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EFFECT OF FLUID DENSITY ON SHIP HULL RESISTANCE AND POWERING

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ABSTRACT- Vessels move through waters by overcoming the resisting force from the water and air. This force, known as the total resistance is overcome by the provision of effective power from the propulsion system so that the ship can sail at a given speed. In this work the effect of water density on the ships hull resistance and powering was analyzed. Densities of water were taken at different sources, tides, temperature and at different hours of the day and simulated against various types of resistances encountered by the ship when moving in still water (sea or fresh) and air. The ITTC 1957, 1963 line, ATTC 1947, 1957 line and the Froude's ship resistance models were employed for the simulation and results have shown a positive correlation between water density and ship hull resistance and ultimately the effective power of a vessel. Standard charts and existing equations were used to estimate the total resistance and power for situations of varying water and atmospheric temperatures resulting in varying fluid (Water) and air densities. A computer program using c++ was developed to carry out the necessary computations and from the excel plot, it was discovered that the R_T and P_E varied in a similar trend with the density of the fluid fresh or sea water.

Keywords: Density, Hull Resistance, Effective Power, Tide, Sea and Fresh Water Displacement, draft

NOMENCLATURE

A_T	=	*Transverse project area of ship*
C_B	=	*block coefficient*
C_f	=	*coefficient frictional*
C_A	=	*coefficient of air resistance*
C_T	=	*coefficient of total resistance*
D	=	*displacement*
L_{pp}	=	*length of the ship between perpendicular (ft)*
R_T	=	*total resistance*
R_F	=	*frictional resistance*
T	=	*draft*

1. INTRODUCTION

The development of building different types of ships to serve for whatever purpose it is built for, led to the calculation of the ship resistance on the water surface and studying of densities and effective power of ships. This enables the naval architect or builder to know the necessary component to be installed in the vessel.

One of the most important considerations for a naval architect is the powering requirements for a ship. Once the hull form has been decided upon, it is necessary to determine the amount of the engine power that will enable the ship to meet her operational demands or requirements. Knowing the power required to propel a ship also enables the naval architect to select a propulsion plant, determine the amount of storage required, and define the ships center of gravity.

However, resistance in a ship is of various types or components. These include frictional resistance, residuary resistance, wave-making resistance, eddy-making resistance, air resistance and appendage, resistance; and finally the total bare hull resistance.

In this project we will be limited to the total resistance of a vessel and its effective power. In the design of the hull, certain requirements must be met i.e. the hull vessels must suit the hull resistance and densities of the water. To be more explicit in our research goals and scope, densities of three or more creek were calculated at low and high tide and different temperatures. The results and data collected were used to determine resistance and effective power of a ship and different densities at specified temperatures [6], [13].

1.1 Components of Ship Resistance.

The force opposing motion of a ship in a fluid is referred to as ship resistance. A ship moving through water at speed experiences a force or resistance exerted by the water on the ship. The ship must therefore exert an equal thrust to overcome the resistance and travel at that speed. There are various components of resistance on ship include Frictional resistance, Wave - making resistance, Eddy-Making resistance and the Air - resistance
The above four main components make up the total resistance (R_T) of Ships; and both the wave and Eddy resistance are commonly taken together under a name called Residuary resistance." [7], [11]. Hence;

$R_T = R_f + R_R$ 1

And the effective power can be determine
$P_E = R_T \text{ x } V \text{ x } (0.514) \text{ KW}$ 2

Where V = m/s and by transposition
$\frac{P_E}{0.514} = R_T \ x V \ (KW)$ 3

1.2 Frictional Resistance (R_F)

Frictional resistance R_f is developed only by the shearing action in a very thin wetted surface lying among the projected roughness, not withstanding that this action may be frequently governed by what is happening in those portion of the boundary layer not touching the hull. In other words frictional resistance is the largest single component of the total resistance of the ship. Experiments have shown even smooth new ships account for 80% to 85% of the tot resistance R in slow-speed ships and as much as 50% in high speed ships [3], [9].

The frictional resistance of a ship depends on the following;

- The speed of the ship
- Density of water of operation
- Length of ship
- The wetted surface area
- The nature of the surface i.e. roughness of hull.

Froude in the nineteen (19th) Centuries undertook a basic investigation on frictional resistance of smooth planks in this tank at Torgugy (England). And he gave an empirical formula for the resistance in the form [1].

$R_f = F.S.V^n$ 4
Where,

R_f = Resistance
S = Total surface are (wetted surface) (ft^2)
V = Speed (knots)
F = Coefficient which depends upon the length
n = an index of about 1.825

1.3 Modern Frictional Resistance Formulations

Reynolds, after performing series of experiment came up with a suggestion that there are two different flow regimes possible, each consisting of different law of resistance. At low value of Reynolds number, $\text{Re} = \frac{V_L}{V}$, the flow is called laminar and was associated with a relatively low resistance. When Reynolds number increases, the laminar flow broke down and the fluid mixes transversely in eddying motion and the resistance increased. This flow is called turbulent flow.

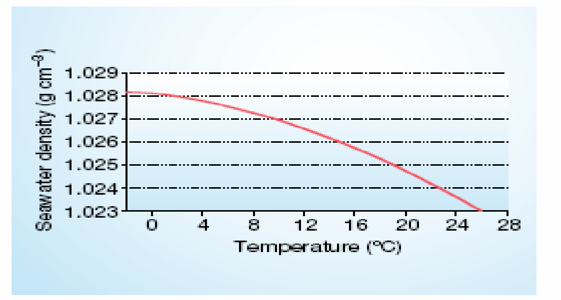
In modern frictional resistance formulations the specific frictional resistance coefficients C_f has been introduced and is assumed to be a function of the Reynolds number.

