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BERKAY ÇİLLİ

EVALUATION OF DESIGN PARAMETERS BY THE IMPLICATION OF PAYLOAD FACTOR OF NAVAL COMBATANT SHIPS

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PİRİ REİS UNIVERSITY

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MSc. , High Performance Oceam Platforms , Piri Reis University

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The last but not the least ,I would like to thank to my family for everything.

ABSTRACT

This thesis is interested with the naval ships which wants to carry more payload as combat systems .

Basic ship design is interested with relation between main specifications,characteristics and functionality of new design with similar purposed ships.

Advanced ship preliminary design is based on performance parameters such as specific power,specific resistance,endurance efficiency and transport factor differently from basic ship design.

Payload factor defines fraction of combat capability for different naval combatant types like frigates,destroyers at variable displacement and speed ranges.This provides creating a design space with functions of speed,displacement and payload. The aim of this project is making assumptions about maximum payload for combat ships at preliminary design stage in different speed and displacement ranges which have similar performance parameters.Payload factor is combined with Kennell's 'Transport Factor' approach.As a result of this combination,design space is created for different speeds and lengths with maximum payload according to her mission.

ÖZET

Bu tez çalışması yararlı yük olarak harp sistemleri taşımak isteyen gemiler hakkındadır.
Temel gemi dizaynı sürecinde benzer maksatlı gemiler için temel gemi boyutları,gemi karakteristiği ve fonksiyonelliği konusunda çalışılmaktadır.
İleri gemi ön dizaynı sürecinde temel gemi özellikleri haricinde ileri performans parametreleri de incelenmektedir.Bu parametreler başlıca spesifik güç,spesifik direnç, seyir verimi,güç verimi ve ulaşım faktörü olarak sınıflandırılabilir.
Yararlı yük faktörü;fırkateyn,destroyer gibi harp gemilerin savaş sistemlerinin kütlesinin geminin deplasmana oranını farklı gemi hızı ve gemi deplasmanı için tanımlamaktadır.Yararlı yük faktörü; hız,deplasman ve yararlı yük kütlesini parametrik olarak değerlendirmeyi sağlar.
Bu projenin amacı;farklı hız ve farklı deplasmanlarda maksimum yararlı yük kütlesini bulabilmek için kabullerden faydalanmaktadır.Yararlı yük faktörü metodu ; 'Kennell's Transport Factor' yaklaşımı ile birlikte kullanılarak dizayn alanı yaratılmıştır.Böylece gemi misyonuna uygun gemi temel özellikleri seçilebilmektedir.

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LIST OF SYMBOLS/ABBREVIATIONS

D	Drag:Resistance of ship
EHP	Effective Horsepower
Fn_{VOL}	Volumetric Froude Number
g	Gravitational constant
L	Lift:the weight of ship
OPC	Overall Propulsive Coefficient
P	Payload
Ps	Shaft Horse Power
R	Range of Ship
SFC	Specific Fuel Consumption
SHP	Shaft Horsepower
TF	Transport Factor
TF_{SHIP}	Ship Transport Factor
TF_{PROP}	Power Transport Factor
TF_{FUEL}	Fuel Transport Factor
$TF_{PAYLOAD}$	Payload Transport Factor
V	Ship speed in meters per second
Vk	Ship speed in knots
W	Weight of Ship
ρ	Density of Sea Water
Δ	Displacement

β	Endurance Efficiency
α	Speed Efficiency
Δ	Total ship's displacement
Δ_{PROP}	Weight of the propulsion system
Δ_{FUEL}	Weight of the fuel
Δ_{CARGO}	Weight of the cargo
$\Delta_{PAYLOAD}$	Weight of Payload

1. INTRODUCTION AND BACKGROUND

Ships are designed to cover the needs according to her design missions.These needs may be on commercial or noncommercial basis.Main mission is generating a profit during the service life of ship.Differently from conventional merchant ships,naval ships have requirements like operability, survivability,vulnerability and carrying more combat system.

Traditional ship design process consists of four design phases:

- Concept Design
- Preliminary Design
- Contract Design
- Detailed Design

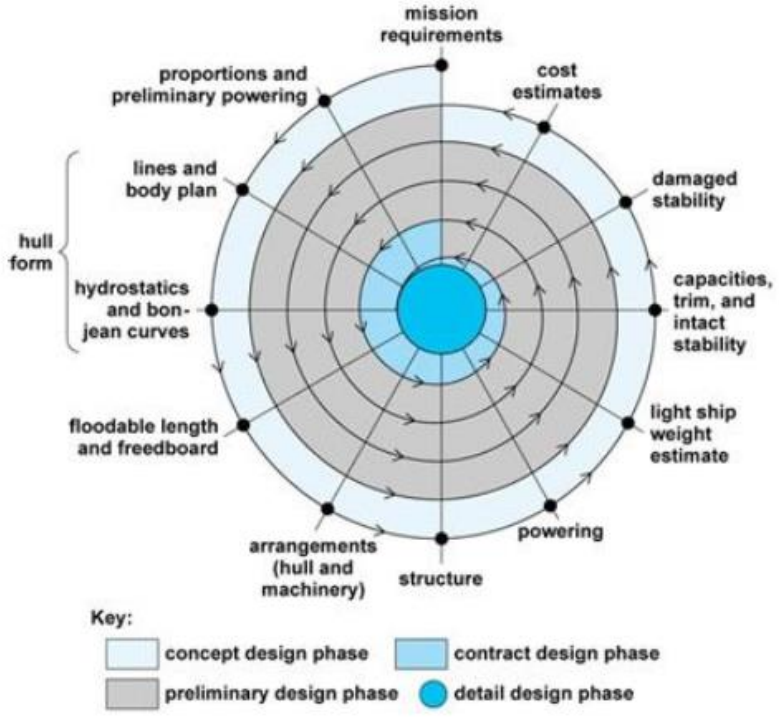

Figure 1-1 Ship Design Spiral

1.1 Aim of the Project

In this thesis,affects of advanced design parameters on first two phases which is also called basic ship design are surveyed.

Figure 1-2 sketches the course of the design of a ship, which is designed to service specific requirements or a mission (*Mission*), disposing certain functional (*Function*), form, space, weight (*Form*), technical performance (*Performance*) and economic characteristics (*Economics*).

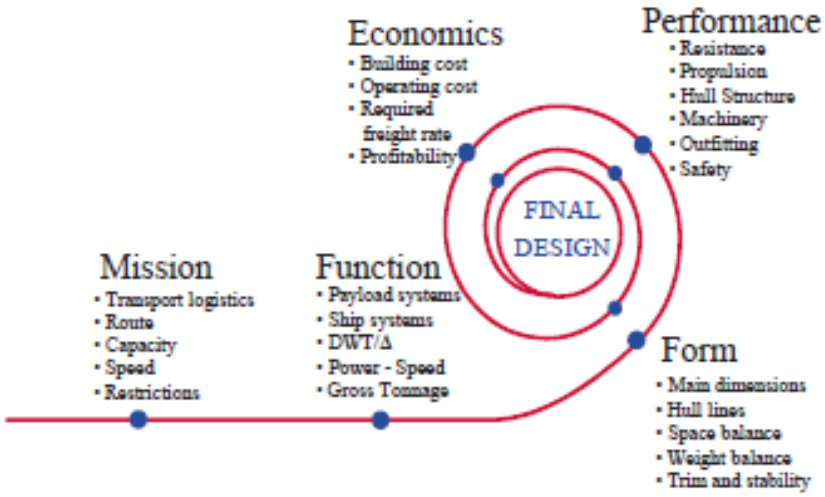

Figure 1-2 Ship design procedure

1.2 Literature Review

G.Gabrielli and TH.von Karman published the paper 'WHAT PRICE SPEED'[1] to express the relation between speed,weight and power of vehicles.Specific power and specific resistance terms are defined to express this relation.Datas from nautical,aerial,terrestrial vehicles are collected and power for unit weight is calculated according the speed of vehicles.Power for unit weight is called specific power(Figure 1-3).

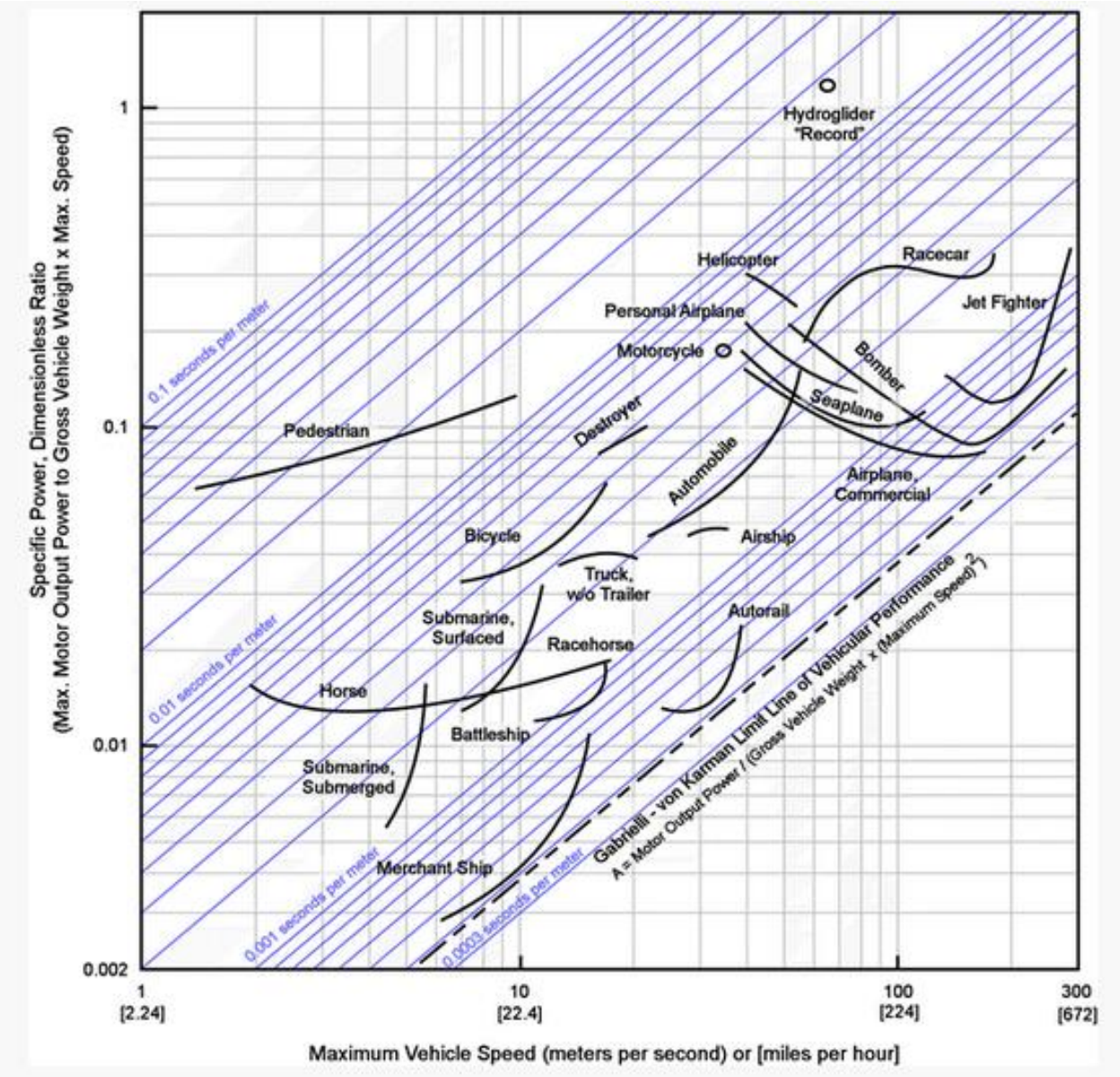

Figure 1-3 Speed-Specific Power Graph

It is easy to see the limiting curve for whole type of vehicles in Figure 1-3. Vehicles with different missions are gathered together in the data set.All vehicles are not designed to obtain the maximum speed with minimum power for unit weight.

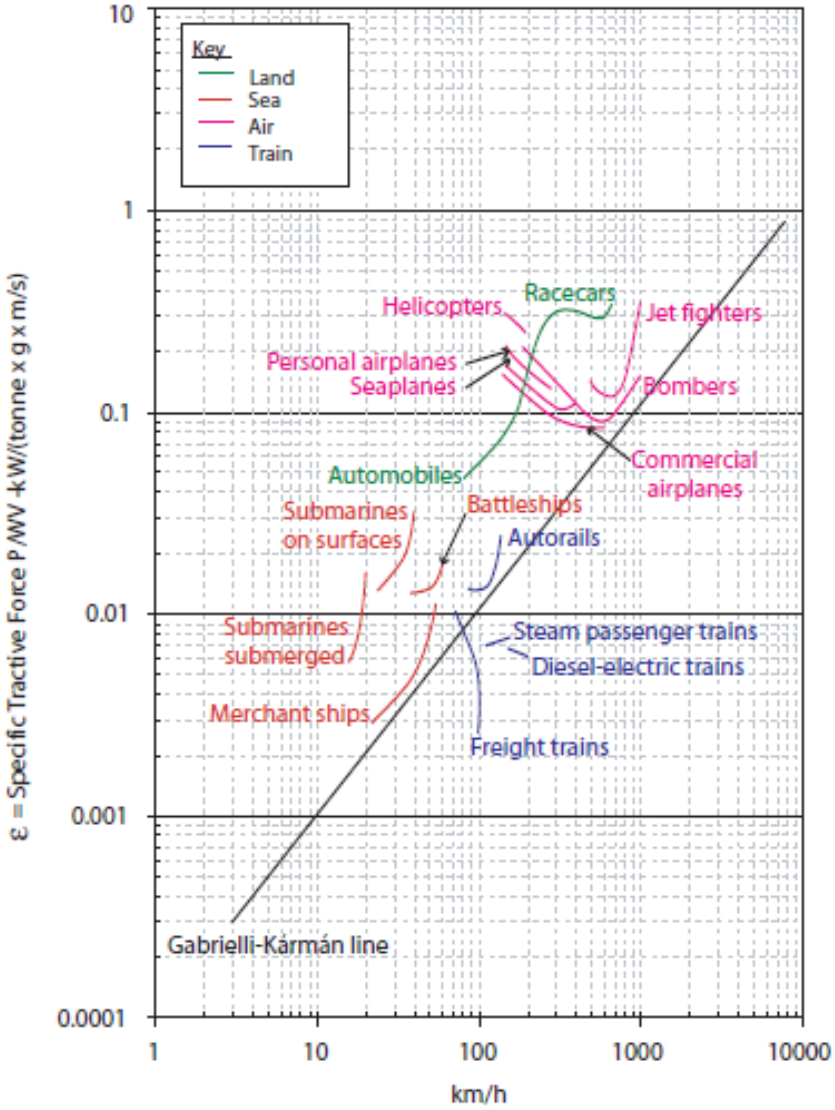

Figure 1-4 Speed-Specific Resistance Graph

Figure 1-4 shows specific resistance which defines power per unit divided by maximum speed.In Figure 1-3 and Figure 1-4 marine vehicles have lower specific power and specific resistance rather than oher vehicles.

Rapid increment is available at curves for battleships in both figures in 30-40 mph range.The main reason is increment in wave resistance according to dimensionless parameter known as Froude number.

These two figures maps the cost of speed for different missioned vehicles.Cost is not mentioned as financial term in this case.Cost mentioned amount of weight or power which ship paid from possible payload weight.

Advanced marine vessel designers aims to carry more payload with higher speed and endurance with less power. Peter G. Rainey published the paper 'BASIC OCEAN VEHICLE ASSESMENT'[2] to answer the question 'What price speed?' and embodies these demands.Rainey defines endurance and speed parameters for different missioned nautical vessels.

$$V = \alpha.\left(SHP.g.L/W\right) \tag{1}$$

$$T = \beta.\left(W/SHP.SFC\right) \tag{2}$$

V is vehicle's maximum speed.SHP is propulsion power.T is endurance time.L is length of ship.g is universal constant of gravity.SFC is specific fuel consumption and taken as $2x10^{-4}$ t/hp-hr for all cases.

Simplifying assumptions and restrictions are used while defining these parameters.

- The speed parameter is maximum speed.
- Endurance parameter is maximum time at maximum speed with full displacement.
- The length parameter is overall length.
- Power is installed thrust power.

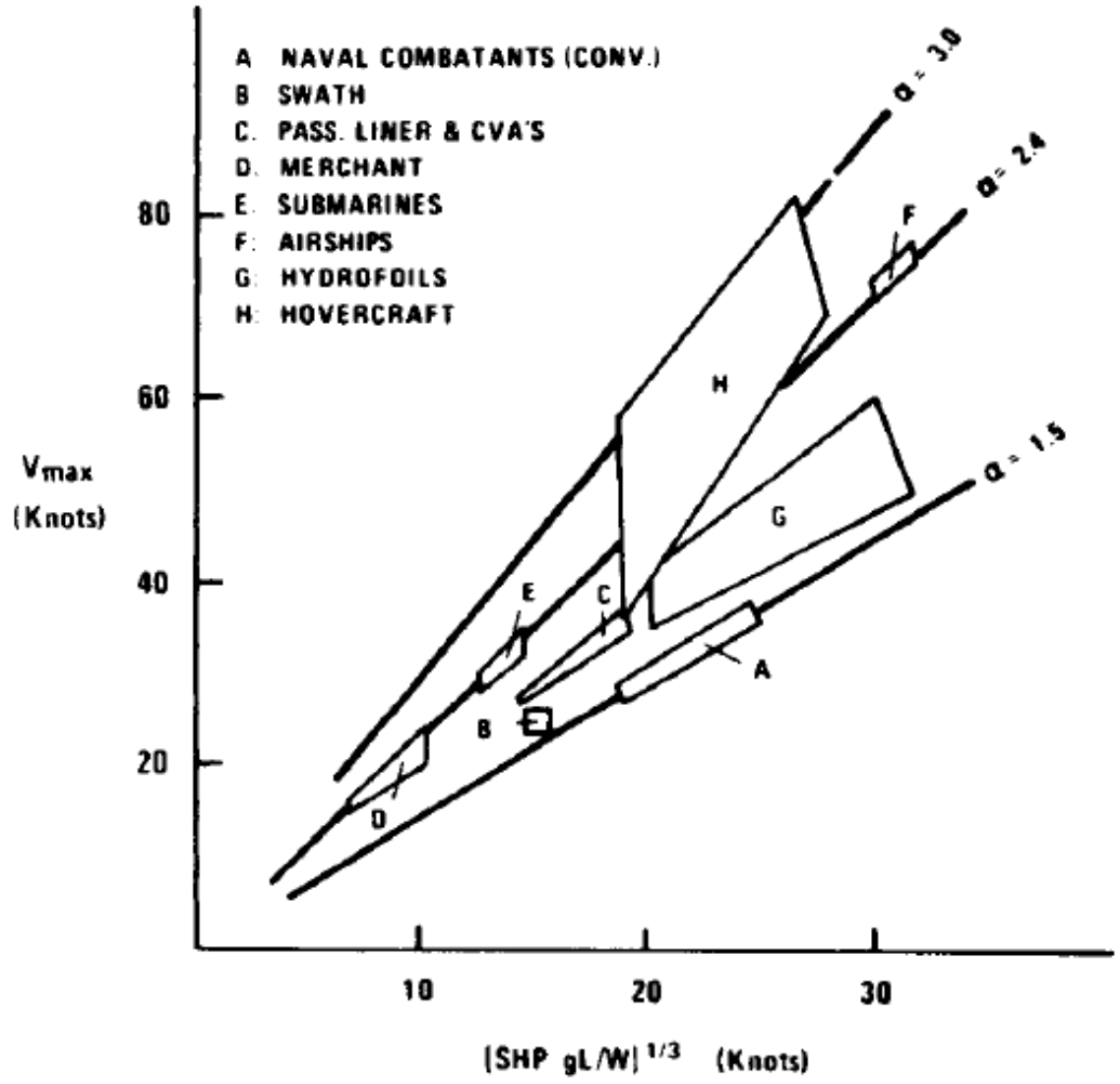

Figure 1-5 Speed Effiency Graph

Speed efficieny graph represents advanced relation between speed,power and weight differently from specific resistance(Figure 1-5). Combatant ships have speed efficiency value of 1.5 except aircraft carriers.This value shows trending line for naval combatants in basic design phase.

