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Presented by RAD-CON, Inc
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TAKING BATCH ANNEALING OPTIMIZATION TO THE NEXT LEVEL.

Abstract

More efficient BAF operation not only increases throughput and profitability but also improves scheduling and effectiveness of downstream operations. With the current use of software for stacking, heating and cooling cycle optimization, anneal facilities are achieving significant efficiencies.

Yet, today more than ever, the need to squeeze out more at every turn is critical.

So what can be considered the next generation in anneal optimization? And how can more output be obtained without adding manpower or equipment?

The current focus of optimization typically emphasizes improving software involved with inventory management and heating/cooling cycle management. But in taking a broader view of the anneal shop, a new optimization model more demonstratively directs the diverse activities on the shop floor to optimize operations, crane and equipment, and floor operator and general manager efficiency.

There are two steps for this new, next generation optimization.

First is *Shop Optimization*—which utilizes heating, cooling and stacking model outputs—but goes further by determining the most efficient use of man and machine by identifying and minimizing the delay of the constraint resource.

Second is *Operations Planning*—which directs resource activities according to the Shop Optimization output, such as real-time task assignments to the crane, floor, and furnace operators. With the addition of a crane (locator), navigational functionality is available that

maximizes efficiency of crane movement. Together, this new model provides the highest utilization of assets in the BAF.

This new model squeezes more out of HN or hydrogen BAF, even those operating a mixture of equipment manufacturers.

RAD-CON will present the benefits of their Shop Optimization and Operations Planning software to be installed as part of the BAF portion of the New CRM project at SAIL's Bokaro Steel Plant.

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Introduction

To remain competitive in the current economic climate, steel companies need to focus their attention on the cost of production. This challenge will be complex as the economy recovers with reshaped markets and as new and idled steel capacity is brought back on-line. The ability to be flexible and operate efficiently during these dynamic market conditions will be key factors to turning a profit.

SAIL's project in Bokaro for a new Cold Rolling Mill (CRM) complex includes cutting edge automation to control operating costs while maintaining the flexibility to adapt to changes in the market. The mill, which is designed for automotive applications, will utilize RAD-CON's Batch Anneal Furnace (BAF) modeling capabilities to easily shift product mix without equipment changes or production disruptions.

Bokaro will operate with the new CAPS™ Shop Optimization Model which builds on the process models previously developed by RAD-CON to optimize the heating and cooling times of the coils as well as the stacking arrangement of charges. Shop Optimization takes a broader view of the anneal shop to include the equipment, cranes, and operating personnel. The model not only creates a plan to optimize the process but also implements the plan through real time communications to the cranes, transfer cars, and personnel.

This new software further optimizes the process to maximize throughput capacity, minimize operating costs, and maintain the highest level of mechanical property consistency.

BAF Optimization

There are three layers of optimization that apply to the anneal shop, each layer building on the previous. The first layer addresses the coil and control of the heating and cooling processing manner. The second layer of BAF Optimization addresses the grouping of individual coils into batches or charges, considering each individual coil's needs as well as the charge as a whole. Finally the third layer takes into account the charges along with the equipment and manpower in the shop to arrange and manage the complete shop. It is from this third layer that new efficiencies are being achieved in the BAF through the addition of optimization modeling.

