Impact of welding seam fairing on ship hull drag

Stefan Moeller Olsen

Hempel A/S
Lundtoftegårdsvej 91
2800 Kgs. Lyngby
Denmark

Phone: +45 4593 3800
E-mail: hempel@hempel.com

Welding seams protruding from a smooth ship-hull are a significant contributor to the disruption of water-flow over the hull(Weinell, 2003). Previously CFD modelling has been used to study the drag of the weld seams transverse to the sailing direction. One study concluded that welding seams can account for up to 4.3% of the plate resistance for a 3 mm weld height and 11% for a 5 mm weld height (Ciortan C, 2014).

Rotor experiments using torque measurements showed similarly a significant decrease in drag when welding seam heights were reduced from 9 to 5 mm (Xueting W, 2018). A drag reduction of 8.4% was reported at a density of 1 weld per 5 meter.

It is thus well established that welding seams transverse to the sailing direction are contributing significantly to the overall ship hull drag. It therefore seems intuitive that fairing out the welding seams leading to a hydrodynamically smoother surface will reduce the impact of the welding seams on the overall drag of the vessel. This document describes the quantification of the effect of welding seam fairing by CFD modelling and towing tank tests.

Shape of hydrodynamic fairing
In order to assess the impact of fairing out the welding seams, a CFD model based on Reynolds Averaged Navier-Stokes (RANS) turbulence model and k as the resistance parameter was used. Using an arc shaped welding seam and 3 different welding seam heights (3, 5 and 9 mm) the added resistance of the welding seam was estimated to be 6.7% for a 3 mm seam, 11.2% for a 5 mm seam and 18.3% for 9 mm seam, when simulating at 20 knots. These data compares somewhat to the original data reported by Ciortan et al. (Ciortan C, 2014).

One sided versus two sided fairing
In order to assess the impact of fairing of both sides of the welding seam versus the downstream side only, a comparison of the two different geometries was made using the 9 mm welding seam height.

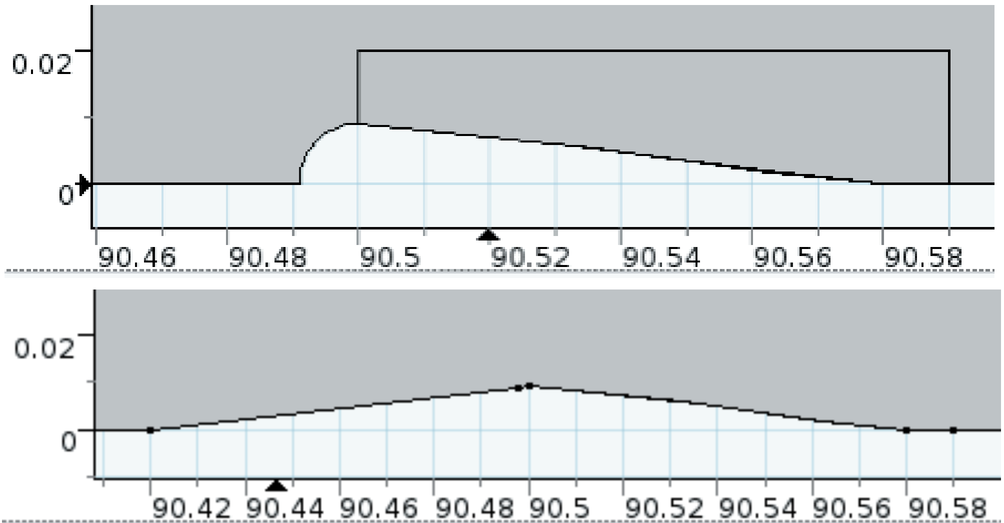

Figure 1: One-sided (top) versus two-sided (bottom) fairing profiles.

