ABSTRACT

Magotteaux adopted the concept of Rapid Pattern Making machine and developed first industrial prototype machine for its Pulaski plant in 2017. A paper was presented on the development and machine design during SFSA T&O December conference in Chicago. This technical & operating paper is a continuation on this subject that provides a summary of Rapid Pattern Making machine’s usage at Magotteaux in the last 2 years by comparing the KPI's and Direct Benefits. This paper starts with a brief background on project history and machine layout, followed by a report card of machine usage at Magotteaux plant. This paper also presents an introduction to Magotteaux’s second Rapid Pattern Making machine that is now developed and shipped to company’s Spain plant.
1. INTRODUCTION

Company Background

Magotteaux was founded in Belgium in 1918 by Mr. Lucien Magotteaux. It started as a small foundry producing grinding media for the cement industry. Over the years, Magotteaux developed an international network of production sites and sales offices. In North America, Magotteaux has production facilities in Pulaski, TN, since 1973, but also in Magog (Canada) and in Monterrey (Mexico). As a world-leading supplier of process optimization products & services for high-abrasion extracting industries Magotteaux provides the widest range of optimized solutions (products, services and systems) to industries involved in comminution (material size reduction): mines, cement, coal power stations, quarries, recycling, etc. and also designs specific solutions for the dredging industry.

To optimize the customers’ operations, Magotteaux researches, designs, manufactures and distributes solutions, leveraging a thorough understanding of:

- The customers’ production processes,
- The wear mechanisms (abrasion, corrosion, impact) involved,
- The material (alloy) aspects.

Magotteaux pioneered the use of high chromium alloys in grinding media as well as composite materials in the manufacturing of high added value products. This unique technology which combines an increased resistance to wear and shocks offers solutions differentiated from standard steel and iron foundry products.

Our services cover pre-sales (audits, analyses, diagnoses...), sales (including installation, supervision and equipment fine-tuning) and after-sales (performance follow-up, real time mill management...).

Magotteaux is part of Sigdo Koppers, listed in Santiago, Chile. The company employs about 3,000 skilled talents, has a market footprint of above 500,000 tons of grinding media and castings through its 15 specialized production sites and 24 sales offices.

All the Magotteaux manufacturing plants are certified according to ISO9001:2008 (quality) ISO14001:2004 (environment), and OHSAS 18001:2007 (health & safety) standards. SA8000:2008 (social accountability) and ISO50001:2011 (energy) are implemented in most plants.
2. BACKGROUND

Magotteaux International is a keen follower of SFSA events and conferences where the industry experts and academic groups share new technologies, latest research in the area of metallurgy and best foundry practices. The idea of using Rapid Pattern Making Machine (RPM) at Magotteaux was from T&O conference of 2008 where Dr. Frank Peters [Iowa State University (ISU)] presented a paper on student version of RPM. Later, a collaboration was established between ISU and Magotteaux to develop industrial version of RPM.

The industrial prototype of RPM was installed at Magotteaux’s Pulaski factory in July 2017 as first machine. This version of machine is very advanced, faster & reliable than university version of machine. There were many advancements made in this new industrial prototype of RPM, for example:

1. Programming of the machine was improved to increase the build size of patterns from 4’X4’ to 4’X8’
2. Industrial scale CNC router was used which was 3X faster than student version of machine
3. Glue system was drastically improved from top-down style spray system to CNC router mounted bead type system, which is more simpler & reliable
4. Old gantry style material handling system was replaced with modern ABB robotic system for more accuracy and reliability

I presented in-depth technical & operational details during 2017 T&O conference presentation in the paper titled “Industrial Prototype of Rapid Pattern making Machine”. Just for a quick recall, below are pictures showing structural & layout difference between ISU’s RPM version and Magotteaux Industrial prototype machine.