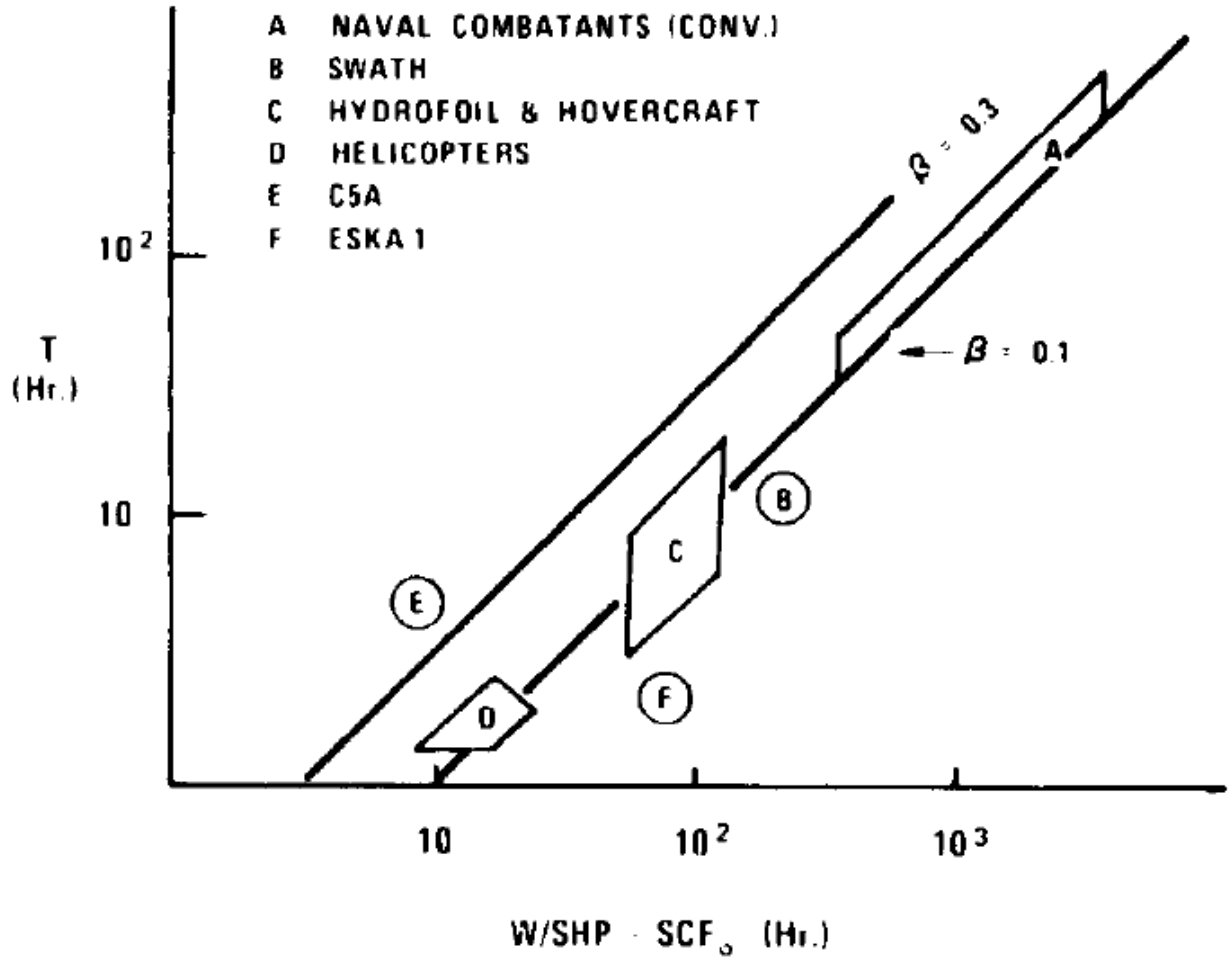

Figure 1-6 Endurance Efficiency Graph

Endurance efficieny graph (Figure 1-6) represents advanced relation between weight,power and endurance time.For a constant W/SHP value,endurance time can be increased by decreased SFC or increased fuel weight.Increaed fuel weight causes less payload weight. β is basically defined as ratio of fuel weight and full load displacement.

2. LITERATURE REVIEW

Speed,displacement,range and maximum power datas are collected from 22 aircraft carriers, 38 corvettes,52 destroyers,50 patrol forces and 50 frigates.Specific power,specific resistance,speed efficiency,endurance efficiency,froude number and admiralty constant values are calculated using those datas.

Values of power,specific resistance,endurance efficiency,admiralty constant,speed efficiency,specific power and froude number for each naval ship type and plotted in Figure 2-1,Figure 2-2,Figure 2-3,Figure 2-4,Figure 2-5,Figure 2-6,Figure 2-7,Figure 2-8,Figure 2-9 and Figure 2-10.In the graphs both linear and logarithmic scale are used.Values of blue colored label are read from linear y-axis in left side of graph. .Values of red colored label are read from logarithmic y-axis in right side of graph.

