to this operation, which has a direct influence on the cost per component. The cost is not only affected by the extensive time spent, but also by other variables such as operator fatigue, scrap, overproduction, and other production wastes that arise as a result.

1.3. Objective

The primary aim of this project was to create a production workstation with a Cobot collaboration in order to address the issue of excessive manpower hours and costs in the wax injection operation. An automated tool was developed to enhance the throughput from 1 piece each injection cycle to 2 pieces per injection cycle, in order to support the primary goal. Safety was a key consideration throughout the design process, and the team deliberated on methods to ensure the design was safeguarded to prevent any harm to humans during the operation, particularly by keeping the automated tool from causing injury.

2. How is the innovation being used by the nominee?

The implementation of the Cobot was modified to assist in the manufacturing of one of the plant's production parts that has a high volume of orders. Given the significant quantities and potential for increased profitability, the team opted to use this part for the pilot project.

2.1. Methodology

The following figure represents the approach used to uniquely establish the innovation.

Figure 1: The DMAIC approach utilized for the project.

This five-step technique facilitated the identification of several variables that need attention to successfully deploy the Cobot. The subsequent analysis dissects each stage in relation to the installation of Cobot.

- **D**efine: (High labour hours to product resulting in high cost)

During the define stage, the issue of expensive manpower and expenses associated with the injection process was identified. However, due to the large number of orders received, the idea of using a Cobot to help with wax injection was introduced and the development process was initiated.

- **M**easure: (Prior state time and cost – Post state time and cost)

The present efficiency of the prodution part was measured. The discussion also emphasised the need of comprehending the constituent aspects of the injection process and identifying areas for enhancement. The team mechanised a previously manual tool for the injection process, subsequently instructing the Cobot to autonomously retrieve and position the part from the injection tool.

- **A**nalyze: (Actions that contribute to time and cost)

During the analyze phase, a deep dive into what are the main contributors to spending many hours injecting parts and how can we reduce this time and ultimately lowering cost. It was established that automating the tool as well as the utilization of the Cobot would help improve this. However, the following factors for the new development were taken into consideration and were highlighted as important to achieve the new concept during the analyze stage:

  - Repeatability
  - Reproducibility
  - Accuracy
  - Stability

- **I**mprove: (Assign and integrate technology to reduce and eliminate time and cost)

Currently, the Cobot has been implemented and a trial production has been carried out under engineering control to detect and address any possible design flaws. The relevant variables were discovered and adjusted to optimise the production process of the Cobot. The team engaged in a collaborative session to generate several strategies for improvement and then implemented them.

- **C**ontrol (Continually measure and improve to the objective of time and cost)

The problem is fixed, and a firm solution is in place and improvements are being tracked via the ERP system which monitors labour hours and costs. Now it's time to sustain the solution to where the new process maintains the positive changes. The control phase of DMAIC is where your team creates a monitoring plan to measure improvements of the new process(es) and a response plan in case there is ever a dip in performance.

2.2. Project Requirements

For selecting the ideal Cobotic candidate, it was essential to identify and select the ideal required peripheral devices for the cobot, as well as connecting the COBOT to the injection units PLC. The main challenge in integrating third-party devices lies in the lack of intrinsic interfaces provided by COBOT providers for items such as cameras, grippers, and other devices. Hence, it is crucial to provide a universal approach to integration in order to eliminate any limitations that may arise from proprietary robot software. Therefore, the following items were used in our project:

2.2.1. Ideal tool applications:

The team identified that the ideal tool application for integration of a cobot is a tool that cycles and produces part(s) that are easily accessed and removed by an operator.

