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ENERGY-EFFICIENT INLAND CARGO SHIP DESIGN BASED ON FUEL CONSUMPTION AND CO_2 EMISSION CONTROL USING CFD

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Abstract:

Inland ships usually face some additional restrictions in comparison to sea-going ships. Apart from the regulations imposed by each country, the effect of restricted waterways governs the major ship design constraints. For this reason, designing energy-efficient inland ships incorporating shallow water effects is very challenging. There is little research done to overcome these challenges; most of them lack the comparison of improved design with the existing one. This paper has analyzed 1634 general cargo ships from existing Bangladeshi inland cargo ships' data and considered 281 ships only for performance evaluation after data verification. The selected cargo ships were further assessed by using revised Energy Efficiency Design Index (EEDI) parameters applicable for inland ships of Bangladesh. Fuel efficient and less CO2 emitter efficient cargo ships were identified. After considering the effect of shallow water, a set of ship design suggestions is proposed. These suggestions were validated by redesigning an existing cargo ship based on the suggestionsand comparing their resistance with the parent hulls. Computational Fluid Dynamics (CFD) is used to calculate the shipresistances and it is found that a 13% reduction in total resistance can be achieved simply by choosing improved principalparticulars based on the proposed design suggestions.

Keywords: IMO, MEPC, EEDI, $EEDI_{BD}$, CO_2 emission, inland cargo ship

1. Introduction

The International Maritime Organization (IMO) approved EEDI as a required indicator for seagoing ships for more than a decade. Design and technology for seagoing ships have been compelled by EEDI to become more energy efficient. According to a study, these laws forced widespread use of technology that had previously been abandoned due to a lack of incentives (Simic, 2014). Nevertheless, even though there are thousands of inland ships operating within the national border, there are currently no restrictions pertaining to the energy efficiency of inland waterway ships. Additionally, inland ships do not have a benchmark requirement for CO2 emission or energy efficiency, unlike seagoing ships, which prevents naval architects from creating a design with a minimal level of energy efficiency.

Inland watercraft transportation has influenced the long-term development of both new nations and old economies over many decades. It also helped to build international bridges (Bonnerjee et al., 2009). It has the potential to help poor countries achieve many Millennium Development Goals (MDGs), particularly MDG 7 (Ensure Environmental Sustainability) and MDG 8 (Achieve Economic Growth and Poverty Reduction) (Develop a Global Partnership for Development). The goal of EEDI was to reduce CO2 emissions from seagoing ships throughout the design phase (IMO, 2011). However, studies on environmental sustainability and GHG reduction from inland transportation were restricted, even though many studies on sea-going ships were found (Ebert, 2005). Even though inland shipping accounts for approximately 9% of total CO2 emissions from global shipping(Naya et al., 2017), the lack of appropriate energy and emissions requirements for inland waterway self-propelledships is a key impediment to increasing their performance (Simic, 2014). According to the 4th GHG report (GHG,2020), global inland ships emitted 76 million tonnes of CO2 in 2012, which grew to 97 million in 2018 (28% increase). At the same time, foreign shipping increased by only 8% between 2012 and 2018. As a result, more emphasis is needed to construct energy-efficient inland ships.

Inland waterways are made up of a complex network of diverse sectors that involve a wide range of vessels serving various purposes (Walker et al., 2011). In general, inland ships require more power at the same speed than open

water/sea-going ships of comparable type, owing to the speed decline caused by the shallow water effect and design constraints due to the constrained river/channel depth and width.
Because of the unfavorable conditions, CO_2 emissions per tonne mile for sea-going ships are often higher. The design of an inland ship has several specific design constraints that enhance power. The primary causes behind this are as follows:

a. The shallow-water effect reduces speed.
b. River width and depth substantially influence ship design.
c. As an open sea ship design, the choice of ship primary particulars, such as propeller diameter, is limited.
d. The density of freshwater is lower than that of seawater. As a result, the deadweight capacity is reduced at the same draft as compared to a seagoing ship. EEDI computation is heavily influenced by dead weight.