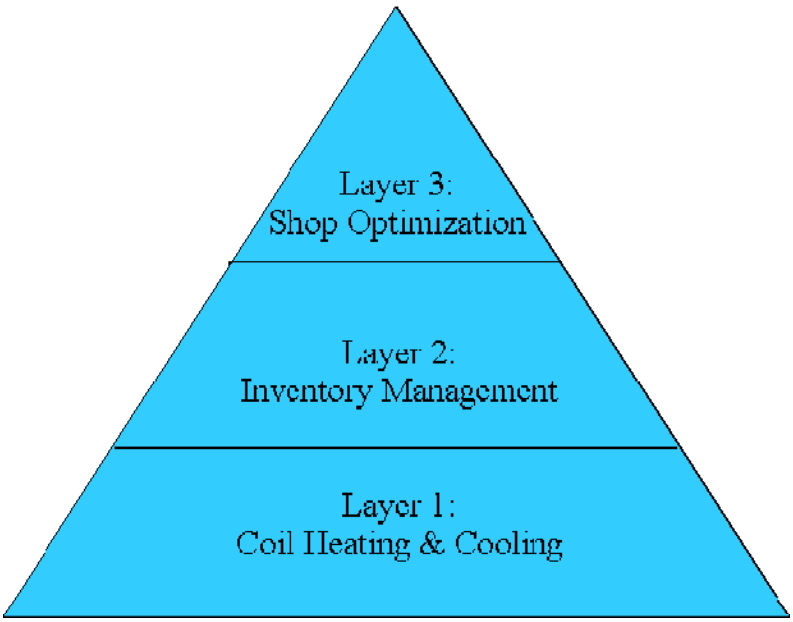


Figure 1: BAF Optimization Layers

The activities addressed by each of these layers are handled at every shop with either manual decision making or with the use of production models. RAD-CON's Computerized Annealing Process Software (CAPS™)—which is used to process over 50% of all batch annealed sheet steel in North America--handles each of these layers with different software modules. RAD-CON's newest software improves the efficiency of Layer 3 by minimizing the processing time of coils within BAF and therefore reducing work-in-process inventory, increasing predictability of the system, and most importantly maximizing the throughput capacity of the shop.

Improving Shop Performance with Optimization Modeling

When shop management is handled manually, there are a large number of variables for the personnel to consider in order to optimize the operation. The person managing the shop is typically just trying to keep everything moving and has little time or ability to develop and manage a plan much beyond the current turn. The larger the shop, the more difficult this is to coordinate and the more inefficiencies that sneak in.

RAD-CON's approach increases shop capacity instead of just managing tasks within the shop. Since CAPS™ has information about the shop such as processing times for each charge, equipment availability, manpower, as well as productivity targets, a plan can be developed and implemented that not only keeps everything moving for the current turn but reduces delay time, shortens processing time, decreases work-in-process inventory and increases shop capacity.

Shop Optimization Plan

First an optimized Shop Plan is generated. The software uses the heating, cooling and stacking model outputs to determine the most efficient use of resources. The resource with the least capacity is determined from the current inventory and equipment information maintained in CAPS™. Protecting this bottleneck resource becomes the primary focus of the plan.

The Shop Plan is developed using Mixed Integer Linear Programming (MILP) which is a technique for determining the most efficient method for allocating resources while still meeting all of the system constraints or rules. In LP an objective function is developed and the LP solver is asked to either minimize or maximize the function. The result is a solution that minimizes delay time of the bottleneck resource which will give the maximum shop throughput.

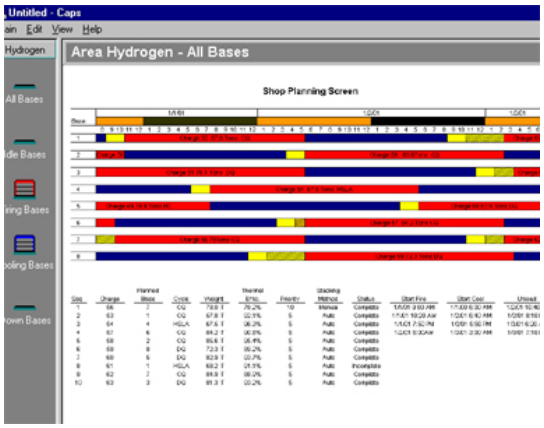


Figure 1: Shop Planning Overview Screen

The operator views the plan through a Gantt chart view of the base overview screen. This chart shows a blend of the current status of the shop along with the planned future arrangement of charges and equipment. The operator is allowed to modify the plan to accommodate trials, maintenance, or other specific requests.

Operations Planning

Now that a plan is developed, it needs to be implemented. The Operations Planning module directs resource activities according to the Shop Plan, such as real-time task assignments to the crane, floor, and furnace operators. With the addition of a crane (locator), navigational functionality is available that maximizes efficiency of crane movement.