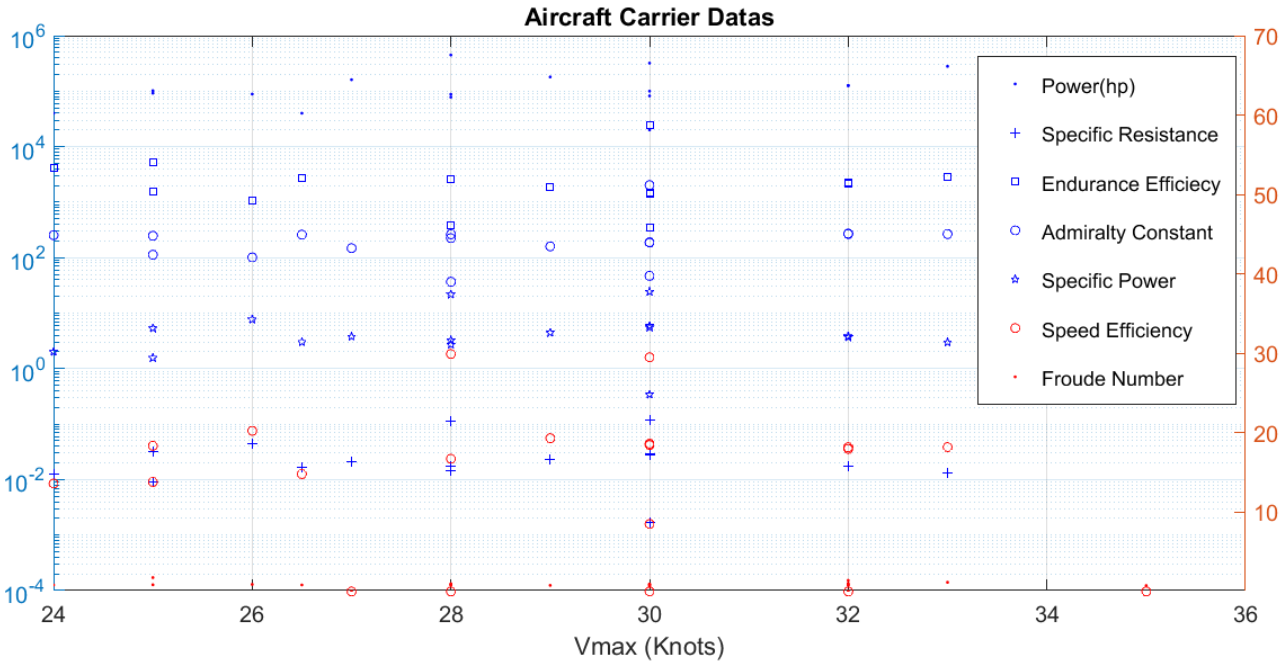

Figure 2-1 Aircraft Carrier Datas

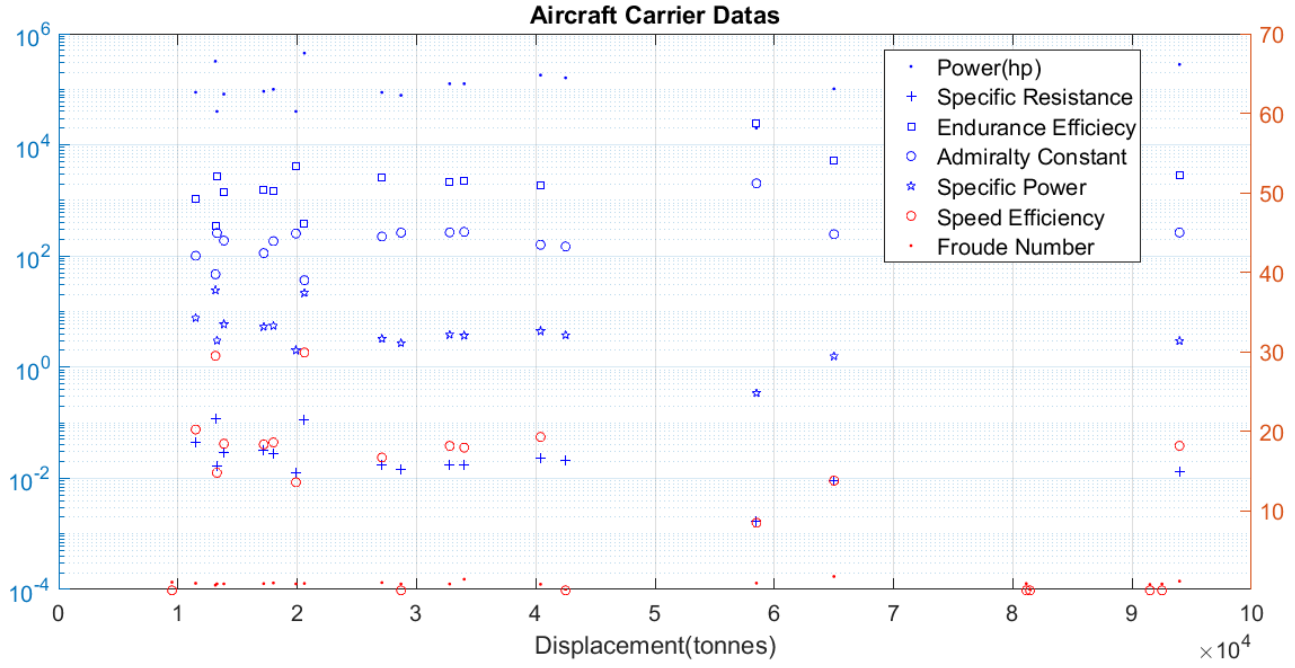

Figure 2-2 Aircraft Carrier Datas

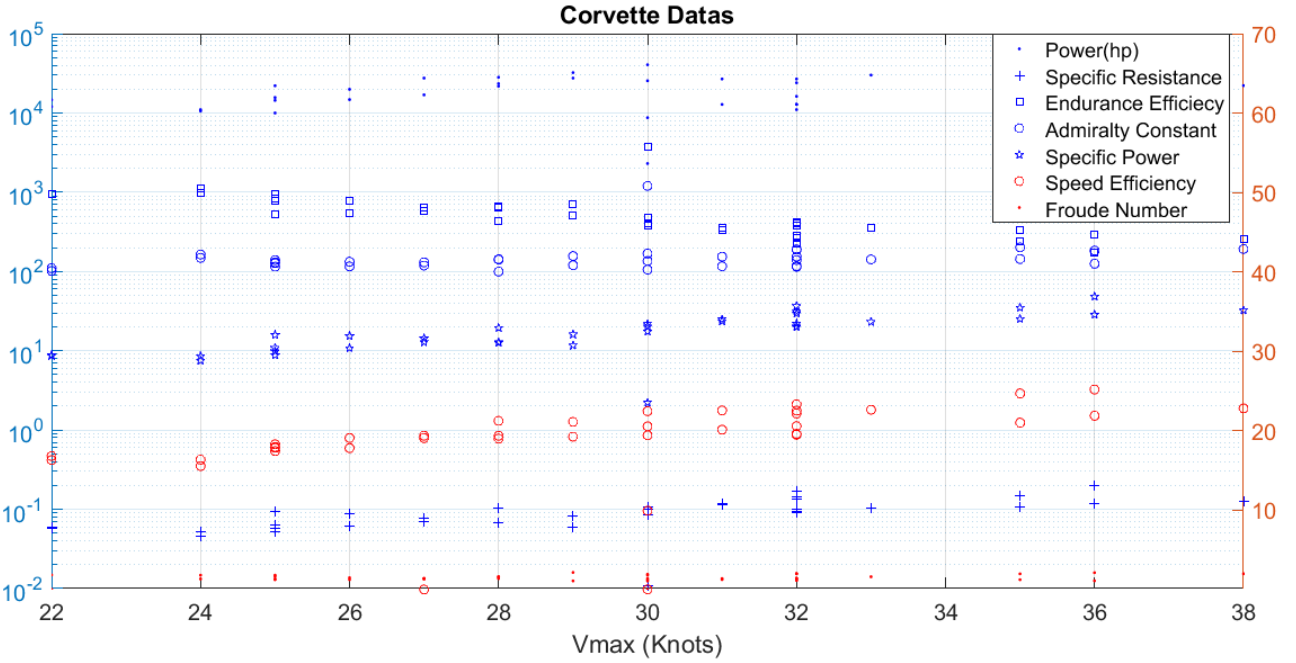

Figure 2-3 Corvette Datas

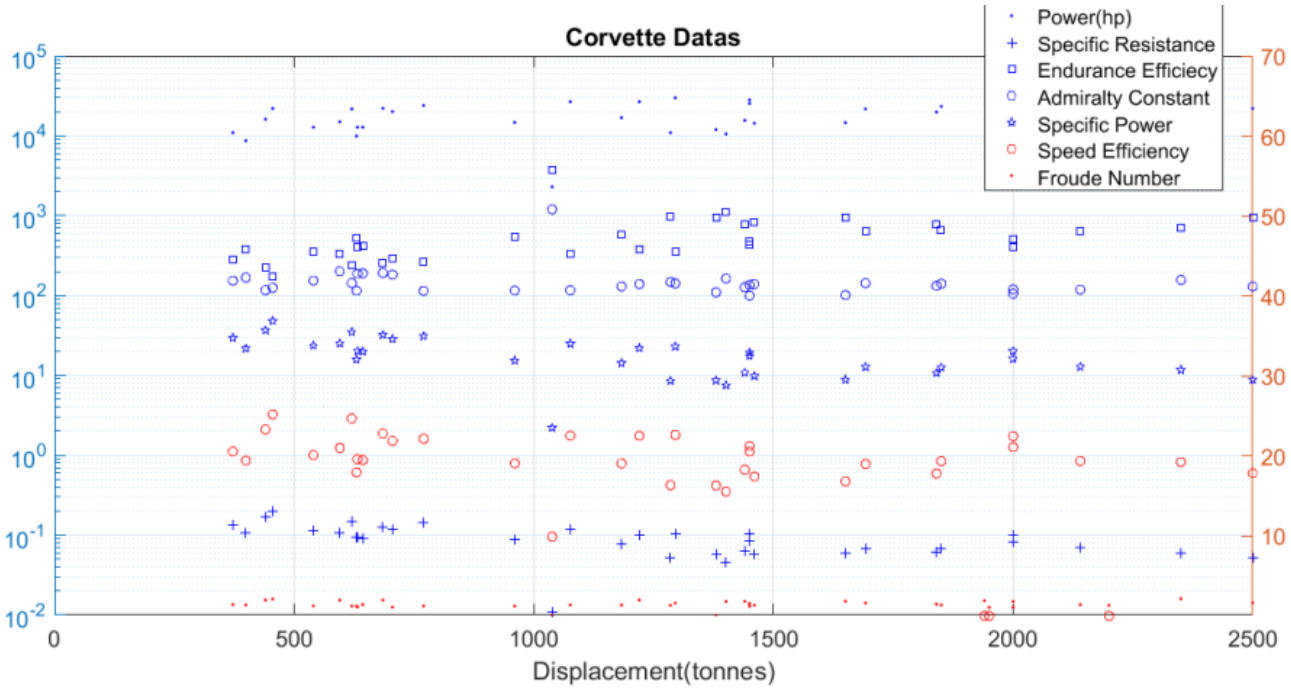

Figure 2-4 Corvette Datas

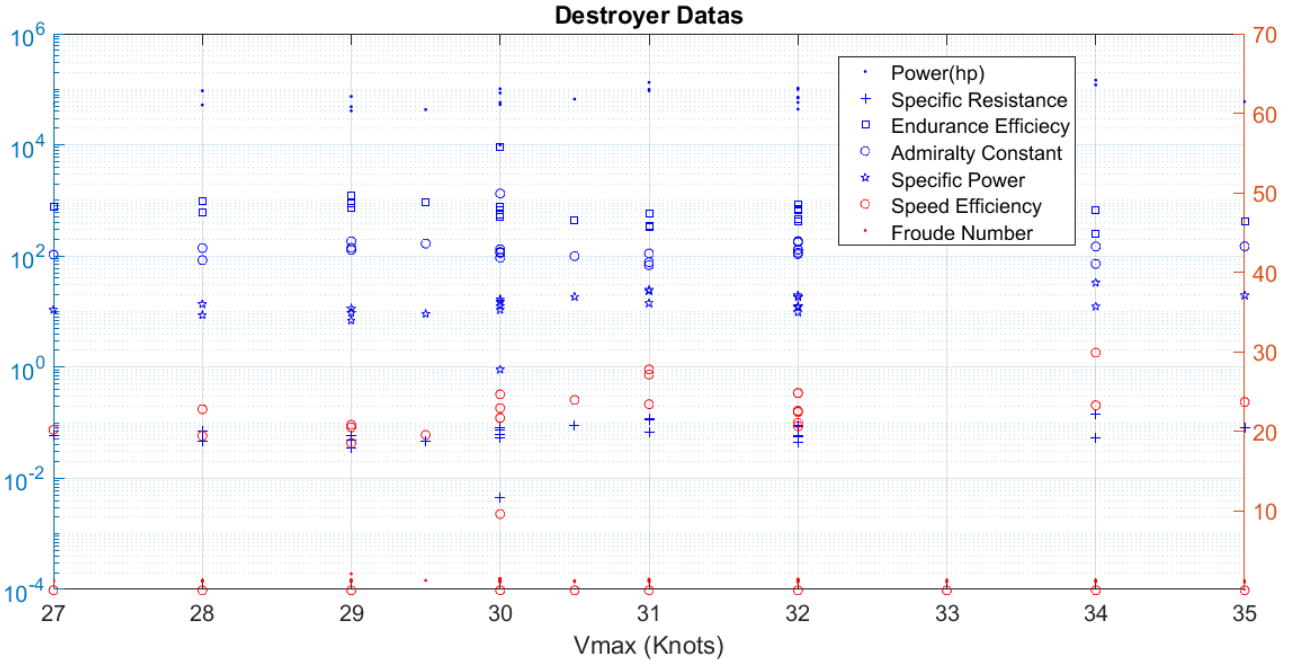

Figure 2-5 Destroyer Datas

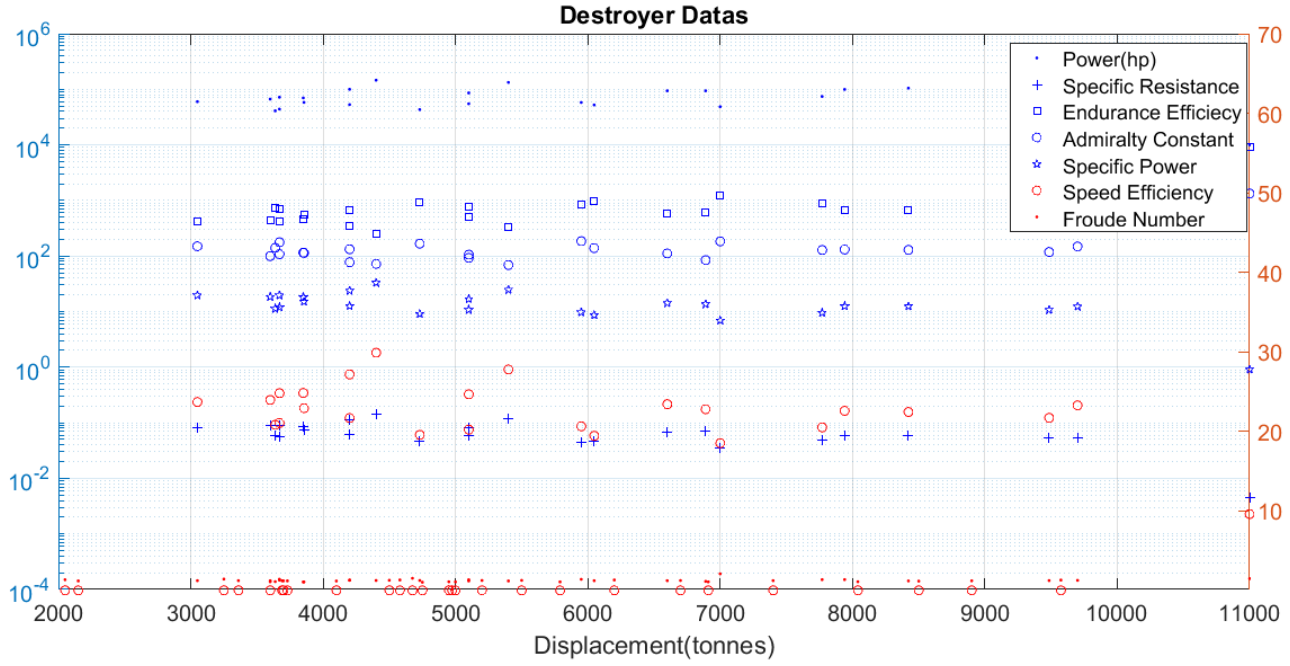

Figure 2-6 Destroyer Datas

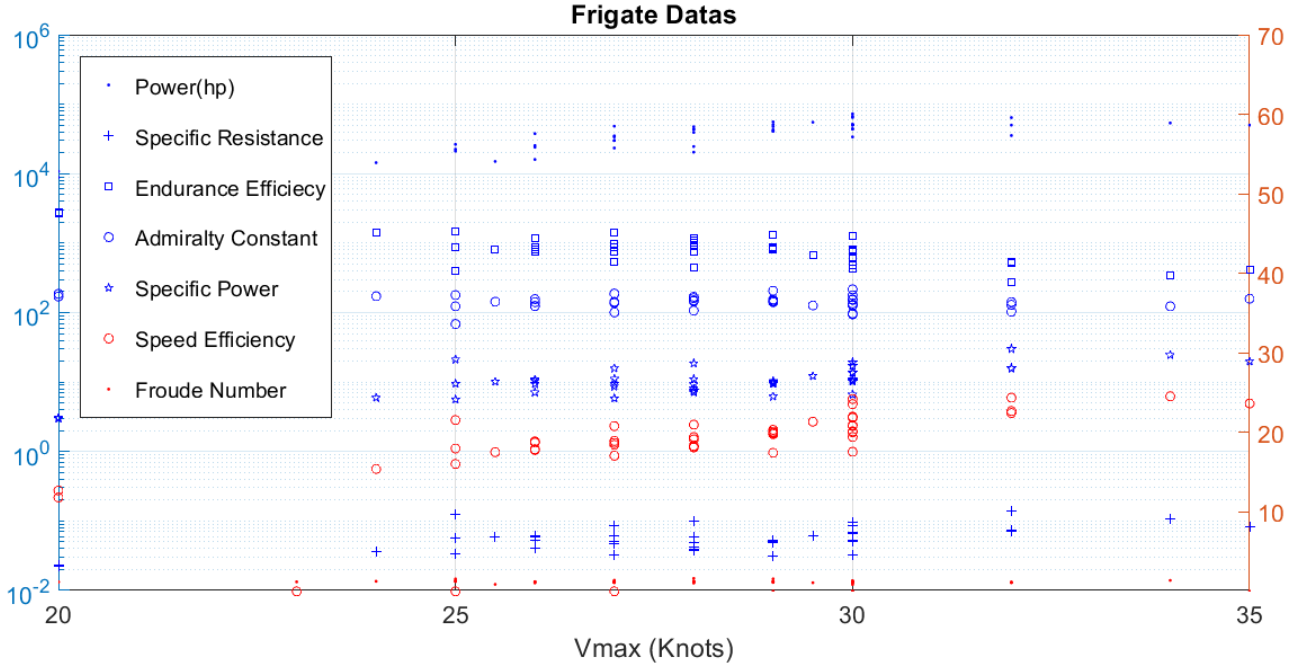

Figure 2-7 Frigate Datas

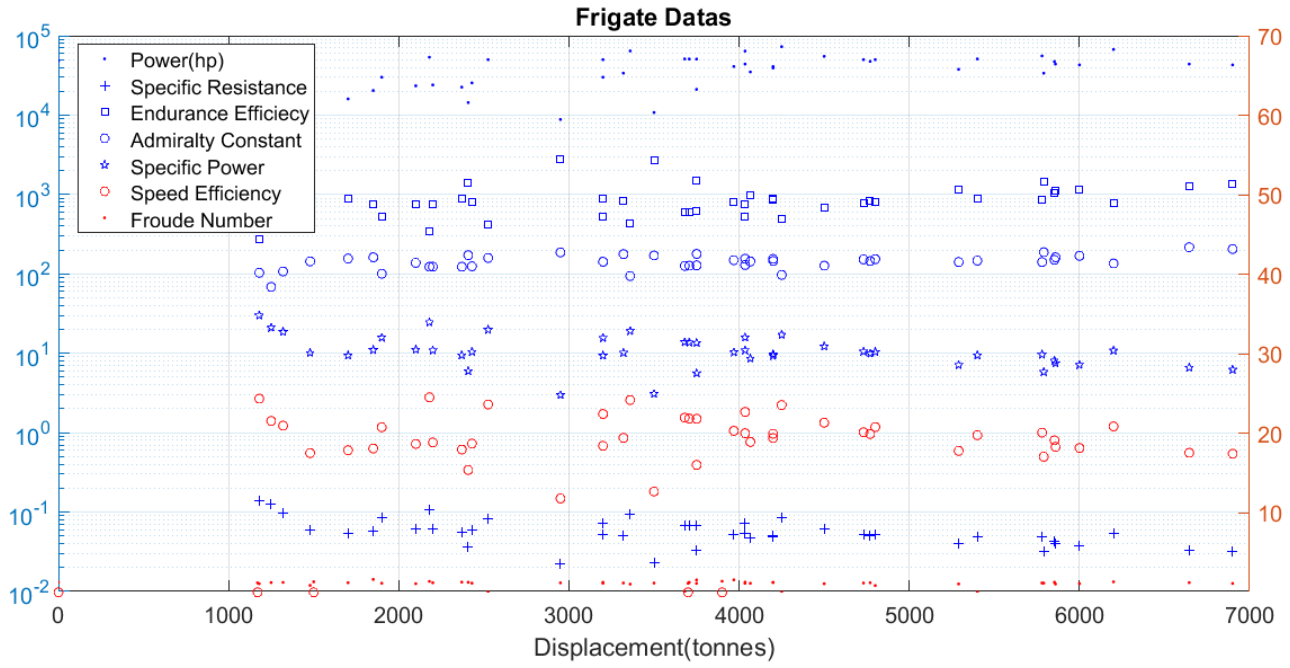

Figure 2-8 Frigate Datas

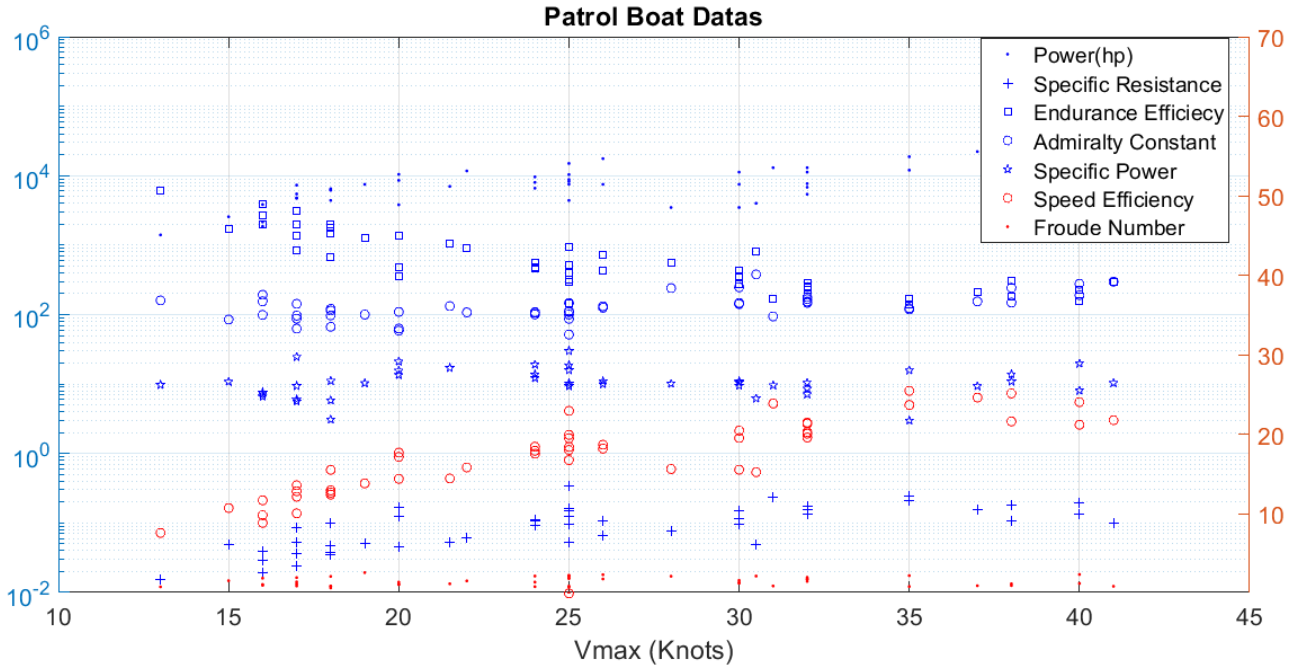

Figure 2-9 Patrol Boat Datas

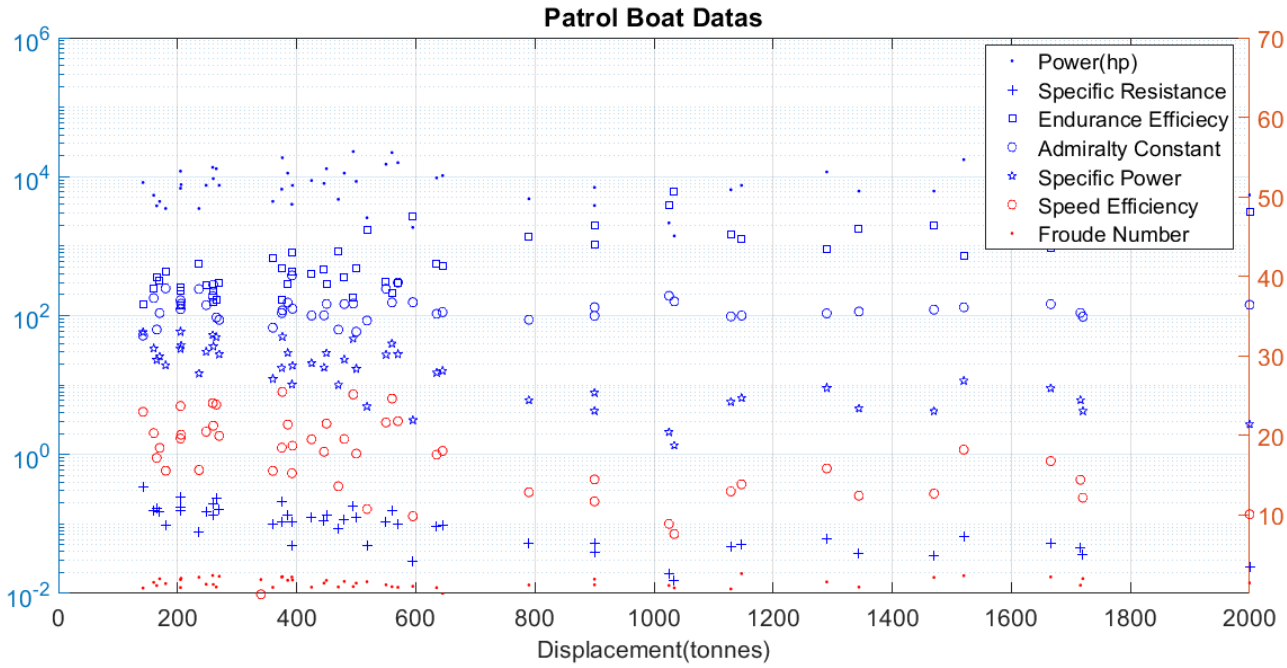

Figure 2-10 Patrol Boat Datas

Specific power-speed , specific power-displacement , specific power-speed , specific power-displacement graphs are plotted for data set likrly as Figure 1-5 and Figure 1-6.Naval ships are grouped in graphs(Figure 2-11 , Figure 2-12).These limit lines will be also plotted to generate design spaces in further parts of project.Each circle represents frontier for naval ship types for same colored labels.

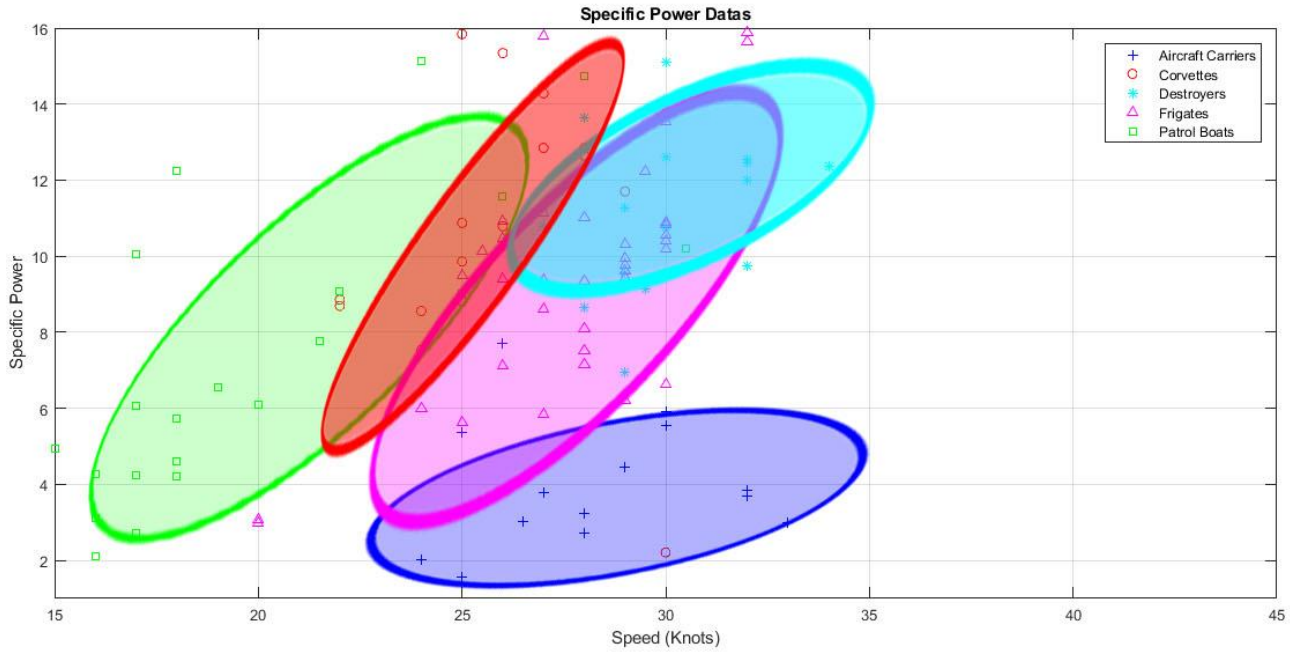

Figure 2-11 Speed-Specific Power Graph

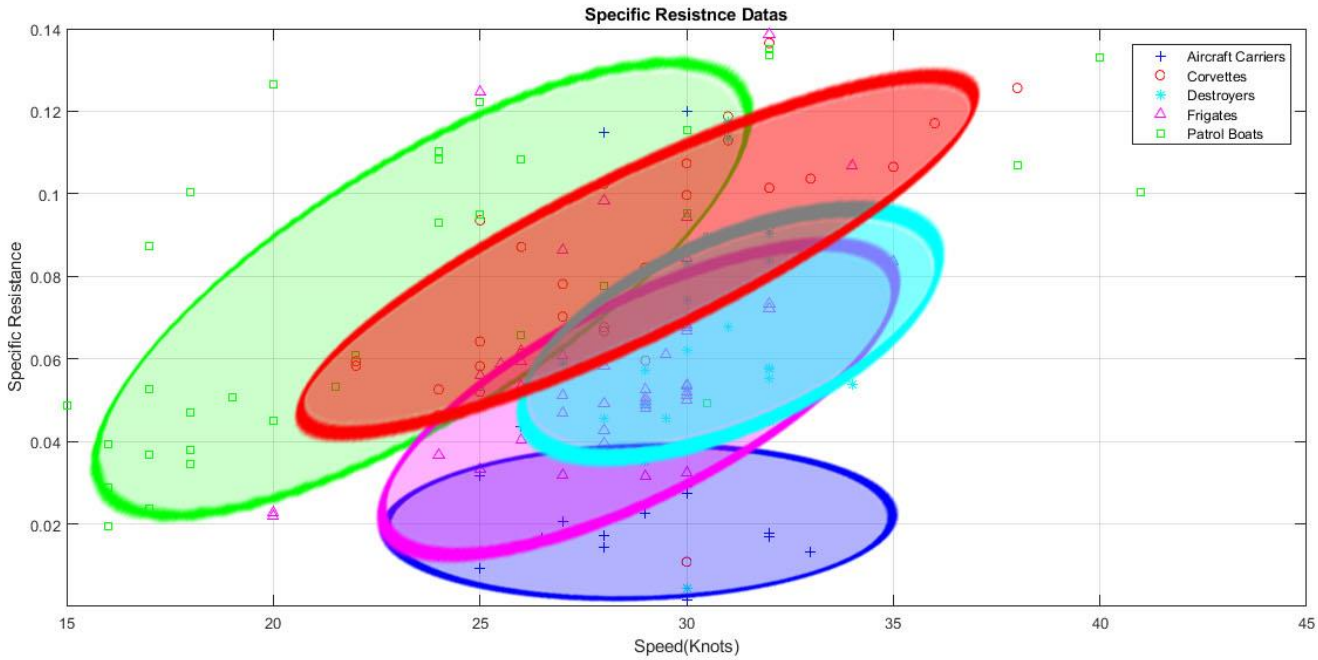

Figure 2-12 Speed-Specific Resistance Graph

Speed efficiency and endurance efficiency values are calculated for all ships in data.Regression lines are generated for varying efficiency values in Figure 2-13 and Figure 2-15 .Naval ships are grouped and efficiency limit lines are also plotted on graphs in Figure 2-14 and Figure 2-16 .