Ship hydrodynamics deals with many aspects; One of the main aspects is the resistance of the ship when moving through the water. The design of a ship begins with a hydrodynamic analysis of the previously selected key characteristics of a ship. From propulsion and fuel economy estimates to structural and maneuvering safety, everything is solved using hydrodynamic information. Proper hydrodynamic analysis and knowledge is required for hydrodynamically correct hull geometry. However, hydrodynamic problems in ship design have always been complex (Aksenov, et al., 2015). The problem arises for the design of inland facilities due to consideration of the effect of the limited river/canal depth, which is the "shallow water" effect. "Shallow waters have a very pronounced effect on the resistance of a ship. Since inland waterway vessels are under the jurisdiction of a sovereign state, the rules of inland waterways vary from country to country.

A vessel performance study provides different types of information and data. Vessels performing well in shallow water in terms of required speed, main engine power, fuel consumption, CO_2 emissions and stability all have to do with certain reasons. This study analyzed 1634 inland freighters running on Bangladesh's inland waterways. The analysis identified the hydrodynamic causes of the ship's good performance in terms of speed, main engine power required, fuel consumption and CO_2 emissions. Identifying these reasons leads to a range of ship design proposals that could make ships more energy efficient. These proposals were verified by comparing the strength of existing ships with their improved designs.

1.1 Literature Review

Hasan investigated the hydrodynamic impact of EEDI on ship design parameters (Hasan, 2011), however, the study was mainly focused on the impact of individual ship design parameters on the EEDI of the sea-going ship. To understand the actual and total hydrodynamic influence of ship design parameters on EEDI, a comprehensive approach should be considered.

The German Federal Ministry for Transport and Digital Infrastructure assessed the energy needs of domestic ships using energy efficiency indicators (German Federal Ministry Report, 2020) . Research is based on IMO's EEDI where certain parameters differ specific to inland navigation. The study revealed that inland vessels on the Rhine use significantly less energy than the power of their installed engines. For this reason, the study could not use the MCR as suggested by IMO. This finding is also true for Bangladesh's domestic vessels, which were fielded in this study. The study also recognized the problem of tight draft and the percentage of idle capacity used to quantify energy efficiency. The specific fuel consumption (SFC) has been generalized to 220 g/kWh (Gram kilowatt-hour) which they claim is available from test reports for domestic boat engines. However, in the case of Bangladesh's domestic ships, it is difficult to generalize this SFC. The Central Committee for the Navigation of the Rhine (CCNR, 2012) investigated CO_2 emissions from inland traffic on the Rhine. The results of this study are far-reaching. These studies therefore make it difficult to reliably calculate the carbon footprint of road traffic for climate protection legislation. Furthermore, it is not possible to accurately calculate the CO_2 emissions of the coordinated chains. This raises the issue of the output data required to calculate the quality of the emission factor model. Emission factors are either existing or under development, so they can be confirmed using data from domestic shipping companies on fuel consumption and total transport efficiency of all types. different ships, as well as shipping statistics. On this basis, accurate and acceptable data, and statistics on CO_2 emissions from inland waterway transport will be easily generated.

A study on the energy efficiency of self-propelled inland waterway cargo ships recommended that EEDI baseline be taken for each speed of the same type of IWT to free the vessels from disturbances. externally and adjust for

the same flow conditions (Simic and Radojcic, 2013). Contrary to the proposal, in this study, the proposed baselines are not made for different speeds, but by train type. Kristensen (Kristensen, 2010) has developed a computer model for the systematic study of container ship design that can be used to calculate the emissions of container ships, including CO_2. This type of model is useful for specific conditions and designs. The model studied different ship design parameters to test the influence of ship design parameters on EEDI.

2. Governing Equation

EEDI in its simplest form can be expressed as Hasan (2011),

Since this study is focused on the inland cargo ships of Bangladesh, the considered values of different parameters and coefficients will be different from the sea-going ships as proposed by IMO. This will be termed as '$EEDI_{BD}$' (Hasan and Karim, 2022) and following Table 1 presents the descriptions of different parameters which are different as per IMO guideline (MEPC, 2018)).

