

# Bare hull ship resistance computation of an offshore supply vessel using the Holtrop and Menenn method: A MATLAB implementation

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**ABSTRACT** Resistance and powering prediction analysis is a very important analysis during the initial design phase of a vessel. It enables the naval architect in determining the required propulsive combinations needed in propelling the vessel more economically during the vessel service life cycle. This has become important for all moving marine craft and as such need the necessary attention. This paper aims at computing the bare hull resistance and powering of a hypothetical supply vessel MV Queen, operating along the warriwaters using the Holtrop and Menenn method. The total resistance and powering of the given vessel fulfilling the Holtrop and Menenn method is computed. This is achieved by the computation of the various resistance components such as the frictional resistance, the appendages, the wave making resistance, the added resistance due to wave, the additional pressure resistance due to the transom and the model –ship resistance were all computed using the Holtrop and Menenn method. The algorithm for these computations were developed. Simple MATLAB scripts were written using the developed algorithms and attempts were made in comparing the programs with the supply vessel particulars and using a standard commercial software, the MAXSURF resistance module. The results showed a good agreement for both cases. The research is further discussed for applicable feasibility in predicting ships resistance and powering

**KEYWORDS** Resistance, appendages, wave, pressure, effective power, hull, transom, model, correlation, friction,

## I. INTRODUCTION

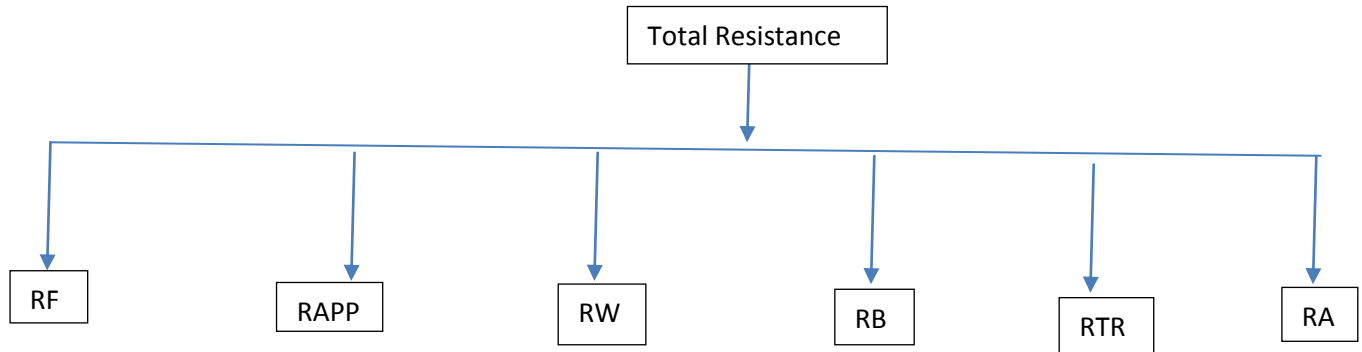
The realistic seaway through which vessels move along is one that requires a lot of energy to push through. This seaway offers so much ‘resistance’ to the structure that if not checked can impede the operational behaviour of the vessel and its overall performance. It is therefore necessary that the naval architect can predict the resistance that a typical vessel can face during initial design phases to enable it make proper powering estimations.

The resistance prediction of vessel has been given a lot of attention and many approaches have been adopted over the years. Most notable amongst these methods are the Holtrop and Menenn’s method, Van Oortmerssen method, Guldhammer-Harvald Method, Fung Method and Mercier and Svitsky method. These methods are named so as a result of collaborative efforts by investigators. Some have employed the regression methods coupled with test results which have yielded good empirical solutions that have stood the test of time. Very notable amongst them is the Holtrop method which also has a wide range of applicability.

The Holtrop method which utilizes the regression approach gives rooms for analysing the various components of resistance ranging from the viscous frictional effect of the fluid which is the sea water, the appendages of the vessel which basically houses the anchors and the bilge, the possible resistance effects by the wave, the components which arise from the bulbous bow and the theoretical ship [1],[2].

