Installation of integrated computer systems to optimally manage coil inventory and to build optimized stacks from that inventory has resulted in higher shop throughput, consistent product delivery, and workforce reduction thus providing short-term return on investment and long-term continued cost savings.

Optimization of Coil Storage and Stack Building for Bell Annealing

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In order to optimize material flow at the US Steel hydrogen annealing facility in Dravosburg, PA, the Bell Annealing Stack Builder (BASB) was installed to build optimal stacks from a large inventory while simultaneously guaranteeing that coils were delivered on time. Moreover, in order to know where a given coil could be found within an inventory of several hundred, the Bell Annealing Coil Tracker (BACT) was employed. These two systems were interfaced to an existing charge request generating program. Using touch-screen equipped radio frequency terminals (BACT), crane operators track the movement of each and every coil from conveyor to location, location to other location, and finally location to rail car for shipment to an annealing base. BASB builds optimal stacks from existing coil inventory whenever a charge build request is received from the USS computer system. The result has been smoother material flow, better heats in terms of tons/hour, and substantial productivity improvements.

Optimized Stack Building - BASB

The primary goal of this system implementation was the optimization of coil stacking. USS recognized that more production could be accomplished if furnaces were used at capacities closer to their maximums. Moreover, through optimized cycle mixing, USS believed that cycle times could be shortened overall.

Drawbacks of Manual Stack Planning—

The system in place prior to this undertaking involved purely manual stack generation. Because inventory levels could exceed several hundred coils, optimization by even the most intelligent individual was simply not possible. Stacks were typically generated once per turn (i.e. every 8 hours) by the floorman. Since the annealing shop is a 24x7 operation, 4 employees were required to man the position. Moreover, the crane operator's schedule would be generated in a batch mode once every 8 hours. Consequently, his workflow could easily change from being heavy (i.e. building several charges and moving coils from the cold mill conveyor into inventory) light. Finally, because the stack planning was done essentially once every 8 hours, this restricted the planner's ability to be flexible in responding to production outages, material availability changes, cold mill schedule changes, or changes to customer orders (e.g. rush or hold).

BASB System Benefits—

It was clear that an automated stack building program could benefit in several ways including:

- Increased through-put due to maximized stack height and weight. BASB maximizes stack volume relative to theoretical maximum volume of inner cover and weight capacity of base.
- Increased through-put and lower production costs due to optimized heating times. BASB avoids mixing cycles/qualities that would unnecessarily extend heating times.
- Avoidance of "Orphan" coils. BASB recognizes coils which fall outside of the norm relative to weight, O.D. and/or quality. Because BASB can "look ahead" to see the consequences of not choosing an orphan coil, it can make the best choice possible when deciding which other coils should be annealed with the orphan thus minimizing the impact of the orphan on productivity.
- Guaranteed delivery. BASB makes certain that coils approaching their respective delivery dates are given a higher priority and are therefore more likely to be chosen for a stack.
- Guaranteed selection of high priority coils when building stacks.
- Smoother work flow because stacks would be generated "on the fly" as needed rather than once per shift.
- Significant productivity improvement.

BASB Operational Summary

BASB is triggered by an external program whenever a charge is required. This normally occurs when a base is within a few hours of being split (unpacked). BASB begins by considering the available coils in inventory and sorting them by the various coil properties listed below.

Coil properties considered when building a stack include:

- Coil weight
- Coil height (i.e. strip width)
- Coil outside diameter

- Coil inside diameter
- Coil quality/cycle
- Date coil should be delivered
- Amount of time coil has already spent in inventory waiting to be annealed
- Coil priority (e.g. coil is for a high priority customer and should be taken sooner)
- Anticipated annealing time - based upon quality/cycle and weight of coil
- Coil availability - can be used to restrict selection of coils from inventory when coil inventory management system (BACT) is used

Next, BASB organizes these coils into stacks which are then sorted by their respective "goodness weights." The goodness weight is calculated by a complex algorithm based upon user definable weighting factors, which are applied to the individual criteria listed below.

Factors considered when evaluating the relative "goodness weight" of a stack include:

- Stack weight vs. maximum allowable stack weight
- Stack height vs. maximum allowable stack height
- Stack topography, i.e. stack must not have inverted pyramid shape
- Stack priority based upon constituent coil priorities
- Stack quality, calculated using customer's custom cycle mixing rules
- Stack heating throughput (tons/hr) calculated from individual coil weights and qualities
- Stack delivery deadline, equal to that of the constituent coil with the shortest delivery time
- Stack volume
- Time already in inventory, equal to that of the constituent coil with the longest time already in inventory
- Accessibility of constituent coils based upon current location in inventory

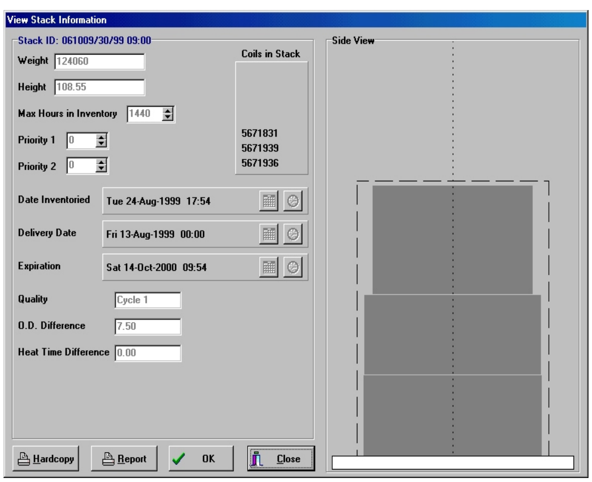

Figure 1 - Detailed View of Stack Created by BASB

The resultant stack with the highest overall goodness weight is then chosen and reported back to the USS planning system. The charge is added to a line-up of charges that must be pulled from inventory, placed onto rail cars, and finally sent down to the annealing base to be charged. It is also possible to force BASB to build a stack that includes one or more specific coils. For example, suppose BASB has built a charge from coils A, B, C and D. Subsequently, coil B is damaged by the crane operator. BASB can now be asked to form a stack using coils A, C, D along with whatever else it can find available in inventory.

