Experimental Study on Slamming Loads by Simplified Substructures

EERA DeepWind`18

[17th ~19th /Jan/2018]

University of Ulsan, Wide Tank

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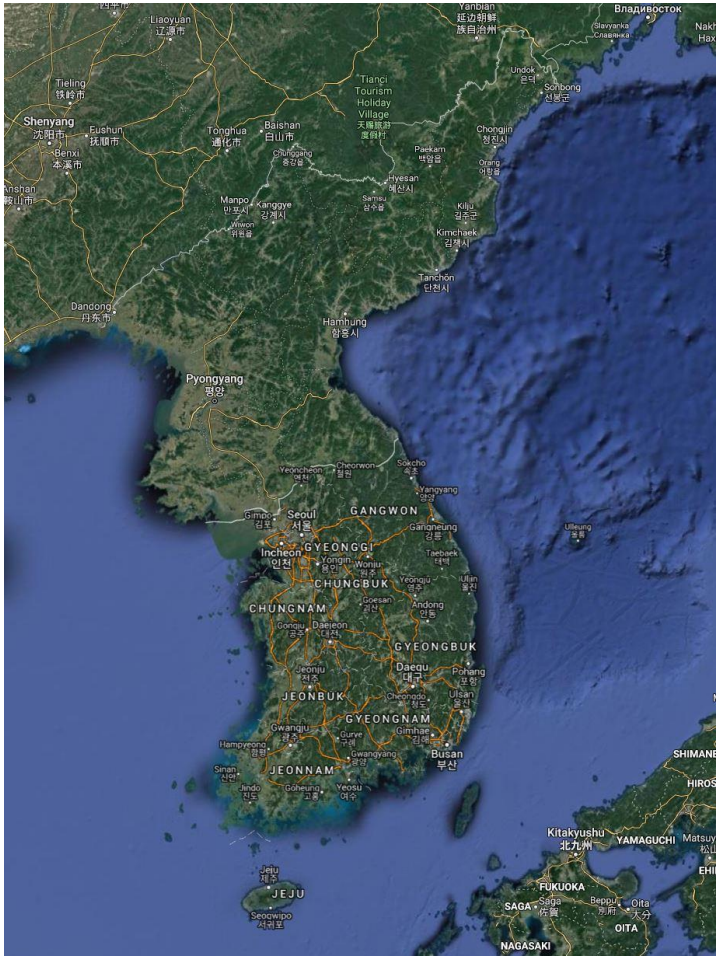
Professor : Hyunkyoung Shin

Presenter : Byoungcheon Seo

Contents

Introduction

Area : 99,720㎢, 109th in the world
Population : 51,778,544 people, 27th in the world
(CIA, The World Factbook)



Introduction

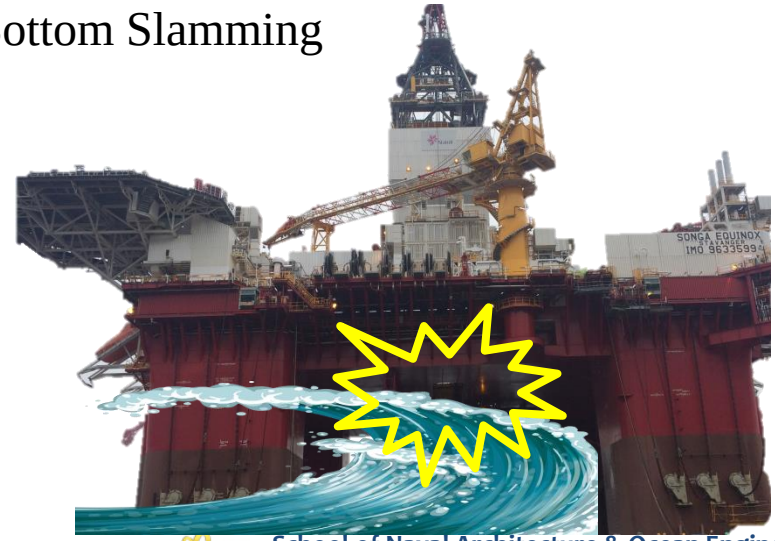
Introduction

Breaking Wave

Horizontal Slamming

Wave Run-up

Bottom Slamming

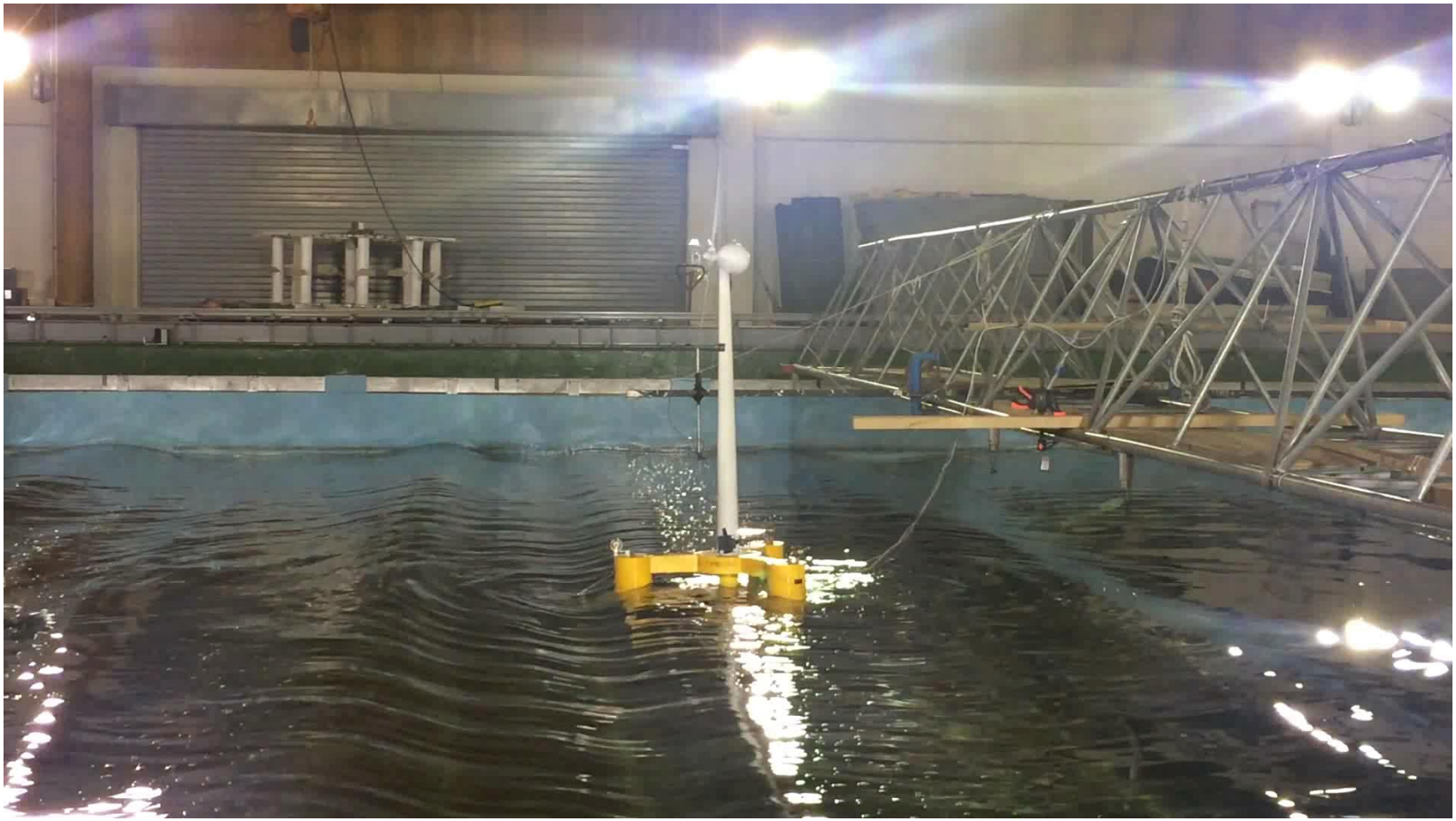


Introduction

- 30.Dec.2015
- Windows and Structures in upper hull failed due to horizontal Slamming
- Wave Height : 16.38 m
- Dead : 1 person
- Injury : 4 person

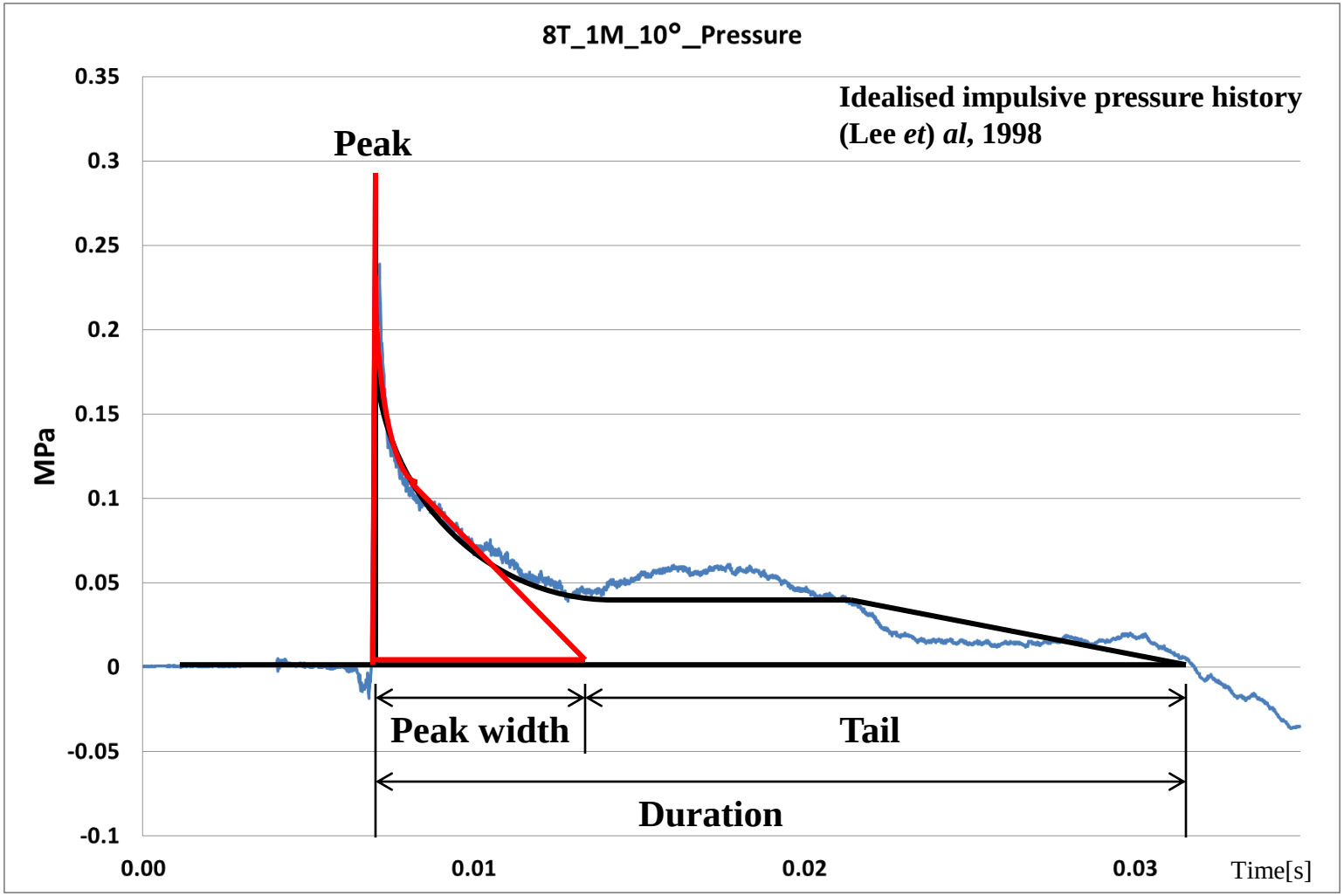
Introduction

- Test model in wide tank, UOU -
- Freeboard : 6 m(full scale), 150 mm(model scale)
- Condition : Irregular wave, sea state 6(extreme)

