Selection of Water Tunnel

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Model Test and Evaluation of an Advanced Axial Flow Waterjet Pump
Designed for the Coastal Commercial Ship Sealift Application

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STATUS REPORT

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SELECTION OF WATER TUNNEL

System:
Selection Of The Water Tunnel For Model Testing and Evaluation Of An Advanced Axial Flow Waterjet Pump Designed For The Coastal Commercial Ship Sealift Application

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FOREWORD

CDI Marine Systems Development Division (CDIM-SDD) prepared the work described in this Status Report for the Center for the Commercial Deployment of Transportation Technologies (CCDoTT) at California State University, Long Beach. The principal point of contact at CDIM-SDD was Mr. John Purnell. The principal point of contact at CCDoTT was Mr. Stan Wheatley.

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1.0 INTRODUCTION

Testing will be performed at the Carderock Division, Naval Surface Warfare Center (CDNSWC) in West Bethesda, MD. Two water tunnel facilities located at CDNSWC are capable of being used for the model waterjet pump evaluation required for the present CCDoTT effort to evaluate an advanced axial-flow design. These are the 36-inch and the 24-inch Variable Pressure Water Tunnels. This status report discusses some of the considerations for the selection of the water tunnel for the actual waterjet pump testing.

2.0 TUNNEL SELECTION

Selection of the water tunnel is an important requirement, as it affects the construction of test fixtures and hardware needed in support of the planned testing. The 36-inch Variable Pressure Water Tunnel is described in Reference 1. Modifications have been made to allow tests of pump models mounted in a suspended duct system within this water tunnel test section. A second water tunnel at CDNSWC, the 24-inch Variable Pressure Water Tunnel described in Reference 2, provides another suitable facility for conducting the testing of the 7.5-inch waterjet pump model. Each of the two facilities is capable of meeting the model test program requirements, but there are differences and tradeoffs, as well as similarities, between the two facilities. These include the following:

Waterjet Model and LDV Arrangements

The 36-inch water tunnel setup uses an open-jet test section in which the waterjet model is suspended from the test section “ceiling”, and tunnel flow passes through the model as well as around it. An additional large flooded section surrounding the model and tunnel test section flow accommodates an array of traversing LDV probes and instrumentation. The traversing feature of this instrumentation is oriented towards propeller testing, allowing multi-component velocity surveys at different locations around an open propeller. This LDV system has been used extensively, but would require minor modification to survey the proposed waterjet model. The 24-inch water tunnel also uses an open-jet test section, but the upstream entrance of the test section is sealed off to force all of the tunnel flow through the waterjet model. Ample flooded space exists around the model to allow a modified fiber optic LDV system to be attached to the outside of the model and provide velocity surveys similar to those of the 36-inch water tunnel. Because the tunnel flow does not pass over the outside of the model in the 24-inch water tunnel, the instrumentation does not have to be strengthened to withstand flow loads and vibration. Hence, both tunnels allow LDV velocity surveys over sufficient sections of the model flow with minor modifications.

Drive Shaft Arrangements

The 36-inch water tunnel uses an upstream drive shaft to rotate the pump model rotor from the front, while the 24-inch water tunnel uses a downstream drive shaft, which drives the model from behind. The upstream shaft is advantageous because it is representative of most, if not all, actual waterjet system arrangements. The rear drive shaft must pass through the waterjet nozzle section to drive the pump impeller, and the nozzle shape must be modified to account for the shaft blockage to maintain the same exit area as without the shaft being present. Thus, the nozzle exit area is correctly maintained, but the nozzle shape is slightly modified from an actual waterjet system design. The pump loading and performance should not be significantly affected as long as the nozzle area is corrected to account for the shaft blockage. Because the main concern in this testing is evaluating the pump performance, the rear drive shaft of the 24-inch water tunnel will be satisfactory.

