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HULL OPTIMISATION OF FISHING TRAWLERS USING ULSTEIN X-BOW AND BILGE KEEL

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***Abstract*—The most recent ships incorporate a number of significant design enhancements to improve the vessel's seaworthiness. Ulstein X-bow, bulbous bow, bilge keel, stern wedge, stern tunnel, spray rails, and others are some examples. Increasing the vessel's speed while lowering energy consumption necessitates lowering the vessel's resistance. Improved propeller efficiency and reduced vibrations can be achieved by optimizing the hull form. Hull shape modifications can potentially increase safety by reducing roll motions. These enhancements have not been adopted or evaluated on fishing vessels, despite the fact that they have been employed on seagoing ships The X-bow was discovered to be a feasible design upgrade, with a stem angle range of 6-8 degrees and the lowest resistance offered by a 10-degree stem angle. Also adding bilge keels to a fishing trawler resulted in a 40 percent increase in roll period and a 15% reduction in roll amplitude.**

***Keywords*— Ulstein X-bow, trawler, angle of stem, resistance, fuel savings, bilge keel, roll motion, roll decay simulation, sea keeping.**

I. INTRODUCTION

Fishing is a demanding and labour-intensive activity, and most fishermen operate in harsh conditions with boats that aren't up to the task. As a result, fishing boats are engaged in the bulk of global maritime accidents, resulting in the loss of many lives each year. To improve the safety and efficiency of fishing vessels, significant improvements in safety or performance enhancement are required. The Ulstein X-bow is a more recent bow design, first appearing in 2005. Due to the obvious bow shape with the top reversed towards the back, it's called an Inverted Bow. The Ulstein X-bow was originally created for offshore vessels. To lower the risks of capsizing of fishing vessels due to the large roll motion under extreme sea and weather conditions some for of roll damping such as bilge keel could be used. The purpose of this study is to determine if Ulstein X-bow and bilge keels can be used on fishing trawlers and, if so, to OPTIMIZE their design and performance using theoretical calculations.

II. MATERIALS AND METHODS

2.1.Bow Form Variation

In comparison to the conventional bow, the X-bow has the capacity to break waves coming towards the ship more gently and lower its resistance. The Ulstein X-bow has been found to be more successful in reducing ship resistance than the bulbous bow. However, its suitability for fishing vessels must be investigated. A trawler with a displacement of 86.9 tonnes and a waterline length of 19 metres was designed for the study. The Holtrop and Mennon resistance values of this model were estimated using MAXSURF motions for speeds up to 12 knots. The vessel's bow shape was then altered, taking inspiration from the X-bow hull form. The length of the vessel has to be expanded slightly due to the change in shape and a sharper bow region, in order to maintain the same displacement as a conventional trawler vessel.

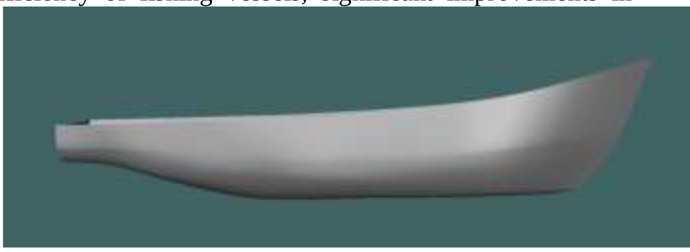


Figure 1: Conventional trawler model

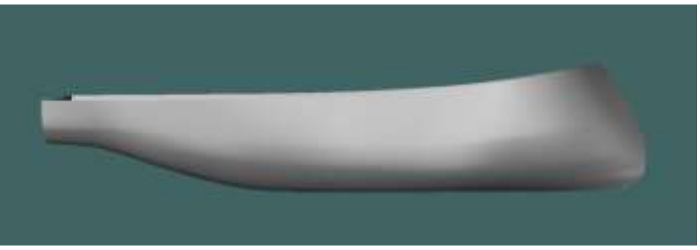


Figure 2: X-Bow inspired trawler model

The Holtrop & Mennon resistance was calculated up to 12 knots for both the models and compared. Next, the angle of stem of the X-Bow model was varied to find the optimum angle. Angle of stem is the angle that the bow makes with the horizontal at the point where it meets the waterline.

