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Deep Neural Network (DNN) Method to predict the displacement behavior of neutral axis for ships in vertical bending

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Introduction

Motivation

DNN Method

Results: Leave-one-out technique

Results: Wild Data

Conclusions

Several methodologies for computation of ultimate hull girder strength exist:

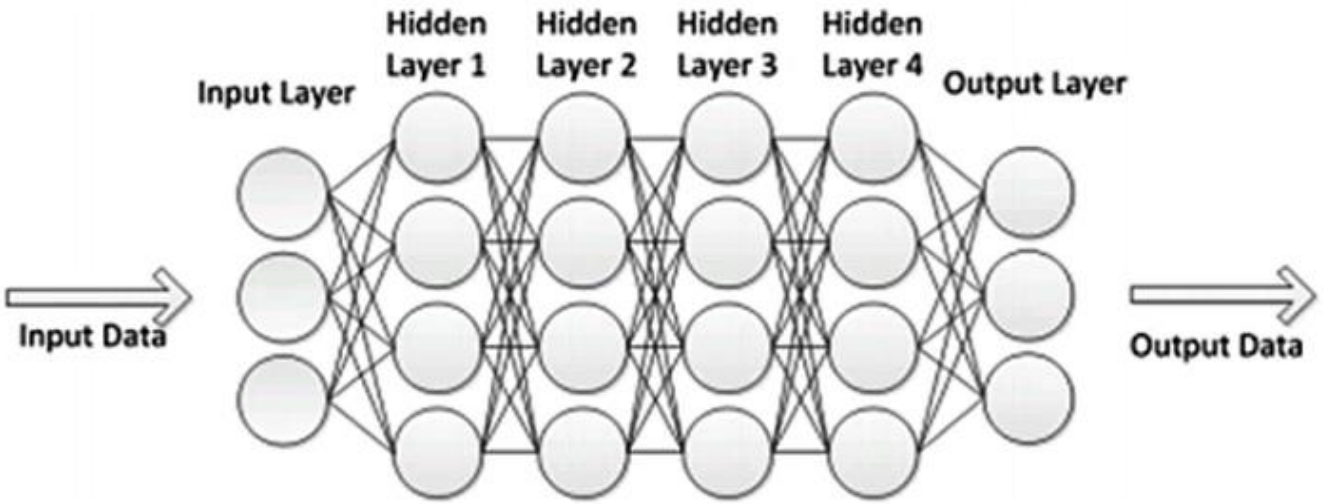
- Presumed stress distribution-based method
- Finite Element Method (FEM)
- Idealized Structural Unit Method (ISUM)
- Intelligent Supersize Finite Element Method (ISFEM)

Some further methods could be employed?

- DNN (Deep Neural Network)

DNN successfully applied in various marine engineering fields

- Shorten the computation time for the result prediction
- Typical High Accuracy Estimation
- Reduced Modeling efforts



Reference:
Kamaljit, I., and D. Modi. "Deep Learning: Architectures and Applications." In Handbook of Research on Deep Learning Innovations and Trends, by Aboul Ella Hassanien, Ashraf Darwish and Chiranji Lal Chowdhary, 133-136. 2019.

