Accuracy Control

The journey to becoming a learning organization

Applying geometric tolerancing throughout the shipbuilding design, manufacturing, and quality processes to improve accuracy control; how an effective accuracy control program can improve the way a shipyard organization learns and adapts; and leading the change effort.

Joe Boyle

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Northern Michigan University

Abstract

This thesis adds to the body of research on accuracy control and its relationship to organizational learning by exploring three distinct themes that will not only address technical issues, but also soft issues of leading change, and building a learning organization. The themes include:

1. Using geometric tolerancing throughout ship design, manufacturing, and quality processes to improve accuracy control.
2. How an effective accuracy control program, involving production people upfront in the design process, can improve the way a shipyard learns and adapts, improving competiveness.
3. Provide a methodology and discuss struggles of leading the organizational change effort needed to implement an effective accuracy control system.

Introduction

Ship manufacturers need to control process and product variation through each stage of the design, manufacture, and quality processes. To stay competitive shipbuilders are required to understand and control variation through accuracy control. Although North American shipbuilders are improving accuracy and modular construction methods, traditions and methods shipbuilders have used for hundreds of years based on building ships on incline ways plus the sporadic nature of the industry, impede the use of new improved methods. This thesis does not suggest time honored shipbuilding traditions and methods be discarded, however because ship construction and ship manufacturing have morphed, the shipbuilding industry needs to integrate the craft skills traditionally used by shipyard tradespeople with the effective methods used by manufacturers who produce interchangeable parts. Relying on craft and stick built methods of construction, shipbuilders will make things fit in the end, but usually fitters will need a bigger hammer, more come-alongs, grinders, and torches, employing a burn, bang, and bend rework method to make things fit.

Call to action *establish a sense of urgency*

To improve the outcomes of accuracy control, top leaders in shipbuilding need to establish a sense of urgency to adapt geometric dimensioning and tolerancing, the international design language per ASME Y14.5-2009. A bottom-up change effort will not bring lasting accuracy control success. The effort will need to assemble a group of leaders with enough horsepower to support the change effort. It will require leaders with enough influence to encourage collaboration between not only design, manufacturing, quality, but eventually include key stakeholders such as the US Navy and marine operators, to require geometric dimensioning on ship designs to reduce waste in ship building process.

Benefits: Overt Benefits, Dramatic Difference, Reason to Believe C. Alter (personal communication, November 29, 2012).

Overt Benefits *(what's in it for the customer?)*

- Customers expect value in terms of longer life, performance, reliability, and low operating costs. Fulfill customer needs by delivering lightweight, high quality, long-life structural components, delivered under budget and on time.

Dramatic Difference *(why should shipbuilders care?)*

For the Designer, Engineer and Naval Architect-

- Understanding and reducing process and product variation leads to designs with reduced weight and stronger structure. Accuracy control provides a means of continuously improving shipbuilding processes of design, manufacturing, and verification, by organizational learning and adapting.
- An international design language, the ASME Y14.5-2009 geometric dimensioning and tolerancing standard provides a clear and concise method to communicate design intent. It bridges the organizational structure gap, linking design, manufacturing, and quality processes with a common language and a common datum reference system.
- Allows designers to understand the relationship between features, to accurately calculate tolerance stack ups, and indicate allowable zones of variation for the features to diverge.

For the Manufacturer

- Eliminate ambiguity, make large, precise, welded steel components, integrating with features such as outfitting and pipe. The design, manufacturing, and quality plans link using geometric dimensioning and tolerances specified in the ASME Y14.5-2009 standard. Eliminate confusion and incorrect assumptions, caused by the lack of clearly identified datums, qualified datum features and a specified range of variation established by tolerances. Manufacturers stop making assumptions of what is important to measure, where to measure from, when to measure, and how to make measures.
- End the notion "we make structure the best we can" relying too heavily on low cost qualitative verification or attribute testing, "the part is good or bad." Control process variation by measuring and understanding results of quantitative methods. Employ variable testing, to not only know if a part/process is good or bad, but also know how good or bad; how far does the process deviates from normal, to what side of the mean, and if it is within normal range, then make adjustments before process goes out of control. This is a very powerful continuous improvement tool.
- Stop measuring from structure that varies and unqualified datum features. Understand how to establish simulated datums from a datum reference system based on the datums established on the design. Understand why a flat level platen is important, many times, it provides a simulated datum that represents a water line datum, much akin to that of a granite inspection table. A laser level or plumb bob set mutually perpendicular to the platen may represent a buttock line or frame line. Depending on need, manufacturers use several means to verify location and

relationship between features, a common practice is to use a coordinate measuring machine or CMM. The CMM, based on a xyz datum reference system, provides a small-scale model for shipbuilders to apply the benefits of a CMM to large structure.

