

JoySmart Solutions – Utilizing Mechanized Mining for Salt Extraction

Paper Track: Salt Production

Main Corresponding Author: Toby Cressman

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Abstract

As the mining community continues to focus on safety, while increasing productivity, Joy Global Underground Mining, LLC, a member of the Komatsu Mining Corp. Group (KMC) has a complete system approach to converting conventional drill and blast mine operations to industry leading, all-electric, mechanized mining. Minimizing diesel particulate matter (DPM) levels, as well as potential slope instability resulting from over breaks, and other mining related hazards are at the forefront of technological advances as the journey toward full automation continues. The implementation of mechanized mining includes utilizing a Joy 12HM continuous miner (CM), flexible conveyor train (FCT), and conveyor system to extract salt from the production face and transport it to the hoist. KMC also offers the ability to monitor the complete mechanized mining system from the production face to the hoist. The JoySmart Solution is an integration of our smart connected products and systems, advanced analytics and direct services customized to solve customer's toughest challenges. JoySmart puts real time data at the fingertips of the customer, Komatsu service, and engineering teams for the purpose of enabling the customer to optimize safety, productivity, and cost.

The operation of a JoySmart CM, FCT, and conveyor system from KMC, in its most basic state, only requires (2) two individuals. Using a phased approach to implementing technological advances, the JoySmart Solution can, in a more advanced phase of automation, operate with a single operator utilizing the connectivity between machines (because both the FCT and CM are aware of their position relative to each other in this phase, the Joy Smart Solution can be controlled by one operator). The final phase, which has not yet been implemented by KMC, is relocating the CM operator to a remote location away from the salt face extraction environment. As there is still a requirement to handle cables manually, this cable management can set up to operate for a specified distance (15-60m) during shift changes or other breaks to maximize the cutting time of the system. The implementation of a JoySmart Solution has resulted in: productivity exceeding projected targets, a prevention of the need for increased ventilation to manage rising DPM levels, fewer mine personnel at the production face, and improved analytics resulting in leaner and smarter operations. Although an operator-free face is still in the future, these advances in technology provide a line of sight to that future goal.

Body

Three teams contribute to our JoySmart Solution: our application team, product team, and remote health monitoring team with advanced analytics. This three-in-one approach combines boots on the ground analytics, with smart connected products, and remote diagnostics/analytics to provide the customer with an optimized solution.

The process of converting a mine from drill and blast to mechanized, all electric equipment starts with KMC's application team. This team works directly with mine management to understand production targets, mine parameters, and other critical success factors. Critical success factors often include future expansion, lowering operating costs, increased productivity, and automation. With major objectives established, a productivity model can be

focused on providing the optimal solution. In order to customize and mold the model to a specific application the team will spend shifts, days, and weeks onsite over a period of time collecting operational data working side by side with operators and underground personnel performing time studies. This data will go into the model understanding current state operations and extrapolating to what production would look like with a JoySmart system. This extrapolation comes from a database of productivity models that have been created and validated against actual production information where JoySmart systems have been implemented. This model will map every movement of the continuous miner and haulage system as it moves through its cut sequence. From the time studies, existing delays associated with current operations will be added into the model along with delays associated with the proposed solution.

These delays are reviewed by the way of a sensitivity analysis showing the mine what impact certain behaviors, delays, and mine parameters can have on production. As the model advances and develops the application team will work with Engineers at the mine to understand flexibilities in their mine plan in terms of entries and pillar sizes. Commonly, adjustments to current mine plans can result in significant improvements in productivity. The application team will present the findings of the sensitivity analysis generally providing productivity numbers for several different scenarios. From this sensitivity analysis, the mine can generate new metrics to be measured to drive meaningful change that will result in increased productivity and ultimately lower operating cost. This analysis generates an output that recommends what type of haulage is best for a specific application whether shuttle cars, battery haulers, or a FCT. For the purpose of this paper and discussion the focus will be on a JoySmart system utilizing the FCT.

The second part of a JoySmart Solution are the product teams designing smart connected products. Being “smart and “connected” means that the products are not only communicating between each other but are also communicating information back to the surface and ultimately out onto a secured network. For this to be most beneficial, you must have products that are monitoring the right data. This is where acquiring a system from a single supplier that is responsible for cutting the material with a 12HM continuous miner, transferring the material to the panel belt with a FCT, and conveying it all the way to the hoist with a Joy conveyor system provides real tangible value.