The software works like a navigation system for BAF operation, planning the sequence of activities for the operators, cranes, and transfer cars to avoid conflicts that would delay the completion of a task.

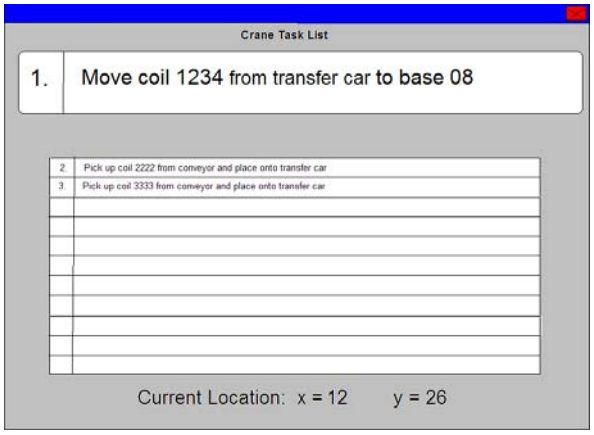


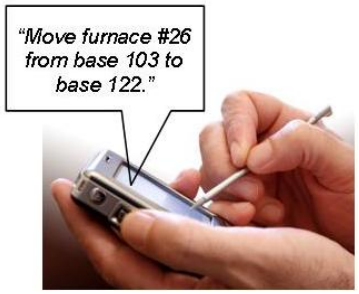
Figure 2: Crane Task List

For example, in a shop with multiple cranes, the crane activity must be coordinated to make sure that they do not interfere with each other and more importantly that they work

together to complete the high priority tasks. Each crane has a task list of items to be completed that is dynamically updated based on task completion and other events in the shop. If one of the cranes is taken out of service then the tasks are redistributed.

Similar information is provided to the floor operator via a handheld Portable Digital Assistant (PDA). Since the information is available to the operator while they are on the shop floor, they are able to spend more time completing assigned tasks instead of constantly checking back to the control room to decide on the next task. Also, since the computer is determining the task sequence the operator will be assigned the proper tasks required to meet the Shop Plan requirements.

Figure 4: Operator Receiving Message on PDA



The PDA is also used to collect information relating to the operators activity. Coils are scanned to avoid identity mix ups and manual tasks such as verifying tank levels or safety checks are input from the location that the activity is completed instead of recorded later. This allows each operator to be more productive which can reduce the number of operators necessary to run the shop.

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Layer 3 optimization, with RAD-CON's Shop Optimization and Operations Planning modules, provides the highest utilization of human and equipment assets in the BAF. Like all of the CAPS™ models, Shop Optimization increases throughput, decreases operating costs, and improves product quality.

Bokaro BAF

Bokaro Steel Plant, a Steel Authority of India company, located in Jharkhand, INDIA is currently installing a complete hydrogen bell-type batch annealing facility that will be the most advanced BAF in the world, in terms of overall productivity efficiency. When completed, the facility will process 860,000 tons per year of cold rolled steel, primarily destined for the automotive market, using only 47 bases. The product mix of grades is as follows:

Mix [%]	Grade	Description
10	CQ	Commercial Quality
20	DQ	Drawing Quality
30	DDQ	Deep-Drawing Quality
20	EDDQ	Extra-Deep-Drawing Quality
10	IF	Interstitial Free
5	HSLA	High-Strength Low-Alloy
5	BH	Bake-Hard

RAD-CON is overseeing the complete production and turnkey installation of the company's H_2SHC™ (100% Hydrogen Super-High Convection™) annealing system consisting of:

47 bases with 2m charge diameter and 6.5m stacking height;

26 mixed gas fired furnaces;

20 air/water coolers;

49 base post-cooling facility for de-humidified air cooling;

- **All associated controls.**

The project features the tallest stack for 508mm ID coils, utilizing RAD-CON's unique high pressure Super-High Convection™ system. The system at Bokaro combines the leading convection system with the leading thermal modeling system, CAPS™. The Shop Optimization system merges equipment and models, to maximize output of the combination. In addition to productivity, the matching of coils at schedule-time also reduces variability—giving consistent quality that should give pause before committing to systems based on CAL.

