White Paper On SBIR Phase II Project

Background

Production process performance variability has significant importance for complex products like ships, cars, and aircraft that are assembled through several sequential and dependent stages. Within production systems that produce these complex products, intermediate product variances are accumulative. That is, as parts and subsequent subassemblies are concatenated to form larger assemblies through several sequential stages, small dimensional variances that occur at each stage can substantially impact the amount of dimensional variation in major assemblies and the final product, as well as the amount of rework required during assembly. This in turn can significantly impact productivity, and product cost, lead-time, and quality.

Over the last ten years the US automotive industry has made tremendous advances in reducing the production costs of their vehicles, while at the same time achieving significant increases in quality. Through the development and implementation of strict process control and production engineering methodologies together known as Dimensional Management, the automotive industry has been able to identify and resolve design and/or production process dimensional variation problems through simulation during product design. Through the use of Dimensional Management practices, including SPC/SQC and dimensional variation simulation, communication between design engineering and manufacturing is greatly improved, greatly facilitating formal production engineering. Dimensional Management has been a primary driver in the resurgence of the US automakers competitiveness in the global market. Formal Dimensional Management methods and tools have also been in use for two decades in other industries like aerospace.

ONR (Office of Naval Research) SBIR Program has been the major driving force behind bringing dimensional variation simulation technology to the shipbuilding industry. Dimensional Control Systems, Inc. (DCS), the world leader in Dimensional Management, was funded by the ONR SBIR Program to carry out a feasibility study of the applicability of dimensional variation simulation technology to the shipbuilding industry. ONR has just awarded a Phase II SBIR project to DCS to modify its existing dimensional variation simulation methods and technologies to make them more useful for the shipbuilding industry.

The intent of this white paper is to:

briefly describe Phase I feasibility study results,
describe plans for Phase II prototype technology development, and
solicit support, cooperation, and involvement from the shipbuilding community.

SBIR Phase I

In May 2000 DCS was awarded a Phase I SBIR project by ONR. The objective of the Phase I project was to demonstrate the feasibility of using dimensional variation simulation practices and tools within the shipbuilding domain. The DCS team applied its existing methods and tools to several representative ship double bottom blocks consisting of stiffened double bottom / tank tops, frame stiffeners, transverse webs, longitudinal girders, stiffened bilge radius, and piping. Dimensional variances specified in the model included:

- Cut length and width of each tank-top plate.
- Cut length and cut position of stiffener slots in transverse webs.
- Cut stiffener length.
- Rolled radius of bilge radius plate.
- Position of all assembly datums in the X-Y plane.
- Positioning of all structural webs, girders, and stiffeners perpendicular to their axis in the plane of the plate relative to datum.
- Positioning of all structural webs, girders, and stiffeners parallel to their axis in the plane of the plate relative to datum.
- Shrinkage across all butt and fillet welds.
- Positioning of pipe measurement points in three dimensions relative to datum.

Associated design tolerances were applied for all critical dimensions and 3-D dimensional variation simulation was carried out. Out-of-tolerance conditions were identified and sensitivity analyses were carried out to identify the specific variances that were contributing most to out-of-tolerance conditions. Mark Spicknall of UMTRI Marine Systems Division provided shipbuilding domain knowledge and assisted DCS with this modeling and analysis work.

The Phase I feasibility study verified that dimensional variation simulation methods and tools can indeed be applied successfully in the shipbuilding domain. However, there are potential weaknesses in the existing methodology and tools as applied within the shipbuilding domain. The present versions of DCS's dimensional variation modeling, simulation, and analysis tools are capable of modeling weld shrinkage and distortion, the primary sources of dimensional variation in shipbuilding. The statistical analyses currently yield appropriate results and the graphic interface represents the resulting shrinkage and distortion properly. However, the process of modeling the dimensional effects of weld shrinkage and distortion with the present tools is very laborious and time consuming. With the improvement of capabilities associated with modeling the dimensional effects of weld shrinkage and distortion, the potential for use of these types of tools within the shipbuilding domain will be greatly enhanced. This is the focus of Phase II prototype development to evolve existing dimensional variation simulation modeling methods and tools to make modeling of the dimensional effects of weld shrinkage and distortion easier.

