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Performance of a Sailing Vessel with a Solid Wing Sail Compared to a Traditional Sail

Authors : William Waddington, M. Jahir Rizvi

Abstract : Sail used to propel a vessel functions in a similar way to an aircraft wing. Traditionally, cloth and ropes were used to produce sails. However, there is one major problem with traditional sail design, the increase in turbulence and flow separation when compared to that of an aircraft wing with the same camber. This has led to the development of the solid wing sail focusing mainly on the sail shape. Traditional cloth sails are manufactured as a single element whereas solid wing sail is made of two segments. To the authors' best knowledge, the phenomena behind the performances of this type of sail at various angles of wind direction with respect to a sailing vessel's direction (known as the angle of attack) is still an area of mystery. Hence, in this study, the thrusts of a sailing vessel produced by wing sails constructed with various angles (22°, 24°, 26° and 28°) between the two segments have been compared to that of a traditional cloth sail made of carbon-fiber material. The reason for using carbon-fiber material is to achieve the correct and the exact shape of a commercially available mainsail. NACA 0024 and NACA 0016 foils have been used to generate two-segment wing sail shape which incorporates a flap between the first and the second segments. Both the two-dimensional and the three-dimensional sail models designed in commercial CAD software Solidworks have been analyzed through Computational Fluid Dynamics (CFD) techniques using Ansys CFX considering an apparent wind speed of 20.55 knots with an apparent wind angle of 31°. The results indicate that the thrust from traditional sail increases from 8.18 N to 8.26 N when the angle of attack is increased from 5° to 7°. However, the thrust value decreases if the angle of attack is further increased. A solid wing sail which possesses 20° angle between its two segments, produces thrusts from 7.61 N to 7.74 N with an increase in the angle of attack from 7° to 8°. The thrust remains steady up to 9° angle of attack and drops dramatically beyond 9°. The highest thrust values that can be obtained for the solid wing sails with 22°, 24°, 26° and 28° angle respectively between the two segments are 8.75 N, 9.10 N, 9.29 N and 9.19 N respectively. The optimum angle of attack for each of the solid wing sails is identified as 7° at which these thrust values are obtained. Therefore, it can be concluded that all the thrust values predicted for the solid wing sails of angles between the two segments above 20° are higher compared to the thrust predicted for the traditional sail. However, the best performance from a solid wing sail is expected when the sail is created with an angle between the two segments above 20° but below or equal to 26°. In addition, 1/29th scale models in the wind tunnel have been tested to observe the flow behaviors around the sails. The experimental results support the numerical observations as the flow behaviors are exactly the same.

Keywords : CFD, drag, sailing vessel, thrust, traditional sail, wing sail
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