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Master Thesis

Influence of the Statistical Properties of Parameters of Steel Products on the Ultimate Strength of Ship Hull

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1. Introduction

- The design strength of a ship structural component is based on **nominal values** for strength parameters such as yield strength, plate thickness, modulus of elasticity etc.

- However, the **actual values** of these parameters are often different from the **nominal values**.

- These actual values tend to behave in random manner, causing **random behavior** of the actual strength.

- Therefore, strength prediction of a structural component needs to consider the random behavior of the properties of steel components.

- The random behavior of the properties of steel components can be assessed by ***Statistical Analysis***.

Objectives

1. To perform statistical analysis for random behavior of material properties of steel plates and profiles.
2. To evaluate the influence of the random behavior of material properties on ultimate hull bending strength of the ship

2. Data Collection

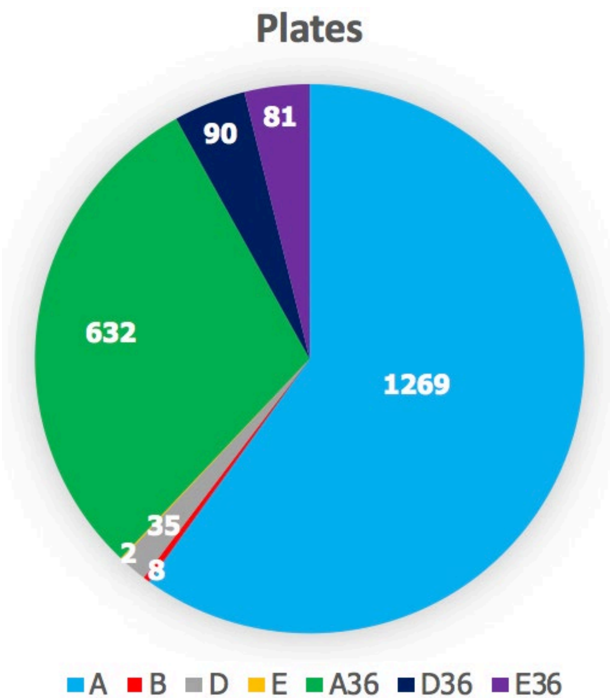
- The actual values of yield strength, ultimate strength and impact energy of plates and profiles are collected from **mill/material certificates** which are usually provided by steel manufacturers.

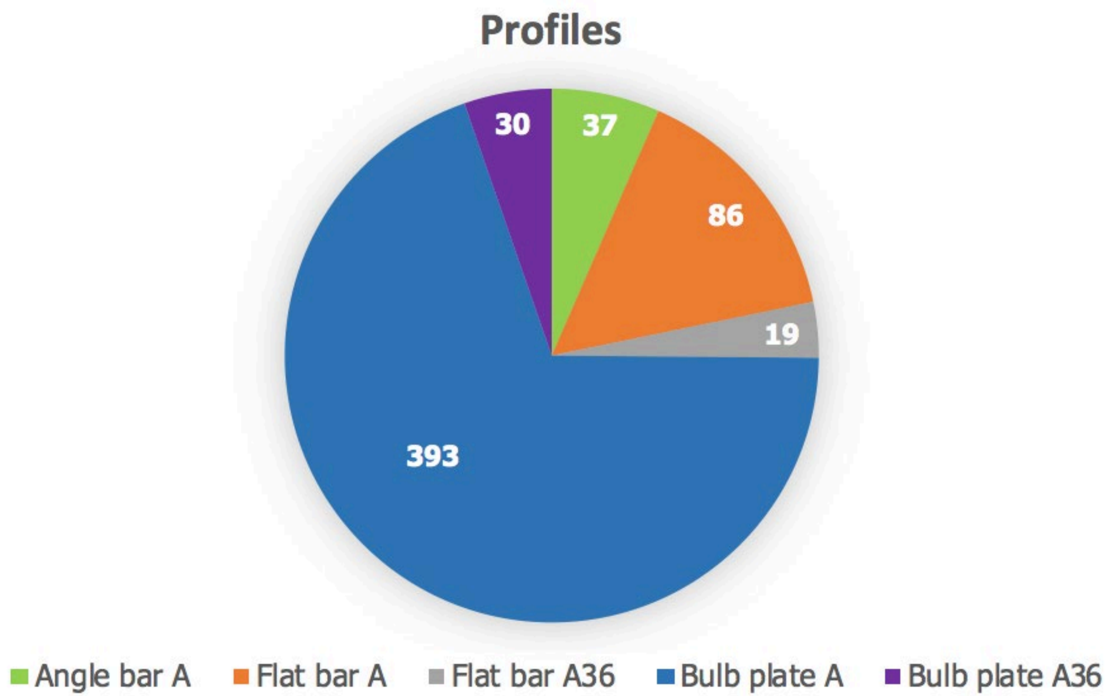
- These mill/material certificates are submitted to Classification Societies such as DNV-GL for verification and approval.