- Improve the metrics that measure your success- reduce cost, improve quality, and deliver on time.

For the Quality Professional

- Use a better process to verify dimensional accuracy: Provides a means of establishing methods of measurement, how to verify conformance, listing step-by-step processes that instruct what characteristics to check, how often, and what measuring tools to use based on datums, qualified datum features and tolerances.
- Improved communication of design intent, with design, manufacturing all working off the same datum reference system, eliminates confusion and conflicts arising from differing interpretations of the design.
- Become an important keeper of the database of process variation knowledge allowing access and analysis to all that need the information to improve their jobs and understand process variation.

Reason to believe

- It is already being done. Caterpillar, world-class designer and manufacturer of large fabricated structures very similar to those made in shipbuilding, provides a great example of how the shipbuilding industry can integrate the skills of traditional tradespeople and the effective methods used by manufacturers to produce interchangeable parts.

Background

Encouraged by the U.S. Department of Transportation Maritime Administration, North American shipyards started implementing accuracy control efforts in the late 1970s. To this day, the functional layout and management structure of North American yards impedes information and product flow needed to implement many continuous improvement efforts and accuracy control. Prior to the revolutionary Toyota Production System, North American auto manufacturers used functional organization structure and layouts. For example: all grinders in one department, all presses in another, mills in another, engineering in another, and so on, to make automobiles. Mechanics did not cross trade boundaries. Managers protected their territory in departmental silos. Engineers used a traditional approach to design, commonly known as "the over the wall approach," resulting in non-value added activity, where designs were thrown back and forth between design and operations. As market demands changed at increasingly faster rates, mass production, employing batch and queue technology kept people busy, caused huge waste, non-value added time and activities such as counting, waiting, moving, over-producing, storing, and rework. Worse yet, the waste from over-production hid problems, created delays, and consumed critical resources such as cash, space, and talent. In the functional structure, batch and queue method of manufacturing, leaders did not even know they had problems. Functional structure impeded flow of material and information and resulted in a fractured wasteful system that inhibited organizational learning and adapting.

The automotive industry slowly adopted Japanese manufacturing techniques. Starting in operations, manufacturers reengineered their processes, creating focused factories within factories; aligning processes to allow information and materials to flow. To control dimensional accuracy, manufacturers employed statistical process control and geometric dimensioning and tolerancing. Soon manufacturers started seeing continuous improvement and accuracy control not just as a production issue, but as part of a system or culture that extended enterprise wide. Quality and accuracy control became part of policy deployment throughout the industry. Leaders modified operating structures to match the needs of market demands often employing hybrid organizational structures.

The question remains, can the North American shipbuilding industry make a similar industry-wide transformation, in a fashion similar to the automotive industry, a transformation to lean manufacturing and continuous improvement, allowing profitable growth, through high quality, low cost, ships delivered on time. Can North American become a world-class maker of ships that compete on the world stage in commercial as well as military ships? This author believes it can be done, but not without employing world class manufacturing methods that include accuracy control and geometric dimensioning and tolerancing. The journey starts with a sense of urgency to make the change.

Literature Review

Caterpillar, world-class designer and manufacturer of large fabricated structures very similar to those made in shipbuilding, provides a great example of how the shipbuilding industry can integrate the skills of traditional tradespeople and the effective methods used by manufacturers to produce interchangeable parts. Non-shipbuilders Jutla, Crilly, and Kelly, (2001) writing in the *Journal of Ship Production*, describe similarities between shipbuilding and making earthmoving equipment. The authors highlight some of the technologies Caterpillar uses to make large, precise, welded steel components. These methods provide a model for how shipbuilders can incorporate proven manufacturing techniques to eliminate variation (and eliminate the resulting waste), and how Caterpillar improved its ability to continuously improve processes (learn and adapt as an organization). Furthermore, Caterpillar's customers demand many of the same things as the customers who purchase ships. The authors describe Caterpillar's customers' need for lightweight, high-quality, long-life structural components, very similar to the needs of a Littoral Combat Ship. Caterpillar uses state-of-the-art design tools such as solid models and geometric toleranacing, process simulation technologies and the latest continuous improvement and manufacturing processes.

