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JOB SHOP LEAN

Ed's Note: This is the sixth article in an eight-part "reality" series on implementing Continuous Improvement at Hoerbiger Corporation. Throughout 2013, Dr. Shahrukh Irani will report on his progress applying the job shop lean strategies he developed during his time at The Ohio State University. These lean methods focus on high-mix, low-volume, small-to-medium enterprises and can easily be applied to most gear manufacturing operations.

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Computer-Aided Finite Capacity Scheduling of a FLEAN Machining Cell

Background

An earlier column (*Gear Technology*, August 2012) described the process shown in Figure 1 that is followed for implementing Job Shop Lean in a comprehensive manner in any high-mix, low-volume discrete manufacturing facility, such as machine shops, forge shops, fabrication shops, mold shops, etc. At the core of this iterative approach is the expectation that (i) a job shop will utilize production flow analysis and/or group technology to identify the stable part families in its product mix, (ii) will implement a FLEAN (Flexible+Lean) manufacturing cell to produce each part family that has a stable demand and (iii) utilize finite capacity scheduling to schedule each cell on a daily shift-by-shift basis.

In theory, every time that one loop of the process shown in Figure 1 is completed, it will result in the implementation of a stand-alone FLEAN manufacturing cell dedicated to producing a family of parts whose manufacturing requirements are completely satisfied by the cell, except for vendor processes that simply could not be brought in-house. *In reality*, numerous constraints will either need to be broken (Example: Operators will need to be trained to operate multiple machines in a cell and suitable group incentives put in place to ensure that the cell's team becomes autonomous) or can't be broken (Example: Heat treatment furnaces cannot be placed inside a cell next to a CNC grinder).

Typically, after several iterations of the process in Figure 1, a job shop will end up being divided into at least two areas: (1) One area consisting of several FLEAN manufacturing cells with each cell dedicated to a product family and (2) Another area being a "remainder job shop" that produces the "cats and dogs" (parts with low volume, low value, and infrequent demand) in the product mix, spare parts, prototypes for emergent business and one-off orders. By dividing the job shop into these two areas, the following benefits are gained: (1) The FLEAN cells provide unquestionable

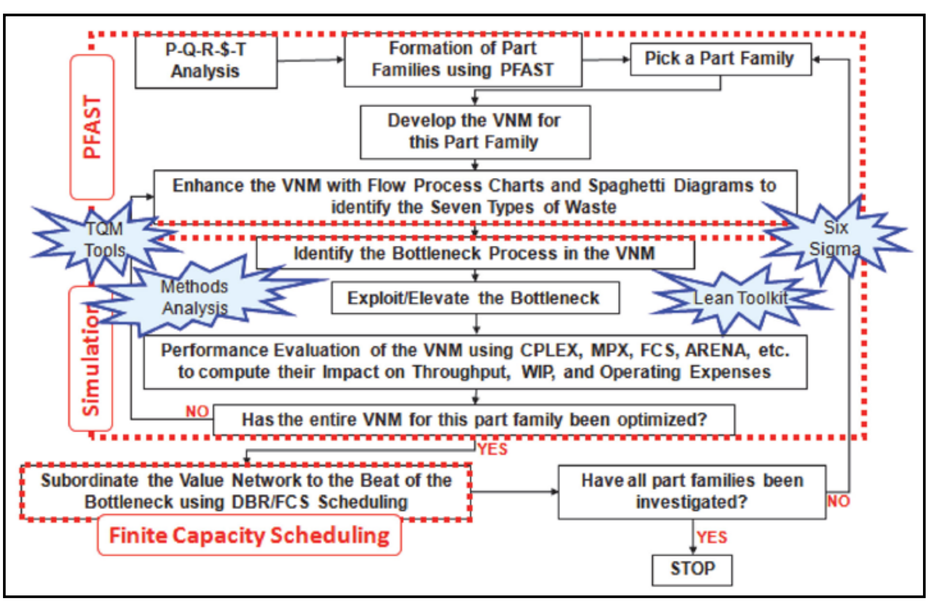

Figure 1 Comprehensive approach for implementing Job Shop Lean.

quick response, high quality, teamwork and other benefits that are guaranteed with flexible cellular manufacturing and (2) Instead of the entire business being managed as a complex job shop, only the smaller non-cellular portion of the shop now remains a complex job shop.

What Follows the Layout Design of a FLEAN Cell?

