Reinventing the (product) wheel

Scheduling strategy makes for better flow

By Peter L. King and Jennifer S. King

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Industrial engineers often are called upon to help operations managers decide how to resolve the challenges that today's dynamic markets present. How can we be ready to respond quickly to normal demand upswings but not waste resources in periods of low demand? How do we determine the product sequence that minimizes the total cost? How frequently should we schedule each product? Which products should we make to stock and which should be made to order?

Product wheels provide an integrated, holistic, time-proven methodology to respond to these challenges. Product wheel design creates a structured pattern for all products, arranges the mix in the optimum sequence, finds the optimum leveling period for each product, and allows for the appropriate amount of each product to be made at its turn in the sequence. Chemical, paint, pharmaceutical, synthetic rubber, sheet goods and automotive fluids companies have found that wheels reduce order fulfillment cycle time, improve customer service and reduce inventories, all while bringing a higher level of regularity and predictability to operations.

Product wheels and versatility

A product wheel is a visual metaphor for a structured, regularly repeating sequence of the production of all the materials that will be made on a specific piece of equipment, within a process system, or on an entire production line. A sample wheel, along with its associated terminology, is shown in Figure 1. The overall cycle time for the wheel is fixed. The time allocated to each product (a "spoke" on the wheel) is relatively fixed, being based on that product's average demand over the wheel cycle. The sequence of products is fixed, having been determined from an analysis of the path through all products that will result in the lowest total changeover time or the lowest overall changeover cost. The spokes can have different lengths, reflecting the different average demands of the various products. High demand products will have longer spokes than lower demand products.

Product wheels support a pull replenishment model. That is, the wheel will be designed based on average historical demand or on forecast demand for each product, but what is produced on any spoke is just enough to replenish what has been consumed from the downstream inventory. This accords with lean pull principles. Thus, the width of each spoke can vary from cycle to cycle based on actual demand, but the total wheel cycle time will remain fixed.
A number of factors can influence the determination of overall wheel time. If short lead-times are paramount, then the shortest wheel time that allows for all required production and all necessary changeovers should be selected. If lowest manufacturing cost is a key driver, then the wheel time can be calculated to give the best balance between changeover costs, which decrease with longer wheels, and inventory cost, which increases with longer wheels. Other factors, such as product shelf life, short-term variability and minimum lot size requirements also might come into play. The most important requirement is that once the wheel time has been

selected, it must remain constant until conditions change enough to require a recalculation of wheel parameters.

The wheel time generally will be selected based on what makes most sense for high-volume products. Lower-volume products will be made at a frequency that makes sense based on their volume; they may be made on every second, third or fourth cycle. Very low demand products, particularly those with highly variable demand, might be made only when specific orders arrive. Most products will be made to stock (MTS), but these low-volume, high variability products are best made to order (MTO). One nice feature of product wheels is that MTO products can co-exist with MTS products quite nicely. Even though the low volume and the MTO products are not made on every wheel cycle, it is important to determine where they fit within the overall sequence. When they are made, always make them at that point on the wheel cycle.

Product wheels can be applied to an entire production line, such as a salad dressing bottling line, a synthetic fiber spinning operation, or a frozen pizza manufacturing/packaging line. Or they may be applied to one piece of process equipment, such as a plastic pellet extruder or a resin reactor used in manufacturing paint.

Product wheels are best implemented as part of an integrated, well-thought-out lean plan, coupled with standard work, visual management, value stream mapping, total productive maintenance (TPM), changeover improvement, bottleneck optimization and cellular flow patterns.

Lubricating BG's success

BG Products is a major supplier of high quality lubricants, brake fluids and other automotive market products that enhance engine performance. The BG plant has a manufacturing area where the automotive fluids are produced and approximately a dozen packaging lines, each tailored to a specific range of product types and package configurations. Product wheels have been designed to schedule four of these lines. The first line addressed was the rotary filling line, where the fluids were packaged into 6-, 12-, 32- and 64-ounce bottles. Then the bottles are labeled, packed into cases and palletized. Figure 2 shows part of this line's value stream map.