(Jutla T. et al., 2001), provide a great benchmarking opportunity, suggesting a cross-industry technology development and knowledge transfer to improve the competitiveness of the United States shipbuilding industry. From the author's personal experience working with continuous improvement teams, visits to world-class manufacturers such as Toyota, helped many improvement teams to create, believe in, and deploy new vastly improved visions of what a world class manufacturing enterprise is. These visits inspired vision, a tension to change, and a belief the team could do better, much better, to improve the current state of their processes and products.

In a special report for the National Shipbuilding Research Program, (Okayama, 2006) relays the days of,

> "Just give us the plans and material on time and we can build ships as productively as anyone." So say traditional production bosses. Nothing could be further from the truth because a critical element is missing. Managers of the most productive shipyards have succeeded in getting their production people highly involved in design matters starting with development of contract plans. The authors offer further, "As early as 1967, the Japanese Society of Naval Architects reported that accuracy control "epoch makingly" laid the foundation of modern ship construction methods." (Okayama et al., 2006)

If accuracy control is so "epoch makingly", why are North American shipyard leaders less than enthusiastic in adapting these methods? Detroit automakers in the 1970s and 1980s showed a similar defensive behavior when faced with Japanese competition producing high quality and low cost products. American carmakers had the same opportunity to implement quality systems introduced by Deming and Juran, American quality experts, who perhaps, became better known for their work in Japan. Argyris (1991), whose work has influenced thinking about the relationship of people and organizations, organizational learning and action research, may help us understand. Argyris conveys,

> "…success in the marketplace increasingly depends on learning, yet most people don't know how to learn. What's more, those members of the organization that many assume to be the best at learning are, in fact, not very good at it. I am talking about the well-educated, high-powered, high-commitment professionals who occupy key leadership positions in the modern corporation." Argyris continues, "Most companies not only have tremendous difficulty addressing this learning dilemma; they aren't even aware that it exists."

In short Argyris indicates it is hard to teach an old dog new tricks, especially highly successful ones.

Many enterprise-wide transformations fail miserably. Kotter (1995) maintains that too many managers do not realize transformation is a process, not an event. Organizational change advances through stages that build on each other, and it takes years. Pressured to accelerate the process, managers skip stages, but shortcuts never work. In most major organizational change efforts intended to improve quality, culture, or just to survive, the efforts generate only meager results. The intent of this introduction is to start the first step, establish a sense of urgency. Convince shipyard leaders, at one major shipyard that the status quo is more dangerous than making the change. Ship manufacturers need to apply geometric tolerancing throughout the ship design, manufacturing, and quality processes to improve accuracy control. Shipyard managers do not need or want another consultant telling them they have an ugly baby. It is not enough just to recommend change; this author needs to become personally active in helping make change happen. Although accuracy control is an endless effort of continuous improvement, this research will be limited to a successful pilot implementation over a two to four hull cycle on projects that have proven tough to align, and costly in terms of rework and time. The intent is to create a sense of urgency to change, helping yard leaders understand of how geometrics can improve accuracy control and how this continuous improvement process can improve the way a shipyard organization learns and adapts. Estimated time of the effort is two to three years.

In comparing Japanese ship manufacturers and American shipbuilders, a philosophical difference still exists. For instance, Japanese manufacturers consider accuracy control as an entire production system. Hills and Storch describe Japanese accuracy control concepts using Ishikawajima-Harima Heavy Industries (IHI) of Japan as an example. They explain how the concept is simple by definition, but hard to apply. Accuracy control requires ship manufacturers to maintain accuracy at each stage of production, including every fabricated piece, part, sub-assembly, assembly, and erected module. Controlling accuracy minimizes waste at the erection stage and helps the shipbuilder to learn and to continuously improve the production process. The authors further explain how accuracy control comprises three elements: planning, field activity; and data analysis and information feedback, and how each of these activities is carried out. One key point the authors make is the Japanese start activities of accuracy control well in advance of developing working drawings and measuring. Accuracy control starts in design prior to the start of fabrication. This planning effort involves a cross functional accuracy control team that includes design, manufacturing, and quality in determining the ship breakdown, the fabrication sequence, the assembly sequence, and the erection sequence. The team develops vital dimensions and points of accuracy, margins for added material, reference planes for lofting and measuring; and tolerances for the ship being planned. (Hills & Storch, 1993, pp. 1.1–1.2)

The Japanese view accuracy control as a long term investment to control variation and set standards essential for continuous improvement, becoming a learning organization. In contrast, North American shipbuilders are still in the early stages of accuracy control and much like manufacturers in the early days of lean manufacturing, American shipbuilders see accuracy control solely as a stand-alone operations issue, a tactical, rather than a strategic interconnected system that includes design, manufacturing operations and quality.