The results of the CFD modelling is shown in Figure 2. It is seen that the reduction in added resistance from the welding seams is significant when the seam is faired. Furthermore, it is seen from the figure that applying to both sides of the welding seams is important to get the highest reduction in added drag. E.g. Applying 7 cm of fairing on both sides increases significantly the reduction potential compared to applying 14 cm on the downstream side only.

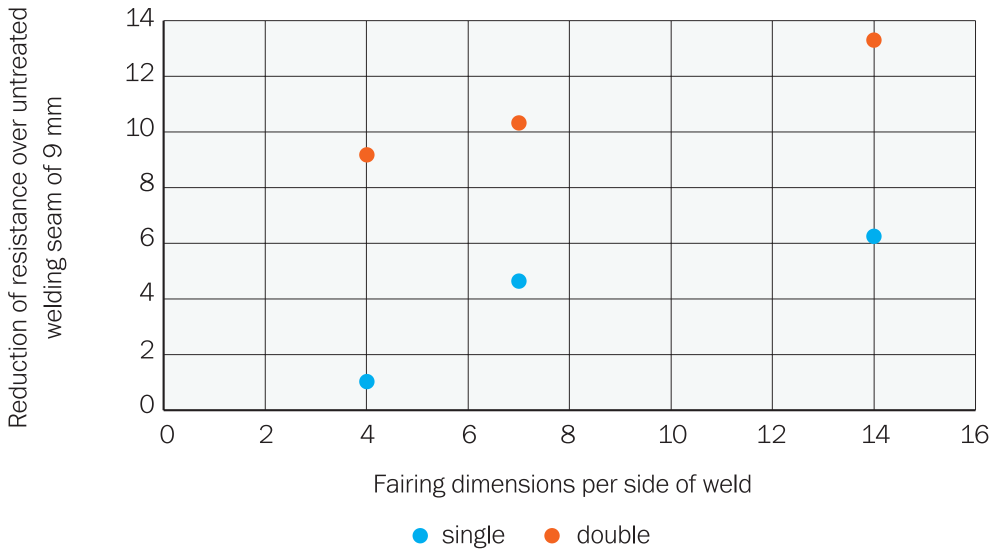

Figure 2: Reduction potential of different fairing geometries around a 9 mm welding seam.

Width of fairing
From Figure 2, it is seen that the reduction potential of the fairing profile is dictated primarily by both sides of the welding seam being faired. Though there is an increasing benefit of increasing the width of the fairing profile, the majority of the savings comes from a minimum of 4 cm on both sides of the fairing.

Due to restrictions in the width of the application instruments caused by applicability and curvature on ship hulls, a fairing profile of 11 cm (5 cm on each side assuming a 1 cm welding seam width) was selected.

Towing tank
To confirm CFD models, towing tank experiments were carried out together with Force Technologies. Measurements on thin flat plates were performed in Force Technology's 240 meter towing tank. For the towing tank test, a 3D printed welding seam was produced to mimic a conservative estimate of the shape and size. The 3D printed welding seam was arc shaped and with a height of 3 mm and width of 12 mm. Three different plates were tested in the set up. One flat reference plate; One with the welding seam glued on and one with a welding seam glued on and a fairing profile applied. The fairing profile was applied by hand using an epoxy filler material, and extended between 3 and 4 cm in each direction from the centre of the welding seam.

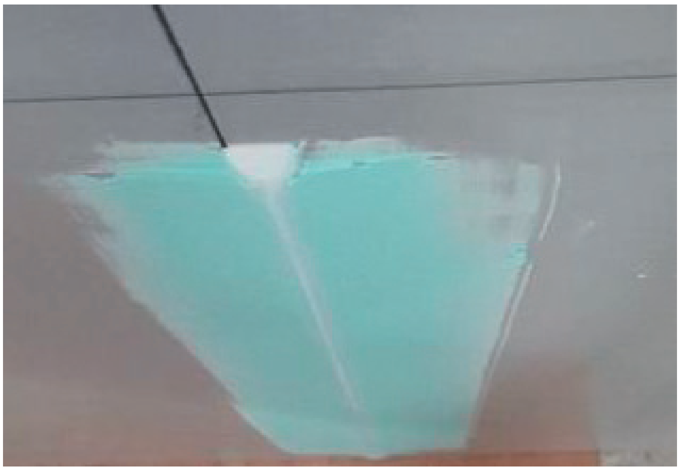

Figure 3: Picture of the untreated welding seam (left) and the faired welding seam (right) used for towing tank experiments.