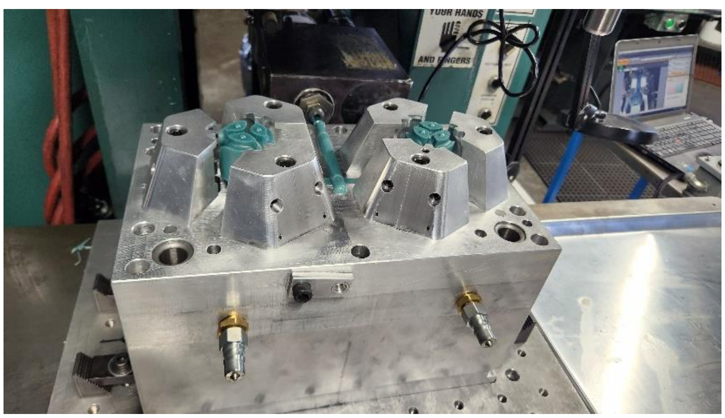

Figure 2: Improved 2-out automatic tool

2.2.2. Cobot:

DP Cast had investigated several Cobot technology options. Including industry benchmark cobots as well as entry level hobbyist cobots. The simple scope of the pick and place need of the technology allowed us to identify a cobot that was readily available did not require outside or contractor integration, minimal user training and development, turnkey, standard accuracy and repeatability of 0.5mm or better, no proprietary software or service agreements with a target price point 10,000.00 CAD ($7,300 USD).

This project utilized a commercially available cobot with the following specifications:

Table 1: Cobot specs

Material	Carbon fiber, aluminum
Software	Non proprietary downloadable
Ambient temperature	0-50 °C
Connectivity	RS-485/Ethernet TCP-IP
Connector type	M5
Control communication mode	RS-485
Footprint	Ø 126 mm
Freedom degree	6
Input power supply	24 V DC, 10 A
Max. speed	1 m/s
Minimum power consumption	1.5 W
Payload	5 kg
Power supply	100-240 V AC, 50-60 Hz
Reach	700 mm
Repeatability	0.1 mm
Status LED	Fault status, power feedback
Typical tool maximum speed	1 m/s
Weight	12,2 kg

2.2.3. Cobot Gripper:

The Gripper is a flexible collaborative gripper with customized fingertips that can extend up to 86mm stroke. It provides intelligent fast deployment paired with simple customization and programming. The gripper is a tool suitable for a wide range of uses, boasting customized fingertips to provide great gripping flexibility.

Figure 3: Gripper for Cobot

The specifications are as follows:

Rated Supply Voltage	24V DC
Absolute Maximum Supply Voltage	28V DC
Static Power Consumption (minimum power consumption)	1.5W
Peak Current	1.5A
Weight	802g
Maximum Gripping Force	30N
Stroke	84mm
Working Range (with default fingers)	0-84mm

Finger Type	Switchable
Communication Mode	RS-485
Communication Protocol	Modbus RTU
Programmable Gripping Specification	Position, Speed

2.2.4. Vision sensor camera

Laser displacement sensors enable non-contact measurement of a target's height, position, or distance. By pairing multiple sensors, measurements such as thickness and width can also be performed. High-accuracy displacement sensors can be grouped into two categories: confocal and laser triangulation.

Figure 4: Vision sensor

2.2.5. Safety fence

Although cobot technology is designed and approved for human collaboration and interaction the team recognized the integration inputs from the cobot to the injection press would require the addition of guarding to prevent access the injection press pinch point hazard during automated operation.

100 ft of 1” angle bar was purchased as well as well as 80ft of H 23-Gauge Welded Wire Galvanized Steel Netting Fence with 1/4-inch x 1/4-inch Mesh.

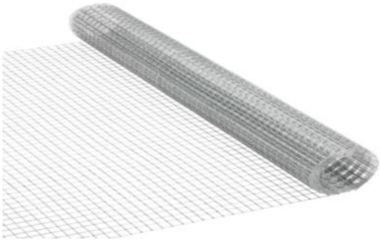

Figure 5: 23" galvanised fence

For the wheels, x16 3 in. Orange Rubber Like TPU and Steel Swivel Plate Caster with Locking Brake and 225 lb Load Rating were procured, this would make the safety fence portable and easy to move to any of the injection machines.

Figure 6: 3" Castor wheels

2.2.6. Start/ Stop Control box

The Start/Stop Control box consists of 4 buttons. An emergency e-stop, start, pause and resume.

