Roll Shop Management Systems

A Roll Shop Management System manages information about rolls, chocks, bearings and grinding wheels. Because of such systems, automation in roll shops has advanced from simply reducing manpower and costs to now supporting day-to-day decisions.

This paper describes some aspects of the impact of software systems on a modern roll shop, analyzing the different ways software brings value, and concentrating on what is called a Roll Shop Management System.

While touching many areas of the roll shop affected by software, this discussion will not focus on the automation at the CNC and PLC levels — a core aspect, but well understood by most people working in a machine shop. Instead, the focus will be one level above, on the software that runs on PCs and computer networks often present on and around roll grinding machines.

From Improved Productivity to Decision Making

The role of automation has increased in importance in the last 20 years, not only in the roll shop, but in any machine shop, as well as in many other fields in almost all industries. Initially, automation was introduced to increase productivity and reduce manpower and therefore costs, but soon it became necessary to keep pace with market demands for improved quality, predictable output and optimized use of available resources. Then, with an increasing attention to safety, automation's role became even more central. Now automation is broadening its reach and becoming a decision support system (DSS) by providing better and more elaborate information, statistics, key process indicators (KPIs) — a lot of aggregate and graphical data to help decision makers do their work. The next step is for automation to take, in part, the role of the decision maker itself; more and more software will be responsible for making some decisions that previously required the intervention of skilled operators or engineers.

Currently, automatic systems not only drive a machine by using a grind program selected by an operator to create a specific profile created by another operator, but they are also able to analyze the grinding schedule, move the rolls around the roll shop from the transfer car through the racks to the grinders, decide what grind program and what profile to use, modify them during the process (taking into account the roll defects that are automatically measured and classified according to information based on previous experience), and decide what to do with the roll, if and how to grind it, and when to accept it.

Roll Shop Network Configuration

Focusing on a typical computer network in a modern roll shop, one will see something like Figure 1. A standard Ethernet network connects all grinders to a central server, where information regarding each machine's grinding activities is kept in a single standard database. Note that grinders from different manufacturers can be connected to a single network, and data from such grinders can be treated uniformly inside the system, although this usually requires some customization work to be performed. As shown in Figure 1, a roll shop network usually fits into a broader network at each customer site, where other complex systems communicate with each other.

The system that is usually connected to the roll shop is often called level 2, level 3 or the mill computer system, and manages the mill's production using the rolls produced in the roll shop. For security reasons, and to improve network management, it is often a good idea to place a router between the roll shop network and the mill system, but this depends on the security polices adopted at each customer site.

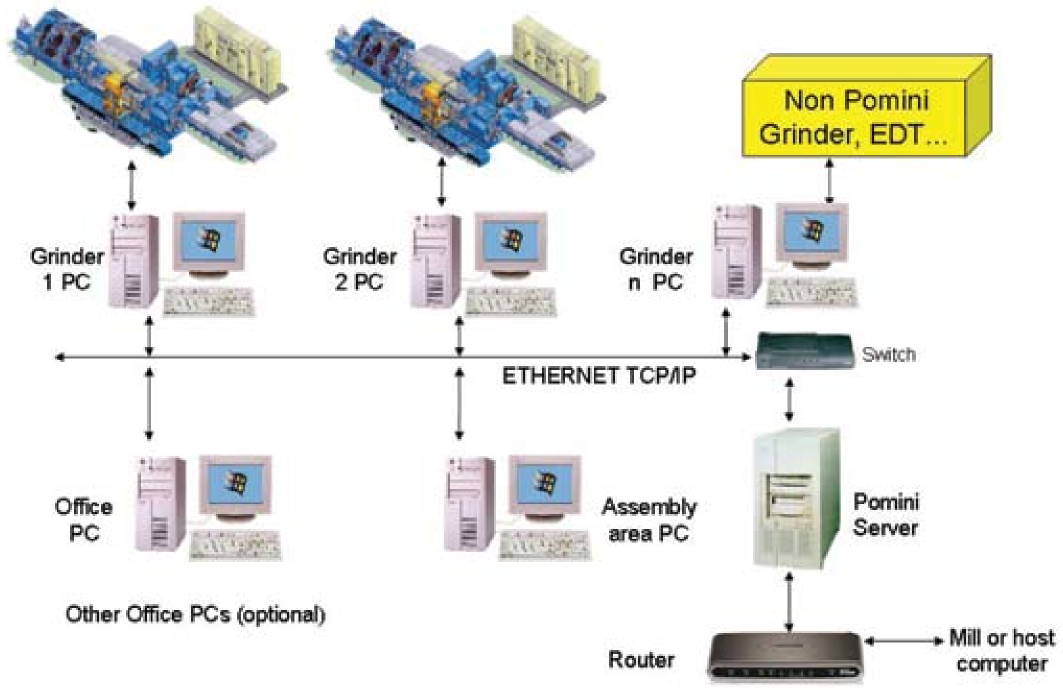
Standard Software and Hardware

Software running in a roll shop is often sold by roll grinder manufacturers, sometimes