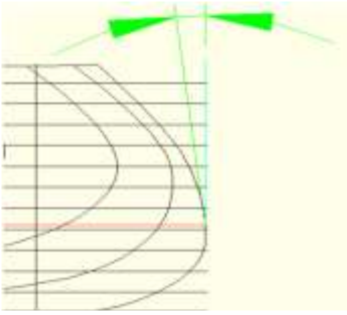


Figure 3: Angle of stem

This paper examines as many as 7 different model variations with changes in angle of stem of the X-bow and 1 original model with conventional bow shape. X-bow design was modified with angle of stems 0°, 3°, 6°, 10°, 12° and 14°. The resistance was calculated and the percentage reduction in resistance of these models with respect to the conventional trawler for various speeds were calculated.

For a fishing trawler the two most important operational speeds are 2 knots and 8 knots. 2 knots is the trawling speed which is the most energy intensive operation and 8 knots is the design speed. The main focus of the study will thus be to reduce the resistance at these two speeds. So, the percentage reduction in resistance at these two speeds were plotted on a graph for various angle of stems to find the most optimum angle.

2.2. Effect of Bilge Keel

Since roll motion decreases the effectiveness of fisherman and aboard equipment, it has a significant impact on the safety and performance of operating boats. Furthermore, the boats are at risk of capsizing due to severe roll motions generated by strong sea and weather conditions. As a result, it is vital to analyse the trawler's roll responses and, if appropriate, utilise roll stabilising measures to lower the roll amplitude. In comparison to other active or passive roll stabilisers like anti-roll fins and anti-roll tanks, bilge keels are significantly easier to manufacture, especially for boat builders, and they don't require any additional operations by fishermen during the sailing course.

The sea keeping performance of the traditional trawler and the X-bow design was verified before the bilge keel was designed by charting the righting lever (GZ) curve of the two vessels. Both vessels have similar features and a nearly identical maximum GZ value. A roll stabiliser, such as a bilge keel, is required to improve the vessel's sea keeping characteristics. Because the angle of deck edge immersion of the vessel was found to be 37.5 degrees, a roll decay simulation was run with a 37.5 degree beginning angle of heel. The vessel is heeled to 37.5 degrees with a fixed trim of 0 degrees and kept for 5 seconds for the roll decay simulation. The vessel is then free to roll until it comes to a stop. The heel angles corresponding to a continuous series of time stamps are calculated and recorded. This was done for both the conventional trawler and X-bow design.

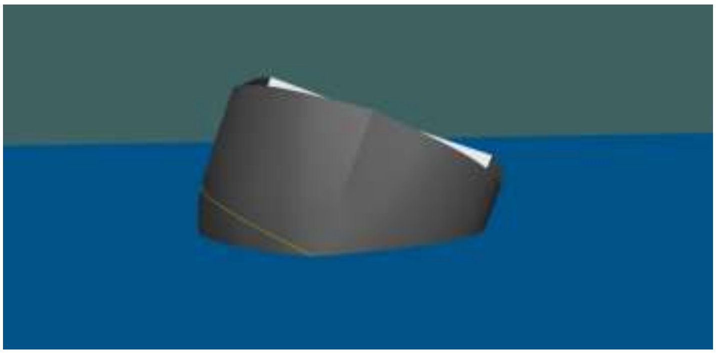
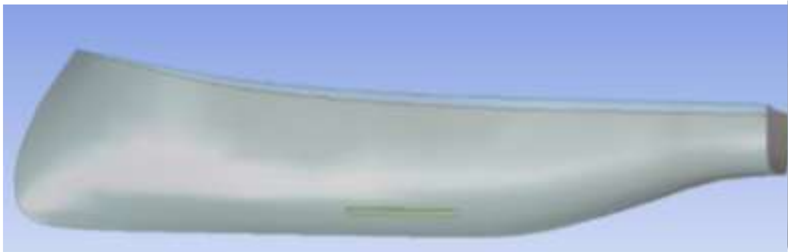