2.3. Project Design

The subsequent section elucidates the chosen design approach for development and the subsequent implementation of the Cobot operating system. The company made an investment in a Cobot with the intention of both appreciating the technology and making use of the "Toy" notion of artificial intelligence. Unbeknownst to us, it would eventually be employed to make a significant advancement, not just at DP Cast, but also one day, in the investment casting business of North America.

The design of this project happened in phases. The phases will be explained as follows:

Phase 1:

The injection die tool was modified to accommodate an automated injection which would be compatible with the utilization of the Cobot.

Phase 2:

The team adopted a straightforward approach to initiate the project, focussing on building confidence in the design and increasing the momentum towards completion. Therefore, during phase 2, the concept of picking and placing was discussed. Figures 2 and 3 represent the picking and placing points.

Figure 7: Picking point from automated injection tool

Figure 8: Cobot separating parts from injection runner

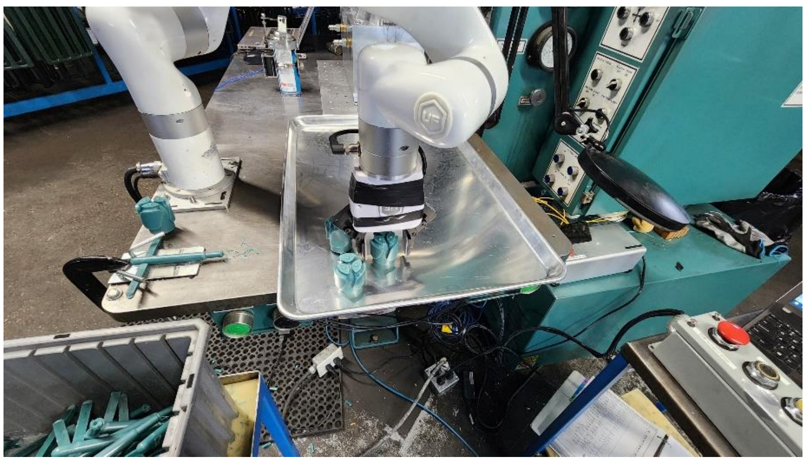

Figure 9: Cobot placing part at the allocated placement point

Phase 3:

Adhesion of components, severe deterioration, and untimely malfunction of moulds can result in interruptions in manufacturing, decrease in output, and damage to wax moulds. Proper lubrication of injection dies is crucial for ensuring smooth movement of ejector pins and safeguarding tools during periods of non-production. The crew encountered the further obstacle of lubricating the aluminium injection die tool during a fully automatic cycle.

While performing a manual operation and during the intervals between cycles, a person operating the injection machine will apply a mould-release lubricant to prevent any adhesion and friction. After several iterations and endeavours, the team ultimately devised a robust concept and a clear path ahead.

The team utilized a solenoid, connected to the machine plc and coded into the Cobots system. After every third cycle, the Cobot picks up the can, and the PLC activates the solenoid, thus completing the spray cycle. The figure below shows the spraying operation.

Figure 10: Cobot getting ready to pick-up mould release spray can

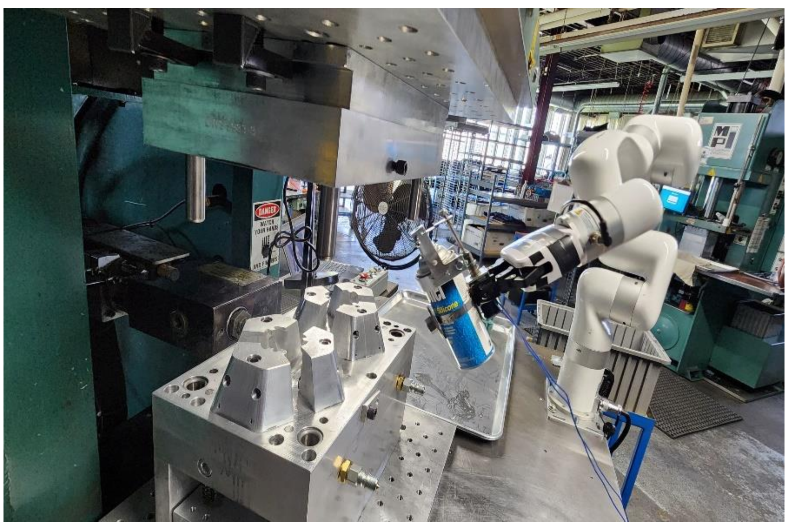

Figure 11: Cobot spraying lower cavity of tool.