One of the early steps in wheel design was to reallocate products to reduce the number of varieties packaged on any line. The 6-ounce and 12-ounce bottles were moved from the rotary filling line to a line that generally packaged these smaller bottles, leaving only the 32-ounce and 64-ounce bottles on the rotary filling line. Thirty-two-ounce and 64-ounce products packaged on other lines were moved to the rotary filling line. Certain fluid types were moved to a line where those fluids were more typically packaged. With fewer bottle sizes and fewer families of fluids, changeovers on the rotary filling line became faster and less expensive.

The next step was to examine order patterns and sales volumes for each product on rotary filling. Quite a number were sold in volumes small enough that it didn't make sense to carry inventory for long periods of time. It was decided that any product with sales of eight pallets per year or less would be made only to fill specific orders with a run of at least four pallets, the minimum practical campaign size. Working down the existing inventory of those products will cut total inventory significantly. This make-to-order analysis was extended to all products at the plant. Roughly 130 products were identified with a potential reduction in working capital of several hundred thousand dollars.

The product wheel sequence was designed to minimize fluid loss, not time lost, on changeover. In BG's market, fluid loss represents a true out-of-pocket cost. Bottle size changes are time-consuming but involve no additional costs. If the fluid type is changed but packaged in the same bottle size, it can be done more quickly. But this process loses fluids when lines are flushed and filters are cleaned, creating the cost penalty.

The most extensive changeovers on the rotary filling line, when changing both fluid and bottle sizes, typically required six to eight hours. Thus, single-minute exchange of dies (SMED, a changeover improvement method) was applied. The initial SMED effort decreased the changeover down to less than three hours. Changeovers were tracked for some period, further decreasing changeover time to less than 2.5 hours.

An inventory versus changeover cost analysis combined with minimum campaign size considerations determined the optimum wheel length to be two weeks. Demand variability also had a strong impact on wheel length. Weekly demand for most products had high variability; however, demand within two-week intervals was more uniform, with coefficients of variation less than 0.5.

The current rotary filling line wheel includes 29 make-to-stock products: 10 of the higher-volume products are packaged on the two-week cycle, while eight others are made every second revolution. Eleven are packaged at a lower frequency based on their forecast sales and the requirement for a minimum lot size of four skids per wheel spoke. About 25 very low-volume products now are made only to order.

Prior to beginning wheel operation, a team that included lead operators designed visual scheduling boards (takt boards) for several packaging lines. The information on the takt boards gave much greater insight into true line performance, revealing the reasons for some of the short but frequent line interruptions. The plant manager called the takt boards a key tool that indicates whether they are winning on that line on that day.

Manufacturing management made a key move that led to the success of the wheel: They downplayed the previously sacred productivity and line efficiency metrics, emphasizing performance to plan measures that used the data recorded on the takt boards.
Another key to success was the interactive team effort, led by BG operations director James Overheul. The cross-functional team included production schedulers, planners and the plant

manufacturing engineer. The team included representatives from maintenance and operations. The plant management staff provided strong support and guidance throughout implementation.

As a result of wheel implementation on the rotary filling line and three other packaging lines, BG has seen a significant reduction in inventories while maintaining high levels of customer service. But perhaps the greater benefit has been the stability and predictability this has brought to the operation. Overheul summarizes his value for wheels as follows: "The process for creating the product wheels allowed us to see why we were having issues in our production environment. The product wheels gave us a process so that we can respond to the changing needs of our customers, yet not lose our way on the routine items."

The Appleton journey

Appleton is a specialty coating, formulation and microencapsulation company headquartered in Appleton, Wis. The corporation serves global customers for thermal, carbonless and security paper production and microencapsulation technology.

