CDI Business Solutions SM

THE QUARTERLY DIGEST

of CDI Marine Systems Development Division (SDD)
(formerly Band, Lavis & Associates)
900 Ritchie Highway, Severna Park, MD 21146

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FROM DAVE'S DESK

The first half of the year is behind us and, in looking back, we have made some very meaningful contributions to a wide range of endeavors. First, we are excited by and proud of our support to homeland security. This has ranged from (a) support to the acquisition of three classes of USCG high-speed security craft, two classes of which have already entered into quantity production, to (b) the continued development of bio/chem/radiation sensor systems for deployment worldwide (see article by John Schech in this issue). We have also completed the design of an advanced Air Cushion Vehicle (ACV) for a foreign customer and have developed and tested, at model scale, new propulsion and lift machinery for the next generation LCAC. This adds to other innovations that we have made in recent years including the LCAC Deep Skirt, the low-profile thrusters on the 74-knot Finnish ACV combatant, and the advanced lift-air supply fans for two classes of Norwegian Surface Effect Ships (SES) described by Brian Forstell below. For the second half of the year, we will increase our support of homeland security and expect to gear up on new ACV and SES projects plus new work on marine waterjet propulsion and the design of other conventional and high-speed ships and craft. These are interesting times, and we are pleased and feel very privileged to be able to make so many significant contributions.

IS THERE AN ACV IN YOUR FUTURE?

By Brian Forstell, Director of R&D

Do you require a truly amphibious capability? Do you have to operate in very shallow water or over mud flats and sand bars? Do you have to transit through environmentally sensitive areas such as marshlands? If you answered "No" to all of these questions, then an ACV is not in your future. There are more economical means of transportation that will most probably meet your transportation needs. However, if your answer to any one or more of the questions above was "Yes", then an ACV is probably your best, if not your only, transportation alternative.

Since its official introduction in the late 1950's, the ACV has evolved in a manner that ultimately improved craft performance and reliability and reduced both acquisition and ownership costs. This evolution was stimulated by research and development that introduced new technology into the ACV community. Examples of some of the more significant technical advances include the adaptation of shipyard construction techniques, the development of new skirt systems that significantly improve performance while reducing maintenance needs, the development of customized centrifugal lift fans that have significantly reduced power consumption while also reducing airborne noise, and the application of composite materials.

Continued on page 2

LCAC Deep Skirt

Low-Profile Bow Thrusters

High-Efficiency Composite Fans

In This Issue . . .

A Tradition of Excellence in Advanced Marine Technology

IS THERE AN ACV IN YOUR FUTURE?
Continued from page 1

CDIM-SDD (formerly Band, Lavis and Associates) has been at the forefront of this ACV evolution since the company was formed in 1977. The senior staff at CDIM-SDD has a combined total of 150 years of experience in ACV research and development. Dave Lavis, for example, started his career in ACV development in 1959. When this is combined with the additional 89 years of ACV experience that the remainder of the CDIM-SDD engineering staff has, CDIM-SDD enjoys a grand total of 239 years of ACV research and development experience.

ACV technology developments for which CDIM-SDD has been directly responsible include the U.S. Navy LCAC Deep Skirt, the highly efficient low-profile bow thrusters that were featured on the Finnish T-2000, and custom designed centrifugal lift fans for the T-2000, and Oksoy and Skjold SES. CDIM-SDD has been continuously involved with advances in ACV technology for more than 27 years. We are proud of the fact that we have supported all significant military ACV/SES development in the United States and in Europe, and have played a key role in all significant ACV developments that have occurred in the last 5 years.

DESIGN OF INLETS FOR MARINE WATERJET PROPULSION

By John Purnell, Senior Engineer

The successful design of an inlet for a marine waterjet propulsion system requires that a significantly large number of design inputs and constraints be considered. The waterjet inlet must draw in water from beneath the ship, with a minimum impact on drag being most important, particularly for a high-speed ship. The flush type inlet provides the lowest inlet drag and will be the inlet of choice for most high-speed applications. Also, the flush inlet does not impact the ship's draft, as nothing protrudes beyond the hull since the inlet is flush with the ship bottom and the waterjet itself will be internal to the hull. For the design of a waterjet inlet, preliminary design optimization and analysis will have established the pump design flow rate and waterjet size for the design speed of the ship.