Figure 12: Cobot spraying upper cavity of tool

Phase 4:

DP Cast places great attention on three fundamental characteristics of the industry. The three fundamental aspects are Safety, Quality, and Integrity. Consequently, the team also had to ensure that the safety of the staff was given utmost importance and included into the design phase. Although collaborative robotics enables human engagement and incorporates safety measures in the construction of a Cobot, the primary safety issue was to the risk of injury to employees or anybody on the shop floor due to pinch points on the injection machine when the Cobot is in operation. Therefore, the team had to develop a physical guard so that nobody will have access to the press pinch point during operation.

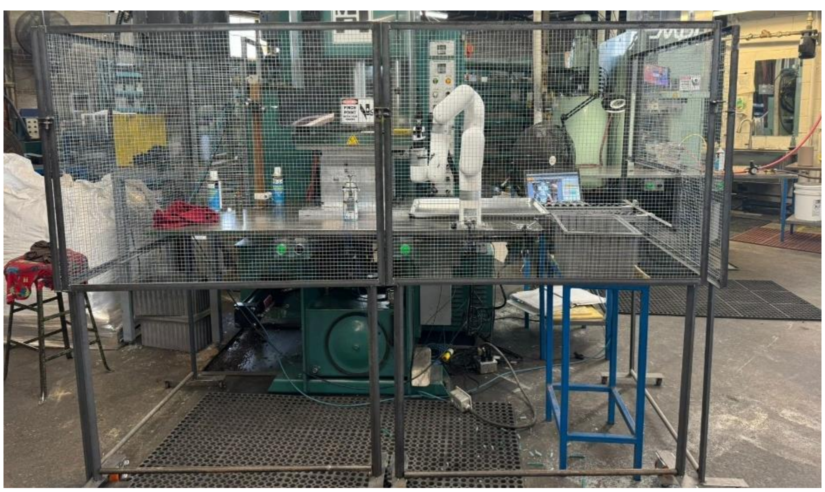

Figure 13: Saety fence

The above figure is the safety enclosure that the team fabricated internally. The lockout system incorporates all necessary safety precautions. The fence serves as a barrier between humans and the pinch points of the injection machines, allowing the Cobot to work safely.

Phase 5:

With the implementation of the safety fence, the next consideration is how to effectively manage the system in case of an incident or if someone has to access the cell to replace a spray can or make machine adjustments. Consequently, the crew constructed a control box from miscellaneous, unused objects found throughout the factory. Not only was this approach cost-effective, but it also resolved the issue of controlling the Cobot cell from outside the gate. The control box is equipped with buttons for initiating, pausing, resuming, and emergency stopping. In addition, the team affixed a compact speaker (Andon system) to the box. In the case of an error or the completion of a cycle, the speaker emits beeps to notify the department supervisor or other team members to inspect the situation.

Figure 14: Cobot cell control box with Andon system (speaker alert)

Phase 6:

The team proceeded to further ascertain and address areas of concern. After taking into account the safety of coworkers, the following objective was to safeguard the production cell from any potential harm. In the event that a component becomes dislodged and falls into the injection mould during the injection process, the Cobot may fail to detect it. Consequently, the Programmable Logic Controller (PLC) would initiate another cycle, possibly resulting in damage to both the Cobot and the injection mould tool. The team had to engage in another round of collective thinking to generate ideas on how to avert it.

