50ft Jib Schooner
Sail Plan Aerodynamic Analysis

Introduction

The aerodynamic characteristics of the jib schooner sail plan are calculated for a range of apparent wind angles (AWA's) from 20-120 degrees. A fisherman sail is included in the analysis in the range of 40°-90° AWA. RANS CFD which captures flow separation and viscous drag is used to calculate the forces on the sails and masts. To facilitate comparison with a standard sloop rig the aerodynamic forces are converted into force coefficients by dividing the forces by *.5*air_density*AWS^2*sail_area*. The calculated aerodynamic force coefficients are compared to a sloop rig with the same mast height. The sloop rig coefficients are derived from the ORC VPP aerodynamic model.

CFD Aerodynamic Force Calculations

The CFD simulations are performed using OpenFOAM's steady state incompressible RANS solver.

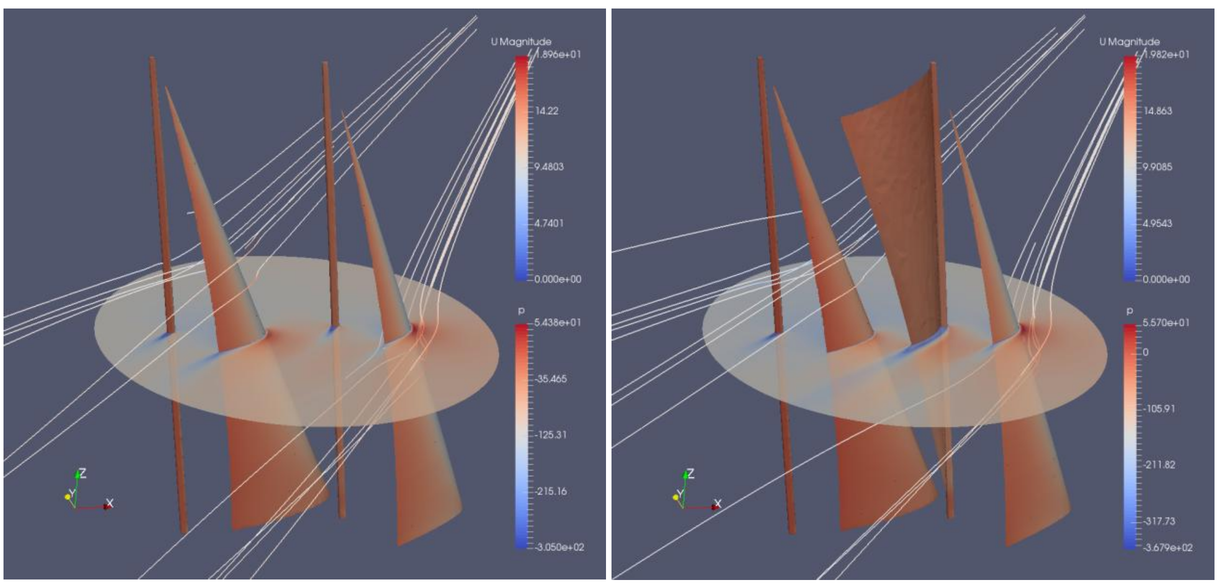
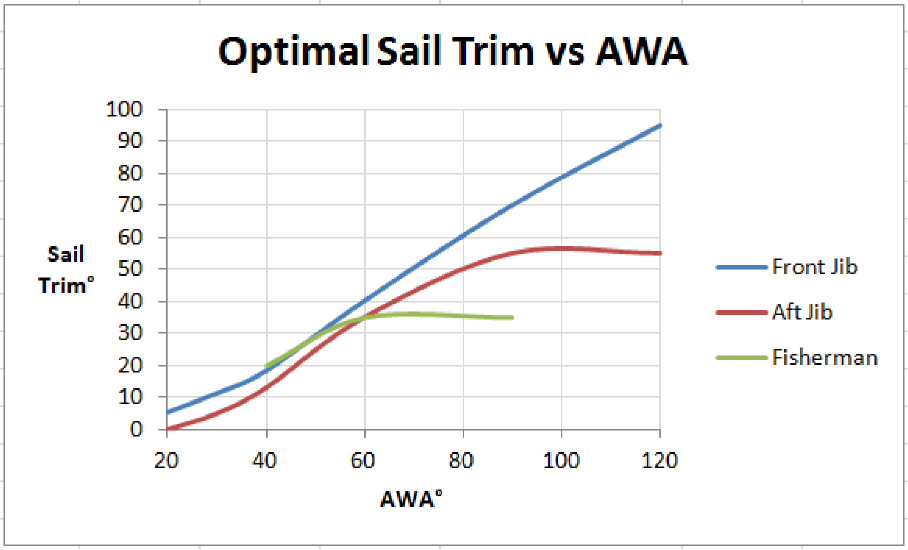


Figure 1.