Managing an anneal shop of this size requires detailed and sophisticated systems and controls. Therefore, as an integral part of the project, the Bokaro facility will utilize CAPS™ Optimization Software, to control the entire anneal process. The complete software suite includes CAPS™ models for, Stacking, Heating and Cooling as well as the new Shop Optimization model. CAPS™ interfaces with the facility's level-3 data to schedule every movement of each coil from the time it passes the anneal bay doors through every phase of the process—including instructions for cranes and coil car operators to ensure full utilization. The software will provide Bokaro with optimized coil selection and stack charging, reduced cycle times and maximum facility and manpower productivity.

A large annealing shop like the one operated at BSL requires diligence in order to fully utilize the assets. Planning for the utilization of the 47 bases, 26 furnaces and coolers, three cranes, multiple transfer cars, and different levels of personnel is done with RAD-CON's Shop

Optimization module in CAPS™.

Coils are received from the Pickle Line-Tandem Cold Mill (PL/TCM) and Electrolytic Cleaning Line (ECL) conveyors and tracked by CAPS™ until the coils are removed by the Skin Pass Mill (SPM) from the soft coil storage area. All equipment and coil locations are maintained in CAPS™ through communication to and from the cranes and transfer cars. CAPS™ coordinates the activities for the entry conveyors, cranes, and transfer cars to move coils to the different processing and storage locations.

Coils are automatically built into thermodynamically efficient charges to improve throughput and also reduce coil to coil temperature variability, giving the most favorable mechanical property performance. The charges are planned on a base by the Shop Optimization Model and as discussed above, tasks are distributed to the appropriate crane and floor personnel to process the charge.

At Bokaro most of the operator tasks are automatically verified by the system without the need for operator input of information into CAPS™. For example, when the operator is asked to disconnect the furnace, the PLC notifies CAPS™ when the task is complete. This allows the Operations Planner to permit the crane to move the furnace. CAPS™ also knows the exact location of the furnace and since the crane has a positioning system, CAPS™ sends the furnace coordinates to the crane and the crane is sent to that location. This eliminates the possibility of moving a furnace that has not been disconnected and also minimizes the wait time between the tasks.

Conclusion

The introduction of the Shop Optimization model addresses the final BAF layer—management of the shop—to make the shop equipment and personnel as productive and efficient as possible. The software allows the BAF to operate with fewer employees, provides significantly improved communication and assignment of tasks, reduces incidents of human error, improves equipment and manpower utilization, increases throughput capacity, lowers production costs, and improves quality levels. In addition, BAF production becomes more predictable and effective which enhances the efficiency and effectiveness of downstream operations. The Shop Optimization model can be added to existing shops or new RAD-CON installations that utilize CAPS™ Heating, Cooling and Inventory Management modules.

All of the CAPS™ models help to improve mechanical properties. The Heating Model accurately calculates core temperature of each coil in the charge and dynamically ends the heating phase when the critical coil has received enough heat. The Stacking Model balances core temperature requirements to build charges with the least variation at the end of the process. Finally, Shop Optimization synchronizes man and machine to ensure that furnaces are not left on bases to overcook the steel.

The RAD-CON supplied BAF and CAPS™ optimization suite will allow Bokaro Steel to provide highly consistent product quality to the automotive market at lower delivered cost than competitors using Continuous Anneal Lines (CAL). Bokaro's willingness to embrace this new technology is indicative of India's progressive approach and the resulting industrial growth that is helping to raise the world out of its recession. For the Indian steel companies, this growth will mean opportunities to develop new markets and expand production. The inevitable addition of

cold rolling capacity will drive the development of associated annealing facilities which will significantly benefit from improved control and optimization.

RAD-CON has a proven record of providing effective optimization software for BAFs. The Shop Optimization Model continues that tradition with next generation process management.

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