It was at this point, the idea of the vision sensor was introduced. Vision sensors utilise pictures obtained from a camera to ascertain the existence, alignment, and precision of components. These sensors are distinct from image inspection systems since they integrate the camera, light, and controller into a single device, resulting in a straightforward and uncomplicated design and operation.

In our scenario, the vision sensor will capture a picture of the tool before injection. If all aspects are deemed satisfactory, it will proceed to execute a cycle. If the vision sensor detects an object that is not within the acceptable range, it will deactivate the system and trigger the buzzer to emit a sound, notifying the supervisor to investigate the issue. Consequently, this avoids any superfluous harm to the tool, cobot, or machine, thereby establishing an additional point of detection in a seamless operational procedure.

Figure 15: vision sensor

Figure 16: vision sensor software

2.4. Project Cost:

Below is a rough estimate of the cost of the project.

Table 2: Cobot project cost summary

Item:	**Qty**	**Price**
Cobot (6 Joints)	1	$11,506.63
Gripper standard option	1	$2,776.39
Vision sensor with cables	1	$550.00
Safety Fence (in-house fab)	1	$450.00
Start/Stop Control box	1	$50.00
Labour (40 hrs total)	40	40 hrs indirect labour
Grand Total		**$15,300.00 CAD** ($11,100.00 USD)

The project required a total of 40 hours to be fully set up. The execution was direct and although there were a few challenges encountered, they were effortlessly resolved.

Whilst the initial investment tallied $15333.02, the ROI will be yielded easily.

2.5. Project challenges faced

Adaptability to Variable Conditions: Wax injection processes often involve handling variable and sometimes unpredictable conditions, such as changes in wax consistency or mold configurations. Cobots need to be adaptable to these variations, and fine-tuning their performance to handle such variability can be challenging,

Countermeasure: In our concept, as this process gets adapted towards other future projects, the only integration that will take place is the pick and place programming function. This is estimated to take an estimated 3 hours.

Workforce Training and Adaptation: Implementing cobots requires training for the existing workforce to operate and interact with the new technology effectively. Employees need to understand how to work with cobots, troubleshoot issues, and adapt to new workflows. Resistance to change and the learning curve associated with new technology can impact productivity during the transition period.

Countermeasure: The team has developed an instruction manual to assist the employees to easily setup and operate the system. Employees are encouraged to be involved and offer input into new projects and improvement ideas as well as set-up and operation.

Quality Control and Assurance Maintaining high-quality standards is crucial in wax injection processes, where precision is key. Ensuring that the cobot consistently meets quality requirements and does not introduce defects or inconsistencies is essential.

Countermeasure: Regular quality checks and calibration may be required to ensure ongoing performance. Sequence programming to end a batch cycle to support quality intervention such as and inspection of part, tool and process parameters can be adapted. The system can also be utilized to send out a electronic communication such as a text message or e-mail to notify of a quality or process verification step requirement.

2.6. Pilot project trial and results

Our pilot project for wax injection has successfully integrated collaborative robots (cobots) to innovate our wax injection process. By leveraging the precision and efficiency of cobots, we have streamlined the wax injection process, enhancing both speed and accuracy. Initial challenges, such as fine-tuning PLC settings, have been resolved, leading to a marked improvement in productivity and profitability. This successful pilot paves the way for a broader rollout, with plans to extend the cobot technology across all wax injection operations. We are optimistic that the advancements made through this project will also benefit other investment casting foundries across North America, setting a new standard for efficiency and innovation in the industry.

The primary objective was to decrease the direct labour production time by a minimum of 50%. This decrease represents a reasonable target and financial benefit. By implementing Cobot automation and utilising the Cobot for pick and place tasks in conjunction with an automated tool, we have successfully decreased the direct labour production time. DP Cast has realized a remarkable 95% reduction in direct labour with its first pilot application project.

The figures below reflects the results of our pilot. As we can see all job numbers (567, 590, 627, 650, 698, 699, 700) reflect data prior to the project. Job number 758 reflects the data of the improvement in place.