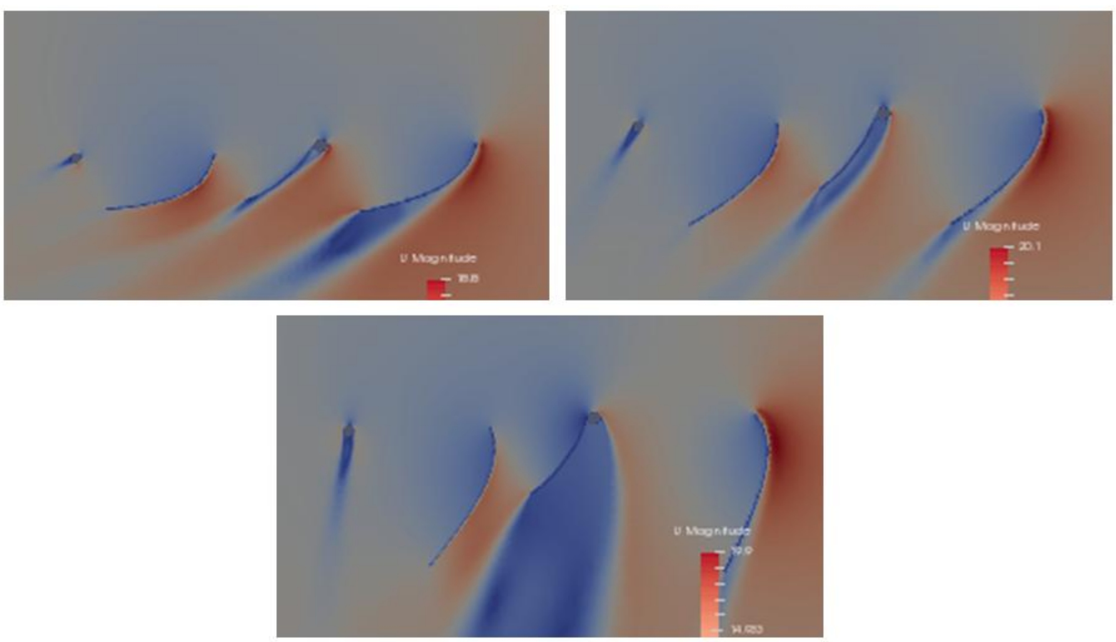
Figure 1 shows post processing results for AWA 60° for the sail plan with and without the fisherman. The horizontal disc shown in the middle of the sails is a velocity cut plane through the 3d flow field. High velocity is shown in red while low velocity is shown in blue. Low velocity indicates flow separation. The sails are colored by pressure with low pressure being blue and high and being red. The highest suction (negative pressure) is seen on the front of the jibs and corresponds to accelerated flow that can be seen with red on the velocity cut plane. Streamlines are shown colored by flow velocity.

Sail Trim

At each AWA the sails are trimmed to achieve maximum driving force. The sails are automatically trimmed by building a response surface of driving force as function of sail trim and then optimizing the trim to achieve the maximum driving force as evaluated by the response surface.