- The data used in this thesis are collected from **DNV-GL** data base.

- A total of **2117** test data for plates with thickness **5 to 90mm** and **565** test data for profiles(angle bar, flat bar, bulb plate) of various size are collected for analysis.

Description	IACS Grade	Number of test data	Total
Plates	A	1269	2117
	B	8	
	D	35	
	E	2	
	A36	632	
	D36	90	
	E36	81	
Angle bar	A	37	565
Flat bar	A	86	
	A36	19	
Bulb plate	A	393	
	A36	30	

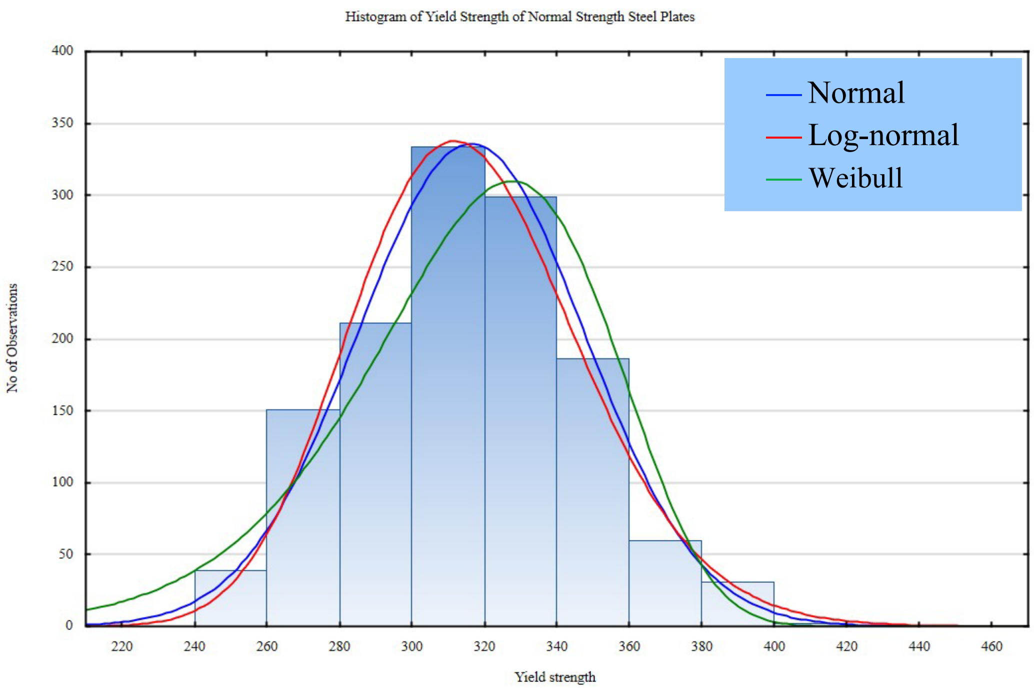


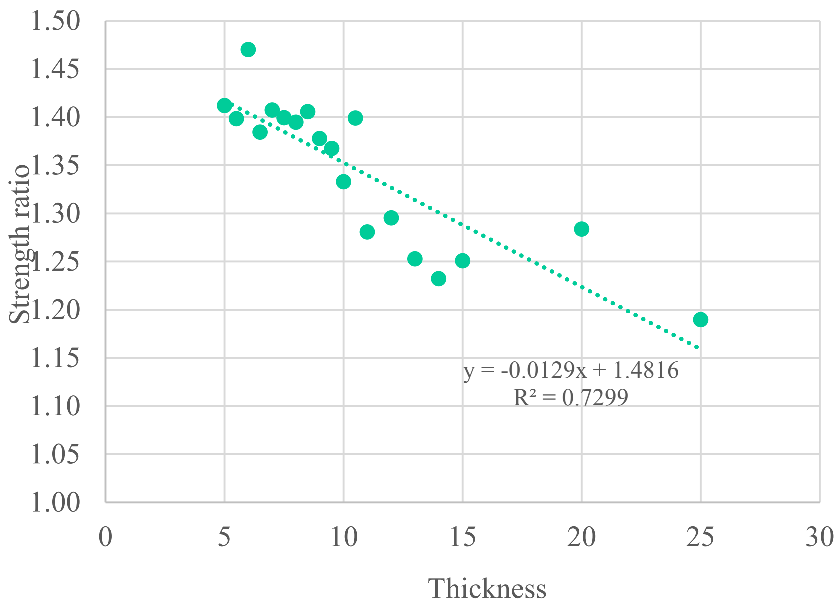


3. Statistical Analysis

• Yield Strength of Normal Strength Steel Plates

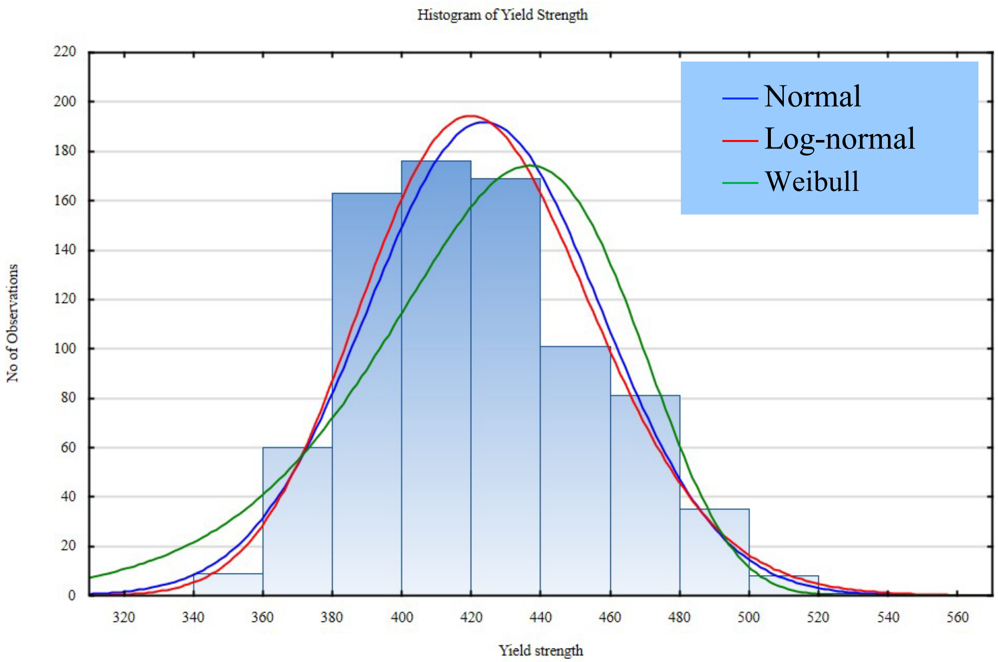
Number of samples	Standard deviation	Mean (MPa)	Nominal value (MPa)	Mean/Nominal ratio	Average ratio bias	Distribution
1314	31.213	315.803	235	1.344	34.38%	Normal

