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Master Thesis

Identification of Uncertainties in Geometrical and Strength Properties of Steel for Shipbuilding

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INTRODUCTION

- Traditionally, the design of a marine structure is based on nominal values for variables such as yield strength of the material, plate thickness, young modulus, etc.

- In reality, they are not unique and present many uncertainties, and because of it the strength of the structure tends to have a random behavior.

- This random behavior heavily impacts the reliability level of the structural system, affecting its performance and safety.

- Once the randomness is known, the designer is allowed to take into account this variability in the design stage as a safety margin, giving to it some reliability level.

- The main goal of this work is to present statistical estimation of the uncertainties of steel plates used in marine structures.

UNCERTAINTIES IN BASIC RANDOM VARIABLES

The variables are grouped into two classes:

- Geometric variables (such as plate thickness)
- Material Variables (such as Yield Strength and Impact Energy test value)

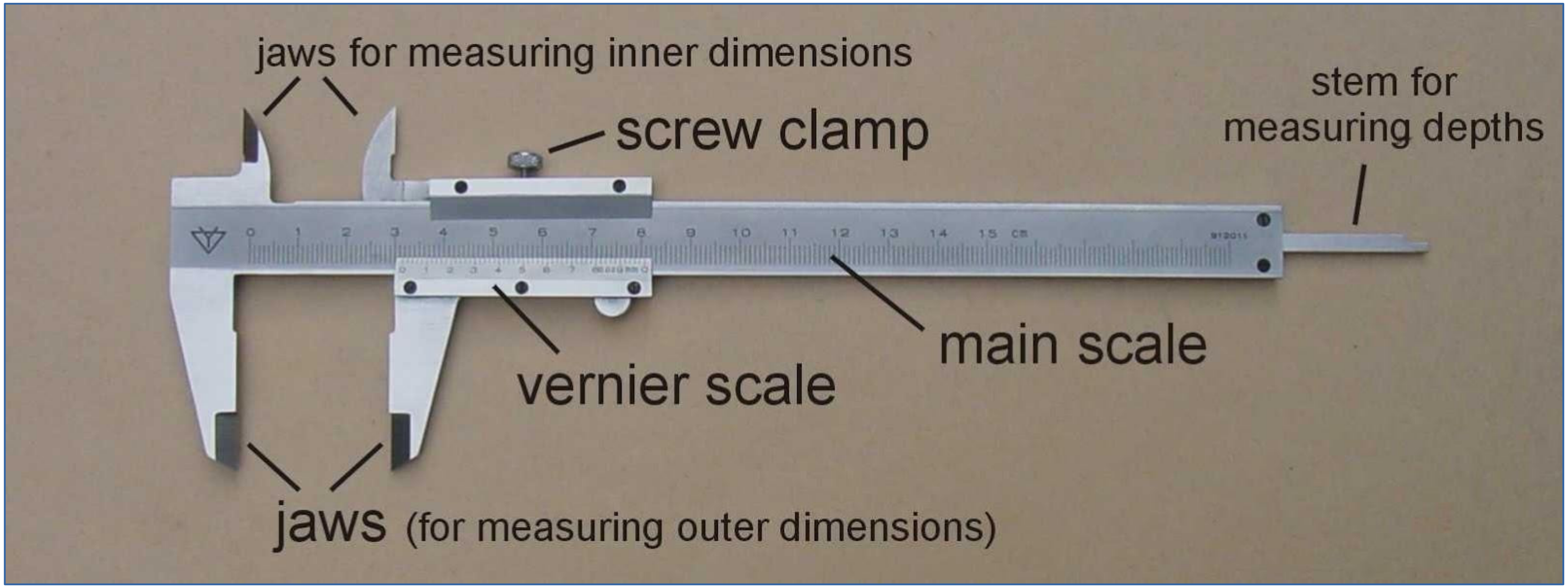
Two type of steel are analyzed in this study:

- Ordinary Mild steel (OS)
- High Strength steel (HS)

DATABASE COLLECTION

Geometrical variables (thickness):

