ETM
ENGINEERING & TECHNOLOGY MANAGEMENT

Title: Rethinking Conventional Labor Hour Benchmarking

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Abstract

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RETHINKING CONVENTIONAL LABOR HOUR BENCHMARKING

For Dr. Dick Deckro
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Manufacturing Management

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ABSTRACT

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INTRODUCTION

U.S. manufacturing industries have seen radical changes in the last couple of decades as a global marketplace has replaced our domestic market. Aggressive foreign competitors, modernized following the post-World War II devastation, have forced U.S. companies to change their mode of operation. Deming's 14 points, TQM, JIT, MRP, Kaizen, etc. are all relatively recent revelations affecting American manufacturers. However, certain industries have been slower to adopt these techniques and philosophies. One such industry is the aircraft industry. With little global competition, there has not been the external drive to adopt new manufacturing philosophies. Precision Castparts Corp. (PCC) is one such company. PCC is one of two primary casting suppliers of very large investment castings used in aircraft engines.

A basic foundation of modern manufacturing philosophy involves benchmarking the internal manufacturing process so that changes in the process are detected and resolved. PCC's internal benchmarking can be improved. This paper will investigate the system used at PCC's Titanium Business Operation (TBO), a plant employing approximately 900 people and annual sales of $70 million. Specifically, TBO's current benchmarking practice for manufacturing standards will be reviewed. Included in this review will be an analysis of the impact of casting quality, learning curves, customer orders and manufacturing practice on benchmarking.

MANUFACTURING STANDARDS

Historically, TBO has not placed much emphasis on setting accurate standards. Manufacturing standards are determined initially while setting up the manufacturing process router. The estimating department makes the initial labor hour estimate at each operation (typically about 35 operations per part number), which is subsequently reviewed for approval by the appropriate Engineering, Planning and Manufacturing personnel. This estimate is based on information obtained from similar part configurations (if any) and professional expertise.

These standards can be modified once a year per company policy, but this is often a power struggle between Manufacturing, who wants more hours for their earned standard hour evaluation, and Engineering, who work to control overall costs. Sufficient data is seldom available in order to make a qualified change. TBO employes no industrial engineers or anyone with significant training in setting appropriate standards. TBO attempts to set standards via MIS evaluation and supervisory opinion. Unfortunately, the current MIS system does not provide enough data for a proper analysis. While it is possible to track primary sequential operations fairly well, the system fails to adequately distinguish the amount of time spent in NDTE evaluation and salvage/rework operations. Rework accounts for 25-35% of total manufacturing hours on typical production parts, and is often much higher on development parts. These hours are lumped together, and it is very difficult to discern where these hours were charged. Furthermore, the data is not statistically analyzed and controlled.

QUALITY

The investment casting process, as shown in Appendix 1, lends itself to some difficulties in ensuring repeatable quality. During the process, the wax pattern and gating are repeatedly dipped and blanketed in a ceramic slurry mixture and allowed to harden between coats. The wax is melted out and the subsequent shell placed in a burnout furnace at 2000 degrees to sinter the ceramic shell. The hot shell is transferred into the vacuum casting furnace and molten titanium poured into the shell. Molten titanium reacts violently with oxygen and thus requires the vacuum during all thermal cycles. With all of the wax-to-ceramic-to-metal transformations, thermal changes and ceramic binder evaporation, it is easy to understand that this process is prone to high variability. Surface gas, shrinkage, shell cracking, inclusions, buckling and other defects affect all castings to some degree at various times. Subsequently, rework and total manufacturing hours swing wildly, due in part to this process variability. Historically, these hours have been used as a primary indication of casting quality, but quality is not the only variable affecting labor hours.

LEARNING CURVE ADJUSTMENTS

TBO is aware of the learning curve inherent to manufacturing their complex products, and sales prices reflect this knowledge. However, this information is not translated into the manufacturing standards. While standards set at T-infinity are good as long term goals, it sets the precedence that it is acceptable to be over standard for quite some time. This practice provides no immediate standard by which to measure oneself.