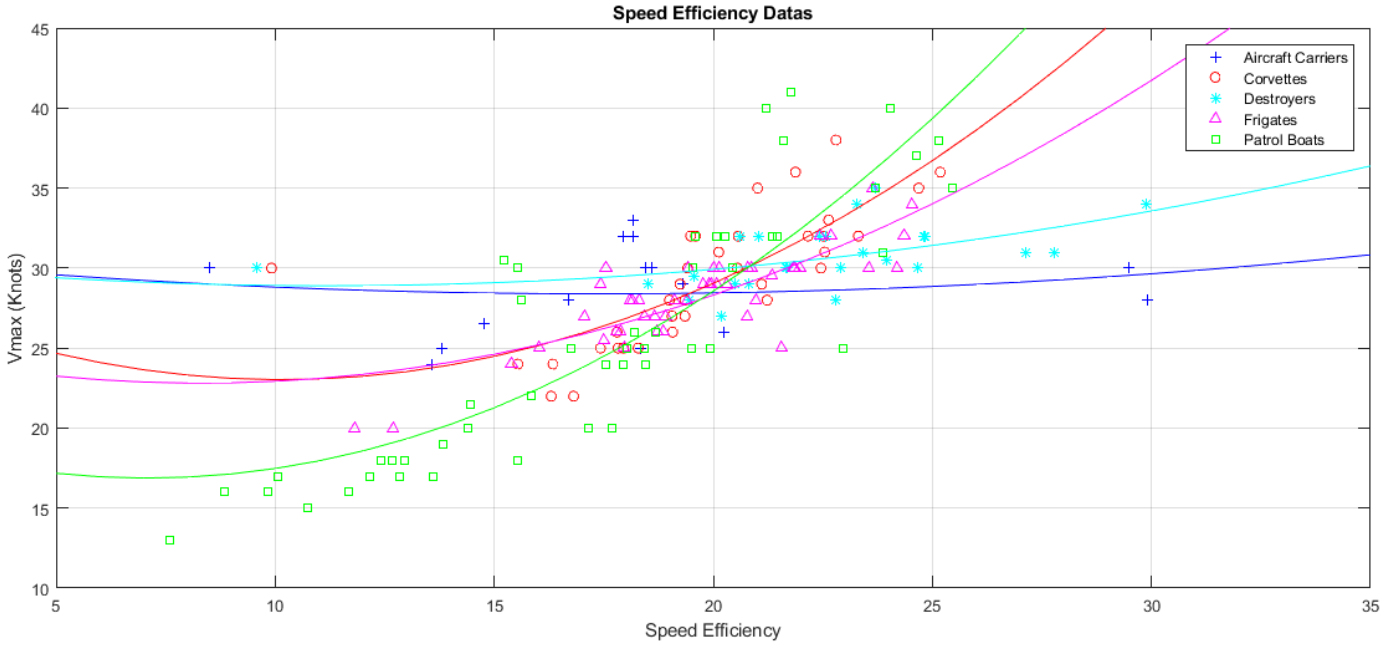

Figure 2-13 Speed Efficiency-Speed Graph

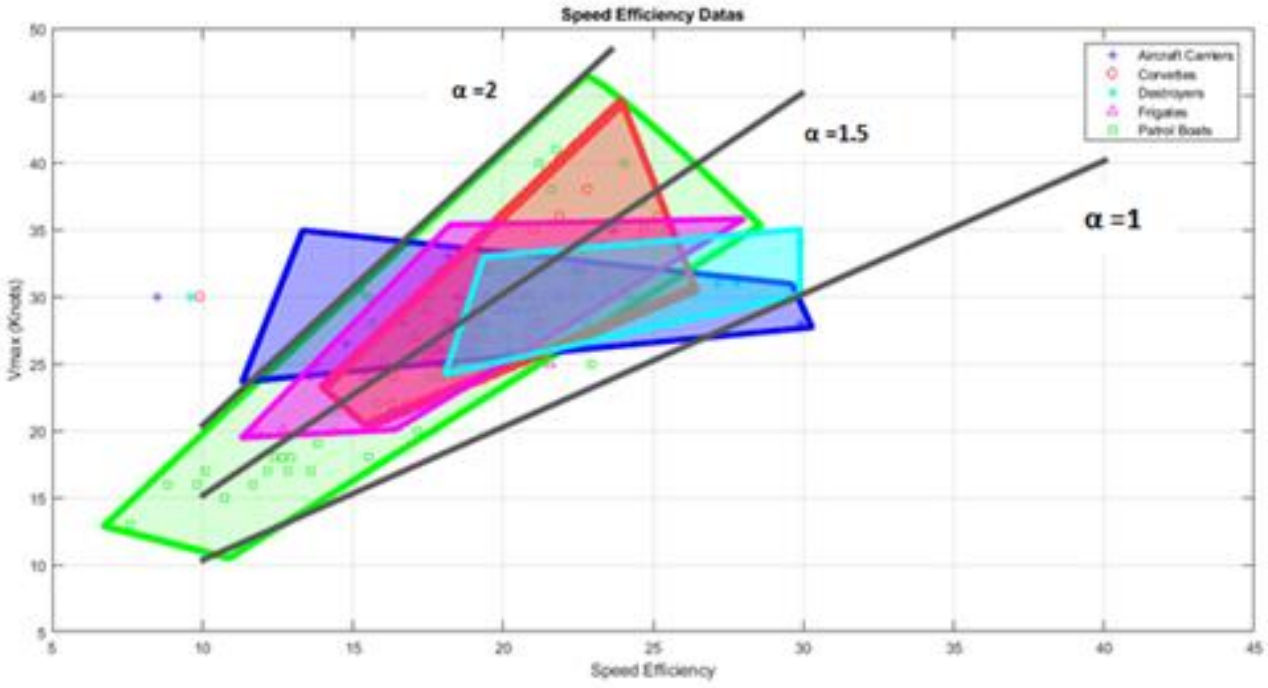

Figure 2-14 Speed Efficiency-Speed Graph

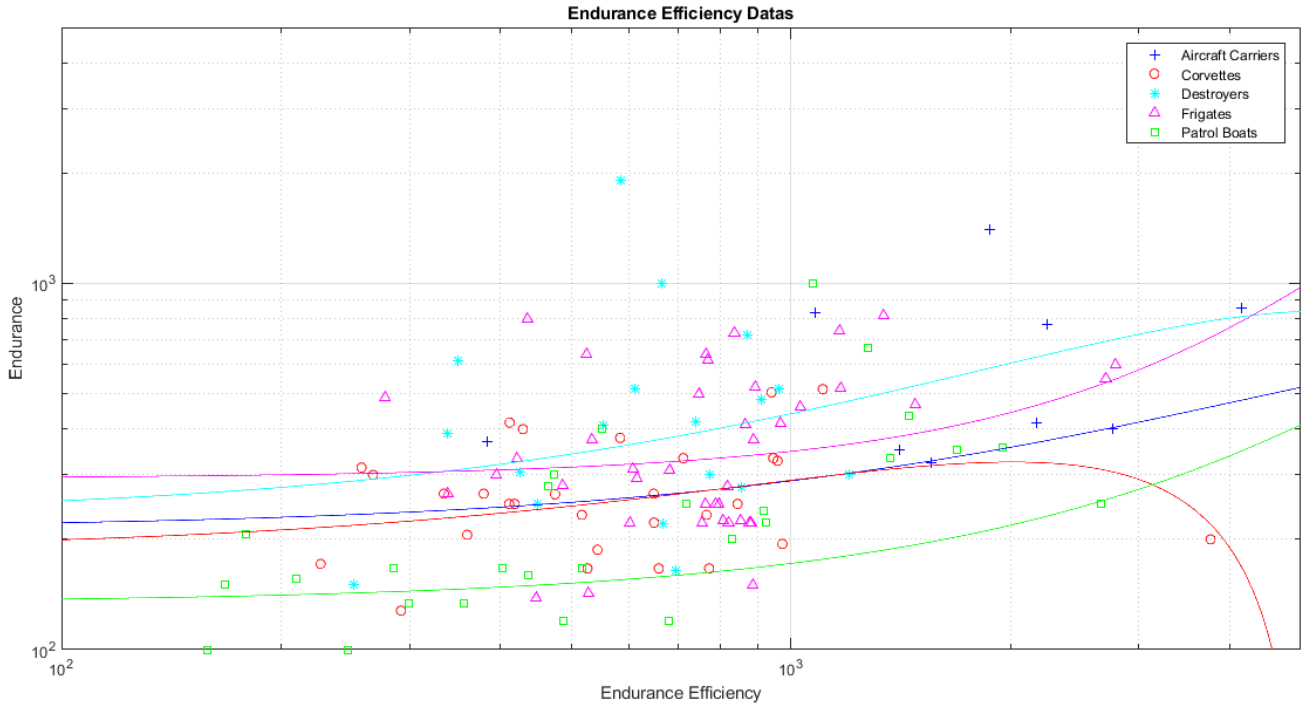

Figure 2-15 Endurance Efficiency-Endurance Time Graph

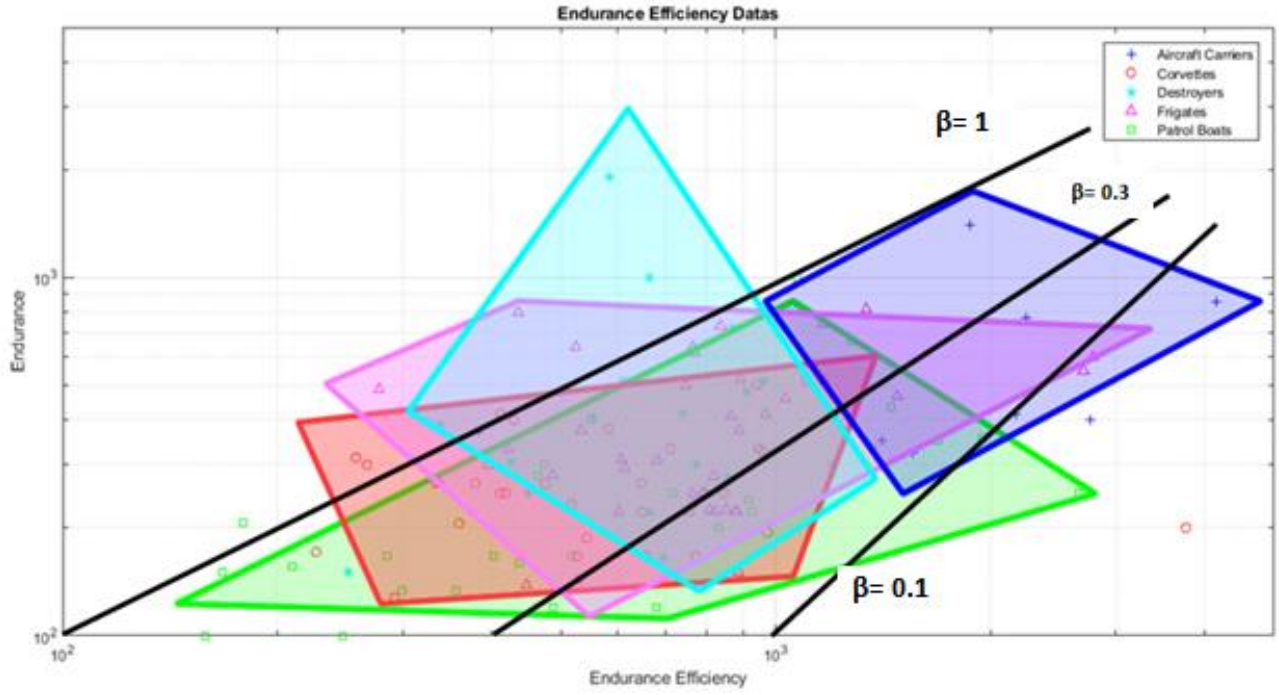

Figure 2-16 Endurance Efficiency-Endurance Time Graph

3. MATHEMETICAL MODEL

Weight components can be calculated with main parameters while using the ship's displacement as a basis.

$$\Delta = \Delta_{SHIP} + \Delta_{PROP} + \Delta_{FUEL} + \Delta_{PAYLOAD} \quad (3)$$

'$\Delta_{PAYLOAD}/\Delta$ ' is called *payload factor*.Payload factor is unitless value.This helps adopting the factor for varying displacement range.

In the same manner;

$$TF = TF_{SHIP} + TF_{PROP} + TF_{FUEL} + TF_{PAYLOAD} \quad (4)$$

Δ is displacement of ship. Δ_{SHIP} is weight of structure and ligtship weight excluding propulsion systems. Δ_{PROP} is weight of propulsion systems of ship. Δ_{FUEL} is weight of tankage and its' auxiliaries. $\Delta_{PAYLOAD}$ is weight of rest of the ship.

Δ_{SHIP} is assumpted a constant fraction of total ship displacement.This value is picked from existing ships.TF_{SHIP} is also calculated according to this fraction.

The weight components which are defined in Equation (3) is calculated as:

$$\Delta_{PROP} = \beta \times P_S \quad (5)$$

$$\Delta_{FUEL} = (SFC \times R / V) \times P_S \quad (6)$$

Ps is total power of ship. β is power factor.It expresses needed propulsion system weight for gaining one unit of power. SFC is specific consumption of fuel. V is ship's maximum speed. R is range of ship.

McKesson's 'Observed Frontier' is used to calculate the power of ship.

$$L / D = 5 + 40 \times (Fn_{VOL})^{-3} \quad (7)$$

L is displacement of ship. D is drag of ship.

$$EHP = D \times V \quad (8)$$

EHP is effective horse power of ship.

$$SHP = EHP / \eta \quad (9)$$

η is efficiency of propulsion.SHP value is used in equation XX to calculate the weight of propulsion system.

$$\Delta = \Delta_{SHIP} + [\beta \times P_S] + [(\frac{(SFC)xR}{V}) \times P_S] + \Delta_{PAYLOAD} \quad (10)$$

$$\Delta = \Delta_{SHIP} + \Delta_{PAYLOAD} + P_S [\beta + (\frac{(SFC)xR}{V})] \quad (11)$$

$$\Delta = \Delta_{SHIP} + \Delta_{PAYLOAD} + \frac{\Delta x V x \eta}{5+(40x(Fn_{VOL})^{-3})} [\beta + (\frac{(SFC)xR}{V})] \quad (12)$$

Equation (12) is the governing equation which shows relationship between speed,range and displacement.

4. PROGRAM OUTPUT

A MATLAB code is generated with mathematical model which is defined in '3.Mathematical model' is calculated with assumptions listed below:

β = 30 lbs / hp
SFC = 0.4 lbs / hp-hr
g = 9.81 m/s^2
ρ = 1,025 t/m^3

Constants g and ρ are universal values which are used in engineering calculations. SFC value is estimated and taken from McKesson's mathematical model. β value is assumpted using datas of existing ship designs.

4.1 Constant Displacement Design Approach

4.1.1 1000 t Design Case

In this case ; displacement value is selected 1000 tonnes for design approach.Design parameters of naval ships in database whose have displacement of 500 to 1500 tonnes are plotted in result graphs(Figure 4-2,Figure 4-3,Figure 4-4). These values shows the relations between displacement,range,power and speed.Graphs are made up from 22 corvettes,18 patrol forces and 6 frigates.

Design space for varying displacement and range values are plotted in Figure 4-3 and Figure 4-4 . Speed value varies from 10 to 45 knots and range value varies from 0 to 8000 nautical miles in this mathemetical model. Mathematical model which is defined in **'3.MATHEMETICAL MODEL'** is calculated for varying displacement and range values.Colors in the bar specifies the weight of payload for each value in the X and Y axes in the graph. Marks on the graphs specifies the values for existing naval ships which is in the database.

Speed – Payload/Displacement relationship is plotted in Figure 4-1.Colored bar is payload (tonnes) in Figure 4-1.

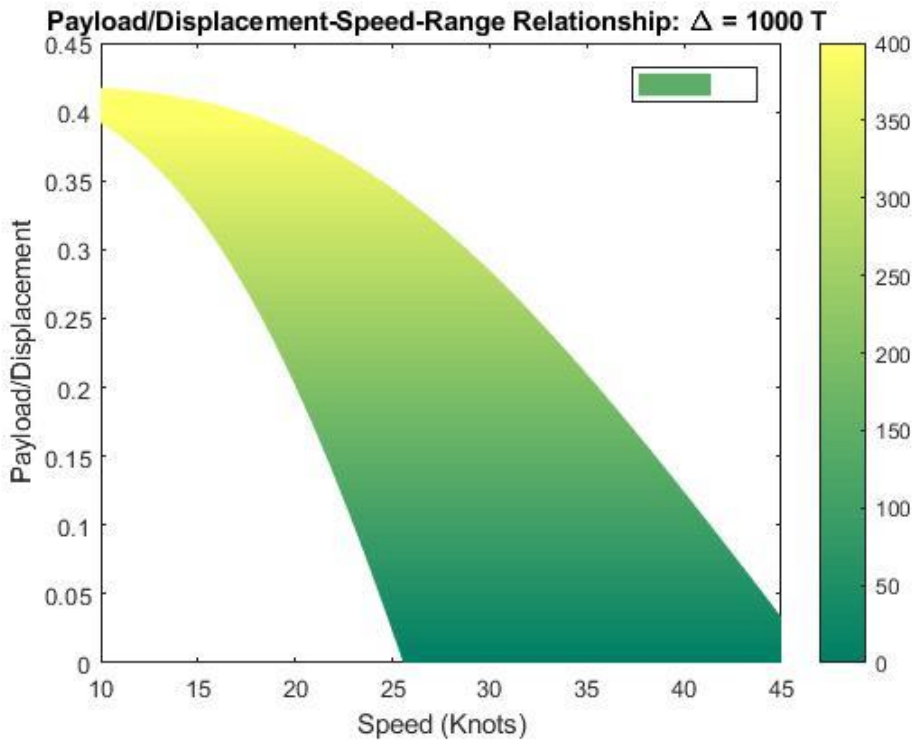

Figure 4-1 Speed – Payload/Displacement Relationship

Speed – Range relationship is plotted in Figure 4-2.Colored bar is payload (tonnes) in Figure 4-2.

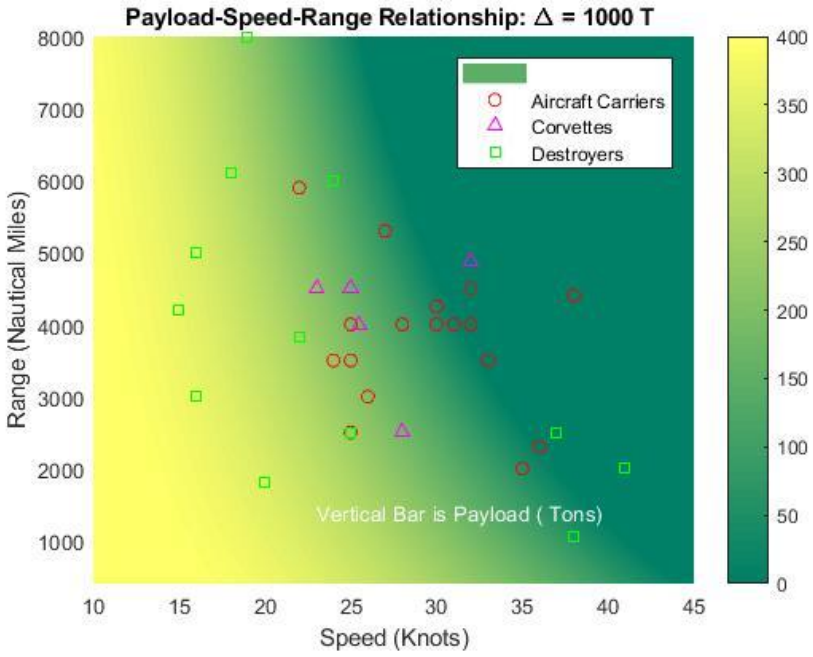

Figure 4-2 Speed-Range Relationship

Speed – Specific Power relationship is plotted in Figure 4-3.Colored bar is payload (tonnes) in Figure 4-3.

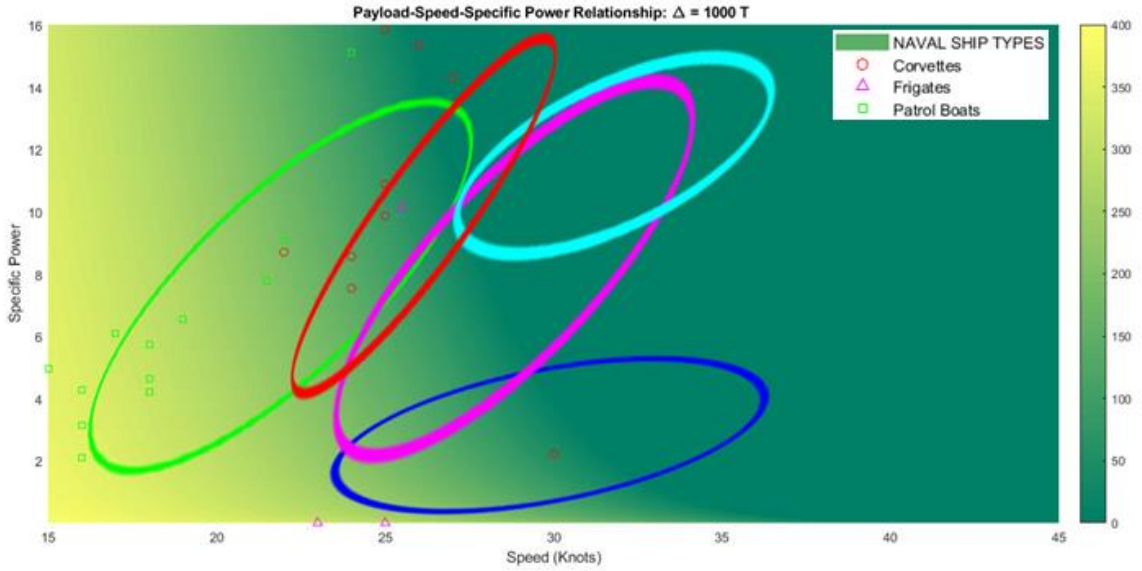

Figure 4-3 Speed-Specific Power Relationship

Speed – Specific Resistance relationship is plotted in Figure 4-4.Colored bar is payload (tonnes) in Figure 4-4.

