AUTOMATIC ROLL LOADERS FOR ADVANCED ROLL SHOPS[1]

Giovanni Bavestrelli[2]

Abstract

In many roll shops automatic roll loading systems take care of the movement of the rolls, however the level of automation is changing with advances in technology and increasing customer demands. Nowadays automatic loaders are controlled by a CNC and provide a software interface connected to the mill automation and upper level systems, scheduling all roll movements in the roll shop to maximize roll grinding throughput, and preparing all the rolls for the mill without operator intervention. In some new plants, automatic loaders are also interfaced with main-crane automation systems, so that all roll movements in the roll shop can be planned, scheduled, executed and tracked by a single software system. RFID tags are often placed on rolls and on racks so that the roll ID can be read automatically by the automatic loader, and an operator with a manual RFID reader can identify a roll and assign it to a rack at the click of a button. RFID technology makes it easier to send the correct information to various parts of the system and avoid errors usually associated with manual input, thus ensuring data integrity is preserved. All in all, automatic loaders can manage the exchange of rolls and information between mill and roll shop and make some of the decisions previously left to operators. This presentation describes the latest automatic loader projects by Pomini Tenova.

Keywords: Automatic roll loaders; Roll shop; Roll grinders.

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[2] *Software Engineering Director, Pomini Tenova S.p.A., Castellanza (Va), Italy*

1 INTRODUCTION

The level of automation in steel plants is increasing like everywhere else, pushed by advances in technology that go hand in hand with customer demands, creating a virtuous circle towards innovation. Individual machines have been fully automatic for many years, but the focus is shifting towards better integration of heterogeneous machinery into a complete system that functions as if it were coordinated by a single “mind”. This article attempts to describe some of the logic and decisions that are delegated to automatic systems in modern roll shops.

2 ROLL SHOPS

Roll Shops are areas of steel plants designated to the reconditioning of rolls which wear out during mill campaigns and need to be restored to a specified surface condition before being reused in the mill. The most critical machine in this process is the roll grinder, but the machinery around the roll grinder to allow the whole process to be carried out automatically is important too. Some of these machines are chocking/dechocking machines, chock tilters, transfer cars, EDT machines, cooling stations, and last but not least, automatic loaders and main cranes, which are the subject of this article. All these machines can work as part of a single system driven by a single logic, where decisions are made automatically to implement a specified process. Automatic loaders play an important part in this scheme because they manage the movement of rolls and the flow of information between the different equipment. Pomini focuses its offer on complete solutions, supplying all the machinery in the roll shop, to be able to maximize the integration between the different systems and the level of automation that goes with it.

3 AUTOMATIC LOADERS

In a typical roll shop with automatic loaders, there is an automatic area which is fenced from the rest of the shop and divided in different sub-areas so that the automatic loaders can work in each area without putting humans or other machinery at risk. Safety issues are of paramount importance, but their complexity goes beyond the scope of this article. Here it suffices to say that each area where an automatic loader can move in automatic mode needs to be fenced, and that if a gate allowing access to this area or one of its sub-areas is opened the automatic loader will immediately stop (if it is in the area) or avoid entering the area (if it is outside).

Figure 1. Fenced Automatic Area in TKS HSM

The goal of these automatic loaders is to take control of the rolls that are placed in the automatic area by main crane or transfer car, and move them around the roll shop, to make sure they are paired, cooled, chocked or dechocked, ground and if necessary processed by EDT machines according to specifications, then placed back in a transfer car or in an exchange area where they can be picked up by the main crane, so they can be returned to the mill. All the operations in this sequence can be automated and in most part do not require human intervention.

The software application driving the automatic loader has the following objectives:

1. Scheduling roll movements automatically based on requests coming from the mill, or on priorities provided by the roll shop operators.
2. Moving the rolls around the roll shop as they are processed by the various machines.
3. Enabling the exchange of information between all the software systems and the different machines in the roll shop.
4. Keeping track of all roll movements, roll location, roll status and roll pairing to provide reliable information to operators and managers.
5. Providing a user interface where the above operations can be monitored and controlled.