Having implemented a new layout for a FLEAN cell, it is then necessary to schedule daily operations in the cell. In this column, I will support the implementation of finite capacity scheduling software. Depending on the complexity of the part family and the demand patterns for the parts produced in a cell, a manual/visual system of pull scheduling just could suffice. For example, I know of at least one precision machine shop that uses a DBR (drum-buffer-rope) scheduling tool. One of our own cells, the QRC, makes do with a manual scheduling board that is populated with orders by an office manager who can guesstimate work content and overall cell workload. Possibly even an ERP system's schedule adjusted by experienced cell operators who can eyeball capacity requirements by just looking at the queue of parts.

Why Computer-aided Cell Scheduling?

Personally, I just do not wish to learn and implement questionable ad-hoc manual cell scheduling strategies when a solution of the future was already being successfully used in one of our sister facilities in Pompano Beach, FL, prior to my joining HCA. Especially if there are other cells that share resources with this cell, then the schedules of those cells (and outside vendors too), must be coordinated with this cell's schedule. Nor is visual management sacrificed at all. The complete daily schedule for a shop can be visualized using a Gantt chart, such as the one shown in Figure 2 which was produced by *Preactor* (*www.preactor.com*), the FCS (finite capacity scheduling) tool that is used by our sister facility in Pompano Beach, FL. The firm orders and their due dates quoted to customers are downloaded from *SAP* (which is our ERP system) into *Preactor*. After the schedule is generated by *Preactor*, it is input to our MES (manufacturing execution system), *FactoryViewer*, which then publishes twice daily a machine-by-machine sequence for producing orders loaded on every machine in the facility. Since every machine's operator must record the start/stop times for each order processed on his machine, the MES closes the loop between the daily schedule and the real-time execution of that schedule.

Scheduling a Single High-Mix, Low-Volume Cell – But Why?

The MP cell in our HCA-TX (HARP) facility is essentially a small job shop. Therefore, effective scheduling would improve its performance and employee utilization. The complexity of scheduling even a small job shop with four or more machines used in various combinations makes its schedule hard to generate, revise and maintain it manually. Ask any IE graduate who has taken a course in scheduling about how much time it took him/her to produce the schedule for a job shop consisting of just three machines producing four parts with different routings. Similarly, in the case of the MP cell, it has different equipment types, and in some cases, two machines of the same type that are unique, yet capable of processing the same parts if the tools and fixtures are available. In order to complete the implementation of the Job Shop Lean process shown in Figure 1, we undertook an exploratory proof-of-concept project to demonstrate the following "What if?" scenario for the MP cell: *If the daily schedule that was issued to the cell at the start of the day was subject to change due to one or more reasons, such as changing order priorities, machine breakdowns, rush orders, operator taken sick during the shift, due date changes forced by customers, etc., could we rapidly revise and re-generate a new schedule for the cell?*

Why *Schedlyzer Lite* was Chosen over *Preactor* for this Project

Like all other ERP systems on the market, our ERP system (*SAP*) uses MRP (material requirements planning) for production planning and operations scheduling. MRP uses assumptions of infinite capacity, backward scheduling from customer due dates using fixed lead times, batch production, etc. So it was decided not to use *SAP* for scheduling the MP cell.

Although *Preactor* is being used successfully in our Pompano Beach facility, our current license and implementation there is for a factory-wide installation. Due to time constraints, it was difficult to obtain a stand-alone license for the MP cell that would run on a desktop computer dedicated to the cell. Also, our director of manufacturing systems, Paul Mittendorff, who is the architect of the *Preactor+FactoryViewer* integrated system that we use in Pompano Beach, had prior commitments that made him