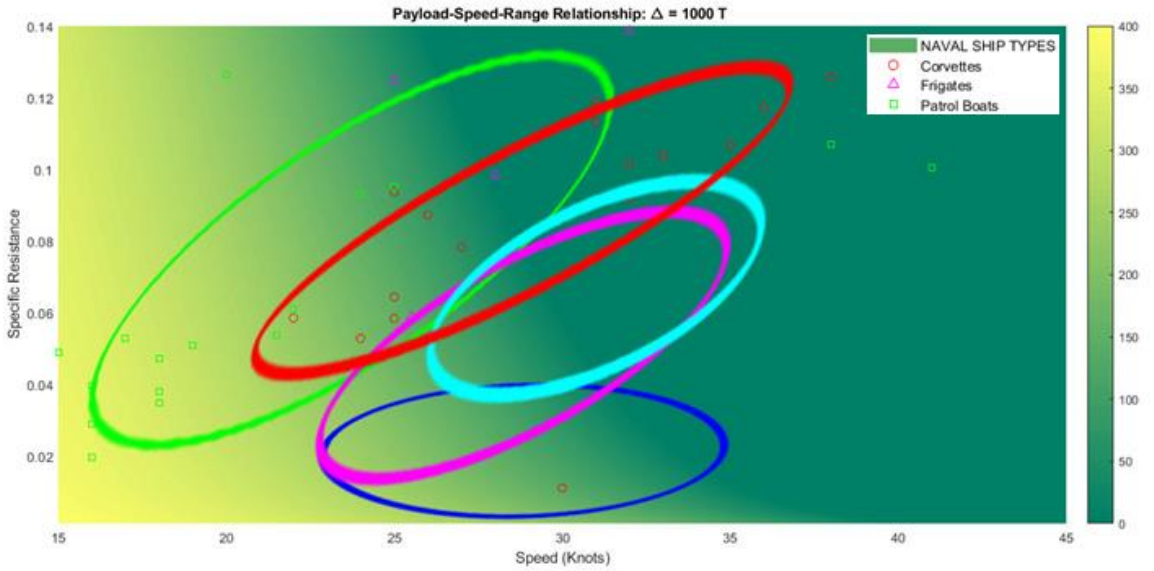

Figure 4-4 Speed-Specific Resistance Relationship

4.1.2 3000 t Design Case

In this case ; displacement value is selected 3000 tonnes for design approach.Design parameters of naval ships in database whose have displacement of 2000 to 4000 tonnes are plotted in graphs(Figure 4-5,Figure 4-6,Figure 4-7,Figure 4-8).These values shows the relations between displacement,range,power and speed.Differences of advanced design parameter values and limit lines for each naval ship type is shown in graphs.Graphs are made up from 3 corvettes,9 destroyers and 12 frigates.

Design space for varying displacement and range values are plotted in Figure 4-7 and Figure 4-8. Speed value varies from 0 to 45 knots and range value varies from 0 to 8000 nautical miles in this mathemetical model. Mathematical model which is defined in '**3.MATHEMETICAL MODEL'** is calculated for varying displacement and range values.Colors in the bar specifies the weight of payload for each value in the X and Y axes in the graph. Marks on the graphs specifies the values for existing naval ships which is in the database.

Speed – Payload/Displacement relationship is plotted in Figure 4-5.Colored bar is payload (tonnes) in Figure 4-5

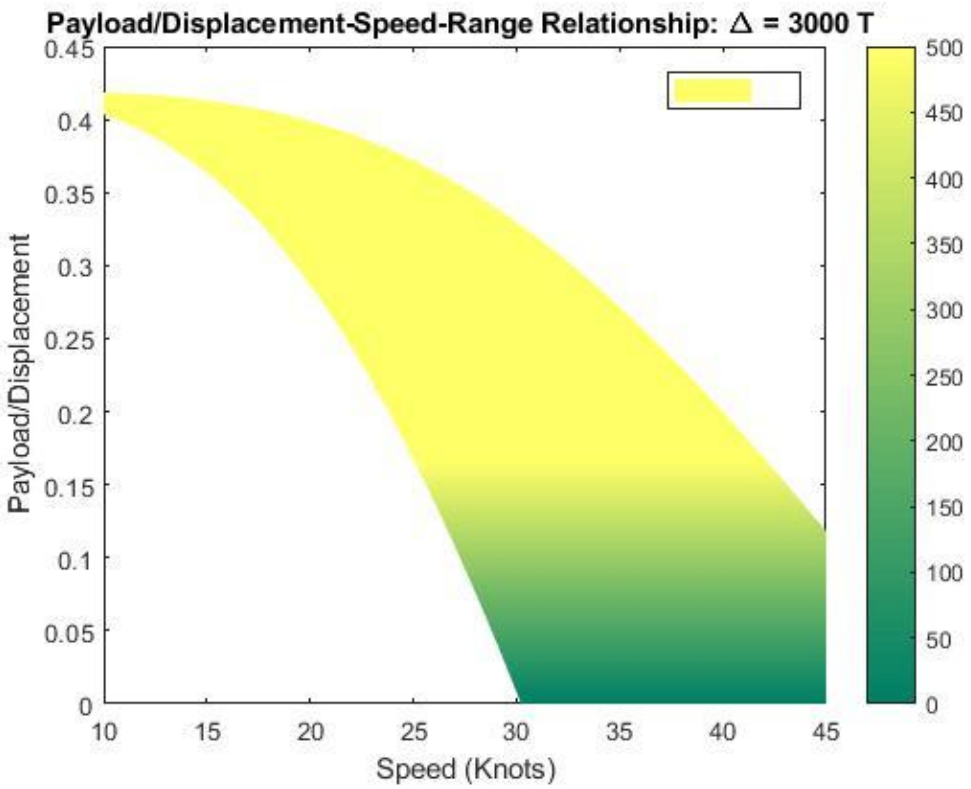

Figure 4-5 Speed – Payload/Displacement Relationship

Speed – Range relationship is plotted in Figure 4-6.Colored bar is payload (tonnes) in Figure 4-6.

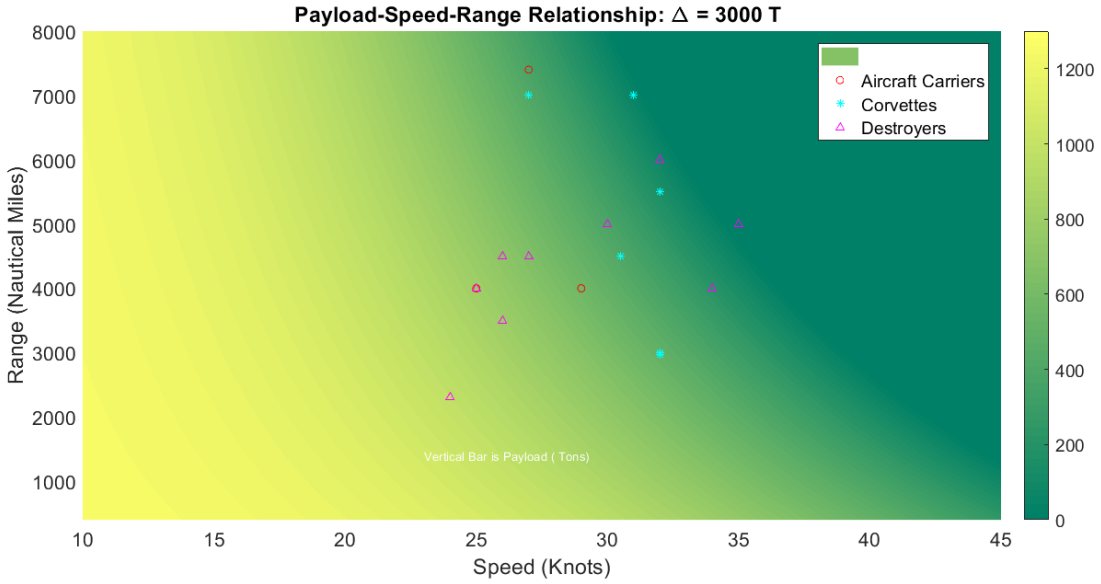

Figure 4-6 Speed-Range Relationship

Speed – Specific Power relationship is plotted in Figure 4-7.Colored bar is payload (tonnes) in Figure 4-7.

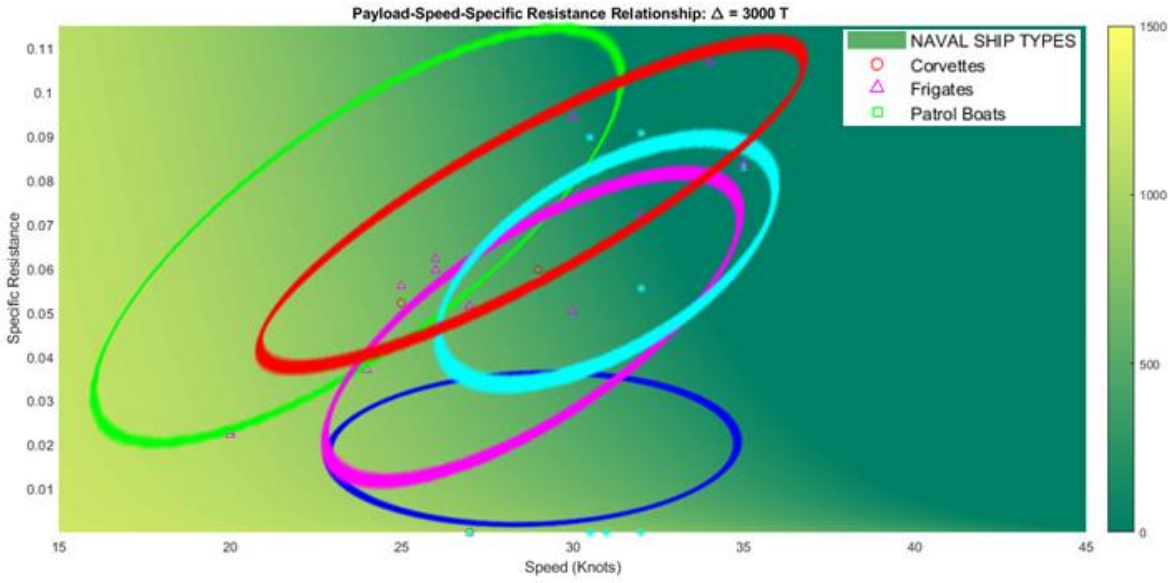

Figure 4-7 Speed-Specific Power Relationship

Speed – Specific Resistance relationship is plotted in Figure 4-8.Colored bar is payload (tonnes) in Figure 4-8.

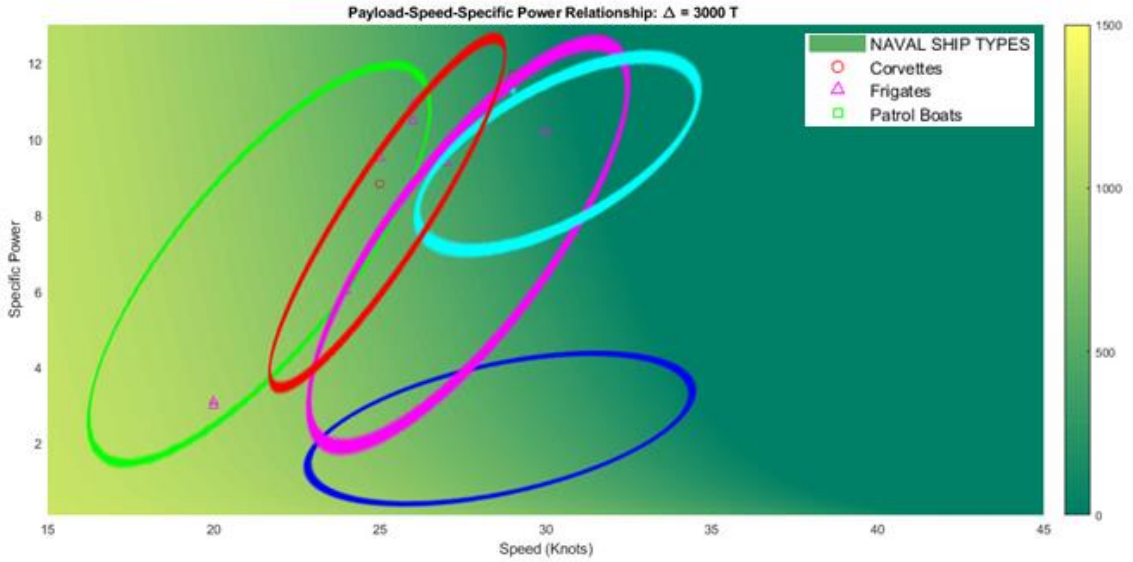

Figure 4-8 Speed-Specific Resistance Relationship

4.2 Constant Speed Design Approach

4.2.1 25 Knots Design Case

In this case ; maximum speed of 25 knots is selected fo design approach.Design parameters of naval ships in database whose have maximum speed 24 to 26 knots are plotted in graphs(Figure 4-9 Figure 4-10 Figure 4-11 Figure 4-12).These values shows the relations between displacement,range,power and speed.Differences of advanced design parameter values and limit lines for each naval ship type is shown in graphs.Graphs are made up from 6 aircraft carriers,11 corvettes,4 destroyers,12 patrol forces and 18 frigates.

Design space for varying displacement and range values are plotted in Figure 4-11 and Figure 4-12. Displacement value varies from 0 to 15000 tonnes and range value varies from 0 to 12000 nautical miles in this mathemetical model. Mathematical model which is defined in **'3.MATHEMETICAL MODEL'** is calculated for varying displacement and range values.Colors in the bar specifies the value for each value in the X and Y axes in the graph. Marks on the graphs specifies the values for existing naval ships which is in the database.

Displacement – Payload/Displacement relationship is plotted in Figure 4-9.Colored bar is payload (tonnes) in Figure 4-9

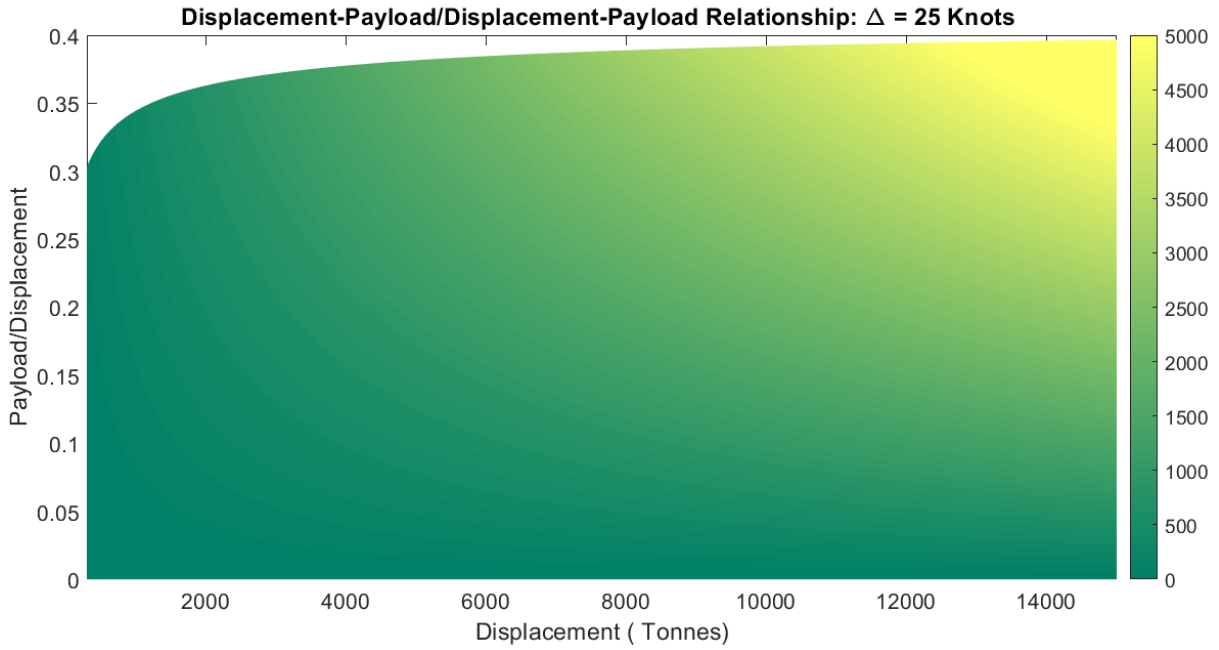

Figure 4-9 Displacement – Payload/Displacement Relationship

Displacement – Range relationship is plotted in Figure 4-10.Colored bar is payload (tonnes) in Figure 4-10

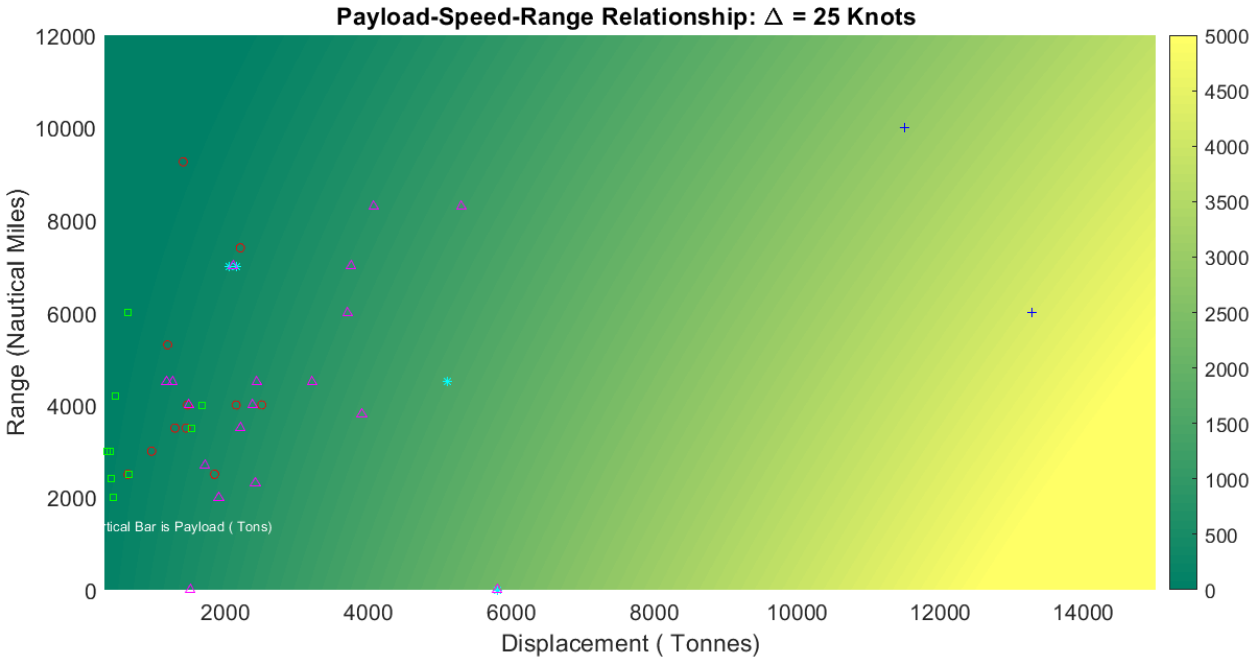

Figure 4-10 Displacement-Range Relationship

Displacement – Specific Power relationship is plotted in Figure 4-11.Colored bar is payload (tonnes) in Figure 4-11.

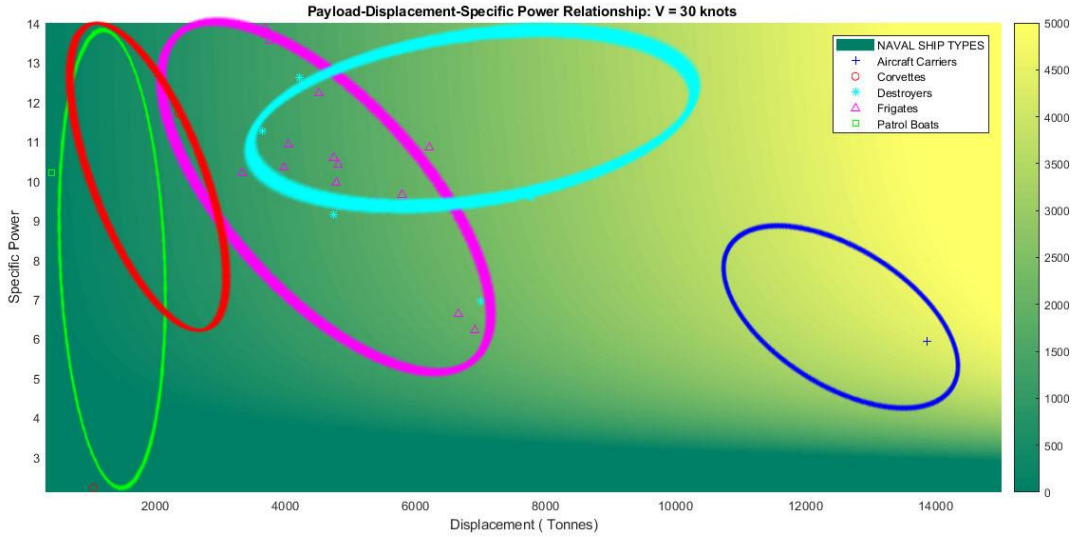

Figure 4-11 Displacement-Specific Power Relationship

Displacement – Specific Resistance relationship is plotted in Figure 4-12.Colored bar is payload (tonnes) in Figure 4-12.