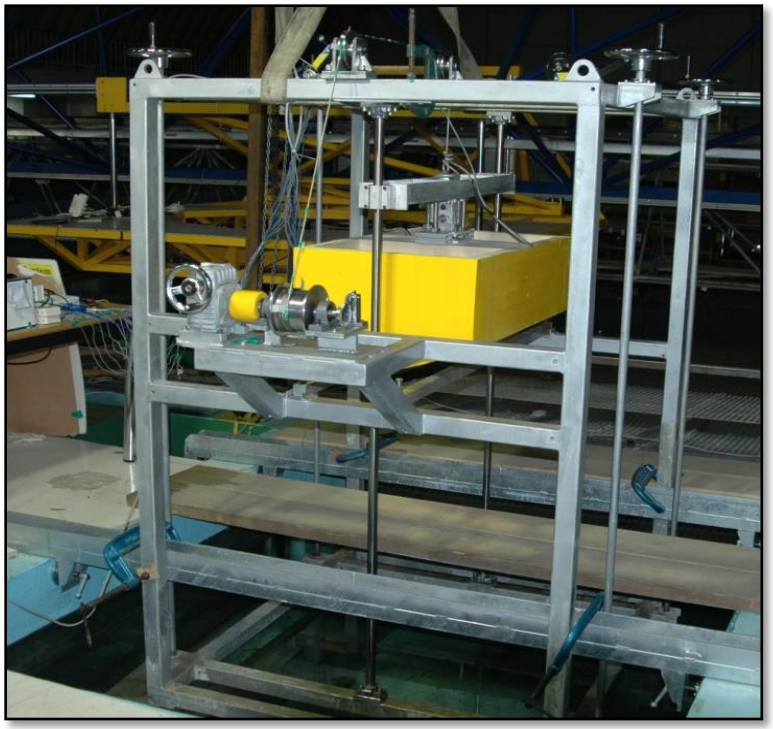


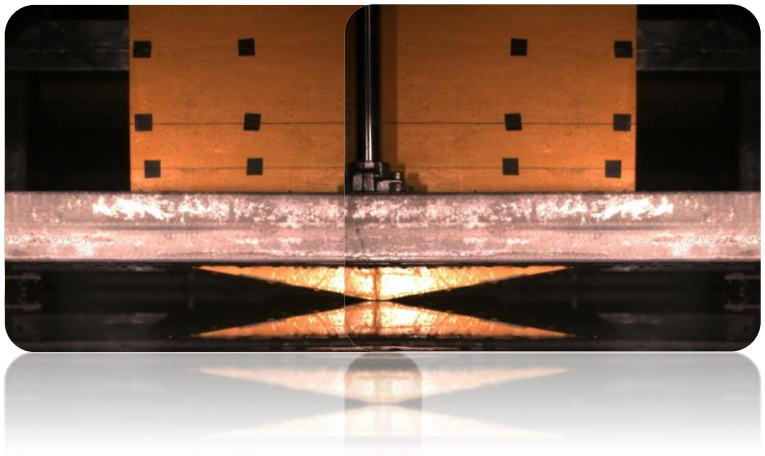
Introduction

- Information of impulsive pressure



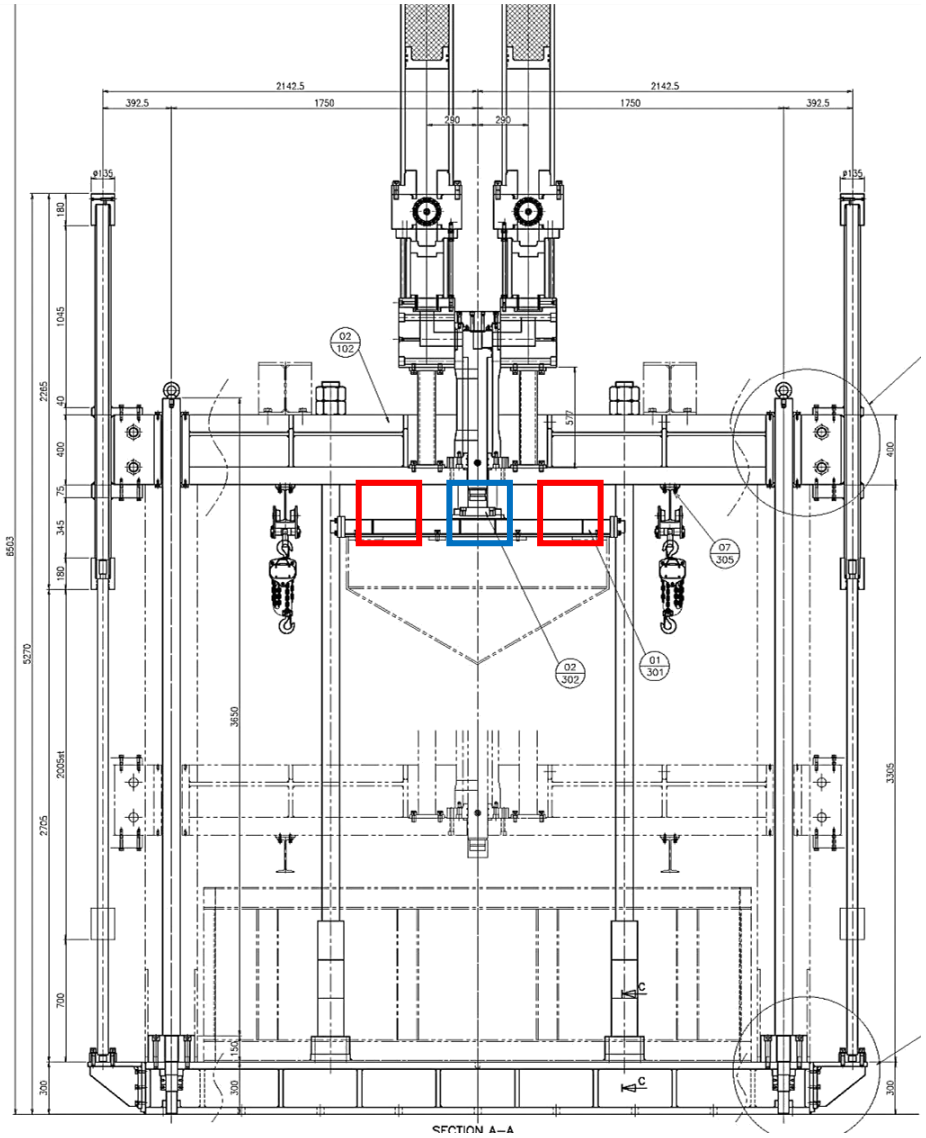
Experimental System (UOU Trimming Tank)

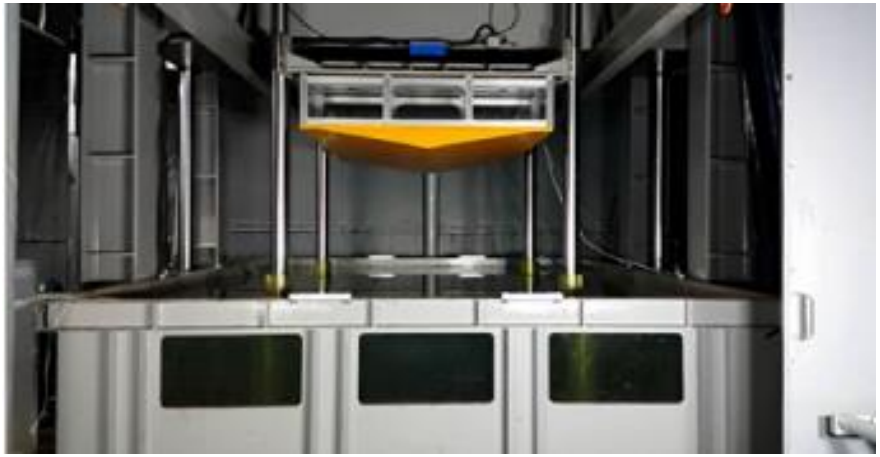


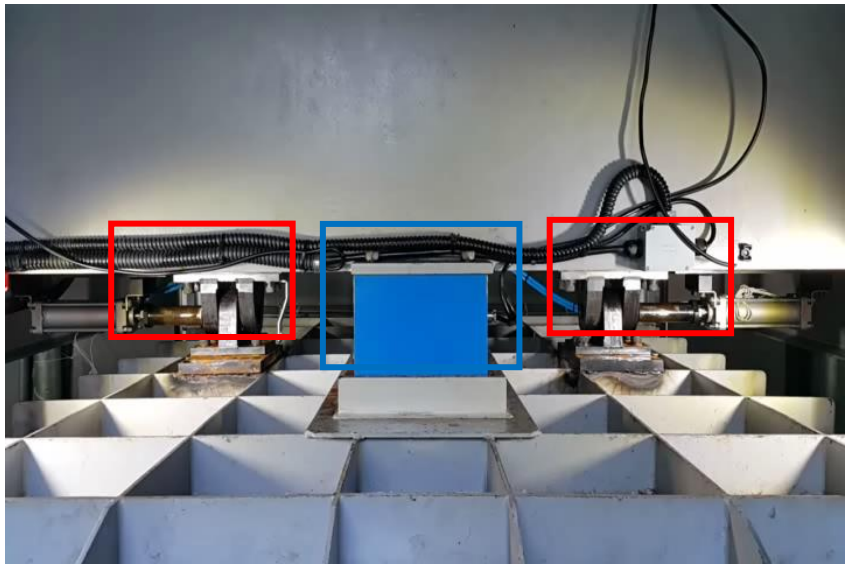


- **Trimming Tank**
- **Width = 2,170mm**
- **Water depth = 1,000 mm**
- **Max. drop height = 1,000mm**

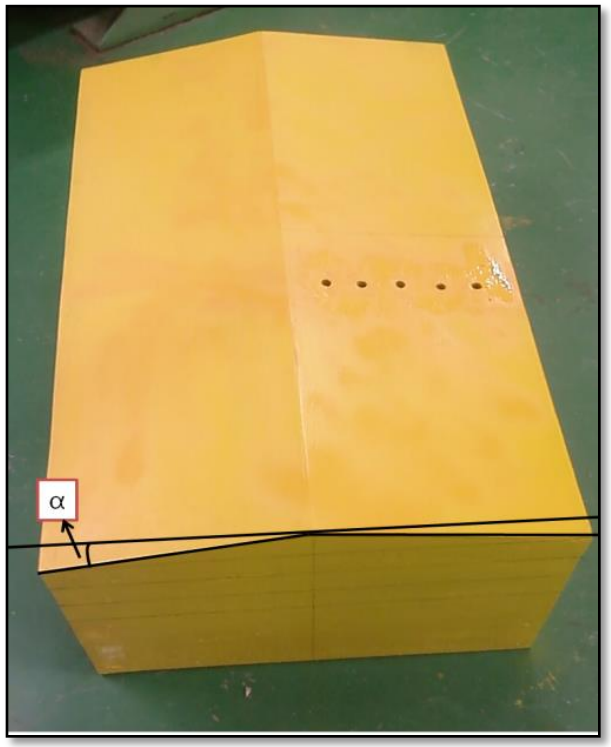
Experimental System (UOU Slamming Tank)

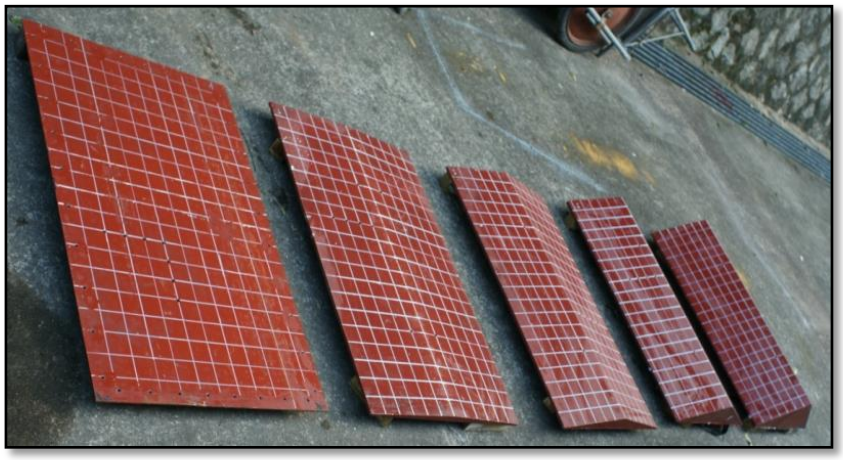






Test model (UOU Trimming Tank)