From collaboration with the application team, the product teams can add the sensors necessary to monitor the data that will be key to the success of the system. As mentioned earlier, critical success factors are discussed and established with mine management. A sensitivity analysis is performed and reviewed with mine personnel to establish meaningful metrics. With this understanding of key metrics and factors critical to success the product team can work in conjunction with the application team to ensure the equipment can collect the data necessary to support meaningful metrics to drive improvement. This equipment not only monitors factors specifically critical to production, it can monitor factors that allow the mine to optimize their system.

It is key for a mine to optimize their system to minimize downtime and operating cost while maximizing production. The team will work with operators trying different sump depths, cutting cycles, and machine parameters to achieve maximum cutting rates. The 12HM miner by nature produces surges of material as it progresses through its sump and shear cycle. The FCT has a hopper capable of managing these surges. From the hopper, the FCT has variable frequency drives (VFDs) controlling the chain in the hopper and VFDs on the belt that moves the material from the hopper to the panel belt. This allows a mine to do two major things. First, conveyor component life is a function of cycles. So, by being able to run the system as slow as possible while not overflowing the hopper allows a mine to

minimize the operating cost of the system. Secondly, as a mine looks to manage multiple systems dumping onto common belts, consistent flow can be critical to preventing spillage and jams at transfer points. With scales on the conveyor the system can be configured to minimize the magnitude of the peaks being dumped onto the mainline belts all while maintaining maximum production levels. This can provide additional value as mines look to transition from drill and blast to mechanized mining. The JoySmart system can be metered by monitoring upstream flow of material already on the belt to prevent belt issues.

The third and final part of the JoySmart Solution is our analytics processes. This includes a remote health monitoring service that is continually monitoring our products to support our customers around the clock. Data from the smart connected products is transmitted into our cloud based analytics platform where advanced algorithms are constantly analyzing the data to detect anomalies or deviations. Monitoring personnel are alerted and notified through the system upon which they can in turn get in contact with mine personnel and be informed of the imminent problem. Corrective action can then be taken to prevent damage or unplanned downtime. This service also provides custom reports to a mine detailing information that will drive metrics critical to the success of the operation. These metrics can be used to manage factors that were initially identified with mine management and the application team as key to the success of the project. The remote monitoring puts real time data at the fingertips of our data analysts, product engineers, and mine personnel. With this data that is being collected, data analysts can prepare weekly, monthly, and quarterly reports that can be delivered to all levels of mine management. Not only will they report the data, but they can analyze the data and provide recommendations to improve performance.

The JoySmart Solution is a product and service that goes beyond connected products and remote diagnostics. It is a system that is most importantly focused on safety. This comes in two parts. One part is reducing exposure to harmful gasses associated with drill and blast mining and diesel equipment, and the other is removing operators from the face through automation and remote operation.

The JoySmart Solution is an ongoing development with an ultimate goal of a mining face with no operators. This has been approached through five major phases each building on the next. These phases are as follows:

- **Automated sump and shear** – This phase provides the operator with a configurable sequence table that can be programmed to mimic a sump and shear cycle that best suits their mining operation. When in this mode, the machine will continue to repeat this programmed cycle over and over again with no required action by the operator until stopped. This utilizes a time-based sump that with the absence of track slip has proven to be highly accurate.
- **Machine spatial awareness** – Also known as collision avoidance, this phase releases the technology for the FCT and Miner to know where each other are in three dimensions. While preventing the machines from colliding provides value, this step is really a building block for future phases.
- **Single operator between the FCT and Continuous Miner** – While in production mode, the operation of the FCT is very simple with the operator positioning the hopper of the FCT under the miner tail. Using machine spatial awareness, a zone can be set for the FCT to automatically follow the miner positioning itself under the

tail of the miner. This removes the requirement for one operator to be in the proximity of the face.

- **Automated cut for a set distance** – Building on the previous phase and incorporating automated sump and shear we can now have the system mine without an operator directly controlling the machines for a set distance. The cables and water hoses for the miner are managed by the FCT running along the machine back to the power center. Along with cable management, this phase introduces new challenges of staying in seam and maintaining heading control. With these challenges overcome an additional operator can be removed from the face. The limit of this system for a mine becomes roof control requirements and changing of the bits on the continuous miner.
- **Remote operation** – The final phase, that runs closely to the previous phase, is remote operation. This allows an operator to sit in a remote operation center (ROC) and control the system. This phase can provide a different option to removing operators from the face that may better fit an application depending on mine conditions.