The software system which carries out these responsibilities in roll shops provided by Pomini is called WinLoader. WinLoader is a new system which replaces the previous RollHandler software and was completely redesigned and rebuilt using new technology for the ThyssenKrupp HSM and CRM plants in Alabama, as well as for all future automatic loader applications by Pomini.

4 A TYPICAL SCENARIO

A pair of work rolls arrives on a transfer car from the mill. While the transfer car travels towards the roll shop, a RFID reader reads the IDs from the RFID tags which are placed on the roll necks and sends the roll IDs to the roll shop system. The roll shop system sends a signal to a hand held device, which a main crane operator is carrying, requesting the crane operator to take the roll pair from the transfer car and place it on a particular cooling station (if the transfer car arrives directly in the automatic area, as is the case in certain plants, there is no need to involve the main crane, the automatic loader can take the rolls directly from the transfer car). The roll pair is taken to the cooling area by main crane, and a timer starts automatically. When the timer indicates the roll should have reached the desired temperature, the automatic loader picks up the top roll and transfers it to an available grinder; if no grinder is available it places the roll in a buffer area near the grinder. When the top roll is ground, the automatic loader will place it next to the grinder, in a rack dedicated for top rolls, and then load the bottom roll into the grinder. When the bottom roll is ground, the automatic loader will place it back in the exchange area, then it will pick up the top roll and place it on top of its mate to reconstruct the pair in the exchange area. The pair will then be picked up by the main crane, as recommended by the system via the handheld device, to take the rolls to the transfer car. All processing and inspection information regarding the rolls which were ground is sent automatically to the mill system. The transfer car will take the rolls back to the mill. All these operations are driven by software systems and involve automatic machines as well as humans who work in coordination with the system. The rest of this paper will describe the different parts of the system which make a scenario like this possible.

5 GRAPHICAL USER INTERFACE

Today graphical user interfaces are everywhere. We are all used to moving a file from a hard disk to a USB stick with a simple drag-and-drop operation, but doing the same dragging a roll from a rack to a grinder with a simple mouse operation and seeing a 20 ton roll being moved gives a different impression.