Table 1: The considered value of different parameters and coefficients for $EEDI_{BD}$

Parameter	Definition by IMO	Definition as per $EEDI_{BD}$
Power	75% of the main engine(s) Maximum Continuous Rating (MCR).	70% MCR of the main engine(s).
Speed (V)	Ship speed at 75% MCR	Ship speed in nautical miles per hour at 70% MCR
CO_2 conversion factor (C_F)	C_F = Carbon Content in the fuel * (Molecular weight of CO_2/Molecular weight of Carbon) = 0.8744 * (44/12) = 3.206 gm CO_2/gm fuel	C_F = Carbon Content in the fuel * (Molecular weight of CO_2/Molecular weight of Carbon) = 0.76 X (44/12) = 2.787 gm CO_2/gm fuel
Capacity	100% dead weight	85% of the design deadweight.

3. Methodology

i. **Ship data collection:** Both verified and unverified raw ship data will be collected.
ii. **Ship Data verification:** Unverified ship data will go under verification processes.
iii. **Calculation of $EEDI_{BD}$:** EEDI of the verified Inland Ships of Bangladesh, using the revised EEDI parameter ($EEDI_{BD}$) will be calculated based on only verified ship data.
iv. **Sensitivity Analysis:** Ships will be divided into well, average, and poorly performed ships based on their $EEDI_{BD}$ values. Later, the sensitivity of $EEDI_{BD}$ upon different ship design parameters will be identified.
v. **Ship design suggestion:** Based on the sensitivity analysis, a set of '**Qualitative**' and '**Quantitativ**e' ship design suggestions will be produced that will ensure a more energy-efficient inland ship.
vi. **Verification of suggestion:** An existing inland cargo ship will be redesigned based on the ship design suggestions. Later, both parent and redesigned ships will be analysed in CFD software and resistance, fuel consumption and CO_2 emission will be compared.
vii. **Checking Stability Requirements:** Since stability criteria must be fulfilled in all aspects, improved designs' stability will be checked as per IMO criteria.
viii. For a **fair comparison**, both the parent and redesigned ship will have the same dead weight capacity and speed. Improvement in ship resistance for the improved hull will validate the ship design suggestions.

4. Data Analysis and Calculation

4.1 Ship data verification

Total 1634 Bangladeshi inland general cargo ship data were collected. Out of 1634 number vessel data, 70 vessels data verification are based on authors' long field experience/shipyard visit/ship trial data and travel by ships since 2007. These ships have the following ranges of ship design particulars, presented in Table 2.

Table 2: Ranges of proven inland cargo ship design parameters of Bangladesh

Ratio or Coefficient	**Range from proven cargo ships**
Length/Breadth (L_{WL}/B)	3.90-7.0
Breadth/Draft (B/T)	2.12-5.46
Breadth/Depth (B/D)	1.97-4.17
Deadweight/Displacement	0.6-0.81
Block Coefficient (C_B)	0.62-0.83

Other ship data, which did not fall into the ranges presented in Table 2, are rejected. Only 211 ship data passed the verification process. Thus, a total of 281 (Including 70 ship data verified by the authors) inland general cargo ships of Bangladesh have been considered for further analyses. Ship data outside the ranges as presented in Table 2 were discarded for further use. Table 3 summarizes the ship data verification result with the reasons for rejection.

Table 3: ship data verification result

Total number of ship data	**The total number of ship data passed the first verification test**	**Reasons for selection/rejection of unverified ship data**
1634	281 (17.20% of the total)	a. L_{WL}/B ratios of 47 cases were out of the verified vessels range. b. B/T ratios of 324 cases were out of the verified vessels range. c. DWT/Disp. ratios of 1263 cases were out of range of verified vessels. d. Inappropriate main engine data for 7 cases.

4.2 Sensitivity analysis of inland cargo ships of Bangladesh

$EEDI_{BD}$ was implemented on the verified 281cargo ships of Bangladesh. Based on length and $EEDI_{BD}$ values, thefindings were further separated into the following categories.

a. ‘Group-1’ consists of ships that have lengths below 41.00 m.
b. ‘Group-2’ consists of ships having a length ranging between 41.00 and 60.00 m.
c. ‘Group-3’ consists of ships having a length above 60.00 m.