L. Chirillo, R. Chirillo, and Storch describe the American philosophy of accuracy control:

> Accuracy Control (A/C) is not quality control nor is it similar. AC means regulation of accuracy as a means for continuously improving design details and work methods so as to maximize productivity. Thus, A/C is properly in the realm of operations managers.

The authors continue, later describing where the accuracy control process starts:

> A/C starts with statistical analysis of variations generated at each of the prerequisite work processes for hull erection, i.e., work processes during block assembly, sub-block assembly, part fabrication, lofting and design.(U.S. DEPARTMENT OF TRANSPORTATION Maritime Administration in cooperation with Todd Pacific Shipyards Corporation, 1982, p. 6)

Action oriented and wanting quick results, American shipbuilders have taken a short term view, applying accuracy control in localized areas or spot accuracy control, much like when manufacturers started a lean journey, they adopted spot lean manufacturing interventions, primarily on the shop floor. Shipbuilders go straight to measuring, bypassing essential parts of the accuracy control system and treating accuracy control as a department rather than an integrated system. Perhaps this is caused by a disconnect between functional areas design and production. Operation managers do what they can within their realm of influence; they may not be able to influence the design agent to revise designs and the design agent may be an outside company. By contrast, Japanese manufacturers start the accuracy control process much earlier, in the design phase.

Geometrics Dimensioning and Tolerancing and The datum reference Frame

To be effective, accuracy control needs to be deployed as a system and it starts not on the shop floor, but in design where engineers and designers establish a datum reference system usually based on water, frame, and buttock lines (planes that form a Cartesian coordinate or datum reference system). Current ship designs employ an ineffective system of plus/minus tolerances, lacking geometric dimensions and tolerances to relate the location of features and profile of surfaces. Designs usually do not include what Japanese ship manufacturers call vital dimensions and points of accuracy. Manufacturing and quality make assumptions to establish a datum reference frame because they lack specifics on the sequence of applying datums indicating primary, secondary, and tertiary datum references. Ship designers have yet to specify requirements on drawings defining the functional requirements qualifying datum features. Machine designers have employed geometric tolerancing for years, yet naval architects and marine engineers have shown little-to-no enthusiasm to implement geometric tolerancing in ship design to locate features such as surfaces, slots or hole patterns.

Authors and geometric tolerancing (ASME Y14.5-2009) subject matter experts, Al and Scott Neumann describe how designers in the manufacturing sector select and qualify datum features based on function. The link below gives greater detail, providing a real life application, working from design, through manufacturing and then finishing up with verification of manufactured parts: http://www.jboyleengineering.com/TCI/appsandstacks/unit8/unit8.htm)

> The Y14.5 standard is considered the authoritative guideline for the design language of geometric dimensioning and tolerancing (GD&T.) It establishes uniform practices for

> stating and interpreting GD&T and related requirements for use on engineering drawings and in related documents. GD&T is an essential tool for communicating design intent — that parts from technical drawings have the desired form, fit, function and interchangeability. By providing uniformity in drawing specifications and interpretation, GD&T reduces guesswork throughout the manufacturing process — improving quality, lowering costs, and shortening deliveries. (*Y14.5 - 2009 Dimensioning and Tolerancing - ASME*, n.d.)

