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Manufacturing Tolerance Effects on Ship Rudder Performance

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Manufacturing tolerances can affect ship rudder lift, drag, torque, cavitation, and surface erosion. Computational fluid dynamics is used in this study to evaluate the effects of manufacturing variations from an ideal design. Study findings indicate that the construction tolerances associated with leading-edge droop and longitudinal misalignment can be oosened, spanwise-twist tolerances should be maintained pending further analysis, and tolerances associated with trailing-edge twist should be maintained.We used CFD to analyze four different types of variations: (1) leading-edge droop, (2) trailing-edge twist, (3) spanwise twist, and (4) longitudinal misalignment. We examined the effects of variations on a typical navy-type spade rudder, using the CFD code Unstructured, Unsteady Computation of Field Equations (U2NCLE) in the numerical simulation.

The resulting computations for the deformed rudders reveal that construction variations that cause trailing-edge twist have the greatest effect on rudder performance, with a lift performance deficit of 4% for a 0.2% construction variation. More significant, the numerical investigation shows that, despite a negligible effect on lift and drag, geometric variations related to trailing-edge twist can strongly affect rudder torque performance. All other manufacturing variations result in less than a 0.5% performance deficit for the same 0.2% construction variation, although further analysis is needed to determine the effect of spanwise twist on ship maneuverability. Those findings indicate that the construction tolerances associated with leading-edge droop and longitudinal misalignment can be loosened, spanwisetwist tolerances should be maintained pending further analysis, and tolerances associated with trailing-edge twist should be maintained.

John P. Hackett is Chief Scientist and Director of Advanced Ship Design, Hydrodynamics, and Signatures at Northrop Grumman Ship Systems. His area of expertise is conceptual and preliminary ship design, as well as hydrodynamics. Dr. Hackett's 30+ years of marine experience include service as chair of the School of Naval Architecture and Marine Engineering, University of New Orleans. He received Litton's 1996 Charles B. Thornton Advanced Technology Achievement award for his work on hull form design and hydrodynamics. He holds two patents, with a third pending. Dr. Hackett is active in the Society of Naval Architects and Marine Engineers and has served as its vice president. His technical papers, focused on ship hydrodynamics and design, have appeared in *Ocean Engineering* and publications of the Society of Naval Architects and Marine Engineers, American Society of Naval Engineers, The Royal Institution of Naval Architects, Society of Automotive Engineers, and Office of Naval Research. He holds a BSE in naval architecture and marine engineering, MSE degrees in applied mechanics and in naval architecture and marine engineering, and a PhD in naval architecture and marine engineering, all from the University of Michigan.

Wesley H. Brewer is currently an adjunct professor at Mississippi State University and president of Fluid Physics International. Previously, he worked as a test engineer and operations team leader at the U.S. Navy's William B. Morgan Large Cavitation Channel, where he performed experimental work on the Navy's Virginia-class submarine. He was honored with two U.S. Navy awards for his work. His numerous technical papers have appeared in or are awaiting publication in such journals as *Journal of Ship Research*, *Journal of Fluids Engineering*, and *AIAA Journal*. Dr. Brewer holds a BS in engineering science and mechanics from the University of Tennessee, an MS in ocean engineering from the Massachusetts Institute of Technology, and a PhD in computational engineering from Mississippi State University.

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