When it comes to the safety of the JoySmart Solution utilizing an FCT there are several facts that should be highlighted:

- Fewer operators at the face
- Fewer pieces of mobile haulage equipment
- Reduced operator exposure to DPM and other toxic gasses

All pieces of equipment included in the JoySmart Solution are electrically powered eliminating any emission of DPM or toxic gasses. The regulations around these toxins have become increasingly stringent over the last 20 years making drill and blast mining continually more difficult. Table 1 – *EPA Emission Regulation* shown below highlights how much these regulations have changed over the last two decades.

Table 1 - EPA Emission Regulation

| EPA Emission Regulation | | | |
|----------------------------|------|------|-------------|
| Engine Power: 175 - 750 HP | | | |
| Emission (PPM) | 1997 | 2017 | % Reduction |
| NOx | 6.9 | 0.3 | 2200% |
| HC | 1 | 0.14 | 614% |
| CO | 8.5 | 2.6 | 227% |
| DPM | 0.4 | 0.01 | 3900% |

Reference: Bugarski, Aleksandar D., et al. Controlling exposure to diesel emissions in underground mines. SME, 2012.

With regulations continuing to reduce acceptable levels of operator exposure to these toxins ventilation is a growing issue. At times, overcoming this issue is not economically feasible. A mine that recently switched from drill and blast to a JoySmart Solution was able to reduce

their main ventilation requirement by 50% idling one of two main shaft fans. This is with a portion of their production still coming from drill and blast as they transition to an all-electric system. It was clear that to continue on their previous path an additional shaft would need to be added to provide the ventilation required to meet the constricting emission regulations referenced in Table 1. An additional shaft is no longer needed avoiding a significant capital expenditure. Along with the capital expenditure, these increased ventilation requirements result in a reoccurring and growing addition to a mines cost per ton. Working with the KMC application team a cost per ton analysis can be performed comparing current operations to a JoySmart Solution.

Other factors that should be considered when comparing operations are efficiency and cost effectiveness. These are both engineering measures of quantifying reliability and sustainability of mining operations. Mechanized mining provides efficiency by reducing concerns such as over breaks (fracturing beyond the intended dimension) and underbreaks (fracturing less than the intended dimension) during blasting activity. Over break from blasting operations reduces the safety of underground support structures, increases operational cost due to reconstruction, and extends production time. More importantly, mechanized mining eliminates the need for explosives in the underground environment and the cost associated with its storage. Room and pillar systems, which are dependent on dimension and shape for self-support, require high precision mining methods such as mechanized mining.

The inconsistency in fragmentation and muck pile size distribution that result from blasting is also a major concern for material handling in underground mines. In contrast, mechanized mining uniformly sizes excavated material from the production face providing ease of loading and reduces time spent handling material.

Conclusion

With continuing pressure to lower DPM and other toxic gas emission levels alternate methods of mining industrial minerals, such as salt, are required. The measures required to meet current ventilation standards are often no longer economically feasible and at times not even feasible from a geological perspective. KMC has a solution with its completely electrically powered JoySmart Solution that utilizes a 12HM continuous miner, an FCT, and a conveyor system. The products are backed and managed by a combination of our application team interacting directly with mine management and operators, an engineering staff with real time machine data at their fingertips, and our data analytics team providing remote health monitoring and custom analytics. The JoySmart Solution was designed with a focus on safety, productivity, and cost per ton. While development of the JoySmart Solution is ongoing, we now have a 12HM continuous miner and FCT combination running with a single operator. The ultimate goal for the JoySmart Solution is to be capable of running without an operator at the face, which not only increases safety for mine personnel, but allows mining during typical downtimes between shifts. This reduction in non-productive time is expected to drive mine utilization to unprecedented levels, while removing the operator from the face is expected to increase safety. For now, KMC is focused on continuing with our phased approach. At each step, spending time in the field, going to the work site, evaluating progress and adjusting our path forward, we are working to enhance the ability of the JoySmart Solution to solve our customers' challenges.