The Groups were determined in such a way that a good number of vessels were available for analysis in each Group. For each Group, major ship design particulars have been presented in Tables 4, 5 and 6.

Table 4. Ship design particulars of Group-1, (91 ships below 41.00-meter length)

Ship Designparticulars	**Well Performing Vessels ($EEDI_{BD}$< 38.00)**			**Average Vessels ($EEDI_{BD}$ = 38-45)**			**Poor Performing Vessels ($EEDI_{BD}$>46)**		
	Min.	**Max.**	**Avg.**	**Min.**	**Max.**	**Avg.**	**Min.**	**Max.**	**Avg.**
L_{WL}/B	3.96	5.59	4.72	3.90	6.68	4.81	3.91	5.60	4.69
B/T	2.45	4.80	3.01	2.12	3.95	3.17	2.32	3.94	3.27
DWT/Disp.	0.60	0.85	0.70	0.59	0.79	0.70	0.69	0.78	0.73
V (Knot)	7.00	9.00	8.22	7.00	8.50	8.01	6.25	8.50	6.93
Froude Number (F_N)	0.18	0.23	0.22	0.22	0.24	0.22	0.20	0.22	0.21
C_B	0.68	0.75	0.72	0.65	0.78	0.71	0.65	0.71	0.69
$EEDI_{BD}$	29.55	38.99	35.66	38.46	45.95	41.58	46.21	60.55	52.23

Table 5. Ship design particulars of Group-2 (89 ships between 41.00-61.00-meter length)

Ship Design particulars	**Well Performing Vessels ($EEDI_{BD}$< 31.00)**			**Average Vessels($EEDI_{BD}$ 31-35)**			**Poor Performing Vessels ($EEDI_{BD}$>36)**		
	Min.	**Max.**	**Avg.**	**Min.**	**Max.**	**Avg.**	**Min.**	**Max.**	**Avg.**
L_{WL}/B	4.66	6.64	5.51	3.93	6.32	5.45	4.16	6.96	5.43
B/T	2.36	3.61	2.69	2.20	3.37	2.67	2.13	5.46	2.87
DWT/Disp.	0.63	0.80	0.76	0.60	0.80	0.72	0.59	0.83	0.70
V (Knot)	9.00	11.00	9.76	8.00	10.50	9.16	8.00	9.50	8.97
Froude Number (F_N)	0.19	0.25	0.21	0.20	0.24	0.22	0.20	0.24	0.22
C_B	0.70	0.83	0.76	0.68	0.83	0.73	0.62	0.78	0.73
$EEDI_{BD}$	24.85	29.93	27.03	30.03	32.96	31.71	33.03	41.78	34.43

Table 6. Ship design particulars of Group-3 (101 ships above 61.00 meters length)

Ship Design particulars	**Well Performing Vessels ($EEDI_{BD}$< 26.00)**			**Average Vessels($EEDI_{BD}$ 26-28)**			**Poor Performing Vessels ($EEDI_{BD}$>29)**		
	Min.	**Max.**	**Avg.**	**Min.**	**Max.**	**Avg.**	**Min.**	**Max.**	**Avg.**
L_{WL}/B	4.96	6.67	5.95	5.02	6.77	6.16	5.18	6.56	5.98
B/T	2.20	3.90	2.80	2.28	4.37	2.84	2.90	4.02	3.35
DWT/Disp.	0.72	0.82	0.78	0.72	0.82	0.78	0.72	0.85	0.78
V (Knot)	10.00	13.00	10.31	10.00	10.50	10.04	10.00	11.50	10.29
Froude Number (F_N)	0.18	0.23	0.20	0.20	0.21	0.21	0.20	0.23	0.21
C_B	0.73	0.80	0.77	0.65	0.80	0.75	0.66	0.83	0.76
$EEDI_{BD}$	22.93	25.99	24.86	26.14	27.81	26.98	28.19	30.02	29.01

Table 7 summarizes the results of tables 4, 5 and 6 by presenting the relative differences between well performing and poor performing ships.