In 1904, Blasin's achieved a success in calculating the total resistance of the plank in laminar flow and gave the following formula.

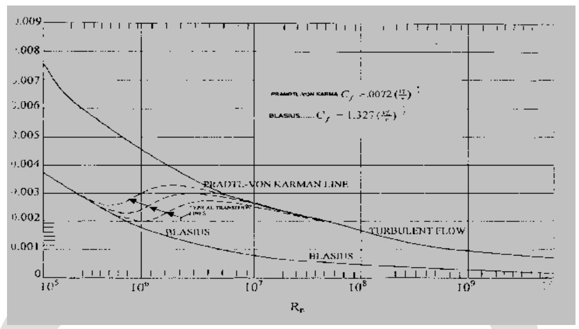
$$Cf = \frac{R_f}{0.5\ell SV^2} = 1.327 \left(\frac{V_L}{\mu}\right)^{-1/2} \quad 5$$

In 1921 Prandle and Von Karman published the equation for turbulent flow as

$$Cf = \frac{R_f}{0.5\ell SV^2} = 0.072 \left(\frac{V_L}{\mu}\right)^{-1/2} \quad 6$$



(a) Density and Temperature variations [4]



(b) Skin Friction lines for Laminar and turbulent flow [6] [10].

Fig 1: Skin Friction Lines turbulent and laminar flow
[Source: Koumako (1999)]

In 1935, the international Conference of ship tank superintendents (ICSTS) proposed the formulation.

$$R_f = \left[0.00871 + \frac{0.053}{8.8 + L}\right] SV^{1.825} \quad 7$$

Other formulae have been proposed and used in practice. They are the ITTC line and ATTC line methods. [2], [5]
ITTC (1963) has

$$C_f = \frac{0.075}{Log_{10}(R_n - 2)^2} \quad 8$$

And ATTC (1957) line has,

$$\frac{0.075}{\sqrt{C_f}} = Log_{10}\ (R_n\ x\ C_t) \quad 9$$

Also Hughs has it that

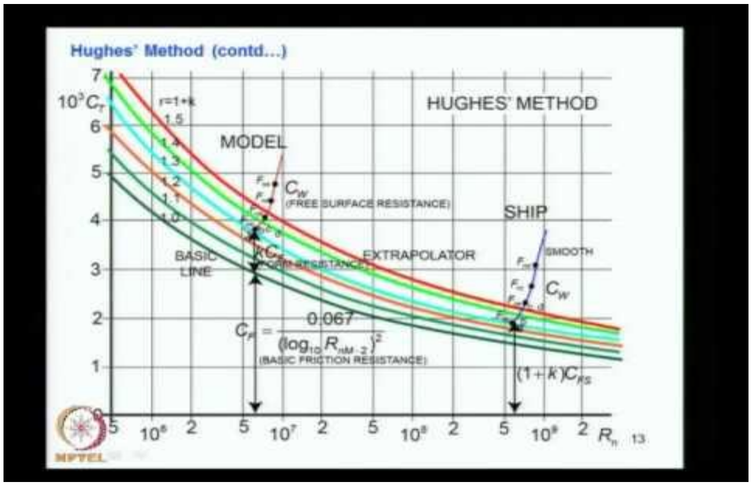
$$C_f = \frac{0.066}{Log_{10}(R_n - 203)^2} \quad 10$$

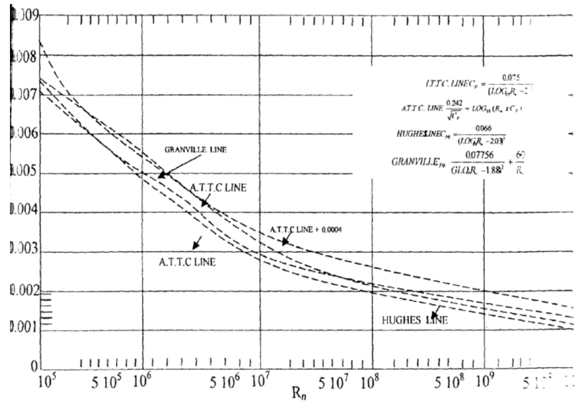
The wetted surface area S maybe estimated using some empirical formula such as

Munford formula S = $1.7Lpp\ x\ d + \frac{\nabla}{d}\ (m^2)$

Bruckhoffe's formula S = $\frac{(4d + B)\ x\ L/2}{1.625 - C_B}$

Where;
L_{pp} = length of the ship between perpendicular (m)
d = draught of the ship (m)
∇ = Volume displacement (m^3)
C_B = block coefficient





a. Hughes Method [4] [10]

b. ATTC, ITTC and other lines [6],

Fig: 2 Comparison of method of Hughes, ATTC, ITTC and others

1.4 Residuary Resistance (R_R)

Residuary resistance R_R, comprise of Wave-making resistance and eddy resistance. Wave resistance refers to the energy loss caused by waves created by the vessel during its propulsion through the water while eddy resistance refers to the loss caused by flow separation which creates eddies, particularly at the aft end of the ship. The residual resistance normally represents 8 - 25% of the total resistance for low speed ship, and up to 40- 60% for high speed ships.