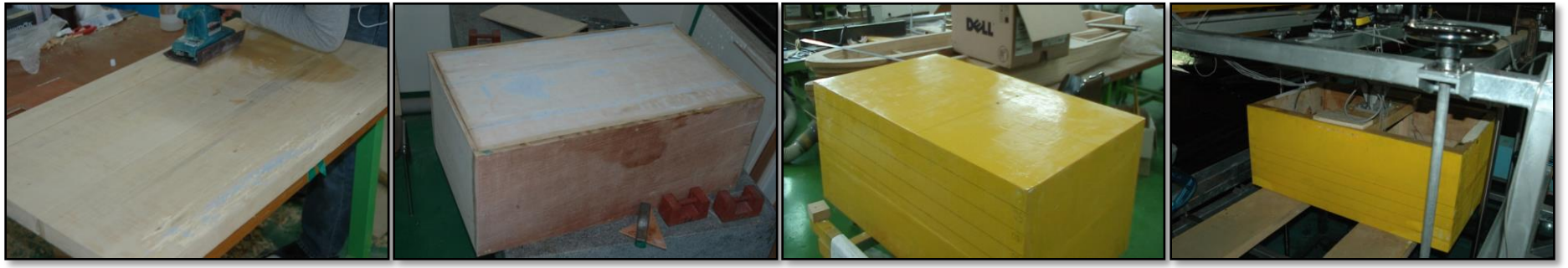




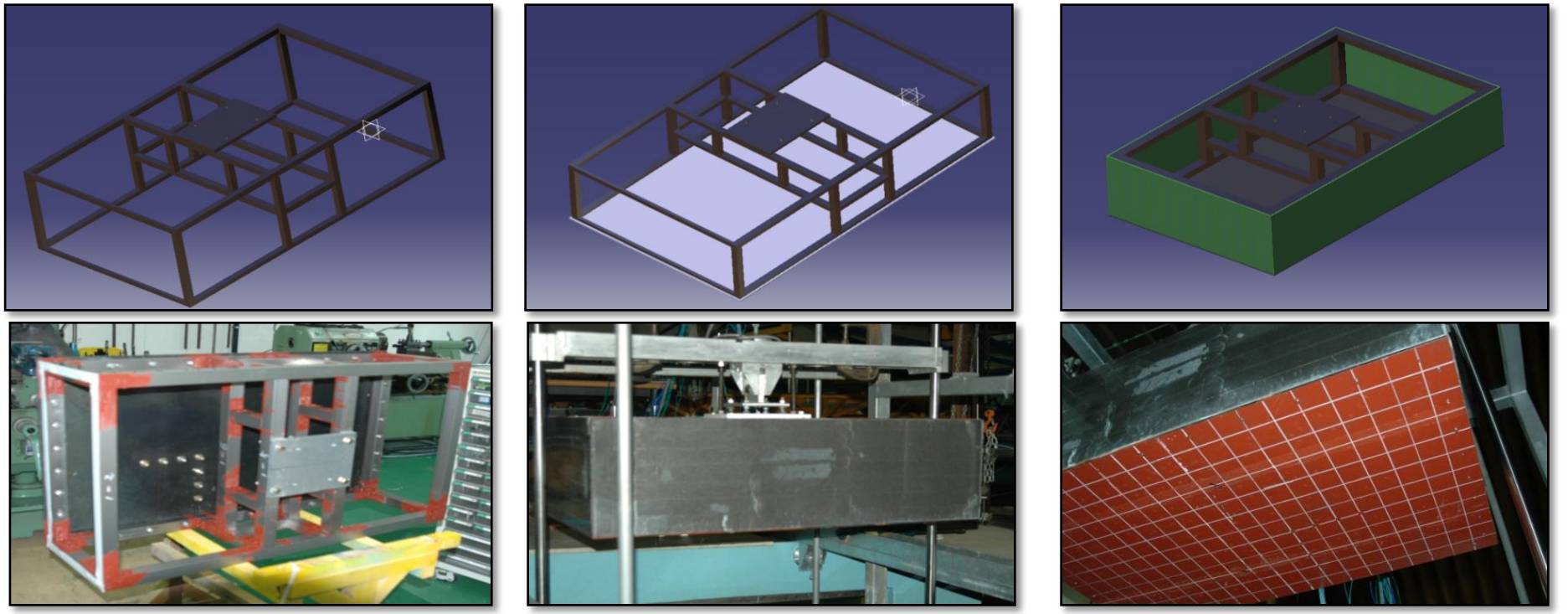
Model	Wood	Steel
Dead-rise angle [deg.]	0, 3,10	
Length [mm]	1,000	
Width [mm]	600	
Height [mm]	400	
Mass [kg]	60	
Bottom plate thickness [mm]	50	3,4,5

Test Model (Production process at UOU Trimming Tank)

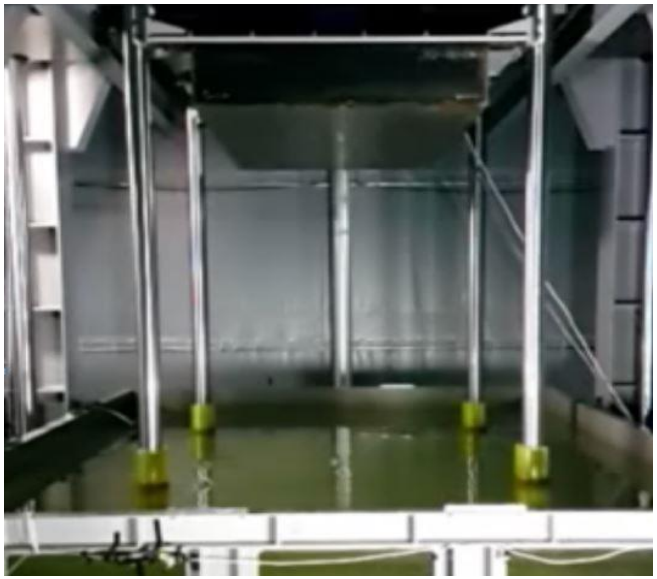
Wood

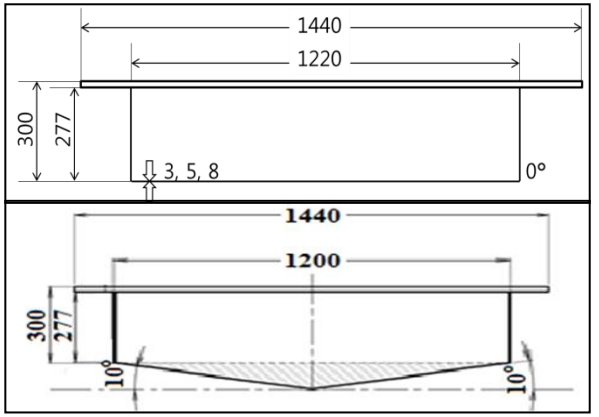


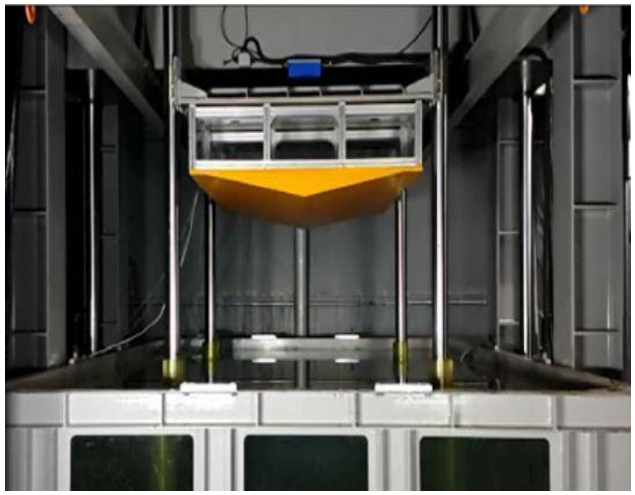
Steel



Test model (UOU Slamming Tank)

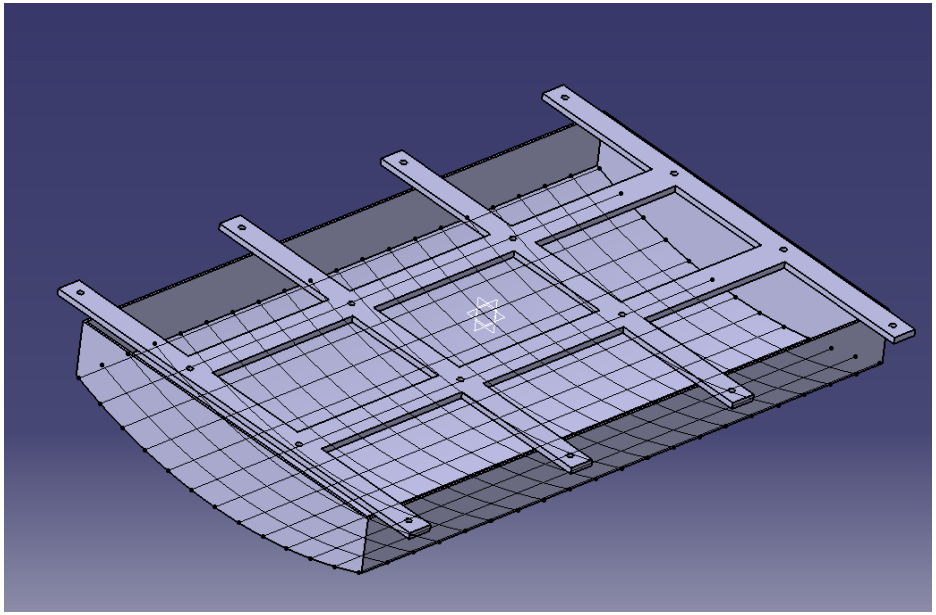






Model	Steel / Wood
Bottom plate thickness [mm]	3, 5, 8 / 100
Height [mm]	300
Length [mm]	2,000
Width [mm]	1,200
Mass [kg]	820
Dead-rise angle [deg.]	0, 10

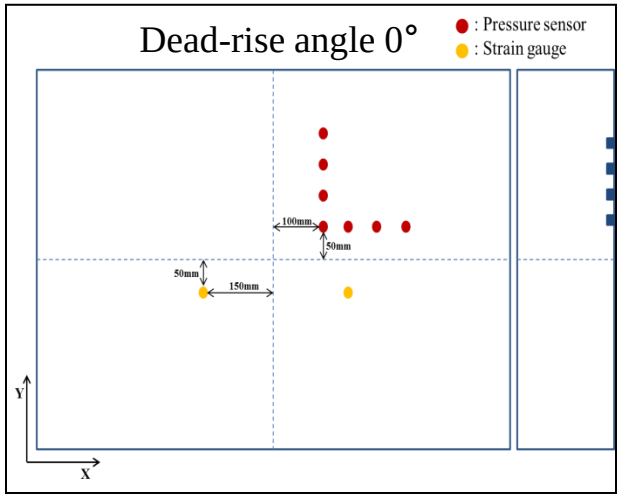
Test model (UOU Slamming Tank)

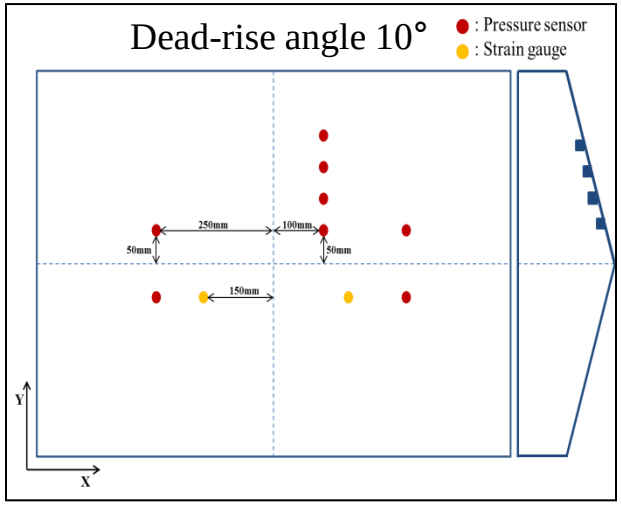


Model	Steel
Bottom plate thickness [mm]	8
Height [mm]	300
Length [mm]	2,000
Width [mm]	1,200
Mass [kg]	820
Dead-rise angle [deg.]	Cylindrical

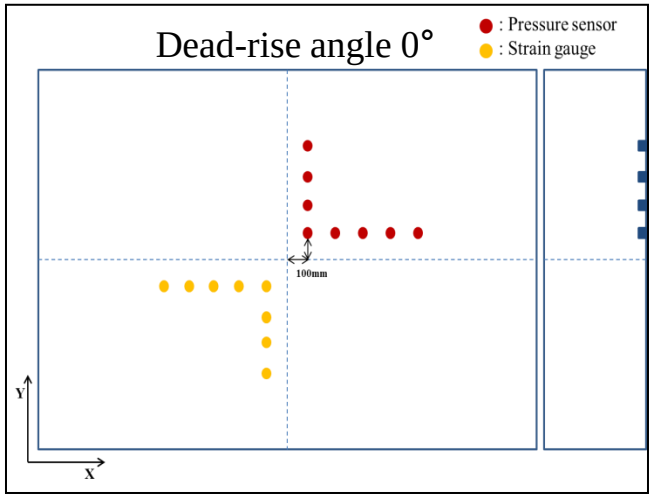
Measurement (Sensor location)