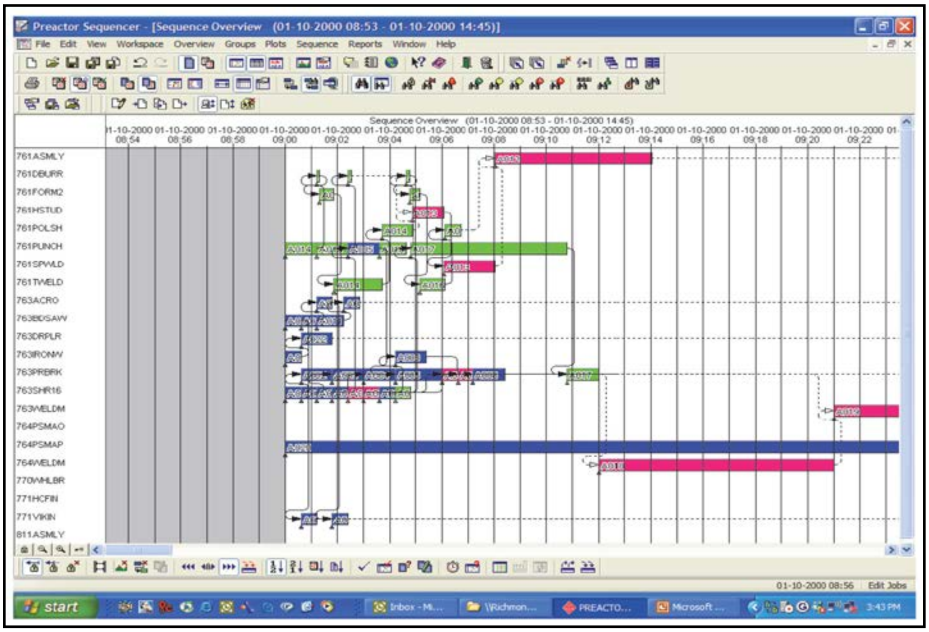

Figure 2 Gantt chart representation of a production schedule for visual management.

unavailable during the period when we wanted to do this project.

Therefore, we decided to work with another FCS vendor, Optisol Inc. (*www.Optisol.biz*) and use their *Schedlyzer Lite* tool for the project. *Schedlyzer Lite* is easy-to-learn and allows a user-friendly VBA (Visual Basic) interface to be developed for shop floor employees. Its price tag easily makes it affordable to purchase a single license for a computer that will be dedicated to a cell. It is well-supported by a local vendor resident in Bryan, TX, who boasts a track record of successful implementations in several job shops.

Figure 3 shows the VBA interface between *SAP* and *Schedlyzer Lite* that was developed by Clement Peng, the graduate intern we hired to work on this project. Since *SAP* query authorization was not allowed for our project, a macro in *SAP* was adapted to automatically generate data for daily orders. First you would click on the button highlighted in red then click on the button highlighted in yellow. Voila, the input data file for *Schedlyzer* would be ready with data extracted from *SAP*.

Next, as shown in Figure 4, we would open the input data file for *Schedlyzer* that was produced from *SAP* and, with one click on the "Schedule" button, we would schedule all jobs for production in the MP cell. By default, *Schedlyzer Lite* releases all jobs to complete by earliest due date (EDD) subject to labor and machine capacity constraints. Queues of jobs at individual machines are prioritized using the same dispatching rule (EDD).

Figure 5 shows the cell schedule summary screen in *Schedlyzer Lite* with detailed information on every job (Job ID, Job Start Time, Job Finish Time, Relative Earliness/ Lateness compared to Due Date, etc.). In the case of our pilot project, 30 jobs and 139 operations were scheduled to minimize the average # of in-process jobs to 8.2 orders. Some immediate benefits of this report are (i) it would help customer service to decide whether a new order can be done by its customer-specified due date and (ii) when the shipping department can expect the order to begin packaging it for shipment.

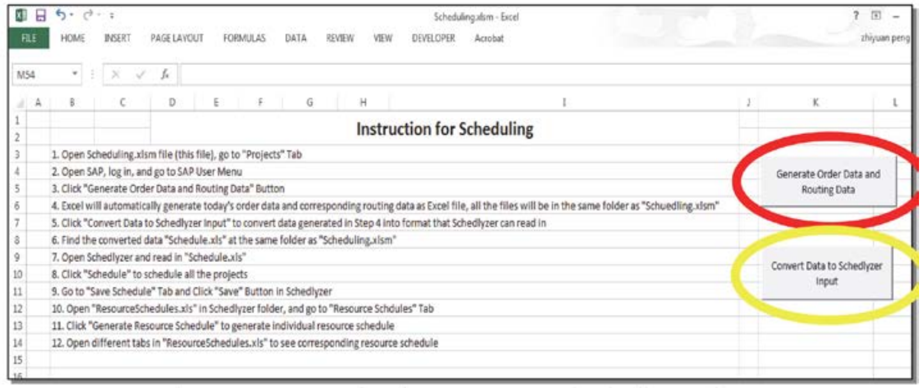

Figure 3 VBA interface between SAP and Schedlyzer Lite.