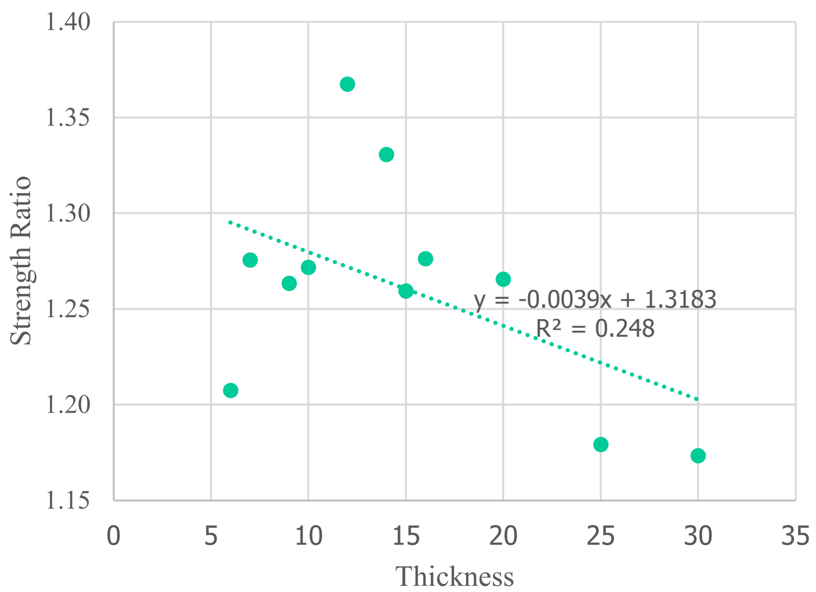




• Yield Strength of Higher Strength Steel Plates

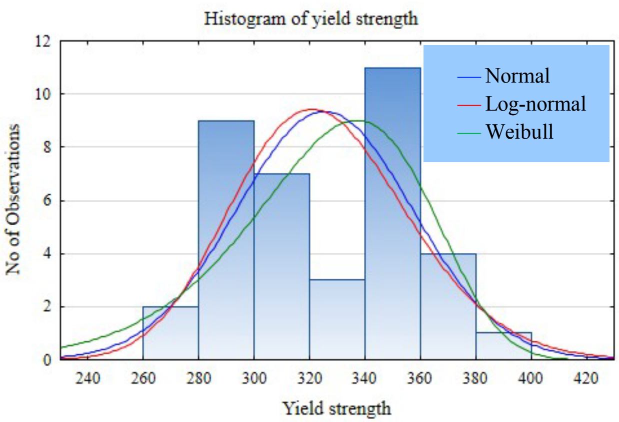
Number of samples	Standard deviation	Mean (MPa)	Nominal value (MPa)	Mean/Nominal ratio	Average ratio bias	Distribution
803	33.389	423.217	355	1.192	19.22%	Log normal



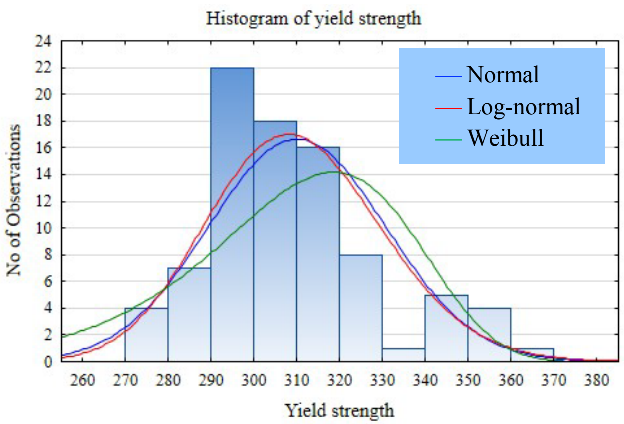


• Yield Strength of Normal Strength Steel Profiles

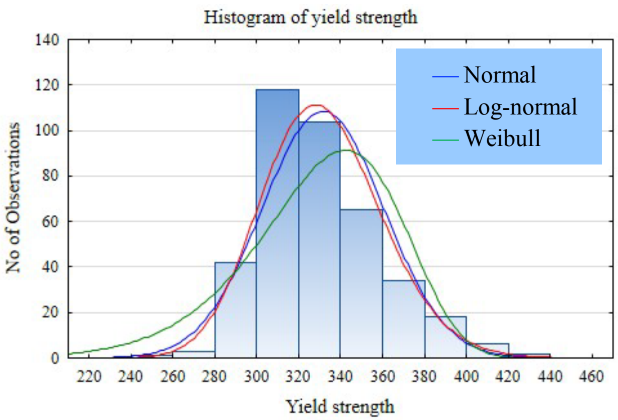
Profiles	Grade IACS	No of samples	Standard deviation	Mean (MPa)	Nominal value (MPa)	Mean/Nominal ratio	Average ratio bias	Distribution
Angle bar	A	37	31.61	324.97	235	1.38	38.29%	Weibull
Flat bar	A	86	20.61	309.70		1.32	31.79%	Log-normal
Bulb plate	A	393	28.91	330.96		1.41	40.83%	Log-normal



