Study at Investment Casting Facility Compares Manual & Robotic Grinding

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Investment casting finishing departments have long sought affordable, flexible and process reliable techniques to provide consistent high-quality production. In the past, some industrial robots have been applied to standard grinding machines, and in product-specific production, and quality benefits have been achieved, specifically in medical and aerospace component finishing.

Until recently, these systems have been characterized as expensive to apply, and inflexible to operate, and have therefore had little impact on the investment casting finishing process in general.

Modern industrial robots are now available with payload capacities up to 500kg. with reliability typically exceeding 50,000 hours MTBF, serviceability costs are low, and performance benefits are high. Sophisticated programming capabilities enable robots to perform powerful movements to achieve rapid metal removal rates and consistent achievement of precise dimensional parameters.

Similarly, with sophistical control and simplified mechanics, purpose-designed cutoff and power grinding machines are now available to optimize the benefits available from the robot. With predictable performance available from the abrasive media, robotic grinding is feasible for general industrial investment casting applications.

Lost Wax Developments Ltd. (LWD), a UK-based supplier of commercial precision castings, recently compared manual with robotic grinding on specific applications.

The company was established 29 years ago, is staffed by 38 employees, and specializes in quick turnaround of precision castings. Typical batch sizes range from 50 to 12,000 components. The finishing department at LWD is typically staffed with seven employees, working 10-hour shifts daily. The average part processed requires two cutting processes and one grinding process.

Previously, the quality of the finished part was assured by using experienced long-term employees. However, in recent years, it has become increasingly difficult to attract skilled workers to join the finishing department, and the problems of recruitment, training, and staff turnover have become a major management preoccupation.

The shellroom had undergone similar headaches in the distant past. Since then, two robotic shell manufacturing systems have been installed, and staffing problems ceased. Thus, it was natural to consider using a robotic system in the finishing department.

The following case study describes the actual results on typical parts processed at LWD, using both manual techniques and the VA Tech IC-Flexible Grinding System. Component A required flat-

Table 1: Cycle Time Analysis- Component A

Process	Manual Description	Manual Time	Robot Description	Robot Time
Loading	Loading 16 parts into a box for the man to pick up	5 seconds	Loading 16 parts onto the jig plate	31 seconds
Pickup	Time to pick up from a box	3 seconds	Time to pick up & place jig plate including approach to & return from grinding wheel	10 seconds
Process time on cutting wheel for 16 parts	Man takes all 16 parts to the cutting wheel and removes the bulk gate	109 seconds	Robot grinding eliminates this process	0 seconds
Time between Processes	Time to exchange the parts from cutting station to the grinding station	10 seconds	Robot grinding eliminates this process	0 seconds
Grinding time	Man takes all 16 parts to the cutting wheel and finishes to an acceptable level	64 seconds	Robot grinds each face at the grinding wheel and interchanges between each face	60 seconds
Unloading	Time to place into box	3 seconds	Time for operator to unload 16 parts	28 seconds
Total Time		194 seconds		129 seconds

Component A: Fuel flow linkage unit
Material: Carbon steel
Gate Volume: 3000 mm^3
Process Requirement: Remove gate, leaving witness face not exceeding 0.5 mm.
Batch quantity: 100 to 2000

face finishing, and Component B required circular face finishing. These are considered representative of small-to-medium sized commercial grade precision castings.

Component A: Fuel Flow Linkage Unit

A representative batch quantity (200) was processed using the established manual technique, and an equivalent batch quantity was processed using the IC-Flexible Grinding System (see p. 11).

The manual process included two operations (1) removal of excess gate using cutting wheel, and (2) removal of gate to finished dimension.

The robotic system uses a multi position jig plate. The jig plate is equipped with a proprietary reference location device and is attached to the robot using a safety lock system. The jig plate is used to secure simple fixtures to which the parts for processing are clamped.