Magotteaux acquired the exclusive rights of ISU version RPM and is the sole owner of the newly developed Intellectual Property of Magotteaux’s version of RPM. The purpose to develop industrial prototype of RPM was to validate the concept by actually putting RPM patterns in production, have an overall feel of pattern quality and capture real production metrics to analyze if the company should make a long term investment in this project or not. The results of 2018 and YTD 2019 on the use of RPM patterns clearly show a strong business case and this year Magotteaux has developed second RPM machine for its Spain plant.
2.1. CHRONOLOGICAL ORDER

Below is the chronological order of events associated with evolution of RPM machines at Magotteaux:

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>ISU RPM presented at T&amp;O conference</td>
</tr>
<tr>
<td>2012</td>
<td>Magotteaux established initial contact with ISU</td>
</tr>
<tr>
<td>2013</td>
<td>Official NDA signed with ISU and start of design exchange</td>
</tr>
<tr>
<td>2014-15</td>
<td>Magotteaux finalizes supplier and signs NDA</td>
</tr>
<tr>
<td>2016</td>
<td>Magotteaux industrial prototype machine development starts (November)</td>
</tr>
<tr>
<td>2017</td>
<td>RPM 1 installed at Pulaski factory (July)</td>
</tr>
<tr>
<td>2018</td>
<td>RPM 2 development starts for Magotteaux’s Spain factory (March)</td>
</tr>
<tr>
<td>2019</td>
<td>RPM 2 complete and en-route to Spain factory (December)</td>
</tr>
</tbody>
</table>

3. REPORT CARD OF RPM 1 MACHINE AT PULASKI

RPM 1 made production patterns in Pulaski for 2 years (2018 and 2019), and is still in continuation. Just to remind from 2017 T&O paper, the design of RPM 1 was of an industrial prototype machine, yet with a target to make at least 80% of plant’s production patterns in its design envelope (4’ by 8’). In actuality, we made 94% in 2018 and YTD 93% patterns of total Pulaski production patterns in 2019. Only a handful patterns representing small percentage were made in conventional way due to the size constraint.

3.1. VALIDATION OF KPIs

Following KPI’s were listed as performance targets of RPM 1 during 2017 T&O paper, and using the same format, below is the comparison of targeted vs actual metrics recorded in 2018 and YTD 2019:

<table>
<thead>
<tr>
<th>Metric</th>
<th>Target</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLUE CYCLE TIME</td>
<td>12 mins</td>
<td>12 mins</td>
</tr>
<tr>
<td>CYCLE TIME TO MACHINE 1 LAYER</td>
<td>150 mins (2.5 hrs)</td>
<td>240 mins (4 hrs)</td>
</tr>
<tr>
<td>LEAD TIME TO MACHINE COMPLETE PATTERN (running 8 hrs shift)</td>
<td>4 days (max)</td>
<td>3 days (max) (Reduction in wait times)</td>
</tr>
</tbody>
</table>

The table below shows the comparison of Direct Benefits of using RPM 1, between target percentage impact vs actual impact in Pulaski manufacturing system:
4. FUTURE RPM MACHINES AT MAGOTTEAUX

The overall results of RPM 1 at Pulaski over a span of 2 years proves it to be a strong business case for Magotteaux. Despite of meeting overall production demand for the full year, the machine has been idle for nearly one quarter of the year, showing that RPM capacity is more than plant’s yearly demand. In order to keep up machine utilization, several trial patterns were also made for Magotteaux’s Mexico and European plants and these patterns were shipped to those plants for production, but the business case to continue was not so strong when shipping costs and wait times get bundled with actual pattern making lead time & costs. But these trials proved to be very beneficial to help develop further case studies for use of RPM machines at other Magotteaux plants.

Prior to the use of RPM machine, the pattern making process was quite often considered as bottleneck with long backlogs for new orders. For example in several cases it took more than 10 to 13 weeks to make a new pattern ready for first article trial. The RPM machine removed those lead-time bottlenecks/issues in a very subtle way by opening up pattern manufacturing capacity. It also resulted in reduced labor costs because in the RPM process there are no man- hours spent on CNC programming, prepping and manual pattern assembly anymore. Although, a certain time (depending on pattern complexity) is spent in cleaning the pattern surface by sanding off rough machine and glue marks because RPM 1 was built as a prototype but those issues are resolved in the next version of the RPM machine.