1.5 Air Resistance

A ship moving on a smooth sea and still air encounters a resistance due to the movement of the above water hull through the air. From experiment Admiral Taylor suggested the following empirical formula for the determination of ship's air resistance

$$R_A = 0.004 \times \frac{1}{2B^2} \; x \; (V_R)^2 \qquad 11$$

Where;

B = beam of the ship

V_R = relative velocity of the wind

V = speed of the ship in still air

For ship moving in still air

$$R_A = CA \times \frac{1}{2} \; x \; \rho \; x \; A_T \; x \; V^2$$

Where;

C_A = Resistance coefficient

ρ = Mass density of air

A_T = Transverses projected area of above water hull

V = Ship speed.

1.6 Eddy - Making Resistance (R_E)

This is the resistance due to the eddy formulation or disturbed streamline flow caused. It occurs as a result of abrupt or sudden changes in form of projecting part such as bossing and bilge keel.

1.7 Wave- Making Resistances (R_w)

The wave- making resistance is due to the wave system created on the surface of the water as the ship passes through it. This wave generation is dependent on the air - water free surface and gravity.

The net fore and aft forces upon the ship due to fluid pressure acting normal to all parts of the hull are the wave making resistance. There are three types of wave form as a ship moves through still water.

1. Diverging wave
2. Diagonal wave
3. Transverse wave

1.8 Appendage Resistance

In some certain ships, the appendage resistance is due to the rudder and bilge keels in the case of a single screw ship, while in multi screw ships, there are also resistance components due to open shaft and struts. All these items give rise to additional resistance, which is best determined by model experiments. Many model experiments have been carried out over the years but the expansion of such estimates to the ship is a very difficult question which is yet to be satisfactorily solved as a means of making approximate estimates of appendage resistance for design purposes. Appendage resistance is expressed as % of bare hull resistance

1.9 Relationship between Density and Resistance

The formula for totals resistance $R_{T\ is}$ given by

$$R_T = C_T \, \frac{1}{2} \rho . V^2 . S \qquad 12$$

From the formula above, it is clear that as the density of the fluid in which the ship hull is submerged increases the resistance also increases and verse versa.

Type of ship	Value of $\frac{V}{\sqrt{L}}$	
	0.7	1.00
Large fast and 4 screws	10-16	1.0 – 16
Small fast 2 screws	20-30	10-23
Small medium speed 2 screw	12-30	2-4
Large medium speed 2 screw	8-14	8-14
All screw ship (single)	2-5	2-5

Table 1: Types of Ships and their values of V/√L
[Source: Koumako, (1999)]

2.0 Methodology

The Froude Reynolds ITTC and ATTC adopted in 1993 were used to show the variations of resistance resulting from densities of fresh and salt water taken at different temperature and investigate the densities of creeks in different time, and at low and high tides. These densities were used to verify the density previously stated by ITTC and ATTC methods in values of C_f in 1957. Due to the in availability of materials used for determination of density of water as experimented in the physical sense using chemical balance and its volume and graduated density bottle for determining mass and volume of the liquid, the formula for density equal to mass over volume was used [8].

Samples of water were collected from different creeks in Rivers State of Nigeria such as Rumumasi and Choba Creeks are Fresh Water, while Iwofe and Abonnema Wharf creeks are Salt Waters. The mass of water from each creek was measured per liter and ten liters. The unit of the measuring apparatus is in grams and conversions where made to kilograms. Calculation of density in its standard international unit of kg/m^3 was also achieved [12].

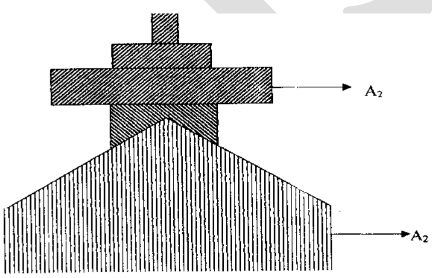


Fig. 2.2: Transverse Project Area

Fig 3 Transverse Projection Area

Simulation Model

Length of water line (m) L_{wl} 131

Length between perpendicular (m) Lpp	134
Beam (m) (B)	18
Draft (m) T	8
Displacement (Tonnes)	6680
Block coefficient C_B	0.90
Wetted surface sq m	2403
Speed knots v	12
Super …….m	499
Main hull area m^2	273

Harbor Tug Principal Dimensions

Length overall (m)	32
Length of water line (m) L_{wl}	30.4
Length between perpendicular (m) L_{pp}	30.4
Beam (m) (B)	8
Draft m (T)	4
Block coefficient C_B	0.58
Wetted surface sq m	292
Speed knots v	9
Displacement (Ton)	433

Data Collection And Processing For Low Tide

1 litre of Empty container weighs 55.96grm = $\frac{(55.96)}{1000}kg = 0.05596kg$

1 Litre of Empty container weighs 55.96grm = $\frac{(55.96)}{1000}kg = 0.05596kg$

Note:

$1000cm^3 = 1dm^3 = 1$ litre

$1000\ dm^3 = 1m^3$

1000 liters $= 1m^3$

$1litre = 0.001m^3$

<u>Abonenema wharf creek (salt water)</u>

Mass of container + mass of 1 litre of water = 1051.73grm =

$$\frac{1051.73}{1000} = 1.05173kg$$

Mass of water = mass of container with water – mass of empty container

= 1.05173 – 0.05596 = 0.99577kg

$$density = \frac{mass}{vol} = \frac{0.99577kg}{0.001m^3} = 995.773kg/m^3$$

Measurement for 10 liters of water + container Mass of container + mass of 10 liters of water = 10,013.66grm = $\frac{10013.66}{1000} = 10.01366kg$