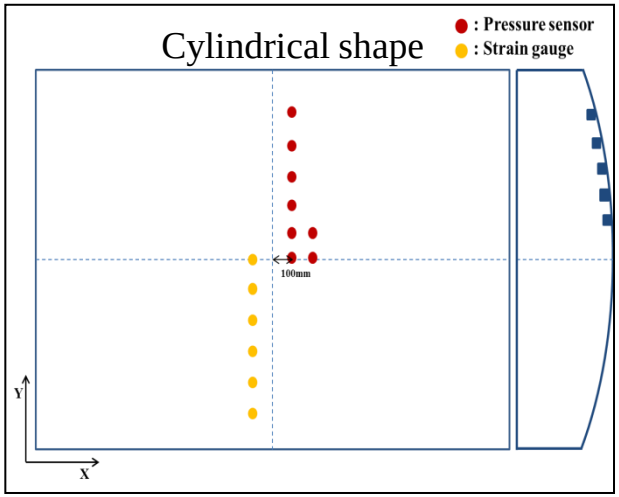
UOU Trimming Tank Model

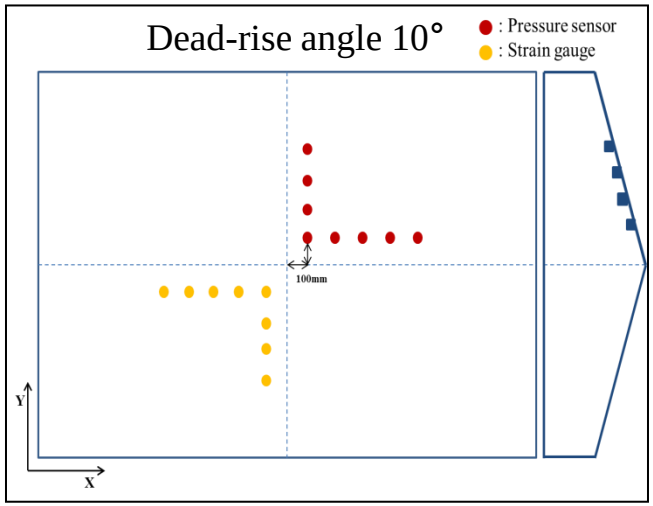


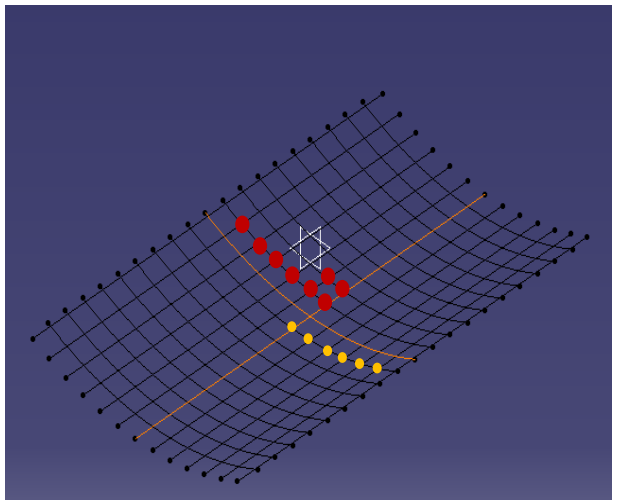


UOU Slamming Tank Model

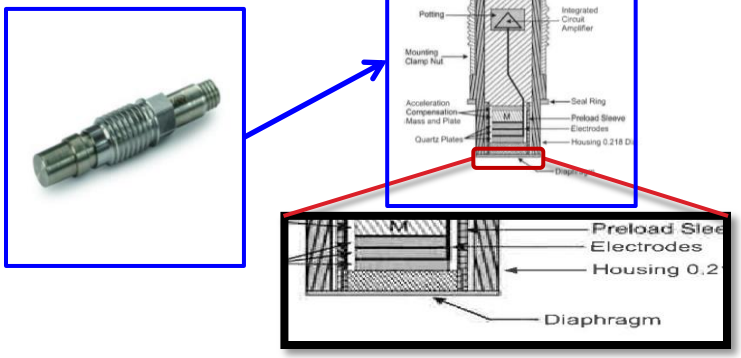


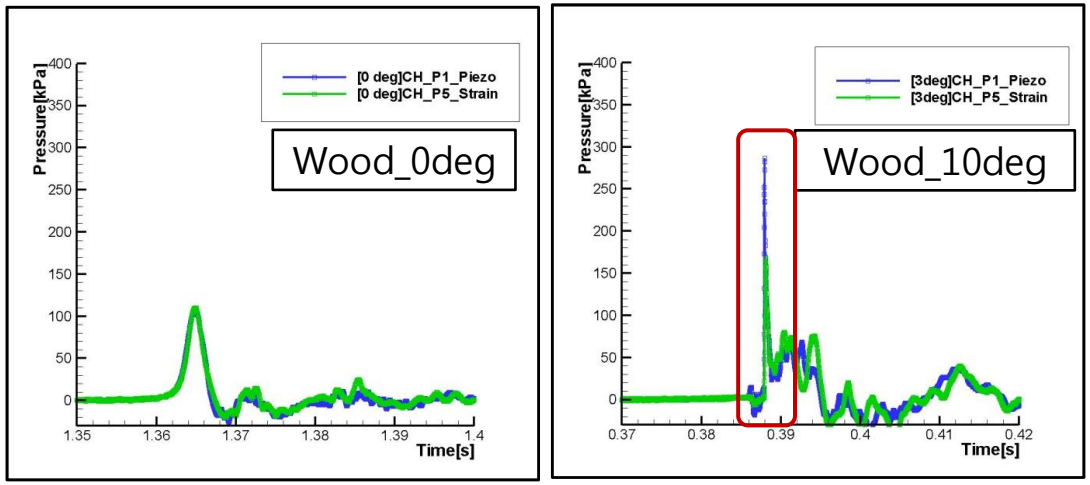




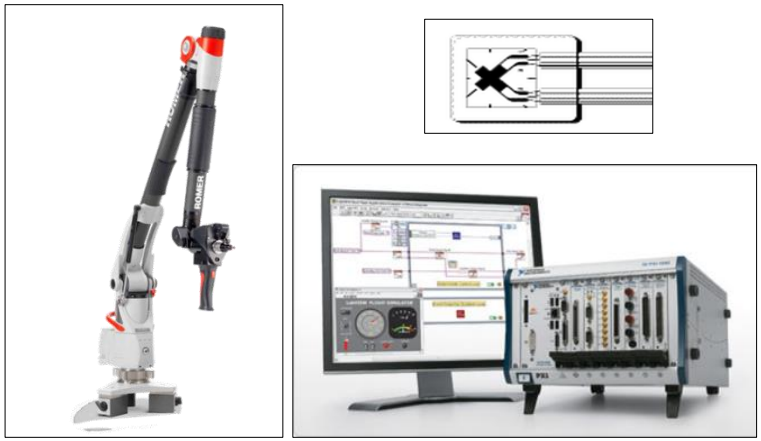


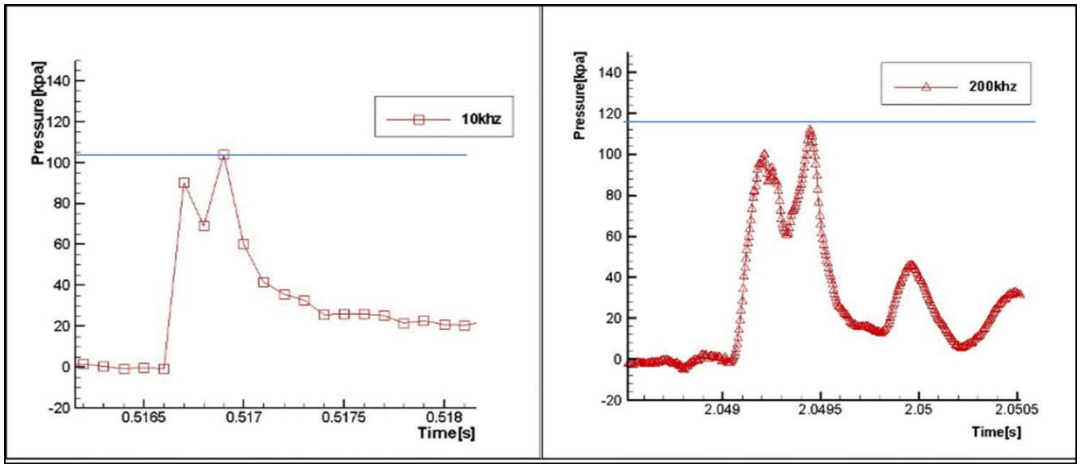
Measurement





➢ Comparison between Strain type and Piezoelectric type sensor

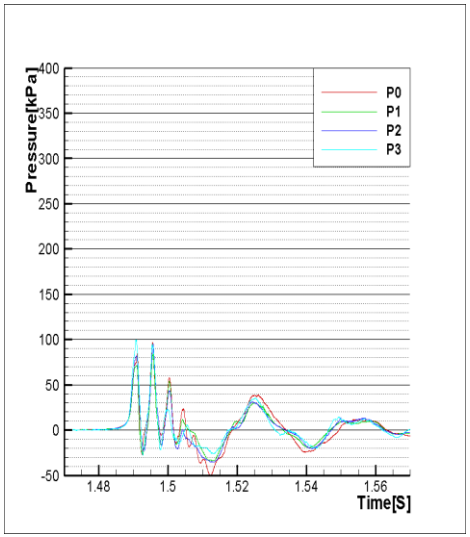


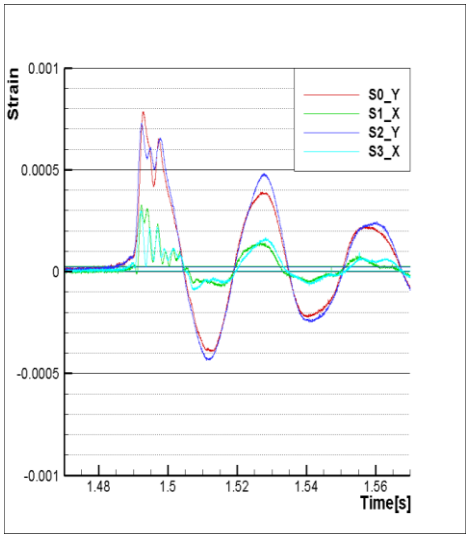


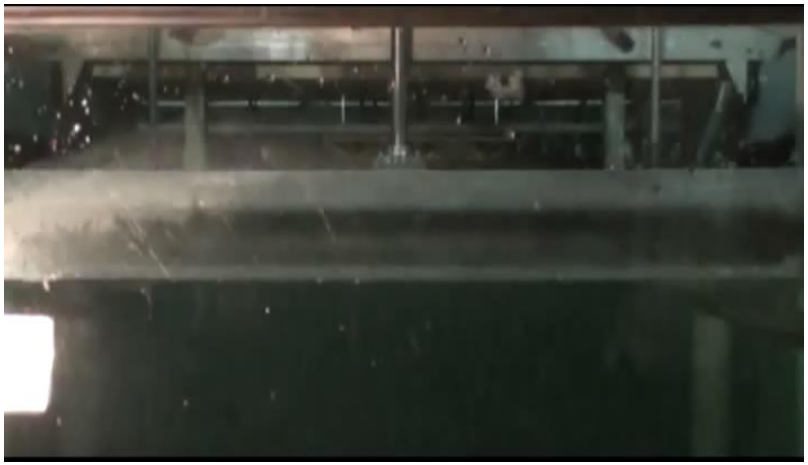
➢ Comparison sampling rate

Free wet drop test (UOU Trimming Tank)