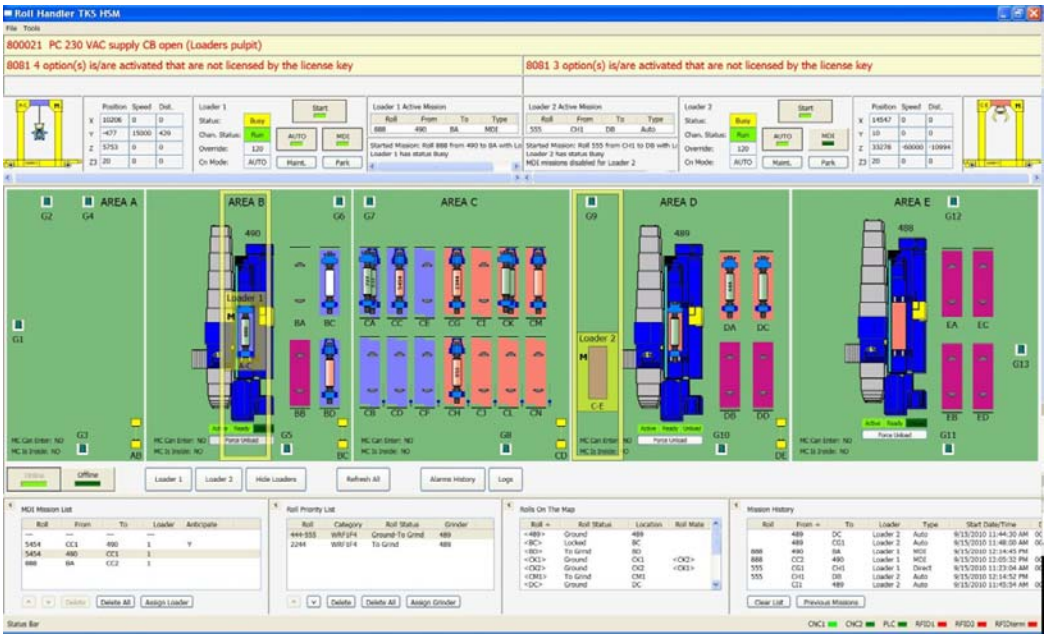


Figure 2. WinLoader User Interface in TKS HSM

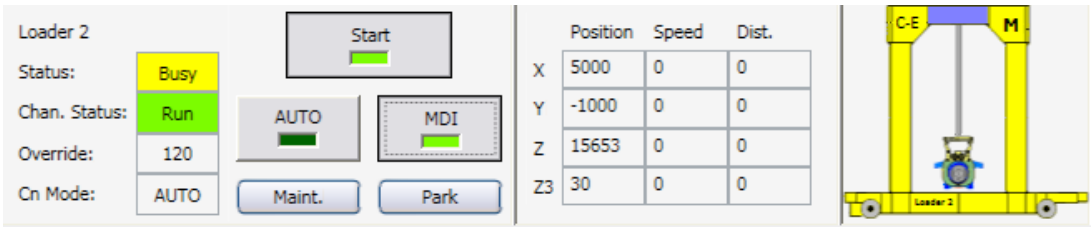


Figure 3. Control panel for automatic loader

The WinLoader application provides drag and drop functionality to move rolls around the roll shop, indicating clearly where a roll can be placed (the location below the roll being dragged with the mouse is shown in green) and where it is not possible to place the roll (the location below the roll being dragged with the mouse is shown in red), as shown in Figure 4.

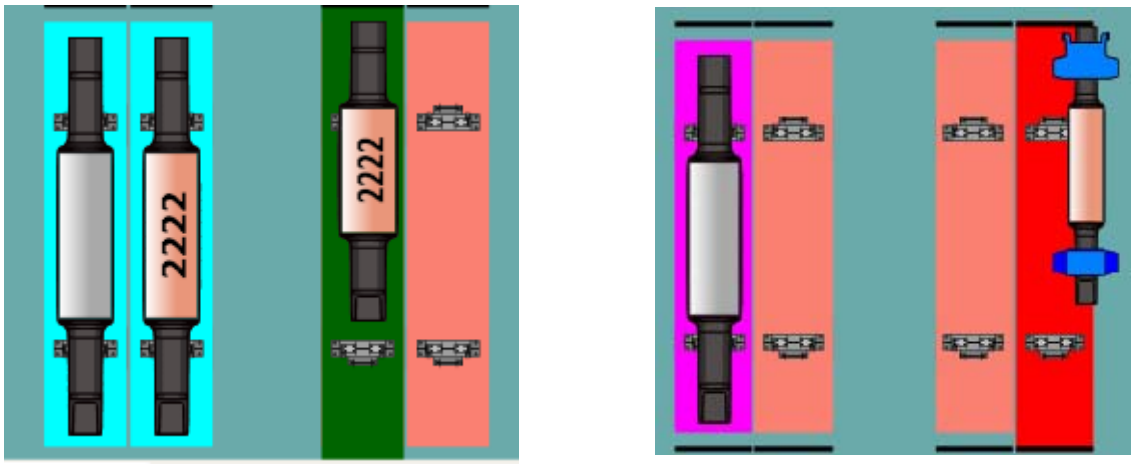


Figure 4a. The roll can be placed here; **b.** The roll cannot be placed here.

It is also possible to program a list of roll movements by dragging and dropping a sequence of rolls from location to location and having the loader perform all the movements in the list, in the order specified or in an optimized order, automatically, as will be described later. WinLoader's display includes animations showing the actual position of the roll loader carrying the roll around the roll shop, as seen from the side (Figure 5a) or from above (Figure 5b).