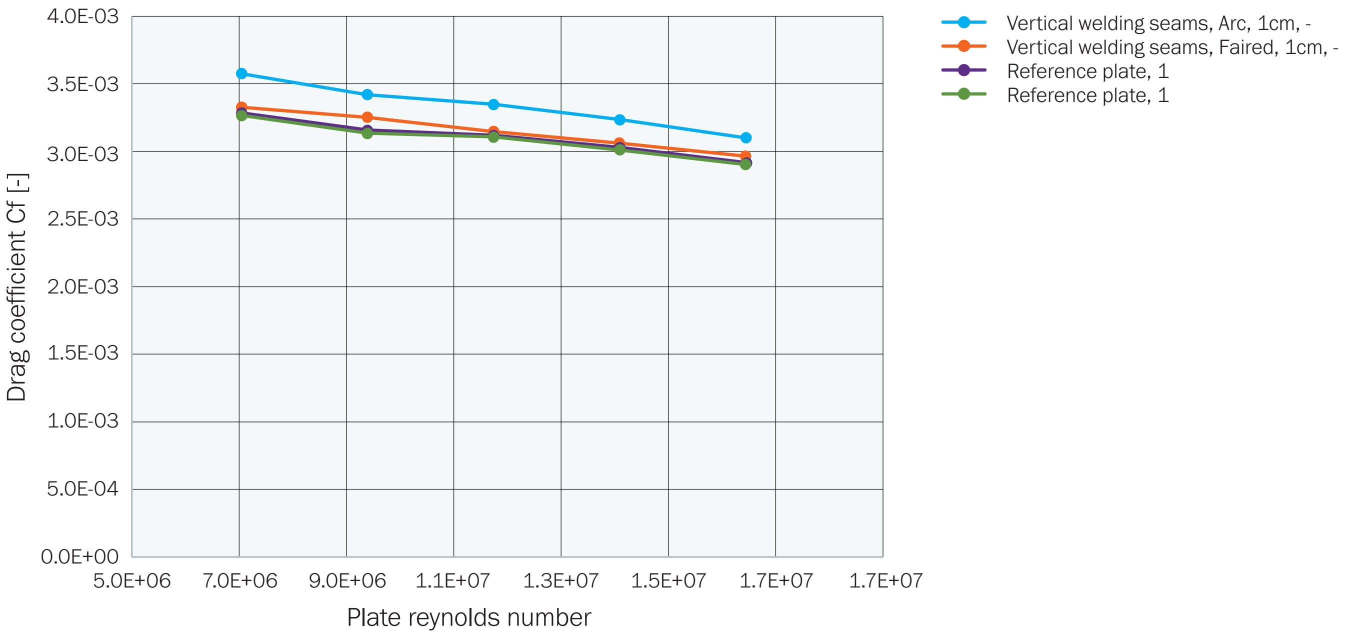

Figure 4: Measured drag of flat plates, and plates with faired and unfaired welding seams.

It is seen from the results in Figure 4 that the drag reduction of fairing out the welding seams was confirmed when measured in real laboratory towing tank scenario. The results were used to extrapolate to a 350 m container ship using the effective pressure principle. Figure 5 below shows the increase in resistance for a ship with faired vs unfaired weld seams relative to no weld seam scenario (flat plate). It is seen that almost independently of the speed the reduction potential of fairing a welding seam is approximately 2.5% it should be emphasised that these numbers are based on conservative welding seam dimensions.