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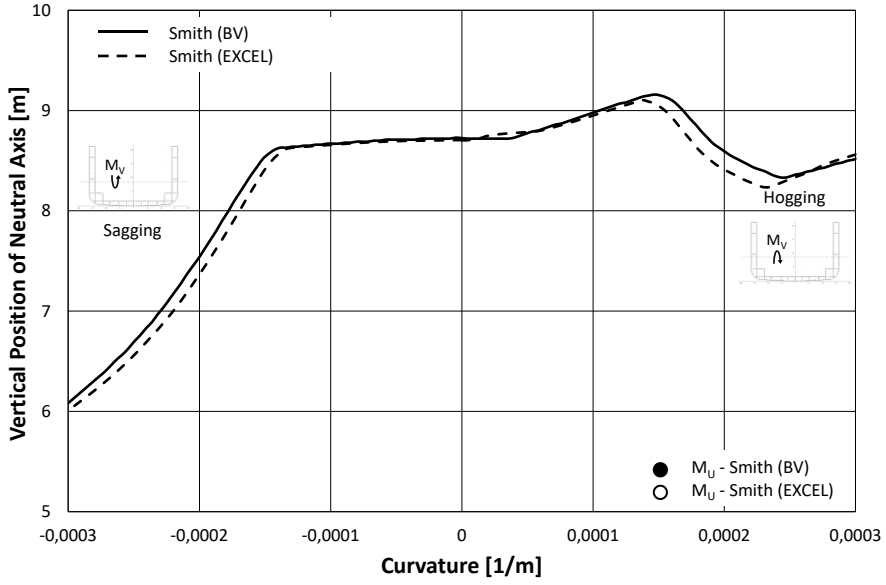
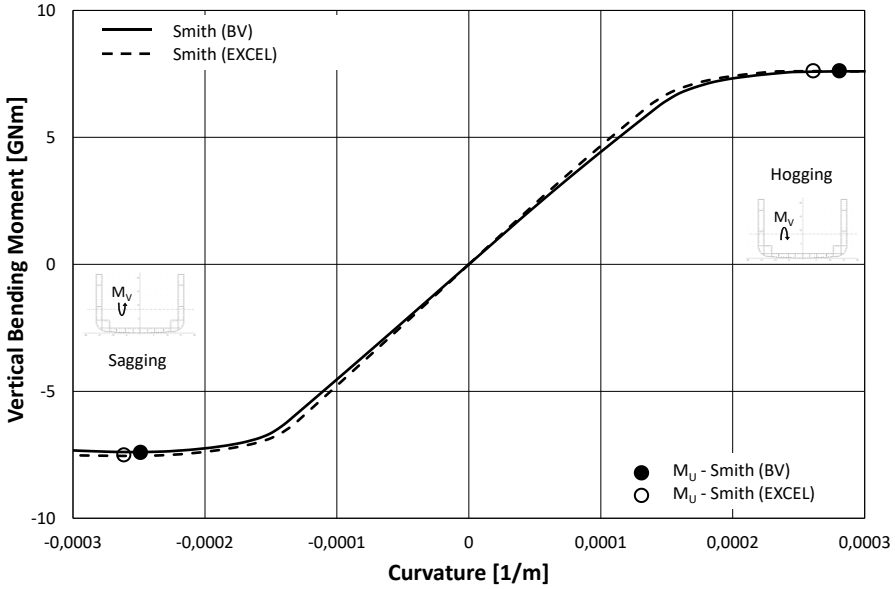
- Study can be counted as initial phase for successive prediction of residual ultimate strength
- Understanding of the DNN results and of specific feature weights play a paramount role for further steps which consists into more relevant prediction of ultimate hull girder strength

Neutral Axis (3500 TEU Container Vessel)



Moment-Curvature Curve (Vertical Bending)



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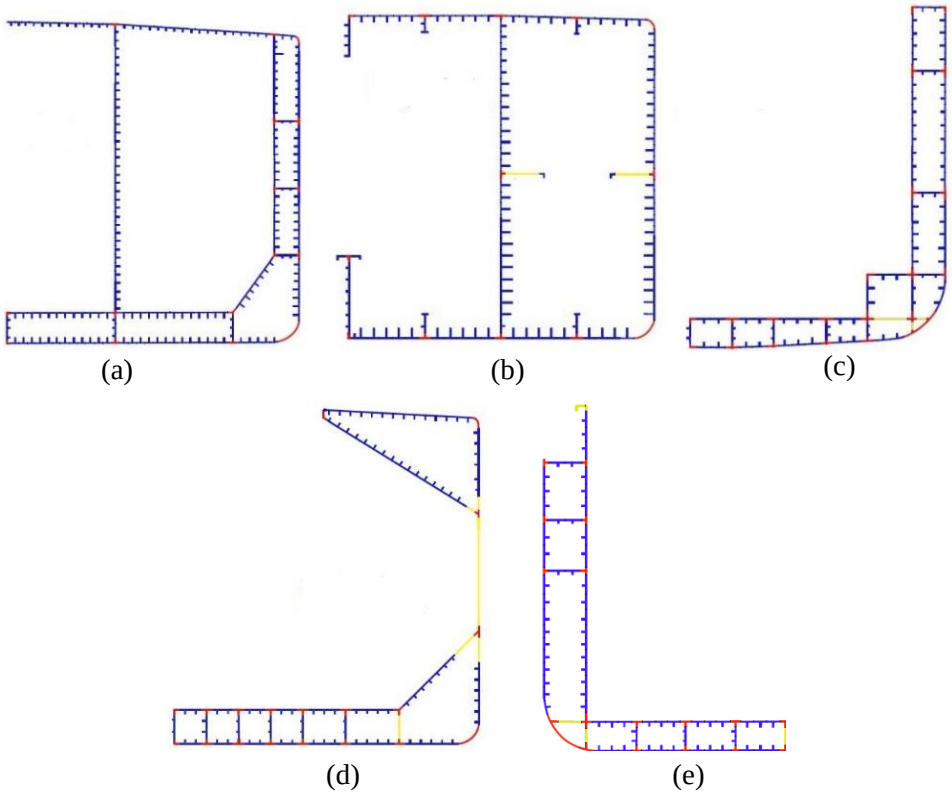
Five different Cross Sections have been considered