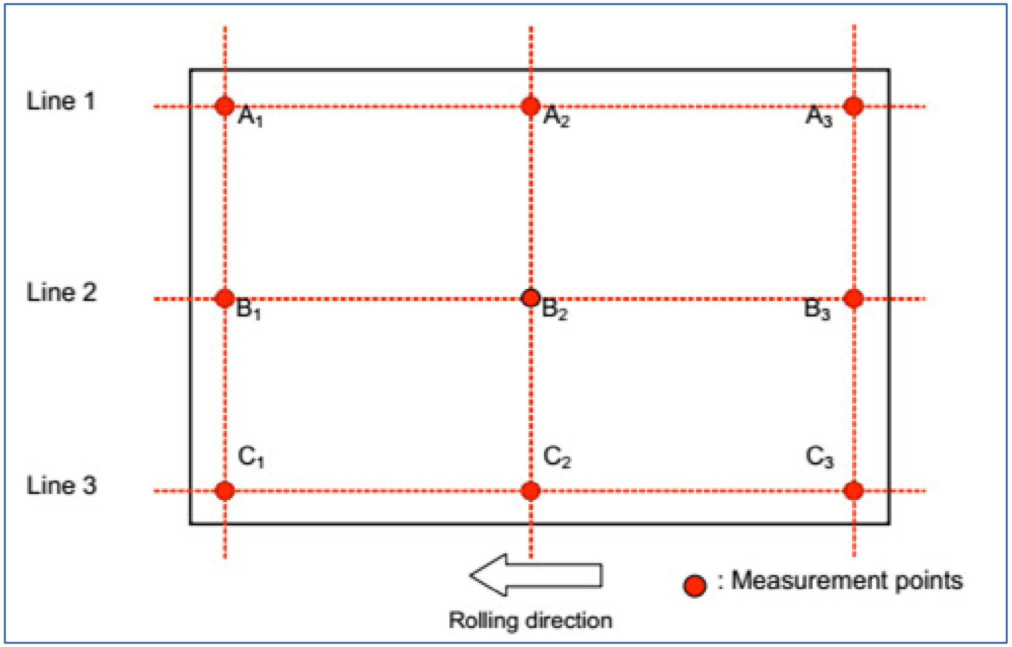
- Collected manually by using a Vernier caliper.
- Reading error: 1/20 = 0.05mm



DATABASE COLLECTION

Geometric variables (thickness):

- According to International Association of Classification Societies (IACS), at least two lines among Line 1, Line 2 and Line 3 must be selected, and at least three points on each selected line.
- The measuring points at sides are to be located not less than 10mm but not longer than 100mm from the transverse or longitudinal edges of the product.



DATABASE COLLECTION

- Geometrical variables (thickness):
  - Data collected:
    - Nominal thickness,
    - Plate heat number,
    - Manufacturer,
    - Grade of steel.

- Material variables (yield strength and energy impact):
  - Data collected:
    - Yield strength (ReH),
    - Ultimate strength (Rm)
    - Elongation percentage (%)
    - Average impact energy value
    - Nominal thickness
    - Grade of steel
    - Manufacturer
    - Classification Society in charged.

METHODOLOGY FOR DATA ANALYSIS

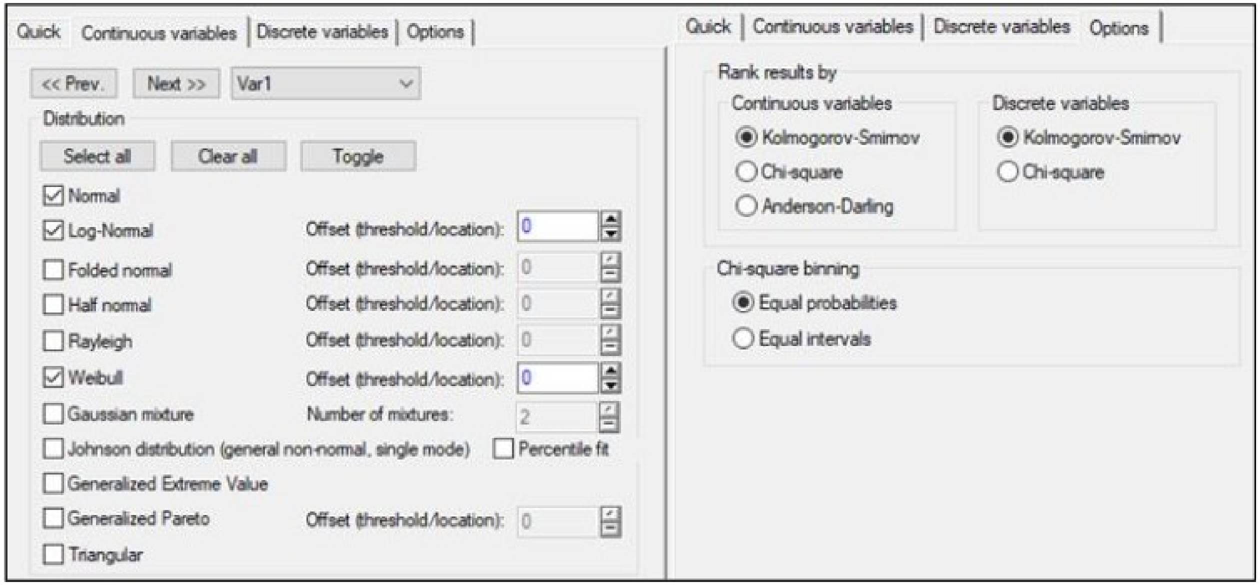
Model Uncertainty: Bias (Quantify the model inaccuracy)