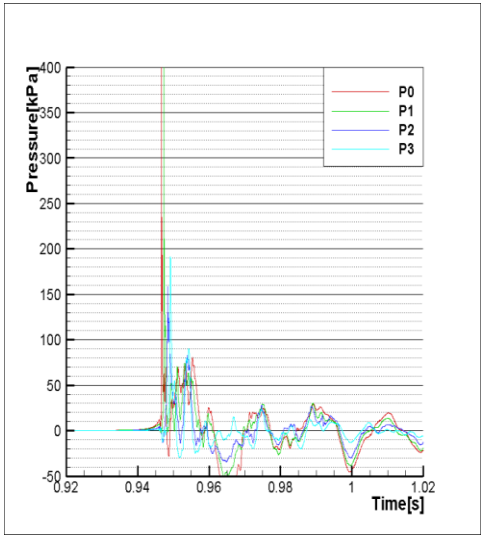
➢ Dead-rise angle 0°

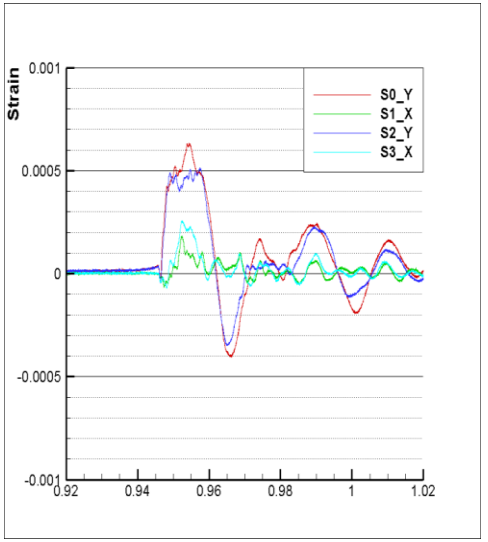




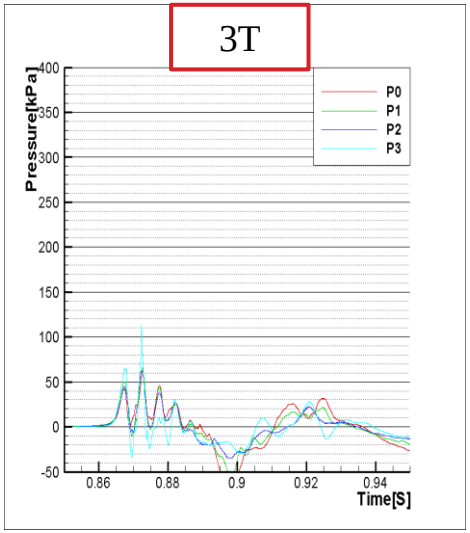


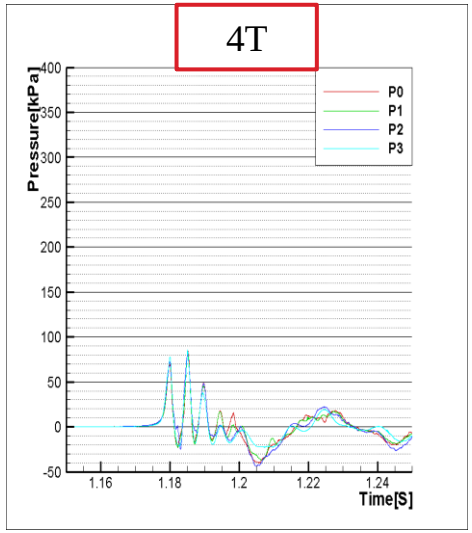
➢ Dead-rise angle 3°

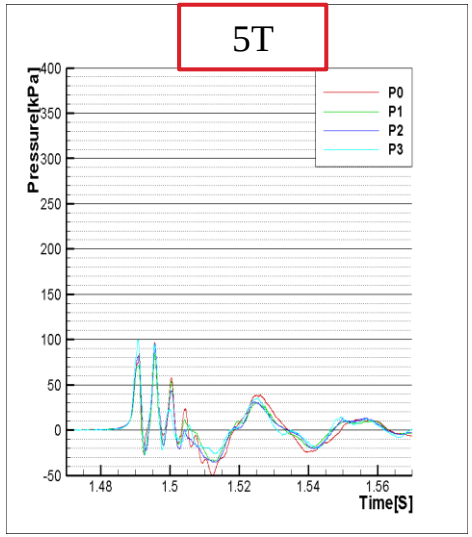


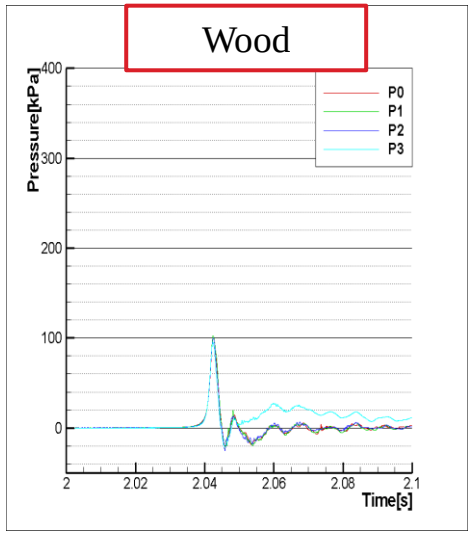


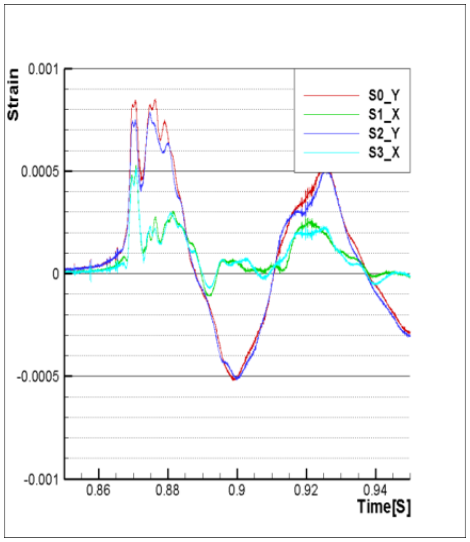
0° - 500mm Free drop test (UOU Trimming Tank)

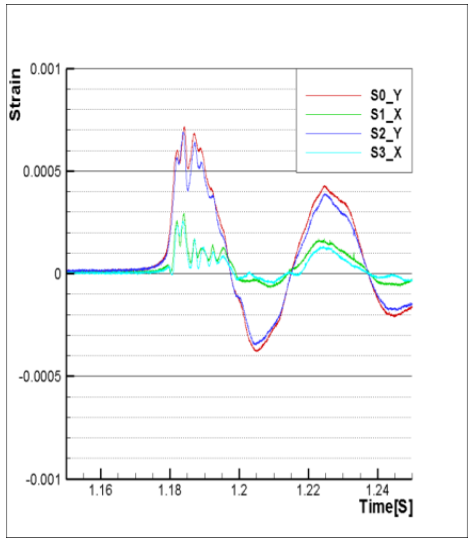


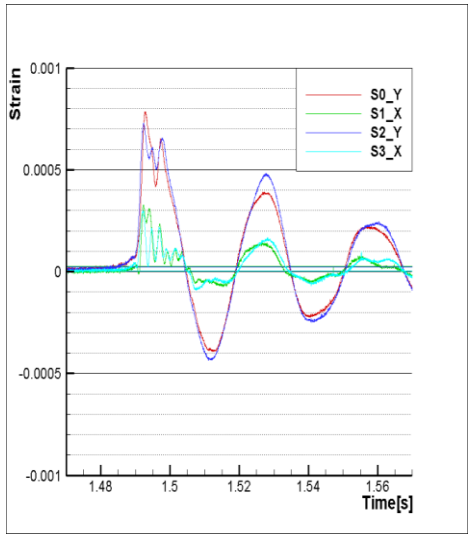


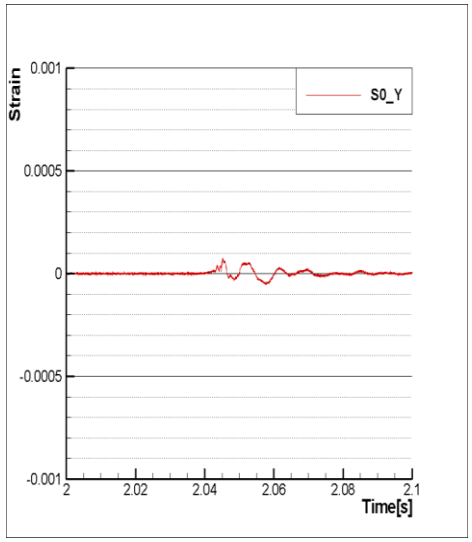




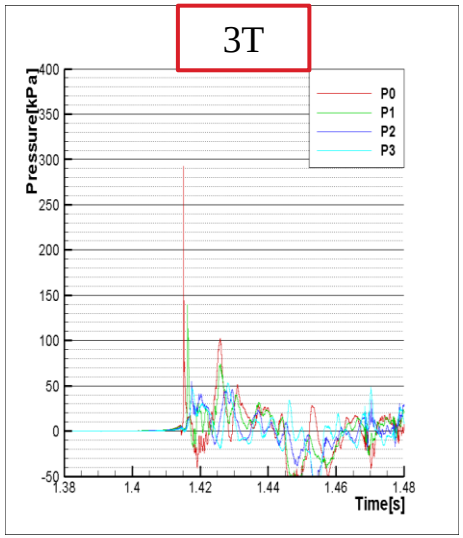


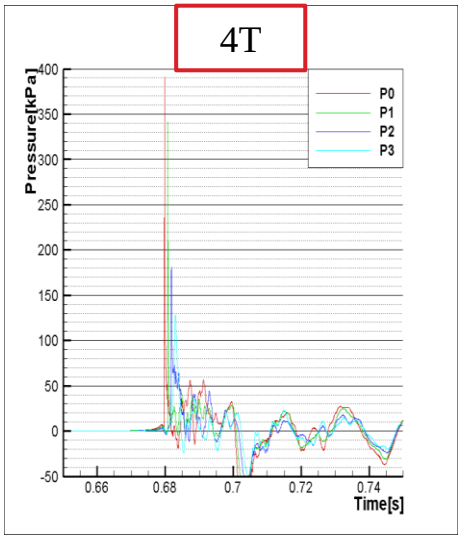


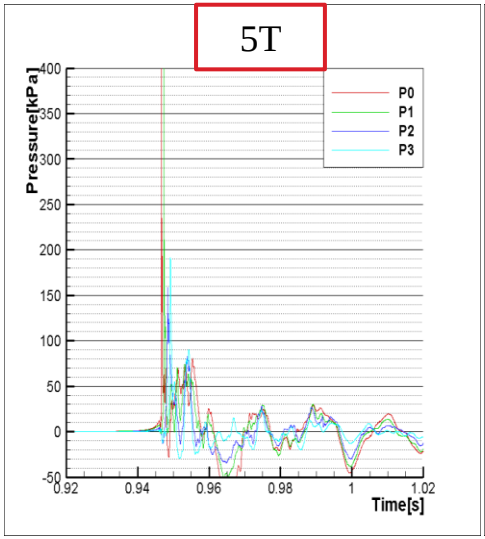


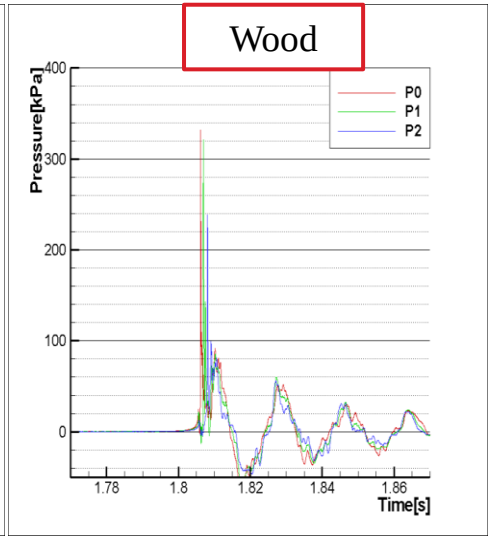


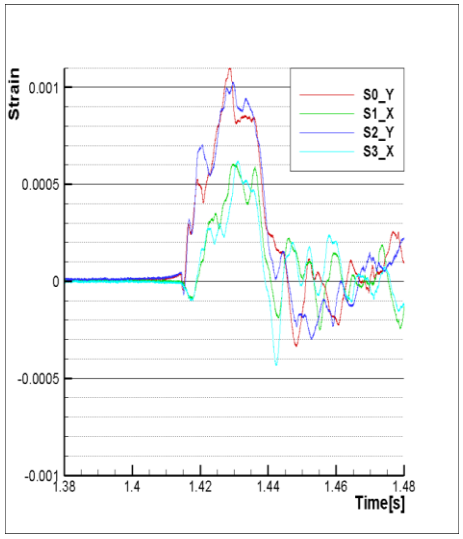
3° - 500mm Free drop test (UOU Trimming Tank)