Figure 4:Roll decay simulation graphical representation of X-bow trawler

A rectangular bilge keel was selected due to the difficulties faced in analysis when using more complex shapes of bilge keel. The width, length and thickness are the two main dimensions of the bilge keel. Bilge keel's width is typically 3 to 5% of the width of the boat. Therefore, a bilge keel 4% of the boat's width was used, resulting in a 20.4 centimetre bilge keel. For the purposes of this study, the bilge keel thickness was set to 0 and it was treated as a surface body. Usually the length of the bilge keel varies from 25 to 75 % of the vessel's waterline length. But, due to the shape of a trawler being different from other vessels and shorter parallel mid-body, the length was set to 3 metres. It was fixed at the parallel mid-body of the vessel at a length of 8.9 metres from the aft at a depth of 80 cm from the waterline.



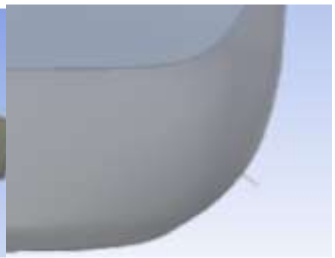


Figure 5: X-bow inspired trawler with bilge keel attached
Figure 6: Transverse view of the bilge keel attached on a trawler

The same roll decay simulation was performed as before on the vessel with the bilge keel attached and compared to the model without bilge keel.

III. RESULTS AND DISCUSSION

3.1 Ulstein X-Bow inspired model

The Holtrop & Mennon [10] resistance calculated up to 12 knots for conventional and X-bow model is shown in table 1.

Table 1:

Speed (knots)	Resistance value		Percentage Reduction in resistance (%)
	Conventional trawler model (N)	Xbow inspired model (N)	
1	257.08	215.83	16.04
2	1186.33	1045.99	11.82
3	2383.33	2208.58	7.33
4	3559.24	3415.73	4.03
5	4666.05	4579.92	1.84
6	5780.7	5731.74	0.84
7	7049.53	6964.21	1.21
8	8887.79	8528.08	4.04
9	10977.19	10245.01	6.67
10	13059.93	12035.75	7.84
11	17302.45	15294.82	11.60
12	22592.23	20024.71	11.36

The data was plotted on a graph and shown in figure 7.

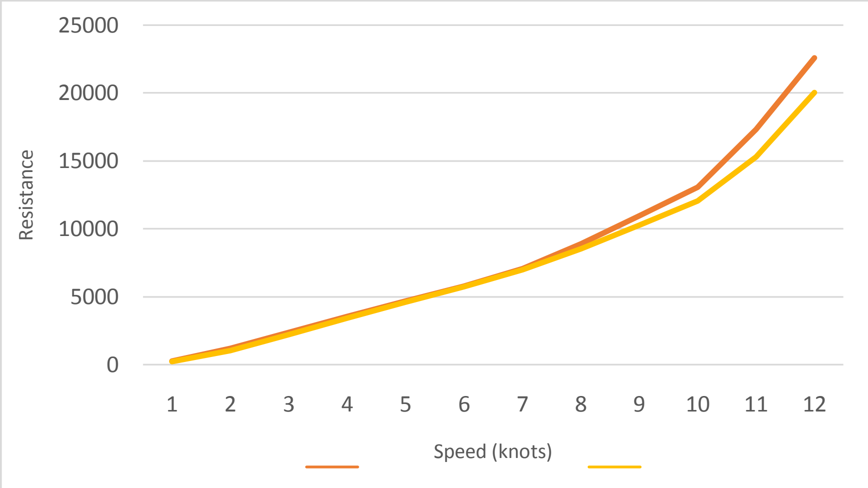


Figure 7: Resistance comparison Xbow vs Conventional trawler

From the above data it is clear that the X-bow inspired model has a significantly lower resistance than the conventional trawler for most operational speed ranges of a trawler vessel.
After identifying than X-bow has a lower resistance the X-bow design was modified with angle of stems 0°, 3°, 6°, 10°, 12° and 14° to find the optimum stem angle. The resistance was calculated and the percentage reduction in resistance of these models with respect to the conventional trawler is shown in the table 2 below.