Author

Giovanni Bavestrelli, software engineering director, Techint Compagnia Tecnica Internazionale SpA, Pomini Division, Castellanza, Italy (g.bavestrelli@pomini.it)

Figure 1



Roll shop network configuration.

developed in-house by steel producers, and other times developed by external software houses specializing in automation. Even when a software system is purchased on the market, it usually requires some level of customization and integration to function with existing systems. To facilitate this process, as well as to facilitate maintenance to the system, it is becoming increasingly important to use market standard software and hardware.

First, it is necessary to adopt adequate operating systems and databases. Having a standard operating system, such as Microsoft Windows or Linux, and a standard database, like Microsoft SQL Server or Oracle, means that the system is easily connected to other systems, but more importantly that the data is open. At the early stages of automation, it was common to have niche operating systems and custom databases, where it was almost impossible to access the data from external applications, but today this is totally unacceptable. Today, standard operating systems and standard databases facilitate access to all the data kept inside a Roll Shop Management System. Customers can easily extend the systems they purchase by accessing internal data to create new reports, statistics or graphs through the use of simple and often inexpensive off-the-shelf software products that facilitate the task.

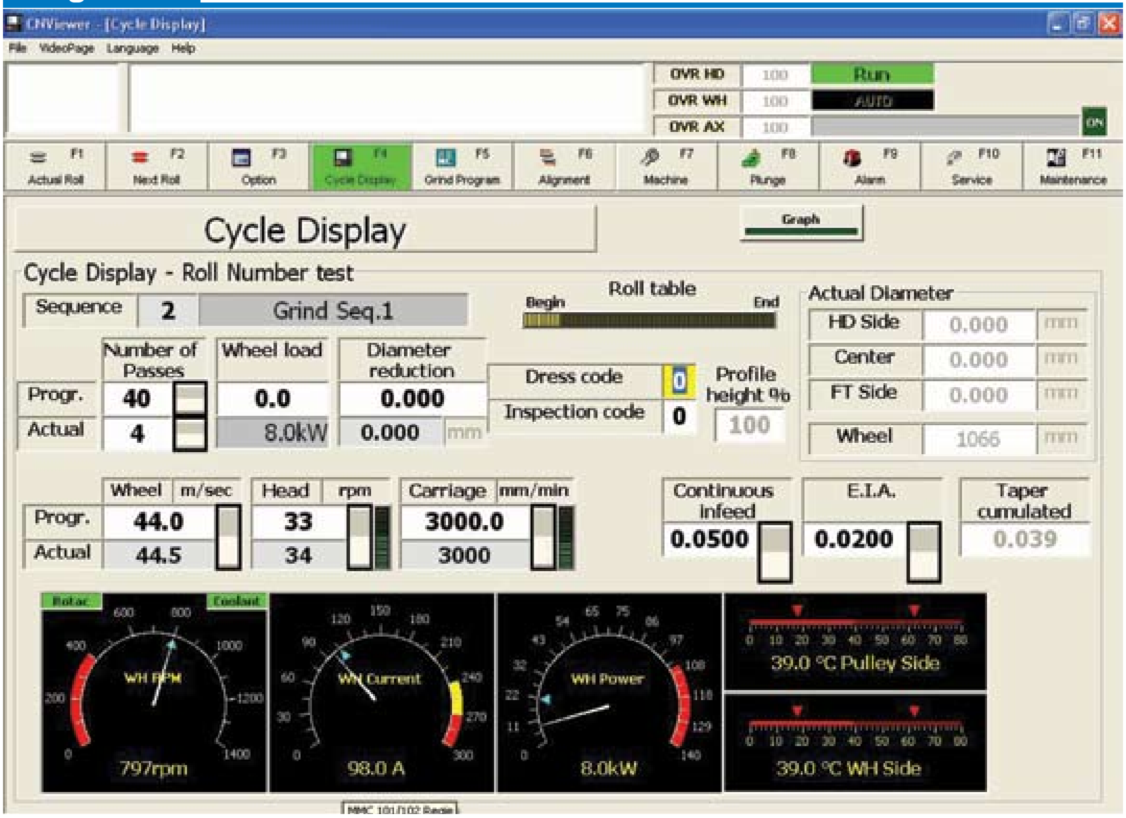
As far as network standards are concerned, today's choices are Ethernet networks and TCP/IP protocols. Some old mills might have different solutions, but for a new system this should be the first, and perhaps only, configuration to consider.