Also affecting the learning curve is cyclic customer orders. Some customers order a steady supply of product, while others order a bubble of parts, with a long delay (one, two or even four years), then another bubble of parts. This hinders refining the process to make it more efficient. The time delay is essentially like regressing back to the early stages of the learning curve.

MANUFACTURING PRACTICE

As noted, labor hour variability is a concern. In practice, labor hours for standard router operations are watched closer than rework operations because earned standard hours are only monitored for standard router operations. All rework is charged to one account. Thus, this account has seen abuse. For example, when product volume decreases, rework hours increase despite equal quality. Manufacturing practice, along with planning, can have a significant impact on rework hours and standard hour conformance.

DISCUSSION

Gaining control of this situation is a monumental task. As has been discussed, setting and monitoring standards, quality control, learning curve adjustments and manufacturing practices are all areas that could be improved. This paper will not attempt to solve each one of these areas, instead, a more cursory analysis of these areas with possible avenues for further study will be discussed.

MANUFACTURING STANDARDS

Arguments can be made to maintain set standards throughout the life of a program. This allows productivity numbers to be easily tracked over time. However, comparison of actual labor hours over time is an alternative that provides essentially the same information. In practice, productivity goals are easily manipulated and thus not a good measure of performance. As described by Goldratt in The Goal, a company's primary goal is to make money - and throughput, inventory and operational expense are the three primary measures of making money. Actual labor hours translate directly into operational expense and is thus a better measure than earned standard hours. However, labor standards are useful in providing a benchmark for workers. But this benchmark must be realistic or it loses all validity. Adjusting standards to account for varying quality, learning curve effects, new manufacturing practices, etc. can provide realistic goals for manufacturing. Variable standards provide an immediate target at each operation, not a lofty target that may not be achievable due to factors beyond the operator's control at each operation.

The variable manufacturing standards would be known by all workers, and it would be known that their actual hours will be judged against the target. Knowledge is a powerful motivator. Scott Sink relays a story that while working in an appliance factory painting refrigerators, the reject rate went from 30% to 5% simply by posting these results for the workers to see. People want to do a good job, if Theory Y applies, and performance feedback is necessary for them to assess the quality of their work. TBO could benefit from this as well.

To set these variable standards, a small cross-functional team would review castings and set realistic manufacturing standards for them, based on the most recent information regarding quality, sales, etc. Again, these standards would be known by all workers. This would be a dynamic cross-functional group, ever evolving their method of estimating the amount of time to complete the manufacturing operations.

In addition, total hours and rework hours would be tracked over time to check for improvement. If properly monitored and managed, one would expect to see a decrease in hours that roughly fits the classic arithmetic learning curve.

Inherent to the success of these changes is a refined MIS system that easily allows one to obtain information on total hours, rework hours and hours at individual operations. The system must be able to perform statistical analysis of the data for real-time use. This would allow the team to address spikes in the hours versus the "normalized" standards. TBO has been making great strides in this direction as of late. A new barcoding system will be in place to track worker hours and part movement. This replaces the antiquated timecard system currently being phased out. An accurate, user-friendly database is essential to becoming more efficient.

QUALITY MODIFIER

As noted earlier, salvage standards should be adjusted for quality variability. For titanium parts, an inspection immediately after the Hot Isostatic Pressing (HIP) operation is the opportune time to analyze casting quality. Severe shrinkage will show up as dimpling that requires subsequent welding. Surface gas and major/moderate surface shrink can be visibly identified. This is the area where the cross-functional team would review casting quality for possible modification to the manufacturing standard set for these castings. The team's observations and estimates would be input into a database. The database must be easily accessible at this point so that the team can review their performance in estimating the hours. In addition, chronic problem areas would be easily identified and the appropriate action taken to correct the problem. Again, accurate and consistent information is vital to never-ending quality improvement.