Note: The jig plate can be used to simultaneously attach four different component fixtures so that different parts can be processed simultaneously within any power grinding cycle, or the jig plate can be equipped with more than one jig for the same component. For Component A, four fixtures for the same component were attached, allowing 16 parts to be processed in one cycle.

Table 1 summarizes and compares the use of robotics and manual labor under a number of different categories for this part. It is important to note that manual labor includes both a cutoff and grinding process, whereas the robot accommodates both of these processes within a single cycle.

Overall the time analysis shows the robot to be 34% faster.

Table 2 provides a visual analysis of three critical categories for this part: (1) quality of surface finish of the component, (2) accuracy, measured by the ability to adjust to a minor change such as removal of an extra 0.2mm, and (3) repeatability, measured by measures the consistency of the parts throughout a batch. The following table averages figures for 10 runs of 16 parts.

The quality of finish achieved by the IC-Flexible Grinding System equals a manual laborer. In manual grinding a finishing cut is often used after removal of the main gate to achieve a high quality surface finish. The robot program accommodates for this by varying the final cut to provide the preferred finishing characteristic.

Table 2:
Quality, Accuracy, Repeatability Analysis

Category	Robot	Manual
Quality of Finish	10	10
Accuracy	9	8
Repeatability	10	5
Results	29	23

The repeatability of the robot greatly exceeds the capability of the manual worker. With different workers, repeatability is further reduced.

Figures 3 and 4 display the repeatability of the robotized system and its ability to compensate for external factors such as belt wear. Without compensation for belt wear part dimensions would gradually increase until the life of the belt expires as shown below.

The three lines on **Figure 3** represent three different components being processed simultaneously on the same multiple fixture. On closer inspection the relationship of the three graphs remain constant. The distances between these lines are the offsets between the parts from the manufacture of the jig. This demonstrates the outstanding repeatability of the robot.

Figure 4 shows 50 runs of the three parts. After run 12 and run 34 the robot automatically moves closer to the grinding wheel to compensate for belt wear, thus maintaining the dimensional tolerance of the part within 0.25mm.

Figure 3:
Increasing Part Dimension as a Grinding Belt Wears

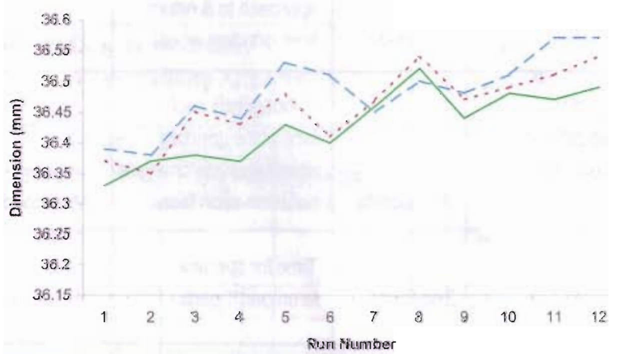
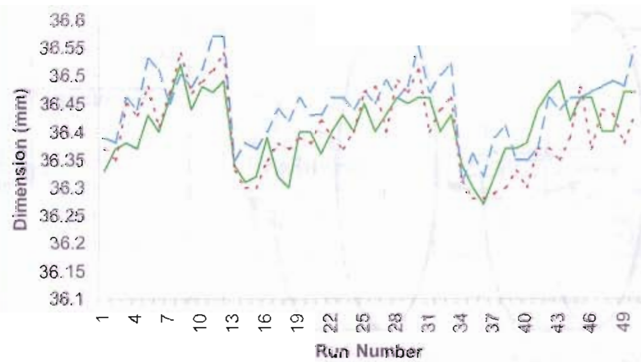


Figure 4:
Belt Wear Autocompensation from the IC-G System



Component B: Pump Stator

A representative batch quantity 50 was processed using the established manual technique. An equivalent batch quantity of 50 was simultaneously processed using the IC-Flexible Grinding System

The manual process included removal of gate to finished dimension. The automated process included using IC-Flexible Grinding System.

The component is secured to the Jig plate with a simple, low cost fixture unit. Due to the low quantity of parts to be processed, a single fixture is used, and alternative parts are fixtured on the other three sides of the jig plate.