Mass of 10 liters of water = mass of container with water - mass of empty container = (10.01366 – 0.05596) kg = 9.9577kg

Density for 10 liters of water = $\frac{9.9577}{0.001} = 9957.7 kg/\text{m3}$

<u>For Iwofe Creek (Salt Water)</u>

Mass of container with 1 liter of water = 1053.84g = 1.05384kg, Mass of water = 1.05384 – 0.05596 = 0.99788kg

$$density = \frac{0.997884\,kg}{0.001 m^3} = 997.88 kg/m^3$$

Measurement For 10Litres

Mass of container with water (10 lit) = 10034.76grm = 10.03476kg

Mass of 10 Liters of water = 10.03476kg – 0.05596kg = 9.9788kg

$$density = \frac{9.9788 kg}{0.001 m^3} = 9978.8 kg/m^3$$

<u>Choba Creek (Fresh Water)</u>

Measurement of 1 litre of container + water.

Mass of container + water = 1046.54g = 1.04654kg

Mass of water = mass of container with water - mass of empty container

= 1.04654 – 0.05596 = 0.99058kg

$$density = \frac{0.99058 kg}{0.001 m^3} = 990.58 kg/m^3$$

Measurement For 10Litres

Mass of container with 10 liters of water = 9961.76grm = 9.96176kg

Mass of 10 Liters of water = 9.96176kg – 0.05596kg = 9.9058kg

$$density = \frac{9.9058 kg}{0.001 m^3} = 9905.8 kg/m^3$$

<u>Rumumasi Creek Fresh Water (low Tide)</u>

Mass of container with 1 liter of water = 1050.3grm = 1.05030kg

Mass of water = mass of container with water – mass of empty container = 1.05030 - 0.05596 = 0.99434kg

$$density = \frac{0.99434 kg}{0.001 m^3} = 994.34 kg/m^3$$

Measurement For 10Liters of water.

Mass of container with 10 Liters of water = 9999.36grm = 9.99936kg

Mass of 10 liters of water = 9.99936 -0.5596 = 9.9434kg

$$density = \frac{9.9434 kg}{0.001 m^3} = \frac{9943.4 kg/m^3}{}$$

Data Collection and Processing for High Tide

Abonnema Wharf

Mass of container with 1 liter of water = 1059.73grm = 1.05973kg

Mass of 1 liter of water = 1.05973 – 0.05596kg = 1.00377kg

$$density = \frac{1.00377}{0.001} = 1003.77 kg / m^3$$

For 10 liters of water.

Mass of container + water = 10.09366kg

Mass of 10 liters of water = 10.09366 – 0.05596 = 10.0377

$$density = \frac{mass}{vol} = \frac{10.0377 kg}{0.001} = 10037.7 kg / m^3$$

For Iwofe Creek

Mass of container with 1 liter of water = 1057.3grm = 1.0573kg

Mass of 1 liter of water = 1.0573 – 0.05596 = 1.00134kg

$$density = \frac{mass}{vol} = \frac{1.00134}{0.001} = 1001.34 kg / m^3$$

For 10 liters of water.

Mass of container with 10 liters of water = 10069.36grm = 10.06936kg

Mass of 10 liters of water = 10.06936 – 0.05596 = 10.0134kg

$$density = \frac{mass}{vol} = \frac{10.0134 kg}{0.001} = 10013.4 kg / m^3$$

Rumuomasi

Mass of container + 1 liter of water = 1028.464grm = 1.028464kg

Mass of 1 liter of water = 1.028464 – 0.05596 = 0.972504kg

$$density = \frac{0.972504}{0.001} = 972.504 kg / m^3$$

For 10 liters of water.

Mass of container + 10 liters of water = 9781.0grm = 9.781kg

Mass of 10 liters of water = 9.781 – 0.5596 = 9.72504kg

$$density = \frac{9.72504}{0.001} = 9725.04 kg / m^3$$

Choba Creek

Mass of container + 1 liter of water =1043.73grm = 1.04373kg, Mass of 1 liter of water = 1.04373 – 0.05596 = 0.98777kg

$$density = \frac{mass}{vol} = \frac{0.98777}{0.001} = 987.77 kg / m^3$$

For 10 liters of water.

Mass of container + 10 liters of water = 9.93366kg

Mass of 10 liters of water = 9.93366 – 0.5596 = 9.8777kg

$$density = \frac{9.8777}{0.001} = 9877.7kg/m^3$$

3.0 Results and Discussions

ATTC and ITTC methods was used to determine the effect of temperature to the density and resistance in the Ship to the Water. And also to know it's effect in effective power. However, the calculation results for resistance at various creeks are shown in Table 3.

3.1 Data Collection and Processing for Different Temperature Procedure

The collection of dates was made at different consecutive time and temperature. And the process for collection of data was made as follows.

i) The temperatures of the creeks were taken and the volumes of water collect in one's and 10 liters,
ii) The temperature of the water collected was measure and recorded.
iii) The temperature of the laboratory at which the mass will be measured was be measured was recorded.
iv) Masses were measured in grams and recorded for a conversion to kilograms.
v) The density of the different volume of water was also calculated.
vi) The measurement when made in time 6: 30- 700am, 12- 1pm, 6pm - 7pm, morning, afternoon and evening respectively.