In practice, the quality modifier would be a multiplication factor to use with the baseline standard. A poor quality part would have a modifier greater than 1.0. For example, for a poor quality casting, the welding operation may require 1.2 times the 5 hour baseline, so it is expected that it would take 6 hours to perform the operation.

LEARNING CURVE

Product learning curves require more attention than they have previously received. Tracking total labor hours is important to determining the appropriate learning curve. Classic learning curve study assumes consistent product flow so that the process can become more efficient and drive down cost. Product flow at a job shop like TBO hinders efficiency. Sporadic orders, often with critical and compressed due dates are part of the business and classic learning curve theory may not apply. Comparing the past performance versus order activity would be vital in determining the effect of sporadic orders. This information could be used to adjust the variable standard. The cross-functional team should have access to this information while making the variable standard modification.

MANUFACTURING PRACTICE

TBO manufacturing needs to modify their current mode of operation. While currently judged on productivity via earned standard hours, in addition to dollar shipments, they need to shift their emphasis to making money by controlling throughput, inventory and operational expense. The new proposed system can help.

By reviewing parts before they arrive in the finishing operations, they can better staff these areas and improve operational expense. With the improved MIS system, they can track employee performance against the realistic standard. For poor quality parts, there will be less incentive to hurry the part into the rework cycle because they will have allotted adequate time to repair the casting at the proper operation the first time through. This will also aid in scheduling the work flow better and result in lower inventory and increased throughput, as well.

CONCLUSION

This paper has identified some opportunities for improving the manufacturing operations at TBO. As discussed, employees have been overwhelmed in trying to identify and solve fluctuations in manufacturing hours and costs. The problem stems in part from a cumbersome system that assesses so many labor hours into a single rework hour pool. Deciphering what portion of this rework is due to quality variability, manufacturing variability, product flow, total product volume, etc has been very difficult.

The proposal suggested in this paper involves using variable labor standards to provide realistic goals for current product. Beginning with an improved, more accurate labor standard, it can be adjusted for fluctuations in casting quality, learning curve changes or manufacturing practice. The result is an improved technique for assessing the high cost of rework to its root cause. Only then can the cause be addressed and corrected. With an improved MIS system, this change could be implemented soon.

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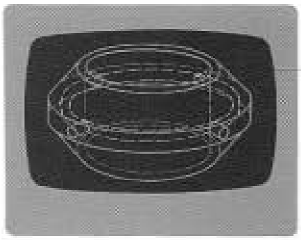
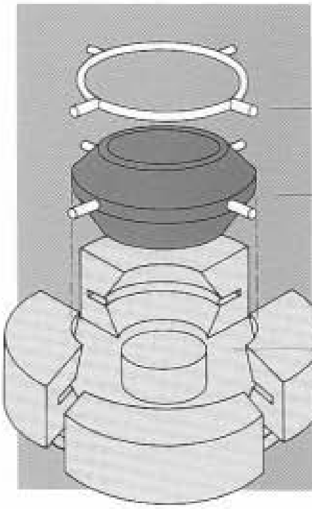
APPENDIX 1

The Investment Casting Process



Customer supplied electronic data details casting's shape and size.

DESIGN: Investment castings begin with a customer-supplied drawing or electronic data which describes a casting's shape, size, finish requirements and acceptance criteria. PCC engineers convert the information for the casting process.

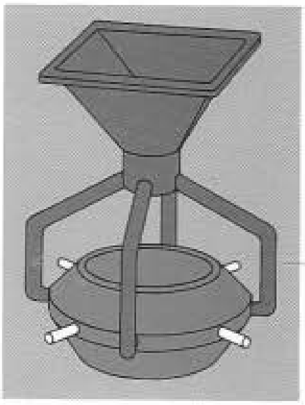


Ceramic core placed in die prior to wax injection.

