Feedback: Job Shop Lean (ongoing lean series in *Gear Technology* 2013)

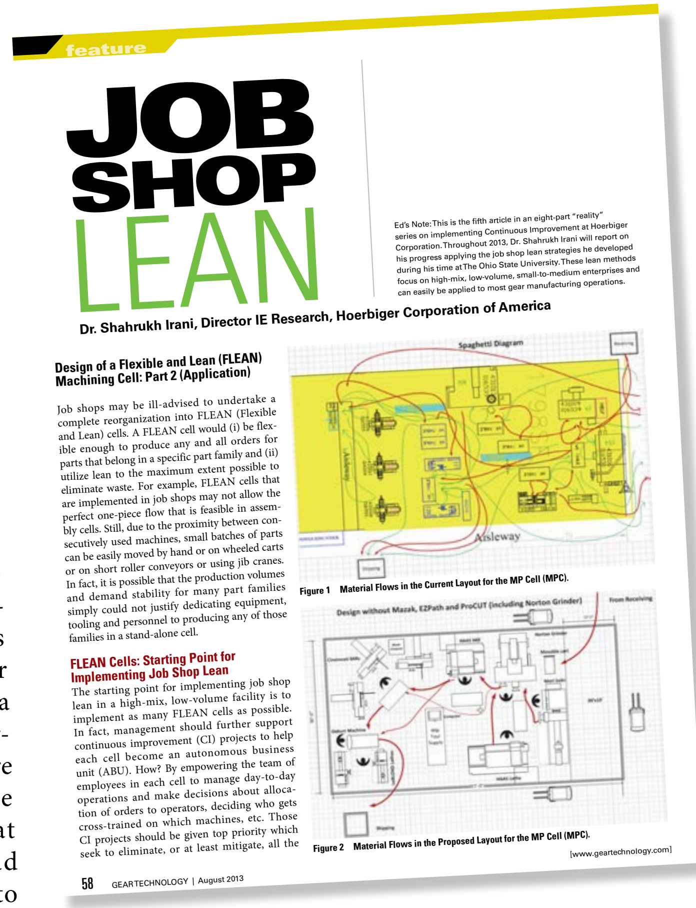
Dr. Irani,
Congratulations. Many industries have been slow to implement celluar manufacturing. At the former New Venture Gear, we implemented work cells in 1995. Our work cells were heavily influenced by the design of work cells at Toyota, Mitsubishi, and Aisin A.I. in Japan. We took their design and elevated cell manufacturing to a much higher level. We realized that copying the Japanese layout design would only keep us even with the competition. We began analyzing the manufacturing process and how to revolutionize gear manufacturing.

Gear cutting has traditionally involved using heavy cutting oil. Cutting oil creates hazards itself. It creates slip hazards on the floor. It creates breathing health hazards for employees. It creates environmental hazards as it must be prevented from running off and contaminating the ground water supply and it must be disposed of properly. We had already moved past using heavy gear oil and were utilizing Cimcool water-based coolant, but we still had the same hazards.

We began to envision how we could cut gears without coolant. We were told [at that time] by gear cutting equipment manufacturer Pfauter that it was impractical if not impossible to cut gears without liquid coolants. We were told gear cutting hobs won't hold up to the heat generated from the cutting process without coolant. Despite this advice, our team remained true to the vision.

We brought in engineers from Mitsubishi Heavy Industries in Japan. Mitsubishi had developed a titanium aluminum nitride coating for cutting tools. If one knows anything about machine tools, they know that the coating on a tool performs as a lubricant. Cutting oils are also lubricant but additionally cool the gear that is being cut. By using gear hobs coated with TiAIN, the cutting speed required is approximately four times as fast as conventional gear cutting. Compressed air is utilized to evacuate the chips from the part. The heat goes away with the chip, leaving the gear lukewarm. Dry cutting gears reduces cutting time significantly: a gear that formerly required four minutes to cut with traditional gear cutting practices requires less than a minute to complete dry cutting.