Table 7. Comparison of Principal particulars of well-performed cargo ships

	Group-1	**Group-2**	**Group-3**
Length/Breadth (L_{WL}/B)	Higher	Higher	Lower
Breadth/Draft (B/T)	Lower	Lower	Lower
Deadweight/Displacement	Lower	Higher	Higher
Speed V (Knot)	Higher	Higher	Higher
Froude Number (F_N)	Higher	Lower	Lower
Block Coefficient (C_B)	Higher	Higher	Higher

4.3 Ship design suggestions for inland ships of Bangladesh based on sensitivityanalysis.

Table 7 shows inconclusive mixed results. For example, well-performed general cargo ships under Group 3 have a lower L_{WL}/B ratio, which contradicts the result of Group 1 and 2. Similar inconsistencies are also found for other ship design parameters. It would be much easier to conclude the design suggestion if the well-performing vessels of each Group showed a similar trend. As the grouping is based on the $EEDI_{BD}$ values, the main reason for these inconsistencies lies in the definition of $EEDI_{BD}$. $EEDI_{BD}$ reflects the 'Benefit to the Society' at the 'Cost to the Environment.' Thus, hydrodynamic efficient ships may not always be in the 'Well Performed' group. To explain this issue, $EEDI_{BD}$ values of two vessels have been compared which have the same dimension, but different Block Coefficients (C_B) (Table 8).

Change in C_B for 'Vessel-B' has reduced total resistance by 2.67% and increased speed by 7.69%. This is hydro-dynamically efficient vessel in comparison to 'Vessel-A.' However, reduction in dead weight capacity has increased the $EEDI_{BD}$ value by 5.81%. As ship dimensions and coefficients are responsible for both hydrodynamic and economic performance, hydrodynamic efficient vessels may not be efficient in terms of $EEDI_{BD}$, as this index considers the 'Socio-Economic Benefit' as well.

Table 8. Comparison of $EEDI_{BD}$ and resistance two cargo ships that have same ship dimension (Water Line length = 71.94-meter, Breadth = 13-meter, Draft = 4 meter, Installed Engine = 537X2 kW, MCR at 70%)

Particulars	**Ship-A**	**Ship-B**	**Change**
C_B	0.794	0.70	-11.84%
Displacement (Tonne)	2970	2618	-11.85%
DWT (Tonne)	2200	1940	-11.82%
Resistance (kN)	68.58	66.75	-2.67%
Speed at 70% MCR (Knot)	10.40	11.20	7.69%
$EEDI_{BD}$	29.41	31.12	5.81%

Based on the sensitivity analysis and above discussion, a set of ship design suggestions have been produced focusing on the reduction of $EEDI_{BD}$ by improving the hydrodynamic performance of the ship is presented in Table 9.

Table 9. Ship design suggestions based on sensitivity analysis (Qualitative)

Ship Design Particulars	**Ship Design Improvement Suggestion**	**Impact on Energy Efficiency**
Water Line Length (L_{WL})	The length of the vessel should be the maximum possible that meets the required displacement and surface area.	a. Frictional resistance increases, but wave resistance decreases with the increase of length. b. When the length is increased in such a way that the decrease in wave resistance is higher than frictional resistance.
Length/Breadth (L_{WL}/B)	Increasing the L_{WL}/B ratio is recommended. However, all types of stability criteria must be fulfilled.	A higher L_{WL}/B ratio ensures a slender and sharp hull, which provides better performance in waves by reducing wave resistance and required propulsion power.
B/T	Decreasing the B/T ratio is recommended. This should be done by lowering breadth and/or increasing the draft. Since inland ships face draft restrictions, the maximum achievable draft should be used to achieve the required displacement.	a. The beam-draft ratio correlates strongly with residuary resistance, which increases for large B/T. b. A decrease of B/T ratio by decreasing breadth will also increase the L_{WL}/B ratio. As discussed before, having a higher L_{WL}/B ratio is desirable to reduce wave resistance. The increasing draft will lower the B/T ratio and allow a larger propeller to have better propulsive efficiency. c. For the cases with a high B/T ratio, the propeller slipstream area is small concerning the midship section which reduces propulsion efficiency.
DWT/Displacement	High DWT/Displacement is desirable. This will decrease the numerator of the $EEDI_{BD}$ Equation, which will decrease $EEDI_{BD}$	This can be achieved by decreasing the lightship weight. A lighter ship will face lower hydrodynamic forces.
Block Coefficient (C_B)	Minimum C_B to achieve the desired displacement is recommended.	Reduction of C_B slightly increases in hull steel weight. However, lowering the C_B lowers the required propulsion power, engine plant weight, and fuel consumption.
Ship Speed (V) and Froude number (F_N)	Lowering Froude number and speed are recommended.	A decrease in the Froude number will reduce wave-making resistance. This can be achieved by decreasing speed and increasing ship length. Increasing the length has been suggested for the L/B ratio. Decreasing the speed will decrease the denominator of the EEDI equation, which will increase the index. Thus, speed and Froude number shall be chosen very carefully. Since the reduction in speed reduces the engine power requirement by the cube, reduction in speed is a safe option to reduce $EEDI_{BD}$ to a great extent.