Wax pattern

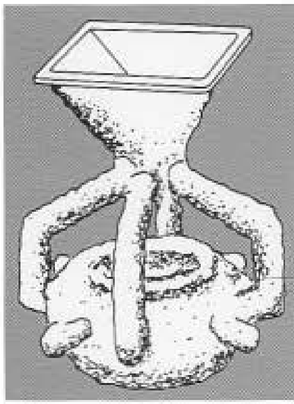
Metal Die

CREATING PATTERNS FROM TOOLS: A pattern is a facsimile of the desired casting, made by injecting wax into a die. Dies are generally constructed from metal and feature sections which slide apart for removing the hardened wax pattern. Ceramic cores, also produced from metal dies, create hollow sections within castings. Cores are placed inside pattern dies prior to wax injection, and remain in place during casting.



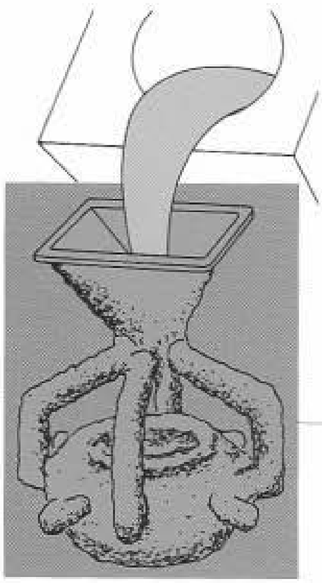
Gates added to wax pattern

WAX ASSEMBLY: Many PCC castings are created from one-piece patterns—waxes that emerge from the die complete. However, large or complex castings often require that waxes be created in sections which are then wax-welded together. Gates and risers are added to create pathways for molten metal to flow through the ceramic mold during casting, allowing the mold to fill quickly and completely before the metal can solidify.



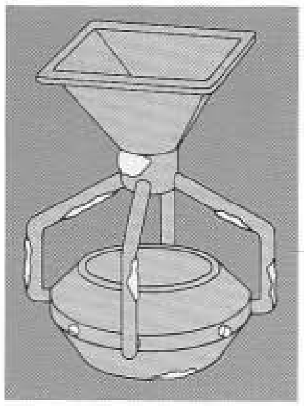
CREATING A CERAMIC MOLD: Once a pattern is complete, robots dip it in a proprietary ceramic slurry, alternated with fine grain sand, to produce a mold or investment. Finished molds are heated to melt out the pattern material, leaving a hollow shell.

Ceramic shell built around wax pattern and gating.



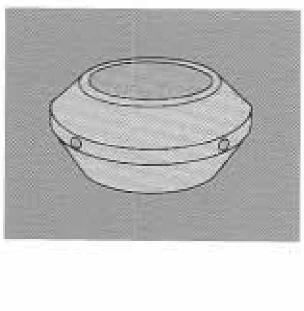
CASTING: Like most phases of the production process, casting methods differ depending on the alloy used. Alloys are blends of metals formulated for specific properties of strength, hardness, ductility, temperature tolerance, bio- or chemical-compatibility. Some alloys can be melted and poured in the open air. Others, titanium for example, must be cast in a vacuum. Molds are preheated, then filled with molten metal which solidifies inside the shell. Temperature and cooling rate are controlled to ensure metal purity and casting integrity.

Alloy being poured into mold after wax pattern removal.



CERAMIC SHELL REMOVAL AND FINAL PROCESSING: After casting, the shell, gates and risers, and any ceramic cores are removed using mechanical methods, water blast techniques and chemical leaching. Some castings undergo hot isostatic pressing (HIPping). Extreme heat and pressure during HIPping eliminate internal voids and porosity. All castings are heat treated to obtain required mechanical properties.

Ceramic shell removed from casting.



INSPECTION: Castings undergo numerous quality checks. Non-destructive testing using X-rays, ultra-sound, fluorescent penetrant and magnetic particle inspection certifies a casting's internal quality. Dimensions are also inspected and alloy samples are tested to ensure correct chemistry and mechanical properties.

After gates and ceramic core have been removed the part undergoes extensive inspections.

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