Other resistance components such as the model resistance, which are basically derived from the various models and the transom resistance all form

the total resistance experienced by the vessel along a realistic sea way. These are all depicted in the figure below.



Other methods such as the panel method uses the computational fluid dynamic approach which combines the super speed of modern computing machines to predict the resistance.[3] Also, direct model testing approach is another method.[4],[5] Here the ship model is towed through a towing tank and the resistances are estimated at various speeds. This model and the tanks are dimensionally correlated to the actual shape of the vessel and the realistic seaway.

## II. EXPERIMENTATION/METHODOLOGY

The famous Holtrop and menen ship's resistance equation which was modelled from regression principles is given as [1]

$$R_{\text{total}} = R_f(1 + k_1) + R_{\text{App}} + R_w + R_B + R_{\text{TR}} + R_A$$

Where

$R_f$  = frictional resistance according to the ITTC-1957 friction formula

$(1 + k_1)$  = form factor describing the viscous resistance of the hull form with regards to the frictional resistance.

$R_{\text{App}}$  = resistance of the appendages

$R_w$  = wave making and wave breaking resistance

$R_B$  = additional pressure resistance of bulbous bow near the water surface

$R_{\text{TR}}$  = additional pressure resistance of immersed transom

$R_A$  = model-ship resistance

Each of this resistance components will be briefly described

### Frictional Resistance

The frictional resistance  $R_f$  is given by the relation

$$R_f = \frac{1}{2} \rho_{\text{water}} A_{\text{wetted}} V^2 C_f$$

Where

$\rho_{\text{water}}$  = density of sea water in  $kg/m^3$

$A_{\text{wetted}}$  = wetted surface of the vessel hull in  $m^2$

$V$  = ships speed in knots

$C_f$  = coefficients of frictional resistance according to ITTC-1957. The relation for the computation of the coefficient is given in the appendix.

### Form factor

The form factor relation,  $(1 + k_1)$  is given as

$$(1 + k_1) = C_{13} \{ 0.93 + C_{12} \left( \frac{B}{L_R} \right)^{0.92497} - C_p \}^{-0.521448} (1 - C_p + 0.0225 lcb)^{0.6906}$$

Where

$C_p$  = prismatic coefficient based on the waterline length  $L$

$lcb$  = longitudinal position of the centre of buoyancy forward of 0.5L

$C_{13}$  = after stern effect and the details is given in the [2].[1].

### Resistance due to appendages

The resistance due to the appendages,  $R_{\text{App}}$  is given by

$$R_{\text{App}} = \frac{1}{2} \rho_{\text{water}} A_{\text{hull}_w} V^2 C_f (1 + k_2)$$

Where

$A_{\text{hull}_w}$  = hull wetted surface of the vessel

$(1 + k_2)$  = appendage resistance factor. The detailed table for this is found in the appendix.

### Wave resistance

The wave resistance  $R_w$ , is given as

$$R_w = C_1 C_2 C_5 \nabla \rho g \exp\{m_1 F_n^d + m_2 \cos(\lambda F_n^{-2})\}$$

Where

$\nabla$  = vessel displacement in  $m^3$

$\rho$  = density of sea water in  $kg/m^3$

$g$  = acceleration due to gravity

$F_n$  = Froude number based on waterline  $L$ .

The remaining coefficients  $C_1$ ,  $C_2$  and  $C_5$  are detailed in the appendix.

### Additional Pressure Resistance due to the bulbous bow

The additional resistance due to the presence of a bulbous bow near the surface is determined by

$$R_B = 0.11 \exp(-3P_B^{-2}) F_{ni}^3 A_{BT}^{1.5} \rho g / (1 + F_{ni}^2)$$

Where

$F_{ni}$  = Froude number based on the immersion.