The manual worker uses his hands with which to manipulate a part to obtain the required result at the grinding wheel. The force he can apply to the grinding wheel is limited by his strength as a human being; the force a robot can apply far outweighs that required for the gate removal process and is more suited to the high forces required to optimize power grinding belts. The manual worker uses a feedback loop between his eyes and hands to determine many different parameters such as part dimensions, angle of approach, feed rates etc. Overall the movement of the manual laborer can be identified as being three dimensional at varying speeds.

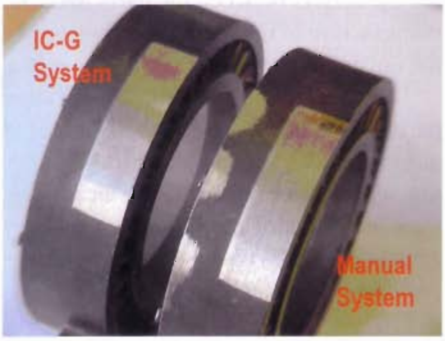
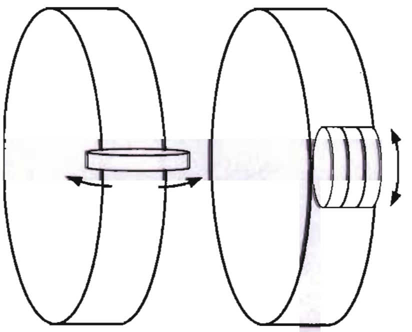


Figure 5



Manual Method   Robotic Method

Component B: Pump Stator
Material : Carbon Steel
Gate Volume : 12000 mm^3
Process Requirement : Remove gate, leaving witness face not exceeding 0.5 mm.
Batch quantity : 50 to 100

The robot applies three dimensions to a jig plate and uses them to identify part location, orientation, size and many other factors. **Figure 5** demonstrates the tool coordinate system used by both methods.

The ability of the robot to rotate about the three axes combined with mathematical software models allows manipulation of parts with complex profiles. Dimensions are input by an operator as part of an initial jig set up process. Once this is complete, the robot records the information allowing the jig to be used to grind parts in the future.

Table 6 summarizes and compares the use of robotics and manual labor under a number of different categories for this part. It is important to recognize manual labor includes both a cutoff and grinding process, whereas the robot accommodates both of these processes within a single cycle.

Overall the time analysis shows the robot to be 34% faster.... and the robot does not get tired... 24 hours a day. **Table 7** is a visual analysis of 3 critical categories for this part. Quality interrogates the surface finish of the component. Accuracy is measured by the ability to adjust to a minor change such as removal of an extra 0.2 mm. Repeatability measures the consistency of the parts throughout a batch. The following table averages figures for 10 runs of 16 parts.

The quality of finish achieved by the IC-Flexible Grinding System equals a

Table 6: Cycle Time Analysis- Component B

Process	Manual Description	Manual Time	Robot Description	Robot Time
Loading	Loading 16 parts into a box for the man to pick up	5 seconds	Loading 1 part onto the jig plate	10 seconds
Pickup	Time to pick up from a box	3 seconds	Time to pick up & place jig plate including approach to & return from grinding wheel	10 seconds
Grinding time	Man takes 1 part to the grinding wheel and finishes to an acceptable level	70 seconds	Robot grinds each face at the grinding wheel and interchanges between each face	45 seconds
Unloading	Time to place into box	3 seconds	Time for operator to unload 1 parts	10 seconds
Total Time		81 seconds		75 seconds

manual laborer. In manual grinding a finishing cut is often used after removal of the main gate to achieve a high quality surface finish. The robot program accommodates for this by varying the final cut to provide the preferred finishing characteristic. The repeatability of the robot greatly exceeds the capability of the manual worker. With different workers, repeatability is further reduced.

The Future of IC-Robotized Grinding Systems

The next generation of IC-Robotized Grinding Systems provide an exciting future.