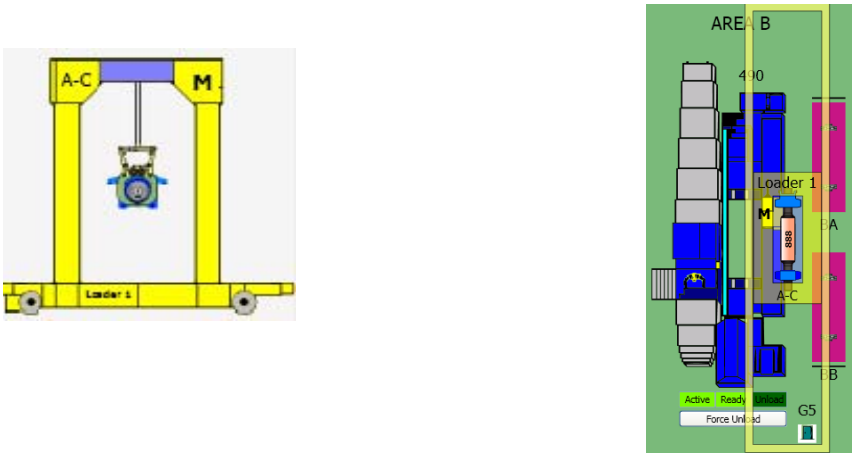


Figure 5a. Loader side view; **b.** Loader top view.

This way operators “get the picture” very easily and intuitively, know where each loader is and what it is carrying, see where each roll is and in what state, and do not need to read long lists to find the information they need.

6 RFID

RFID technology is currently being used in most new plants with automatic loaders commissioned by Pomini. RFID tags are mounted on each roll, usually placed on the roll neck, as shown in Figure 7.

Figure 6. RFID Tag

Figure 7. RFOD Tag mounted on roll neck.

These RFID tags must be of a type specifically designed to be placed on metal surfaces, as normal RFID tags do not work well in the presence of other metal. Tags must also be resistant to high temperature, vibration, acids and the like. Fortunately, many RFID system manufacturers today provide tags of this type. A hole should be designed in the roll neck, with the exact dimensions of the tag, so that the tag can be embedded in the hole and protected from impacts against the roll neck. Tags can also be placed on racks and chocks, to facilitate tracking roll and chock position and performance in the roll shop. Typically RFID reading antennas are placed on automatic loaders and/or on roll grinders.
Placing the antennas on automatic loaders makes it possible for rolls to be identified sooner during their processing in the roll shop, but placing them on the grinders allows the rolls to be identified even when placed by the main crane on the grinding machine. Depending on the roll shop, one solution is usually preferable to the other.

RFID technology is not just a convenient way to avoid some manual input by operators; it is a way to consistently send correct information to other systems connected to the roll shop, typically the mill / level 2 / level 3 systems. Mistyping a roll ID by manual input when putting a roll on a roll grinder can cause wrong information to be sent to the mill and this could cause an accident in the mill or, at a minimum, corrupt the historical data for the rolls and thus make it more difficult for operators and managers to analyze the data later to get reliable indicators. RFID technology today is relatively cheap, stable and very simple to implement, we predict it will spread to many plants in the near future.

7 MODES OF OPERATION

There are various ways in which a roll movement (which we call “mission”) can be entered into the system and monitored by it:

- Direct mode: a single roll movement is entered by an operator and is executed immediately by the automatic loader.
- MDI Mode (Manual Data Input): a list of roll movements is entered into the system by operators via a simulation page and the list of movements is later executed by the automatic loader.
- Automatic Mode: the automatic loader decides and schedules all the movements for a set of rolls and executes them.

The next few paragraphs will go into a bit more detail with regards to these three modes of operation.

7.1 Direct Mode

Here a single roll movement is entered into the system, usually via a single drag-and-drop operation on the user interface, and the loader will execute the mission immediately after asking for confirmation. This is a quick and easy way to move a roll without affecting other scheduling logic and scheduling lists that might have already been prepared.