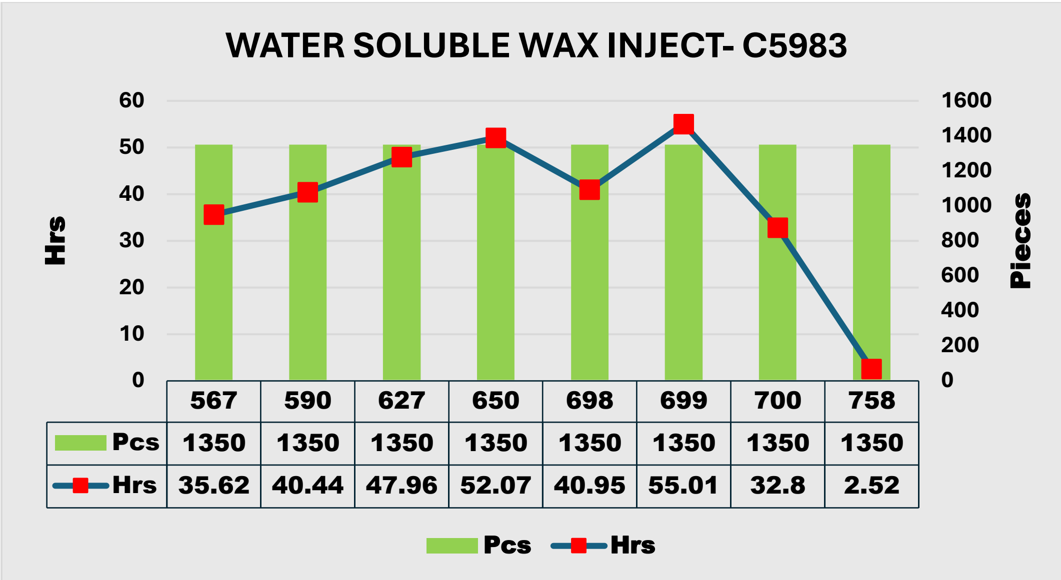

Figure 17: 43.55hr avg direct labour production time reduced to 2.52hr for total production cycle.

3. Describe the impact the innovation has had on the investment casting industry.

Although the new design has not yet been used or adopted by other foundries in the industry, its potential future influence on the industry would be highly favourable and inventive. It would also enhance financial margins, productivity reduce human repetitive strain and labour shortages.

Cobots, also known as collaborative robots, can provide several advantages to an investment casting foundry. Here is the significance of their value:

a. **Precision and Consistency:** Cobots can handle repetitive tasks with high precision, reducing human error. In investment casting, this can be crucial for tasks like mold handling, pouring, and inspection, ensuring consistent quality in the final castings.

b. **Increased Efficiency:** Cobots can work alongside human workers to speed up processes, work through planned downtime (breaks, off production hours). They can automate tasks such as sand blasting or cleaning, allowing human operators to focus on more complex or higher-value activities.

c. **Enhanced Safety:** Cobots can take over dangerous or physically demanding tasks, such as handling heavy molds or high-temperature materials. This reduces the risk of injury for human workers and helps maintain a safer work environment.

d. Flexibility: Many cobots are designed to be easily reprogrammed and adapted to different tasks. This flexibility can be particularly useful in a foundry where the types of castings and processes might frequently change.

e. Quality Control: Cobots equipped with vision systems and sensors can perform detailed inspections and quality control checks more consistently than manual methods. This helps in identifying defects early and ensures high-quality standards.

f. Reduction of Waste: By improving precision and consistency, cobots can help reduce material waste and defects, leading to cost savings and more sustainable operations.

g. Training and Support: Cobots can assist in training new employees by providing a controlled environment to practice with automated tasks. They also support experienced workers by taking over repetitive tasks, allowing them to focus on more skilled activities.

h. Cost Efficiency: Although there is an upfront investment in cobots, their ability to work continuously and their low maintenance costs can lead to long-term savings. They can also help in optimizing labor costs by automating tasks that would otherwise require additional human resources.