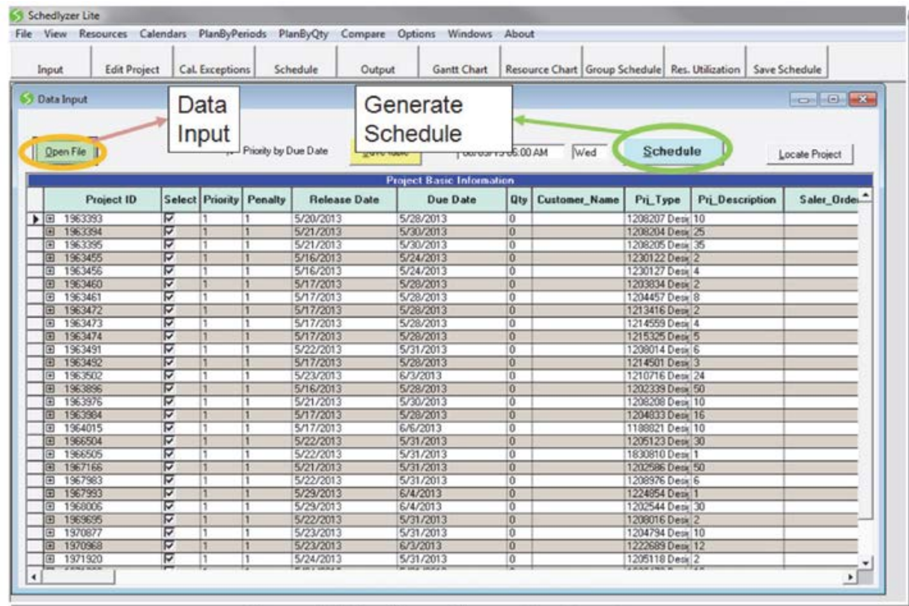

Figure 4 Schedlyzer screen for data input.

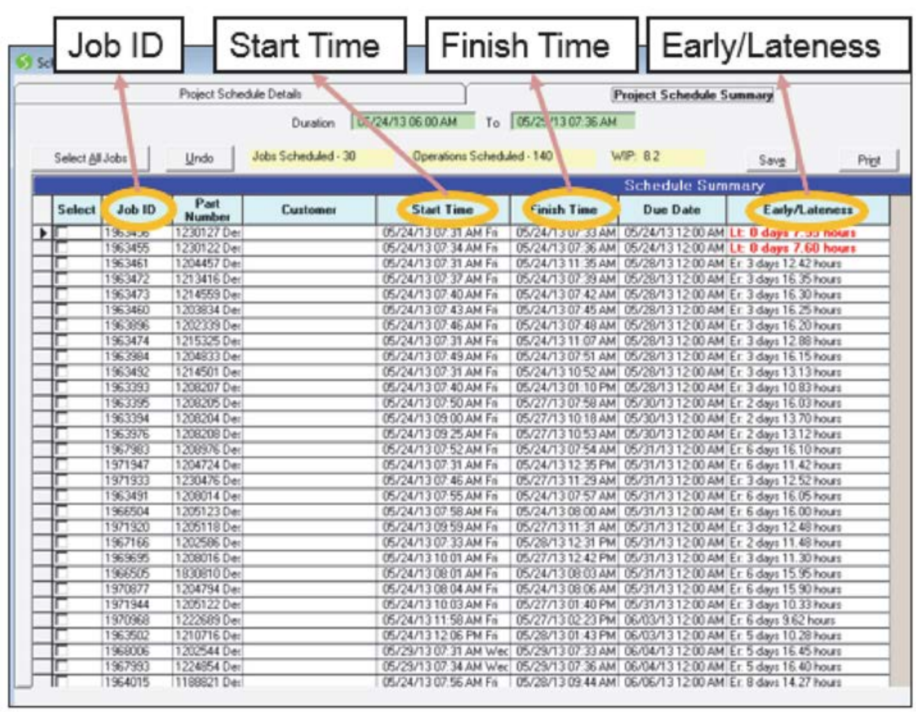

Figure 5 Cell schedule summary.