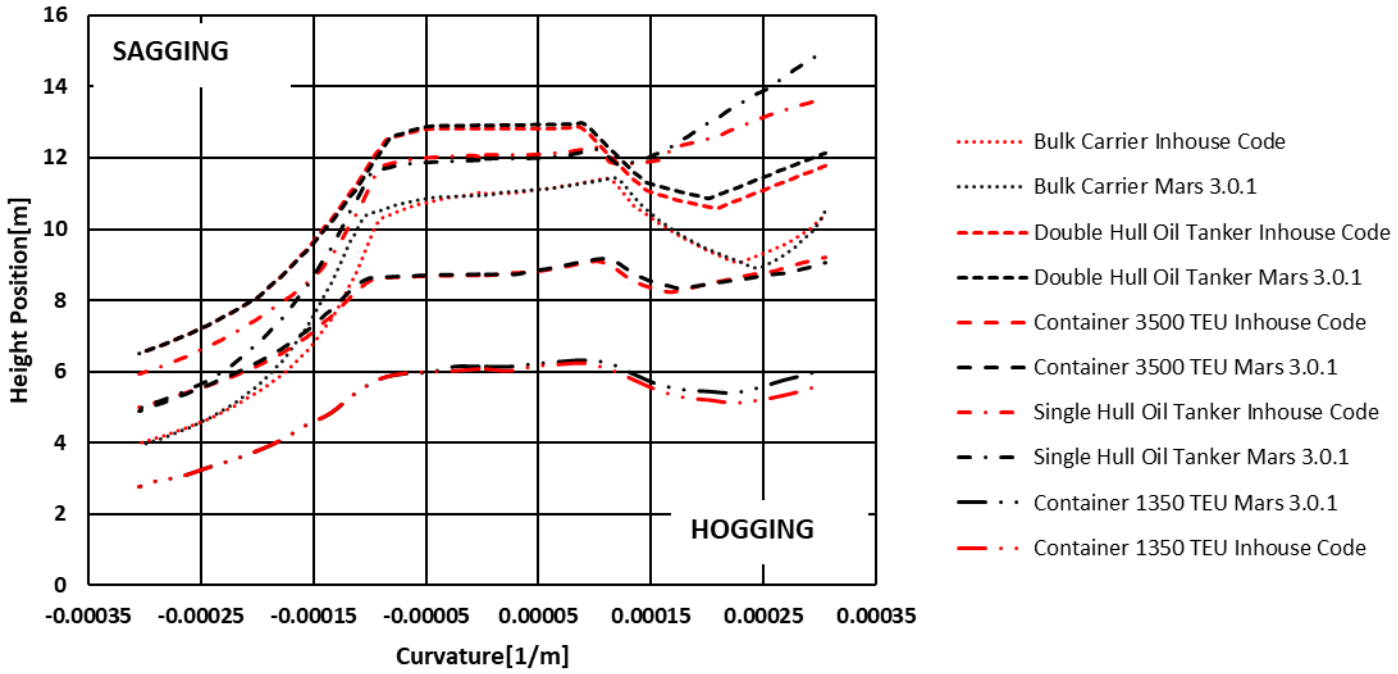
Vessel	Length [m]	Breadth [m]	Depth [m]
Double Hull Oil Tanker	315	58	30.3
Single Hull Tanker	313	48.2	25.2
1350TEU Container	147	25	14.8
3500TEU Container	230	32.2	21.5
Bulk Carrier	285	50	26.7



Cross section discretization:
(a) Double Hull Oil Tanker, (b) Single Hull Tanker, (c) 3500TEU Container, (d) Bulk Carrier, (e) 1350TEU Container

Reference:
ISSC Committee VI.2: Ultimate Hull Girder Strength. Proceedings of the 14th International Ship and Offshore Structure Congress, Vol 2: pp. 321-391, Nagasaki, Japan, 2000.