Water Quality

Water temperature and air content are more readily controlled in the larger water tunnel. The energy input to drive the test pump is ultimately dissipated as heat to the water in the tunnel. The larger size and water volume of the 36-inch water tunnel would allow longer run times with little significant change in water temperature; however, extended run times are not likely to be required, so the 24-inch water tunnel should not have problems with water temperature rise. The resorber feature of the 36-inch water tunnel would minimize undissolved gases in the test section, which is desirable for cavitation testing. Previous cavitation testing with similar pump models in the 24-inch water tunnel has been successful and any present testing in that water tunnel would be expected to provide good results.

Model Size Considerations

The 24-inch water tunnel is designed to handle propeller sizes up to 18 inches in diameter, while the 36-inch water tunnel can handle propellers up to 27 inches in diameter. The present waterjet model test pump has a 7.5-inch impeller diameter. Ducting and shrouds that enclose the pump model will increase the installation diameter, but the overall installation size will be well within the capability of either water tunnel.

Upstream Contraction

Both water tunnels are designed with contraction ratios of 9:1, with typical contraction ratios for water tunnels ranging from 4:1 to 9:1. A large contraction ratio is desirable because it produces lower velocities and higher static pressures in regions of the water tunnel other than the test section and provides a more uniform inflow to the test section, as described in Reference 3. Because the 24-inch water tunnel uses a plate to force all the tunnel flow through the model, an ASME flow nozzle is used to induce the flow into the model and provide a simple means of overall flowrate measurement during testing. This feature is not possible in the 36-inch water tunnel because the tunnel flow can pass around the model exterior as well as through the model.

Waterjet Flowrate Control

Neither water tunnel currently features an adjustable downstream throttling valve for control of model flow and backpressure, yet flow control is required to adjust the flow coefficients over the desired range for developing head-flow maps and other required data sets. To vary the flow resistance, an exit-throttling device was successfully used in previous testing for the 24-inch water tunnel that consisted of different size rods arranged across the nozzle exit to bring the flow coefficient to a minimum value. The water tunnel circulation pump was then ramped up to force additional flow through the pump to get the higher flow coefficients needed to generate a head-flow map independent of waterjet RPM. This approach was possible because the entire tunnel flow in the 24-inch water tunnel was forced through the waterjet model by closing off the test section entrance. The 36-inch water tunnel test section cannot be closed off to achieve the same flow control without expensive manufacture of new, large hardware components.

Shaft Dynamometry

Each water tunnel features model drive motors that include shaft torque and thrust dynamometry. Specifications for each drive system indicate adequate shaft speed and powering margins for the planned waterjet pump model. The maximum net positive suction head requirement for the planned testing is about 45 feet of head. The 24-inch water tunnel is capable of delivering up to 69 feet of pressure head, while the 36-inch water tunnel can operate with up to 139 feet of pressure head. Thus, both are adequate.

Facility Testing Costs

The 36-inch water tunnel costs about three times as much as the 24-inch water tunnel for operating costs during testing; hence, the 24-inch water tunnel offers a longer, more comprehensive test program for the same budget.

3.0 CONCLUSIONS

Both the 36-inch and the 24-inch water tunnels have been recently modified for pump testing and could encompass the necessary 7.5-inch diameter waterjet pump models for performance evaluation and flow-field measurements. The advantages of the 24-inch water tunnel are total pump flowrate measurement, flowrate control, and lower operating costs. The 24-inch water tunnel has also been used for the testing of a similar sized waterjet type pump, so procedures and testing requirements are well understood. Installation of the waterjet pump in the 24-inch water tunnel will benefit from the past lessons learned during those previous tests. The previous tests also provide some existing hardware that may be used or modified for these tests. The smaller size of the 24-inch water tunnel offers a benefit in that access to the tunnel test section can be accomplished in less time than the 36-inch water tunnel in order to make any adjustments or needed modifications. The 24-inch water tunnel will be available for the expected duration of the testing, even if scheduling of events needs to be changed due to whatever circumstances arise. Thus, the 24-inch water tunnel has been selected as the preferred facility for this program.

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