Angle bar



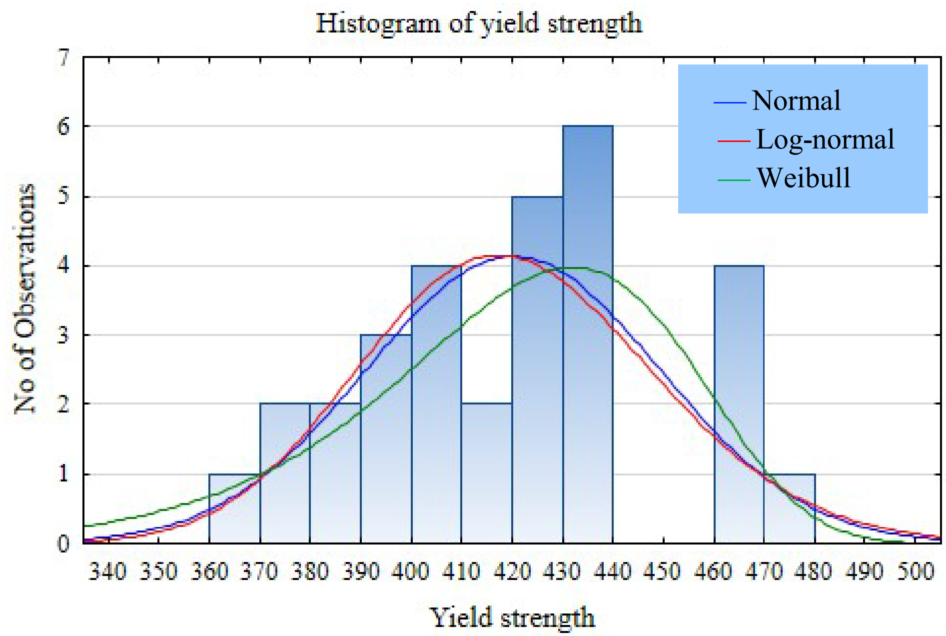
Flat bar



Bulb plate

• Yield Strength of Higher Strength Steel Profiles

Profiles	Grade IACS	No of samples	Standard deviation	Mean (MPa)	Nominal value (MPa)	Mean/Nominal ratio	Average ratio bias	Distribution
Flat bar	A36	20	17.74	412.84	355	1.163	16.29%	
Bulb plate	A36	30	28.96	419.8		1.183	18.25%	Log-normal or normal



Bulb plate

4. Prediction of Ultimate bending strength of ship hull

- Prediction of ultimate bending strength of hull was performed by ***HullUlt*** computer code written in **FORTRAN** language by Taczala.

- ***HullUlt*** is a simplified algorithm to predict ultimate bending strength which is developed based on the modified Smith's method by Taczala.

- A hull model of very large crude carrier ***ENERGY CONCENTRATION*** was used for calculation of ultimate strength.

- During discharging at Mobil Terminal Rotterdam on 21st of July 1980, ***ENERGY CONCENTRATION*** 'broke its back" due to a hogging bending moment arising from the load distribution along the length of the ship.

Prediction of ultimate bending strength of hull was done in two ways.

Prediction of ultimate hull bending strength

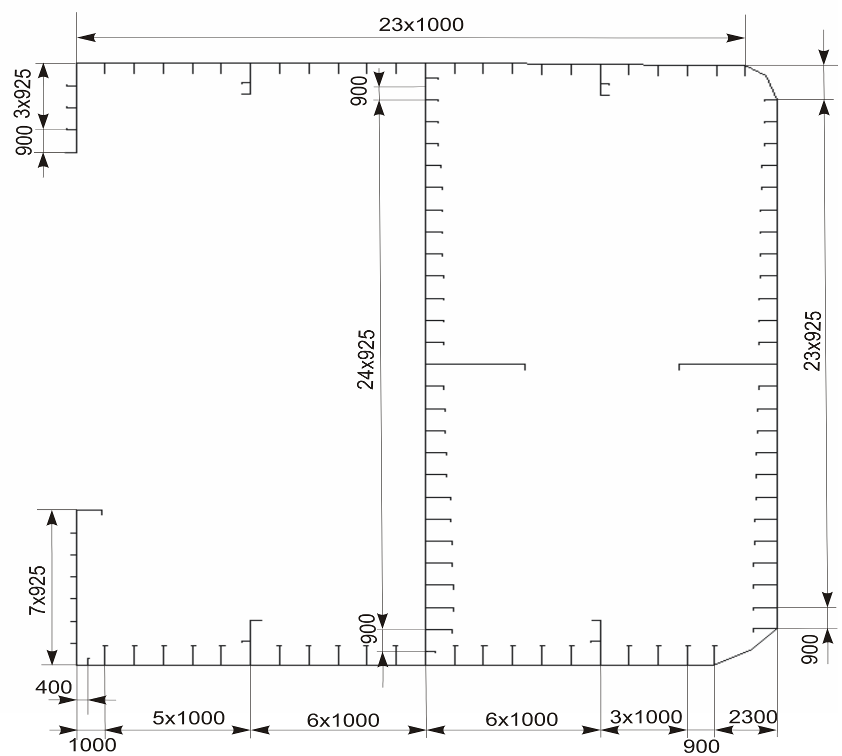
Using ***nominal values*** for mechanical properties of steel