Initial source data have been generated by considering numerical residual strength calculations (obtained with a self developed code based on Smith Method), where the **neutral axis** at each iteration is established by imposing the force equilibrium over the whole midship section.

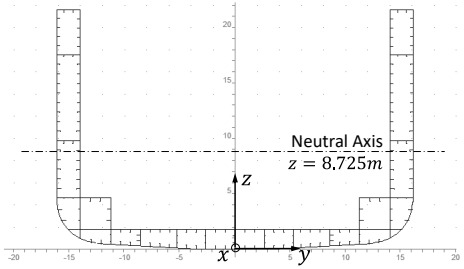


Damage Scenarios

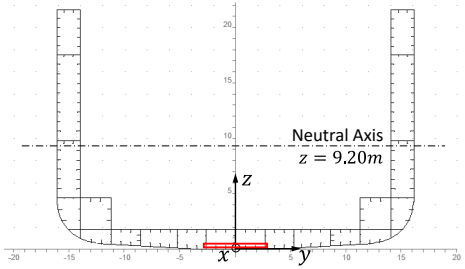
Scenario	Damage Width Extension	Damage Height Extension (DB)
Intact	0%	0%
A	20%	0%
B	40%	40%
C	60%	60%
D	80%	80%
E	90%	90%

- Simulated cases have been chosen by increasing progressively damage height and damage width with respect to the vessel center line
- Only symmetrical damages have been considered