Integrating cobots into an investment casting foundry can streamline operations, improve safety, and enhance overall productivity.

4. Is innovation available for use by others in the industry? If so, how can others obtain the innovation for their use? Are other companies currently using the innovation and if so, please describe.

Cobots,, are readily available from several providers that customise them to meet the specific requirements of end users. The North American investment casting sector should increasingly embrace the prominent use of Cobots, given the abundance of suppliers. Cobots are specifically engineered to collaborate with human operators and may be seamlessly incorporated into different phases of the investment casting procedure to optimise productivity and accuracy.

4.1. Availability and Integration

4.1.1. Suppliers and Manufacturers:

4.1.1.1. Companies like Universal Robots, Rethink Robotics, and KUKA offer cobots that can be adapted for use in investment casting operations. These companies provide various models of cobots that can be tailored to specific needs within the casting process.

4.1.1.2. Investment casting companies can obtain these cobots directly from the manufacturers or through authorized distributors and integrators who specialize in automation solutions.

4.2. Customization and Integration:

Cobot technology is designed to be user integrated and flexible. DP Cast's project was 100% integrated with the in-house staff and there was no need for external support, However, integrators specializing in automation and robotics can help customize cobots for investment casting applications. They work with companies to design, install, and optimize cobot systems to fit processes and workflows. Alternatively, the integration can be done in-house as the programming language is user friendly and one does not need special qualifications to code and set the process up. DP Cast encourages the in-house developemnt approach to the technology to better foster the proliferation of the technology by an internal cultural drive.

4.3. Current Applications

4.3.1. Handling and Loading:

Cobots are used for handling and loading raw materials into casting machines or transferring finished products. They can handle repetitive tasks such as placing molds or handling cast parts, reducing the need for manual labor and increasing throughput.

4.4. Quality Control:

Cobots equipped with vision systems can perform quality control checks on cast parts. They can inspect dimensions, detect defects, and ensure consistency, which helps in maintaining high quality standards.

4.5. Cleaning and Finishing:

Some cobots are used in the post-casting stages, such as cleaning and finishing. They can perform tasks like deburring, sanding, or polishing, which improves the surface finish of cast components.

4.6. Examples of Use

4.6.1. Foundries and Casting Facilities:

4.6.1.1. Casting facilities can successfully integrate cobots into their operations. For example, some foundries can use cobots to assist with the intricate task of removing sprues or runners from cast parts, which traditionally required manual labor or as our team as managed to successfully prove, Cobots can be used to pick and place completed wax parts. With more advanced vision systems, Cobots could even be integrated into quality checkpoints in the foundries production line reducing the defect rates.

4.6.1.2. Overall, cobots represent a significant advancement in the investment casting industry, offering benefits such as increased efficiency, improved safety, and enhanced quality control. Companies interested in adopting cobots can work with automation specialists or D.I.Y to explore the best solutions for their specific needs and to ensure successful integration into their existing processes.

5. Discussion on innovation impact

The deployment of the Cobot has a significant influence on several innovation kinds, if not all of them, and maybe even more. Below, we outline the impact that our project has on each form of innovation, further demonstrating the advantages of a simple design and its significant influence.

5.1. New Process Introduction

Automating Wax Injection: Introducing a cobot into the wax injection process often requires designing and implementing a new workflow. The cobot can automate tasks such as loading and unloading molds, injecting wax, and even handling the cooling process.

Impact: This new process can streamline operations, reduce manual labor, and enhance consistency. However, it involves initial setup and integration efforts, including programming the cobot and modifying existing workflows.

5.2. New Product Introduction

Automating Wax Injection: When introducing new products, cobots can quickly adapt to new mold designs and injection parameters through reprogramming.

Impact: The flexibility of cobots allows for rapid adjustment to different product specifications, reducing the time needed for product changeovers and improving the ability to handle complex or custom designs.

5.3. New Machine Introduction

Automating Wax Injection: If introducing new wax injection machines, cobots can integrate with these machines to automate various stages of the process, such as mold handling and wax filling.