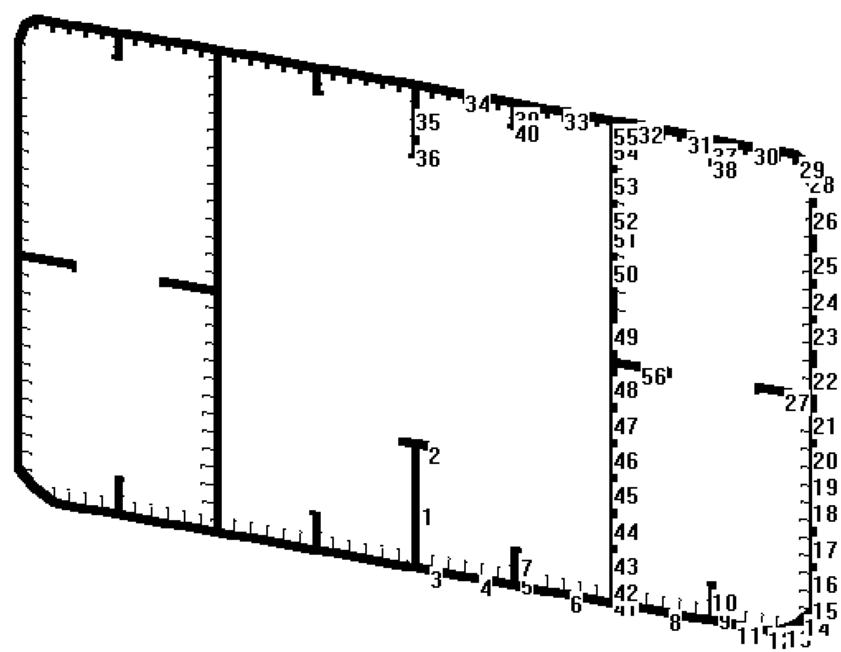
Using ***random values*** for mechanical properties of steel generated by based on the probability distribution function obtained from statistical analysis

Principal Particulars

Length, overall	326.75 m
Length, between perpendicular	313.0 m
Breadth, molded	48.19 m
Depth, molded	25.2 m
Draft, summer extreme	19.587 m
Gross tonnage	98.894 tons
Transverse web frame spacing	5.1m

