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We're big fans of lean manufacturing practices, 5S and Six Sigma based on the results we've seen in metal casting plants as well as in other manufacturing companies. If you are not embracing and implementing these concepts, chances are your company is not moving forward. If you are not continually improving you are moving backwards relative to your competitors.

LEAN MANUFACTURING

Lean manufacturing is the implementation of the concept that anything that does not create value in the product is to be eliminated. It is the concept of more value for less work. As trained industrial engineers, it seems pretty basic to us. Its simplicity is what makes it work. While the Japanese are rightfully given credit for re-vitalizing the concept of lean, its roots really go back to Frederick Winslow Taylor of Bethlehem Steel in the 1880s and 1890s. Then it was called "Scientific Management."

The Taylor approach starts with a clean slate – it designs the process to, as much as possible, only include steps that create value in the product. It is well suited for new plants, new products or new processes. The Japanese approach addresses existing plants, products and processes. It is focused on eliminating "waste" (anything that is not adding value). As waste is reduced, quality improves, production times are reduced and cost is minimized. Various methodologies are used as tools to achieve this including Value Stream Mapping, 5S, Kanban (pull systems) and error-proofing.

Our view is that starting with Taylor's approach lets you establish the perfect world as a base line. Using the Japanese approach then helps you work toward the perfect world. Let's use a casting example. A typical process might be to cast, clean, finish, re-clean, machine and ship. Why do we clean, finish and machine? We know these processes often can't be eliminated but why not try? If the casting can be produced as-cast either by achieving best practice methods or changing casting methods (investment casting and lost foam often achieve as-cast parts), machining can be eliminated or minimized. If you don't put the stock on you don't have to take it off. Why is finishing (or at least why is so much) required? We know a state-of-the-art OEM producing iron castings in green sand that require almost no finishing. Are you grinding/trimming parting lines? Then your patterns or molds may need attention. Are you grinding rough casting surfaces? Then your sand is not right or your die casting practices need improvement. Grinding gates? Can they be relocated to areas where they can be left untouched and minimized using knife gating? Are you welding? If you are not joining parts in welding all you are doing is fixing mistakes. Why do you clean before finishing? Good sand and shake-out practices should produce castings that are clean enough for finishing. Just clean one time after finishing.

What's your scrap level? If you're not under 3% total scrap, no matter what casting method you use, you are not achieving best practice. That's without welding and other salvage operations by the way. There are metal casters achieving these levels every day. How do they do it? They share a lot of common traits. First, they understand what best practice is for the process they are using. That includes melting, molding, sand preparation, finishing or what-ever process they are using. They know the best practice way to do everything. You would be surprised at how many metal casters we visit who don't know what can be done. Next, they are fanatic about doing it the right way. That means equipment is well maintained, systems are defined, documented and implemented the same way every time and everyone is well trained and does their job right. After that they focus on problem jobs – ones that require re-design, special gating, handling or other steps to insure they are scrap free. Finally, they document all scrap and attack issues.

There are other lean practices to implement. If production flows perfectly, there is no inventory waiting to be worked on. Metal casters have helped minimize work-in-process by installing conveyor lines to keep castings moving right through to finished goods storage. This eliminated putting the castings in totes and the added handling. One low to medium volume gray/ductile iron jobbing foundry (casting weights under 50 pounds) we know now ships 30% of its production the same day and believes they can achieve 70% same day shipment. These standards aren't just for the high volume or dedicated metal casting companies any more.

"Autonomation" or "smart automation" is a part of lean manufacturing as well. Autonomation refers to automating the process so humans can focus on what humans do best. The objective here is to design the machine so it knows when it is working abnormally and alerts a human. The human no longer has to monitor normal production but can focus on abnormal or fault conditions. Removing routine and repetitive activity reduces the chance for error.

Lean manufacturing is focused on doing the right tasks, at the right place, at the right time, in the right quantity to achieve perfect work flow while eliminating waste (scrap) and with the ability and flexibility to change.

Implementing lean manufacturing often requires a cultural change in all levels of the organization. Once management is committed, a program needs to be started that begins with small successes and grows to include the <u>entire</u> organization.

The Toyota Production System (TPS) focuses on *muri* and *muda.* Muri focuses on the preparation and planning of the process, or what work can be eliminated in the design process. Muda are those waste steps and processes that add cost. Muri is used in new product design and muda is used to improve existing operations. TPS identifies 7 key muda*. They are:

- Transportation (moving products that is not actually required to perform the processing)
- Inventory (all components, work-in-process and finished stock not being processed)
- Motion (people or equipment moving or walking more than is required to perform the processing)
- Waiting (waiting for the next production step)
- Overproduction (production ahead of demand)
- Over Processing (due to poor tool or product design creating activity)
- Defects (the effort involved in inspecting for and fixing/scrapping defects)

**From "Lean Thinking", Womack, James P. and Jones, Daniel T., Free Press, 2003, p. 352*

What are the steps to developing a lean culture?