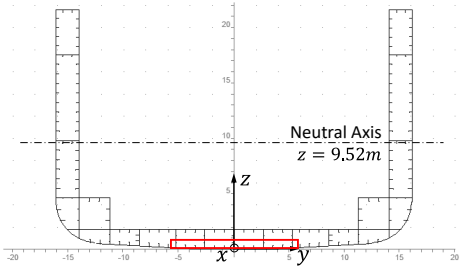
Scenario Intact



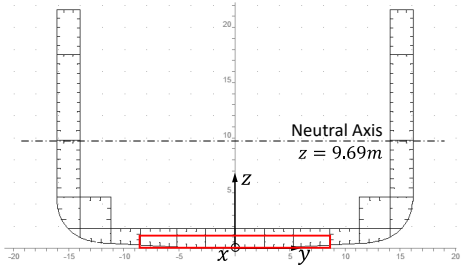
Scenario A



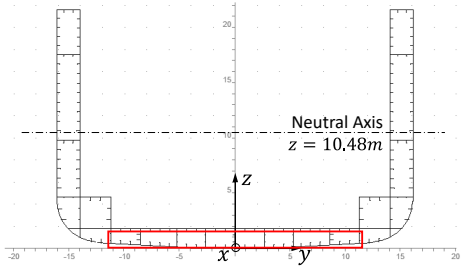
Scenario B



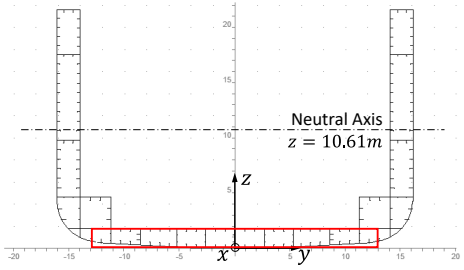
Scenario C



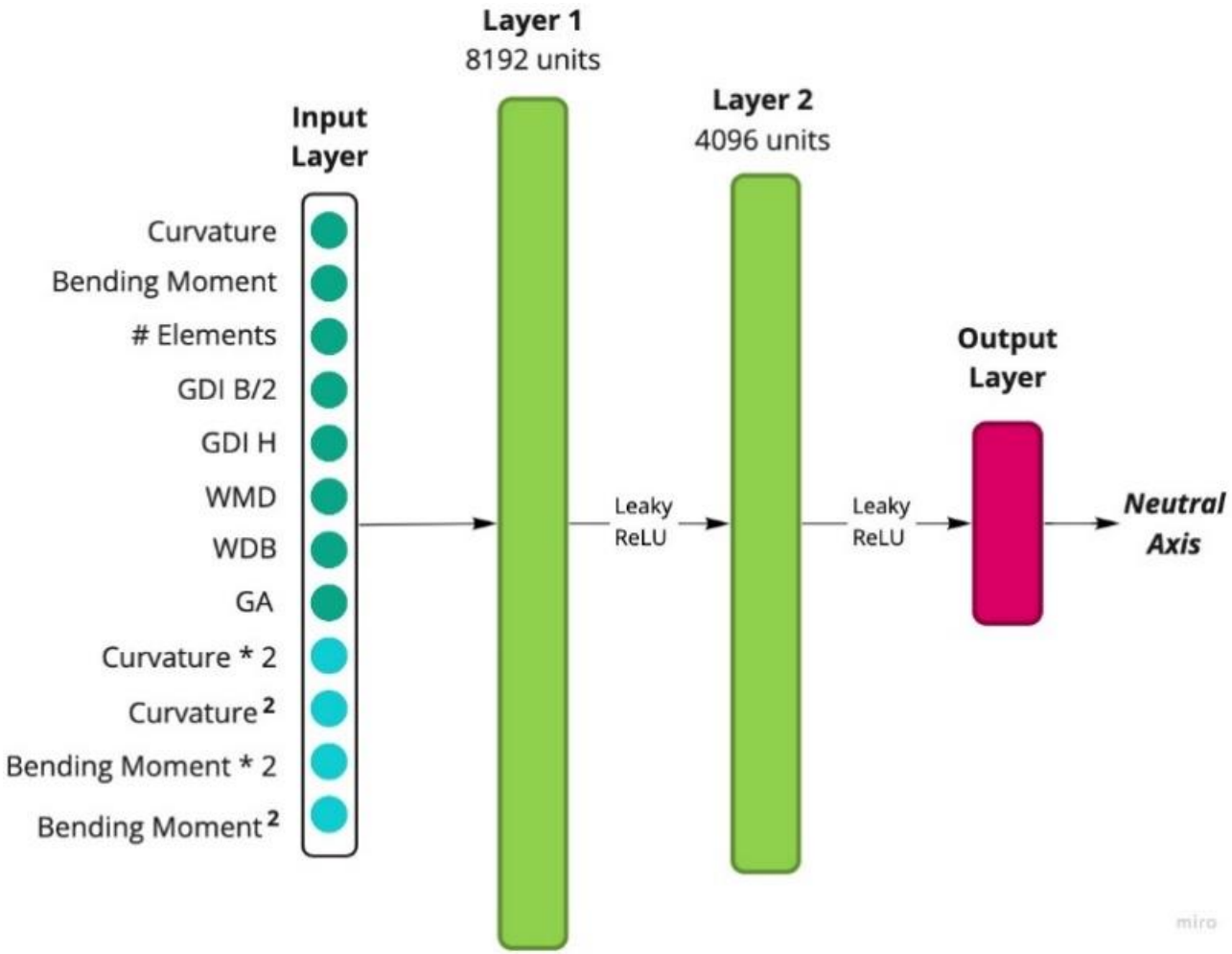
Scenario D



Scenario E



DNN Architecture



Due to limited number of data and features, the input layer is composed of not only the initial parameters (green bullets), but a slightly data augmentation is performed to extrapolate more information (light blue bullets)

