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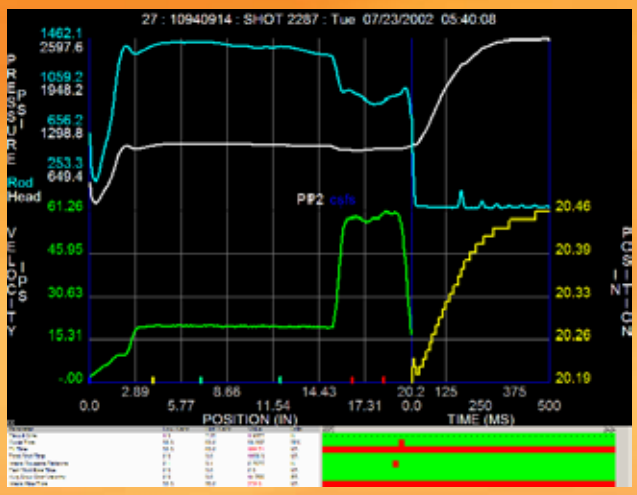

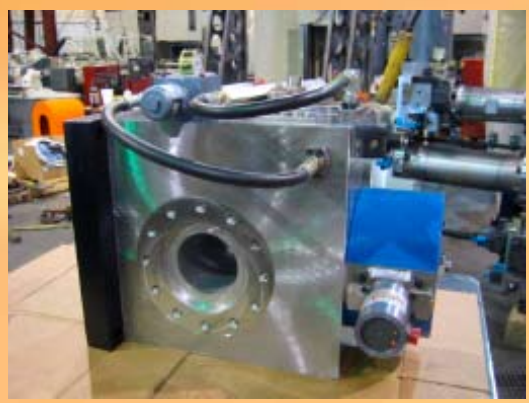

Visi-Trak®
SENSE, MONITOR, CONTROL

Shot Control Retrofit Extends Machine Life, Enhances Performance and Capability of Shot System – A Lot More Bang for the Buck!

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Introduction

The Toro Company operates numerous manufacturing plants in North America and Europe that produce power turf maintenance equipment and snow removal products. The Toro manufacturing plant in Windom, MN, includes a captive die casting facility with five die casting machines, which produce a range of castings that are used both in Windom and other Toro plants.

The die casting area is neat and clean, and like most die casting facilities in existence for more than 20 years, growth and change over time have resulted in a layout of equipment that one would not design if starting with a clean piece of paper. So, changes to the facility have been made over time to maximize the efficiency of the plant, with an eye to the future.

The fabrication group consists of a project engineer, tooling engineer, injection molding process engineer, production scheduler, three supervisors and department head. In a three-shift operation, this lean team manages the five die casting machines and seven injection molding machines in an adjacent area. They produce high quality castings and molded parts at costs consistently lower than parts quoted from outside sources.

The largest of the die casting machines, a 1,600-ton Prince purchased in 1990, is a real workhorse. The available production capacity of the machine is sold out from October through June when the summer season products are being produced. Also, the cells are automated. The combination of lean staff, high volume requirements and automation, place a premium on robustness, repeatability and low scrap rates.

A dozen different lawn mower decks are also run — three of which dominate the volume. Over the years, some of the decks have increased in size and now require a process that approaches the available clamp tonnage of the upper half. The decks are center shot, and for this reason have a limited area available for the ingate. The metal has a long way to travel through the die to completely fill the decks, so consistent shot performance is critical. Tip sizes have been increased to achieve shorter fill times, but the consistency is still critical to a robust process and a low scrap rate.

After being cast, the parts are trimmed, cleaned and painted — no machining is done to most of the decks.

Case Study

The 1,600-ton Prince was originally supplied with a Binary II three-speed shot system (Figure 1). The shot system was upgraded by adding ramping capability to the proportional control of slow and intermediate velocities. There is no low impact system. Over time, the Binary II shot valve developed leakage issues, which became a maintenance problem. One cause of leakage was determined to be an occasional cracked segment in the Binary II valve, which changed the velocity profile.

***Figure 1** – Shot end of 1,600-ton Prince machine with Binary II shot valve.*

Inconsistent performance also resulted from the failure of various segments in the Binary II valve that would not collapse properly and failure of the pilot valves which drive the segments, resulting in inconsistent shot speeds in the fast shot. The direct consequence of the shot speed variations was scrap castings, where poor fill resulted from increasing fill times. Another consequence of this inconsistency was that operators were always adjusting the shot control setting for the Binary II valve to maintain the required filling velocity. This resulted in more process variation and scrap, and the rising impetus to make a change.