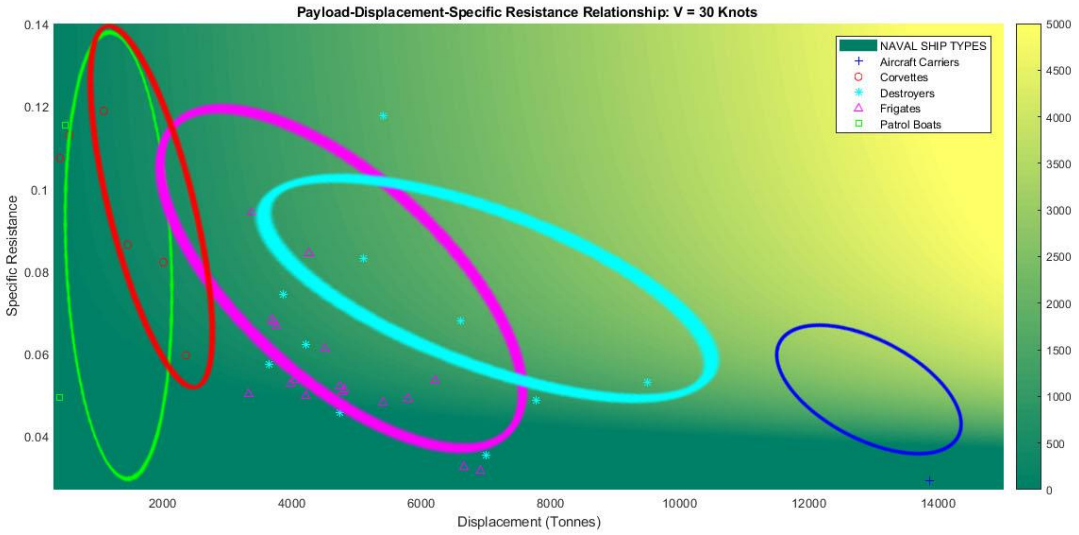

Figure 4-12 Displacement-Specific Resistance Relationship

4.2.2 30 Knots Design Case

In this case ; maximum speed of 30 knots is selected fo design approach.Design parameters of naval ships in database whose have maximum speed 29 to 31 knots are plotted in graphs.These values shows the relations between displacement,range,power and speed.Differences of advanced design parameter values and limit lines for each naval ship type is shown in graphs(Figure 4-13,Figure 4-14,Figure 4-15,Figure 4-16). Graphs are made up from 6 aircraft carriers,11 corvettes,4 destroyers,12 patrol forces and 18 frigates.

Design space for varying displacement and range values are plotted in Figure 4-15 and Figure 4-16. Displacement value varies from 0 to 15000 tonnes and range value varies from 0 to 12000 nautical miles in this mathemetical model. Mathematical model which is defined in **'3.MATHEMETICAL MODEL'** is calculated for varying displacement and range values.Colors in the bar specifies the value for each value in the X and Y axes in the graph. Marks on the graphs specifies the values for existing naval ships which is in the database.

Displacement – Payload/Displacement relationship is plotted in Figure 4-13.Colored bar is payload (tonnes) in Figure 4-13

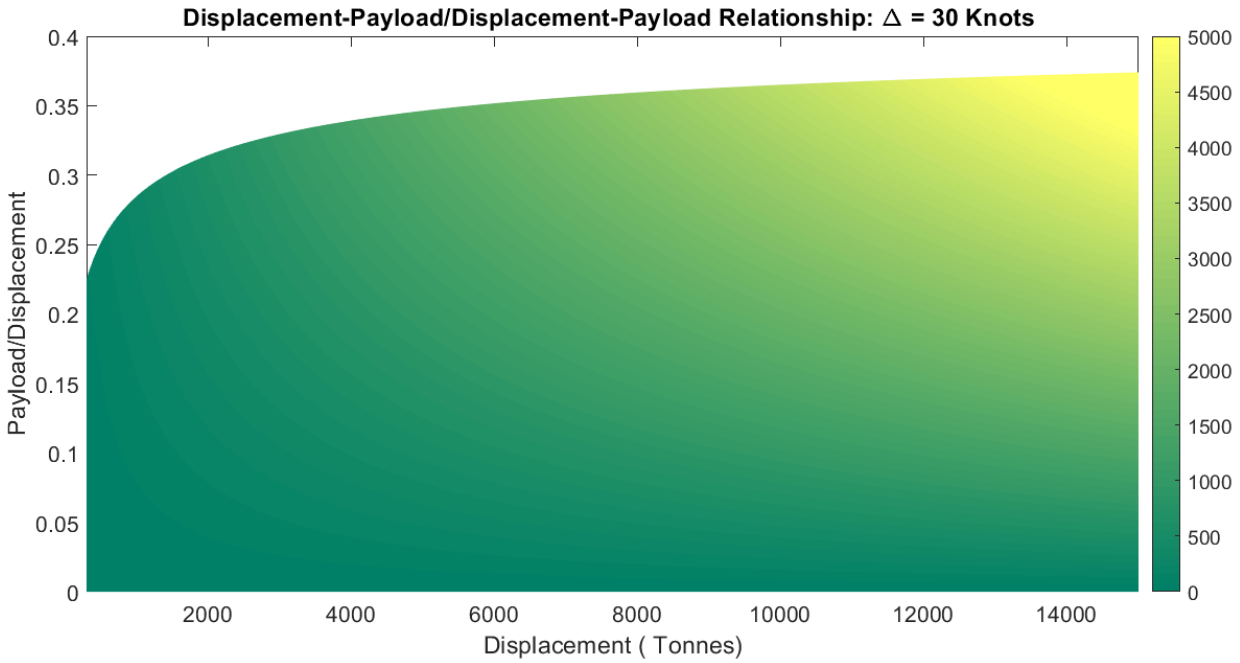

Figure 4-13 Displacement – Payload/Displacement Relationship

Displacement – Range relationship is plotted in Figure 4-14.Colored bar is payload (tonnes) in Figure 4-14

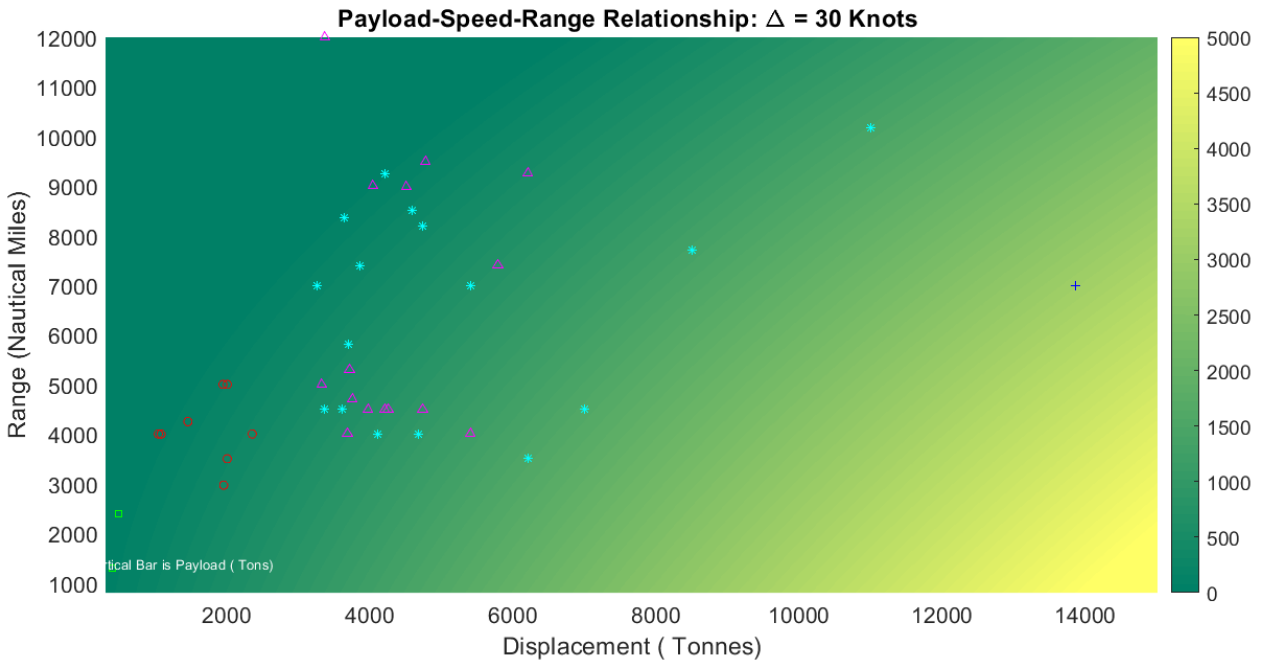

Figure 4-14 Displacement-Range Relationship

Displacement – Specific Power relationship is plotted in Figure 4-15.Colored bar is payload (tonnes) in Figure 4-15.

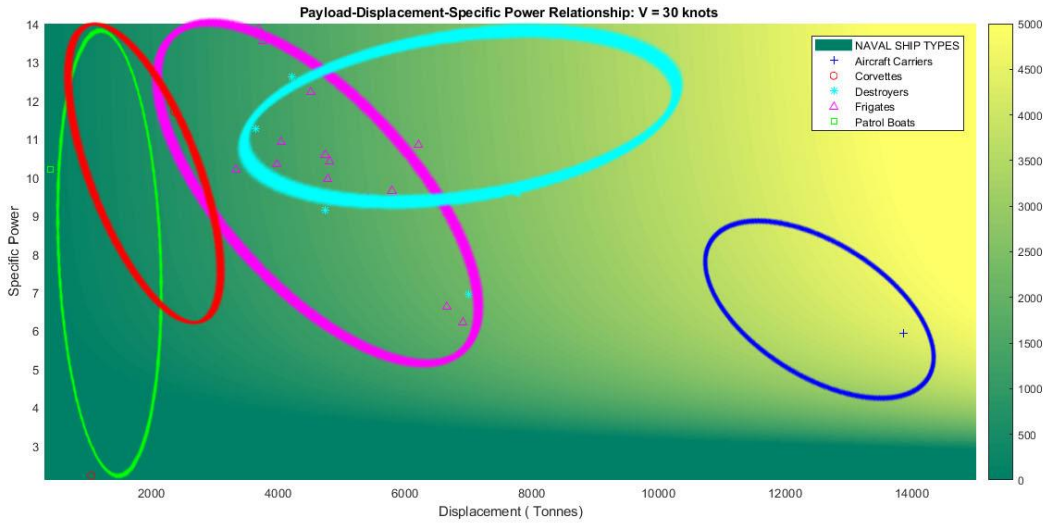

Figure 4-15 Displacement - Specific Power Relationship

Displacement – Specific Resistance relationship is plotted in Figure 4-16.Colored bar is payload (tonnes) in Figure 4-16.

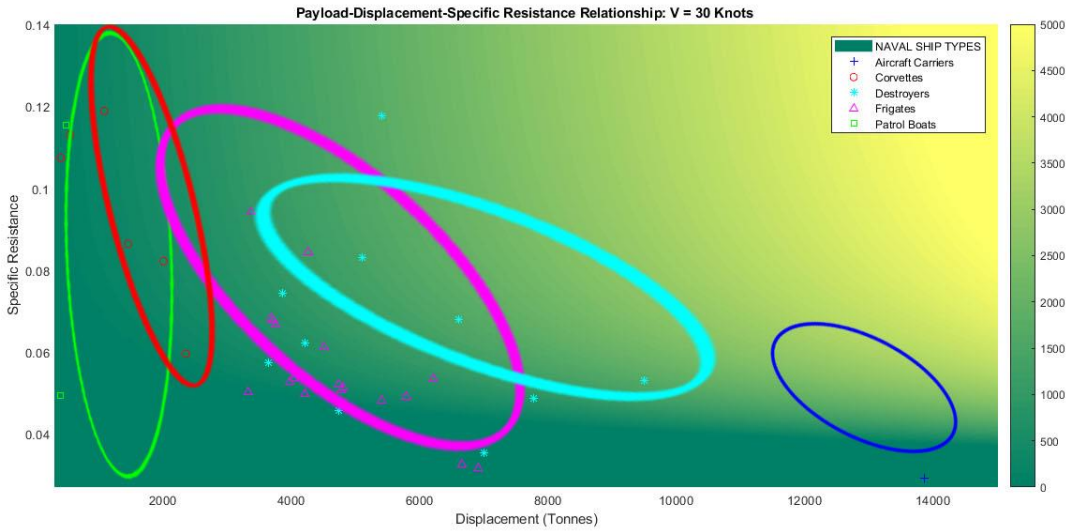

Figure 4-16 Displacement-Specific Resistance Relationship

4.3 Design Approach for Optimal Payload Weight

In this case payload weight of 750 tonnes is selected for design approach. Design parameters of naval ships in database are plotted in graphs.These values shows the relations between displacement, range,power and speed.Differences of advanced design parameter values and limit lines for each naval ship type is shown in graphs.

Displacement value varies from 0 to 20000 tonnes,maximum speed value varies from 10 to 40 knots and range value varies from 0 to 12000 nautical miles in this case. Mathematical model which is defined in **'3.MATHEMETICAL MODEL'** is calculated for varying displacement,speed and range values.Colors in the bar specifies third variable which is not used in the X and Y axes in of graph. Marks and regression lines on the graphs specifies specifications of naval ships which is in the database.

In optimal payload case,there are three variables in mathematical model.This induces higher degree equations in color change zones in 2-D top view plot.Therefore results are plotted in both 3-D and 2-D maps.

Displacement – Speed relationship is plotted in Figure 4-17 and Figure 4-18.Colored bar is payload (tonnes) in Figure 4-17 and Figure 4-18.

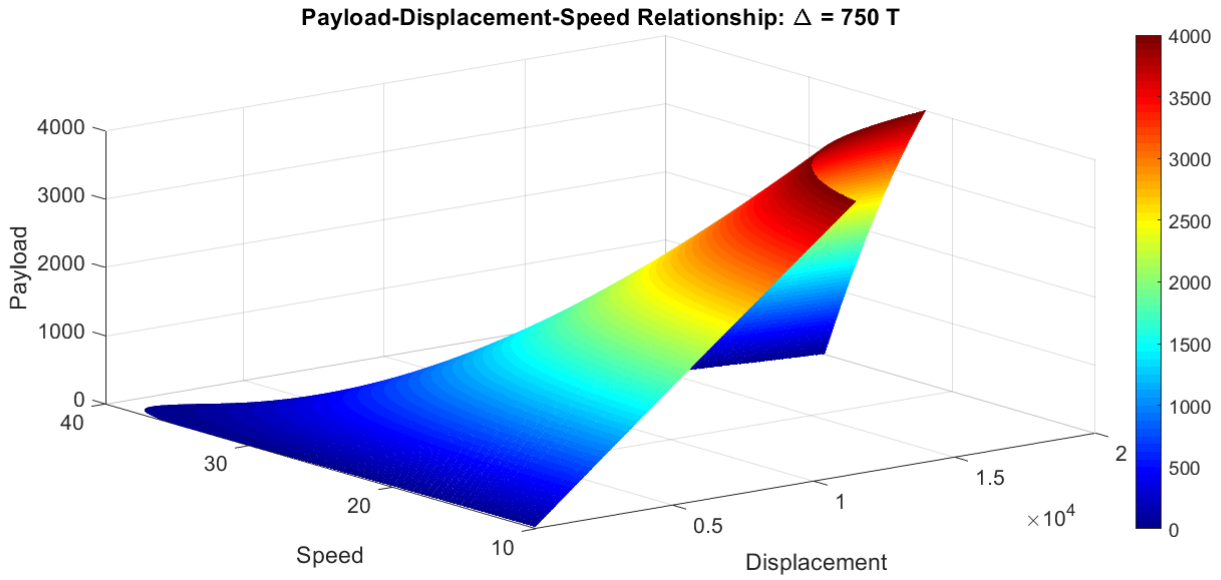

Figure 4-17 Displacement-Speed-Payload Relationship

Top-view of Figure 4-17 is plotted in Figure 4-18.Displacement and speed values of existing ships are also plotted in Figure 4-18. Colored lines represents the regression lines for same colored naval ship type which is defined in table on Figure 4-18.

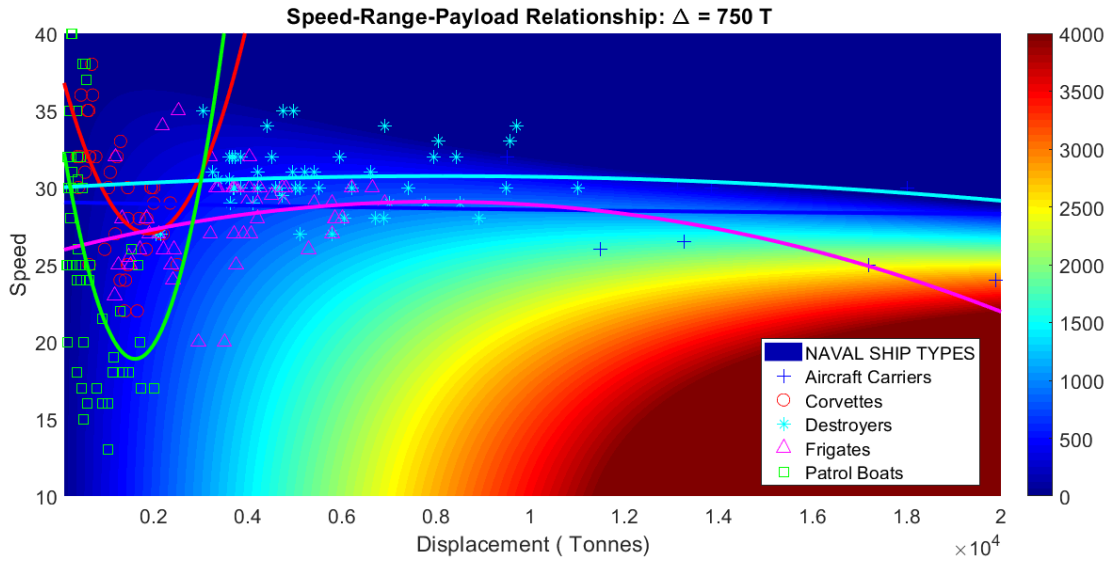

Figure 4-18 Displacement-Speed-Payload Relationship

Displacement – Range relationship is plotted in Figure 4-19 and Figure 4-20.Colored bar is payload (tonnes) in Figure 4-19 and Figure 4-20

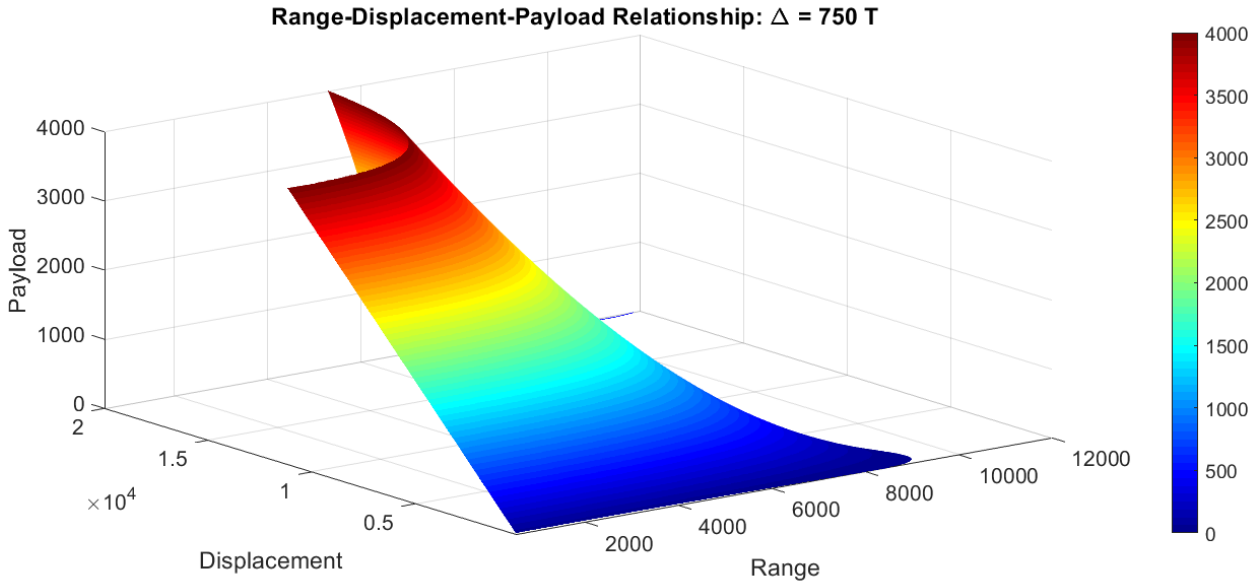

Figure 4-19 Displacement-Range-Payload Relationship

Top-view of Figure 4-19 is plotted in Figure 4-20.Range and speed values of existing ships are also plotted in Figure 4-20