Another important aspect related to standardization in software is the computer language adopted to develop the applications. A standard computer language means that standard, well-known tools can be used to develop and debug the software; that software developers skilled in that language can be easily found on the market; and that the software system can communicate easily with other systems. All this leads to better evolution and maintenance of the programs. Currently, the more commonly used languages in the development of software applications in the roll shop are C#, C++, Visual Basic and Java.

As with software, it is important to select an appropriate standard for hardware to facilitate getting support and spare parts, and to simplify the maintenance of the equipment. Besides the choice of computer manufacturer, an important decision is whether to use normal PCs or industrial PCs, a selection dependent on the operating conditions of the plant. Industrial PCs have better resistance to vibration, high temperature and humidity ranges, electromagnetic fields and dust; they often have redundant disks and power supplies; and therefore, they are more reliable and sometimes more appropriate. It is advisable to stay as consistent as possible; getting a certain type of equipment from the same supplier makes everything easier.

Another useful feature in modern software is the ability to export data directly to Microsoft Excel. Many systems provide predefined graphs, calculations, reports and statistics, but allowing the raw data to be

Figure 2



Example of a computer screen in a grinder console.

exported to Excel gives end-users the ability to easily create their own reports, perform what-if analysis, display new types of graphs, or create presentations and new reports.

Roll Grinder Software

On each modern roll grinder, there is a CNC, a PLC and a powerful PC. CNC and PLC systems are not the focus here; instead, the focus in this paper is on what is running on the PC. Each roll grinder PC normally has a number of software applications used to control the machine:

- A machine console, with a graphical interface to monitor and control the grinding machine and the grinding operation.
- An application to show the results of the grinding operation: profiles, tolerances, errors and other measures.
- A nondestructive testing (NDT) device responsible for finding surface and subsurface defects on the rolls.
- An application that manages all the data that is used to grind rolls (profiles, grind programs and other parameters).
- An application to generate grind profiles according to specific mathematical formulas.
- An application that keeps track of when and where to perform maintenance to the machine.

In some cases, some of these applications can be combined.

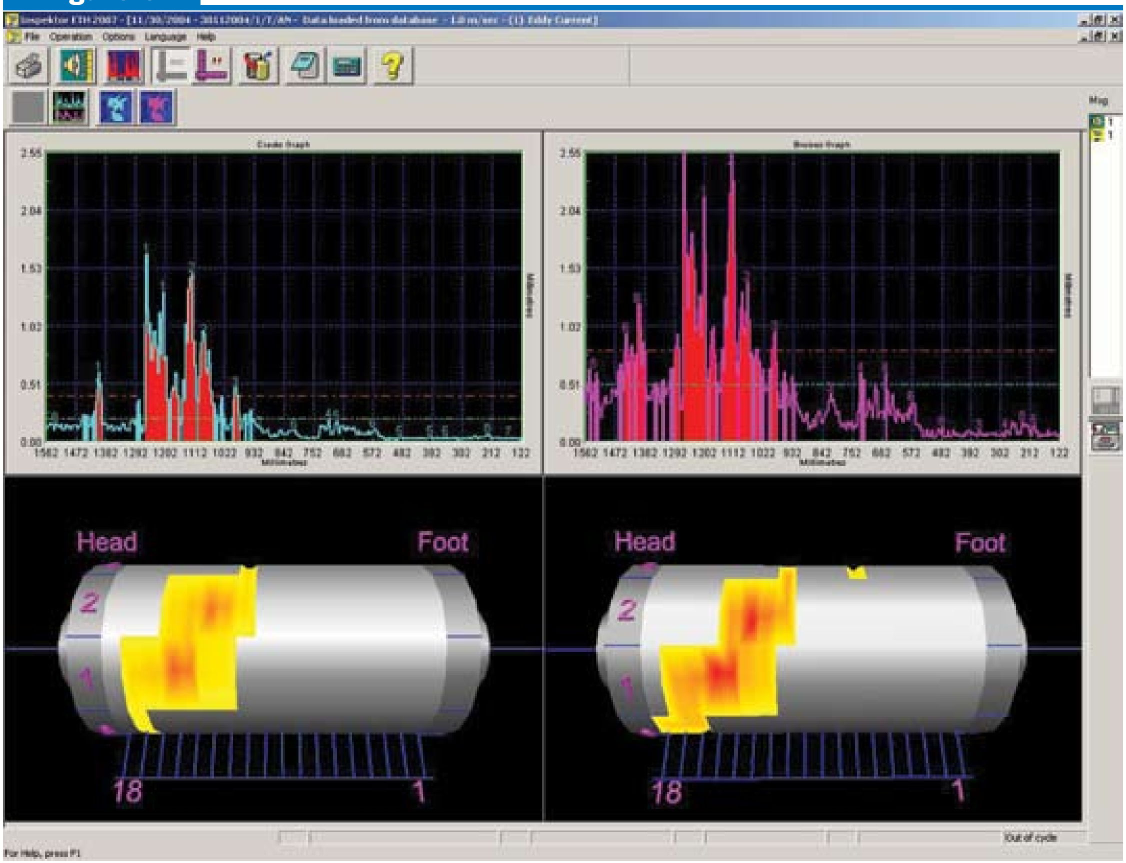
With the advances in software technology, these applications have become ever easier to use through a graphical user interface, and normally come with on-line help systems, video pages localized in the language of the customer, interactive 2-D and 3-D graphs and elaborate reports. Manuals and documentation have also moved to the grinder PC in electronic form, as will be discussed later in this article.