1. Senior management needs to agree on a lean vision.
2. Identify the project leader and set objectives for the leader.
3. Communicate the plan and vision to the workforce
4. Solicit volunteers to form the Lean Implementation Team. Five to seven people with varied backgrounds seems to work best.
5. Appoint the Lean Manufacturing Implementation Team
6. Train the team in various lean tools. 5S is often a good starting point.
7. Select a pilot project for implementation.
8. Implement the pilot. Evaluate the results, review and learn from mistakes made.
9. Roll out the next project(s).
10. Train supervisors how to teach and train their employees.
11. Continue adding and training in additional lean manufacturing tools.

FIVE S

Companies frequently select 5S as a method to start their lean manufacturing program. Five S is a manageable process that is relatively easy for people to understand and get their arms around. Five S is a reference to five Japanese words that have been transliterated and translated into English. The technique is often characterized, incorrectly, as a "standardized cleanup." It is more than that. Five S is a method to organize and manage the workspace and work flow with the intent of improving efficiency by eliminating waste, improving work flow and reducing process inefficiencies.

The 5S's are: Sort (Seiri), Straighten (Seiton), Sweep (Seiso), Standardize (Seiketsu) and Sustain (Shitsuke).

Sort – This means going through the work area and making sure only essential items are present. This is eliminating tools, materials, fixtures or any other items not used in the process. Everything else is stored or, preferably, discarded.

Straighten - Straighten focuses on setting the workplace in order to focus on efficiency. This is more than just arranging the tools and equipment where they will be used and in the sequence they will be used. It is "straightening" the work path for materials, tools and the work process. Of all the steps this is the one that typically produces the greatest cost reductions. Straightening the work process can include changes in dies or tooling that reduces finishing labor, for example. It may include interaction with the customer to implement design changes that result in cost reduction or quality improvement. It is also the step that bears the most repeat visits to implement continual improvement.

Sweep – This is just what it says: keeping the workplace clean as well as neat. At the end of the shift, the work area is cleaned and everything is restored to its proper place. In straighten, the workplace is clearly marked where things go and gives confidence in the ability to find what is needed when it is needed. The key point here is that cleanliness is a regular part of the daily work effort, not an effort initiated when the workplace gets too messy.

Standardize – Standardizing the work practices means operating in a consistent and standardized fashion. Everyone knows their role and exactly what his or her responsibilities are. Actions are taken the same way – the right way – every time.

Sustain – This means more than just maintaining what has been established. Five S becomes a way of life and a new way to operate. It is important that management does not allow a gradual decline back to the old ways of operating. Sustain also means that when an issue arises – a suggested improvement, a new tool becomes available, or a new output requirement – the process is reviewed for improvement.

At times a sixth S – for Safety – is added. Five S purists argue that implementation of the 5S protocols will result in safety.

Implementation of the 5S program usually starts with a manageable project. These tend to be in limited work areas or warehouse locations. Once implemented, the results are publicized and the concept is expanded to other areas.

The strength of 5S is the ease of understanding and implementing the concept.

SIX SIGMA

Six Sigma is a quality improvement technique developed by Motorola in 1986 to improve manufacturing processes and eliminate defects. Motorola still owns the service and trade marks for the name Six Sigma. Six Sigma refers to 3.4 defects per million opportunities. For reference, Five Sigma is 230 DPMO and Four Sigma is 6,210 DPMO. Three Sigma is 66,800 DPMO or 93.32% good opportunities per million.

Most people recognize Six Sigma by the Green Belts and Black Belts. In an organization fully committed to Six Sigma there are also Champions (responsible for implementation across the organization) and Master Black Belts (in-house coaches for Black and Green Belts). Black Belts are typically dedicated full time to the process and Green Belts take Six Sigma implementation along with other responsibilities.

The weakness, in our view, is that practitioners become so enamored with the process that they over analyze and fail to act.

Six Sigma has two key methods – DMAIC (used in existing processes) and DMADV (used in new products/processes). Here's what those acronyms mean.

DMAIC

- ***D***efine high level project goals and the current process.
- ***M***easure key aspects of the current process and collect relevant data.
- ***A***nalyze the data to establish cause and effect relationships. Determine the nature of the relationships and attempt to insure all factors have been considered.
- ***I***mprove the process based upon the results of the data analysis.
- ***C***ontrol the process to insure that any deviations from the process are corrected before they result in defects.