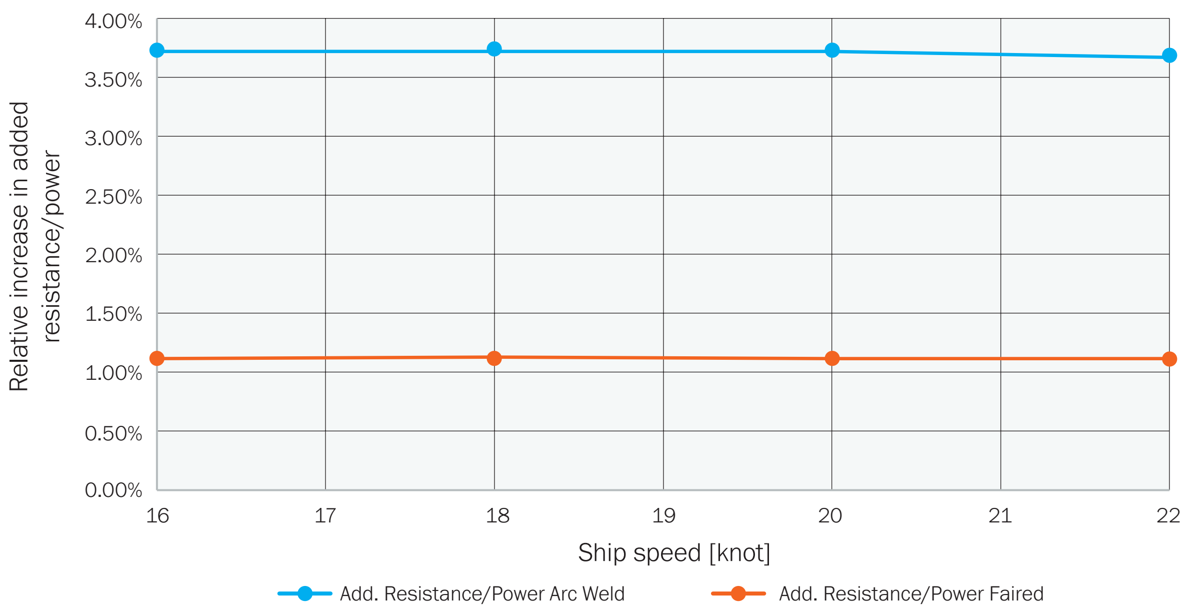

Figure 5: Increase in added resistance of welding seam and faired welding seam compared to flat plate.

Fuel savings for various ship types

Using the data from the towing tank results, full ship estimations were carried out using CFD modelling.

Three ship types were identified for evaluation of full scale effects on welding seam fairing on fuel consumption. The ship parameters are summarised in Table 1 below.

Vessel nr.	Vessel name	Vessel type	Speed [kn]	No of transverse welds	Length O A [m]	Draught [m]	Wetted area [m²]
1	KVLLC2	Very Large Crude Carrier Tanker	12.0	73	340	20.8	30000
2	KCS	Panamax Container	18.0	94	244	10.8	9500
3	Generic Ro/Ro	Generic RO/RO Cargo/Pax	21.0	93	200	8.2	6700

Table 1: Ship type parameters for comparison of fuel saving potential on different ship types.

CFD modelling using RANS code and kω resistance was used to evaluate the overall impact of welding seams along the entire ship hull on the fuel consumption of the ship. The results are summarised in below table. It is seen that the fuel saving potential varies with ship type. From 1.4% for a VLCC to 3.2% for a Ro/Ro.

	KVLCC2	KCS	Ro/Ro
No seams	0	0	0
3 mm arc	1.96	3.13	4.56
faired 3 mm arc	0.6	0.96	1.41
fuel saving potential	1.36	2.17	3.15

Table 2: Fuel saving potential in %. For various ship types when comparing a 3 mm weld with a faired ditto.