- For thickness variables
  - *Difference* bias $B_D = measured\ value - nominal\ value$
  - *Ratio* bias $B_R = measured\ value\ /\ nominal\ value$

- For strength variables
  - *Total* bias $B_T = Real\ value\ /\ Nominal\ value$

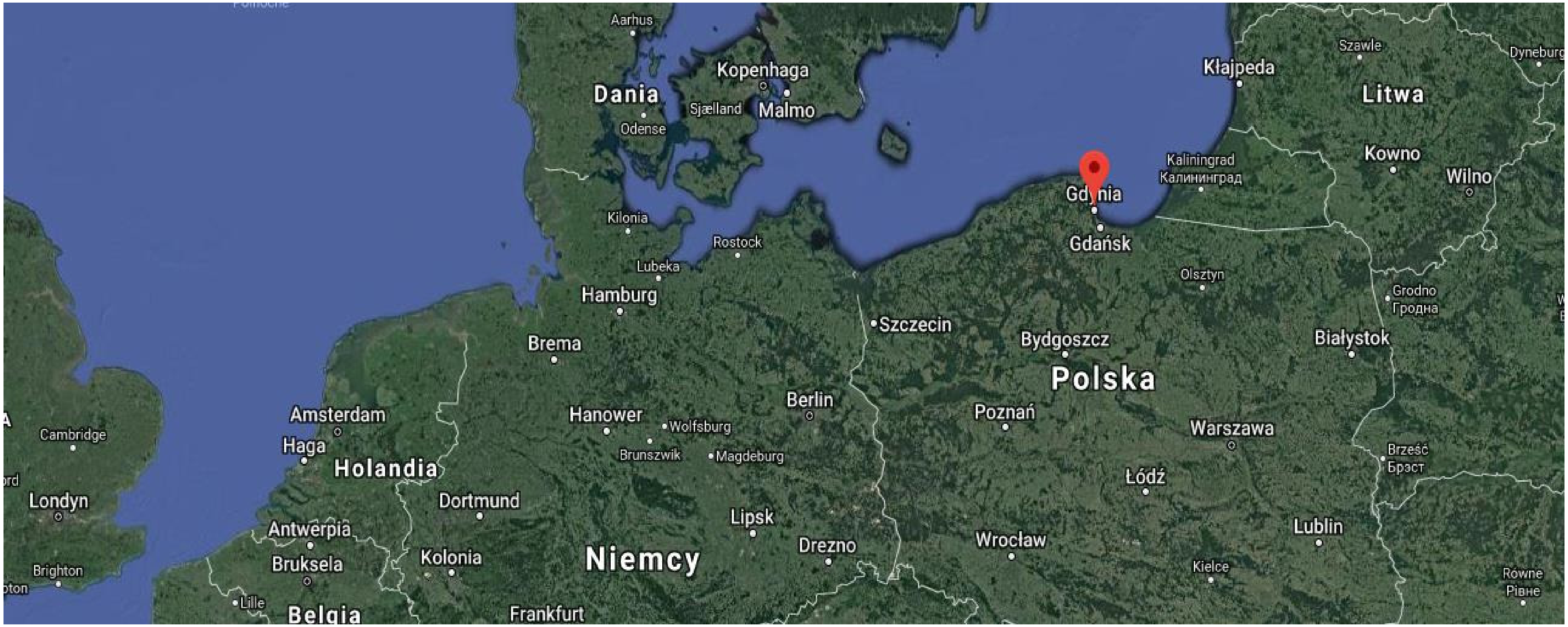
DELL^{TM} STATISTICA 13.1

- The software Dell^{TM} Statistica 13.1 was used.
- *Normal, log-normal and Weibull distribution are used to represent the sample.*
- *Kolmogorov-Smirnov goodness-of-fit test* was used to explore which PDF is the most representative of the sample data



CRIST S.A. SHIPYARD

- The data source was provided by CRIST S.A. Shipyard



SUMMARY OF PROBABILISTIC CHARACTERISTICS

- Thickness variables
  - Overall uncertainty
  - By different thicknesses
  - By type of steel
- Yield strength variables
  - Overall uncertainty
  - By type of steel
  - By grade of steel
  - By different thicknesses
  - By manufacturer
- Impact energy test value
  - Overall uncertainty