The datum features define how parts mount or how they set up for functional requirements and this information is needed before making and checking interchangeable parts. Manufacturing can then define how to make product, identifying processes, procedures, work instructions, sequence, tooling and fixtures, based on datums and tolerances specified in engineering. Manufacturing goes on to develop simulated datums using back gages, machining x-y tables, collets, platens, tooling, scopes, levels, plumb bobs, plus more advanced measuring technology. These are flexible manufacturing plans that can be changed and manufacturers may have multiple manufacturing plans, making the collection of statistical data more complex. Quality, a verification process (not to be confused with a quality department), can then establish methods of measurement, telling how to verify conformance, listing step by step processes that instruct what characteristics to check, how often, and what measuring tools to use based on datums, qualified datum features and tolerances. (Neumann & Neumann, 2009, pp.5.3-5.4)

The design, manufacturing and quality plans link using geometric dimensioning and tolerances specified in the ASME Y14.5-2009 standard. Without clearly identified datums, qualified datum features and a specified range of variation established by tolerances, manufacturing and quality departments make assumptions of what is important to measure, where to measure from, when to measure and how to make measures. Accuracy control engineers may vigilantly measure and fill out dimensional check sheets, but without clear datum and tolerance specifications from design, they assume where to take measurements from. They may base measures from a frame, bulkhead, or accessible part of deck (these features all vary) and assume their own tolerance standards. In the end, supplied structure and parts may all be within specified plus or minus tolerances found in the design title block, yet nothing fits.

Since the Toyota Production System became popular, manufacturers worldwide have adapted continuous improvement tools to remove variation. The shipbuilding industry and construction industry in general have been slow to adapt continuous improvement tools of accuracy control and geometric dimensioning, for several reasons:

1. In many cases North American shipbuilders still use a tradition of “we make structure the best we can” relying too heavily on low cost qualitative verification or attribute testing, “the part is good or bad.” To control process variation manufacturers need to measure and understand results of quantitative methods. Manufacturers need to employ variable testing, to not only know if a part/process is good or bad, but also know how good or bad; how far does the process varies from normal, to what side of the mean, and if it is within normal range, then make adjustments before process goes out of control.
2. Geometric dimensioning and tolerancing is an international engineering language used on engineering drawings and, like any language, it takes time and practice to learn the geometric tolerancing system. Few in the ship building industry can be considered experts or even conversational in geometrics. Some may be able to recognize and read geometric symbols, but cannot write or speak the language. In many cases North American shipbuilding still employs 2D plus/minus tolerancing used in manufacturing until the late 1930s.

3. Cost entry is high. It is a major investment to build systems to measure, record, and analyze data needed for accuracy control. Change to geometrics means a major change throughout the industry, much akin to turning a large ship around.
4. Construction and shipbuilding are cyclical hindering an effective accuracy control system. The accuracy control effort cannot be sporadic. Statistically valid data that describes normal variation needs long term consistent effort.
5. People are needed in operations and on the production floor with higher skill level, who understand and can employ statistics, geometrics, design methodology, computer tools and communications; all skills needed by accuracy control engineers.
6. Shipbuilding involves the skill of tradespeople more than the skill of operators who use repetitive production processes. Repetitive manufacturing allows accuracy control engineers to develop part statistics because they have high volume parts, a higher population to measure and learn from. In shipbuilding, volume is low and the variety of parts high, closer to custom made parts. Shipbuilding needs to take a different approach to understand variation of process.
7. Complex solutions requiring the use of sophisticated mathematical models create a high hurdle to overcome. (Zhang, Dai, & Li, 2012) offer deviation diagnosis and analysis of hull flat block assembly based on a state space model. The linear programming model requires understanding of advanced math principles, calculus, statistics, and strong programming skills to crunch numbers. For accurate predictions, systems need to be in statistical control. In the real world, life is not linear and shipyard construction is far from statistical control. Sources

of variation, the 5 M's (variation from man, machine, method, measures, and materials) all need to be programmed into the model. Just the fact that Zhang, Dai, & Li, measured structure had a Hawthorne effect on results. The experiment may have just as well adjusted lighting conditions and produced a corresponding change in dimensional accuracy.

D. Roehm, vice president at Marinette Marine(personal communication, December 3, 2012) offers, "The ease and understanding of the process to control the interface dimensions without making it to complicated is critical. Whether that is providing level platens to build, sequencing the welds, checking dimensions at critical times prior to locking in the error, etc. is not well known or people believe it is too hard. You have a work force that needs simple methods and repeatable."