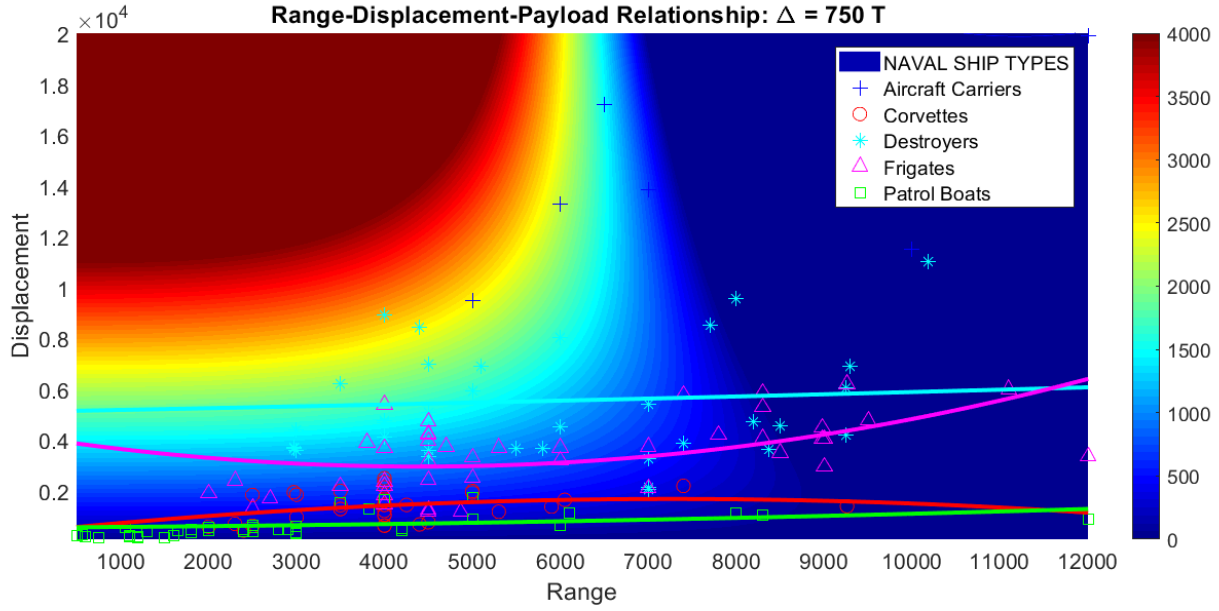

Figure 4-20 Displacement-Range-Payload Relationship

Range– Speed relationship is plotted in Figure 4-21 and Figure 4-22.Colored bar is payload (tonnes) in Figure 4-21 and Figure 4-22 .

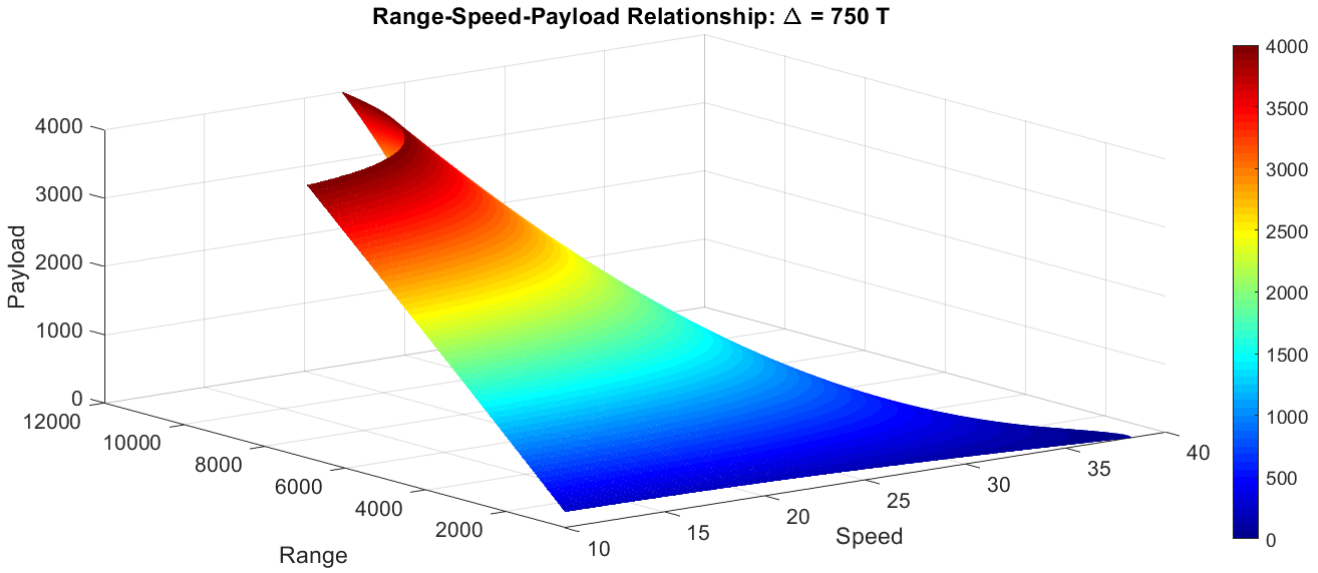

Figure 4-21 Speed-Range-Payload Relationship

Top-view of Figure 4-21 is plotted in Figure 4-22.Displacement and speed values of existing ships are also plotted in Figure 4-22. Colored lines represents the regression lines for same colored naval ship type which is defined in table in Figure 4-22.

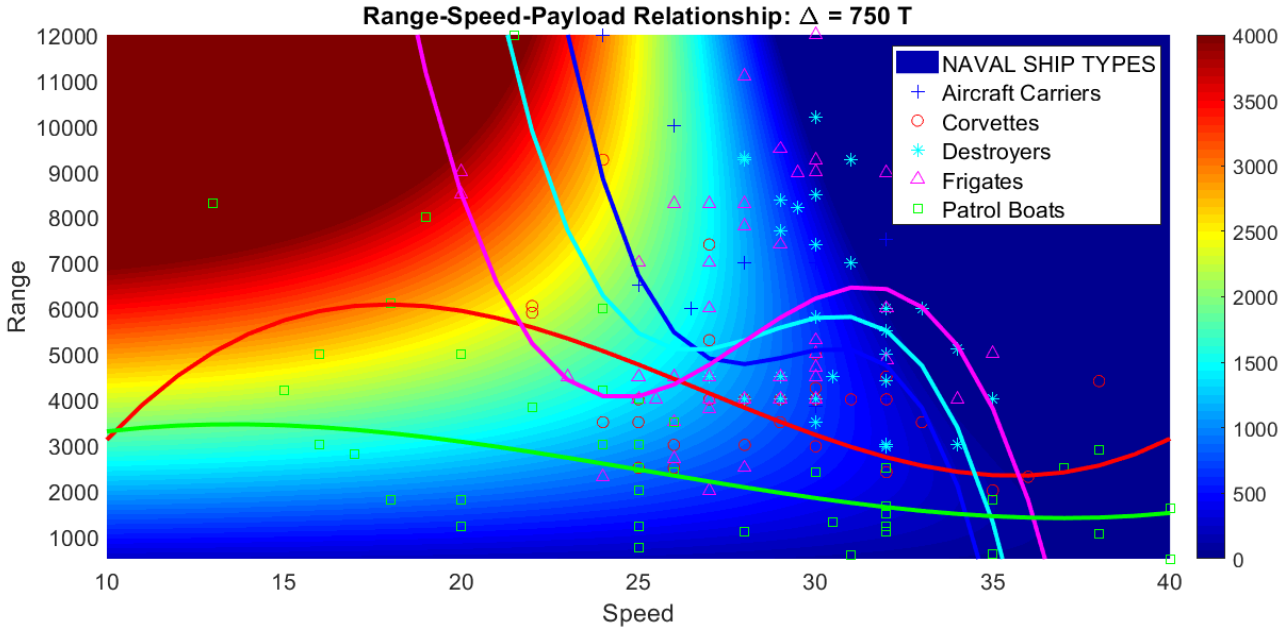

Figure 4-22 Speed-Range-Payload Relationship

5. COMPARISON OF NAVAL SHIPS BASED ON PERFORMANCE PARAMETERS

In this section relation between main specification and performance parameters of 8 naval combatants are surveyed.Specific resistance,specific power,endurance efficiency and speed efficiency are calculated using main specification of combatants.

Table 1 Main Specifications of Naval Ships

		Displacement (t)	Length (m)	Beam (m)	Draught (m)	Maximum Speed (Knots)	Endurance		Propulsion	
							Range (nm)	Service Speed (Knots)	Propulsion Type	Power (hp)
Oliver Hazard Perry Class	Destroyer	3638.00	136.00	13.70	4.50	29.00	8370.00	20.00	COGOG	41000.00
Stereguschiy Class	Corvette	2200.00	105.00	13.00	3.70	27.00	7400.00	14.00	Diesel	23320.00
Serviola Class	Patrol Force	1147.00	68.70	10.40	3.40	19.00	8000.00	12.00	Diesel	7500.00
Rattanakosin Class	Corvette	960.00	76.80	9.60	2.40	26.00	3000.00	16.00	Diesel	14730
Badr Class	Corvette	1038.00	74.70	9.60	2.70	30.00	4000.00	20.00	CODOG	23000.00
Dong Hae Class	Corvette	1076.00	78.10	9.60	2.60	31.00	4000.00	15.00	CODOG	26820.00
Bremen Class	Frigate	3680.00	130.00	14.50	6.50	30.00	4000.00	18.00	CODOG	51000.00
Karel Doorman Class	Frigate	3320.00	122.30	14.40	4.30	30.00	5000.00	18.00	CODOG	33800.00

Table 2 Performance Parameters of Naval Ships

		Performance Parameters			
		Specific Power	Specific Resistance	α - Power Efficiency	β - Endurance Efficiency
Oliver Hazard Perry Class	Destroyer	15.113	0.563	0.650	0.759
Stereguschiy Class	Corvette	14.215	0.569	0.673	0.902
Serviola Class	Patrol Force	8.769	0.499	0.641	0.701
Rattanakosin Class	Corvette	20.576	0.856	0.636	0.463
Badr Class	Corvette	29.714	1.071	0.655	0.713
Dong Hae Class	Corvette	33.426	1.166	0.641	1.070
Bremen Class	Frigate	18.585	0.670	0.637	0.496
Karel Doorman Class	Frigate	13.653	0.492	0.720	0.455

Oliver Hazard Perry Class Destroyer and Bremen Class Frigate has similar displacement weight.Oliver Hazard Perry Class has higher maximum range as a destroyer..Both ships have similar power efficiencies differently from their specific power values.Destroyers need higher endurance range according to their naval missions and endurance efficiency is in higher grades than Bremen Class combatant.

Stereguschiy Class Corvette and Badr Class Corvette has similar maximum power and power efficiency values. Stereguschiy Class combatant is two times heavier than Badr Class combatant.This causes inversed ratio in specific power for these combatants.Stereguschiy Class combatant has two times more range with less service speed. As a result of this,Stereguschiy Class combatant has higher endurance efficiency with higher displacement.

Rattanakosin Class Corvette and Karel Doorman Class Frigate has similar endurance efficiencies with different ranges and displacement.Karel Doorman Class combatant is longer and heavier than Rattanakosin Class Corvette.As a result of this,Rattanakosin Class Corvette has higher specific power and specific resistane values.

Serviola Class Patrol Force and Dong Hae Class Corvettes have maximum power and displacement at similar grades.Dong Hae Class combatant has specific resistance and specific power at higher grades.Difference of maximum speed between two combatants causes this situation.

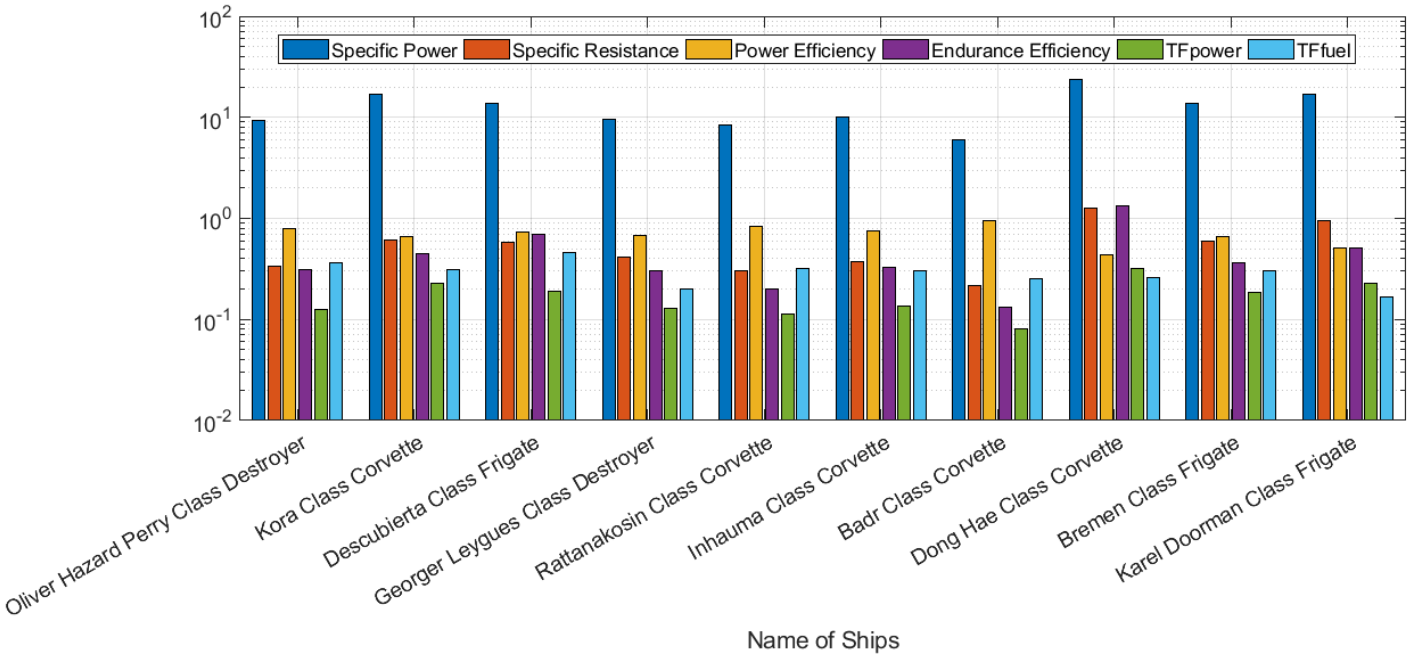

Figure 5-1 Performance Parameters of Naval Ships

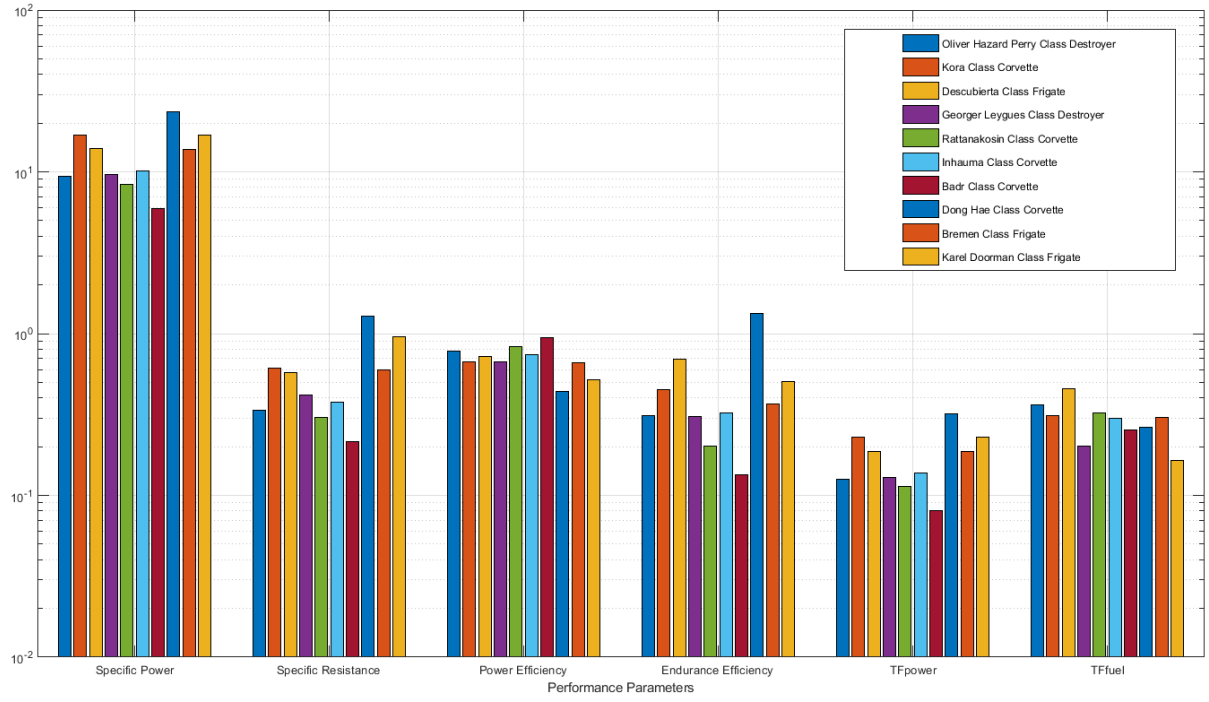

Figure 5-2 Performance Parameters of Naval Ships

6. CONCLUSION

In this thesis, impacts of advanced design parameters to the payload factor are surveyed and design spaces are created in design approaches using main specifications of naval ships.The mathematical model used in project is intented for basic design and works as a lie detector.The mathematical model provides trade-off capability between main specifications to gain more payload weight.

There are assumptions used in this thesis.Development in technology,propulsion type,hull type or advanced structural and hydrodynamical capabilities affects the assumptions.

Ship's weight,speed and power are cost of designer.Designer pays from payload weight to gain more power and speed.If the value of payload weight is more than the cost of displacement weight; design will be counted as good design.