Today, it is common to have a single operator sitting in front of a number of PCs in a central pulpit driving the operation of multiple grinders by himself without leaving the pulpit.

Finding Roll Defects

As demand for quality and safety increases, the role of an NDT system has become central. Presently, eddy current systems are often used with repeatable success to scan the surface of the rolls and prevent defective rolls from entering the mill with potentially catastrophic effects. Ultrasound systems are also increasingly being used to detect subsurface defects that can be just as catastrophic. An NDT system that prevents only one roll explosion in the mill in its lifetime will have paid for itself just by saving the cost of the damage of the explosion to the production, not to

Figure 3



NDT eddy current and ultrasound inspection system interface.

mention the potential damage to the mill or to other rolls.

Today, NDT systems are being used not only to prevent defective rolls from entering the mill, but also to drive improved decisions on how to process the rolls. Such decisions include how much stock to remove from the roll, what grind program to use, and when to accept the roll — all decisions that previously required the intervention of skilled operators. A software system can classify the defects found, analyze them based on accumulated and formalized experience, and decide what to do on the roll without asking the operator.

Some NDT systems also have vibration analysis modules, and are able to send alarms to the grinding machine when vibration reaches a threshold that could create risks for the quality of the roll's surface finish.

Automatic Loaders

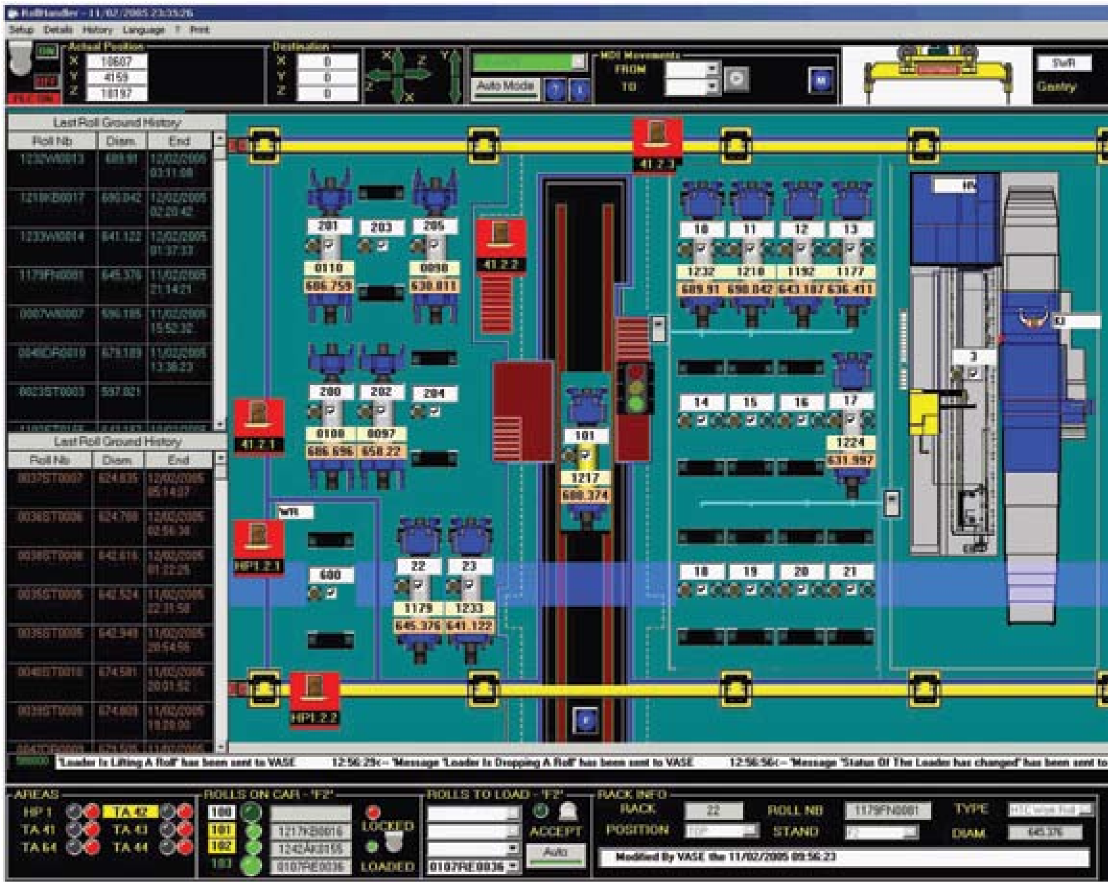
One of the main advantages automation brings to the roll shop is the introduction of fully automatic loaders. Loaders have had a degree of automation for many years. With a mouse and simple drag-and-drop operations on a computer screen, it was possible to start a loader mission to pick up a roll from a specific rack and place it on the grinder. Then it became possible to create a sequence of missions for the loader to execute automatically. Today, automatic loaders can receive information on the rolls coming from the mill after a mill campaign, as well as information regarding future mill production requirements, and automatically create the missions to move the rolls around the roll shop from the transfer cars to the storage racks or cooling stations, then to the grinders and possibly EDT machines, then back to the transfer car that will bring the rolls to the mill for planned rolling campaigns. Roll flow is a key aspect for the success of a fully automated roll shop, and an automatic loader can optimize it well and consistently.

Full loader automation is a complex task with many aspects related to technology, safety, productivity and reliability that need to be planned well in advance, but the benefits are substantial. As an example of technology used in automatic loaders, laser systems are often installed for precise positioning or as sensors to detect the presence of rolls in the storage racks or on the machine.