Table 2:

Speed (knots)	Percentage Reduction in Resistance w.r.t Conventional Trawler (%)						
	0 degree	3 degree	6 degree	8 degree	10 degree	12 degree	14 degree
1	12.7859	14.10067	15.24039	15.99502	16.04559	15.99891	15.98335
2	8.986538	10.12703	11.12085	11.79183	11.82976	11.79351	11.78171
3	5.115532	5.993715	6.75987	7.292737	7.332178	7.294416	7.281828
4	2.340668	2.999236	3.572954	3.986806	4.032041	3.988492	3.974163
5	0.561288	1.046281	1.466551	1.786307	1.845887	1.789522	1.770448
6	0.007439	0.209144	0.499939	0.748698	0.846956	0.756656	0.725518
7	0.450952	0.661037	0.835233	1.034537	1.210293	1.053404	0.997655
8	3.39972	3.465428	3.508184	3.689331	3.95678	3.735237	3.62171
9	6.106754	6.060567	6.000443	6.165512	6.670013	6.232652	6.072501
10	7.319029	7.231126	7.135184	7.291923	7.842155	7.36543	7.191386
11	10.95273	10.74403	10.53539	10.74333	11.60315	10.86644	10.59353
12	10.71736	10.43939	10.16659	10.37627	11.36462	10.52185	10.20838

Since, for a fishing trawler the two most important operational speeds are 2 knots and 8 knots. From the above table the percentage reduction in resistance at these two speeds are plotted on graphs (figure 8 and figure 9) for various angle of stems to find the most optimum angle.

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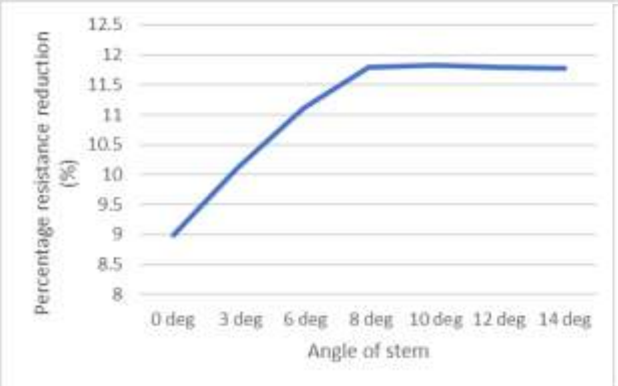

Figure 8: Percentage resistance reduction vs angle of stem at 2 knots

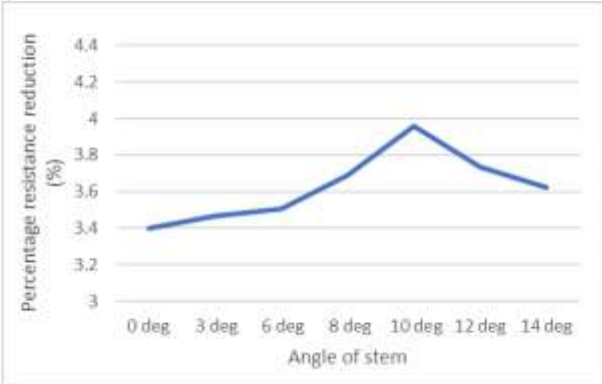

Figure 9: Percentage resistance reduction vs angle of stem at 8 knots

From the plots it is clear that for low trawling speeds like 2 knots the resistance keeps on decreasing upto a maximum value for 10° angle of stem and then starts to decrease slightly with further increase in angle of stem. For higher service speeds like 8 knots the same phenomenon can be observed. But, the increase in resistance is much more prominent. Although X-bow offers a lower resistance than the conventional model in most cases an angle of stem above 10 degrees will reduce the effectiveness of the X-bow. It can be concluded that 6-10 degrees is the most suitable range for angle of stem.

3.2 Guldhammer and Harvald's Validation

To validate the resistance results of the models, the manual calculation of the total resistance value in one model is carried out, namely the conventional trawler and the initial X-Bow model was compared to the total resistance value obtained from the software. The formula for calculating the total resistance value used is the general resistance formula [6].