Figure 6 displays the schedule for a particular machine. This is the preferred sequence in which jobs should be worked on by that machine on any given day. For each job, its Job ID, Material Number, Operation # (with its expected Operation Start Time and Operation End Time), etc. is displayed. Thereby, the machine operator cannot have a doubt as to which jobs absolutely must be ready to run before/after another job. Like the powerful beam that emits from a lighthouse that can be seen by far-away ships, this schedule is the "beat" to which everybody (such as the machine operator, material handler, the cell leader, office manager, etc.) walks. Every violation of this daily sequence would be noted and become a kaizen that the continuous improvement team could solve by first asking, "Why? Why? Why? Why? Why did this happen?" This is a how the core problem-solving tools of lean are essential even in an IT-aided FLEAN manufacturing cell.

Schedlyzer can also generate the complete schedule for all active jobs run on all machines in the cell, either in a standard Gantt chart format or produce an *Excel* spreadsheet version for that chart. Although not as visually pleasing, the spreadsheet showing the sequence of jobs, start/finish times, waiting times, etc. is more effective for use by shop floor employees, the plant manager, or even the president of the company.

Here in our Houston, TX, facility we have a pilot implementation of the *Preactor+FactoryViewer (FV)* integrated system in the PoR Cell. The cell operators are familiar with the FV screen to guide schedule execution and on-time delivery tracking. The FV screen is superior to a simple tabular version of a Gantt chart.

For those readers who are familiar with the takt time counters that are mounted above assembly lines, the Gantt chart, or equivalent display, of the schedule for a high-mix, low-volume job shop cell is equivalent to the "pacemaker" in an assembly line.

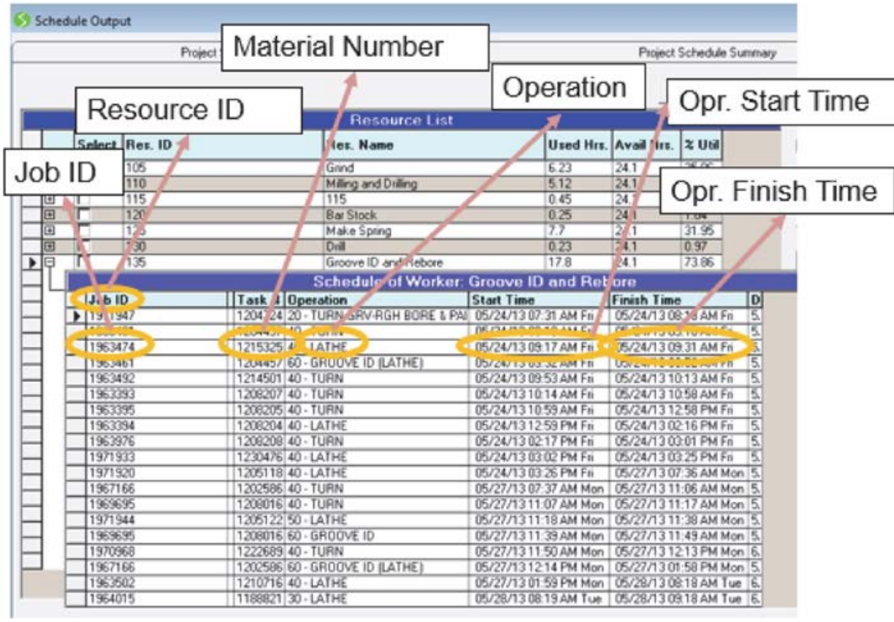

Figure 6 Schedule for a specific machine.

FCS does Facilitate Waste Elimination, Too

Scheduling using *Schedlyzer*, or any good FCS tool for that matter, would help to reduce WIP, minimize job waiting, plan on-hand inventories of raw materials, anticipate short-term overtime needs, etc. for any cell. For example, in this pilot project involving the MP cell, the *Schedlyzer* schedule projected that we could reduce the WIP of in-process orders from 59 orders to 15, which was equivalent to about $12,000 based on the prices of those orders. Why? Because a schedule based on finite capacity constraints automatically defers pre-mature release of orders that will simply end up in queue in front of the bottleneck machine when it is NOT the first machine being used to process the orders. Similarly, there are additional benefits of effective scheduling using an FCS tool that are prominently displayed on any vendor's website or listed in textbooks. But beware the hidden pitfalls and dangers of wanting to have those benefits without investing in the personnel and support systems essential for the success of FCS and MES.

Who Will Implement, Deploy and Manage your Implementation of FCS?

In *Preactor* (*www.preactor.com*), like *Schedlyzer* (*www.optisol.biz*) and *Tactic* (*www.waterloo-software.com*), high-mix, low-volume job shop-like manufacturers have a choice of powerful, widely-used and well-supported FCS tools. For example, in the case of *Schedlyzer Lite*, Dr. Prasad Velaga, president of Optisol Inc., ensured that being able to use his software was never a bottleneck during the execution of our project.