The waterjet inlet moves flow from outside the hull, through the flush-mounted inlet, and delivers it to the inlet face of the waterjet impeller. Many variables affect the design of the waterjet inlet, such as flow rate, ship speed, hull rake angle, nozzle elevation, ramp angle, etc. The inlet needs to duct the flow to the waterjet impeller with a minimum of losses while providing a reasonably uniform flow velocity at the impeller face. Depending on the design requirements of the impeller, the waterjet inlet will need to be designed to change the flow velocity to match the required inlet flow velocity at the impeller face for the design point. This requires control over the flow areas of the inlet and, in turn, control of the inlet geometry to provide a smooth transition of flow through the inlet to the impeller face.

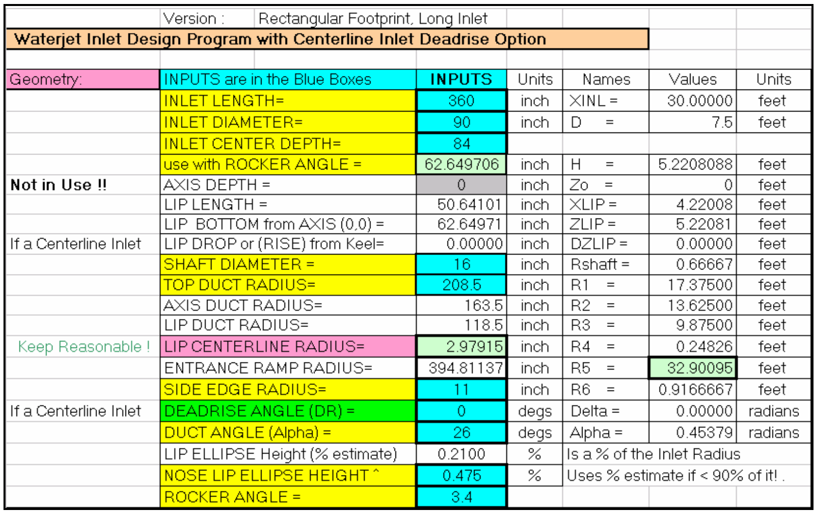
Two primary types of flush inlets are in use for marine waterjet propulsion. The shape of the opening that is made in the hull, which is either an elliptical or a rectangular inlet opening, basically classifies these, although combinations of the two are used. The inlet approach that is preferred in our applications is a more rectangular inlet arrangement, with a rectangular hull opening forward and a slightly elliptical shape aft to accommodate the changing lip radius as it grows towards the outside of the inlet to match the side radius of the inlet. The overall rectangular inlet provides a more compact arrangement that requires less fore/aft length in the hull than the elliptical inlets and is thought to provide a better approach to getting more of the mass flow to the upper parts of the inlet, which has been a problem in inlet design, and will thus reduce the non-uniform inflow velocities at the impeller face.

Since the inlet design will need to be modified frequently during the overall design process, it is necessary to develop analytical approaches that would allow the inlet design to be revised and updated in a timely manner as layout requirements in the hull and CFD computational results dictate. A macro driven spreadsheet program has been developed to layout the centerline cut through a waterjet inlet from the basic geometric parameters. Figure 1 shows the spreadsheet geometric inputs and the plot of the resulting centerline cut.

Basic inputs are the overall inlet length, the inlet diameter (which is the impeller inlet diameter), and a hull rocker angle. The inlet center depth is the vertical distance between the shaft centerline and the inlet ramp tangency point with the hull. When a hull rocker angle is included in the design, the inlet is laid out as though it has a smaller inlet center depth.