Impact: Cobots can help bridge the gap between old and new machinery by automating transitions and operations, ensuring smoother integration and consistency across different equipment.

5.4. Safety Improvement

Automating Wax Injection: Cobots are designed to work safely alongside human operators, with built-in safety features such as collision detection and emergency stop functions.

Impact: By automating repetitive or hazardous tasks, cobots reduce the risk of workplace injuries. They also ensure safer working conditions by minimizing human exposure to potentially dangerous machinery or processes.

5.5. Cost Reduction

Automating Wax Injection: Initial costs include purchasing and integrating the cobot, but long-term savings can be substantial. Cobots can reduce labor costs, decrease waste, and improve process efficiency.

Impact: Over time, the reduction in manual labor and the increased efficiency can lead to significant cost savings. Lower operational costs and fewer errors contribute to a better overall financial performance.

5.6. Creative Business Concept

Automating Wax Injection: Using cobots allows businesses to explore innovative applications and product designs that were previously impractical.

Impact: This technological flexibility can enable the development of unique products and processes, fostering a competitive edge and opening up new market opportunities.

5.7. Operational Improvement

Automating Wax Injection: Cobots enhance operational efficiency by performing tasks with high precision and consistency.

Impact: The automation of repetitive tasks improves throughput and reduces cycle times. Cobots can operate continuously, leading to increased production capacity and smoother operations.

5.8. Quality Enhancement

Automating Wax Injection: Cobots ensure uniformity in wax injection, reducing variability and defects.

Impact: Enhanced accuracy and repeatability lead to higher-quality products with fewer imperfections. Consistent quality control results in fewer rejections and higher customer satisfaction.

5.9. Environmental Impact

Automating Wax Injection: Efficient automation with cobots can reduce waste through precise control of the wax injection process.

Impact: Lower waste generation and reduced energy consumption contribute to a smaller environmental footprint. Improved process control helps in optimizing material use and minimizing environmental impact.

5.10. Customer Satisfaction

Automating Wax Injection: Improved quality, reliability, and faster production times directly impact customer satisfaction.

Impact: Higher-quality products, delivered on time, enhance customer satisfaction and strengthen customer relationships. Reduced lead times and consistent quality can lead to better reviews and increased customer loyalty.

5.11. Process Improvement Enhancement

Automating Wax Injection: The integration of cobots leads to continuous process improvement by identifying and eliminating inefficiencies.

Impact: Automation allows for ongoing optimization of the wax injection process, leading to enhanced performance and productivity. Data collected by cobots can also provide insights for further improvements.

5.12. Technology

Automating Wax Injection: Implementing cobots involves adopting advanced robotics and automation technologies.

Impact: The use of cutting-edge technology can modernize the production environment, provide a competitive edge, and prepare the company for future technological advancements. Embracing new technology often leads to innovation and improved business practices.

In summary, automating a wax injection process with a cobot can bring about significant improvements in safety, quality, efficiency, and overall business performance. While there are initial challenges and costs associated with implementation, the long-term benefits often outweigh these challenges, leading to a more streamlined and effective production process.

6. Conclusion

Based on the numerous advantages it offers, it is highly recommended to utilise a Cobot in conjunction with the automated injection tool. This combination not only reduces worker fatigue, but also decreases cycle time, ensures uniform injections, increases yield, and improves overall efficiency in the wax department. Implementing this process design has the potential to significantly improve productivity across the foundry industry if other foundries choose to adopt it. With the decreasing cost of automation, it becomes increasingly viable to implement process automation in various areas such as wax assembly, foundry metal pouring, and post casting operations.

7. Development Team:

Figure 18: Development team (Left to right): Joel J Munilal, Anil Kumar, RJ Peters

The team would like to thank you for taking the time to read through our project. We thoroughly enjoyed every minute of it and are looking forward to our next project and collaboration with ICI and continued networking with the industry.

If there are any further questions or any help needed on implementing this project in your company, please feel free to reach out to us.