SUMMARY OF THICKNESS VARIABLES

- Overall uncertainty of the sample
  - 765 measurements of OS steel and HS steel
  - Grades of steel: A, B, A36, D36 and E36

0.371mm thicker

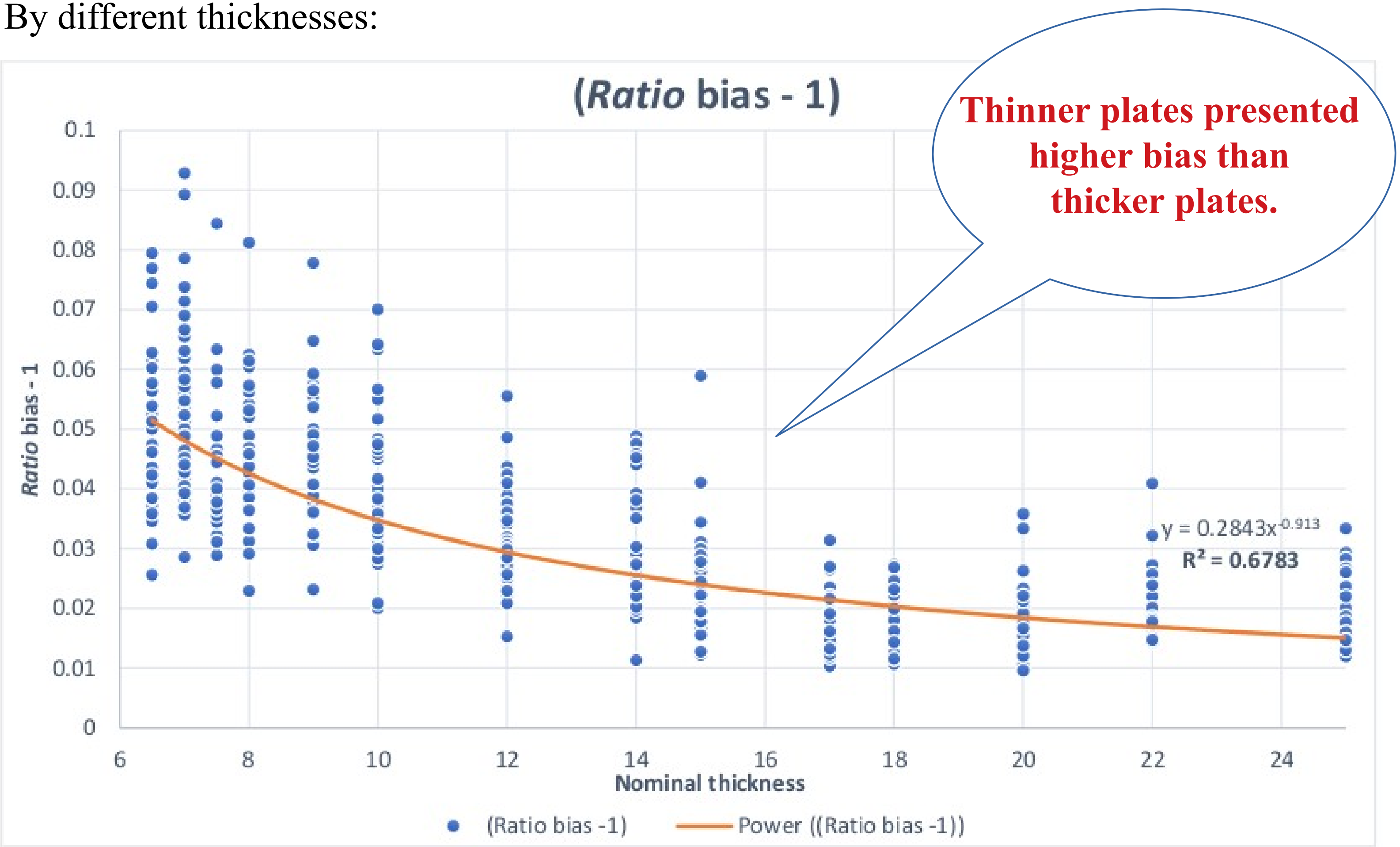
3.3% thicker

	Ratio Bias	*Difference* Bias (mm)
Average	1.033	0.371
Minimum	1.010	0.133
Maximum	1.097	1.000

Bias	***Mean***	***Median***	***Variance***	***Standard deviation***	***COV***	***Skewness***	***Kurtosis***
Difference bias	0.371	0.3500	0.014237	0.1193	32.150	1.356474	3.153415
Ratio bias	1.033	1.0305	0.000266	0.0163	1.579	0.934252	0.654193