7.2 MDI Mode

Operators enter a sequence of roll movements into the system through a simulation page where the rolls are moved on the screen as they would be moved by the loader. As operators move the rolls on the screen via drag-and-drop operations, a list of roll movements is created for later execution. As operators scroll through the list, they can see the rolls as they would move in the roll shop if the mission selected in the list were executed. That is, if the mission of the roll from rack CA1 to CB1 is selected, as shown in the image below, the roll shop map in the MDI simulation page will show the result of the current roll shop map state after the first two MDI missions in the list are executed but before the third one is.

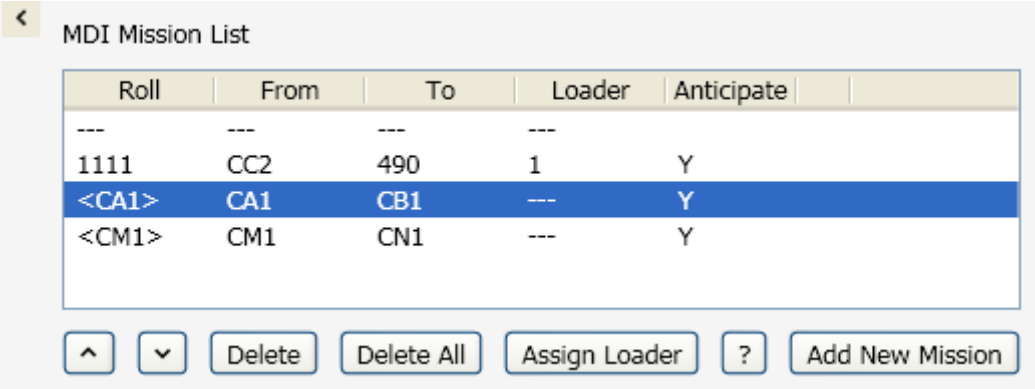


Figure 8. A list of MDI missions

The list can contain any number of missions. These missions can be executed later either in the order in which they were entered into the system or in an optimized order, where the software is able to separate subsequences of missions which are independent of each other and execute them in parallel to maximize roll throughput. For example, if the 1st mission in the list is to move roll 1111 from rack CC2 to grinder 490, but the grinder is now busy, the system can decide to execute the 2nd mission in the list if it knows that anticipating such a movement does not change the final results. The system does this by calculating all dependencies between all missions in the list, and also uses this information to allow operators to change the order of the missions, as well as to add/remove missions to/from the middle of the list, but only where appropriate. In the list above, the "Y" in the "Anticipate" column indicates that the mission is independent of the other missions before it in the list and could be started at any time.

Operators create this mission list starting from the current state of all rolls in the roll shop. It is possible, actually probable, that the roll shop state will change in time independently of the system which is controlling it. For instance, a main crane operator might place a roll in the exchange area in a rack which another operator used in the MDI simulation. Or the same main crane operator can pick up a roll which was scheduled to be moved in the MDI list and place it elsewhere. Such changes in the roll shop state can cause one or more scheduled MDI missions to be invalidated. The system is able to keep these changes constantly under control, show the missions in the MDI list that become invalidated in red, and allow operators to see the reason they were invalidated by pressing a help button.