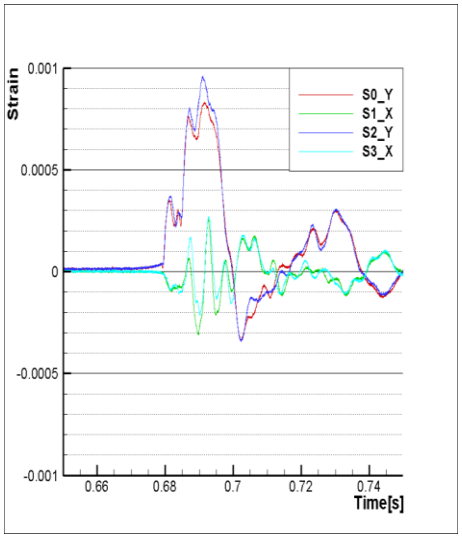


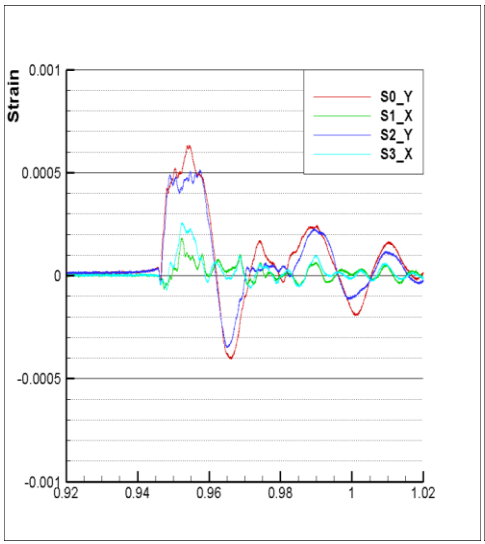


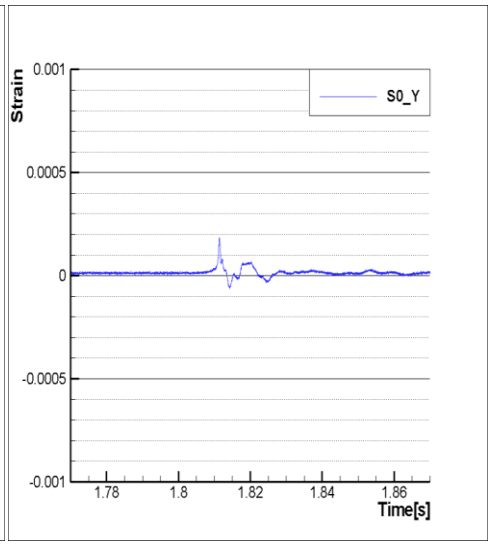






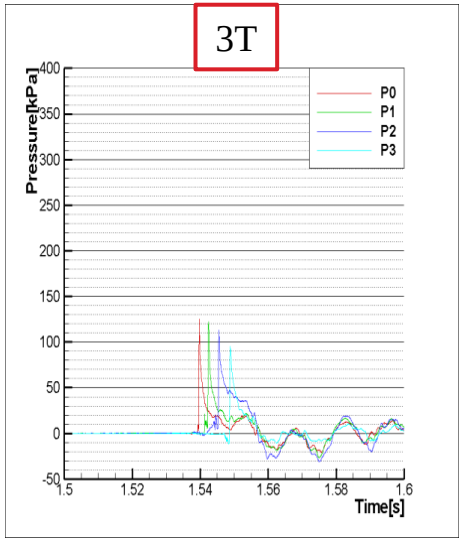


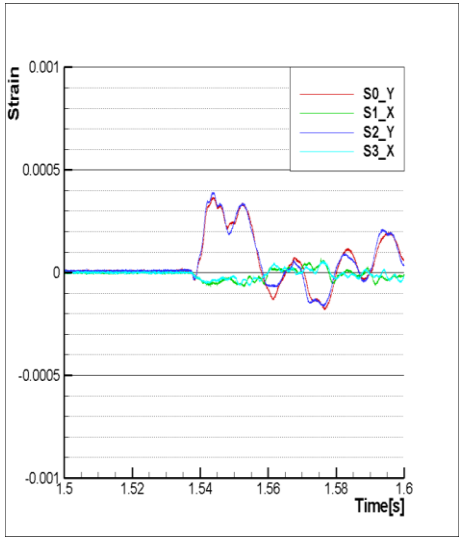




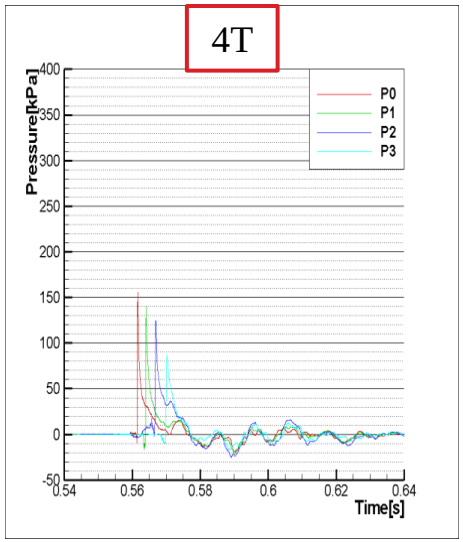
10° - 500mm Free drop test (UOU Trimming Tank)

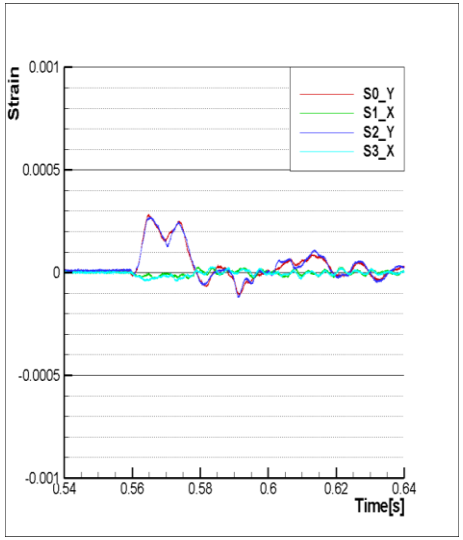
3T





4T





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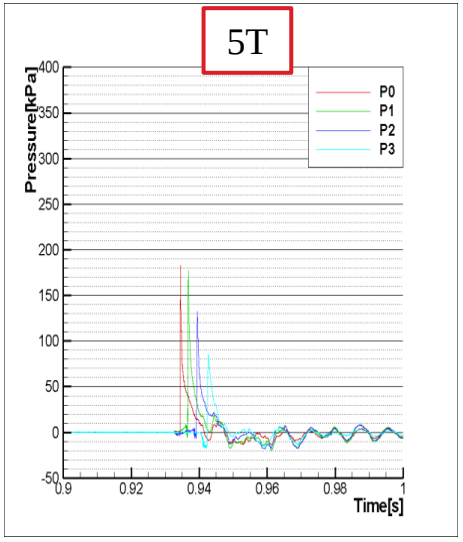
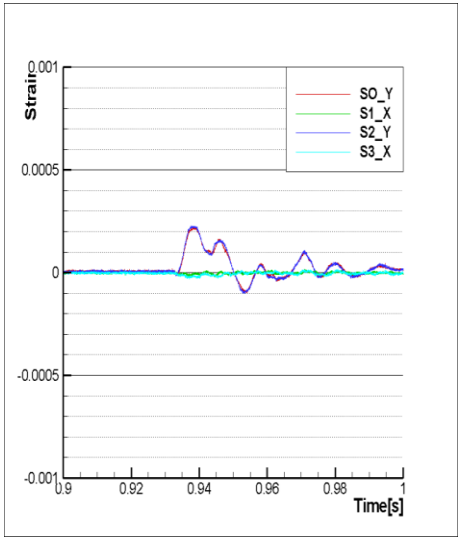
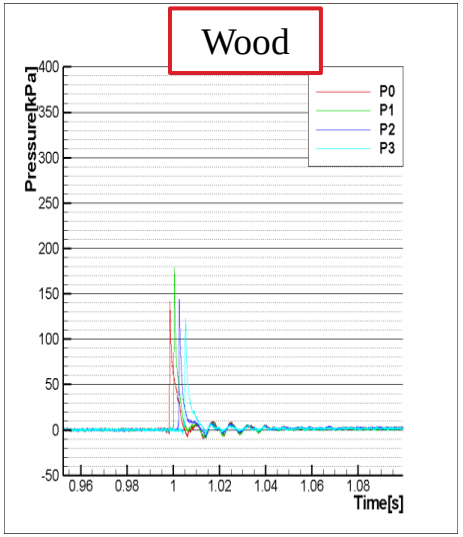
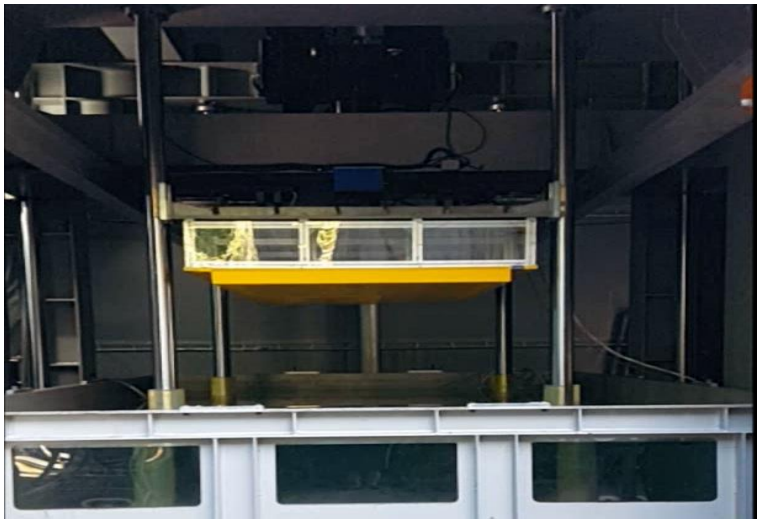




Wood



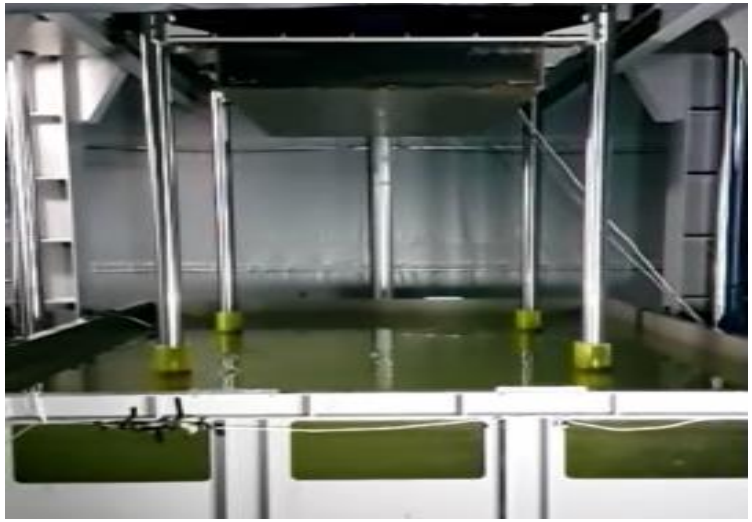
Free wet drop test (Wood & Steel_0° in UOU Slamming Tank)



➢ Wood - Dead-rise angle 0°, Drop height : 1m

➢ Wood - Dead-rise angle 0°, Drop height : 1.7m

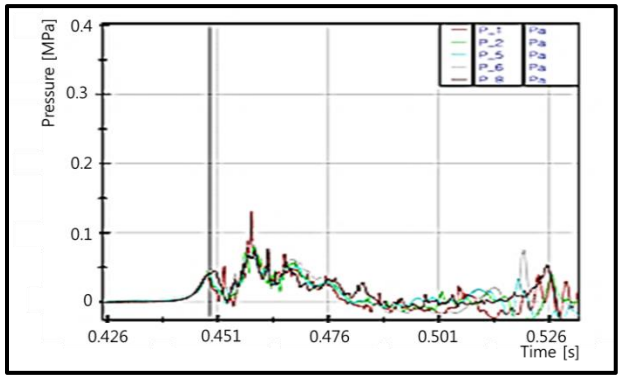
➢ Steel - Dead-rise angle 0°, Drop height : 1m