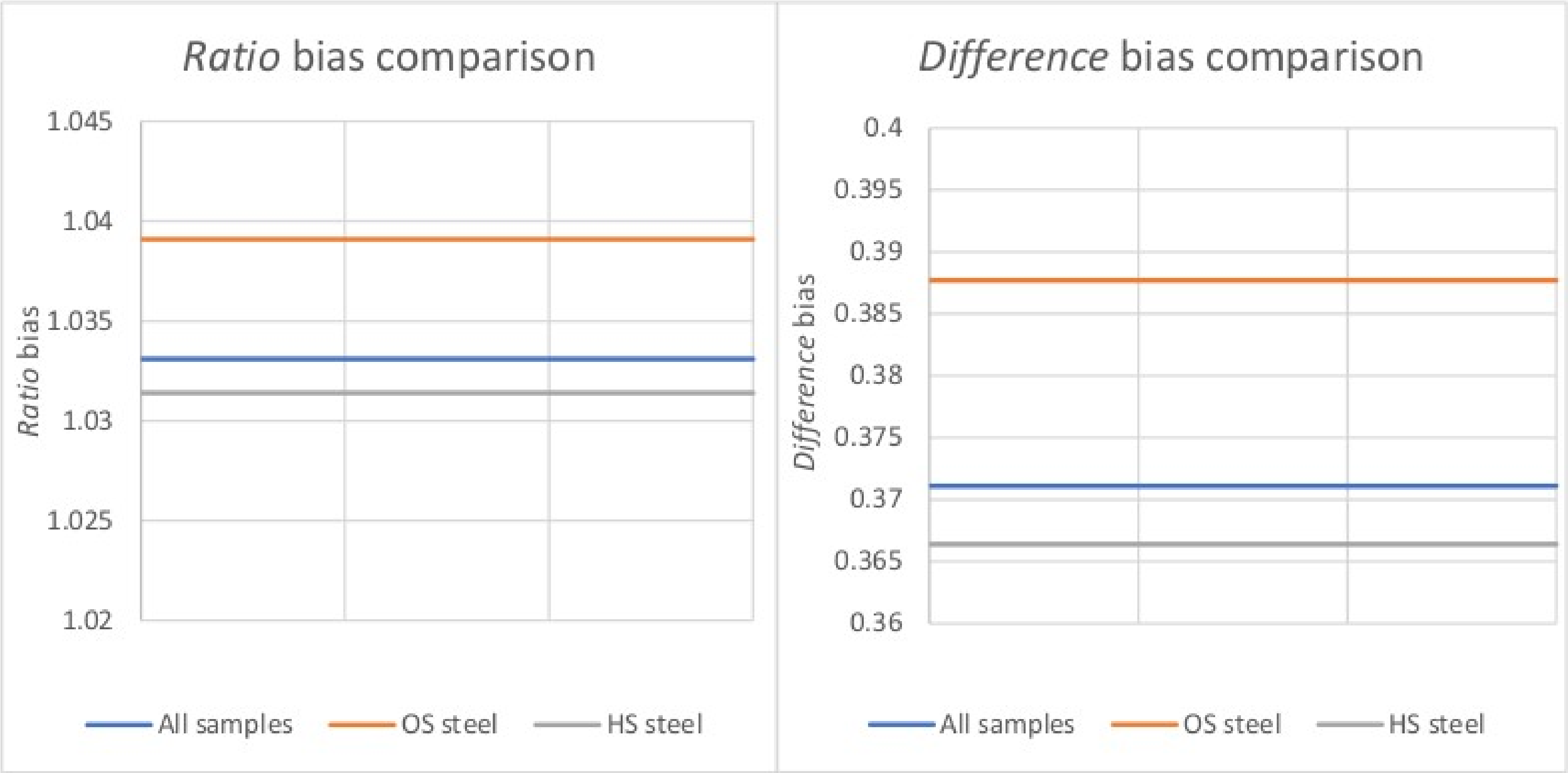
SUMMARY OF THICKNESS VARIABLES

- By different thicknesses:



SUMMARY OF THICKNESS VARIABLES

- By type of steel



SUMMARY OF YIELD STRENGTH VARIABLES

- Overall yield strength uncertainty
  - Data collected:
    - 1661 certificates
    - 9 different manufacturers
    - 6 different Classification Societies

17.5% higher yield strength than nominal value

Mean	*Median*	*Variance*	*Standard deviation*	*COV*	*Skewness*	*Kurtosis*	Distribution
1.175020	1.163380	0.009480	0.097364	8.286187	0.798559	1.012686	Log-normal