For the conventional trawler,

$R_T = 0.5\ Ct\ \rho\ Vs^2\ S = 0.5 * 9.564*10^{-3} *1025 * 4.11^2 *107.071 = 8865.2$ N

R_T from software = 8887.79 N

which is within 10% margin of error.

For X-bow model,

$R_T = 0.5\ Ct\ \rho\ Vs^2\ S = 0.5 * 8.6637*10^{-3} *1025 *4.11^2 * 108.525 = 8139.74$ N

R_T from software = 8528.08 N

which is also within 10% margin of error.

Hence validated.

Further models with angle of stem variations were not validated as they all fall within the 10% margin of error.

3.3 Roll Motion

Next, roll decay simulation was done for the X-bow model with a heel angle of 37.5° and fixed trim of 0°.The model showed a roll period of 4.5 seconds and also come to a complete rest in 96 seconds respectively. To improve the sea keeping characteristics of this vessel and increase the roll period to a human comfortable range of 8-10 seconds a roll stabilizer such as bilge keel is necessary.

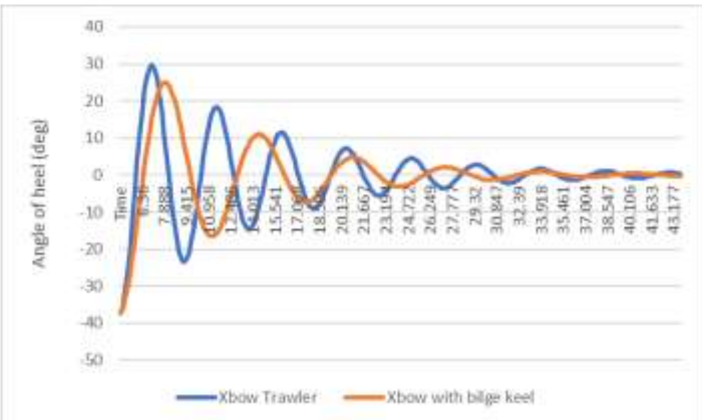

Figure 10: Roll decay simulation of X-bow trawler with and without bilge keel attached

From figure 10 above which represents roll decay simulation of the X-bow trawler it is clear that there is a significant increase in roll damping when bilge keel is attached for vessel. There is a clear increase in roll period and a reduction in amplitude for both cases with bilge keels. The roll period increased to 6.5 seconds from 4.5 seconds which is a 44% increase in roll period. There is also a 15% reduction in roll amplitude for the X-bow trawler when fitted with a bilge keel. The vessels with bilge keel comes to a complete rest in 68s compared to the original time 96 seconds.

The human range for comfortable roll period is from 8 to 10 seconds. When bilge keels are attached the vessel tends towards this comfort range. Therefore, bilge keels are necessary for the comfort of fishermen on onboard.

Since there is an increase in waterline length of the X-bow model compared due the conventional trawler to maintain the same underwater displacement, this increase in length can be proportionally used for a slightly longer bilge keel to further increase the roll damping if necessary. The summary of percentage changes for X-bow model with bilge keel attached w.r.t X-bow without bilge keel is shown in table 3.

Table 3:

Model	Percentage increase in roll period (%)	Percentage decrease in roll amplitude (%)	Percentage decrease in time to come to rest (%)
X-Bow Trawler with bilge keel attached	44	15	28

IV. CONCLUSION

Adopting X-bow hull form for fishing trawlers was found to be a highly promising improvement to the existing hull forms in terms of resistance and fuel savings. Feasible range of angle of stem was found to be from 6-8 degrees, with the lowest resistance being provided by 10-degree angle of stem, above which the advantage starts to slowly decline. The optimum design was found to provide about 11% reduction in resistance at trawling speeds and 4% reduction at design speed. Resulting in increased operational efficiency and reduced fuel costs as well as emissions for local stakeholders. The annual fuel consumption of mechanised and motorized fishing fleet of India has been estimated at 1220 million litres of fuel in the year 2000 [5]. Introducing X-bow hull form can therefore save up to 68 million litres of fuel annually in India.