Three keys to continuous improvement include 1) a clean and organized workplace, 2) a workforce that understands and can identify waste, and 3) standardized processes. Without these three keys in place, learning and improving performance will be limited or sporadic. All three are important, but without standardization, organizations don't learn. Accuracy control provides a major contribution to standardization and learning, and accuracy control cannot be effective with using tools of Geometric Tolerancing per ASME Y14.5

Request- A plan to deployment

Concepts such as continuous improvement and accuracy control are simple but deployment is hard. Kotter (1995), in *Leading Change, Why Transformation Efforts Fail,* provides to us a model for leading change, and a means to deploy sustainable system-wide changes needed to implement effective accuracy control. This introduction may help take the first step in the process, establish a sense of urgency in at least one major ship manufacturer, to adapt geometric dimensioning and tolerancing to improve the outcomes of accuracy control.

A bottom-up change effort will not bring lasting accuracy control success. The effort will need to assemble a group of leaders with enough horse power to support the change effort, leaders with enough influence to encourage collaboration between not only design, manufacturing, quality, but eventually include key stakeholders such as the US Navy, to require geometric dimensioning be used on all ship designs to reduce waste in ship building process.

Creating the vision is the next step. This author clearly remembers working on an earlier project in a metal working industry just beginning its lean journey. We were tasked to reduce change-over times on presses from 12 hours to one minute. Many had a hard time believing this could be accomplished. Until the team including this author, took trip to a Toyota plant to see mechanics change presses over (ones that were more complex) in less than one minute, success was not possible. A supportive management team and powerful vision provided the key elements to a successful change effort. The team had to see, it could be done, to make it happen. In four months, the team developed and deployed strategies to change presses over in less than one minute with a huge impact on economic outcomes.

The guiding coalition of top leaders needs to communicate the accuracy control vision, showing how this strategy is vital to the shipyard, and teach new behaviors leading by example. System changes are tough and leaders become instrumental empowering others to act. Many obstacles or perhaps departmental-head territorial anchor draggers will try to undermine change efforts. This effort will need strong influential leaders in (or above) design, manufacturing and quality that will remove roadblocks and create an environment that encourages ideas, activities and actions of the accuracy control team. Over time, consolidate improvements and produce still more change, use increased credibility gained from successes to change systems, traditions, and policies that do not match actions and behaviors critical to accuracy control. To keep the progress going; establish new accuracy control teams and projects, thereby creating more change agents. Institutionalize accuracy control and connect the efforts between efforts and success. The last step includes developing means to ensure the effort is sustainable developing leaders who will take over.

Accuracy control is not gained by passive learning, it is a learn-by-doing process. Leaders need to plan for and create short-term wins on projects that will be visible, for instance the launch handling and recovery system or shaft alley on LCS class of ships. Pick one, or two tough projects that previously had enormous rework and delays, employ an accuracy control cross functional team, start in design, apply GD&T and accuracy control throughout the process. It will work. Publicize the success and reward efforts with recognition. Geometric dimensioning and accuracy control provide proven tools that work, and are essential to standardization. Make accuracy control and geometric tolerancing a part of your yard's continuous improvement efforts.

Benefits

Lack of accuracy control or variation causes costly waste in terms of time, dollars, rework, quality defects, materials, talent, and waiting. More importantly, this lack of understanding of variation negatively affects how an organization learns, limiting its capacity to improve its effectiveness, customer satisfaction and profitability. Effective accuracy control improved by using geometric dimensioning will help North American yards become learning organizations to continuously improve their performance and profitability.

Dramatic Difference

If shipbuilders choose to continue building ships, much like a custom stick built house, where skilled mechanics use ingenious ways to make things fit, the builder will not see much difference. Perhaps the builder may experience the Hawthorne effect; a phenomena were significant improvement can be measured just because the tradespeople knew their work was being measured. Where a dramatic difference will be seen is where the shipbuilder employs modular construction methods. Accuracy control methods that remove variation will dramatically:

- Reduced cycle and lead times: Modular construction enables concurrent work, reducing cycle and lead times.
    - Reduced cycle times in construction has strong correlation with reduce cost.
    - Reduced lead times provides a competitive advantage- it can mean the difference between getting a bid, or losing a bid.
- Improved Quality: Less variation leads to better design and stronger structure- less variation means less stress in hull structure induced by fitters constraining structure to fit weld seams
- Improved Cost- when fitters do rework it not only costs more, the end result is not as good

  - Reduced rework- fitters spend less time making structure fit
  - Less material cost - Lighter ships- stronger structure means less safety factors and excess material needed for strength and reduces scrap.

- Most importantly, accuracy control will provide a growing environment for the shipbuilding industry to learn as an organization, able to recognize and eliminate variations that cause waste.

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