Later programming, which develops all the details of the inlet surfaces about the centerline profile, rotates the inlet by the rocker angle and a cylindrical wedge is added at the impeller inlet face of the inlet to match the rocker angle rotation to give a vertical exit face for the inlet. Additional inputs are the ramp angle of the straight section of duct and the radius of the top arc to match the duct angle with the top of the impeller inlet face. Deadrise angle is included only if the inlet is located on the ship centerline, which would account for designing the inlet to conform to the V-shaped surface of the hull. Keeping the centerline lip radius to reasonable values within a couple of percent of the inlet diameter is desirable and requires adjustments of the inputs to modify its value. Too large a center lip radius will add drag, and too small or sharp a lip radius is prone to cavitation.

Since significant flow can come in across the sides of the inlet, a side edge radius is needed in the inputs. The centerline lip radius will grow across the width of the inlet to match the side radius to ultimately define the entire lip surface. The spreadsheet macros will calculate the additional details of the inlet centerline layout, which are then updated and displayed with each variable change, as shown in Figure 1.



	Version :	Rectangular Footprint, Long Inlet				
Waterjet Inlet Design Program with Centerline Inlet Deadrise Option						
Geometry:	INPUTS are in the Blue Boxes	INPUTS	Units	Names	Values	Units
	INLET LENGTH=	360	inch	XINL =	30.00000	feet
	INLET DIAMETER=	90	inch	D =	7.5	feet
	INLET CENTER DEPTH=	84				
	use with ROCKER ANGLE =	62.649706	inch	H =	5.2208088	feet
Not in Use !!	AXIS DEPTH =	0	inch	Zo =	0	feet
	LIP LENGTH =	50.64101	inch	XLIP =	4.22008	feet
	LIP BOTTOM from AXIS (0,0) =	62.64971	inch	ZLIP =	5.22081	feet
If a Centerline Inlet	LIP DROP or (RISE) from Keel=	0.00000	inch	DZLIP =	0.00000	feet
	SHAFT DIAMETER =	16	inch	Rshaft =	0.66667	feet
	TOP DUCT RADIUS=	208.5	inch	R1 =	17.37500	feet
	AXIS DUCT RADIUS=	163.5	inch	R2 =	13.62500	feet
	LIP DUCT RADIUS=	118.5	inch	R3 =	9.87500	feet
Keep Reasonable !	LIP CENTERLINE RADIUS=	2.97915	inch	R4 =	0.24826	feet
	ENTRANCE RAMP RADIUS=	394.81137	inch	R5 =	32.90095	feet
	SIDE EDGE RADIUS=	11	inch	R6 =	0.9166667	feet
If a Centerline Inlet	DEADRISE ANGLE (DR) =	0	degs	Delta =	0.00000	radians
	DUCT ANGLE (Alpha) =	26	degs	Alpha =	0.45379	radians
	LIP ELLIPSE Height (% estimate)	0.2100	%	Is a % of the Inlet Radius		
	NOSE LIP ELLIPSE HEIGHT ^	0.475	%	Uses % estimate if < 90% of it! .		
	ROCKER ANGLE =	3.4				

Figure 1a. Waterjet Inlet Centerline Cut Design Input Spreadsheet

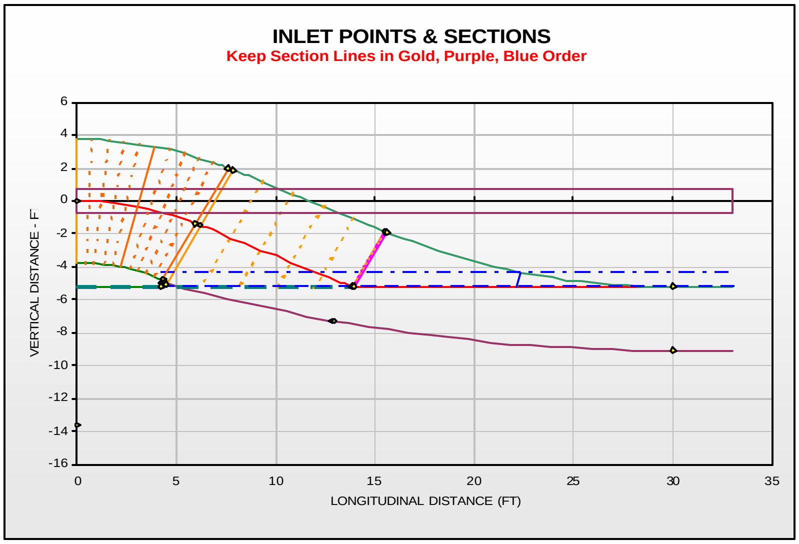


Figure 1b. Waterjet Inlet Centerline Cut Design Input Plot with Dividing Streamline Estimate