➢ Steel - Dead-rise angle 0°, Drop height : 1.7m

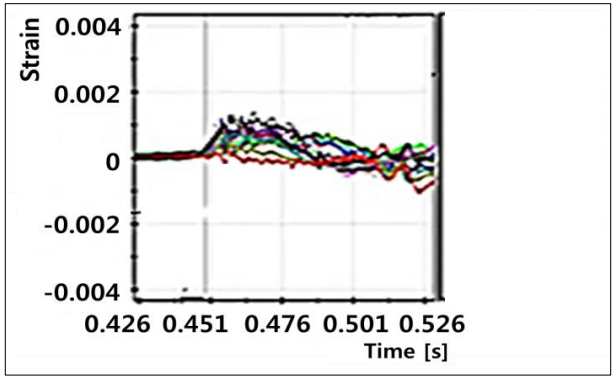
Experimental Results - 3T_0°

3T-0°-1m Pressure



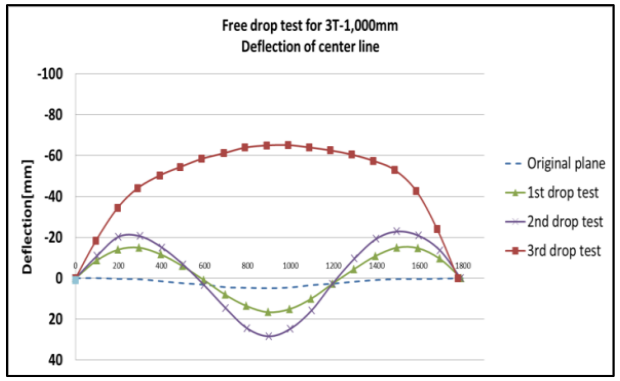
Max. Pressure : 0.08MPa

3T-0°-1m Strain



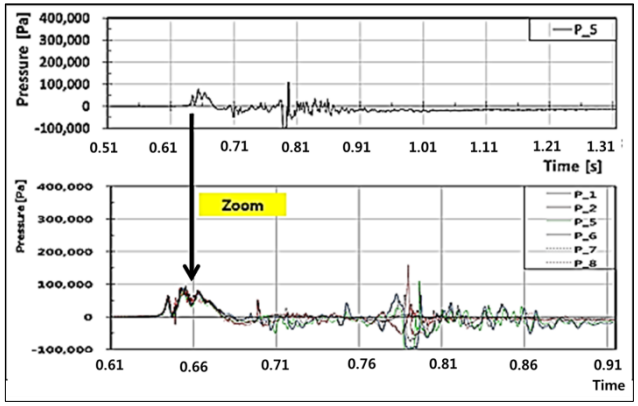
Max. Strain : 0.0017

3T-0°-1m Deflection



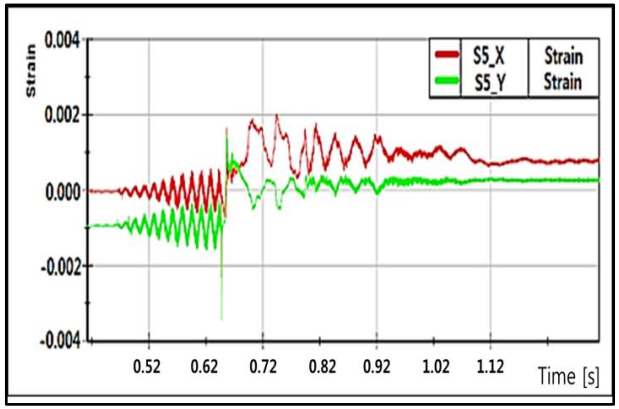
Max. Deflection : 65mm

3T-0°-1.7m Pressure



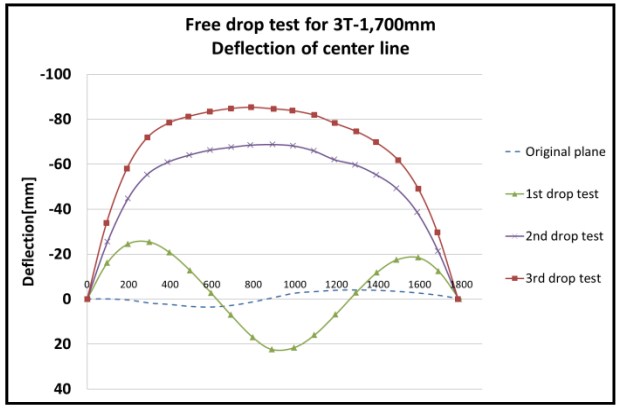
Max. Pressure : 0.10MPa

3T-0°-1.7m Strain



Max. Strain : 0.0020

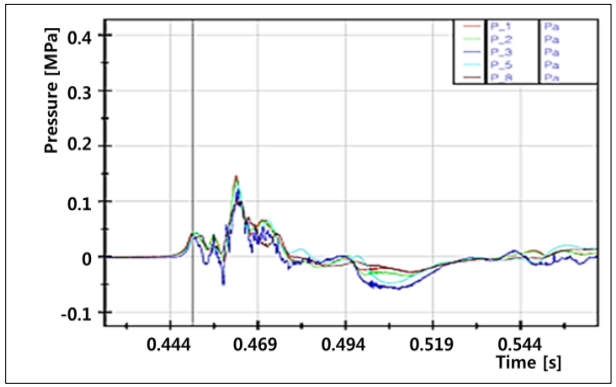
3T-0°-1.7m Deflection



Max. Deflection : 85mm

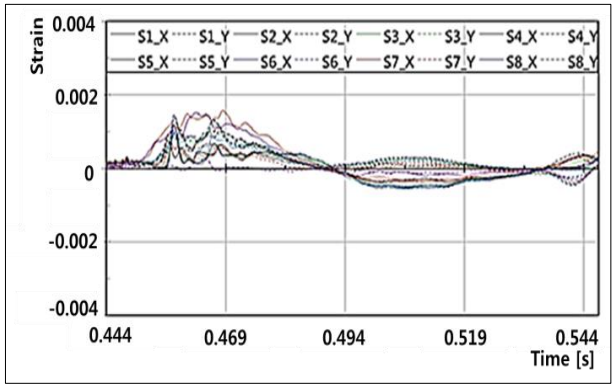
Experimental Results - 5T_0°

5T-0°-1m Pressure



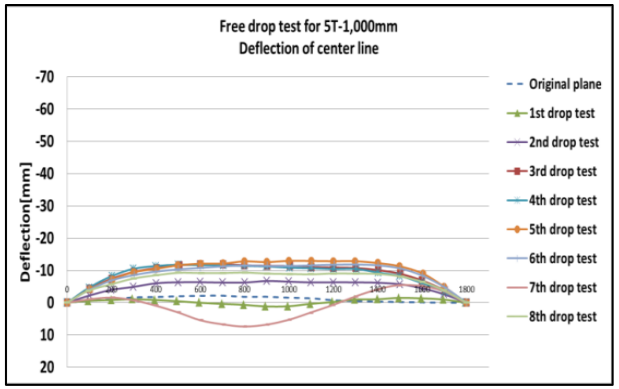
Max. Pressure : 0.15MPa

5T-0°-1mm Strain



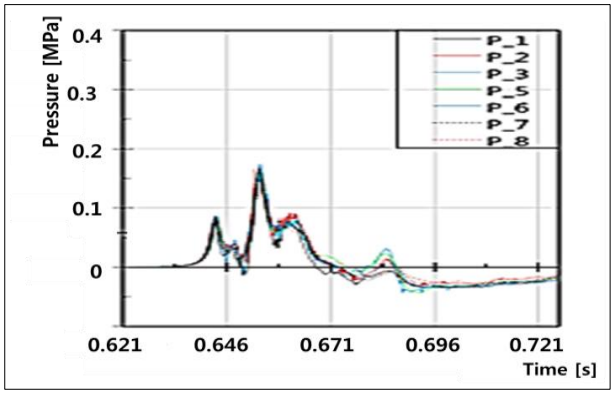
Max. Strain : 0.0015

5T-0°-1m Deflection



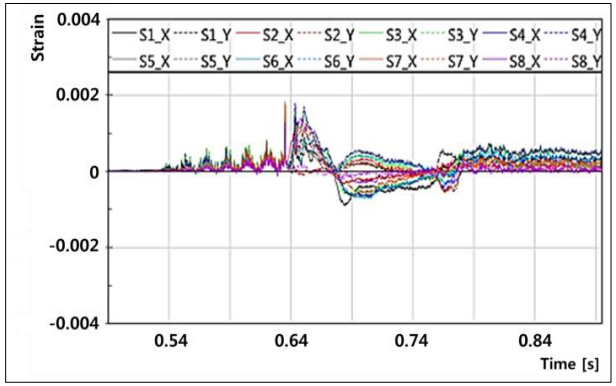
Max. Deflection : 15mm

5T-0°-1.7m Pressure



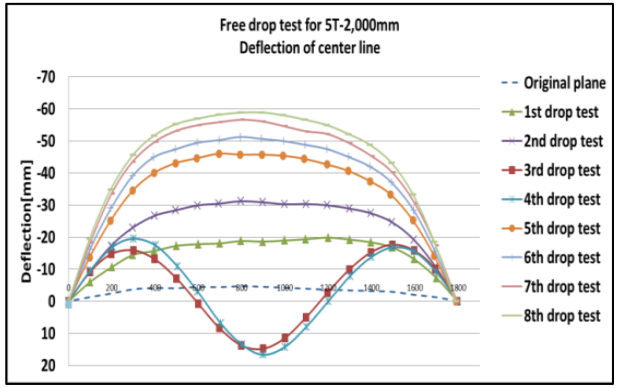
Max. Pressure : 0.17MPa

5T-0°-1.7m Strain



Max. Strain : 0.0018

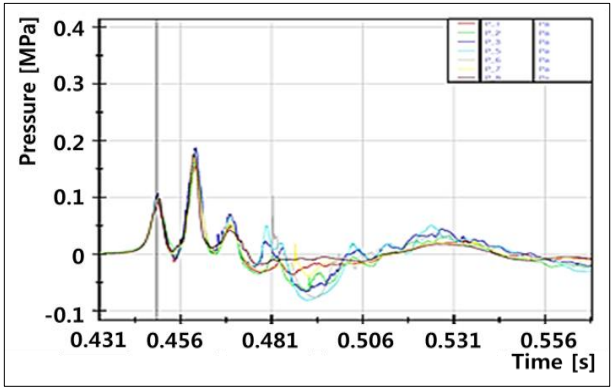
5T-0°-1.7m Deflection



Max. Deflection : 55mm

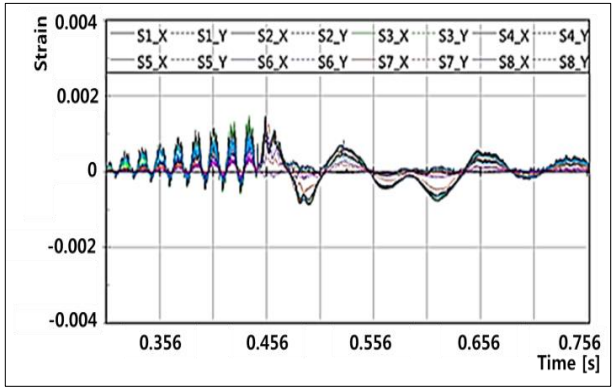
Experimental Results - 8T_0°

8T-0°-1m Pressure



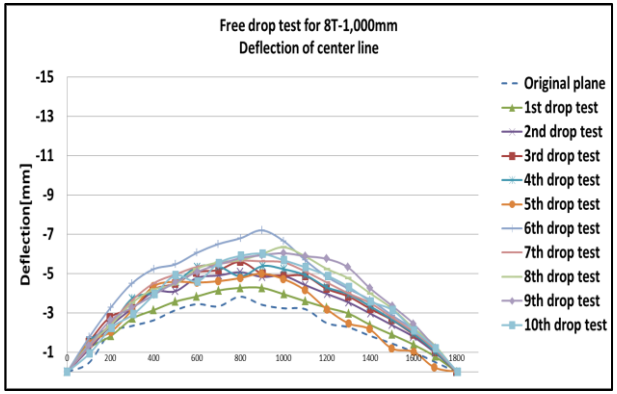
Max. Pressure : 0.19MPa

8T-0°-1m Strain



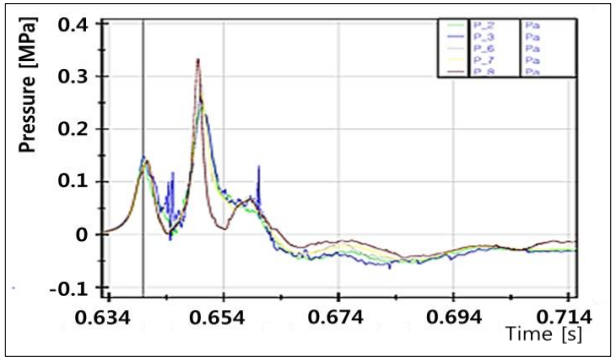
Max. Strain : 0.0010

8T-0°-1m Deflection



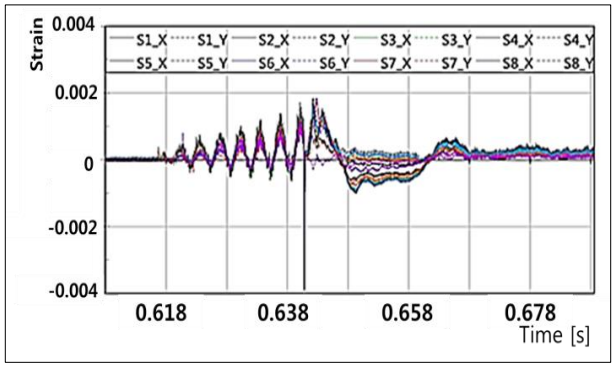
Max. Deflection : 7mm

8T-0°-1.7m Pressure



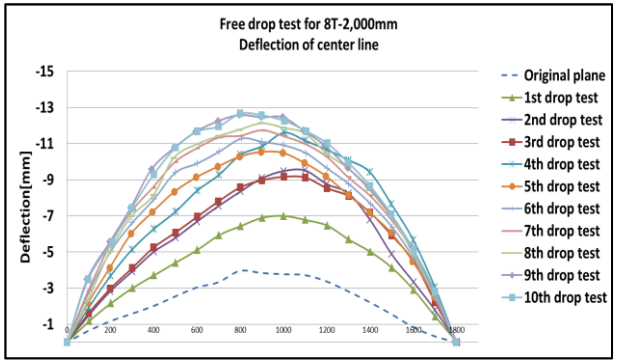
Max. Pressure : 0.33MPa

8T-0°-1.7m Strain



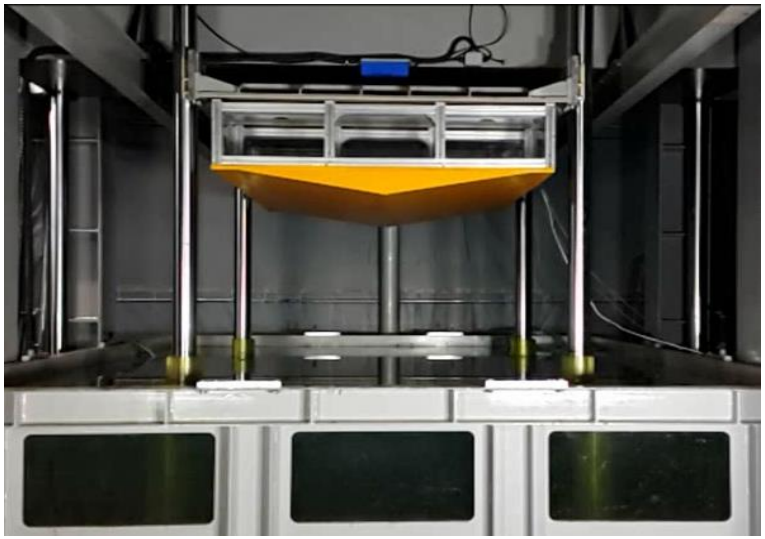
Max. Strain : 0.0015

8T-0°-1.7m Deflection

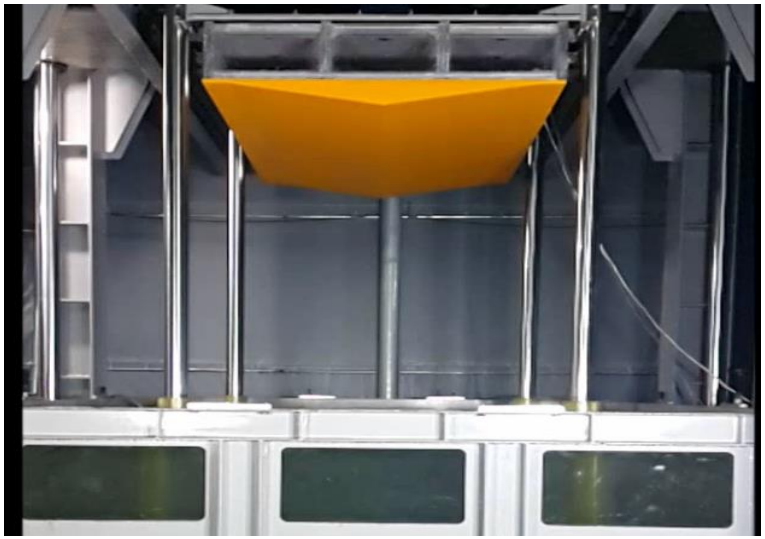


Max. Deflection : 9mm

Free wet drop test (Wood & Steel_0° in UOU Slamming Tank)