The measurements procedure for the masses were made as described in chapter three below the mass and density calculation made.

3.2 Comparison between Total Resistance and Effective Power.

In the initial simulation which results is tabulated in Table 1 the calculation of the ship hull resistance and affective power. The results of increase in coefficient of friction of ITTC line table. The data of density collected shows that the densities of high tide creeks are more than low tide creeks. Densities increase more from low to high tide fresh water creeks than the salt water creeks. Consequently, the increase in density increases in the hull resistance and effective power of ship.
In the second simulation which results is tabulated in Table 3 same result of initial simulation is achieved by using the harbor tug but different figures [12].
In the table 5 there is a decrease in density as result of increase in temperature but in this case the result in slightly abnormal. Table 5 compares the results of ITTC and ATTC, the results of ITTC method is better due to the reasons stated in Table 4 [2], [4]. Figures 5 to 8 shows the graph representation of relationship of Resistance and Power with respect to the density of the salt water considering the ATTC and ITTC models which agrees with the theoretical explanation. Similarly Figures 9 to 12 shows the graph representation of relationship of Resistance and Power with respect to the density of the fresh water considering the ATTC and ITTC models which also agrees with the theoretical explanation.

4.0 CONCLUSION

In comparing the densities of salt and fresh water, low or high tide and at different temperatures, it was noted, that these densities differ. They were used to calculate the hull resistance and effective power of a ship and harbor tug using ATTC and ITTC methods. The methods employed in making the calculation shows that the hull resistance and effective power of the both vessel increases with increase in density.

However, it is noted that the densities of water at high tide is more than low tide. And temperature increase result to density decrease. Here, the matter rest for the present but it is clear that the subject is far from it final solution. Researches should be carried out to fits the recent improvement or requirement on this topic. By king recent conferences held by the ATTC and ITTC committee respectively.

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Appendix

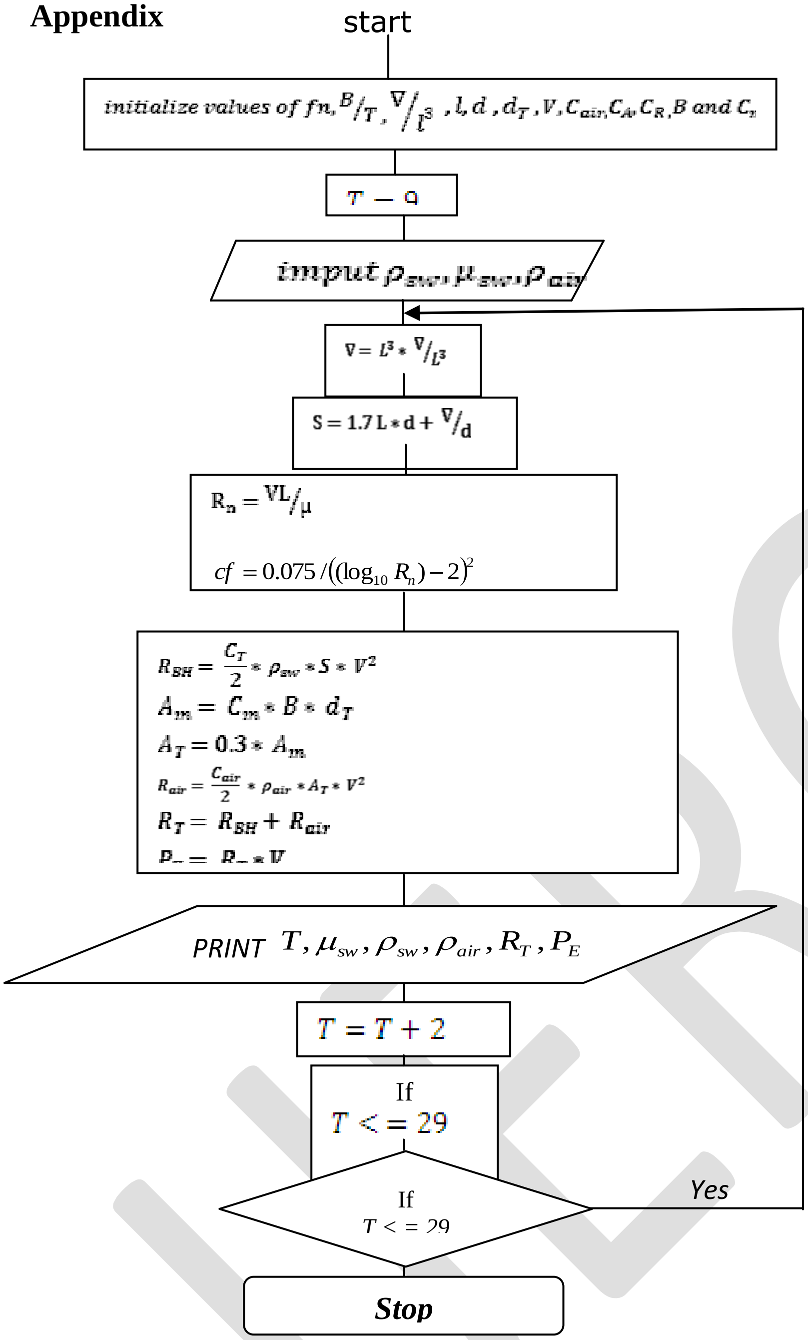

Fig : 4 Flowchart

Table 2: Data Collection and Processing for High and Low Tide

Creeks	Low Fresh water p (kg/m^3)	Low Tide Salt water p (kg/m^3)	High Fresh water p (kg/m^3)	High Tide Salt water p (kg/m^3)
Abonnima (SW)	-	995.773	-	1003.77
Iwofe (SW)	-	997.88	-	1001.34
Rumumasi (FW)	994.34	-	972.504	-
Choba (FW)	990.58	-	987.77	-

