INTRODUCTION

The Rod Mill Billet Surface Quality Reporting System that was developed for Bethlehem Steel’s No. 3 Rod Mill was designed to provide a mechanism for tracking and reporting on the surface quality of rod mill billets so that management could ensure production of quality rod products. The system was developed over the past two years and was designed to fill the needs of the General Management, Quality Assurance and Operating Departments at both the Bar, Rod and Wire Division, which manages the mill; and the Sparrows Point Plant, which supplies most of the billets. The need for a reliable and comprehensive quality monitoring system at this mill was particularly acute because the billets are sourced from both ingot and caster steel produced at multiple locations. Even during normal operation, there are multiple points for inspection, surface preparation and rejection. This system was designed to monitor surface quality at all points, to relate any quality problems back to their appropriate source, and to compare the quality of billets from different sources (e.g. Johnstown and Sparrows Point Plants) and/or different processes (e.g. ingot and caster).

BACKGROUND

Before describing the billet surface quality system, we will start with a brief overview of the steelmaking process with particular emphasis on those aspects that impact the system. As shown schematically in Figure 1, the making of steel is a batch process which requires refining of molten iron to steel in one of three types of melting furnaces to remove impurities. The batch of liquid steel, which is called a "heat" of steel, will typically weigh about 250 tons when the refining is completed. This liquid steel is cast into a solid shape in one of two manners -- continuous casting or ingot pouring. In either case, the molten steel is transferred to a bottom-pour ladle for movement to the casting area. In the case of the newer continuous casting, the molten steel is poured into a trough-like reservoir called a tundish that controls the flow of the steel through a water-cooled permanent mold which controls its shape as it solidifies into a continuous ribbon-like slab of steel which is typically 8-10 inches thick by 36-86 inches wide and may be thousands of feet long if it involves the sequential pouring of a number of heats. In the case of the older ingot process, the molten steel is poured into a series of smaller ingot castings -- perhaps 2x4x8 feet. Each heat will produce about 20 ingots which are reheated in a soaking pit and rolled down to a bloom (essentially a rectangular slab) in a blooming mill. In either case, the slab/bloom is reheated in another furnace and then rolled down into a billet which, in the case of the No. 3 Rod Mill, would be 30 feet long with a four-inch, round-cornered square cross-section. These billets would, in turn, be reheated and rolled to rod which is a wire-like final shape that is typically 0.1-0.5 inch in diameter and is sold in 1000-5000 pound coils. The quality of the final rod is strongly correlated with the surface quality of the starting billet; therefore, to ensure the production of the highest quality rod, we must have billets with a defect-free surface.

As shown in Figure 2, the processing of billets into rod at the No. 3 Rod Mill involves both caster and ingot steel from multiple sources. Tracking and monitoring of billet surface quality is critical to ensuring the production of quality rod products.
quality is further complicated by the fact that the defects occur infrequently and, depending on the source and the final product, there may be multiple points for inspection, surface preparation and rejection. Therefore, a reliable and comprehensive quality monitoring system was required to collect, summarize and report surface quality data and relate the observed defects back to their assignable cause. For example, a billet shape problem would be related to a specific operation in the billet rolling process whereas other defects would be related to the steelmaking, casting, or ingot-rolling processes.

SYSTEM OVERVIEW

The system was designed in cooperation with the users as a four-step operation to minimize interference with other rod mill operations. All four operations -- data entry, data validation, file building and report generation -- were combined into one user-friendly, menu-driven, SAS-based computer system. It will handle billets produced by different sources and, when appropriate, will generate separate summary reports for each source. Standard classifications of defects and billet steel grades were established as part of the development of this system. User ID-level security is used to restrict access to the data-entry and file-building functions while allowing general access to the report generation functions and reading the data files for generating ad hoc reports. Finally, the system includes extensive on-line and written documentation as well as a large number of Help screens to aid the users.