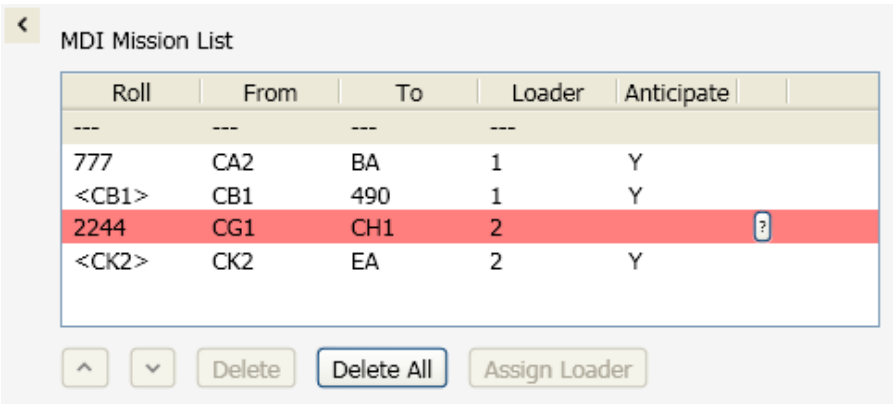


Figure 9. MDI Missions List with an invalid mission and associated help button

Operators can then edit the MDI list by removing the invalidated missions or replacing them with valid ones, without clearing the complete MDI list. The system is very flexible because it does not require recreating lists of roll movements that become partially invalid but allows the required editing of the invalid parts.

7.3 Automatic Mode

Automatic mode varies in the amount of automation depending on customer needs. In basic automatic mode, an operator will indicate that a roll or roll pair should be treated automatically, and the system will take care of scheduling all roll movements to process the roll in the automatic area, from the exchange area or transfer car, to the cooling stations, closer to the grinders, onto the grinders or EDT machines and back to transfer car or exchange area, all automatically, according to a specified priority.
In full automatic mode, a list of scheduled roll changes is sent from the mill to the roll shop, and the system will select appropriate rolls for each stand, move them around the roll shop to process them, and place them back ready to be taken to the mill. In shops where transfer cars and dechockers are placed in the automatic area, the system can schedule all roll movements from the time the roll arrives in the roll shop via transfer cars to when the roll is placed back on the transfer car, after grinding it. In many shops, though, dechockers, transfer cars, cooling stations and other roll shop equipment are outside the automatic area and cannot be managed by automatic loaders. In these cases, other equipment, like main cranes, enter the picture.
As in the case of MDI missions, the system displays a list of rolls or roll pairs in order of their priority, and will schedule missions for all these rolls automatically without operator intervention. Should conditions change to make it impossible to process a roll in automatic mode (for instance if a grinder changes configuration and there are no grinders configured to grind a specific roll) again the system will show the rolls in red and display a help button which will explain the reason for the anomaly.

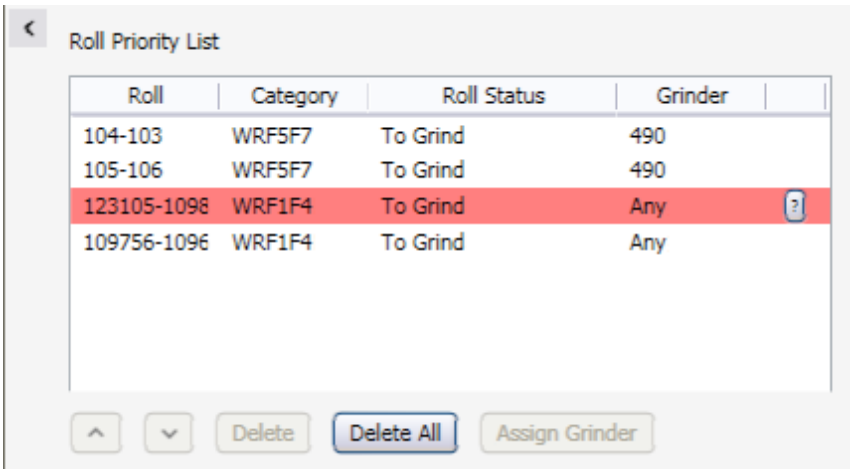


Figure 10. Roll Priority List showing a pair of rolls that cannot be processed and associated help button