Initially, BASB was installed and run in parallel to the existing manual stack building. While the manually built stacks were still used for production, those stacks created by BASB were logged as well. After several months, the stacks created were compared with the following results:

- BASB improved overall throughput (i.e. tons/hour) by 5% due to optimized loads as well as better cycle mixing thus holding anneal times to a minimum.
- BASB improved product delivery consistency by making certain that no coil missed its "next facility" delivery date.

Coil Inventory Management - BACT

Although it is possible to derive benefits from a stand-alone stack building program like BASB, the results can be dramatically improved with the integration of a coil inventory tracking system. Such a system provides a real-time inventory locator database whereby the location of each and every coil is known.

BACT Operational Summary—

Inventory management is a problem in any manufacturing operation. Knowing what one has and where it is located is absolutely necessary to have an efficient operation.

BACT consists of a man-machine interface both for crane operators and for floormen. The crane program runs on a touch screen equipped computer located on the crane. This computer communicates with the database server using radio frequency (2.4 GHz spread-spectrum) ethernet.

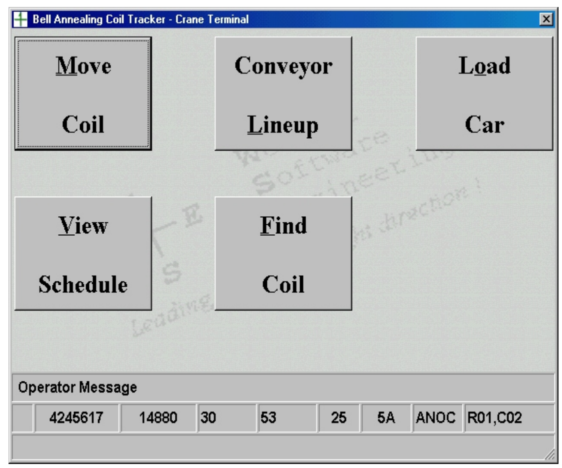

Figure 2 - BACT Crane Terminal Main Screen

The application provides functions to be used by the crane operator whenever a coil is moved from point A to point B. Such moves include:

- Lifting a coil from the incoming conveyor and placing it into an inventory location (identified by column/row and position in stack)
- Moving a coil from one inventory location to another
- Moving a coil onto a railcar to be subsequently charged onto a base
- Marking a coil as being "On Hold" or "Not-in-Annealing"

In addition, BACT provides a line-up of charges that have been built by BASB. When the crane operator wants to pull coils for a charge and place these onto a rail car, he simply touches the coil listed on the line-up and then presses a button on the touch screen to indicate that he has set this coil onto a rail car. When all coils in a given charge have been placed on a car, BACT sends a signal to the USS computer system indicating that the charge has been "shipped." The charge then later appears on a screen for the annealer to select for charging onto a base.

BACT also provides a line-up of coils on the conveyor coming into the annealing shop inventory area. When the crane operator wants to lift a coil from the conveyor and place it into inventory, he simply touches that coil on the list and then enters the two-digit row and one-digit column indicating the inventory location where the coil was set. BACT automatically recognizes the coils that were already in that location and "stacks" the new coil on top of them. BASB can then recognize the amount of coil "digging" that would be required to use a given coil in a stack and can then minimize this material movement. Minimizing the number of times a coil needs to be moved obviously reduces the chances that the coil would be damaged.

Future BACT Enhancements—

In order to improve reliability and accuracy, the BACT crane system could be enhanced with an automated crane positioning system. Such as system would provide dynamic (X,Y) crane position information. Therefore, the crane operator would need only indicate that he is performing a coil lift or set operation. Since BACT would know which coil was at a given location, it would also know which coil was lifted. In addition, when the currently loaded coil was set down, BACT would know whether it had been set on a rail car, into a storage location, or back onto the conveyor.

In situations where inventory space is limited, BACT could suggest an inventory location where a coil should be set. To do so, BACT would look ahead using some of the same criteria used by BASB to build stacks. It could then derive the best possible inventory location to minimize the amount of coil digging that would be required later on to build a charge. For example, all things being equal, BACT would not suggest placing a coil on top of a second coil if the second coil's delivery date was sooner than that of the coil being set down. BACT contains logic to make these suggestions but must have an accurate picture of coil inventory and coil positions within that inventory.

Summary

The integration of both BASB and BACT has resulted in significant process efficiency enhancements. No longer is it possible for a coil to be misplaced and not annealed on time. In addition, since coil locations are tracked, material movement is greatly reduced thus minimizing the chances for damaging a coil. Due to optimized coil stacking and cycle mixing, annealing charge throughput (i.e. tons/hour) has been increased. Finally, since process planning is now automated, improved efficiency and productivity were possible thus justifying the short-term costs for the implementation of the BASB and BACT systems as well as providing continued, long-term cost savings for years to come.