JOB SHOP LEAN

Ed's Note: This is the fifth 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.

Dr. Shahrukh Irani, Director IE Research, Hoerbiger Corporation of America

Design of a Flexible and Lean (FLEAN) Machining Cell: Part 2 (Application)

Job shops may be ill-advised to undertake a complete reorganization into FLEAN (Flexible and Lean) cells. A FLEAN cell would (i) be flexible enough to produce any and all orders for parts that belong in a specific part family and (ii) utilize lean to the maximum extent possible to eliminate waste. For example, FLEAN cells that are implemented in job shops may not allow the perfect one-piece flow that is feasible in assembly cells. Still, due to the proximity between consecutively used machines, small batches of parts can be easily moved by hand or on wheeled carts or on short roller conveyors or using jib cranes. In fact, it is possible that the production volumes and demand stability for many part families simply could not justify dedicating equipment, tooling and personnel to producing any of those families in a stand-alone cell.

FLEAN Cells: Starting Point for Implementing Job Shop Lean

The starting point for implementing job shop lean in a high-mix, low-volume facility is to implement as many FLEAN cells as possible. In fact, management should further support continuous improvement (CI) projects to help each cell become an autonomous business unit (ABU). How? By empowering the team of employees in each cell to manage day-to-day operations and make decisions about allocation of orders to operators, deciding who gets cross-trained on which machines, etc. Those CI projects should be given top priority which seek to eliminate, or at least mitigate, all the

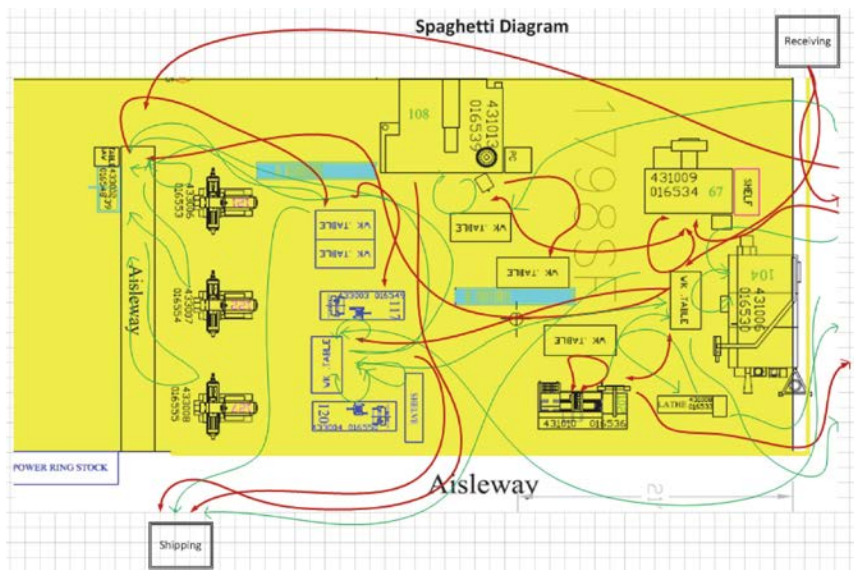

Figure 1 Material Flows in the Current Layout for the MP Cell (MPC).