DMADV

- ***D***efine the design goals that consider both customer demands and enterprise strategy/capabilities
- ***M***easure and identify the characteristics critical to quality, product capabilities, production process capabilities and risks.
- ***A***nalyze to develop and design alternatives. This is a product improvement strategy.
- ***D***esign details in a manner to optimize the design. Verify the design details.
- ***V***erify the design, set up pilot runs, implement the production process and turn it over to the process owners.

While many metal casters would scoff at Six Sigma – that's .00034% scrap – a number of metal casters are achieving that level of shipped quality. If you are producing safety critical parts for passenger vehicles, Six Sigma isn't good enough. For example, if you are making 4 million steering knuckles a year Six Sigma would mean 12 vehicle failures per year. Or if you are making vanes for aircraft engines, Six Sigma just won't do it.

Since most metal casters are working to improve their processes, let's work through the DMAIC process. When we started in metal casting over 30 years ago, the old timers (now us) said metal casting was an art, not a science. As engineers right out of college we knew better. Metal casting is a science with a whole lot of variables that interact in ways we may not fully understand. We're going to use scrap reduction in a green sand foundry to explain the Six Sigma process. Also, we're going to focus on green sand for our example since it is probably the greatest cause of scrap and one of the most complex ingredients in any of the casting processes.

- ***D***efine high level project goals and the current process

This is pretty straight forward and not too hard to get right. A goal may be to lower scrap from 6% to 3%. Defining the sand selection and conditioning process is a relatively easy documentation procedure.

- ***M***easure key aspects of the current process and collect relevant data.

A little tougher but not all that hard. Many green sand foundries measure green strength, sand grain distribution, methylene blue (active clay levels) and moisture. All are very quantifiable and lend themselves to the standard SPC charts. We do know a few foundries that still use the molder's hand, however, for sand quality. Wait! There's more. To be of value later on, we need to track the scrap and the reason for the scrap. Remember – the goal is to reduce scrap not produce molding sand within all its parameters on the SPC charts.

- ***A***nalyze the data to establish cause and effect relationships. Determine the nature of the relationships and attempt to insure all factors have been considered.

This is the tough one and where people tend to get bogged down. On the cause side there are moisture, grain size distribution, active clay levels, levels of fines and other additives (cereals and sea coal, etc.). On the effect side are a lot of defects – surface finish, sand holes, veining, etc. Some of the defects may be caused by something other than the sand creating even more complexity. Dedicated Six Sigma practitioners would collect tons of data and develop a complex multiple linear regression analysis to develop the ideal sand mix.

A common mistake at this point is to assume your ingredients are correct, just not in the right proportions. The first step is to understand what best practice sand preparation is and what it can do for you. Sand is not sand is not sand. Foundries on the East Coast frequently use sea sand. This sand contains calcium that has an impact on the casting process. Some East Coast foundries buy Lake Sand from the Midwest because it tends to be purer. Clay is not clay is not clay. There are Southern Bentonites and Western Bentonites and now, some clays coming from Greece seem very attractive.

Selection of the tool to analyze the process and defect causes is a major reason for Six Sigma failures.

A better tool selection here would have been axiomatic analysis. Axiomatic analysis places the parameters (moisture, sand type, bond types/levels, etc.) in a matrix and makes well thought out, controlled changes and analyzes the results. It's a sophisticated trial and error method.

- ***I***mprove the process based upon the results of the data analysis.

This is where the value comes in. By making the changes indicated, costs are reduced and quality is improves. If you don't get to this point, everything else is wasted.

- ***C***ontrol the process to insure that any deviations from the process are corrected before they result in defects.

Once you've determined an improved way to formulate and prepare the sand, now you have to make sure everyone sticks to it. Generally, that part is not too hard. You set the parameters, record the results and hold people accountable. Now here's the tougher part. A number of years ago Ford and Honda developed a common engine with Ford producing them in a plant in California and Honda at an identical plant in Japan. After they were in production for a while, there was a noticeable difference in the warranty claims between the engines produced in the U.S. and those in Japan. The U.S. engines had higher warranty claims, although still within reasonable levels. Engineers carefully analyzed the U.S. and Japanese manufacturing processes (the processes were identical, remember). In the U.S. operators were very careful to stay within the SPC guidelines for each process. They met all the quality requirements. In Japan, the operators tried to stay as close to the mid-point of the parameters as they possibly could. A whole difference in attitude to quality. Doing it good enough or doing it the best you can.

What's the attitude at your company? Doing it good enough or the best you can?