We use advanced turbomachinery CFD software to check the performance of each inlet. To do this, the entire geometry of the inlet must be developed in detail so that the surfaces can be defined for meshing. The waterjet inlet must transition from the basic rectangular opening in the hull to the circular inlet face of the waterjet impeller at its other end. Extensive programming has been developed over the years to handle the calculation details to create full three-dimensional inlets starting from the appropriate centerline profile cut. The basic inlet width is kept the same as the impeller inlet diameter since flaring the inlet in the width dimension would require additional hull width for installation, which is restricting on high-speed slender hulls. Figure 2 shows the details of the sections that are developed to define the inlet, and these sections can be further controlled to generate more appropriate inlet geometries. The shaft centerline shown is for reference and will be shifted in later programming to account for any rocker angle. The inlet is defined by a large number of curves. By appropriate grouping of these curves, B-splines can be used to create several surfaces that will define the entire inlet and that can then be meshed for CFD analysis.

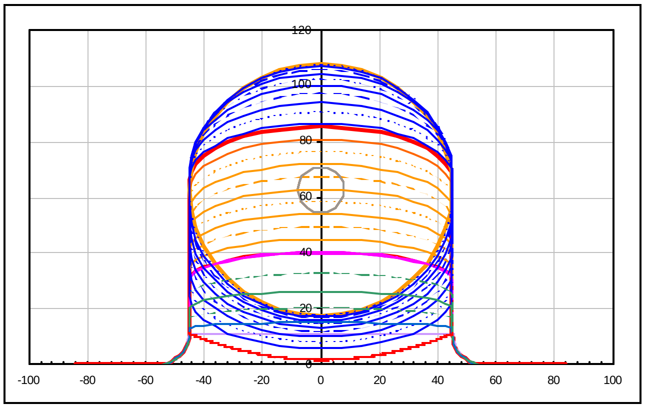


Figure 2. Stacking of Section Geometries to Build the Inlet along the Shaft Axis

Figure 3 shows several views of the inlet, including a rocker angle correction and a CFD analysis run of the inlet. The shaft is not shown in all the figures since most drawing packages can easily add it to intersect at the correct location once the inlet surfaces are defined. Without appropriate inlet layout design tools, such as have been developed at CDIM-SDD over the years, inlet design would be a very tedious task. The programming will indicate combinations of inlet input design variables that cannot produce an inlet design, however, a large range of inlet input variables could provide a design. Engineering judgment and experience is still needed to narrow down choices to realistic inlet input design parameters without choosing designs that, in the long run, will be less than desirable.