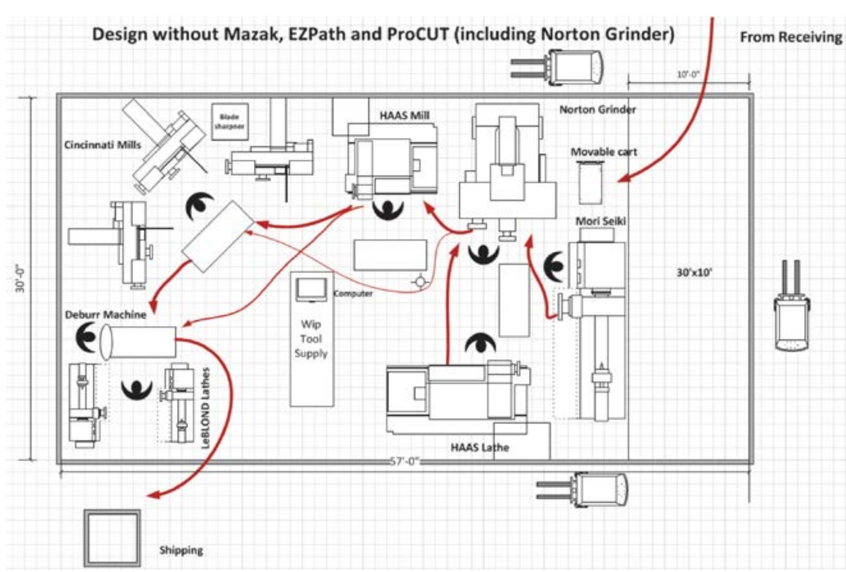

Figure 2 Material Flows in the Proposed Layout for the MP Cell (MPC).

constraints that force the cell to send its orders to external resources, both in-house or vendors, for processing. Ideally, each cell would be allowed to communicate directly with their customers on changing delivery dates, questions about part drawings or routers, etc.

Origins of FLEAN Cells and Job Shop Lean

Serck Audco Ltd. pioneered the use of group technology and cellular manufacturing as a complete manufacturing and business strategy as early as the middle of the 20th Century. During the period 1961–1967, they reported the following improvements in company performance using GT and CM from John Burbidge's book *Group Technologies in the Engineering Index*:

- **Sales:** Up by 32 percent
- **Stocks:** Down 44 percent
- **Ratio of stocks/sales:** Down from 52 percent to 22 percent
- **Manufacturing time:** Down from 12 weeks to four weeks
- **Overdue orders:** Down from six weeks to one week
- **Output per employee:** Up about 50 percent
- **Capital investment:** Cost recovered four times by stock reduction alone

Interestingly, the benefits of GT and CM reported in Burbidge's book published in 1979 are similar to those attributed these days to the Toyota Production System designed for repetitive high-volume assembly. A very recent implementation of high-mix assembly cells reported in the open literature is at Metcam Inc.'s Alpharetta, GA, facility, according to an article in the May 2013 issue of *Industrial Engineer* entitled, "Cellular Precision."

Design of a FLEAN Cell at HCA-TX

In the previous issue of *Gear Technology* magazine, we had described the theory underlying a methodology for identifying potential part families and machine groups that would constitute one or more FLEAN cells. We had chosen one of the existing five machining cells, the MP cell (MPC), to test this computer-aided methodology for implementing Job Shop Lean. We collected the routers of all the parts that were being processed in the MPC during a 5-day week to create the *PFAST* input file. Using the from-to chart produced by *PFAST* for this sample of parts and the current layout of the MPC, we produced the flow diagram shown in Figure 1. In the figure, the flows shown in red represent large values in the from-to chart, and the flows shown in green represent low values.

In this issue, we will explain how we designed a future state for the MPC whereby it would have no external resource requirements and, hopefully,

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Part No	Work Center No	Sequence No
1210954	705	1
1210954	240	2
1210954	210	3
1210954	205	4
1210954	255	5
1210954	710	6
1872434	705	1
1872434	240	2
1872434	210	3
1872434	205	4
1872434	255	5
1872434	710	6
1867043	705	1
1867043	240	2
1867043	210	3
1867043	215	4
1867043	205	5
1867043	255	6
1867043	710	7

Figure 3(a) Routings Spreadsheet in the PFAST Input File.

Part No	Description		Annual Quantity	Revenue
1210954	PISTON RING	HY113	25	25
1872434	PISTON RING	0804-00	12	12
1867043	RIDER RING	0872-00	5	5
1206113	RIDER RING	HY112	26	26
1203600	PISTON RING	HY112	4038	4038
1205489	RIDER RING	HY112	178	178
1205702	PISTON RING	HY112	110	110
1230010	PRESSURE BREAKER	HY112	4	4
1203361	PACKING RING	HY112	2,273	2273
1204876	PISTON RING	HY112	100	100
1205529	PACKING RING	HY112	1022	1022
1233569	PISTON RING	HY103	83	83
1233281	PISTON RING	HY112	247	247
1385526	SEALING RING	0309-01	845	845
1875646	PISTON RING	0703-00	8	8
1210542	PISTON RING	CL40CI	6	6

Figure 3(b) Parts Spreadsheet in the PFAST Input File.