Mill Communication

To bring the automation of a roll shop to a new level, one step is fundamental: communication to the mill system. This communication implies the exchange of information in one

Figure 4



Automatic loader software in Outokumpu, Finland.

or two directions. First, information is sent from the grinder to the mill system. This way, the mill system can access the data resulting from the grinding operation on the roll. Typically, the information sent to the mill system after a grinding operation includes the following:

- Identification of grinding machine.
- Date and time of grinding operation.
- Information identifying roll and its characteristics (type, material, geometry, etc.).
- Identification of mill and stand.
- Program and parameters used to grind the roll.
- Profile of the roll, profile height, profile error, etc.
- Dress program and dress height for wheel dressing.
- Diameters of the roll measured before and after grinding in different positions.
- Measured taper.
- Roundness and runout measurements.
- Eddy current and ultrasound defects, their positions and values.
- Identification of the wheel type and number.
- Starting and ending diameters of the wheel.
- Roughness and hardness measures.
- Operator identification and comments.
- Status of roll grinding operation.
- Amount of stock removal.

This data is useful to the mill in selecting and using the correct rolls.

Next, information can be sent from the mill to the roll shop. This is less common, but it closes the cycle and enables the full features of a Roll Shop Management System. Such data is specific to production and usually includes the following:

- Roll number and mate roll.
- Mill and stand number.
- In-stand and out-stand time.
- Change reason.
- Rolled tons, kilometers and operating minutes.
- Rolled material code.

A number of technologies can be used to exchange information between the roll shop and the mill system, but currently the most widely used technology is either Direct Database Access (for example, through ODBC or OLEDB) or TCP/IP Sockets. These two approaches are very different and have very different advantages and disadvantages.

TCP/IP Sockets is a standard message exchange protocol providing software application writers a portable means of accessing the communications hardware of the network. Since sockets allow point-to-point communications between processes, it is used in most of the networked workstation implementations of message-passing libraries, and is the basic message exchange method used over the Internet. Sockets are popular in the steel industry because they are a modern message exchanging system, and message exchanging systems were popular in the past when Direct Database Access was difficult or impossible across heterogeneous networks. In the past, the mill system was often a Digital VAX, and Direct Database Access was difficult or impossible, so message exchanging protocols like DECMessageQ by Digital became popular. Now that Digital VAX machines are disappearing, the message-passing protocol of choice has become TCP/IP Sockets.