Converted to absolute numbers the savings coming from fairing of welding seams along the entire ship hulls approximate 0.6 to 2 tonnes of bunker per day. Since the results are based on 3 mm welding seam heights, increasing saving potential is expected if the original welding seams exceed 3 mm.

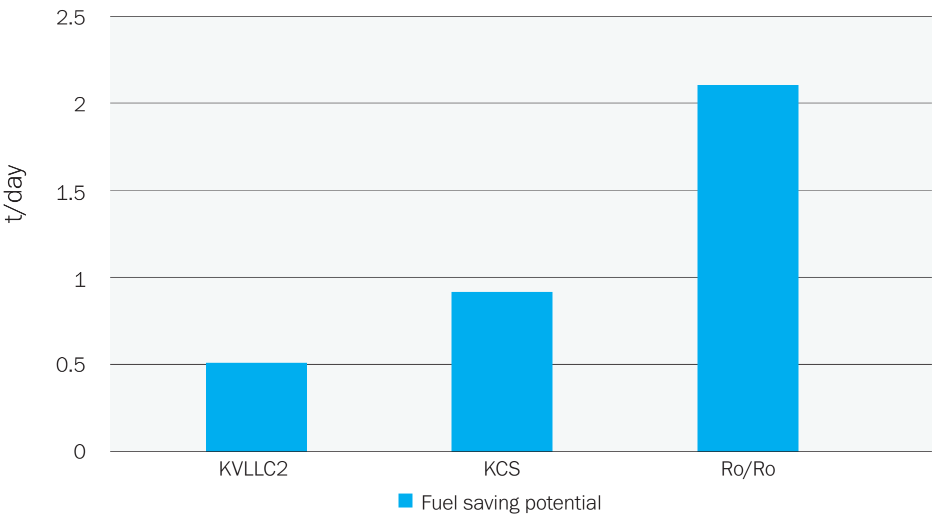

Figure 6: Absolute savings in tonnes per day for three different ship types. With a 3 mm weld height being faired.

Effect of weld height

Since the towing tank measurements were done with a 3 mm weld height only, data for higher weld seams can only be obtained by approximation and interpolation using data from CFD modelling Similarly to the results reported in Figure 2, model predictions for a 3 mm welding seam height with and without a 3 cm fairing profile on each side was carried out. The total resistance of these systems are shown in Figure 7. It is seen that for both 3 mm and 9 mm a double sided fairing reduces the friction almost to the same level, while the increased friction from an untreated 9 mm seam significantly increases over the 3 mm seam.

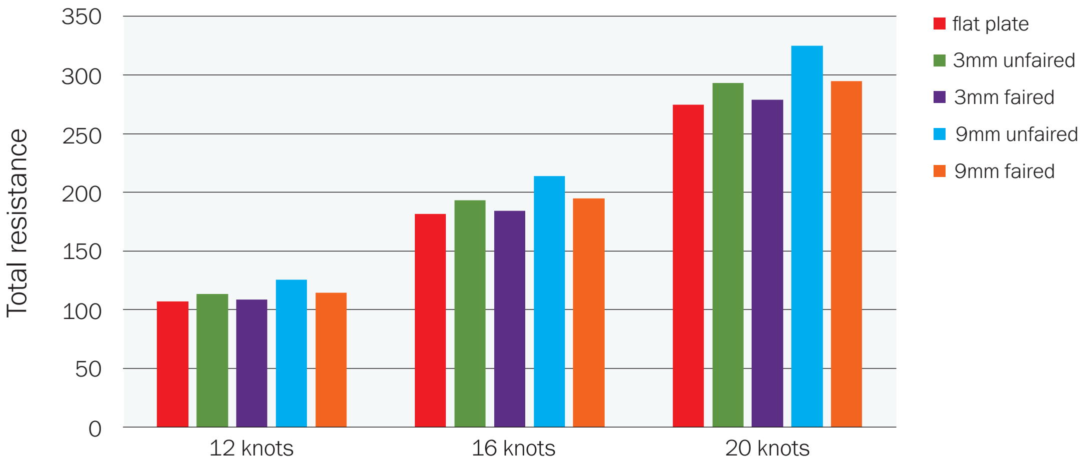

Figure 7: Total resistance of faired and unfaired welding seams as predicted by the RANS model.