Work Center No	Description	Area
105	PACKING DOUBLE DISC	1
110	PACKING CNC MILL	1
115	PACKING SPRINGS	1
120	PACKING MANUAL LATHE	1
125	PACKING MISCELLANEOUS	1
126	PACKING SPRINGS AND MISCELLANEOUS IN CELL	1
130	PACKING DRILL & PIN	1
135	PACKING CNC LATHE	1
145	PACKING REBORE	1
150	PACKING SLITTER	1
155	PACKING DEBURR	1
170	PACKING SEGMENT CNC LATHE	1
180	PACKING MELCHIORRE LAPPING	1
205	P/R RING SAW	1
210	P/R RING GRINDER	1
215	P/R RING MILL	1
227	P/R RING HEAT TENSION	1
240	P/R RING MANUAL LATHE	1
245	P/R RING SANDBLAST	1
305	BLANCHARD GRINDER	1
255	TACLOC/EXPANDER BENCH GRIND	1
410	POWER RING GRINDER	1
705	MATERIAL ISSUE	1
710	STOCK & STAGE	1
915	TINNIZE	1
250	P/R RING CNC LATHE	1

Figure 3(c) Workcenters Spreadsheet in the PFAST Input File.

evolve into an ABU (autonomous business unit). Figure 2 shows the new layout for the MPC that was designed, and even partially implemented, by blending:

- Outputs produced by the *PFAST* software
- Outputs produced by the *STORM* software
- Work done by an IE intern (Dhananjay Patil) who was dedicated full-time on the project and engaged daily with the employees in the cell
- Work done by our Tiger Team who partnered with the employees in the cell to implement 5S, housekeeping and ergonomics-related improvements
- Time study data provided to us by our in-house IE (Shalini Gonnabathula)

As the above list of bullets will indicate, the major take-away from this project is that computer analytics are simply an aid to implement Job Shop Lean. They are necessary but not sufficient and should enhance the effectiveness of the decisions and designs produced by the project team and the employees responsible for designing and implementing the cell.

Application of the Job Shop Lean Methodology at HCA-TX

Figure 3a shows the routings spreadsheet in the *PFAST* input file. Figure 3b displays the parts spreadsheet. Figure 3c displays the work centers spreadsheet. Together, these three spreadsheets constitute the *PFAST* Input File that is submitted to the *PFAST* (*Production Flow Analysis and Simplification Toolkit)* software developed by the Department of Integrated Systems Engineering at The Ohio State University, Columbus, OH.

Figure 4a shows the product-process matrix analysis produced by *PFAST* using the data for the sample of parts produced in the MP cell. This visual display that aggregates many different/similar routings immediately picked up a major obstacle that we would face if we chose to implement a self-sufficient new cell with no external machining resource requirements. The two part families displayed in Figure 4a correspond to parts in the MPC part family and parts from the family produced in another cell, the PRR cell (PRRC). The machines required by the PRRC part family could not be fitted into the room that housed that cell; hence, they were intermingled in the same area with the machines that constitute the MPC.

Figure 4b shows the sequence similarity analysis of the routings for the same sample of parts. Like the product-process matrix analysis, Figure 4b is an alternative visualization of a large number of different/similar routings of parts being produced by machines in a single cell (or a large machine shop or an entire vertically-integrated factory).

Now we were ready to design an actual layout for the MPC. This required us to arrange the group of machines required to produce the part family into a U-shape, else some composite of other alphabets, such as S, Y, M or F whose shapes could "fit" the flow of the variety of routings processed by the cell. Figure 5a shows the from-to chart that *PFAST* produced using the data in the input file submitted to it. Figure 5b shows the flow diagram that *PFAST* produces to help contrast the high-volume and the low-volume flows between various machines in the cell. Essentially, Figure 5b is a visualization of Figure 5a to assist anyone who may want to manually design the cell layout.