A more modern approach, though, is Direct Database Access (DDA). DDA allows information to be accessed directly from the database in which it resides, without necessarily duplicating it or reformatting and sending it over to the receiving application. This is usually achieved in one of two ways: either the roll shop system writes the grind result data directly on the mill system database and reads the production data from the mill system database, or the mill system reads the grind result data from the roll shop database and writes the production data into the roll shop database.

DDA is often implemented through a technology called Open Database Connectivity (ODBC). ODBC is a standard application programming interface (API) developed by Microsoft for accessing data in both relational and non-relational database management systems. Using this API, database applications can access data stored in database management systems on a variety of computers, even if each database management system uses a different data storage format and programming interface.

The main advantage of DDA over TCP/IP Sockets is that, with DDA, any application can read all the data using standard programming techniques directly from its source — no conversion or message exchange protocol is necessary, and therefore DDA is simpler and quicker to set up.

With TCP/IP Sockets, on the other hand, things get more complex, and with increased complexity there is an increased risk of errors and increased time to set up the system. On one end, software needs to be written to extract data from a database, reformat it into an area of memory (for example, as text), and send it into an appropriate message. On the other end, another application needs to be written to receive such a message, interpret its information according to detailed specifications, and write it to a database. Problems arise related to conversion factors, units of measure, rounding, padding, aligning numbers, messages that fail to reach the destination and must be resent, yet all this is bypassed with DDA. If sockets are used as a mechanism of communication, and the customer decides at a later stage that an extra data item needs to be received from the roll shop management system, software must be modified both at the roll shop and on the mill side. With DDA, all data is there and available to both systems at all times. In short, DDA is less complex, requires shorter testing time, and is easier to implement, modify and maintain.

Roll Shop Management Systems

Strictly speaking, all that has been described up to now is not part of what is commonly called a Roll Shop Management System (RSMS), but is the basic infrastructure necessary to be able to provide data to the RSMS.

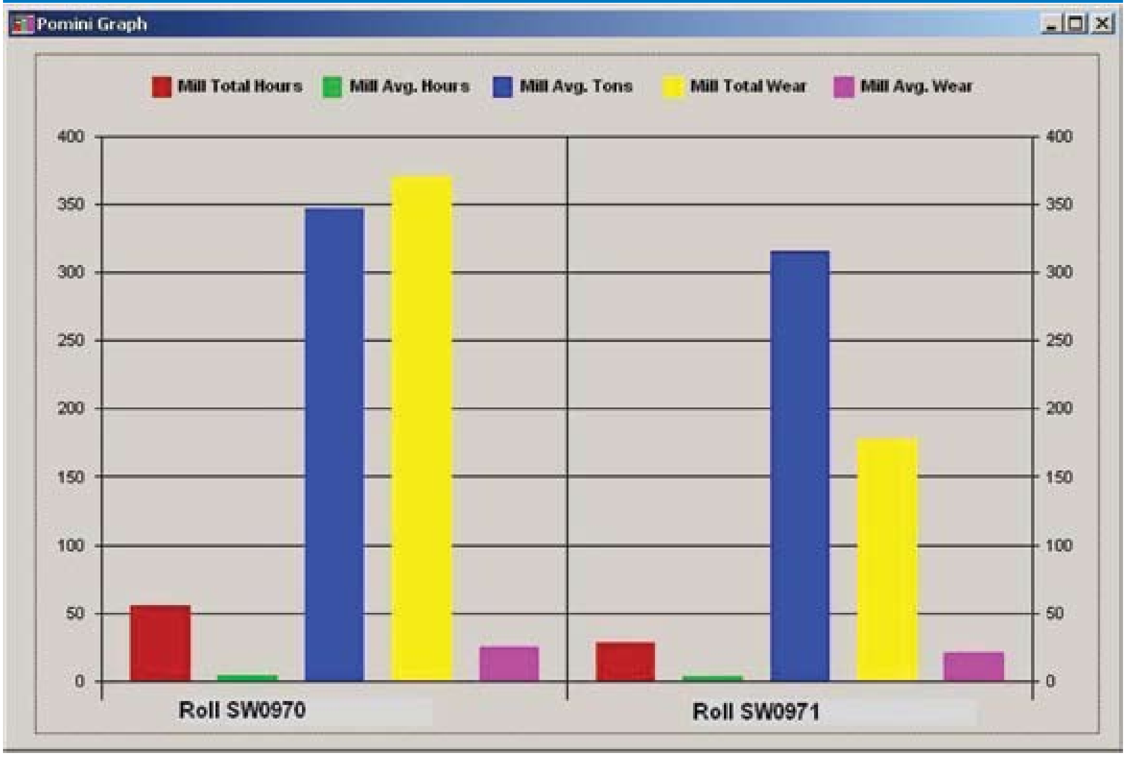
Once the grinding machines store all grind data on a central server, and the mill communication brings in production data, such grind and production data can be integrated by a RSMS to provide aggregate information used to evaluate production, perform vendor analysis, plan maintenance, track the state of specific equipment, etc.