Table 3a: Tabulation of Results for High Tide

TABLE 3: TABULATION OF RESULTS FOR THE SHIP					
TABLE 3a: TABULATION OF RESULTS FOR HIGH TIDE					
SALT WATER					
CREEKS	DENSITY Kg/m^3	ATTC		ITTC	
		R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
ABONNEMA (SW)	1003.77	289.5491701	1786.51838	289.7799234	1787.942127
IWOFE(SW)	1001.34	288.8482083	1782.193445	289.0784029	1783.613746
FRESH WATER					
CREEKS	DENSITY Kg/m^3	ATTC		ITTC	
		R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
RUMUOMASI (FW)	972.504	280.5301275	1730.870887	280.7536932	1732.250287
CHOBA(FW)	987.77	284.9337834	1758.041444	285.1608585	1759.442497

Table 3b: Tabulation of Results for Low Tide (for Standard Density)

TABLE 3b: TABULATION OF RESULTS FOR STANDARD DENSITY					
STANDARD DENSITY(SALT WATER)					
CREEKS	DENSITY Kg/m^3	ATTC		ITTC	
		R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
STANDARD VALUE	1025	295.6732114	1824.303714	295.9088451	1825.757574
STANDARD DENSITY (FRESH WATER)					
CREEKS	DENSITY Kg/m^3	ATTC		ITTC	
		R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
STANDARD VALUE	1000	288.4616696	1779.808502	288.6915562	1781.226902

Table 3c: Tabulation of Results for Low Tide

TABLE 3c: TABULATION OF RESULTS FOR LOW TIDE					
SALT WATER					
CREEKS	DENSITY Kg/m^3	ATTC		ITTC	
		R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
ABONNEMA (SW)	995.773	287.2423421	1772.285251	287.471257	1773.697656
IWOFE(SW)	997.88	287.8501309	1776.035307	288.0795301	1777.450701
FRESH WATER					
CREEKS	DENSITY Kg/m^3	ATTC		ITTC	
		R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
RUMUMASI (FW)	994.34	286.8289766	1769.734785	287.057562	1771.145157
CHOBA(FW)	990.58	285.7443607	1763.042705	285.9720817	1764.447744

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Table 4: Tabulation of Results for Habour Tug.

TABLE 4: TABULATON OF RESULTS FOR HABOUR TUG					
STANDARD DENSITY (SALT WATER)					
CREEKS	DENSITY Kg/m^3	**ATTC**		**ITTC**	
		R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
STANDARD VALUE	1025	24.87225289	115.0590419	25.09748674	116.1009737
STANDARD DENSITY (FRESH WATER)					
CREEKS	DENSITY Kg/m^3	**ATTC**		**ITTC**	
		R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
STANDARD VALUE	1000	24.26561257	112.2527238	24.48535292	113.2692426
LOW TIDE SALT WATER					
CREEKS	DENSITY Kg/m^3	**ATTC**		**ITTC**	
		R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
ABONNEMA (SW)	995.773	24.16304183	111.7782315	24.38185333	112.7904535
IWOFE(SW)	997.88	24.21416948	112.014748	24.43344397	113.0291118
LOW TIDE FOR FRESH WATER					
CREEKS	DENSITY Kg/m^3	**ATTC**		**ITTC**	
		R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
RUMUOMASI (FW)	994.34	24.12826921	111.6173734	24.34676582	112.6281387
CHOBA(FW)	990.58	24.0370305	111.1953031	24.2547009	112.2022463
HIGH TIDE SALT WATER					
CREEKS	DENSITY Kg/m^3	**ATTC**		**ITTC**	
		R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
ABONNEMA (SW)	1003.77	24.35709393	112.6759165	24.5776627	113.6962677
IWOFE(SW)	1001.34	24.2981285	112.4031424	24.51816329	113.4210234
HIGH TIDE FRESH WATER					
CREEKS	DENSITY Kg/m^3	**ATTC**		**ITTC**	
		R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
RUMUOMASI (FW)	972.504	23.59840529	109.1662229	23.81210366	110.1547915
CHOBA(FW)	987.77	23.96884413	110.879873	24.18589706	111.8839598

Table 5: Data Collection and processing for different Temperature

	Time: 6-7am			Time: 12-1pm			Time: 6-7pm		
CREEKS	T (^{0}C)	FW DENSITY Kg/m^3	SW DENSITY Kg/m^3	T (^{0}C)	FW DENSITY Kg/m^3	SW DENSITY Kg/m^3	T (^{0}C)	FW DENSITY Kg/m^3	SW DENSITY Kg/m^3
Abonima	29.2	-	991.33	35	-	990.6	30	-	998.2
IWOFE	30	-	994.93	34	-	994.23	33.2	-	994.59
Rumuomasi	28.9	990.48	-	34.7	990.27	-	32.9	990.6	-
CHOBA	29.5	994.22	-	33.5	995.59	-	31.2	994.39	-