We input the from-to chart produced by *PFAST* to *STORM*. The student version of the *STORM* software is affordable software for quick-and-dirty facility layout design. Figures 6a–c show examples of the different arrangements of the machines in the cell that could be produced simply by changing layout settings permitted by the algorithm programmed in this educational software.

But how good were these computer-generated layouts? So next we had to verify if any of these "layout skeletons" for the MPC were viable for implementation. We did this using a multi-pronged approach as follows: We met with the MPC team and asked them to walk us through the machining pathways of several active orders being processed in the cell that day. Also, we conferred with the two machine shop supervisors, Greg Oakley and Ziggy Skora, as well as our IE, Shalini Gonnabathula.

Based on these multiple inputs, we realized that whoever had identified the part family for the MPC in the past *using no software at all* had done a good job. The generic/composite routing for the MPC part family was as follows: Turn→Grind→Mill→Rebore→Drill→Insert Pins→Attach Spring. While this became the "backbone" of the cell layout, several adjustments were made to accommodate the differences among the routings that were highlighted by the Sequence Similarity Analysis of Routings shown in Figure 4b.

This is how the proposed layout in Figure 2 was designed by integrating computer analytics with established rules for precedence among different

PART FAMILY: PRR Cell

PART FAMILY: MP Cell

Part	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1205489	705							240	210	255	205			
1210929	705							240	210	255	205			
1220824	705							240	210	255	205			710
1203600	705							240	210		205		255	710
1205702	705							240	210		205		255	710
1210954	705							240	210		205		255	710
1216179	705							240	210		205		255	710
1233281	705							240	210		205		255	710
1233569	705							240	210		205		255	710
1233619	705							240	210		205		255	710
1234524	705							240	210		205		255	710
1234525	705							240	210		205		255	710
1867043	705							240	210	215	205		255	710
1872434	705							240	210		205		255	710
1206113	705							240		215	205		255	710
1204876	705							240	210	215			255	710
1210587	705							240	210	215			255	710
1203603	705							240	210		250		255	710
1214280	705							240	210		250		255	710
1233620	705							240	210		250		255	710
1386617	705							240	210		250		255	710
1210542	705							240		305	205	227	915	710
1874774	705							240	410	215		227	245	710
1875646	705							240	410	215				710
1208644	705		115	170	180		110		150	145	126	130	915	710
1202570	705		115	135	180	135	110		150	145			155	710
1204037	705	125		135	105	135	110		150	145	125			710
1208014	705	125		135	105	135	110		150	145	125	130		710
1237548	705	125		135	105	135	110	145	150		125	130		710
1202635	705	125	120	135	105	135	110		150		125	145		710
1203287	705	125	120	135	105	135	110		150		125	145		710
1208783	705	125		135	105		110		150		125	145		710
1205529	705	125		135	105		110		150	145				710
1203361	705	125		135	105		110		150	145			126	710
1385526	705	125		135	105		110		150	145			126	710
1230010	705	125		135	105				150	145			126	710
1790502	705	125		135	105				150	145			126	710

Figure 4(a) Product-Process Matrix Analysis.