### Additional Pressure Resistance due to the immersed transom

The additional pressure resistance,  $R_{TR}$  due to the immersed transom is given as

$$R_{TR} = 0.5 \rho V^2 A_T C_6 \quad (3.7)$$

Where

$C_6$  = coefficient based on Froude number around the transom immersion.

### 3.2.5 Model-ship correlation resistance

The model-ship resistance  $R_A$  is given by

$$R_A = \frac{1}{2} \rho S V^2 C_A$$

Where

$C_A$  = correlation allowance coefficient

### Effective Power

The effective power required to overcome a given resistance,  $R_{tot}$  with a given speed  $V$  is given as

$$P_E = R_{tot} V$$

Where  $P_E$  is in KW,  $R_{tot}$  in KN and  $V$  in  $m/s$

### Shaft Power

The shaft power required to overcome a given resistance,  $R_{tot}$  with a given speed  $V$  is given as

$$P_S = \frac{P_E}{\eta}$$

Where  $P_S$  is in KW,  $\eta$  is the efficiency.

### Source code Implementation

The implementation of the above mathematical models can best be done via functional implementations [7]. Here, only the frictional part of the total resistance would be shown which is `r_f.mfile`. All the other components can be seen in the toolbox and downloaded at [https://www.mathworks.com/matlabcentral/fileexchange/100466-res\\_holt\\_men](https://www.mathworks.com/matlabcentral/fileexchange/100466-res_holt_men)

```
function rf=r_f(d_s, v, l, v_c, b, c_wp, c_b, a_bt, t, c_m, l_cb)
%// method to return the ITTC-1957 FORMULATION resistance
% where the form factor uses the ITTC-1957 FORMULATION
% c_p=0;
    c_12 = 0;
    c_stern = 0;
    c_p=c_b/c_m;
%
% if(v_shaped.isSelected())
%     c_stern = -10;
%     disp("v-typed displayed");
%
% elseif(normal_shaped.isSelected())
%     c_stern=0;
%     disp("normal-typed displayed");
%
% elseif (u_shaped.isSelected())
%     disp("u-typed displayed");
%     c_stern=10;
% end
    c_stern=10;
    c_13=1+0.003*c_stern;
if((t/l)>0.05)
    c_12 = Math.pow((t/l), 0.2228446);
```

```

elseif(0.02<(t/l)                                &&                                (t/l)<0.05)

    c_12=48.20*(((t/l)-0.02)^2.078)+0.479948;

elseif((t/l)<0.02)

    c_12=0.479948;
end
v_pp=0.06*c_p*1_cb;
v_dp=(4*c_p)-1;
v_ddp=v_pp/v_dp;
l_r=1*(1-c_p+v_ddp);

k_1=c_13*(0.93+c_12*(((b/l_r)^0.92497))*(((0.95-c_p)^-0.521448))*(((1-c_p+0.0225*1_cb)^0.6906)));
r=(v*0.51444*1)/v_c;
c_f=0.075/((log10(r)-2)^2);
s=1*((2*t)+b)*sqrt(c_m)*((0.453+(0.4425*c_b)-(0.2862*c_m)-
(0.003467*((b/t)))+0.3696*c_wp))+2.38*(a_bt/c_b);
rf=                                                    (0.5*d_s*((v*0.5144)^2)*s*c_f*k_1)/1000;

end
  
```

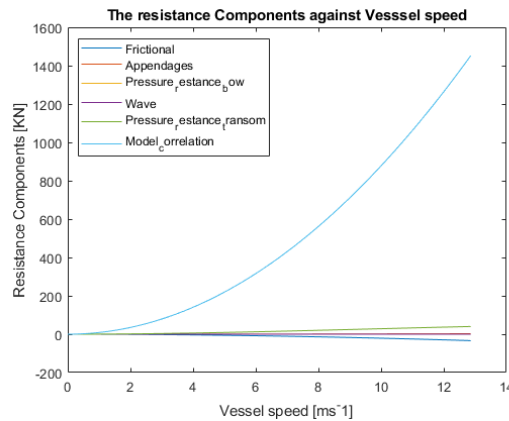
The frictional resistance  $r_{f.m}$

### III. RESULTS AND DISCUSSIONS

The source codes was testes for an offshore supply vessel with the following particulars with a shaft efficiency of 75%