Another major opportunity for improvement in gear manufacturing is to eliminate the damage from material handling while the gear is in a "green state." The damage to gear teeth prior to heat treating results in gearbox noise. The typical solution is to add manpower to grind the nicks off the gear teeth after heat treating. We did a cost analysis and determined that it was more economical to purchase additional heat treat alloy fixtures to load the gears directly onto at the gear cutting process instead of placing the gears into plastic dividers in a shipping container and then having an employee damage the gear teeth as he places them on the alloy fixture in the heat treat department.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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).

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Another major improvement we made was the transition from finishing the bores and faces by grinding to hard turning the surfaces with special inserts on CNC turning lathes. We achieved the same micro-finishes by hard turning that we did with the grinding process while eliminating the coolant that had all the hazards I mentioned with cutting oils in gear cutting. We also hard turned all diameters on all shafts instead of grinding.

We eliminated roving inspectors and placed the responsibility of quality upon the cell operator. We still had to verify gear geometry in the gear lab but only after a hob change or after a changeover from one gear part number to another. I mention the changeover because we invested in quick change over fixtures that allowed us to run more than one gear in a work cell. We had no dedicated work cells for any one gear. Since larger gears require heavier gear cutting equipment while smaller gears require less robust equipment, we grouped gears into size categories and routed them to the correct size equipment. This is batch running of gears, but heat treat operations forced batch processing of gears in furnaces anyway. When I left the company, we were working with a company out of Indianapolis on contour hardening of gear teeth utilizing induction hardening. If that process could have been developed, we could have had a true one-piece flow from forging to finished gear process ready for a gearbox assembly.

The most important success factor to our gear cutting was our reliance on machine capability and our TPM system. With capable equipment and scheduled tool change frequencies, the operator always produces a quality part.

For a work cell to be most efficient, the operator must be able to walk the entire cell continuously only stopping to load and unload each machine as he travels around the cell. Never should he be waiting for a machine to finish its cycle. In gear cutting, sometimes a gear has clutch teeth cut on a shaper machine such as a Fellows shaper in addition to the gear cutting operation. Shaping clutch gear teeth is a slower operation, so you may have to add an additional shaper into the cell and alternately load each shaper machine each time the operator cycles through the cell.

One of our typical gear cutting cells consisted of the following pieces of equipment: a lathe to turn the rough forging into a gear blank; a gear hobbing machine; a gear teeth chamfering machine; a clutch gear shaper; an oil hole drilling or slot cutting machine; and a washer for cleaning. At the time, we still used coolant on drills and clutch cutting machines because dry cutting had not been perfected at that time. That required the use of a washer in the work cell.

What was unique about our company was that being a joint venture between Chrysler and G.M. we produced the exact same products for both companies. The only difference between the transmissions we provided for each was the bell housing that mounted the transmission to the engine. I left the company two years before the joint venture was dissolved in 2002. I was the first employee hired by the Muncie division after the joint venture agreement was signed in 1990. If you have not adopted the above processes, there is much to be gained by doing so.

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Dr. Irani,

Congratulations. All those times we had our heated discussions of lean in job shops, and you have now done exactly what we did between 2006-2008 when I worked for the gearbox manufacturer. Your process is almost verbatim on the "what and how" we rationalized and worked through. Reading your article was like walking through that time period all over again! Our next step was to look at software (like Prasad's system), once our schedulers understood what they were doing well enough to have software do it for them.

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Feedback: My Gear is Bigger than Your Gear (*Gear Technology* March/April 2013 and reprinted in *Gear Technology India* Q2 2013)

The article "My Gear is Bigger than Your Gear," made interesting reading. It is still debatable as to what criteria qualifies a gear to be BIG. Does it qualify on the basis of diameter, weight or power transmission capability? A very important parameter totally missing in your article is the qualification based on module of the gear. Having spent 25 years in the gear line, I feel that the largest module manufactured in the world should also be a serious contender for the achievement. The module of a gear has a direct relation to diameter and power transmitted. Also, it does not differentiate between a rotating gear and a rack, thereby putting to rest the controversy whether a rack should be considered for such a comparison or not. On checking the Internet, I found the largest module manufactured to be 50, made by David Brown.

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