PART FAMILY: PRR Cell

PART FAMILY: MPC Cell

Part	250	710	705	210	255	240	205	215	410	227	305	245	915	180	115	155	170	130	126	125	105	135	150	145	110	120
1386617	1	1	1	1	1	1																				
1233620	1	1	1	1	1	1																				
1214280	1	1	1	1	1	1																				
1203603	1	1	1	1	1	1																				
1210929			1	1	1	1	1																			
1205489			1	1	1	1	1																			
1872434		1	1	1	1	1	1																			
1234525		1	1	1	1	1	1																			
1234524		1	1	1	1	1	1																			
1233619		1	1	1	1	1	1																			
1233569		1	1	1	1	1	1																			
1233281		1	1	1	1	1	1																			
1220824		1	1	1	1	1	1																			
1216179		1	1	1	1	1	1																			
1210954		1	1	1	1	1	1																			
1205702		1	1	1	1	1	1																			
1203600		1	1	1	1	1	1																			
1210587		1	1	1	1	1		1																		
1204876		1	1	1	1	1		1																		
1867043		1	1	1	1	1	1	1																		
1206113		1	1		1	1	1	1																		
1210542		1	1			1	1			1	1		1													
1874774		1	1			1		1	1	1		1														
1875646		1	1			1		1	1																	
1202570		1	1											1	1	1						1	1	1	1	
1208644		1	1										1	1	1		1	1	1				1	1	1	
1237548		1	1															1		1	1	1	1	1	1	
1208014		1	1															1		1	1	1	1	1	1	
1790502		1	1																1	1	1	1	1	1		
1230010		1	1																1	1	1	1	1	1		
1385526		1	1																1	1	1	1	1	1	1	
1203361		1	1																1	1	1	1	1	1	1	
1208783		1	1																	1	1	1	1	1	1	
1205529		1	1																	1	1	1	1	1	1	
1204037		1	1																	1	1	1	1	1	1	
1203287		1	1																	1	1	1	1	1	1	1
1202635		1	1																	1	1	1	1	1	1	1

Figure 4(b) Sequence Similarity Analysis of Routings.

machining processes and employee expertise. It is unrealistic to expect (or even want) to do the computer analyses manually.

A Major Challenge that Lies Ahead

The proposed layout in Figure 2 is at best a good starting point. This was the easy part. This layout is theoretical because computer algorithms simply cannot take into consideration many constraints and operational realities. Next, we faced a major hurdle of justifying the investments in re-locating the machines already in the area, as well as moving machines currently located elsewhere into the area. John Sexton, our facilities maintenance and industrial engineering manager, estimated that the following expenses would be incurred:

- Capital Investment
  - Purchase a Norton Grinder
  - Purchase a jib crane for loading/ unloading both the Mori Seiki and Haas lathes
  - Purchase new worktables, toolboxes and cabinets for all machines
- Equipment Re-Location
  - Move Mori Seiki from PRR Cell into MP Cell
  - Move Mazak VTC/Mill, ProCut Lathe and EZPath Lathe out of the MP Cell into the PRR Cell
- Facility Upgrades
  - Relocate and rewire all other machines already in the area occupied by the MPC based on the new floor plan for the cell
  - Resurface the floor

	705	125	115	120	135	105	110	150	145	130	126	155	180	170	240	210	250	215	410	305	227	245	205	255	710	915
705		6976	709												7336											
125				731	6245				2145	54															630	
115					609									100												
120					731																					
135						6976	2024						609													
105					1415		5554	7																		
110								7628	50																	
150		2195							5490																	
145		634						50			3225	609													3167	
130																									54	100
126										100															3125	
155																									609	
180					609		100																			
170													100													
240																7290		26	14	6						
210																	2148	183					4753	206		
250																								2148		
215																					6		31	178	8	
410																		14								
305																							6			
227																						6				6
245																									6	
205																					6			4784	17	
255																							206		7110	
710																										
915																									106	

PART FAMILY: MP Cell

PART FAMILY: PRR Cell

Figure 5(a) From-To Chart for the MPC Part Family.