The installation of bilge keels on X-bow fishing vessels was found to have a significant influence on the roll motion of the vessels, boosting their safety and efficiency. When compared to normal trawlers, the installation of bilge keels increased roll period by at least 40% and reduced roll amplitude by 15%. As a result, such an enhancement can reduce the risk of capsizing caused by excessive roll motion in harsh sea and weather conditions, as well as improve the efficiency of equipment and fisherman onboard.

Due to the limitations of this study, the results are based on numerical analysis and will require further model and tank tests to confirm the results. Also, the location, geometry and angle of the bilge keel could cause improved performance. The most favourable of these factors for a trawler need to be found using further research. But, as far as this study is concerned both X-bow and bilge keels seem to be highly promising and worthy hull form optimizations for a fishing trawler.

V. REFERENCE

[1] Kiryanto, Hadi E.S., Firdhaus A., (2019), Total resistance analysis on bow form model Ulstein X-bow with various angle of flare and stem angle, Department of Naval Architecture, Faculty of Engineering, Diponegoro University, Semarang, Indonesia (pp. 2 – 3).

[2] Liu W., Demirel Y.K., Djantmiko E.K., (2018), Bilge keel design for the traditional fishing boats of Indonesia's East Java, International Journal of Naval Architecture and Ocean Engineering. (pp. 2 – 6).

[3] Molland A.F., Turnock S.R., Hudson D.A., (2011), Ship resistance and propulsion, Cambridge, New York, Cambridge University press (pp. 3 – 6).

[4] Galappaththi U.I.K., Jayathunga R.D.S., (2019), The Effect of Drag Force Reduction for Fuel Efficiency Optimization of Fishing Vessels, Proceedings of the 6th Annual Research Symposium, University of Ruhuna (pp. 2 – 4).

[5] Baiju M.V., Kumar V., Das D.P.H., Sherief M.P. S., Edwin L., (2017), Mechanised Fishing Vessels of India, Cochin, Central Institute of Fisheries Technology (pp. 141).

[6] Andersen P., and Guldhammer, H., (1986), Resistance Estimates – Guldhammer and Harvald's Method, Fundamentals of Ship Hydrodynamics: Fluid Mechanics, Ship Resistance and Propulsion, John Wiley & Sons Ltd., Washington, DC, USA (pp. 12 – 63).

[7] Lee C.M., Yu J.W., Choi J.E. and Lee I., (2019), Effect of bow hull forms on the resistance performance in calm water and waves for 66k DWT bulk carrier, Department of Naval Architecture and

Ocean Engineering, Pusan National University, Busan, South Korea, International Journal of Naval Architecture and Ocean Engineering (pp. 3 – 6).

[8] Chakrabarti S., (2001), Empirical calculation of roll damping for ships and barges, Offshore Structure Analysis, Inc., 13613 Capista Drive, Plainfield, IL 60544, USA, Pergamon, Ocean Engineering 2001 (pp. 4 – 10).

[9] Mohsin A.R, Nallayarasu S., Bhattacharyya S.K., (2015), CFD approach to roll damping of ship with bilge keel with experimental validation, Department of Ocean Engineering, Indian Institute of Technology Madras, Chennai, India, Applied Ocean Research 55 – 2016 (pp. 5 – 9).

[10] Holtrop J. and Mennen G.G.J., (1978), A n approximate power prediction method, Netherlands Ship Model Basin, (Maiin), Wageningen, The Netherlands, Maritime Research Institute Netherlands, Volume 31, Number 363, (pp.166 – 169).

[11] Hasanudin, Chen J.H., Utama I.K.A.P, Hendratmoko H., (2017), An Investigation into the Effect of Bilge Keels to the Roll Motion Response of Fishing Vessel, Department of Naval Architecture and Shipbuilding Engineering, ITS, Surabaya-Indonesia, Applied Mechanics and Materials,Vol. 862 (pp.286 -289).

[12] CAO Z., Shasha GAO., YANG S., (2017), Roll Motion Analysis of a High-Speed Mono-hull Ship, School of Naval Architecture & Ocean Engineering, Jiangsu University of Science and Technology, Zhenjiang, Jiangsu, China, Advances in Engineering Research, volume 141 (pp.745 -755).