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[5] McKesson,Chris B. ; The Practical Design of Advanced Marine Vehicles

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APPENDIX

Ship Name/Class	Ship Type	Displacement full load (tons)	Length(m)	Beam(m)
Charles de Gaulle Class	Aircraft Carrier	42500	261.50	64.40
Clemencau Class	Aircraft Carrier	32780	265.00	104.00
Jeanne D'Arc Class	Aircraft Carrier	13270	182.00	24.00
Garibaldi Class	Aircraft Carrier	13850	180.00	33.40
Kuznetsov Class	Aircraft Carrier	58500	304.50	121.40
Krechyet Class	Aircraft Carrier	40400	274.00	51.00
Principe de Asturias	Aircraft Carrier	17188	195.90	79.70
Chakri Naruebet Class	Aircraft Carrier	11485	182.60	100.10
Colossus Class	Aircraft Carrier	19890	211.80	24.40
Hermes Class	Aircraft Carrier	28700	208.80	27.40
Invincible Class	Aircraft Carrier	20600	209.10	36.00
Enterprise Class	Aircraft Carrier	93970	342.30	40.50
Cavour Class	Aircraft Carrier	27100	244.00	39.00
Giuseppe Garibaldi Class	Aircraft Carrier	13139	179.00	30.40
Hyuga Class	Aircraft Carrier	18000	197.00	33.00
Queen Elizabeth Class	Aircraft Carrier	65000	284.00	73.00
Sao Paulo	Aircraft Carrier	34000	265.00	31.70

Ship Name/Class	Ship Type	Draught(m)	Max. Speed (knots)	SHP
Charles de Gaulle Class	Aircraft Carrier	9.40	27.00	161000
Clemencau Class	Aircraft Carrier	28.20	32.00	126000
Jeanne D'Arc Class	Aircraft Carrier	7.30	26.50	40000
Garibaldi Class	Aircraft Carrier	6.70	30.00	82000
Kuznetsov Class	Aircraft Carrier	34.40	30.00	20000
Krechyet Class	Aircraft Carrier	10.00	29.00	180000
Principe de Asturias	Aircraft Carrier	30.80	25.00	92000
Chakri Naruebet Class	Aircraft Carrier		26.00	88480
Colossus Class	Aircraft Carrier	7.50	24.00	40000
Hermes Class	Aircraft Carrier	8.70	28.00	78000
Invincible Class	Aircraft Carrier	8.00	28.00	448000
Enterprise Class	Aircraft Carrier	11.90	33.00	280000
Cavour Class	Aircraft Carrier	8.70	28.00	88000
Giuseppe Garibaldi Class	Aircraft Carrier	6.70	30.00	320000
Hyuga Class	Aircraft Carrier	7.00	30.00	100000
Queen Elizabeth Class	Aircraft Carrier	11.00	25.00	102000
Sao Paulo	Aircraft Carrier	8.60	32.00	126000

Ship Name/Class	Ship Type	Displacement full load (tons)	Length(m)	Beam(m)
Nachucka II	Corvette	770	59.30	12.60
Bung Tomo Class	Corvette	2000	95.00	12.80
Joao Coutingo Class	Corvette	1401	84.60	10.30
C 58 Class	Corvette	540	58.40	8.50
MGB 62 Class	Corvette	643	63.00	9.30
Barroso Class	Corvette	2350	103.40	11.40
Inhauma Class	Corvette	2140	95.80	11.40
Tarantul Class	Corvette	455	56.10	11.50
Pauk II Class	Corvette	440	58.50	10.20
Esmeraldas Class	Corvette	685	62.30	9.30
Kedah Class	Corvette	1650	91.10	12.85
Victory Class	Corvette	595	62.40	8.50
Visby Class	Corvette	620	73.00	10.40
Göteborg Class	Corvette	399	57.00	8.00
Stockholm Class	Corvette	372	50.00	7.50
Pattani Class	Corvette	1440	95.50	11.60
Rattanakosin Class	Corvette	960	76.80	9.60

Ship Name/Class	Ship Type	Displacement full load (tons)	Length(m)	Beam(m)
Khamronsin Class	Corvette	630	62.00	8.20
Al Manama Class	Corvette	632	63.00	9.30
Braunschweig Class	Corvette	1840	88.80	13.20
Kora Class	Corvette	1460	91.10	10.50
Project 28	Corvette	2500	109.20	14.17
Fatafillah Class	Corvette	1450	84.00	11.10
Sigma Class	Corvette	1692	90.70	13.00
Eilat Class	Corvette	1295	85.00	11.90
Minerva Class	Corvette	1285	86.60	10.50
Po Hang Class	Corvette	1220	88.30	10.00
Dong Hae Class	Corvette	1076	78.10	9.60
Kasturi Class	Corvette	1850	97.30	11.30
Assad Class	Corvette	705	62.30	9.30
Qahir Class	Corvette	1450	83.70	11.50
Kazsub Class	Corvette	1183	82.30	10.00
Baptista De Andrade Class	Corvette	1380	84.60	10.30
Badr Class	Corvette	1038	74.70	9.60
Milgem Class	Corvette	2000	99.00	14.40

Ship Name/Class	Ship Type	Draught(m)	Max. Speed (knots)	SHP
Khamronsin Class	Corvette	2.50	25.00	9980
Al Manama Class	Corvette	2.90	32.00	12820
Braunschweig Class	Corvette	4.80	26.00	19850
Kora Class	Corvette	4.50	25.00	14400
Project 28	Corvette	3.72	25.00	22030
Fatafillah Class	Corvette	3.30	30.00	25440
Sigma Class	Corvette	3.60	28.00	21725
Eilat Class	Corvette	3.20	33.00	30000
Minerva Class	Corvette	3.20	24.00	11000
Po Hang Class	Corvette	2.90	32.00	26820
Dong Hae Class	Corvette	2.60	31.00	26820
Kasturi Class	Corvette	3.50	28.00	23400
Assad Class	Corvette	2.50	36.00	20120
Qahir Class	Corvette	3.60	28.00	28160
Kazsub Class	Corvette	3.10	27.00	16900
Baptista De Andrade Class	Corvette	3.10	22.00	12000
Badr Class	Corvette	2.70	30.00	2300
Milgem Class	Corvette	3.60	29.00	32250

Ship Name/Class	Ship Type	Displacement full load (tons)	Length(m)	Beam(m)
Iroqous Class	Destroyer	5100	129.80	15.20
Luda I/II Class	Destroyer	3670	132.00	12.80
Luhai Class	Destroyer	6600	153.00	16.50
Luhu Class	Destroyer	4200	142.70	15.10
Cassard Class	Destroyer	4730	139.00	14.00
Tourville Class	Destroyer	5950	152.80	16.00
Audace Class	Destroyer	4400	136.60	14.20
De La Penne Class	Destroyer	5400	147.70	16.10
Asagiri Class	Destroyer	4200	137.00	41.60
Kongou Class	Destroyer	9485	161.00	21.00
Murasame Class	Destroyer	5100	151.00	17.40
Tachikaze Class	Destroyer	3850	143.00	14.30
Sovremenny Class	Destroyer	7940	156.00	17.30
Arleigh Burke Class	Destroyer	8422	153.80	20.40
Fletcher Class	Destroyer	3050	114.80	12.00
Meko Class	Destroyer	3600	125.90	14.00
De Zeven Provincien Class	Destroyer	6048	144.20	18.80
Hobart Class	Destroyer	6890	147.20	18.60
Horizon Class	Destroyer	7770	152.87	20.30
Kara Class	Destroyer	9700	173.00	18.60
Luda Class	Destroyer	3670	132.00	12.80
Okpo Class	Destroyer	3855	135.40	14.20
Oliver Hazard Perry Class	Destroyer	3638	136.00	13.70
Sejong the Great Class	Destroyer	11000	165.00	21.00
Luyang Class	Destroyer	7000	155.00	17.00

Ship Name/Class	Ship Type	Draught(m)	Max. Speed (knots)	SHP
Iroqous Class	Destroyer	4.70	27.00	55000
Luda I/II Class	Destroyer	4.60	32.00	44000
Luhai Class	Destroyer	6.00	31.00	94000
Luhu Class	Destroyer	5.10	31.00	100000
Cassard Class	Destroyer	6.50	29.50	43200
Tourville Class	Destroyer	5.70	32.00	58000
Audace Class	Destroyer	4.60	34.00	146000
De La Penne Class	Destroyer	8.60	31.00	133200
Asagiri Class	Destroyer	4.50	30.00	53000
Kongou Class	Destroyer	6.20	30.00	102160
Murasame Class	Destroyer	5.20	30.00	86000
Tachikaze Class	Destroyer	4.70	32.00	70000
Sovremenny Class	Destroyer	6.50	32.00	99500
Arleigh Burke Class	Destroyer	6.30	32.00	105000
Fletcher Class	Destroyer	5.50	35.00	60000
Meko Class	Destroyer	5.80	30.50	66680
De Zeven Provincien Class	Destroyer	5.20	28.00	52300
Hobart Class	Destroyer	5.17	28.00	94000
Horizon Class	Destroyer	5.40	29.00	74310
Kara Class	Destroyer	6.70	34.00	120000
Luda Class	Destroyer	4.60	32.00	72025
Okpo Class	Destroyer	4.20	30.00	58200
Oliver Hazard Perry Class	Destroyer	4.50	29.00	41000
Sejong the Great Class	Destroyer	6.00	30.00	10000
Luyang Class	Destroyer	6.00	29.00	48600

Ship Name/Class	Ship Type	Displacement full load (tons)	Length(m)	Beam(m)
Bahamas Class	Patrol Force	375	60.60	8.90
Protector Class	Patrol Force	180	33.00	6.70
TNC 45 Class	Patrol Force	259	44.90	7.00
FPB 38 Class	Patrol Force	205	38.50	7.00
Madhumati Class	Patrol Force	635	60.80	8.00
Huangfen Class	Patrol Force	205	38.60	7.60
Hainen Class	Patrol Force	392	58.80	7.20
Imperial Marinheiro Class	Patrol Force	1025	56.00	9.30
Pedro Teixeira Class	Patrol Force	900	63.60	9.70
Waspada Class	Patrol Force	206	36.90	7.20
Kondo Class	Patrol Force	360	51.90	7.10
SAAR 4 Claas	Patrol Force	450	58.10	7.60
Tiger Class	Patrol Force	265	47.00	7.00
Micalvi Class	Patrol Force	518	42.50	8.50
HaizhuiClass	Patrol Force	170	41.00	5.30
Reliance Class	Patrol Force	1129	64.20	10.40
Lazaga Class	Patrol Force	393	58.10	7.60
Cormoran Class	Patrol Force	385	56.60	7.50

Ship Name/Class	Ship Type	Displacement full load (tons)	Length(m)	Beam(m)
Balsam Class	Patrol Force	1034	54.90	11.30
Toledo Class	Patrol Force	142	35.40	7.60
Flyvefisken Class	Patrol Force	480	54.00	9.00
Knud Rasmussen Class	Patrol Force	1720	71.80	14.60
Brimil	Patrol Force	2000	63.60	12.60
Kiisla Class	Patrol Force	270	48.30	8.80
Rauma Class	Patrol Force	248	48.00	8.00
P 400 Class	Patrol Force	446	54.60	8.00
Patra Class	Patrol Force	160	42.00	7.70
Comandante Class	Patrol Force	1520	88.40	12.20
Esploratore Class	Patrol Force	165	37.20	7.10
Taechong Class	Patrol Force	425	60.80	7.20
Gumdoksuri Class	Patrol Force	570	63.00	9.00
Holzinger Class	Patrol Force	1290	74.40	10.50
Sierra Class	Patrol Force	1344	70.40	10.50

Ship Name/Class	Ship Type	Displacement full load (tons)	Length(m)	Beam(m)
Duranga Class	Patrol Force	1470	81.80	10.50
Eridan Class	Patrol Force	595	51.50	8.90
Verlarde Class	Patrol Force	560	64.00	8.40
Aguinaldo Class	Patrol Force	236	44.00	7.40
Kaper Class	Patrol Force	470	42.50	8.40
Viana Do Castelo Class	Patrol Force	1716	83.10	12.95
Vita Class	Patrol Force	376	56.30	9.00
Musca Class	Patrol Force	790	59.20	9.50
Sprut Class	Patrol Force	900	65.90	10.60
Al Sıddıq Class	Patrol Force	495	58.10	8.10
Fearless Class	Patrol Force	500	55.00	8.60
Descubierta Class	Patrol Force	1666	88.80	10.40
Serviola Class	Patrol Force	1147	68.70	10.40
Hua Hin Class	Patrol Force	645	62.00	8.90
Kılıç Class	Patrol Force	550	62.40	8.30
Mubrraz Class	Patrol Force	260	44.90	7.00

Ship Name/Class	Ship Type	Draught(m)	Max. Speed (knots)	SHP
Bahamas Class	Patrol Force	2.60	24.00	6600
Protector Class	Patrol Force	2.10	30.00	3483
TNC 45 Class	Patrol Force	2.50	40.00	13640
FPB 38 Class	Patrol Force	2.20	32.00	6810
Madhumati Class	Patrol Force	2.70	24.00	9600
Huangfen Class	Patrol Force	2.70	35.00	12000
Hainen Class	Patrol Force	2.20	30.50	4000
Imperial Marinheiro Class	Patrol Force	3.60	16.00	2160
Pedro Teixeira Class	Patrol Force	1.70	16.00	3840
Waspada Class	Patrol Force	1.80	32.00	7680
Kondo Class	Patrol Force	2.20	18.00	4408
SAAR 4 Claas	Patrol Force	2.80	32.00	13029
Tiger Class	Patrol Force	2.70	31.00	13029
Micalvi Class	Patrol Force	2.90	15.00	2560
HaizhuiClass	Patrol Force	1.80	25.00	4400
Reliance Class	Patrol Force	3.20	18.00	6480
Lazaga Class	Patrol Force	2.60	26.00	7500
Cormoran Class	Patrol Force	2.00	32.00	11250

Ship Name/Class	Ship Type	Draught(m)	Max. Speed (knots)	SHP
Balsam Class	Patrol Force	3.80	13.00	1402
Toledo Class	Patrol Force	2.10	25.00	8240
Flyvefisken Class	Patrol Force	2.50	30.00	11250
Knud Rasmussen Class	Patrol Force	4.95	17.00	7300
Brimil	Patrol Force	4.30	17.00	5452
Kiisla Class	Patrol Force	2.20	25.00	7510
Rauma Class	Patrol Force	1.50	30.00	7510
P 400 Class	Patrol Force	2.50	24.00	8000
Patra Class	Patrol Force	1.90	32.00	5400
Comandante Class	Patrol Force	4.60	26.00	17600
Esploratore Class	Patrol Force	1.90	20.00	3810
Taechong Class	Patrol Force	2.00	25.00	8800
Gumdoksuri Class	Patrol Force	5.00	41.00	15880
Holzinger Class	Patrol Force	3.40	22.00	11700
Sierra Class	Patrol Force	2.80	18.00	6197

Ship Name/Class	Ship Type	Draught(m)	Max. Speed (knots)	SHP
Duranga Class	Patrol Force	2.80	18.00	6197
Eridan Class	Patrol Force	2.90	16.00	1860
Verlarde Class	Patrol Force	2.60	37.00	22200
Aguinaldo Class	Patrol Force	1.60	28.00	3480
Kaper Class	Patrol Force	2.80	17.00	4720
Viana Do Castelo Class	Patrol Force	3.69	20.00	10460
Vita Class	Patrol Force	2.50	35.00	18740
Musca Class	Patrol Force	2.80	17.00	4800
Sprut Class	Patrol Force	3.50	21.50	7000
Al Sıddıq Class	Patrol Force	2.00	38.00	23000
Fearless Class	Patrol Force	2.70	20.00	8554
Descubierta Class	Patrol Force	3.80	25.00	15000
Serviola Class	Patrol Force	3.40	19.00	7500
Hua Hin Class	Patrol Force	2.70	25.00	10372
Kılıç Class	Patrol Force	2.60	38.00	15120
Mubrraz Class	Patrol Force	2.20	40.00	9370

Ship Name/Class	Ship Type	Displacement full load (tons)	Length(m)	Beam(m)
Admiral Gorshkov Class	Frigate	4500	135.00	15.00
Admiral Grigorovich Class	Frigate	4035	124.80	15.20
Alvaro de Bazan Class	Frigate	5853	146.70	18.60
Aquitane Class	Frigate	6000	142.20	20.00
Aradu Class	Frigate	3360	125.60	15.00
Koni Class	Frigate	1900	96.40	12.80
Carlo Bergamini Class	Frigate	6900	144.60	19.70
Fridtjof Nansen Class	Frigate	5290	134.00	16.80
Iver Huitfeldt Class	Frigate	6645	138.70	19.81
Knox Class	Frigate	4066	133.40	14.30
Marasesti	Frigate	5790	144.60	14.80
Sachsen Class	Frigate	5780	143.00	17.40
Shivalik Class	Frigate	6200	142.50	16.90
Talwar Class	Frigate	4035	125.00	15.20
Meko 140 A16 Class	Frigate	1850	91.20	11.10
Oliver Hazard Perry Class	Frigate	4200	138.10	13.70

Ship Name/Class	Ship Type	Displacement full load (tons)	Length(m)	Beam(m)
Project 159A Class	Frigate	1180	81.80	9.10
Modified Ulsan Class	Frigate	2370	103.70	12.50
Jianghu I Class	Frigate	1702	103.20	10.70
Type 61 Frigate	Frigate	2408	103.60	12.20
Karel Doorman Class	Frigate	3320	122.30	14.40
Broadsword Class	Frigate	4731	131.20	14.80
Niteroi Class	Frigate	3707	129.20	13.50
Wielingen Class	Frigate	2430	106.40	12.30
Halifax Class	Frigate	4770	134.70	16.40
Latorre Class	Frigate	3750	130.50	14.60
Type 23 Class	Frigate	4200	133.00	16.10
Type 22 Class	Frigate	4800	146.50	14.80
Almirante Padilla Class	Frigate	2100	99.10	11.30
Thetis Class	Frigate	3500	112.50	14.40
Niels Juel Class	Frigate	1320	84.00	10.30

Ship Name/Class	Ship Type	Displacement full load (tons)	Length(m)	Beam(m)
Ivar Huitfeldt Class	Frigate	5859	138.70	19.80
Leander Class	Frigate	3200	113.40	13.10
Descubierta Class	Frigate	1479	89.80	10.40
La Fayette Class	Frigate	3750	124.20	15.40
D'estienne D'orves	Frigate	1250	80.50	10.30
Floreal Class	Frigate	2950	93.50	14.00
Ulsan Class	Frigate	2180	102.00	11.50
Neustrashimy	Frigate	4250	129.60	15.50
Steregushciy Class	Frigate	2200	104.50	11.10
Maestrale Class	Frigate	3200	122.70	12.90
Santa Maria Class	Frigate	3969	137.70	14.30
Brabdenburg Class	Frigate	5400	138.90	16.70
Bremen Class	Frigate	3680	130.00	14.50
Lupo Class	Frigate	2525	113.20	11.30

Ship Name/Class	Ship Type	Draught(m)	Max. Speed (knots)	SHP
Admiral Gorshkov Class	Frigate	4.50	29.50	55000
Admiral Grigorovich Class	Frigate	4.20	30.00	44000
Alvaro de Bazan Class	Frigate	4.90	28.00	47328
Aquitane Class	Frigate	5.00	28.00	42900
Aradu Class	Frigate	5.80	30.00	64300
Koni Class	Frigate	4.20	27.00	30000
Carlo Bergamini Class	Frigate	8.70	29.00	42900
Fridtjof Nansen Class	Frigate	7.60	26.00	37700
Iver Huitfeldt Class	Frigate	5.18	30.00	44000
Knox Class	Frigate	7.60	27.00	35000
Marasesti	Frigate	4.90	27.00	33760
Sachsen Class	Frigate	4.40	29.00	55636
Shivalik Class	Frigate	4.50	30.00	67200
Talwar Class	Frigate	4.20	32.00	64070
Meko 140 A16 Class	Frigate	3.40	28.00	20400
Oliver Hazard Perry Class	Frigate	4.50	29.00	41000

Ship Name/Class	Ship Type	Draught(m)	Max. Speed (knots)	SHP
Project 159A Class	Frigate	2.90	32.00	35400
Modified Ulsan Class	Frigate	3.80	25.00	22501
Jianghu I Class	Frigate	3.10	26.00	16000
Type 61 Frigate	Frigate	4.70	24.00	14400
Karel Doorman Class	Frigate	4.30	30.00	33800
Broadsword Class	Frigate	6.00	30.00	50000
Niteroi Class	Frigate	5.50	30.00	50880
Wielingen Class	Frigate	5.60	26.00	25440
Halifax Class	Frigate	5.00	29.00	47494
Latorre Class	Frigate	4.30	30.00	50800
Type 23 Class	Frigate	5.50	28.00	39200
Type 22 Class	Frigate	6.40	30.00	50000
Almirante Padilla Class	Frigate	3.70	27.00	23400
Thetis Class	Frigate	6.00	20.00	10800
Niels Juel Class	Frigate	3.10	28.00	24600

Ship Name/Class	Ship Type	Draught(m)	Max. Speed (knots)	SHP
Ivar Huitfeldt Class	Frigate	6.30	28.00	44000
Leander Class	Frigate	5.50	27.00	30000
Descubierta Class	Frigate	3.80	25.50	15000
La Fayette Class	Frigate	5.80	25.00	21107
D'estienne D'orves	Frigate	5.50	25.00	26400
Floreal Class	Frigate	4.30	20.00	8820
Ulsan Class	Frigate	3.50	34.00	53640
Neustrashimy	Frigate	4.80	30.00	72800
Steregushciy Class	Frigate	3.70	26.00	24000
Maestrale Class	Frigate	4.60	32.00	50000
Santa Maria Class	Frigate	7.50	29.00	41000
Brabdenburg Class	Frigate	6.80	29.00	51000
Bremen Class	Frigate	6.50	30.00	51000
Lupo Class	Frigate	2.70	35.00	50000