

Performance Evaluation of the 19th Century Clipper Ship Cutty Sark: A Comparative Study

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Abstract

The Cutty Sark, built in 1869 in Dumbarton, is the last intact composite tea clipper ship [1]. One of the last tea clippers built she took part in the tea races back from China. These races caught the public imagination of the day and were widely reported in newspapers [2]. They developed from a desire for 'fresh' tea and the first ship to return with the new season's tea could charge a higher price for the cargo. Clipper ships were built for speed rather than carrying capacity.

The hull efficiency of the Cutty Sark and her contemporaries is currently unknown. However, with modern CFD techniques, virtual experiments can be performed to model the fluid flow past the hull and so based on the shear stress and the pressure over the surface of the hull to calculate the resistance. In order to compare the hull against other ships three other ships were selected. The Farquharson, an East Indiaman built in 1820 [3]; the Thermopylae, another composite clipper built in 1868 which famously raced the Cutty Sark in 1872 [1]; and finally the Erasmio a later Italian all-steel construction 4-masted barque built in 1903[4]. Fig. 1 shows images of these ships.

As only one of these ships exists today, and she no longer sails, 3D geometries were constructed from lines plans of the ships hulls. The Delftship [5] software package was used to develop 3D CAD representations of the hulls. Delftship was also used to calculate additional parameters to calculate likely ship orientations by way of metacentric height, wetted surface, etc. The constructed geometries were then exported to COMSOL Multiphysics®. Simulations were performed using COMSOL Multiphysics®, with steady-state single-phase (below waterline) and transient multi-phase (wave behavior). The different simulations were used to look at different aspects of the hulls' efficiency.

The single-phase flow simulations used the $k-\omega$ turbulence model to look at the energy lost below the waterline, with the assumption that the waterline is fixed. These simulations give the hull stress and hull pressure, which are used in the calculation of the hull efficiency. As these simulations were steady state multiple speeds and ship positions could be used for comparison.

The multiphase flow simulations were used to look at the waves produced by the hull in calm sea situations. The results from these simulations allow the calculation of the energy lost due to wave generation. To this end transient simulations were run using the level-set multiphase flow module. As these were transient simulations so took longer to run, typical speeds; and heel, trim

and leeway were calculated and used in the simulation.

Results from the simulations have enabled us to calculate and compare the resistances of the hulls. Initial results are interesting and point to a number of differences that can help towards the better understanding of the performances of the ships based on different sailing conditions. Fig. 2 shows plots of the pressure along the hulls.

Reference

- [1] History of Cutty Sark : Cutty Sark press pack : Press office & news : About us : RMG. [ONLINE] Available at: <http://www.rmg.co.uk/about/press/cutty-sark-press-pack/history-of-cutty-sark>. [Accessed 21 May 2014].
- [2] History of the Cutty Sark | History. [ONLINE] Available at: <http://www.history.co.uk/shows/cutty-sark/articles/history-of-the-cutty-sark> [Accessed 21 May 2014].
- [2] David R. Macgregor (1985), Merchant sailing ships, 1775-1815; Sovereignty of Sail, Naval Institute Press, pp 195
- [3] Italian Four-Masted barque Erasmo (Erasmus) | The Model Shipwright. [ONLINE] Available at: <http://www.themodelshipwright.com/high-resolution-ship-plans/sailing-vessels/italian-four-masted-barque-erasmo-erasmus/> [Accessed 21 May 2014].
- [4] Delftship [ONLINE] Available at: <http://www.delftship.net/DELFTship/> [Accessed 21 May 2014].

Figures used in the abstract



Figure 1: Images Showing the different Ships (a) Cutty Sark, (b) Thermopylae, (c) Farquharson, (d) Erasmo.

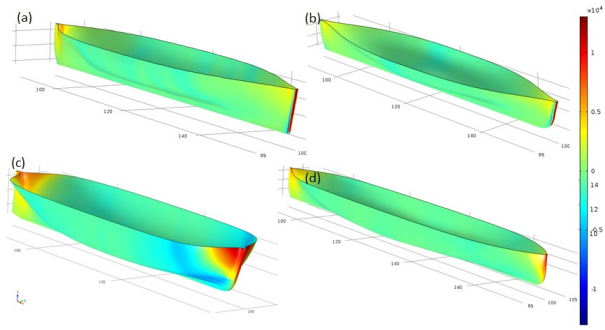


Figure 2: Plots of Hull pressure for: (a) Cutty Sark, (b) Thermopylae, (c) Farquharson, (d) Erasmo.