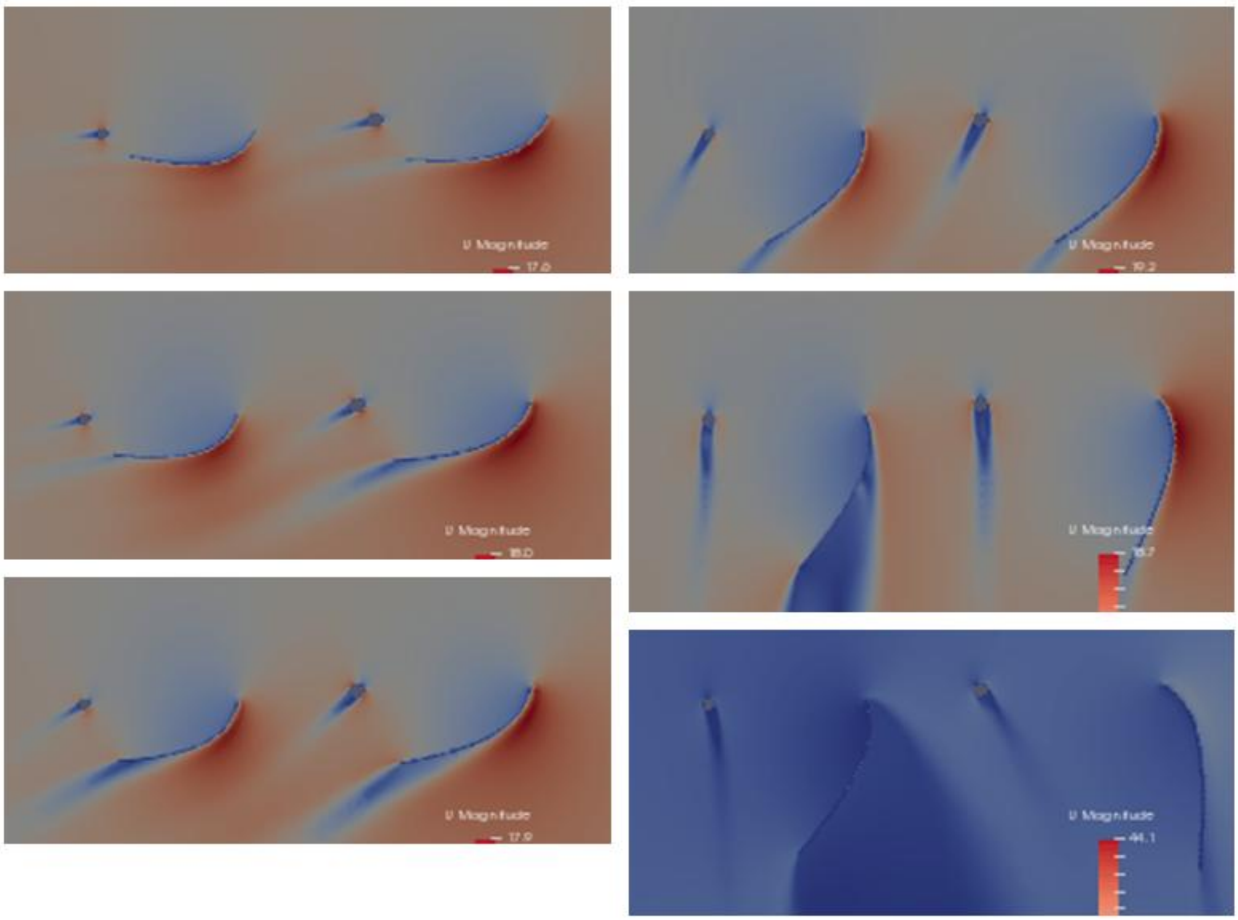


The amount that the aft jib and fisherman can be eased is limited by the forward mast side stays. For this study the aft jib rotation was limited to 55° and the fisherman to 35° which are the rotation angles where the sails first start hitting the rigging. Moving the forward side stays forward as much as possible will increase performance at wider AWA's.