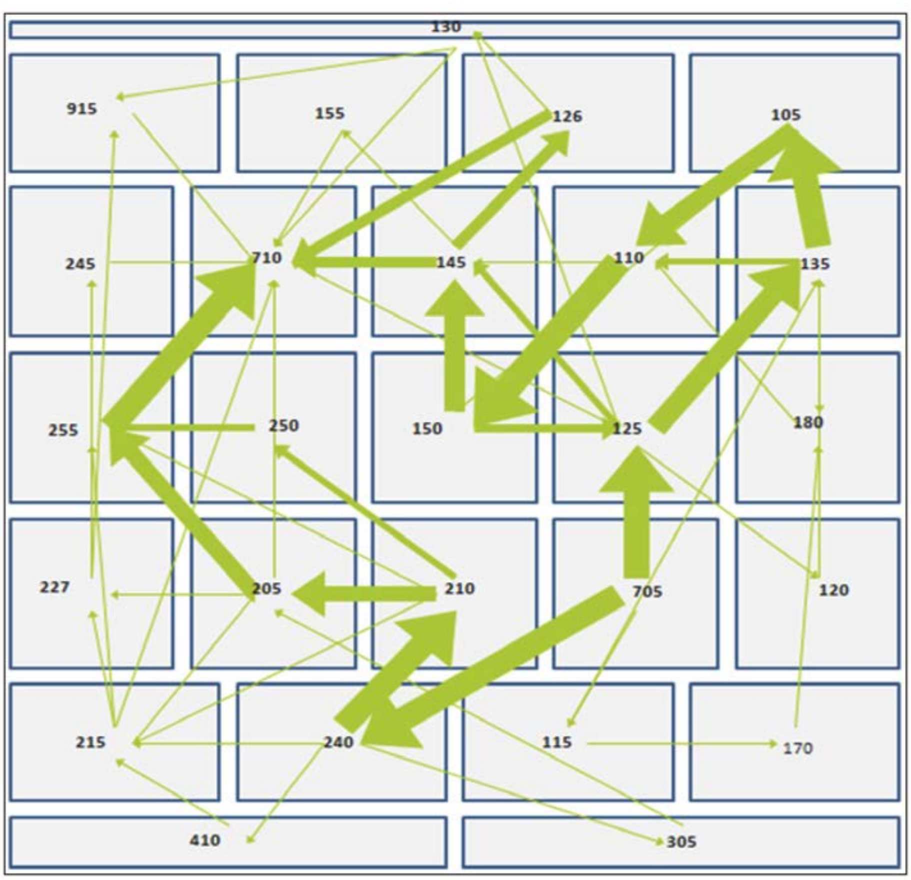

Figure 5(b) Flow Diagram to Visualize the From-To Chart.

180	170	130
105		110
135		150
125		145
120		126
155		710
115		915
705		

Figure 6(a) U-shaped Layout produced by STORM.

705	115
170	180
125	135
120	105
150	110
145	155
126	130
710	915

Figure 6(b) Parallel-Line Layout produced by STORM.

115	705	
170	125	120
180	135	105
	150	110
155	145	
	126	130
	710	915

Figure 6(c) Block Layout produced by STORM.

This is just the initial list of costs that was presented to us so we could prepare a detailed cost/benefit analysis to justify investments in the implementation of the first FLEAN cell in our facility.

But We Did Not Wait To Implement the Simple Changes

Lean encourages us to make any and all improvements that cost nothing or require minimal expense. So, we decided to at least "pluck the low-hanging fruits". In the case of the MPC, the employees have worked in this cell for decades. For example, Luong Dam, who runs the three Cincinnati mills has been with the company for nearly three decades. It took little time for us to convince him that beneficial change was in the air. He worked tirelessly with the Tiger Team over a period of two weeks to raze his workcenter. There were also examples of in-house benchmarking where we tried to borrow ideas that had been successfully implemented in other cells. In another cell, the QRC, we noticed a tool storage cart that had been fabricated by one of our senior multi-talented employees, Phillip Nguyen. All that we needed to do was to request him to design and fabricate a similar fixture for the tools used on the Le Blonde lathes in the MPC. How much do you think it cost him besides his time and effort? Such is the power of lean to motivate and inspire every employee who "gets it."

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Dr. Shahrukh Irani is the Director of Industrial Engineering (IE) Research at Hoerbiger. In his current job, he has two concurrent responsibilities: (1) To undertake continuous improvement projects in partnership with employees as well as provide them OJT training relevant to those projects and (2) to facilitate the implementation of Job Shop Lean in HCA's U.S. plants.