Finally, more speed was needed from the shot system to accommodate castings that were now challenging the performance specifications to which the machine had originally been delivered. Various alternative potential shot end modifications were considered, including the purchase of a new shot end. Ultimately, a new shot end was decided against because the original design was solid, clean and mechanically well-executed. What was lacking was a robust velocity control system, and the shot end needed more speed.

The solution involved the removal of the Binary II shot valve and the manifold block to which it is mounted. In its place was fitted a direct bolt-in replacement manifold that included an Olmsted 80 mm two-way throttling valve — slip-in cartridge format — piloted by an H.R. Textron R-DDV servo pilot valve. The manifold block included a pilot-operated check valve to release oil from the head side during cylinder retraction, a cartridge valve to develop pressure to retract the shot cylinder and a cartridge filter to ensure a clean oil supply to the servo pilot valve. The new throttling manifold is shown in Figures 2 and 3.

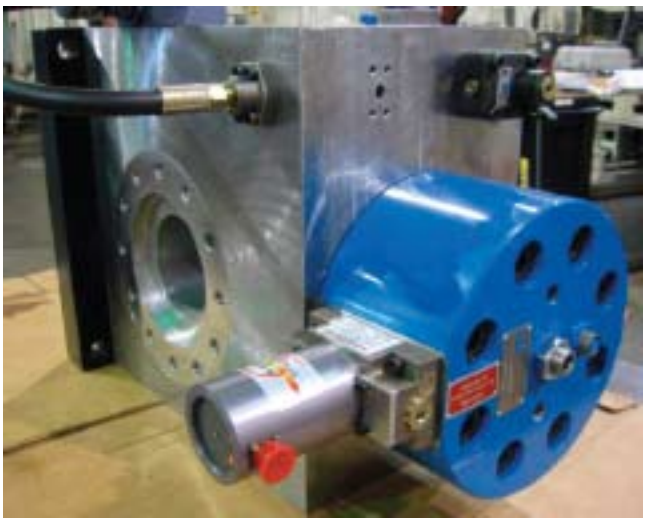

***Figure 2** – Bolt-in replacement manifold, clearly showing H.R. Textron Servo Pilot mounted on cover of 80 mm Olmsted Throttling Valve.*

***Figure 3** – New Throttling Manifold fully installed.*

The manifold block was moved into position, bolted in place and the original connections were replaced with new fittings. The large 3″ high pressure pipe that brought the rod side exhaust oil to the original Binary II manifold block had to be moved three inches to reconnect to the new manifold block — the most challenging aspect of the installation. The manifold block arrived on a Tuesday morning, and by Thursday afternoon the shot system was up and running.

The final change was the removal of the rotary rack and pinion encoder which was replaced by a Visi-Trak Sensor in the form of a 1″ diameter tail rod. No other mechanical or hydraulic changes were made.

The resulting shot system preserved all the strengths of the original Prince design, which was enhanced by the addition of an all-digital, programmable, closed loop shot control system. This die casting specific control drives the two-way velocity control valve mounted on the rod side of the shot cylinder. The clean, efficient, cost-effective modification was physically easy to install and resulted in an extremely robust shot system that now has 300 inches per second velocity capability.

The velocity increase surprised everybody — apparently the 80 mm cartridge and the large bores provided in the manifold block eliminated a restriction in the maximum flow rate that was imposed by the original Binary II valve and manifold. There can be no other possible explanation.

Performance

The original Binary II shot system at full opening delivered the following performance:

- At 800 psi accumulator pressure: 157 ips
- At 1000 psi accumulator pressure: 186 ips
- At 1200 psi accumulator pressure: 208 ips

The enhanced shot system has the following performance characteristic:

- At 1340 psi accumulator pressure: 309 ips

An example of the velocity profile that is used on one of the company's highest running lawn mower decks is shown in Figure 4. Prior to the shot control retrofit, the maximum filling velocity that could be achieved was around 120 inches per second. The maximum dry-shot velocity was 208 ips at a 1200 psi accumulator pressure.

