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Extending the Reach of CAD

The marine industry, an early adopter of CAD continues to integrate CAD/CAM into manufacturing and operations to improve quality and producibility. Today, CAD solutions have been extended outside the design office to the shipyard floor and beyond. And extending the reach of CAD is where the real savings occur in any industry.

The Problem With Ships

Boats and ships differ from most other objects because they are formed of arbitrary curved surfaces instead of well-defined assemblies of geometric shapes. Manufacturing and hydrodynamics also requires that these shapes be "fair" - smooth and free from any sudden changes in curvature. Traditionally, ships were designed using orthographic drafting and real wooden splines and weights. Surface contours drawn in various views were laboriously resolved to develop a consistent surface. Then structure, machinery and other components were designed, and flotation, weight, structural and hydrodynamic calculations were done.

However, due to the large change in scale, the design drawings were not accurate enough to actually make parts that fit, so "laying down and picking up" was required. The hull surface was redrawn, refaired and laboriously resolved view to view at full scale, usually on a whitewashed floor in a loft, hence the term "lofting". Loftsmen developed patterns for piece parts and rolled and curved plates and made full size templates to hand cut and form parts.

Ships are also very complicated objects. They contain miles of pipe and wire, ductwork, furnishings, large specialized machinery and perhaps even weapons systems. Virtually all engineering disciplines are involved in ship design. Even a small tug has piping for fuel oil, lube oil, seawater cooling, bilge water, oil contaminated bilge water, engine exhaust, fresh water, sewage, compressed air, hydraulics, and carbon dioxide and seawater for fire fighting. It also has ventilation ducting, AC and DC electrical systems, two locomotives worth of engines, gears and shafting and a small apartment/office/shop complex for the crew. A naval combatant is probably the most complex product ever manufactured: The drawings for a nuclear submarine weigh more than the vessel itself. Coordinating all of these parts so that they can be installed on schedule in very tight, oddly shaped spaces is a major challenge.

AutoCAD & Others Get on Board

The computer revolutionized the shape definition process. In 1962 the first computer programs were under development to automate this costly effort. By the late 70's several mainframe based systems were available that developed information for surface definition, piece parts and linked to Computer Numerically Controlled (CNC) torches that cut steel. The late 80s saw the emergence of several hull surface definition programs for PCs. Small shipyards adopted these PC-DOS based systems which combined specialized surface definition programs and *AutoCAD* software.

Munson Manufacturing of Edmonds, Washington builds aluminum boats for ferries, fishing, oil spill recovery, and military and police patrol. In 1991, Munson implemented an integrated system CAD/CAM system comprising a number of products. *Baseline,* from Baseline Technology, Redmond, Washington, (http://www.basline.com/basline.com) was used for preliminary hull surface definition. The files were then transferred to *ShipCAM,* from Albacore Research, Ltd, Victoria, BC (http://www.albacoreresearch.com) for detailed fairing, definition of developable surfaces, plate expansions and other lofting functions. The data developed was then transferred electronically to *AutoCAD R10* for detailing in 2D and to *GHS* from Creative Systems, Inc. Port Townsend Washington, for stability and flotation analysis. Structural, weight and mechanical analyses were performed with spreadsheets.

This system allowed piece parts to be developed within a week. Files of the parts nested together on a “burn sheet” were transferred by modem to Farwest Steel, Eugene, Oregon for cutting the next day. By the following morning, a truck with the CNC plasma cut parts arrived, ready to be erected. A major part of Munson’s success was a standard product line. Each subsystem was standardized in CAD and designed for easy construction. Even the basic hull forms were parameterized to use standardized methods and jigging. This allowed rapid, accurate parametric bidding as well as easy construction. As a result, delivery times and costs were reduced and sales and profits tripled in a year.

Smooth Sailing at the YARD

By 1995, AutoCAD based shipbuilding systems were wide spread. The next challenge was to change shipyard practices to best take advantage of the new tools. The Coast Guard YARD, in Curtis Bay Maryland is the Coast Guard’s only repair and overhaul facility and has built many Coast Guard boats and cutters over the last century. It has been some years since their last new construction project, when they were awarded a run of 27 49BUSLs (small buoy tenders). The YARD was also the first federal organization to be ISO 9001 certified. Thus, when the YARD implemented a production CAD/CAM system it was systematically integrated into the production process. This proved to be another advance. The YARD also chose Albacore Research, Ltd.’s *ShipCAM*, a companion program, *NC Pyros*, for developing CNC data.