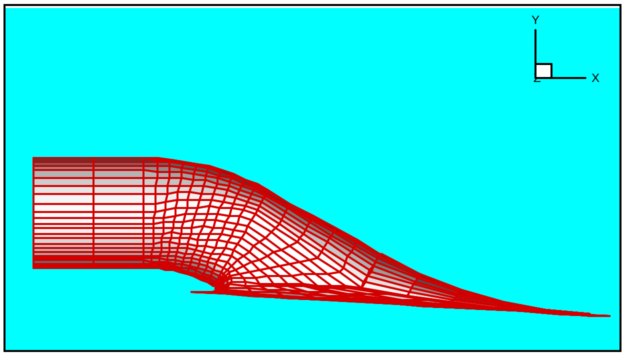


Figure 3a. Side View of the Waterjet Inlet including the Hull Rocker Angle

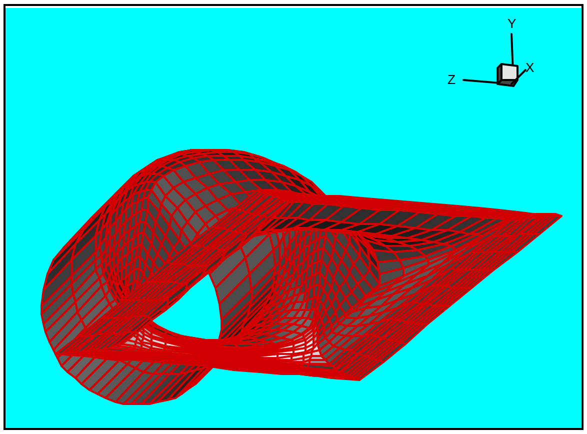


Figure 3b. Waterjet Inlet Viewed from Below and Showing the Lip Region

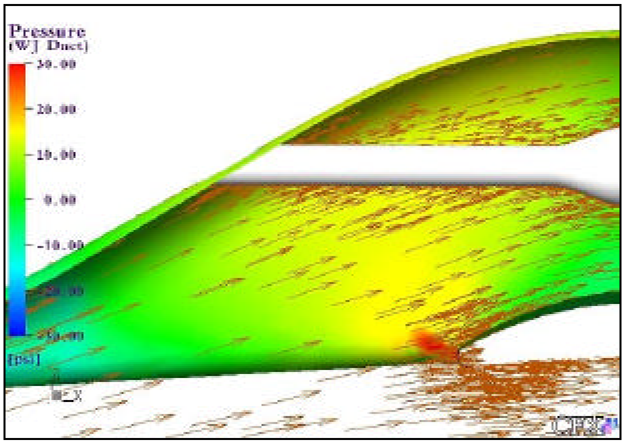


Figure 3c. Waterjet Inlet Duct Pressures and Velocity Vectors from CFD Analysis using CFX

CDIM-SDD DESIGNS MICROCONTROLLER

By John Schech, Senior Software Engineer

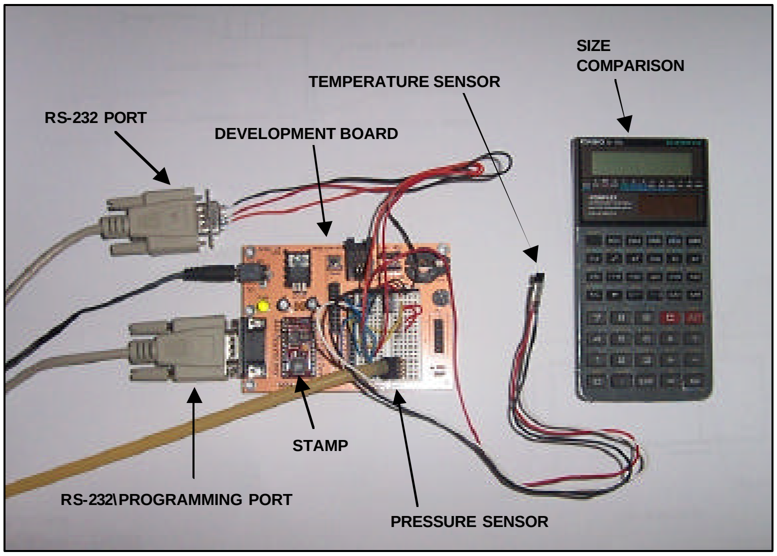


Figure 1. Microcontroller Layout

CDIM-SDD has been tasked by a client to develop a device that can sense temperature and pressure readings from monitoring equipment, then to process the data and send the results along to another device or computer. This work relates to CDIM-SDD's Homeland Security activities.

The main focus of this design is low cost, rapid deployment, and a physically small size. These criteria eliminated the use of a laptop computer with large sensing devices which would have been too costly and too big. CDIM-SDD instead selected several low-cost components that could be assembled to accomplish this task. These include a basic Stamp Micro-Controller (Stamp), a Stamp Development Board, an Analog-to-Digital Converter, a Temperature Chip, and a Pressure Chip.