The company can now more easily fill the difficult lawn mower deck castings, as the machine can easily repeat 200 ips fast shot velocities without challenging the performance limits of the shot end. The system performs with monotonous repeatability (Figures 5 and 6), which has had the interesting side effect that the operators simply leave it alone. Overall Equipment Efficiency, as measured by the post audit of the project, has increased 15.5%. The overall

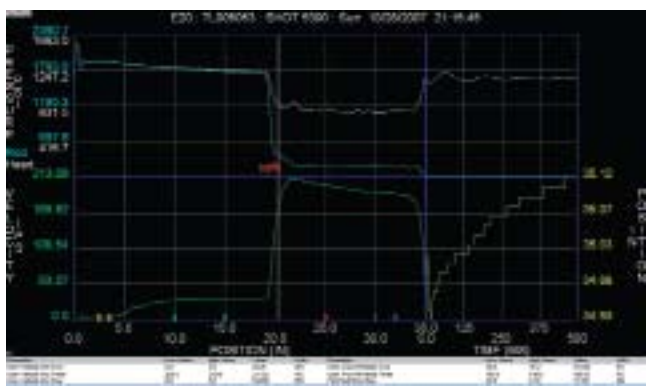

***Figure 4** – Shot profile for making a high volume lawn mower deck. The fast shot velocity gradually declines as the shot accumulator extends itself during an open loop motion block.*

scrap rate has decreased 28.5%. Downtime and maintenance relating to the shot end have been eliminated to zero thus far, and the authors acknowledge that the integration was just brought on line in October of 2007 and should be a very low maintenance item at this point in its life cycle.

Figure 7 is an X-bar chart involving 135 consecutive shots (groups of three) on the shot parameter **Fast Shot Rise Time**. Fast Shot Rise Time was the elapsed time from 40 inches per second to 185 inches per second. The shot system exhibits potent acceleration and outstanding repeatability, with an average of 11.48 mS rise time, and a total range more than 135 shots of 0.87 mS, with a CpK of 1.43.

***Figure 5** – X-bar chart on 135 consecutive shots (groups of three) on average velocity from 10 inches of stroke to 15 inches of stroke show a maximum average velocity of 31.17 ips and a minimum average velocity of 30.68 ips, yielding a CpK on of 9.05.*

***Figure 6** – X-bar chart on 135 consecutive shots (groups of four) shows the repeatability of the fast shot velocity from 25 inches of stroke to 30 inches of stroke on an open loop motion block. The repeatability would be much greater if a closed loop motion block had been specified.*

***Figure 7** – X-bar chart on 135 consecutive shots for Fast Shot Rise Time parameter. Rise Time repeatability yields a CpK of 1.43.*

The low impact system can be used to great advantage. As previously mentioned, using the intensifier resulted in heavy flash. This was not originally an issue, but as deck sizes have increased, the clamp tonnage of the machine has been challenged (Figure 8). The company has begun to use the low impact capability, which results in a softer operating condition. They are now able to use the intensifier on some of the decks by employing the low impact capability of the shot system and the Sure-Trak2™ Control without flashing the die. The overall effect has been a further reduction in the scrap rate. Most of the decks are still run without intensification.

***Figure 8** – Calculator program reveals that Toro's process requires 1667 Tons of clamp force to hold this lawn mower deck closed, challenging the limits of machine's clamp tonnage.*

Conclusion

The integration of the new throttling manifold, which was designed and fabricated by Die Cast Press Manufacturing Co. Inc., and the Sure-Trak2™ Control from Visi-Trak Worldwide LLC, has taken advantage of a solid shot end design. The resulting shot system is robust and exhibits outstanding shot control and performance characteristics. This cost-effective solution extends the service life of the machine and helps The Toro Company continue to make cost-effective castings after they have outgrown the clamp tonnage capacity of the machine. It's a lot of bang for the buck.

About the Author

Dave Brockman is the senior fabrication project engineer for the Toro Company in Windom, MN. He earned a B.S. degree in mechanical engineering from North Dakota State University. After working for Modine Manufacturing Company in Knoxville, TN, He returned to his roots in southern Minnesota and has been with the Toro Company for the past 14 years.

Ron Smidt is the vice president of Die Cast Press Manufacturing Co. Inc., a remanufacturer of die casting machinery and trim presses, as well as a builder of new die casting machinery. He represents the third generation of the Smidt Family to run the business, which also designs and builds various types of capital equipment that involve heavy fabrication and electro-hydraulic expertise.

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