Based on the results of the sensitivity analysis, the following Table 10 presents the efficient ranges of different ship design parameters of inland cargo ships of Bangladesh. It should be noted that careful measures of Table 9 shall be considered while selecting ship design particulars from the following Tables.

Table 10. Proposed efficient ship design ranges for general cargo ships of Bangladesh (Quantitative)

LWL	LWL/B	B/T ratio	DWT/Disp.	V	FN	CB
<41meters	3.96-5.59	2.45-4.80	0.6-0.85	7.00-9.00	0.18-0.22	Lowest possible block coefficient that meets capacity and stability requirements
41-61 meters	4.66-6.64	2.36-3.61	0.63-0.80	9.00-11.00	0.19-0.25	
>61 meters	4.96-6.67	2.20-3.90	0.72-0.82	10.00-13.0	0.18-0.23	

4.4 Ship design suggestion validation

To validate the ship design suggestions as provided in Tables 9 and10 the following procedure has been adopted:

a. An existing cargo ship was investigated physically, and lines plans were developed according to physical measurements.
b. The developed line plan was converted into 3-dimensional models using 'Maxsurf' software. The model wasfurther used for CFD analysis by the software 'Shipflow, and the total resistance was calculated at the service speed.
c. To make an improvement, the parent hull was redesigned by parametric variations based on the design suggestions given in Tables 9 and 10 keeping the same displacement, capacity, and speed for both the parentand redesigned hulls.
d. Results of both the parent and redesigned hulls were compared, and an improved ship hull was obtained.

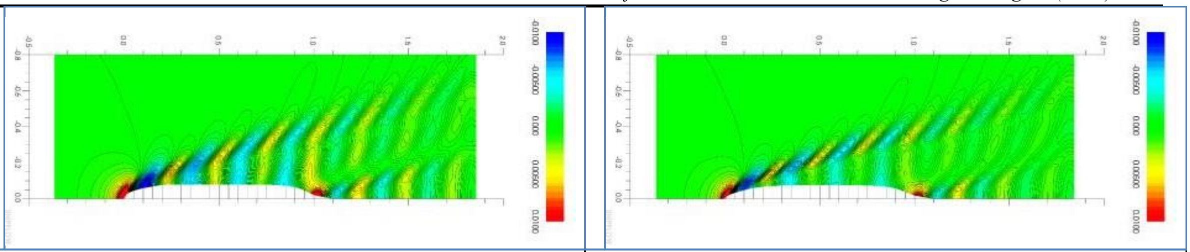
4.5 Implementing design suggestion on

Based on the ship design suggestions, physically investigated one cargo ship has been redesigned. The changes made to improve the parent hull based on the ship design suggestions, are presented in Table 11. Figures 1 to 3 show the free surface wave, wave cut and pressure distribution for both parent and improved hulls, which are produced as a result from the CFD software after analysis. The superiority of the improved hulls is visible by thefigures. Total Resistance Coefficient (C_T) for each model has been presented in Table 12 along with the improvement on the Specific Fuel Consumption (SFC) and $EEDI_{BD}$.