8 TRACKING ROLLS OUTSIDE THE AUTOMATIC AREA

Starting in 2011 with the ATI Allegheny Ludlum HRPF HSM Project in Brackenridge (Pennsylvania) and then in the Ternium Pesqueria CRM project in Monterrey (Mexico) we were asked to schedule missions and track rolls outside the fenced automatic area. This posed a new set of challenges, as we needed to schedule missions for main crane operators, who could take initiative themselves, and we needed to track all roll movements carried out by the main crane to and from many racks which did not have sensors to detect roll presence, as are normally found in an automatic area. In other words, we could not schedule missions which would be executed automatically, as in the case of automatic loaders, but we had to suggest missions to main crane operators and be ready to track completely different roll movements. We also needed to start tracking backup roll movements around the roll shop, as well as edger rolls, pinch rolls, wrapper rolls and the like.
A communication protocol was developed between the roll shop field PLC and the main crane PLC so that the roll shop system is constantly updated with the main crane position and load weight. Using a map of the complete roll shop with an associated database the WinLoader application can track the roll movements using main crane coordinates and load weight signals to figure out which rolls are moved where, and providing roll inventory information that is constantly up to date. This way operators can see a graphical map of the complete roll shop with all the rolls in their current positions.
When a main crane picks up a roll or a pair of rolls, the system will usually know which rolls it is picking up because it reads the load weight and knows what type of rack is in that position. The system also knows that, perhaps the day before, it tracked the movement of a roll to that destination, but it is possible that rolls enter the system in other ways, like by truck, or that the system misses some movements, as would happen if the WinLoader application were not running when a crane operator moved a roll. For these cases, main crane operators carry a handheld device which is used to read RFID tags and identify the rolls. The handheld device is also used by the WinLoader application to recommend roll movements to the crane operators, who can then control the crane to move the rolls. A wireless connection between the handheld and WinLoader takes care of the communication.

9 MILL SCHEDULE

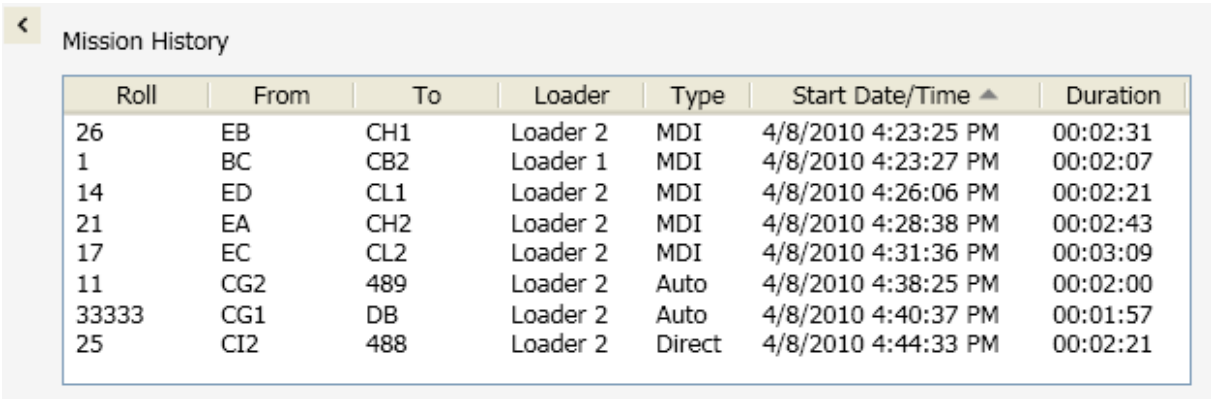
Being able to track rolls outside the automatic area made it possible to track all rolls in the roll shop, together with their actual position. In turn, this made it possible for the mill to send the roll shop a list of work roll changes planned for the future, specifying the roll types and stands but not necessarily the ID of the actual rolls to be used, and the system is able to select the work rolls to be used in the future mill campaigns, schedule main crane operations to bring these rolls to the automatic area, schedule automatic loader operations to process the rolls on grinding or EDT machines, grind the rolls, move them to the EDT machines if necessary (for cold mills), then back to the exchange area, schedule main crane operations again to bring the roll to the transfer cars so they can go back to the mill. This closes the loop making it possible for the system to schedule and track all roll movements from the time they arrive in the roll shop to the time they leave for the mill.