Data entry is simplified by using formatted (i.e. fill-in-the-blank) screens that emulate the arrangement of data on the existing grinder surface preparation and magnaglo inspection production reports from the conditioning areas. Scrap data are also collected from the billet receiving and storage yard reports and from the rod mill's inventory and billet charging systems. In order to minimize interference with other users while maintaining the highest degree of data accuracy, all data are initially stored in transaction data files for validation and correction of any errors before they are added to the process and heat summary data files. These latter historical summary files are well documented and will be retained indefinitely to serve as the basis for future inductive studies to relate quality to metallurgical and process parameters.

Eight different kinds of standard reports are included in the system. These reports range from detailed quality engineering reports through successive levels of increasingly summarized management information, quality trend and scrap summary reports. The quality engineering
reports are used by the Steelmaking and Primary Mills engineers to relate quality and process changes and generate SPC charts on a heat-by-heat basis within grade groups. There are two distinct formats used for the engineering reports depending on whether the billets from that group are normally sent to billet conditioning or used directly from the Primary Mill. In addition, to permit the quality engineers to focus easily on a specific problem, the detailed reports can be limited to a specific grade group of billets and/or a specific time period by proper choice of run-time options.

SYSTEM DESIGN

The system was designed as a four-step operation consisting of data entry, data validation, data file building and report generation. It was configured in this manner to minimize interference with other rod mill operations. The data entry should be done in a timely manner, preferably daily, while the data validation and data file building steps need be done only several times a week on a time-available basis or as needed for report generation. All reports may be run on a demand basis.

The data validation procedure checks for data consistency and mathematical accuracy. For example, data from the steelmaking chemistry file and the primary mills system are used to determine if the heat numbers and grades are valid. Also, since billets are scrapped for specific reasons, another one of the checks determines if the total number of scrapped billets is equal to the sum of the number of billets scrapped for each specific reason.

Four TSO cataloged sequential quality history files are generated by the system. These files consist of three files that record the daily quality information for the grinding, magnaglo and yard areas and a fourth file that contains a summary of the performance of each heat.

The system is written in SAS using the SAS/AF facility, which is a user-friendly system of menus and fill-in-the-blank screens that allow the user to generate reports, and from certain authorized IDs to also enter, edit/browse data and run programs to update the permanent Rod Mill data files.

Help screens are available from almost anywhere within the system. Screens that do not accept user input anywhere except on the command line have one level of help, whereas screens that will accept user inputs from other parts of the screen contain two levels of help.

SYSTEM OPTIONS

As shown in Figure 3, the reporting system has been divided into six major functional areas -- three that are available to the general user community and three involving data entry and file generation that are limited to a select few authorized users. These system options have been translated into two SAS/AF main menus -- one for the restricted users that contains only the first three options and the other one for the authorized users that contains all six options.

Figure 4 shows the latter, six-option SAS/AF Main Menu -- the one that is restricted to certain computer users. All other users, (i.e. those who do not have authorization to edit or update files) will see a similar screen that shows only options 1 thru 3.

FIGURE 3. System Overview

FIGURE 4. SAS/AF Main Menu

General Options

As discussed above, the first three of these system options are available to all users.

SYSTEM OPTIONS 1 & 2

The first two options are self explanatory. Option 1 will give some general instructions concerning the use of the system -- essentially an on-line version of the user's manual; option 2 permits browsing of the layouts of the four main data summary files that are generated by this system.

481
SYSTEM OPTION 3 - Generating Reports

When option 3 is selected, the screen shown in Figure 5 will appear. The main function of this screen is to allow the user to change the default values that will be entered on the job card which will be submitted as part of the batch job that will be run to generate the reports. Any changes to these data fields, which are initially set to the values in the user's TSO profile, will be in effect for the entire session or until changed on a subsequent screen.