The goal is to reduce labor intervention while developing the machines to work with even more complex profiles to even finer tolerances.

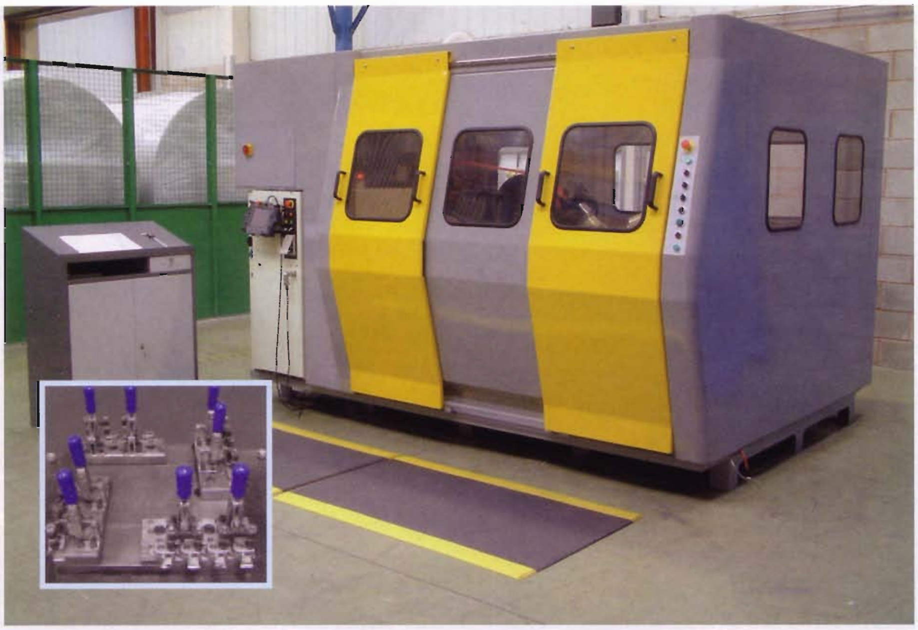
√ CAD integration will allow a .dxf drawing file to be sent to the machine and it will instantly recognize the part it is to grind. The integration of state of the art laser distance technology will inform the operator whether the part is within tolerance to the drawing and if necessary auto-compensate for any required changes.

√ Auto belt wear compensation will be part specific rather than predetermined regardless of part. Laser distance sensors will measure the part while the robot is in movement allowing the machine to calculate approach distances and follow up due to belt wear.

√ A state of the art user friendly touch screen interface will allow production rates and cost analysis will be sent to the operator on demand aiding optimization of part manufacture.

Table 7: Quality, Accuracy, Repeatability Analysis

Category	Robot	Manual
Quality of Finish	9	9
Accuracy	9	8
Repeatability	10	5
Results	28	22



The IC-Flexible Grinding System. The robotic system uses a multi position jig plate (see inset).

Table 8 : Comparison : IC Finishing Person vs IC -Grinding Robot

Attribute	Units	IC-Finishing person	IC-Grinding Robot
Utilization	%	43%	98%
Continuous lifting	kg	5	150-500
Grinding Force	kgf.	8	150-500
Accuracy	mm	1	0.2
Repeatability	mm	1	0.25
Set Up Time	mins	10	30
Training Time	hrs.	40	0
Flat Shapes	rating	3/10	9/10
Circular Shapes	rating	3/10	7/10
Irregular Shapes	rating	6/10	7/10
Quality Assuranc	rating	5/10	8/10
Metal Removal	rating	1	7
Belt Life	parts	140	710
Maintenance	rating	High	Low
Safety	Risk	High Risk	Low Risk
Liability	Risk	High Risk	Low Risk
Fixture Cost	$/part	0	$350

Table 9 : Comparison : Manpower Productivity

	Manual (secs)	IC-Grinding System (Secs)	Productivity Increase %
Flat	194	59	650%
Circular	81	20	801%
Utilization	43%	85%	