The Stamp is basically a tiny computer that can process 6000 instructions per second, has internal memory and I/O pins for RS-232 interface, and is programmed with the PBasic programming language, which is a subset of the Basic language. In a nutshell, the Stamp can gather data, process the data with PBasic, and output the results to another device or computer. The PBasic language includes I/O and math commands that allow sophisticated algorithms to be implemented.

The Stamp plugs into a development board, which has a breadboard and a RS-232 programming port that enables the Stamp to be programmed and to communicate with the outside world.

The Analog-to-Digital (A\D) Converter is a chip that plugs into the breadboard and can accept analog data from two sources. When instructed, the chip converts the analog data to digital data.

The function of this device is as follows: The assembly can start off being hooked to a computer to change its default settings or it can be hooked up to the device with which it is to interface. Upon receiving power, the Stamp's program starts by asking the user if the settings need to be changed. This can be accomplished if the Stamp is hooked to a computer with a terminal and keyboard. If no response is received in 20 seconds, the Stamp assumes no changes are required or that it is only hooked up to a device to which it will be interfacing. The Stamp's default settings request temperature and pressure data from the respective chips every 15 seconds and outputs these findings instantaneously. This is accomplished by the Stamp requesting the A\D converter to access analog data from the temperature and pressure chips, having the A\D converter convert that to digital data, and then the Stamp converts the digital data to degrees Fahrenheit or Centigrade and kilo-Pascals. As the Stamp outputs this data, it also totals each of the pressure readings. After collecting pressure data for 30 minutes, or any other chosen length of time, the Stamp stores that total. The Stamp then repeats the process and accesses the next 30 minute's worth of data. At this point, the previous 30 minute's worth of data can be compared to the current 30 minute's worth of data. The Stamp's program generates a percent difference between the results from two test periods and outputs this number every 30 minutes. The Stamp also outputs alarm status on each of its outputs. This alerts the computer receiving the Stamp's output that one or more of its readings may be in a range that should be looked at more carefully and/or dealt with appropriately.

The current task calls for 100 of these devices to be deployed. We are also interfacing a radiation detection unit into the design. While the function of these units is no different than many individual sensors available commercially, the low cost and compact packaging provide an immediate cost-effective solution for the client. As long as there is memory left on the Stamp, and space available on the breadboard, additional sensors may be field back-fit as required.

CDI MARINE SDD AT RINA

By John Purnell, Senior Engineer

The Royal Institution of Naval Architects (RINA) held its Waterjet Propulsion 4 International Conference on 26-27 May 2004 in London, England. CDI Marine SDD, with its long interest and background in waterjet propulsion, once again participated in the tri-annual conference with Senior Engineer John Purnell presenting a paper entitled "Analysis of Hull Boundary Layer Velocity Distributions with and without Active Waterjet Inlets". The paper was a joint effort with the Naval Surface Warfare Center, Carderock Division (NSWCCD), and Marine Propulsors Company. Contributing authors were M.B. Wilson, C. Chesnakas, S. Gowing, A.J. Becnel and J.G. Stricker.

In the paper, selected results of model testing work accomplished by NSWCCD, under the direction of Mr. Jack Offutt and Dr. Mike Wilson, are presented for the afterbody hull pressure distributions and detailed LDV measurements of velocities for the flow around a high-speed hullform model with four side-by-side waterjet inlets. NSWCCD test conditions covered both bare hull flows (inlets covered) and self-propelled cases with active waterjet intake flows (see Figures 1 and 2). Velocity surveys were taken at a location one-inlet diameter upstream of the inlets for scaled ship speeds of 55 knots (design-speed) and 70 knots, which detailed the hull boundary layer flow region in front of the inlets (see Figures 4 and 5).