YARD personnel developed a hybrid 2D-3D system to produce a true 3D structural product model and an automated interference and weight control system based on XREFs, attributes, and a small suite of simple Autolisp routines. This minimized CAD retraining efforts by allowing most of the designers to work in 2D. The YARD also re-engineered the entire structural design and erection process and moved the computer-aided lofting process upstream to the earliest part of design so that all systems and components could be accurately made and “as-built” drawing cost could be eliminated. This involved reassigning tasks among shops and disciplines, training, and development of full ISO process documentation which increased structural production, reduced interferences and improved weight control, and allowed some piping systems to be designed in 3D for the first time. As a result the structural work was well under budget with almost no rework and the process saved a great deal of taxpayer money. The final BUSLs are being produced now and are being delivered at highly competitive prices and delivery schedules.

Systems Downsize, Production Increases

By the late 90s, desktop hardware and software had improved so that the mainframe systems had migrated to Windows 98 or Windows NT platforms. At the same time, AutoCAD and the related applications for shipbuilding had become more powerful and more tightly integrated. The result was the development of a number of suites that provided most of the functionality of the mainframe based systems at a fraction of the cost.

Ship Constructor is a typical ship building suite. It integrates the latest version of *ShipCAM* with *Ship Report* and *CADLink*, which operate within AutoCAD R14 and 2000 as an ARX application. *ShipConstructor* gives designers a wide range of tools for automatically generating 3D solid models (using yard standard details) of structure while only working in 2D. It also manages data so that the solids are translated into 2D piece parts and are automatically sorted for nesting and CNC cutting with *NC Pyros* and provides for automatic derivation of “block” and “unit” drawings. *Ship Report* maintains structural weight data, steel stocking lists and other materials management information.

Ship Constructor (and *AutoPLANT 97*, a fully compatible piping application which also runs in AutoCAD and provides analogous features) has allowed Bender Shipbuilding of Mobile, Alabama to develop a full 3D CAD product model incorporating structure, piping and machinery. The ship can then be readily subdivided into pre-outfitted units or blocks for easier construction.

Bender designers divided a 220 Offshore Service Vessel (OSV) into five hull blocks and four superstructure units to develop an optimized build strategy. They were able to develop each block for easiest possible construction by improving working conditions and access. The software provides automatic updates throughout the design process. The piping and structure required minimal checking because they were all derived from a single consistent model, which also generated accurate bills of materials automatically. Despite the fact that this was an entirely new system, and provided much greater detail, the design time was less. The big payoff, though, was in production. The OSV was built with labor savings of 25% and more on follow on ships.

Realizing the Potential

A ship needs repairs, overhauls and modifications, must be maintained and must be ready for emergencies. This is a major effort, but here too, CAD offers solutions: The product model can be linked to logistic databases and the Web to make parts a mere mouse click away. The Coast Guard is also now developing prototype interactive "damage control" drawings for the *Island* class cutters. DWF files are displayed on a laptop web page. Clicking on a valve causes a firemain to change color as it is charged. Clicking on a space brings up a photo of the space. Clicking on a machine brings up a tech manual or a warning. These applications save money lives and property as well as money.

Clearly, CAD is fulfilling its promise for improved productivity in the marine industry. CAD information is rich and mutable. It can change from graphics to text to CNC data and beyond. Marine design professionals found change and opportunities in CAD, and have prospered. CAD professionals everywhere need to look at their particular industry to apply CAD data outside of the design office. We must talk to other line workers, managers and customers, because it is through the downstream communication of this data, and radical changes in whole processes, that the real potential of CAD will be realized.

Integrating The Process

Based on the cases in the accompanying article and through similar experiences, the shipbuilding industry is answering the question: How do we integrate CAD/CAM into the entire shipbuilding process to get the most out of it?