Table 6: Results of ATTC and ITTC methods for Ship Densities at Different Temperatures

TABLE 6: RESULTS OF ATTC AND ITTC METHODS FOR SHIP DENSITIES AT DDIFFERENT TEMPERATURES.						
STANDARD DENSITY FOR SALT WATER						
CREEKS		DENSITY Kg/m^3	**ATTC**		**ITTC**	
			R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
STANDARD VALUE		1025	295.6732114	1824.303714	295.9088451	1825.757574
STANDARD DENSITY FOR FRESH WATER						
CREEKS		DENSITY Kg/m^3	**ATTC**		**ITTC**	
			R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
STANDARD VALUE		1000	288.4616696	1779.808502	288.6915562	1781.226902
STANDARD DENSITY FOR SALT WATER						
CREEKS	TEMP ^{0}C	DENSITY Kg/m^3	**ATTC**		**ITTC**	
			R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
ABONNEMA (SW)	29.2	991.33	285.9607069	1764.377562	286.1886004	1765.783664
IWOFE(SW)	30	994.93	286.9991689	1770.784872	287.22789	1772.196081
STANDARD DENSITY FOR FRESH WATER						
CREEKS	TEMP ^{0}C	DENSITY Kg/m^3	**ATTC**		**ITTC**	
			R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
RUMUOMASI (FW)	28.9	990.48	285.7155145	1762.864725	285.9432126	1764.269622
CHOBA(FW)	29.5	994.22	286.7943612	1769.521208	287.022919	1770.93141
12-1PM (STANDARD DENSITY FOR SALT WATER) TEMPERATURE OF ENVIRONMENT= 32^{0}C						
CREEKS	TEMP ^{0}C	DENSITY Kg/m^3	**ATTC**		**ITTC**	
			R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
ABONNEMA (SW)	35	990.6	285.7501299	1763.078302	285.9778556	1764.483369
IWOFE(SW)	34	994.23	286.7972458	1769.539006	287.0258059	1770.949222
12-1PM (STANDARD DENSITY FOR FRESH WATER) TEMPERATURE OF ENVIRONMENT= 32^{0}C						
CREEKS	TEMP ^{0}C	DENSITY	**ATTC**		**ITTC**	

		Kg/m^3	R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
RUMUOMASI (FW)	34.7	990.27	285.6549376	1762.490965	285.8825873	1763.895564
CHOBA(FW)	33.5	995.59	287.1895537	1771.959546	287.4184264	1773.371691
6-7PM (STANDARD DENSITY FOR SALT WATER) TEMPERATURE OF ENVIRONMENT= 30^0 C						
CREEKS	TEMP ^{0} C	DENSITY Kg/m^3	**ATTC**		**ITTC**	
			R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
ABONNEMA (SW)	30	998.2	287.9424386	1776.604846	288.1719114	1778.020693
IWOFE(SW)	33.2	994.59	286.901092	1770.179738	287.1297349	1771.590464
6-7PM (STANDARD DENSITY FOR FRESH WATER) TEMPERATURE OF ENVIRONMENT= 30^0 C						
CREEKS	TEMP ^{0} C	DENSITY Kg/m^3	**ATTC**		**ITTC**	
			R_H (KN)	P_{EF} (KW)	R_H (KN)	P_{EF} (KW)
RUMUOMASI (FW)	32.9	990.6	285.7501299	1763.078302	285.9778556	1764.483369
CHOBA(FW)	31.2	994.39	286.8433996	1769.823776	287.0719966	1771.234219