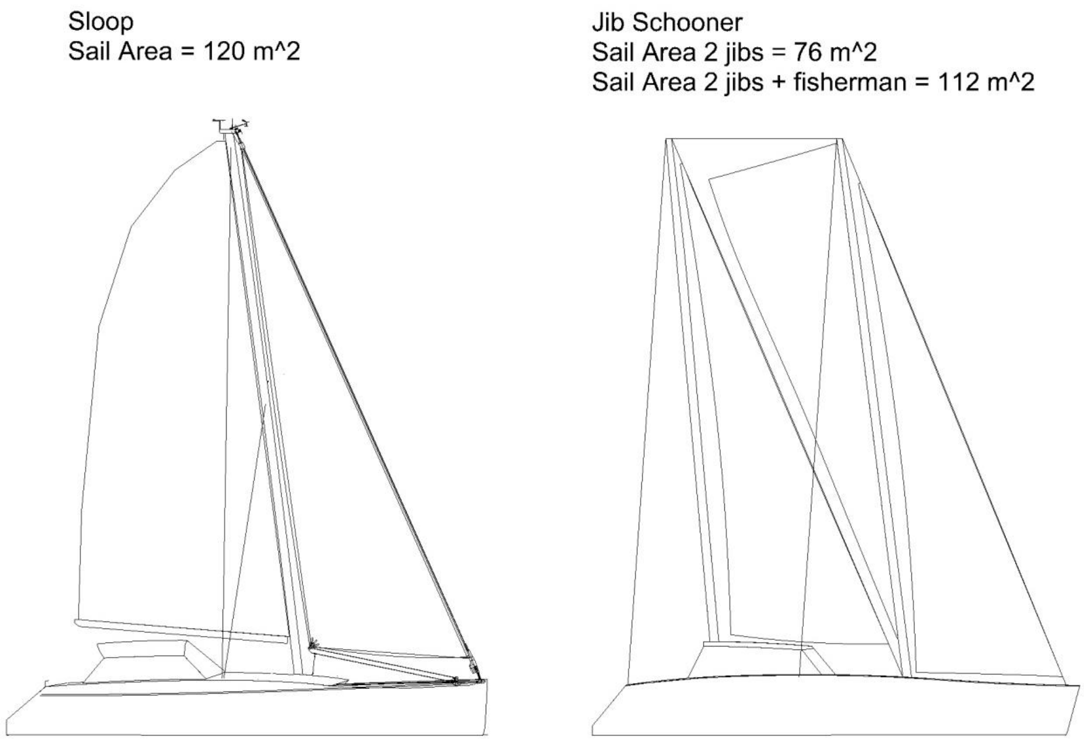
Above are shown velocity cut planes 9m above the waterline for AWA's 40°, 60° and 90° starting at the top left with the fisherman sail included at optimal trim.

Below are shown velocity cut planes 9m above the waterline for AWA's 20°, 30°, 40°, 60°, 90° and 120° at optimal trim. The cut planes start with 20° in the top left and finish with 120° in the bottom right. The velocity scale for 120° is set wrong and that is why the velocity plane looks different than the other AWA's. The separation seen on the aft jib at AWA's 90° and 120° is caused by the sail being restrained from easing further.