10 INTELLIGENT SYSTEM

The title of this paragraph is a bit ambitious, implying that a software system can be “Intelligent”, but it emphasizes the growing trend that is pushing automation from automating operations to supporting or automating decisions.
The WinLoader application uses algorithms to calculate dependencies between missions, so that the mission lists can be executed in a different order maintaining the same result, or be reshuffled as needs change. The system is also able to carry out MDI missions and automatic missions together, giving priority to one type of mission or the other, and even mixing MDI and automatic missions in order of their importance to maximize the efficient use of roll shop equipment.
In the case of two automatic loaders, the system is able to select the best loader to execute a mission, and if a loader is standing in the way of second loader which is trying to execute a mission, it can be moved automatically out of the way just to make it possible for the second loader to complete its task. If a loader goes out of service, the other loader will automatically take care of the areas and the missions previously assigned to the loader that went out of service.
As operators gather experience with the system, they can make recommendation for improving the logic and these suggestions can be implemented in the system becoming the basis for all future installations. The software architecture was designed to allow some modules to be customized for each customer, whereas most modules are kept common between all, so that an improvement in a common module would bring benefits to any future installation or upgrade.

11 ROLL SHOP SIMULATOR

In 2010 Pomini developed the Roll Shop Simulator (RSS) which models the entire roll shop and evaluates the layout and performance of each Roll shop configuration, providing various statistical data. The tool allows correct dimensioning of roll shops to reduce costs and equipment to a minimum. In a few minutes it can simulate years of production in a specific roll shop and mill in different scenarios, providing various parameters useful to estimate machine usage, human resource needs, storage space and other information which allows plant designers to provide a tailor-made plant based on precise analysis and not just on experience and intuition.
WinLoader schedules and tracks all roll movements in the roll shop, and it was designed to register all roll movements and all significant events in the roll shop so that the data can later be used to compare it to RSS simulations in order to improve the RSS system’s predictive accuracy in the future.


Mission History

Roll	From	To	Loader	Type	Start Date/Time	Duration
26	EB	CH1	Loader 2	MDI	4/8/2010 4:23:25 PM	00:02:31
1	BC	CB2	Loader 1	MDI	4/8/2010 4:23:27 PM	00:02:07
14	ED	CL1	Loader 2	MDI	4/8/2010 4:26:06 PM	00:02:21
21	EA	CH2	Loader 2	MDI	4/8/2010 4:28:38 PM	00:02:43
17	EC	CL2	Loader 2	MDI	4/8/2010 4:31:36 PM	00:03:09
11	CG2	489	Loader 2	Auto	4/8/2010 4:38:25 PM	00:02:00
33333	CG1	DB	Loader 2	Auto	4/8/2010 4:40:37 PM	00:01:57
25	CI2	488	Loader 2	Direct	4/8/2010 4:44:33 PM	00:02:21

Figure 11. All roll movements are stored and available for future analysis

12 SUMMARY

Roll Shop automation level is increasing as software systems take more and more responsibilities for running an integrated roll shop consisting of diverse machinery. Automatic loaders and scheduling software take a central role in this scenario and make it possible for mill systems to communicate to roll shop systems and to make the necessary decisions to optimize roll shop performance. The benefits are not only in the roll shop, as better roll tracking, roll data and scheduling of the roll shop will ensure that the mill receives the correct rolls, when required including the complete data to operate the mill. As these systems are commissioned, new ideas come up to optimize roll shop functionality, and they can be integrated in the software system contributing to the growing effectiveness of the plants. This in turn contributed to giving Pomini the largest market share in the roll shop business.

Acknowledgments

I wish to thank all the people in Pomini who contributed to the development of the solutions described in this article and who continue to make work so pleasant, interesting and challenging. Thanks also to all the customers I had the pleasure of meeting in my frequent travels for the stimulus and trust they granted us through the years. A particular thanks to Rick Mc Whirter for reviewing this article and providing his feedback and suggestions.