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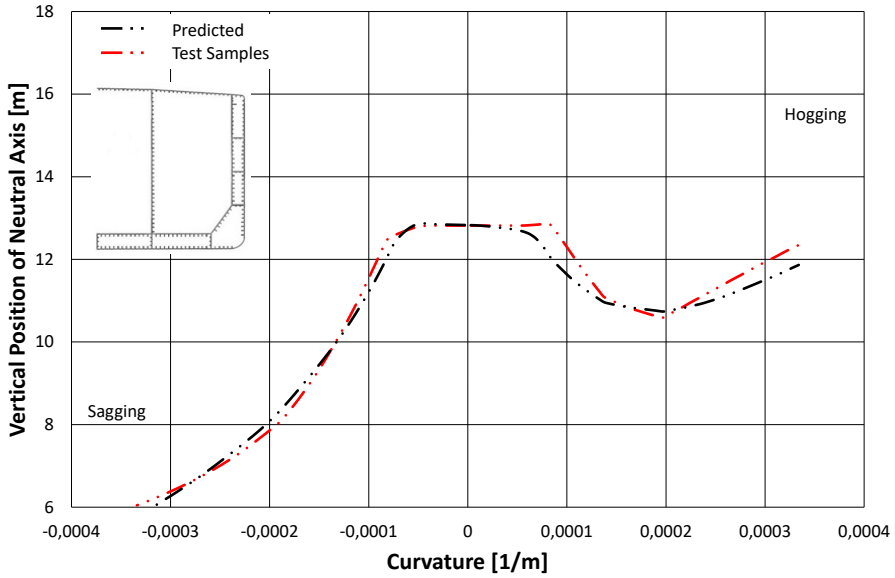
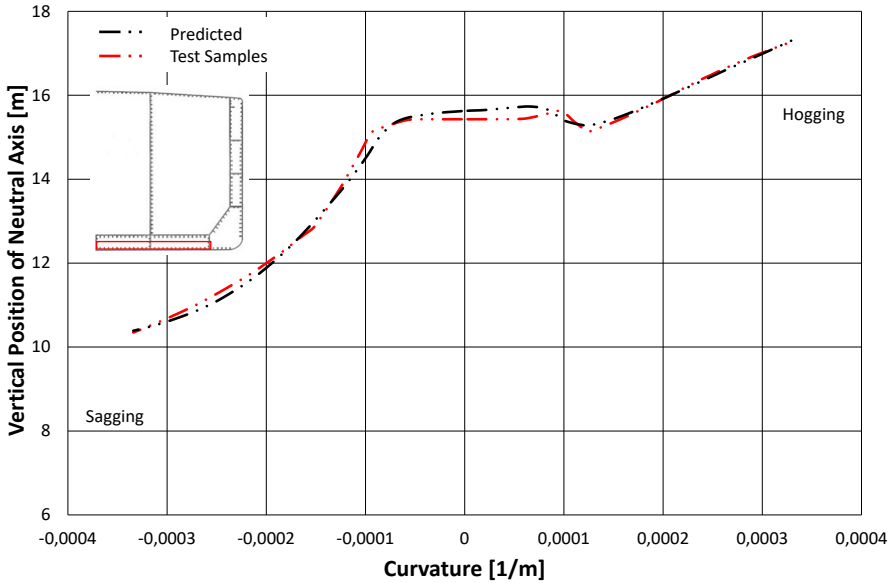
Neutral Axis Displacement Prediction
Leave-on-out approach to validate DNN

Double Hull Oil Tanker (Scenario Intact)

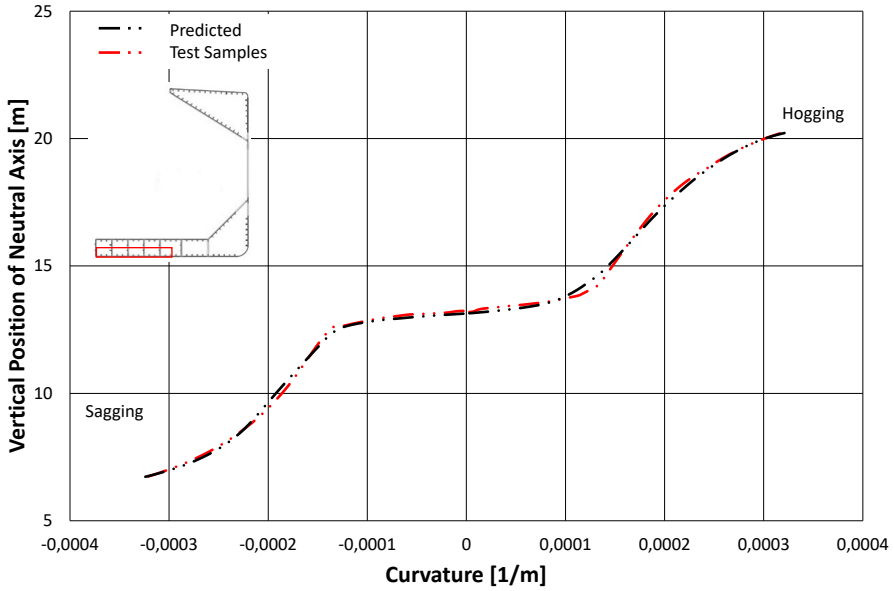


Double Hull Oil Tanker (Scenario D)