SUMMARY OF YIELD STRENGTH VARIABLES

- By type of steel

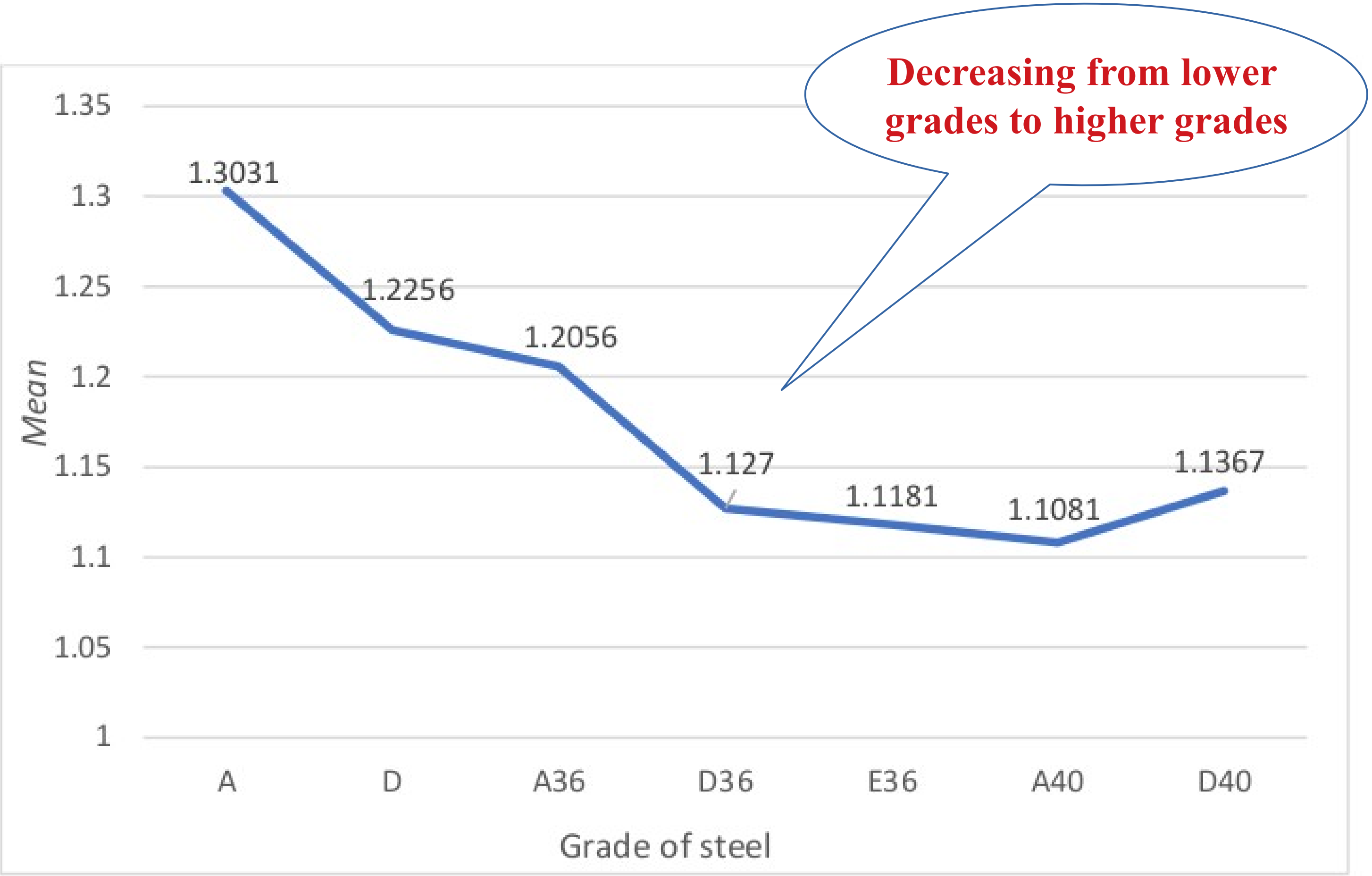
25.7% higher yield strength than nominal value

Type of steel	*Mean*	*Median*	*Variance*	*Standard deviation*	*COV*	*Skewness*	*Kurtosis*	Distribution
OS	1.257463	1.257463	0.009815	0.099815	7.878423	0.908781	0.879754	Log-normal
HS	1.149976	1.146316	0.006692	0.081803	7.113479	0.558988	0.103720	Log-normal