Here are eight keys that can be applied in some form to any industry:

- **Process re-engineering** systematically examines the needs and capabilities of all members of the organization, and looks for opportunities to change for improvement, not only in particular processes, but in the interaction of processes. This is the most important lesson of CAD/CAM in shipbuilding. CAD/CAM improves communications between processes as well as allowing improvements within processes. Deming said: *"Engineers and designers need to gain profound knowledge of the erection process and incorporate product design and process design producibility features into the detail design*." The key to process re-engineering is profound knowledge. Each part of the entire enterprise needs profound knowledge of the rest of the enterprise to give them what they want, when they want it and in the way they want it and no more. ISO 9000, Baldridge, and TQM is about profound knowledge and basically simple: listen to everyone who uses what you make or makes what you use, and together figure out how best to deal with each other. Changes from CAD/CAM affect every part of an enterprise. The ability to premake parts, and the need for accurate data on components affects scheduling, manloading and especially relations with vendors and subcontractors. Vendors who provide early reliable data will cost less than those with lower prices. Software selection must be tied to re-engineering. Often a new software capability will suggest a radical process change.
- **The integrated product model** is the central reservoir of information on the product. CAD enables construction of the product model, while process re-engineering develops the conventions of information in the product model. A product model must be in 3D and includes non-graphic data and usually links to other databases. However, it's a good example of the re-engineering process because it only needs to be as good as the users require and no better, which requires understanding the user's needs. Many components in a ship are bought, not made in the shipyard, so all that is required to depict these items is their size, clearance shapes and interfaces. There is no point in spending the time to build even simple solid models of an engine or a valve. On the other hand, attributing in the weight, cost, supplier or even the delivery date of the engine is very useful.
- **Design for CAM** is incorporating features to improve productivity, and modifying design to take advantage of Computer Aided Manufacturing. Process re-engineering develops these changes so that they meet the needs of production. Design for CAM requires understanding what machines do well and what people do well and

linking them. One example is “Poka Yoke”, Japanese for “foolproof assembly”. People are not good at exact measurements or holding heavy things but are clever at recognizing shapes and fitting them together. CNC torches are good at elaborate cutting and accurate placement. Parts with CNC cut clips and shapes that only go together one way eliminate mistakes, measurement, looking up details and lots of clamping and staging.

- **Advanced outfitting/group technology** is finishing whole components as early as possible, and classifying and organizing tasks by location and type of processes/problems to plan installation. Process re-engineering also ensures that other processes feed the right parts and information. The product model and CNC ensures that the geometry of the structure is accurate and allows better planning. Advanced outfitting is an important part of modern shipbuilding. Ships and boats are generally cramped, not well lit, and uncomfortable. It is far better to do as much as possible outside the ship and just install it in one piece. Just imagine for a moment the time lost in dragging welding leads, lights, and temporary ventilation into a small space deep in the bowels of a ship. Now do it in Louisiana on a hot summer day
- **A flexible standard product line** is building products by using standardized systems, preferably with parameterized details and standard components and thus predictable work, cost and process content. CAD automates and documents the use of standardized products.
- **Concurrent engineering** is doing design simultaneously across disciplines and includes all aspects of production as well as the final product. The product model is the essential communications tool for concurrent engineering, and process re-engineering assures that production concerns are addressed from the start.
- **Advanced workflow control** is a variety of techniques to schedule, predict and control work packages, increasing productivity. The product model gives information on sequencing, resource allocation, cost, and schedule. If work is guaranteed to fit, and classified by space and process, it can be scheduled easily. For example, “Kan Ban”, (“signal card” in Japanese) returns a signal from a finished part to start the next process. This pulls work through the process. Workers never need wait for material.
- **Statistical process measurement and control** is the measurement and application of statistics to the results of all the other processes and changes. It provides feedback to improve schedule and cost reliability and guides further process re-engineering. This closes the circle of continuous improvement.

About the author: Chris Barry is a naval architect and has worked at design firms and shipyards in California, the UK and the Pacific Northwest. He is currently with the Engineering Logistics Center of the U. S. Coast Guard in Baltimore. The opinions expressed are those of the author and do not reflect official policy of the Coast Guard. This material was adapted in part from Barry, Oetter, Lane and Mercier: "Keys to CAD/CAM In Small Shipyards" presented at the 1998 SNAME Annual Meeting, available from the Society of Naval Architects and Marine Engineers, 601 Pavonia Avenue, Jersey City NJ 07306.