Figure 1. Overall View of NSWCCD Sealift Model

Figure 2. NSWCCD Sealift Model with Inlets Plugged

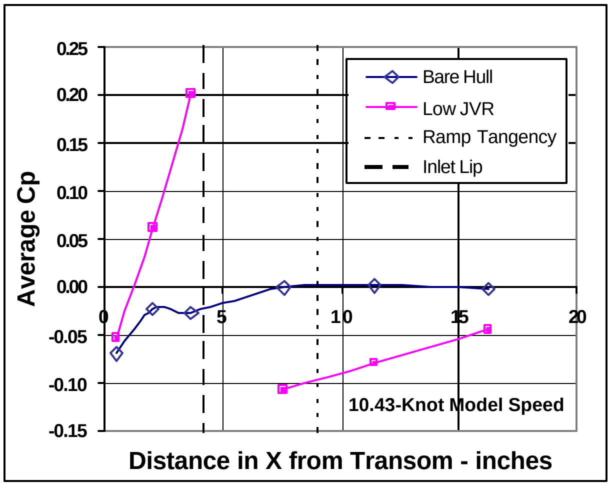


Figure 3. Average Static Pressure Coefficients Along the Hull for 10.43-Knot Model, or 70-Knot Ship Speed

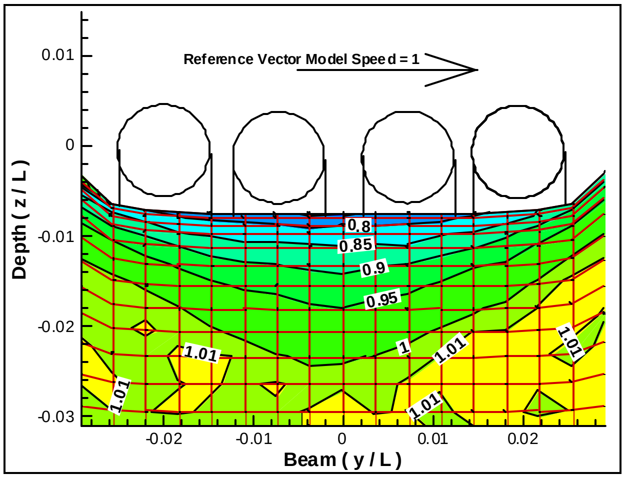


Figure 4. Non-Dimensionalized Axial Velocity Contours (U_x/V_o) with Inlet Covered, Ship Speed 70 Knots

Continued on page 6

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CDI MARINE SDD AT RINA, Continued from page 5

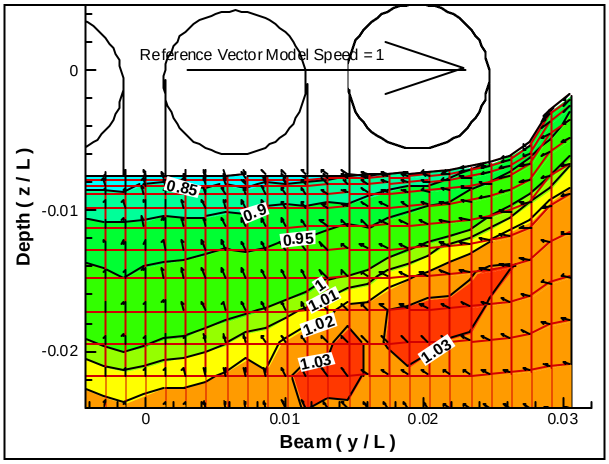

Figure 5. Non-Dimensionalized Axial Velocity Contours (U_x/V_o) with Inlet Operating, Ship Speed 70 Knots

It was found that water velocities around the hull in the direction of ship travel could be greater than ship speed, and operating inlets affected flow near the hull for a significant distance upstream of the inlet. The capture area shape and width did not have a significant effect on the resulting inlet wake factor term, while the inboard inlets had lower inlet wake factors than the outboard inlets due to thicker boundary layers toward the center of the ship.

Since boundary layer ingestion by the waterjet inlets can significantly impact waterjet performance and design considerations, the availability of real data taken at NSWCCD, even at model scale, can benefit future work and understanding of waterjet propulsion. CDI Marine SDD had participated in analyzing the velocity distribution data in terms of various wake factors for the nominal wake based on comparing several configurations for the inlet flow capture area of the waterjet inlets.

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