14.99% higher

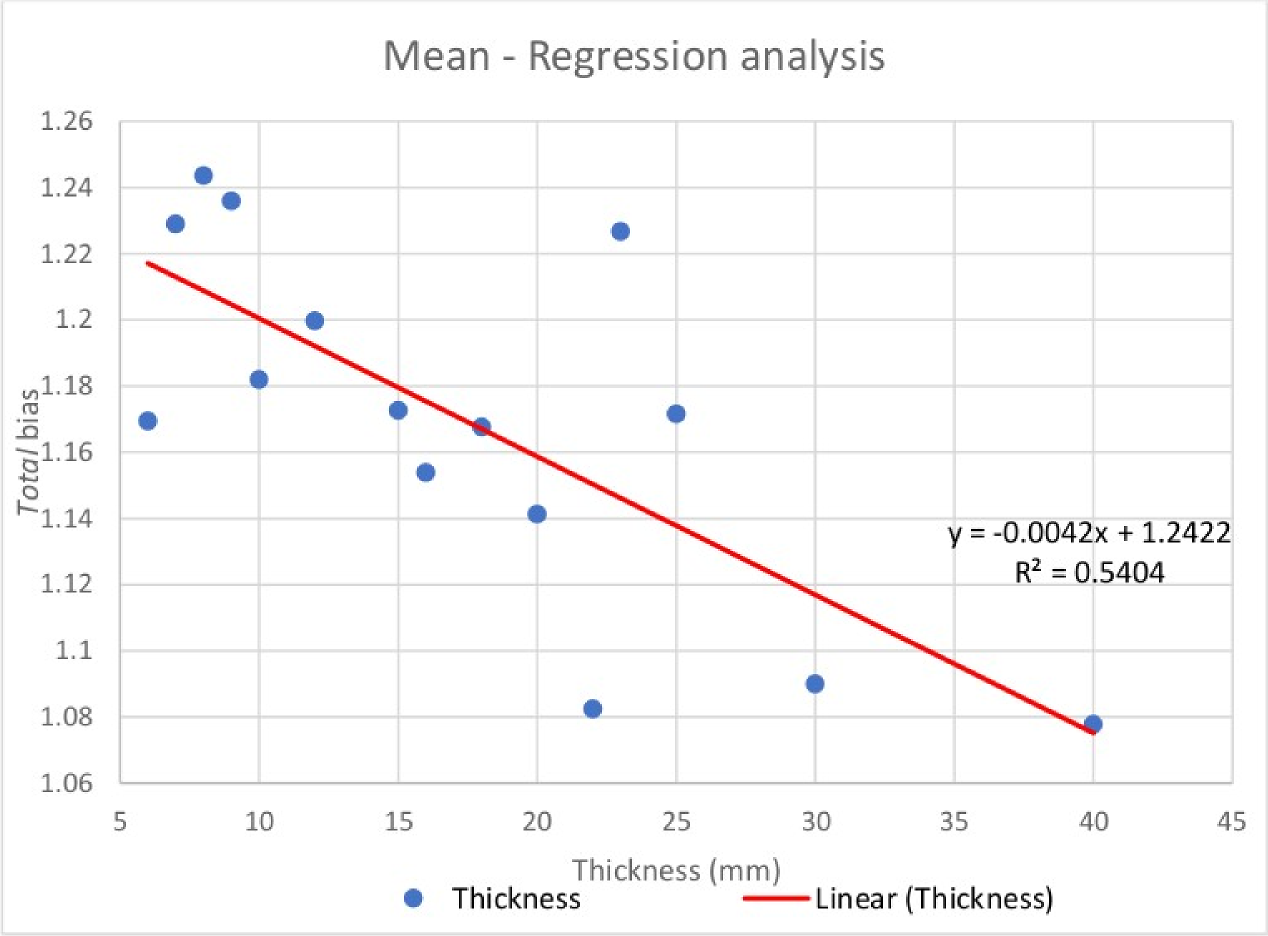
SUMMARY OF YIELD STRENGTH VARIABLES

- By grade of steel



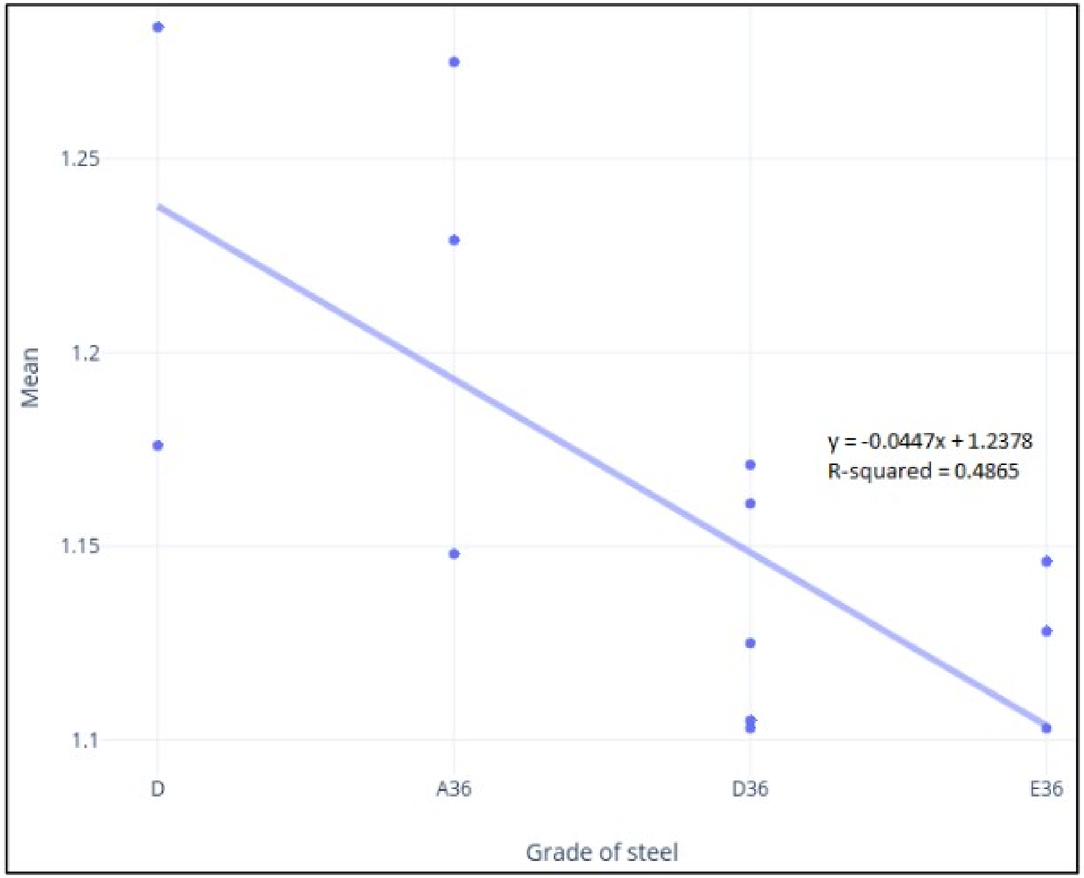
SUMMARY OF YIELD STRENGTH VARIABLES

- By different thicknesses



SUMMARY OF YIELD STRENGTH VARIABLES

- By manufacturer



SUMMARY OF IMPACT ENERGY VARIABLES

- Probabilistic characteristics of Impact Energy data

6.69x to 9.82x higher than nominal value

Type of steel	N. of data	*Mean*	*Median*	*Variance*	*Standard Deviation*	*COV*	*Skewness*	*Kurtosis*	Distribution
OS steel	228	9.824	10.5	4.802	2.191	22.307	-0.3944	0.415	Weibull
HS steel - 355 MPa	1214	6.693	6.833	7.174	2.678	40.019	0.5677	4.096	Weibull
HS steel - 390 MPa	54	8.923	9.326	3.463	1.860	20.853	-0.2902	-1.421	Weibull

CONCLUSION

Plate Thickness, Yield Strength and Impact Energy data analysis

CONCLUSION

- Plate thickness

  – The overall plate thickness is 103.3% (from *ratio* bias) or 0.37mm (from *difference* bias) thicker than the nominal value of each steel plate.

  – It was observed that OS steel presents higher variability in thickness compared to HS steel, so it can be used in favor of ordinary mild steel in the point of view of extra strength and safety margin.

  – There has been observed a tendency of the variability from thinner to thicker plates.

  – Therefore, we do not suggest to use overall average of plate thickness once they may overestimate or underestimate the real value, in the other hand we suggest to use the averages by type of steel because it best represent the reality.

CONCLUSION

- Yield strength
  - The real yield strength of steel plates showed to be much higher than nominal value.
  - OS steel showed to have a safer margin (25.7%) in the yield strength compared to HS steel (14.99%).
  - The maximum values of yield strength found for OS steel is 515MPa, which is much higher than the nominal value of HS steels.
  - The uncertainty of yield strength decreases from OS to HS steel, from lower to higher grades.
  - Plate thickness showed have significantly effect over the yield strength ratio, and it tends to be higher for thinner plates.

CONCLUSION

- Impact Energy

  – Impact energy value showed that its strength in reality is much higher than the nominal value required by IACS:

    - 9.82 times higher in OS steel,
    - 6.69 times higher in HS steel (355MPa)
    - 8.92 times higher in HS steel (390MPa).

  – The safety margin in the impact strength of steel plates is very high.

  – We suggest that more data should be collected in order to draw a solid conclusion about this average value.


Thank you!
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