Table 11: Comparison between parent and improved design

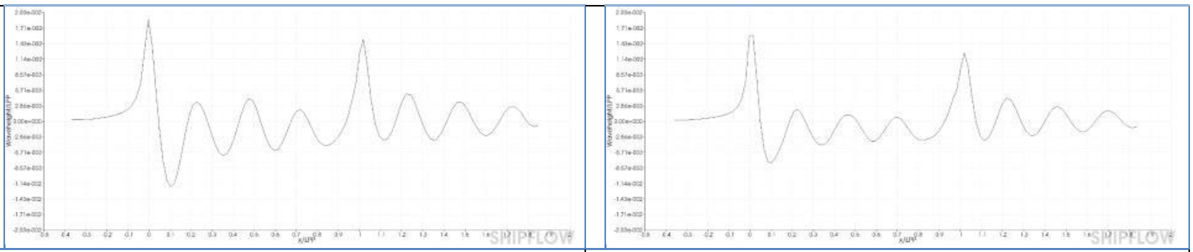
Design Particulars	Parent Design	Improved Design	Change (%)	Efficient Ranges
L_{WL} (meter)	72.024	75	4.13%	-
B (meter)	11.58	11.54	-0.35%	-
L_{WL}/B	6.22	6.5	4.50%	4.96-6.67
T(meter)	4.88	4.88	0.00%	-
B/T	2.373	2.365	-0.34%	2.20-3.90
C_B	0.75	0.7225	-4.00%	Lowest possible block coefficientthat meets capacity and stability requirements
Propeller Diameter,D (meter)	1.88	1.88	0%	-
Disp.(Tonne)	3052	3052	0.00%	-
DWT(Tonne)	2100	2100	0.00%	-
V_{REF} (Knot)	10	10	0.00%	10.00-13.00
F_N	0.194	0.19	-2.06%	0.18-0.23

The change in resistances coefficients and improvements in total resistance, $EEDI_{BD}$ and fuel consumption are presented in Figures 4 and 5.



