Introduction for From the Archives

Introduction By Charles R. Greenwell[1] and Peter E. Jaquith[2]

Reducing Detail Design and Construction Work Content by Cost-Effective Decisions in Early-Stage Naval Ship Design

US Naval Warships Cost Too Much to Design and Build

Asian navies are building highly capable warships that are easier to construct, easier to maintain, and that have greater service life allowances for future Integrated Warfare System (IWS) upgrade. It is also reported that they are doing this at significantly lower cost than US practice, Jaquith (2019).

As a result of this knowledge, coupled with ongoing delays and cost growth on USN shipbuilding programs, the US Navy and its naval shipbuilders are aggressively exploring different approaches and the application of best practices to reduce the cost for design, acquisition, and construction of US Naval Warships (DAC). With increased emphasis by the US Navy customer, it is appropriate to reexamine the many papers written on this topic over the last 10 years.

The subject paper "Reducing Detail Design and Construction Work Content by Cost-Effective Decisions in Early-Stage Naval Ship Design" by Keane, Deschamps and Maguire discusses ship complexity and its relationship to outfit density. It concludes that complexity contributes to increased ship cost in that a complex design leads to overly dense ships. This in turn suggest that Outfit Density is a good measure of complexity and a less dense ship will cost less to build. The paper also discusses use of the Product Oriented Design and Construction (PODAC) Cost Model as a cost estimating tool to accurately evaluate the cost impact of these alternate design arrangements.

Another such paper, Spicknall (2023), suggest that there is an optimal outfit density for surface combatants. The paper describes a detailed approach to developing the outfit density for a series of ships which have like characteristics. It then explores the relationship between Outfit Density and Worker Productivity as a function of Available Work Space. This leads to the conclusion that there is a window for optimal Outfit Density for a surface combatant with the set of characteristics used for the analysis. In addition, a window for optimal Work Space is developed. It concludes that during the design phase there is a minimal and optimal range of area that effects the producibility and cost of said designs.

This Introduction for From the Archives will discuss selected examples of Navy and industry affordability initiatives with the potential to improve product quality while reducing total ship design, acquisition and construction cost and schedule.[3] Additionally, the introduction will highlight the need for the US Navy and industry to adopt more sensitive work content-based cost analysis methodologies to supplement traditional weight-based methodologies to more accurately estimate cost savings of such initiatives.

[1] President SPAR Associates; SME cost estimating, planning and program management

[2] Former Shipyard Executive; SME ship design, production engineering and construction

[3] The authors are/were participants in the subject affordability initiatives

National Shipbuilding Research Program (NSRP) Projects

Examples of some of the techniques discussed in said paper are found in a number of recent NSRP projects. NSRP is a collaborative industry government research program to advance the state-of-the-art of US Naval ship design, construction and life-cycle maintenance. Using this collaborative environment, MAESTRO Marine has conducted a series of research programs to enhance the MAESTRO structural design optimization system to reduce design work content while improving life-cycle structural response. Further details on these initiatives are addressed in McNatt (2019 and 2023).

1. **NSRP Project RA2017-443, Ship Structural Design Optimization (SSDO) for Improved Producibility and Enhanced Life-Cycle Performance**

   The objective of this research project was to develop a ship structural design and optimization (SSDO) modeling and simulation capability that shipbuilders and the US Navy can use to enable ship structures to be holistically designed to meet structural performance and safety criteria, facilitate optimization for producibility, and simultaneously enhance structural life-cycle, in-service performance, and generate total ownership cost reductions.

   - Automated optimization that includes variations in frame and stiffener spacing.
   - Work content and production data associated with the structural design was developed.
   - Enabled storing corrosion and other structural damage and degradation data in the model.
   - DPC 100-4 and MIL-HDBK-519, were fully integrated

2. **NSRP Project RA 21-11 - Minimize Work Content in Production and Maintenance and Reduce TOC Using Early-stage Structural Design Optimization**

   This project implemented the accomplishments of NSRP RA Project 2017-443 into design and production planning software and developed a new generation of ship structural design optimization tools for early-stage design. This project achieved many of the recommendations found in the subject paper demonstrating that these concepts do in fact save time and money.