Appleton has been using wheel concepts aggressively since 2008 and operates 11 wheels successfully. Ryan Scherer, Appleton’s organizational excellence and capacity manager and the primary architect of the company’s wheel design, said Appleton first implemented wheels on two carbonless coating machines to improve flow between them and the rewinders and reduce work in progress (WIP). Wheels were a structured way to deal with the length of large production runs, reducing their inefficiencies and costs. Appleton was able to level load large runs to eliminate the peaks and valleys in the schedule to cut overtime, create better flow, reduce WIP and realize a more predictable production schedule. And that was only the beginning.

This success prompted the carbonless value stream manager to apply the wheel concept to the sheeters. At the time, the same sheet parts would run on different sheeters at the same time, changeovers between cut sizes were very high, and finished goods inventory was out of control due to the unpredictable replenishment lead-time. Forecasts and push scheduling increased these difficulties. The sheeters were split into a "runner" and a "make-to-order/short run" sheeter based on machine capabilities and design. Then, using demand segmentation by SKU, wheels were built and sequenced appropriately to each dedicated sheeter. Again, this added predictability to the schedule, significantly reduced cut size changeovers and decreased finished goods inventory.

Momentum and interest in these improvements were growing across other value streams. Appleton’s goal in 2009 was to get its three thermal coating machines on wheels. They were more of a challenge than the carbonless coaters, but they offered even greater opportunity because of high raw materials costs and growing finished goods inventories. The results were replicated: improved schedule predictability, reduced and more efficient changeovers due to optimized sequencing, improved lead-times and fewer broken service promises.

Scherer said that integrating the three concepts of demand segmentation, product wheeling and pull replenishment provides the key to improving performance dramatically.
Demand segmentation, or analyzing each product by customer demand and by demand variability as measured by coefficient of variation, was the first opportunity to get the business

team to stop thinking in terms of a forecast and start thinking about customers and their true demand.

All wheels were built and implemented using kaizen event methodology to engage equipment operators and process engineers and include a wide range of knowledge and perspectives. The kaizen team also included a production scheduler, inventory control analyst and marketing specialist, with finance as an ad-hoc member. This created a strong cross-functional team with different perspectives on how to implement the wheels.

Wheels are updated and reviewed at least once per year, but they are dynamic and are adjusted as customer demand, production capability and overall business strategy change.

Now, Appleton has 11 machines on wheels: two sheeters (moved to wheels in 2008), five coaters (moved to wheels in 2008 and 2009), and four paper machines (moved to wheels in 2010). All of the Appleton wheels, regardless of the type of equipment on which they were applied, have yielded similar benefits: significantly lower inventories, shorter lead-times, reduced changeover losses due to improved sequencing and greater schedule stability and predictability. This has improved customer performance and reduced broken service promises.

The ongoing benefit of Appleton's lean Six Sigma efforts, including product wheels and pull replenishment strategies, has been $20 million to $30 million annually each year since 2008. Total inventory has been reduced by 21 percent, cash conversion days reduced by 17 percent. Scherer noted that product wheels – when implemented with a cross-functional team, integrated into inventory control with pull replenishment and used correctly – can be a powerful way to align production with customer demand.

More companies are working the wheel

In addition to BG Products and Appleton, the companies pioneering the product wheel methodology include Dow Chemical, DuPont and Exxon Mobil. They have used them to great advantage in producing automotive and house paints, extruded polymers, paper and plastic sheet goods, industrial chemicals, engine oil additives, waxes and pastes, laminated circuit board materials and a host of other products.

In addition to the obvious benefits of reduced changeover cost, reduced inventories, increased capacity and improved customer delivery performance, most users have found the greatest benefit to be the regularity and the predictability it brings to the operation. They have found that the organized, disciplined structure that product wheels provide reduces the chaos often found in production scheduling, allows planners and schedulers to spend less of their personal time resolving schedule problems, and provides a stable platform so that abnormal events can be dealt with in a less stressful, more logical manner.

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