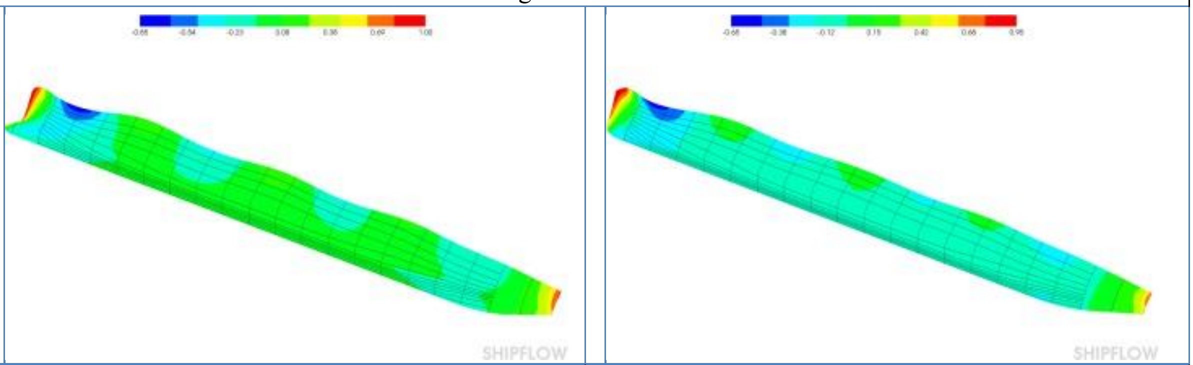
Parent Hull	Improved Hull

Fig. 1: Free Surface



Parent Hull	Improved Hull

Fig. 2: Wave Cut



Parent Hull	Improved Hull

Fig. 3: Pressure Distribution

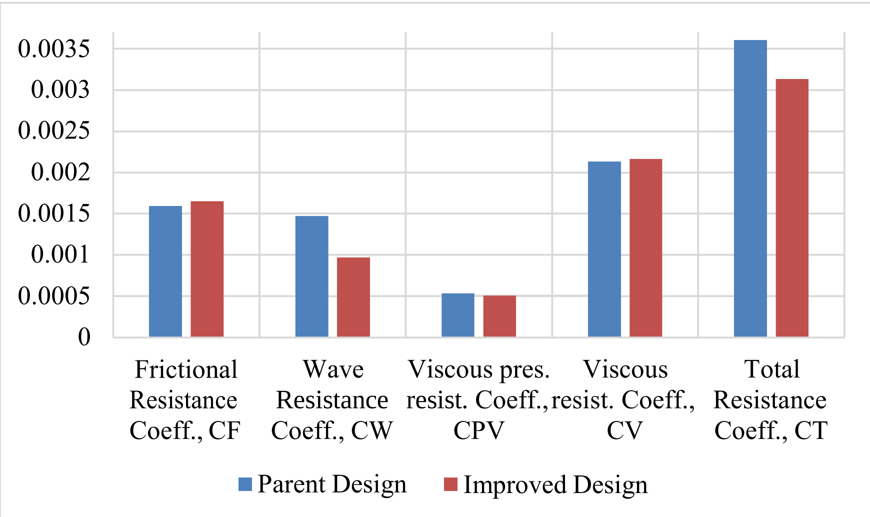


Fig. 4: Comparison of resistance coefficients between parent and improved hull

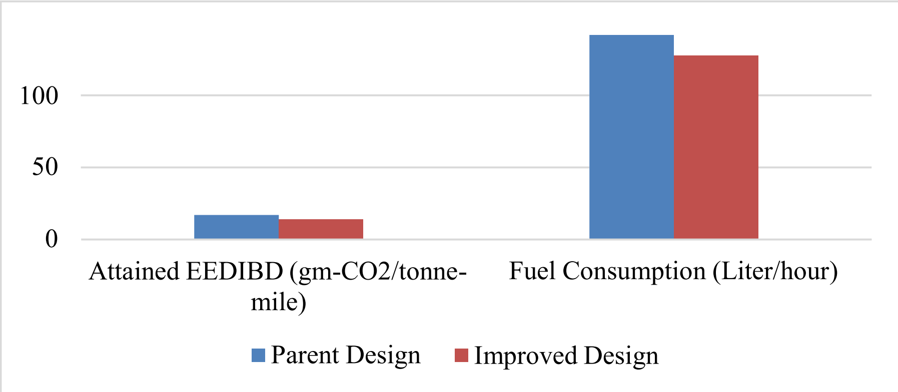


Fig. 5: Comparison of $EEDI_{BD}$ and Fuel Consumption between parent and improved hull

5. Conclusion

Improving the hydrodynamics of a ship can be done in a variety of ways; however, this study focused on improving the hydrodynamic design based on fuel consumption and CO_2 emissions. Since $EEDI_{BD}$ informs us about benefits to society (by transporting goods) to environmental damage (because they release CO_2 into the environment by burning fossil fuels), the dependence of $EEDI_{BD}$ into ship design details was determined throughsensitivity analysis. The result of the sensitivity analysis is a set of ship design recommendations that will reducethe value of the $EEDI_{BD}$.

These ship design proposals were made on an existing inland freighter from Bangladesh. Existing hull lines havebeen prepared after actual survey and measurement. The design of these ships was improved based on the ship design proposals. The resistance of the original circuit and the improved circuit was calculated using CFD software.

The results of the CFD analysis show a 13% improvement in vessel strength for the studied domestic cargo ships.Since the ship's effective power is the product of the ship's total power and speed, an upgraded vessel can reducefuel consumption by more than 10% compared to its current state depending on the design proposal being made.provide. Simple adjustments to these key characteristics improved the ship's hydrodynamic performance, reducing the overall coefficient of drag. More $EEDI_{BD}$ can be reduced with improved hull form, propeller design and otherimproved efficiency measures.

The economic impact on each country is a major additional factor. It is true that only a very small percentage of total global CO_2 emissions come from domestic traffic. However, the economic impact is significant when viewed from a country's perspective. A significant amount of fuel can be saved per trip as this study has shown that morethan 10% of CO_2 emissions can be reduced from current levels in Bangladesh. This will also affect the market asthe lower cost of ownership leads to lower commodity prices. In addition to the immediate environmental benefits, implementing this rule will significantly reduce operating costs without increasing shipbuilding costs.

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