   - Demonstrated and showed a savings in finite element modeling time on the order of the 50%.
   - Using the PODAC Cost Model, demonstrated the capability to leverage existing work content cost estimating relationships and Lean Design Optimization by “designing out complexity” by reducing the number of different types of plates and shapes for the structure.
   - Developed a “Least Work Content” structural design algorithm for implementation in the Navy’s ship synthesis model ASSET supporting early-stage design tools such as RSDE and ISDE.

Lean Design Optimization Initiatives

Seaspan Shipyards conducted a series of Lean Design Optimization studies as part of their commitment to world-class process improvement under the Canadian National Shipbuilding Strategy. Using the Toyota Motors Lean Design methodology, these initiatives focused on early-stage design reduction of design work content and variation and design alignment with manufacturing. Further details on this methodology are addressed in Jaquith (2021).

1. **MOD Auxiliary Oiler**

Starting with a German baseline design, the auxiliary oiler design optimization study focused on total ship reduction in labor work content and variation and design alignment with the shipyard's steel production facilities and modular outfitting plan. The study was conducted at the concept design level by Mr. Harry Kim,[4] Mr. Joseph Park[5] and Mr. Peter Jaquith.

- 40% Reduction in cargo and ballast tanks
- 50% Reduction in structural weld length
- 35% Reduction in tank coating surface area
- 40% Reduction in cargo and ballast tank outfitting
- 50% Reduction in machinery room piping and LV cable length
- Structural arrangements optimized for steel production facilities
- Machinery and accommodation arrangements optimized for modular construction

2. **CCG Polar Class Heavy Icebreaker**
   Starting with the in-process contract design, the Polar Class Icebreaker design optimization study focused on machinery room plant architecture, auxiliary system design, main and auxiliary equipment selection, affinity-based machinery room arrangements, and a modular machinery room construction plan. The study was conducted by an IPT that included CCG Engineering, Vard Marine (class design agent), Seaspan Shipyards, CCG operators and selected suppliers.
   - 25% Reduction in auxiliary equipment count
   - 50% Reduction in machinery equipment variation[6]
   - 50% Reduction in machinery room piping and LV cable length
   - Machinery arrangements optimized for modular construction

Product Oriented Design and Construction (PODAC) Cost Model

These and similar design initiatives demonstrate the potential cost reductions available thru early-stage design optimization. Similar improvements are possible in the case of modern lean manufacturing-based production process improvement. However, in early stage design a critical constraint in analyzing these initiatives is the Navy's weight-based cost methodology and their historic USN Cost Estimating Relationships (CERs). What is needed is a new cost estimating methodology which uses more broad-based process CERs.

As demonstrated by NSRP project RA 21-11 for structure, the processed based CERs used by the Product Oriented Design and Construction (PODAC) Cost Model showed the potential for developing work content during early-stage design for different design/production methodologies. Further expansion of this into the outfit stages of design will allow for additional opportunities to reduce work content and to explore the effects of different technologies.

While expanding the development of work content estimating into the outfit stages of the design, a better method for calculating the effects of outfit density needs to be considered. The method described in the said paper works well at a high level but as alluded to in the Spicknall(2023) paper, a finer approach based on work areas/ship zones would produce a higher quality estimate. This method would provide better insight into the work content where the less dense areas of the ship tend to influence the overall calculation method described in the said paper.

[4] Former Manager Basic Design and Chief Technical Officer, DSME

[5] Former Manager Production Engineering, DSME

[6] Reduced equipment variation and the resulting increased depth of on-board spares was identified as a significant survivability benefit when wintering-over locked in the Polar Ice Cap.

Conclusion & Recommendations

Broad based implementation of industry best practice offers the US Navy and its naval shipbuilders the potential for significant cost savings in design, acquisition, and construction of US Naval warships (DAC). Additionally, these improvements in productivity will support significant reductions in ship construction schedules with resulting increases in industrial capacity. It should be noted that this transformation will require strong Navy and industry executive leadership.

To support this best practice transformation, it is recommended that the US Navy and naval shipbuilders adopt a Product Oriented Design and Construction (PODAC) Cost estimating approach. This will more accurately evaluate the cost and schedule impact of these initiatives during early-stage design when most of the costs are locked in.

In addition, the least work content approach to developing early-stage design optimizations needs further exploration for the outfit stages. The results shown in the forementioned NSRP projects for structure showed promising results. The same approach for outfit design would certainly show additional possibilities.

References

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