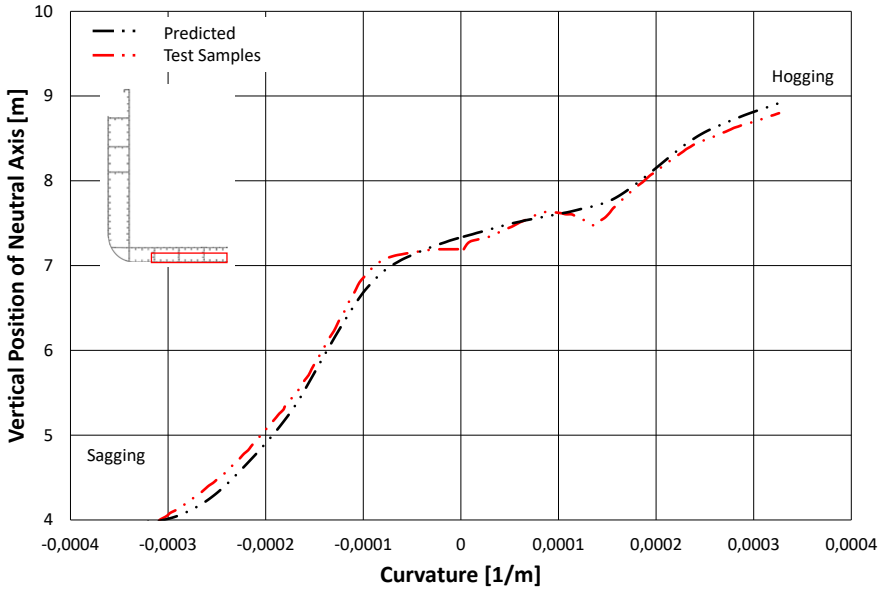


Neutral Axis Displacement Prediction
Leave-on-out approach to validate DNN

Bulk Carrier (Scenario C)



Container 1350 TEU (Scenario C)



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- **Results: Wild Data**
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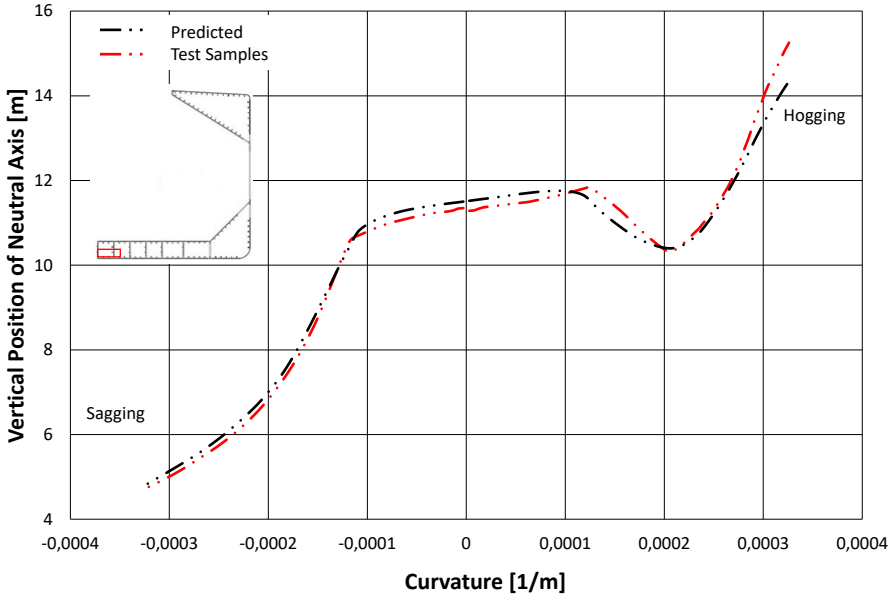
Neutral Axis Displacement Prediction
Wild Data: New Scenarios unknow to the DNN