SBIR Phase II

In October 2001 ONR awarded DCS a Phase II SBIR prototype development project. The primary objective of this Phase II project is to simplify the modeling of dimensional effects associated with weld shrinkage and distortion. Conceptually, the objective is to allow the modeler to select the assembly joint and apply the associated shrinkage and distortion information only once to that joint rather to all of the affected points and features away from the joint. Additional objectives include creating the ability to parametrically access and apply weld shrinkage and distortion distributions generated either statistically from the shop floor or from FEA, and improving the visualization of dimensional variation.

We believe that it is possible to dramatically reduce the effort and time associated with modeling the dimensional effects of weld shrinkage and distortion, which will make the use of dimensional variation modeling, simulation, and analysis tools much more cost effective for the shipbuilding industry. It is anticipated that at the end of Phase II, a shipbuilding-specific version of this technology will be ready for commercialization.

The Work Plan for Phase II is as follows:

Task 1 - Survey of Dimensional Management Processes & Requirements Gathering

Task 2 - Functional Specification Development

Task 3 - Technical Specification Development

Task 4 Software Development Plan

Task 5 - First Phase Software Development

Task 6 - First Phase Beta Testing

Task 7 - Second Phase Software Development

Task 8 - Second Phase Beta Testing

Task 9 - Third Phase Software Development

Task 10 - Third Phase Beta Testing

Task 11 - Documentation / Pre-Commercialization

Task 12 - Enhancement Option I Development

Task 13 - Enhancement Option I Beta Testing

Task 14 - Enhancement Option II Development

Task 15 - Enhancement Option II Beta Testing

Outside Support: DCS is seeking assistance from the shipbuilding community in carrying out this Phase II prototype development project. In particular, we are seeking input on current Dimensional Management and "accuracy control" practices within shipyards and ship design agencies,
weld shrinkage and distortion data from shipyards, and beta testers within the shipbuilding community.
Mark Spicknall of the University of Michigan will continue to work with DCS during Phase II. During Phase I work, Bender Shipbuilding expressed interest in being a beta test site, and Northrop Grumman Ingalls Shipbuilding and General Dynamics Electric Boat Division expressed significant interest in our efforts. Since the announcement of the SBIR Phase II award, Puget Sound Naval Shipyard (PSNS), Alabama Shipyard, SENESCO, Bollinger, Kvaerner Masa and other major universities and marine consulting companies have shown interest in this project. If you would be interested in providing support for this effort, please contact Mr. Ramesh Kumar, the DCS Project Manager, via the telephone number or email address provided below.

About DCS:

The present versions of DCS's dimensional variation modeling, simulation, and analysis tools are widely used within the automotive and aerospace industries. These tools are available in stand-alone form, and are also imbedded within CATIA V5 and UG CAD systems. DCS's tools allow users to model the effects of dimensional variation in piece parts, intermediate products, datums and fixtures on final product fit, finish, and functionality. These tools allow the user to test alternative dimensioning and tolerancing schemes during product design so as to make the product easier to build, and minimize rework and improve finish and functionality. These tools utilize 3D statistical analysis of variation stack-up, and 3D modeling and visualization to animate assembly sequences and show dimensional variation for each critical dimension in the model. Our graphics-based reporting tool allows users to easily evaluate analysis data by combining analysis and measurement data with 3D graphics. Please visit our web site at www.3dcs.com for product details.

In attempting to apply these tools within the shipbuilding domain in the SBIR Phase I project, it was found that the existing tools are capable of modeling the dimensional effects of weld shrinkage and distortion, the primary source of shipbuilding dimensional variation. The statistical analyses yield appropriate results and the graphic interface represents the resulting shrinkage and distortion properly. However, the process of modeling the dimensional effects of weld shrinkage and distortion with the present tools is very laborious and time consuming. The primary objective of the Phase II project is to evolve our products to simplify the modeling of dimensional effects associated with weld shrinkage and distortion, with the intent of commercializing a version of our tools that are more user-friendly for the shipbuilding domain.