Particulars	Values	Units
Length overall	202	metre
Lcb	-0.175	metre
Volume displacement	45909	M <sup>3</sup>
beam	32	m
Vessel speed	25	knots
draft	10.8	m

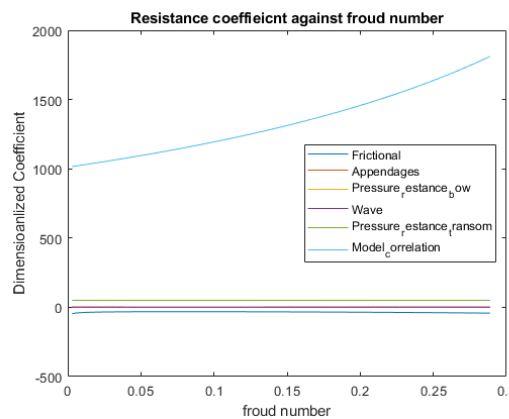
The following results were obtained with the Different resistance components



It can be observed that only the frictional part of the resistance was the main contributing component to the resistance experienced by the vessel. The other components vary fairly constant with the speed. The wave resistance varies quickly

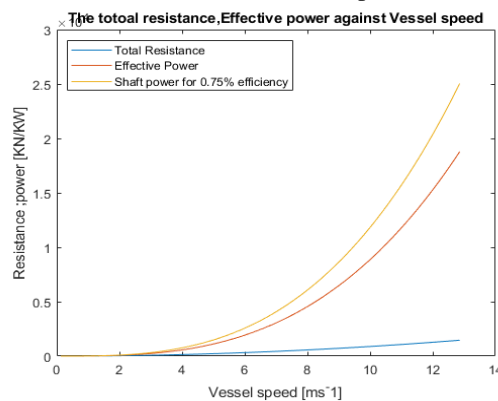
before dropping off. Also, the transom varies monotonically as well.

Again, in terms of coefficients the different resistance components can be shown below

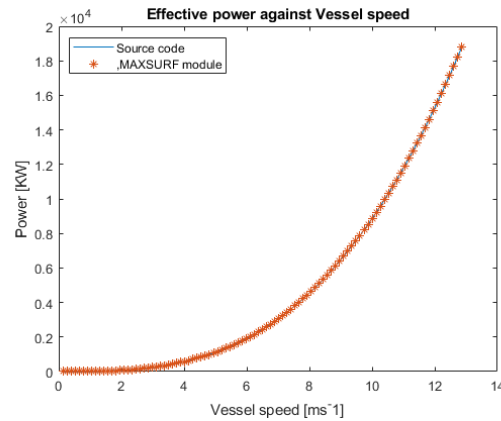


These coefficients are gotten by normalizing each resistance components with the dynamic pressure and the wetted area. Clearly, it shows same variations with the Froude number

With shaft power of 75% the variation of the effective and shaft power measuring up as shown below



With the MAXSURF resistance module tested against this formulation we got the following result below which shows a very good agreement.



#### IV. CONCLUSION

This research looked at the mathematical model formulation for computing the bare hull resistance experienced by the vessel using the Holtrop and Menen method. It went on to develop the algorithm and implementation of these formulations using the functional programming approach with MATLAB, which is a scientific computing language. The developed algorithms in terms of the source codes were then tested for an offshore supply vessel and compared with a standard commercial software, MAXSURF resistance module and found to have very good agreement.

#### SOME OF THE ADVANTAGES FROM THE ABOVE RESULTS

- a) The use of a standard scientific computing language
- b) It can be used for empirical resistance prediction during initial design
- c) Free and easy to use toolbox
- d) Can be used for academic and demonstration purposes in ship design

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