For example, knowing how much stock was removed from a roll during a mill campaign and subsequent grinding operation to restore the initial surface profile and finish, as well as knowing the production that was made with that roll in the mill, the system can provide the productivity of the roll in kilometers of steel produced per millimeter of roll stock removal, or the roll cost per ton of steel produced. This information can be used to evaluate different roll suppliers not based on the purchasing cost of the roll, but on the actual cost of the roll when used in the mill, related to its production.

Similarly, the following is a typical list of reports that can be provided by a RSMS:

- Average roll cost per ton of steel produced for a specific roll material.
- Wheel cost per millimeter of roll stock removal.
- Total tons of steel produced with each roll.
- Total stock removal for each grinder or operator.

Figure 5



Comparing roll production graphically.

Armed with this information, it becomes possible to evaluate roll and wheel suppliers, or to evaluate the average production for different roll materials. Such information can then be used to facilitate the decision-making process in the purchasing department, as well as gain a better understanding of the mill operation.

As described up to now, a RSMS can handle rolls and grinding wheels, providing inventory, performance, statistics, vendor comparisons, etc. Information regarding wheels comes directly from the grinding machine, whereas information relative to rolls comes from the grinding machine and possibly from the mill system as far as production is concerned.

To manage other roll shop equipment, like chocks and bearings, assembly area functions must come into the picture. When bearings are assembled into chocks, chocks assembled into rolls, and rolls paired to be sent to the mill, this information is fed into the RSMS. The RSMS will thus be able to track the production, not only on the rolls, but also on the chocks and bearings mounted on them. This is useful, especially for maintenance and tracking purposes. When assembly area functions are used, other reports provided by a RSMS become available, for example:

- Total kilometers of steel produced with each chock.
- Total operating hours of each bearing.
- Maintenance plan for chocks and bearings.
- Tracking information for chocks and bearings.

Another feature usually available in RSMS when assembly area functions are present is the possibility to select the best roll to use as a mate with another roll. This is simple to achieve in a system that keeps track of all the diameters of all the rolls, as well as their profile, hardness, grind status and history. In a fully automated roll shop system, each roll, chock, bearing and wheel has a unique identification number to track its movements and record its operational history in a central database.

Maintenance and Tracking

Typically, chocks and bearings need some maintenance, and knowing the production relative to chocks and bearings can indicate when to perform maintenance on them. For example, if maintenance needs to be performed on a specific bearing every 10,000 km of steel produced in the mill, the system can show how much production is left before maintenance is required and issue a warning message when the limit is reached. These warnings can also be set on the total number of hours the chock was used in the mill, or on the number of tons of steel produced with the chock. Similarly, bearings are loaded onto the chocks with a specific rotation that changes from time to time, and the system can indicate the correct rotation each time (known as load zone). Such maintenance information is available on all chocks and bearings in the roll shop, and it can be queried at any time.

A medium-size roll shop could contain around 100 rolls, plus their chocks, bearings and grinding wheels. New rolls, chocks, bearings or wheels are regularly purchased. Keeping track of all this equipment, and especially what condition it is in, can be very complex. It might be useful, for instance, to know which rolls are ready to go to the mill in a specific stand and with a specific profile and hardness, or to know which rolls of a certain type need to be ground. A RSMS system offers many ways to visualize and sort this kind of information, providing a complete picture of the roll shop equipment.

Even a fully automatic roll shop needs occasional scheduled equipment maintenance and replacement of consumables, like the grinding wheel itself. A planned maintenance check can be timed to coordinate with the mill's overall planned maintenance activities, and a roll shop predictive maintenance system automatically informs the operators if they need to intervene with maintenance activities on the machine in the meantime. This can be done by conventional alarms on operator screens, and via Internet-based systems to alert supervisory or support groups.