Command

BILLET QUALITY REPORT PRINT OPTIONS

- The information on this screen is used to route your output to the proper location.
- If the default values shown below are correct press PF5/PF11 to continue, if not type over any information that you wish to change and then press PF5/PF11 to continue. If you need more help move to the cursor to the command line (press PF13/PF14) and type HELP or press PF1/PF11.
- For HELP on a particular field place the cursor on that field and press PF1/PF11. To leave without submitting press PF7/PF11.

Print ID Name Location xxxxxxx.xxxxx
Print Class Q = Queue W = Printer N
ACCT. NO. xxxxx

FIGURE 5. Buffer Screen

This screen is followed by the one shown in Figure 6. From this latter screen, the users can run any or all of the eight reports listed. However, if all eight reports were selected the output would be quite voluminous; therefore, we have provided several mechanisms for limiting the scope of the reports (e.g. classifying the grades into standard groups). Specific reports are selected by placing an X in front of the group number. If any of the first three reports are to be run for a specific grade group, fill in the group number; otherwise, leaving 000 as the group number will generate the report for all appropriate groups. For a list of group numbers the user can position the cursor on the group field and press PF1. A list of the appropriate groups will be displayed.

Command

BILLET QUALITY REPORT SELECTION SCREEN

- 1. Report Summary Report
- 2. Report for a Specific Group
- 3. Report for Group
- 4. Quality Trend Charts
- 5. Billet Quality Reports
- 6. Primary Mill Quality Report
- 7. Primary Mill Scrap
- 8. Primary Mill Scrap

FIGURE 6. Report Option Screen

Whenever a job is submitted to generate any reports from Option 3 a banner page will be created and printed as the first part of the package of reports. It will show which reports were created, the date and time of creation and any limiting criteria such as plant, group and time period contained in the reports.

Report option 1 will generate a series of very detailed quality engineering reports (such as the one shown in the top portion of Figure 7) that list every heat processed grouped into standard grade groups. There are two distinct formats used for these reports depending on whether the billets from that group are normally sent to billet conditioning or used directly from the Primary Mill. The reports will print out 44 heats per page and will use as many pages as required. If only one specific group of billets and/or a specific time period is being studied, the report may be limited to that specific group and/or time period by entering the desired group number and/or dates in the indicated data entry fields. Help screens are available to aid in the selection of the group number.

Report option 2 is similar to option 1 except that it will also include Statistical Process Control ("SPC") charts such as the one shown in Figure 8 for every heat processed grouped into the standard grade groups. These SPC Shewhart charts are generated for three different flaw depths and the percentage of billets scrapped. This option will also generate two different kinds of tabular reports and, as in option 1, may be limited to a single group and/or time period by appropriate selection of the input options.

Report option 3 produces a one-page-per-grade-group report such as that shown in the middle portion of Figure 7 that summarizes the monthly, quarterly and yearly performance of all of the billets that are in that group. As with the previous two options, there are two distinct formats used for these reports depending on the billet conditioning requirements, and the report can be limited to a specific group by proper choice of the input options.

Report option 4, by contrast, also produces a summary report but, in this case, as shown in the bottom portion of Figure 7, we are summarizing the performance of every grade group on a single page-one page for the specified time period and/or one page for year to date.

Report option 5 is a departure from the previous four options that generate tabular quality engineering data, in that it generates management quality trend charts. As shown in Figure 9, the trend chart generated by this option contains three curves: one each for total scrap, rod mill scrap and primary mill scrap. The reporting period is determined from input options. The data from the previous year will be plotted on a quarterly basis while the data from the current year will be plotted on a monthly basis. This graph contains three curves showing percent defects at three quality levels for the overall production and for each functional subset of the data.

Report option 6 produces a management quality summary report for a specified time period which, by default, is generally biweekly. As shown in Figure 10, these reports present a composite summary of the quality for the specified reporting time period and compares that data with
FIGURE 7. Sample Heat History Reports from Options 1, 3 and 4

FIGURE 8. Sample SPC Shewhart Chart
The indicated two-week time period. To conserve time we chart shows individual defects as a percent of production for the year-to-date, and the lower portion of the chart shows individual defects as a percent of production for the indicated two-week time period.