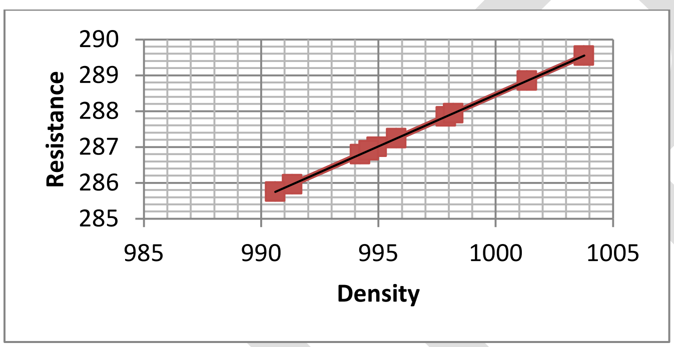


Figure 5 : Resistance Versus Density for ATTC Salt Water

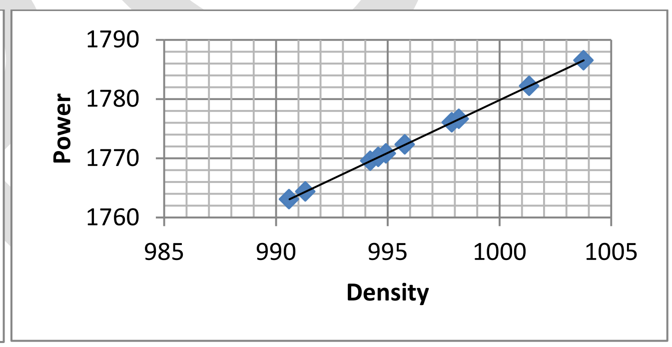


Figure 6 : Power Versus Density for ATTC Salt Water

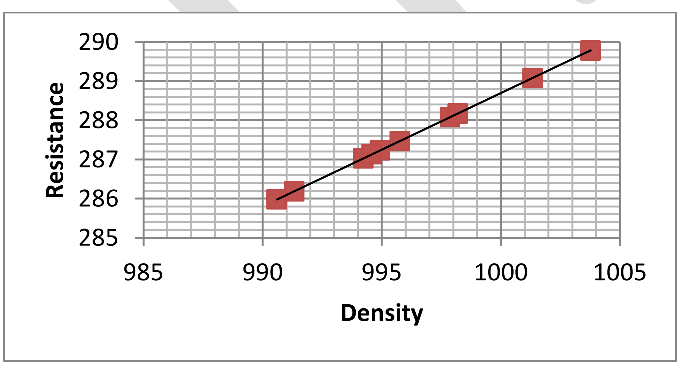


Figure 7: Resistance versus Density for ITTC Salt Water

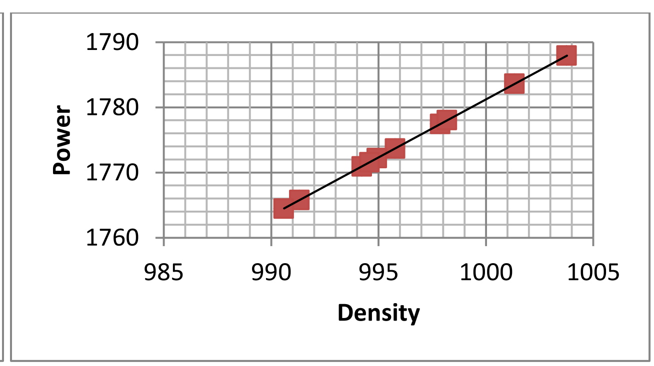
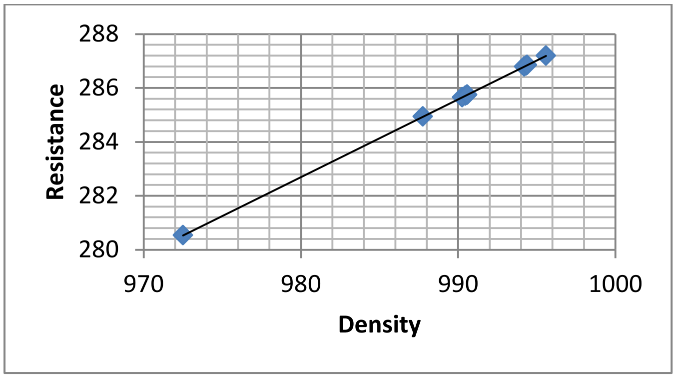


Figure 8: Power versus Density for ITTC Salt Water



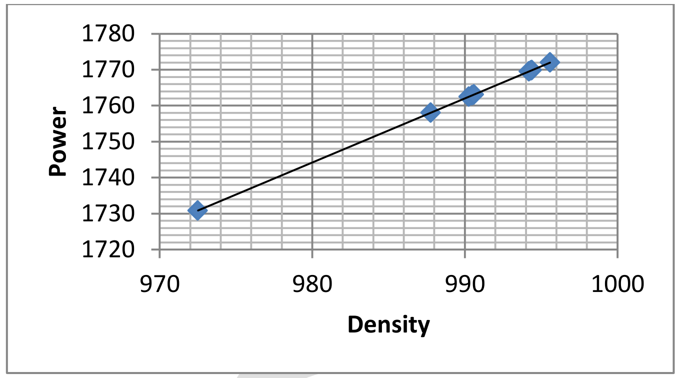
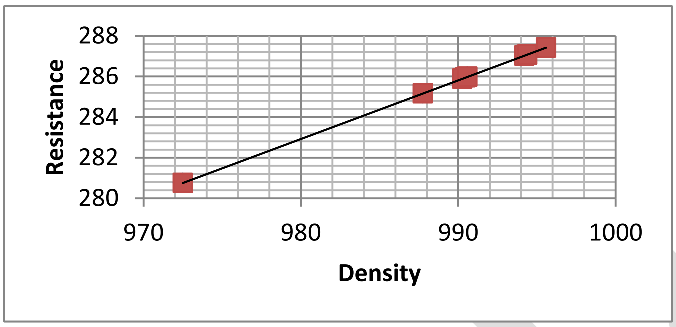


Figure 9: Resistance versus Density for ATTC Fresh Water

Figure 10: Power versus Density for ATTC Fresh Water



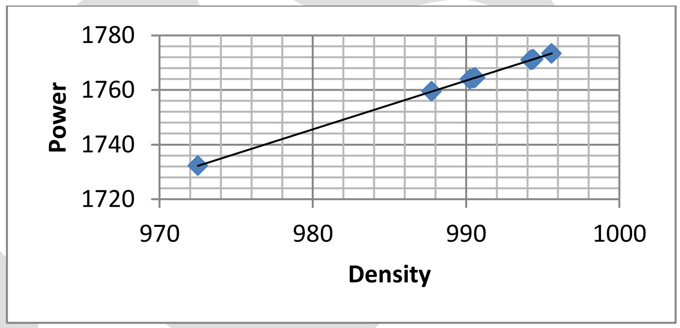


Figure 11: Resistance versus Density for ITTC Fresh Water

Figure 12: Power versus Density for ITTC Fresh Water