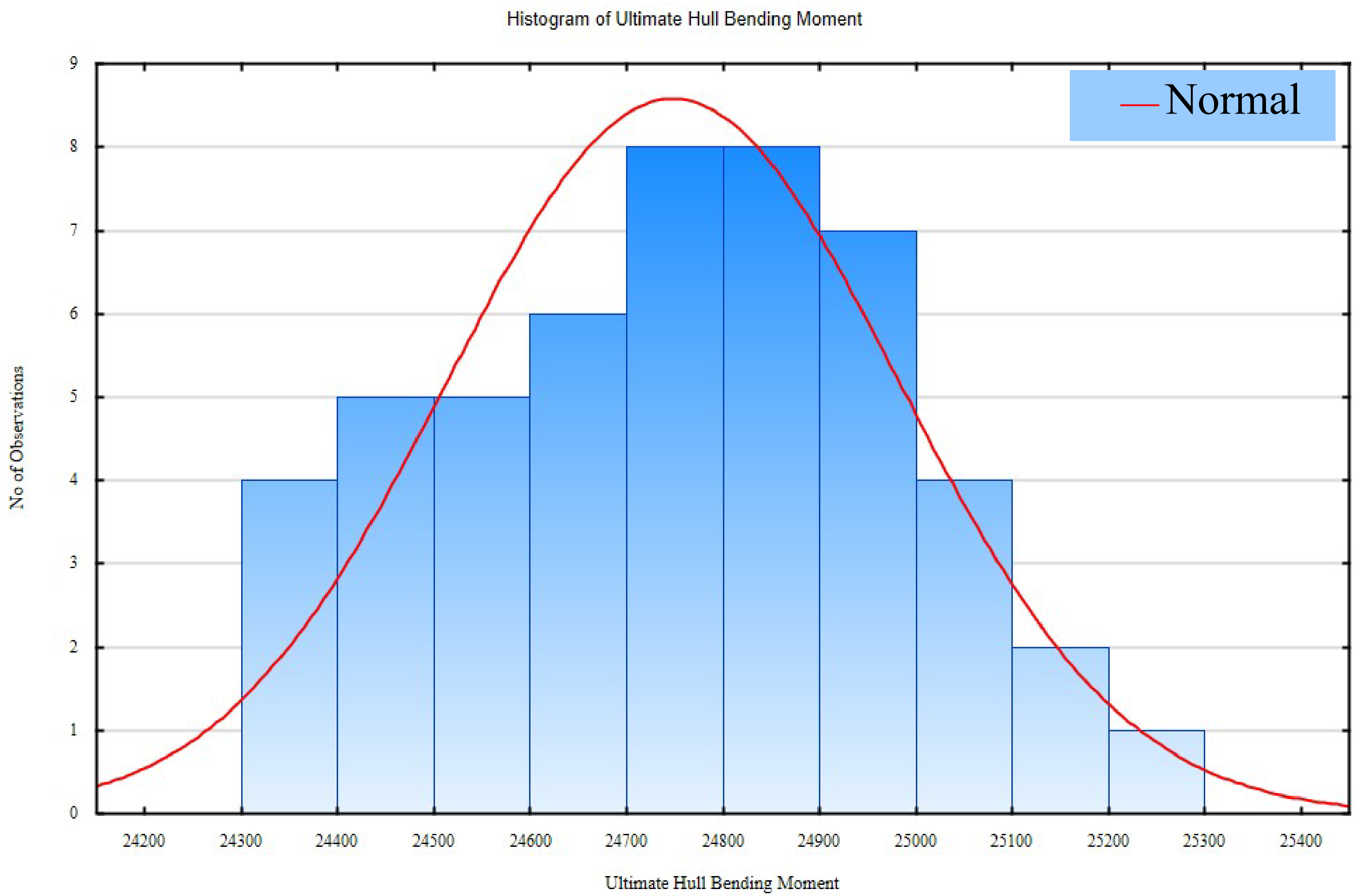
Yield strength				
Type of steel	**Nominal value** (MPa)	**Random value**		
		Mean (MPa)	Standard deviation	Probability distribution function
Mild steel	235	315.803	31.213	Normal
High tensile steel	355	423.217	33.389	Normal





Midship section

Results


Histogram of Ultimate Hull Bending Moment
Normal
No of Observations
Ultimate Hull Bending Moment
0
1
2
3
4
5
6
7
8
9
24200
24300
24400
24500
24600
24700
24800
24900
25000
25100
25200
25300
25400

Ultimate hogging bending moment			
Approximate method			
With nominal value of yield strength of plates and profiles	With random value of yield strength of plates and profiles		
Hogging moment (MNm)	Total number of trials	Average hogging moment (MNm)	difference % (compared to approximate method with nominal value)
21321	50	24745.10	16%

- Average value of ultimate hogging bending moment using random values for yield strength of plate and profile was found to be **16%** higher than the ultimate hogging bending moment using nominal values.

- This finding suggests that the **random behavior** of strength parameter of steel plates and profiles has a **significant influence** on ultimate hull bending strength of the ship.

5. CONCLUSION

1. The actual value of yield strength of normal strength steel (mild steel) could be approximately 34% higher than the nominal value.

2. The actual value of yield strength of higher strength steel (high tensile steel) could be approximately 19% higher than the nominal value.

3. As the **plate thickness increase**, the yield strength of normal strength steel and higher strength steel **decreases**.

4. The actual value of ultimate hull bending strength of the ship could be 16% higher than the value we predicted when nominal values of strength parameters are used.

5. The influence of random behavior of strength parameters cannot be overemphasized.