Documentation and Multimedia Training

Documentation and manuals have also changed a lot with software technology. Today, help files are available on-line, making it possible to go directly via a few clicks of the mouse from an alarm message on a grinder, to a description of the problem, to a drawing or a photo of the mechanical or electrical part in question, to the list of possible remedies that can be applied. Manuals are supplied in paper and in electronic form, often in hypertext format.

Training has changed, too. Computer Based Training (CBT) is an interactive instructional approach in which the computer, taking the place of an instructor, provides a series of stimuli to the trainee, ranging from questions to be answered to choices or decisions to be made. The CBT can then provide feedback based on the student's response. This is particularly useful for new operators. Vendors usually instruct operators in steel plants on the use of new equipment, but when an operator joins the team later, it is difficult for him to catch up. CBT provides a fast start in understanding the basic functionality of a system, and can be used over and over at no extra cost.

Remote Service and the Internet

This is possibly the area that will bring the most benefit in the future for modern roll shop systems, but at the same time it is an area that is struggling to take off.

Remote service has been around for more than a decade. By using slow modems and expensive telephone calls to the other side of the world, machine manufacturers have been able to connect from their support centers to their customer sites, possibly in different continents, to diagnose and troubleshoot the computer systems. When this works, it enables the designers and technicians who built a roll shop to find and resolve problems quickly, in a matter of hours, without the added expenses in time and money for an intercontinental flight.

The downside of this approach, however, is that, as stated above, such connections are slow and expensive, the quality of the telephone link is usually low and the line often drops. For all practical purposes, it is difficult to track a problem to its solution via a remote modem connection alone.

Slow and expensive telephone/modem calls can be avoided with today's ADSL technology, where fast and cheap connections are easily obtainable, almost anywhere. Today it is possible to connect, for example, from a computer in Italy to another in China through cheap, local ADSL lines with a bandwidth in the order of megabits/second. ADSL is 10 or more times faster than a modem connection, at a fraction of the cost of international calls.

With such bandwidth, it becomes possible to connect to remote systems, perform a full troubleshooting session, analyze configuration data, even drive a machine from the other side of the world, as well as exchange live video to see the machine working or to instruct operators on, say, how to change a computer board. In a matter of minutes, many problems can be addressed and resolved, training can be delivered, and software patches can be applied.

There is one downside of this solution, or at least the perception of a downside, and that is security. The Internet is in many ways a dangerous network, where viruses, spyware and hackers abound, and where operators can be distracted from their daily tasks. To protect company networks, the safest approach often seems to be to avoid connecting to the Internet. The author has yet to see a roll shop with a permanent Internet connection, although temporary links at times have been seen to address specific issues. It is this author's belief that this will change in the future. There are already technologies that can be used to connect a local area network to the Internet, reducing security risks to a minimum, and this is probably already done in other areas of each steel plant. Typically, office workers have their PCs connected to the Internet through company networks, where security issues are carefully managed. Many types of remote connection software are available to connect to distant computers through the Internet, respecting the highest security standards, and cables can even be disconnected when remote assistance is not needed. Technically, the solutions are there, but they are seldom adopted. This is unfortunate, because the speed with which problems can be resolved through a fast Internet connection is unprecedented, and the value to the organizations, both customers and suppliers, is huge.

Summary

As in every field of technology, and especially the fields affected by advances in software, automation and electronics, there have been many advances in roll grinding technology in the last few years. Modern roll shops contain a very high level of automation, where less than one operator per machine is required. More importantly, the automation of the roll shop has moved from automating mechanical steps and leaving the decisions to the skilled operators, to automating the decisions themselves and requiring not only fewer but less-skilled operators. Today, automatic roll loaders receive the schedule of the rolls to grind from the upper level systems, decide how to move the rolls in the roll shop, decide how and when to grind them, pass them on to the grinder and then send them back to the mill, all with no or very limited operator intervention. Nondestructive testing systems detect smaller defects at greater depths with higher resolution and precision, and this information can be used by new software to classify the defect, making it possible to automatically decide how to grind a roll in order to eliminate the defect, while at the same time removing the minimum stock possible. Roll Shop Management Systems communicate to mill systems to receive production information, which is used together with grinding information to provide elaborate statistical reports that compare costs, perform vendor analysis, plan and track maintenance, and determine what roll is available in what condition for which stand. The Internet and related technologies make it possible for service engineers to drive, control, see and diagnose a machine that is working on the other side of the planet, and it is possible to set this up in a few minutes while sitting in a lab in the main company offices of the machine supplier. It is also possible to conduct live video conferences remotely to train operators on using the machine, or to provide operator training on multimedia devices, enabling new operators to learn how to use the machine without having to schedule new training sessions.

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