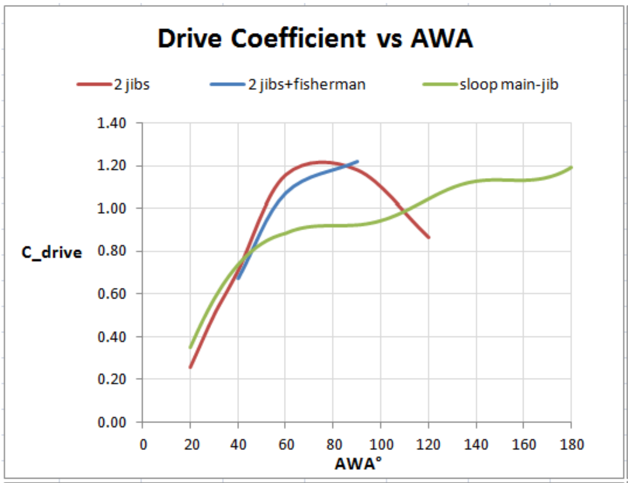


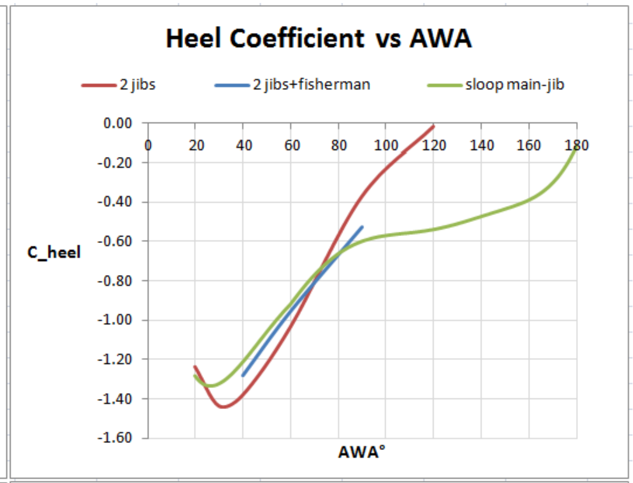
Aerodynamic Comparison

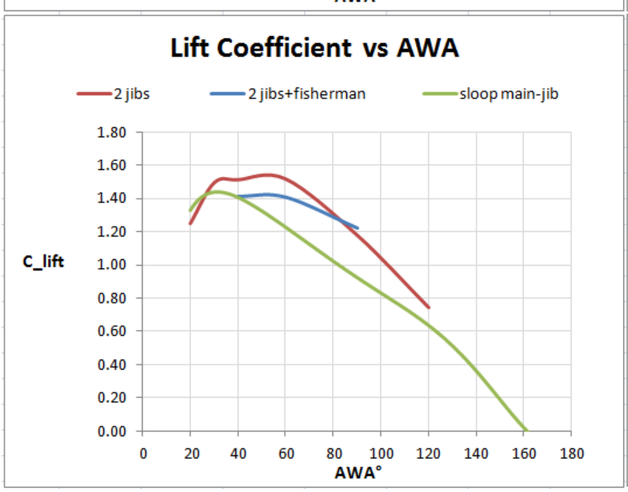
A typical 50ft catamaran sloop is used as comparison point for the aerodynamic forces. The two rigs have equal height. The sail plans for both the sloop and the jib schooner are shown below. The schooner has 37% less sail area than sloop with only jibs and 7% less sail area with a fisherman set. The flying shape of the fisherman sail used in the CFD simulations assumes that the fisherman clue is well supported through the use of a wishbone or some kind of batten system.

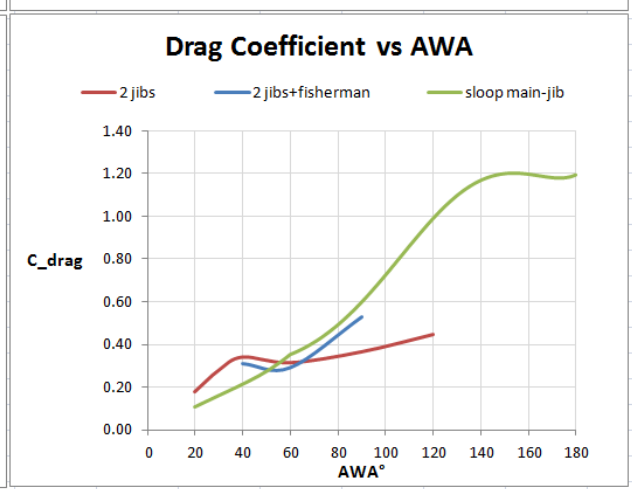


The coefficients of drive, heel, lift and drag are plotted below for the schooner with only jibs, for the schooner with jibs and a fisherman and for the sloop. The fisherman sail is only set between AWA 40°-90°. Upwind at low AWA's the schooner has a slightly lower drive coefficient, however by 40° AWA the schooner has the same drive coefficient and by 60° a much better drive coefficient than the sloop. The schooner drive coefficient drops quickly starting at 80° with only jibs because the aft sail is restrained from rotating by the forward side stays. The fisherman is also restrained by the forward side stays and although the plot below shows the drive coefficient increasing at 90° AWA it is expected that this configuration will also show a sharp drop in drive coefficient at higher AWA's. Because the schooner drive coefficient with the fisherman set is only slightly less than the sloop at 40° and better at 60° and 90° AWA means the schooner should perform well relative to the sloop at these angles since the two rigs have similar sail area in this configuration. The biggest difference in power between these two rigs will be seen upwind in light to moderate breeze at the AWA's too low for the fisherman to work effectively.









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Schooner aerodynamic forces and coefficients used in the comparison

		trim star	trim port	Fx_tot	Fy_tot	Fz_tot	cx	cy	cd	cl
AWS = 20 knots				n	n	n				
two jibs	20	5	0	1,432	-6,871	598	0.26	-1.24	0.18	1.25
two jibs	30	11	5	2,802	-7,981	1,123	0.50	-1.44	0.28	1.50
two jibs	40	18	13	3,945	-7,673	1,585	0.71	-1.38	0.34	1.51
two jibs	60	40	35	6,426	-5,747	2,653	1.16	-1.03	0.32	1.52
two jibs	90	70	55	6,555	-2,048	2,734	1.18	-0.37	0.37	1.18
two jibs	120	95	55	4,823	-100	1,980	0.87	-0.02	0.45	0.74
two jibs-fisherman	40	18	20	5,298	-10,116	1,674	0.67	-1.28	0.31	1.41
two jibs-fisherman	60	40	35	8,475	-7,543	2,844	1.07	-0.96	0.29	1.41
two jibs-fisherman	90	70	35	9,634	-4,162	3,279	1.22	-0.53	0.53	1.22