However, besides its weaponry, a good army needs a good general and many good soldiers, too. I will unequivocally state that the success of this pilot project can be attributed to Clement Peng, the graduate intern from the Department of Industrial and Systems Engineering at Texas A&M University. He single-handedly did this project in partnership with Dr. Velaga, the software vendor. His computer-skills, prior IE coursework related to scheduling, work ethic, ability and willingness to learn *SAP* and *Schedlyzer* on his own, driven nature, determination to make an idea work in practice, desire to learn real-world implementation of Job Shop Lean using computer tools like *PFAST* and *Schedlyzer* — he made the difference! As is the case with any lean implementation, people like him will make the implementation of FCS a success in any company like ours.

Now the Hard Work Must Begin

In order to take the next step towards computer-aided daily scheduling of each of our cells, we must now undertake the following essential tasks:

We must implement the new layout that we proposed for the cell. The new layout will co-locate almost ALL the machines and their operators who will be responsible for completing orders loaded on the MP cell. In my experience, not a single high-mix, low-volume facility that I have assisted has ever been designed correctly. Due to poorly-designed layouts, even in the case of an individual cell, whenever there is a distance of separation between two consecutive operations *that exceeds three feet*, the inter-operation transfer delays can, and will, destroy the best schedules generated by an FCS software resident on someone's computer in an office removed from the shop floor.

Next, we must conduct time studies (else rely on pre-determined standard times based on group technology) to populate the routers in *SAP* with reasonably accurate setup and machining cycle times for all the unique parts produced in the MP cell. Any software, be it an ERP system, FCS tool or MES, will produce garbage output if it receives garbage input, aka GIGO (garbage in, garbage out).

Finally, we will need to engage our IT staff to develop a professional communication interface between *Schedlyzer* (preferably *Preactor*) and our MES (*FactoryViewer*) to standardize how our schedules and employees interact.

Achieving FLEAN (Flexible and Lean) with People First, and IT Next

Lean, IT and flexible automation will co-exist with a motivated, talented and well-trained workforce in the Hoerbiger Production System (HPS). The HPS is in its infancy but it is intended to become a viable production system model for high-mix, low-volume manufacturing environments. Despite the incorporation of computer-aided data analysis and systems optimization, flexible automation, IT-aided production planning and control, etc., people and the standard lean tools are going to be the foundation of the Hoerbiger Production System. In fact, IT-enabled production systems demand an even greater reliance on employees and managers who can undertake continuous improvement projects to eliminate the myriad problems that arise when, say, computer-aided demand forecasts and daily shop schedules are disrupted by the vagaries

Resource ID	Project ID	Material Number	Operation Desciption	Start Time	Finish Time	Ring Type
105	1971947	120472	30 - GRIND	05/31/13 08:19 AM	05/31/13 08:53 AM	Design:PACKING RING
105	1963461	120445	50 - GRIND	05/31/13 09:17 AM	05/31/13 09:27 AM	Design:OIL SCRAPER
105	1963474	121532	50 - GRIND	05/31/13 09:32 AM	05/31/13 09:41 AM	Design:PACKING RING
105	1963393	120820	50 - GRIND	05/31/13 10:59 AM	05/31/13 11:18 AM	Design:PACKING RING
105	1963395	120820	50 - GRIND	05/31/13 12:59 PM	05/31/13 02:08 PM	Design:PACKING RING
105	1963394	120820	50 - GRIND	05/31/13 02:17 PM	05/31/13 03:06 PM	Design:PACKING RING
105	1963976	120820	50 - GRIND	05/31/13 03:07 PM	05/31/13 03:26 PM	Design:PACKING RING
105	1971933	123047	50 - GRIND	05/31/13 03:27 PM	06/03/13 07:43 AM	Design:PACKING RING
105	1971920	120511	50 - GRIND	06/03/13 07:44 AM	06/03/13 07:50 AM	Design:PACKING RING
105	1969695	120801	50 - GRIND	06/03/13 11:18 AM	06/03/13 11:24 AM	Design:PACKING RING
105	1971944	120512	60 - GRIND	06/03/13 11:39 AM	06/03/13 11:53 AM	Design:PACKING RING
105	1970968	122268	50 - GRIND	06/03/13 12:14 PM	06/03/13 12:19 PM	Design:PACKING RING
105	1963502	121071	50 - GRIND	06/04/13 08:19 AM	06/04/13 10:04 AM	Design:PACKING RING

Resource Schedules | 105 | 110 | 115 | 120 | 125 | 130 | 135 | 145 | 150 | 155 | 180 | ...