FIGURE 9. Sample Quality Trend Reports from Option 5

FIGURE 10. Sample Bi-Weekly Quality Reports from Option 6
have limited the example to just the top and bottom reports. Separate charts are generated for all scrapped billets: the billets scrapped at the Primary Mill and the billets scrapped at the Rod Mill.

Report option 7 produces a two page summary of the billets that were scrapped in the specified time period. As shown in the top half of Figure 11, the first page summarizes the total number of billets scrapped by category while the second page (bottom half of Figure 11) summarizes the scrapped billets by heat, grade and the reasons for scrapping them. This report serves as the vehicle for requesting reimbursement for defective material.

Report option 8 is a two-part summary of primary billet surface quality data for all billets produced within the specified time period which, by default, is generally weekly. The first part of this report, shown in the top half of Figure 12, is a listing of the data for every heat produced and is summarized by day and production method (i.e. ingot or caster). The second part of the report (bottom of Figure 12) is a daily summary of the quality and production data.

Data Entry/Validation/Updating Options

As discussed above, these options are restricted to a small number of specifically authorized and trained users.

FIGURE 11. Sample Scrap Reports from Option 7

FIGURE 12. Sample Billet Rolling Mill Reports from Option 8
13 is a flow chart showing the general organization of these three related options. As discussed above, because all of the data are entered from handwritten reports generated by a number of different people, they are first read into a temporary file and are validated before being added to the system's performance summary files.

FIGURE 13. Data Entry/Validation/Update Functions

SYSTEM OPTION 4 - Data Entry

There are three different kinds of data entry screens required to cover the three different types of operations (conditioning, inspection and acceptance) accessed through Option 4 (Ref. Figure 4) and all three of them were written in SAS/FSP. The data files may be browsed or edited using the selection screen shown in Figure 14. All three of the data entry screens were formatted to closely resemble the printed forms that had previously been used for manual reporting purposes. As an example, Figure 15 shows the input screen for the grinder billet conditioning area. These screens save the data as files that are in the form of three SAS permanent data sets so that the data can be validated before being added to the system's performance summary files.

FIGURE 14. Data Entry Option Screen

SYSTEM OPTION 5 - Generate Exception Reports

As with option 4, this option is also restricted to authorized users and, although it is shown in Figure 4, it will not even appear on the option screen seen by the general user community. Its function is to identify questionable data and generate an exception report that suggests corrective action. For example, it checks that valid reasons are provided for every scrapped billet and that the heat number and grades are valid. It also checks previous entries for each heat to determine if more than one grade had been specified or if more billets had been processed that had been produced. Any errors identified in these reports must be corrected before the data are used to update the database.

SYSTEM OPTION 6 - Database Builder

This option is also restricted to authorized users and serves to update the four system data summary files. An update request confirmation screen is included to avoid inadvertent updating of the files.

SUMMARY

The Rod Mill Billet Surface Quality Reporting System, which is written in SAS/AF, was designed to include data entry, data validation and report generation functions in one user-friendly, menu-driven system. The system uses formatted SAS/FSP screens to simplify data entry by emulating the arrangement of data on the existing production reports. All data are initially stored in transaction data files for validation and correction of any errors before they are added to the history and summary data files. Data validation is done at both data entry time and through use of a user-controlled validation program. At key entry time, all pertinent tests available in SAS/FSP (minimum, maximum, character/numeric and required fields) are used to assure that the data are reasonable before they are even added to the transaction file. A diagnostic program is then used to compare the new data with information in the production data files to detect inconsistent or erroneous data. Eight different kinds of standard reports are included which range from detailed quality engineering reports through successive levels of increasingly summarized management information reports. In addition, all data are maintained in a series of formatted files to facilitate ad hoc inquiries.