Scenarios for wild data

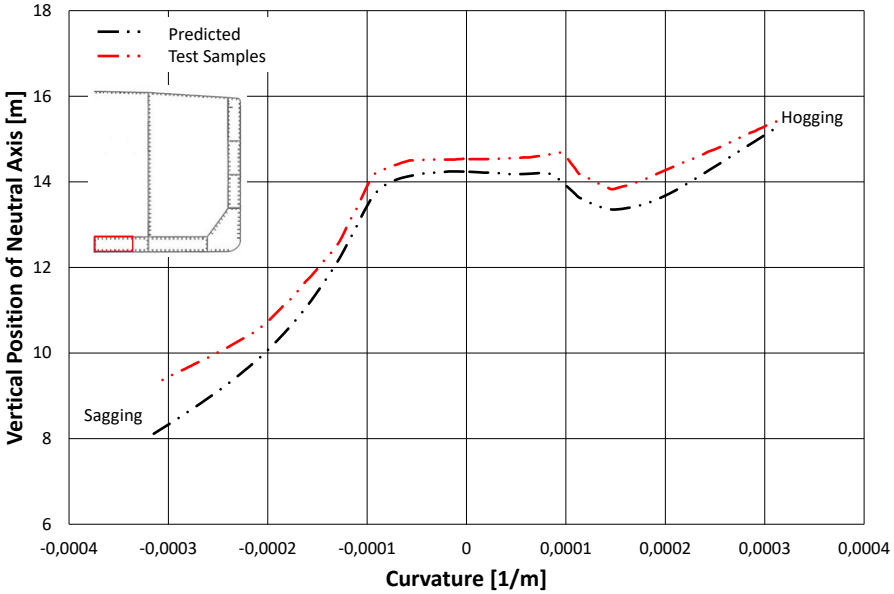
Scenario	Damage Width Extension	Damage Height Extension (DB)
F	12%	35%
G	37%	100%
H	17%	40%

Bulk Carrier (Scenario F)

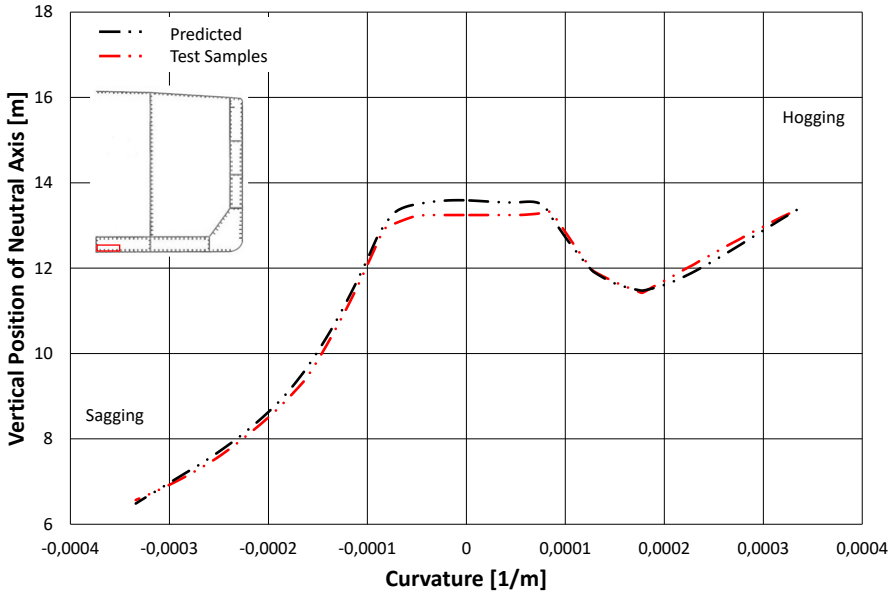


Neutral Axis Displacement Prediction
Wild Data: New Scenarios unknow to the DNN

Double Hull Oil Tanker (Scenario G)



Double Hull Oil Tanker (Scenario H)



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Conclusions

- Results obtained by predicting new scenarios unknown to DNN show good agreement with the actual corresponding values
- Determination of neutral axis position and ultimate capacity strength could evoke application of simple model 2D tools
- Presented approach ensures to successfully determine behavior of instantaneous neutral axis rapidly
- Good agreement prediction for the neutral axis displacement behavior will consolidate development of ultimate hull girder strength computation by applying DNN with increased number of samples and reduced number of features
- Initial source database could be improved and extended considering more precise calculation methods e.g., Finite Element Method (FEM), Idealized Structural Unit Method (ISUM)

Thank You for Your Attention!