In Figure 8 the saving potential is plotted as a function of welding seam height. Though only two different heights have been tested, a linear regression has been made.Using linear regression is considered the best interpolation, based on the linearity between drag and weld seam height reported by Ciortan et al. (Ciortan C, 2014).

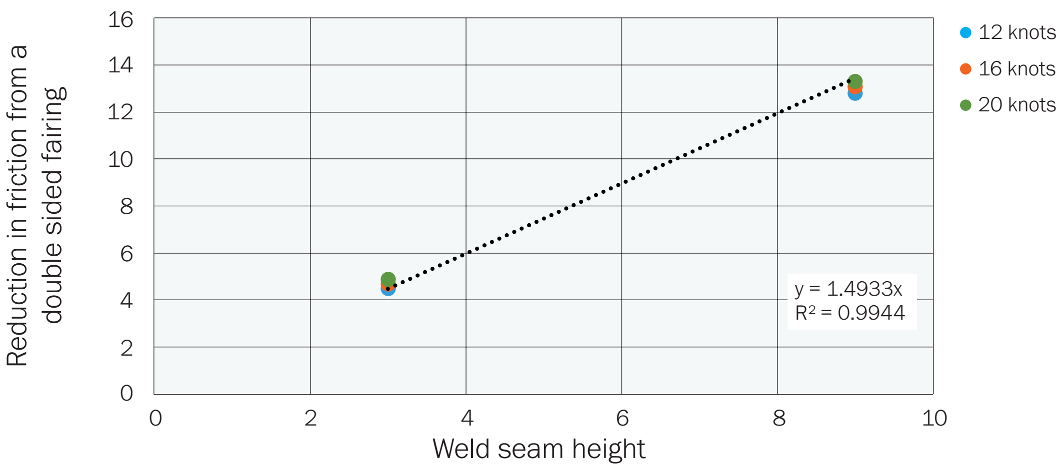

Figure 8: Friction reduction for varying weld heights when a double sided fairing is applied.

From Figure 8 it can be seen that there is an increasing savings potential, with increasing welding seam height. By interpolation, one can approximate the savings for welding seam heights in between 3 and 9 mm. E.g. if a Ro-Ro is found to have weld seams that extends 5 mm out of the surface, an efficient fairing will have a 2.5 times higher effect than if the welding seam was 3 mm high. Thus amounting to 5.5 tonnes of bunker per day for a standard sized Ro-Ro.

Conclusion

This document summarizes the CFD modelling and towing tank experiments that have been done to evaluate the effect of welding seam fairing.

Ship hulls have been reported to have a weld seam height varying between 3 to 7 mm (Ciortan C, 2014). When they are transverse to the sailing direction they will contribute significantly to the drag of the ship and thus contribute to increase fuel consumption.

The results displayed in this document shows that providing a hydrodynamic fairing profile on both sides of the welding seams can lead to fuel reductions of at least 0.6 tonnes per day for a VLCC and 2.2 for a Ro-Ro for the most conservative welding seam height.

When welding seam heights increases, the impact of fairing increases even further. We have seen that a factor of 1.5 is needed for interpolation and approximation of increased welding seam heights. These data should be verified in the future using towing tank studies or further CFD calculations.

References

Ciortan C, B. V. (2014). RANSE Simulations for the Effect of Welds on Ship Resistance. Proc. Numerical Towing tank Symposium.

Weinell, C. O. (2003). Experimental study of drag resistance using a laboratory scale rotary set-up. Biofouling, 19, 45-51.

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