4.1. RPM 2 MACHINE

With a strong business case of RPM 1 at Pulaski and several trial patterns made for sister plants, Magotteaux decided to build second RPM machine for its Spain plant. The work on machine started in fall 2018 and just this month, the machine is shipped to Spain plant. This specific RPM unit is designed to make patterns for three European plants for Magotteaux. The costs and lead times for logistics are already evaluated and are in the favor for this machine collaboration.

4.2 IMPROVEMENTS IN RPM 2 VS RPM 1 MACHINE

RPM 2 machine is 5X times faster, fully automatic in operation and more reliable with improved MASTERCAM plug-in, as compared to RPM 1 machine. Picture #3 below shows the physical layout of RPM 2 machine under final development. The surface quality and finish of patterns made on RPM 2 machine is comparatively much cleaner and smoother. Because of which the pattern is taken off RPM machine and sent directly to molding line, only basic prep steps like applying pattern release paint and bolting the pattern to the molding frame are required.
RAPID PATTERN MAKING MACHINES AT MAGOTTEAUX ... THE CONTINUATION

RPM 2 machine can accommodate three sizes of patterns:

- 1220mm X 2440mm (48" X 96")
- 1300mm X 2700mm (51" X 106")
- 1800mm X 2700mm (71" X 106")

Selecting a suitable size is as simple as clicking on a drop down box and hitting “enter” on computer screen. The reason to use three different machining sizes was to reduce MDF wastage by making maximum use of MDF square footage and increasing the machine speed. Following three possible combinations are used:

- Cope and drag on one RPM sheet → 1 full pattern in one machine cycle
- Cope + drag + cope of 2nd pattern on one RPM sheet → 1.5 patterns in one machine cycle
- Cope + drag + coreboxes on one RPM sheet → 1 full pattern and a set of coreboxes in one machine cycle

The glue system for RPM 2 machine is much improved as compared to RPM 1 machine. On RPM 1 machine, a “continuous” bead type glue application was used which uses a laser guide system to turn “on” and “off” functionality of glue to apply it only to non-machined surface of patterns. The main weakness of this system is that glue can ooze out of corners, which takes labor intensive cleaning at pattern finish stage, and the quantity of glue used is more. Please remember, glue is the most expensive consumable in the RPM system.

RPM 2 machine on the other hand uses “contour” based glue system where a controlled amount of glue is applied to non-machined surfaces of MDF layer and this application operates using the glue algorithm developed in MASTERCAM. Not only this application is fully automatic to select the glue geometry but it also helped to avoid glue oozing issue and using comparatively less glue than RPM 1 system. The complete study of glue usage will be made once RPM 2 is fully commissioned in Spain plant to calculate the overall glue savings with RPM 2 machine.

Overall, RPM 2 is a fully automatic machine, where an operator is just needed to load the MDF and fill the glue tank (4.4 lbs). Then, the operator just needs to “click” on start button on machine’s computer and walk away. The machine does everything by itself: - loading 1st MDF layer on CNC bed, self-identify and apply “contour” style glue, machining the 1st MDF layer, self-cleaning functioning to remove any debris or dust, loading the 2nd MDF layer... and repeating the cycle until complete pattern is built. Whereas, to operate RPM 1 machine, an operator needs to manually “click” every step of function on machine’s computer and also manually clean each
machined layer before the start of next cycle of glue. Hence, in comparison between the two versions, RPM 2 uses less labor hours for its overall operations.

4.3 NEXT STEPS

The immediate next step of the project team is to successfully commission RPM 2 machine in Spain plant. A working plan has been developed for machine’s kick-off, ramp-up and then observatory period for 2 months before the machine will be fully handed over to production team. The installation will begin in early January 2020.

RPM 3 machine is in design stage now and is planned to be installed at Magotteaux’s Mexico plant. The annual pattern demand of this plant is close to 200 patterns. There is no in-house pattern making facility at this plant, a team of two operators does only minor repair work. The team evaluated that there is two fold increase in subcontracting costs for pattern making and long lead times (average more than 3 weeks), it makes a nice business case to make RPM 3 machine for company’s Mexico plant. The third version of machine will have more advanced features in order to improve machining speed and reliability, which could be presented in the coming years at SFSA’s T&O conference. Stay tuned!

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