Figure 7 Detailed machine schedule output.

of the dynamic shop floor. For example, if a machine operator needs to take a restroom break, do you forbid him/her because the schedule generated by *Preactor* shows that he/she should be running Job X at that time?

Further, no ERP, FCS or MES system could ever match the flexibility and response time that good cell operators can provide when any number of unscheduled disruptions (machine breakdowns, missing tools, defective parts requiring rework, scrapped parts, vendor delivery failures, etc.) render the current computer-generated schedule for a cell useless. Will the computer be willing to report to work on a Saturday to get a rush order done and shipped to a key customer?

Sure, *Preactor* or *Schedlyzer* could quickly generate a new schedule but it would still have to be the cell leader who would provide it the data to accommodate and/or override the existing schedule! Specifically, our director of manufacturing systems, Paul Mittendorff, has teamed with our plant managers – Mark Ellis (Plant 3) and Christoph Magnet (Plant 1) – to stress to the shop floor that the dispatch lists that *FactoryViewer* presents them at their machines *must* be followed, that cherry-picking jobs out of the global schedule is *not* allowed. This teaming partnership has already produced results in Pompano Beach.

For Further Information on HCA's Projects Related to Scheduling

Joshi, P. & Irani, S.A. *A Tutorial on Job Shop Scheduling (JSS) using LEKIN Academic Scheduling Software.* Presentation made at the First Lean and Flexible Conference in Houston, TX, on April 1, 2013.

Mittendorff, P. *The Water Strider: How To Get the Right Material to the Right Machine at the Right Time per the Daily Schedule.* Presentation made at the First Lean and Flexible Conference in Houston, TX, on April 1, 2013.

Irani, S.A. *What are the Wastes created by a Jobshop's ERP System?* Presentation made at the First Lean and Flexible Conference in Houston, TX, on April 1, 2013.

Ellis, M. & Mittendorff, P. *Integration of MES (Manufacturing Execution System) with Material and Inventory Management.* Presentation made at the Second Lean and Flexible Conference in Houston, TX, on September 5, 2013.

Irani, S.A. & Velaga, P. *Revisiting Time and Motion Studies: Implementing Lean Improvements for a High-Mix Low-Volume Flexible Manufacturing Cell.* Presentation made at the Second Lean and Flexible Conference in Houston, TX, on September 5, 2013.

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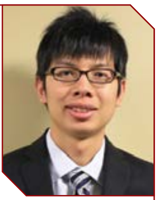

Zhiyuan (Clement) Peng is a graduate student at the Texas A&M University, where he is pursuing his Master's degree in industrial engineering (IE). He is currently working as an industrial engineering intern at Hoerbiger Corporation of America (www.hoerbiger.com). In his current job, he is supporting continuous improvement and inventory control projects in the shipping department and designing a new layout for that department. Previously, he worked as a quality engineering intern in TPT Electronics to apply six sigma skills to increase product quality. His other areas of expertise are data-driven justification of projects related to lean manufacturing, inventory control, and quality control. In the true spirit of continuous improvement, he continues to develop his expertise and work experience in other related areas.

Dr. Shahrukh Irani is the Director of Industrial Engineering (IE) Research at Hoerbiger Corporation of America (www.hoerbiger.com). In his current job, he has two concurrent responsibilities: (1) To undertake continuous improvement projects in partnership with employees as well as provide them on-the-job training relevant to those projects and (2) To facilitate the implementation of Job Shop Lean in HCA's U.S. plants. Previously, he was an associate professor in the Department of Integrated Systems Engineering at The Ohio State University (OSU). There his research focused on the development of new IE methods to adapt and scale lean for use by high-mix, low-volume SMEs (small and medium enterprises). His research group created *PFAST* (Production Flow Analysis and Simplification Toolkit) which is software for material flow analysis and facility layout to implement Job Shop Lean. At OSU, he received the Outstanding Faculty Award for excellence in teaching from the graduating classes of 2002, 2003, 2004, 2005, 2006 and 2009. In 2002, he received the Charles E. MacQuigg Student Award for Outstanding Teaching from the College of Engineering. He is a member of IIE.