➢ Wood - Dead-rise angle 10°, Drop height : 1m

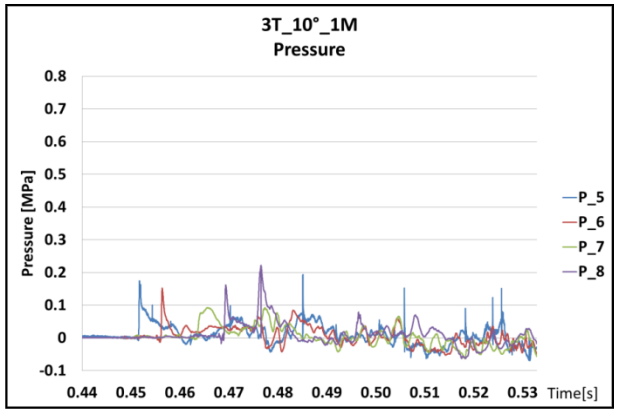


➢ Wood - Dead-rise angle 10°, Drop height : 1.7m

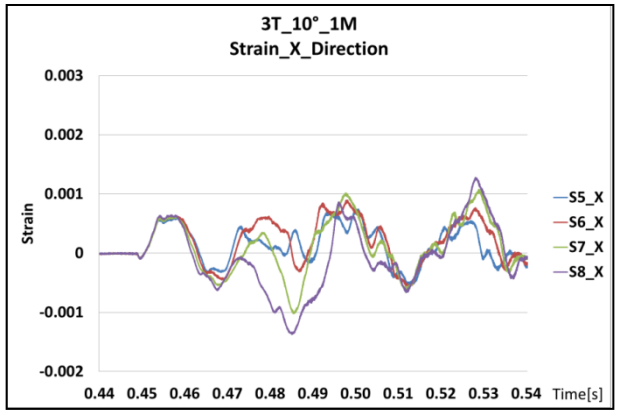
➢ Steel - Dead-rise angle 10°, Drop height : 1m

➢ Steel - Dead-rise angle 10°, Drop height : 1.7m

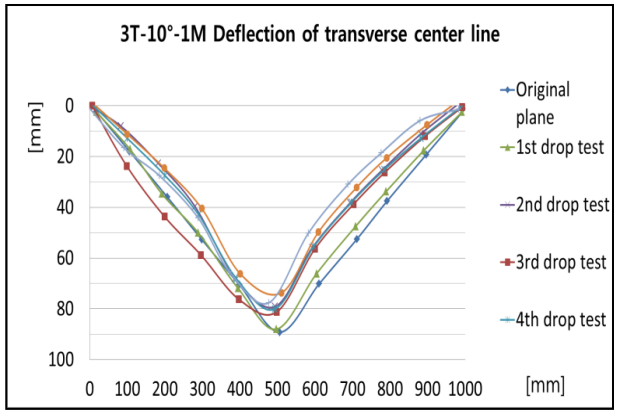
Experimental Results - 3T_10°



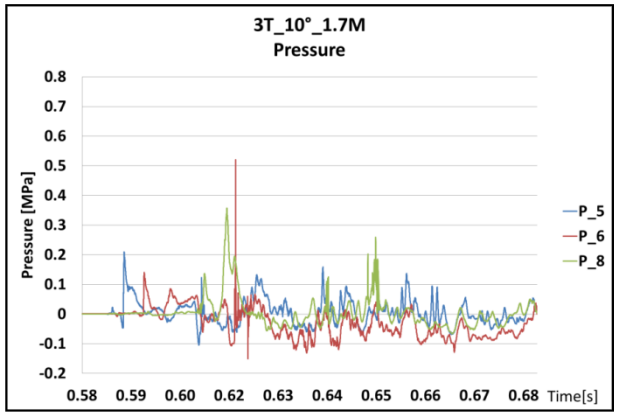
Max. Pressure : 0.18MPa



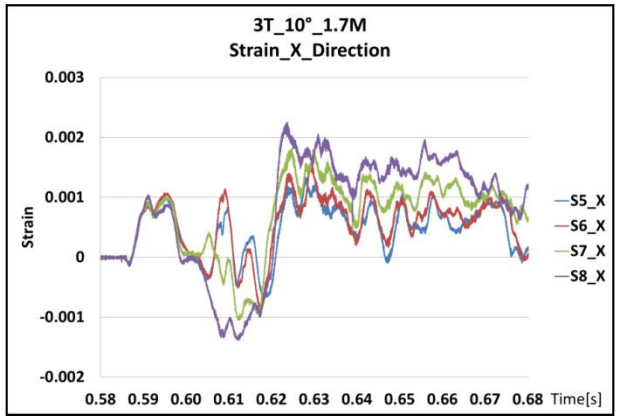
Max. Strain : 0.0007



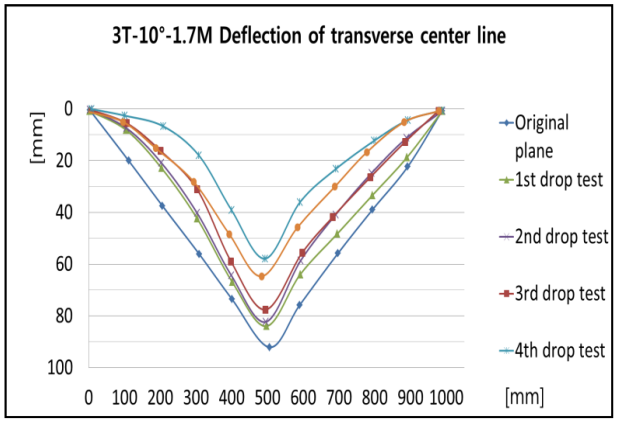
Max. Deflection : 30mm



Max. Pressure : 0.22MPa

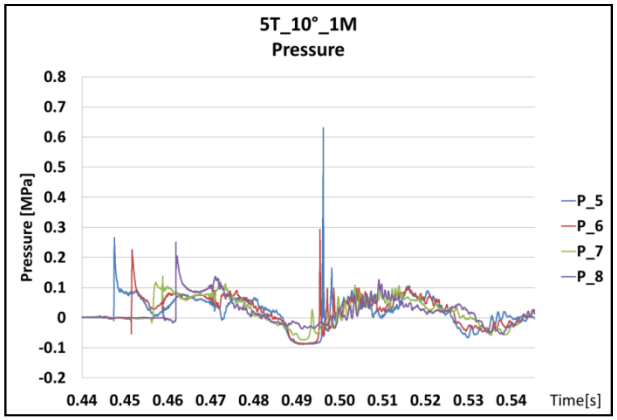


Max. Strain : 0.0012

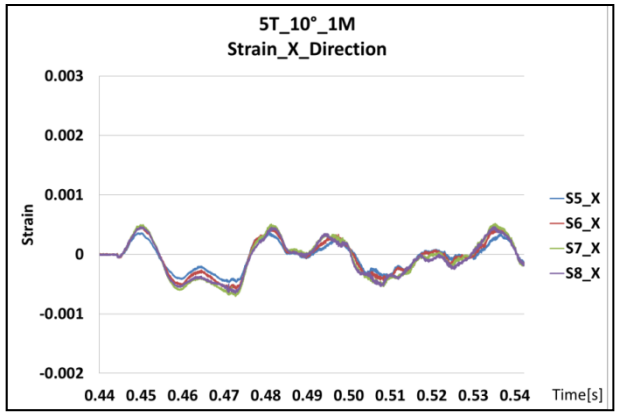


Max. Deflection : 40mm

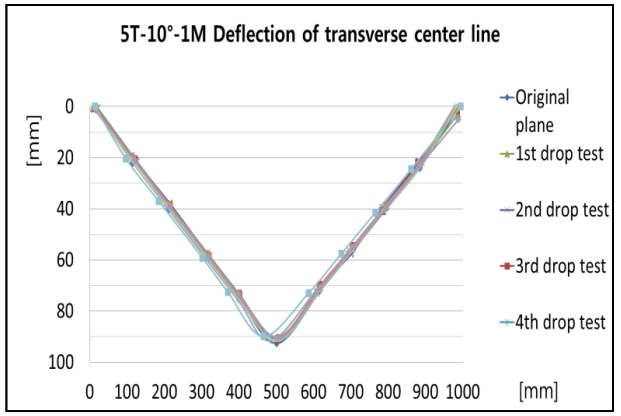
Experimental Results - 5T_10°



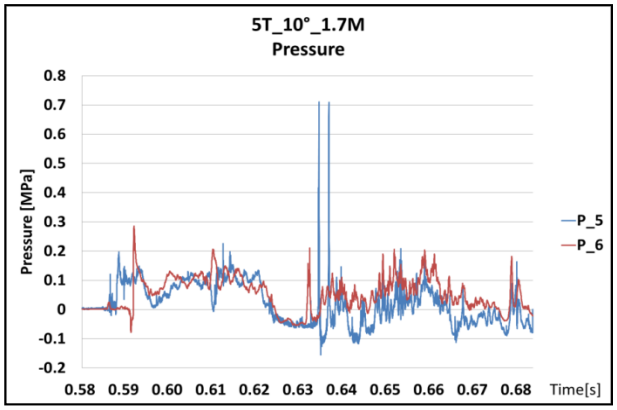
Max. Pressure : 0.27MPa



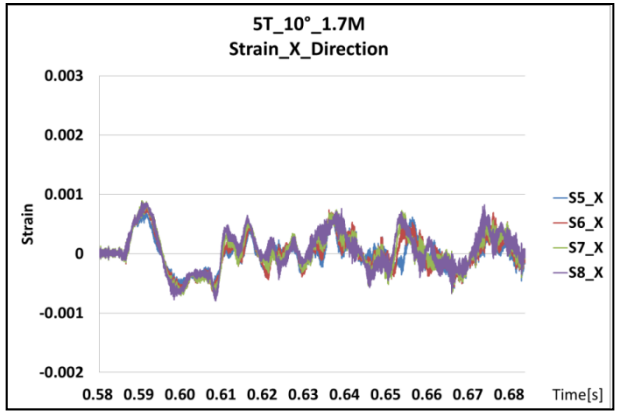
Max. Strain : 0.0005



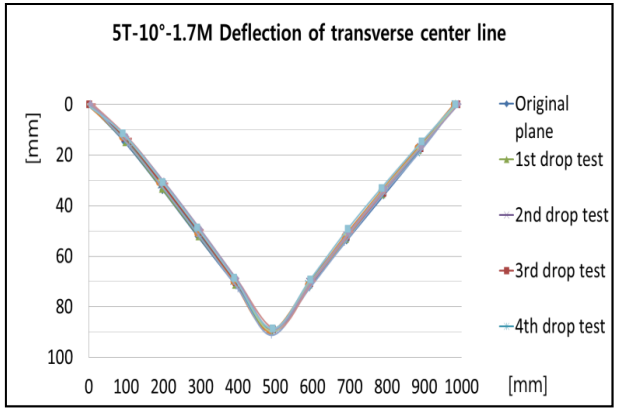
Max. Deflection : 4mm



Max. Pressure : 0.29MPa

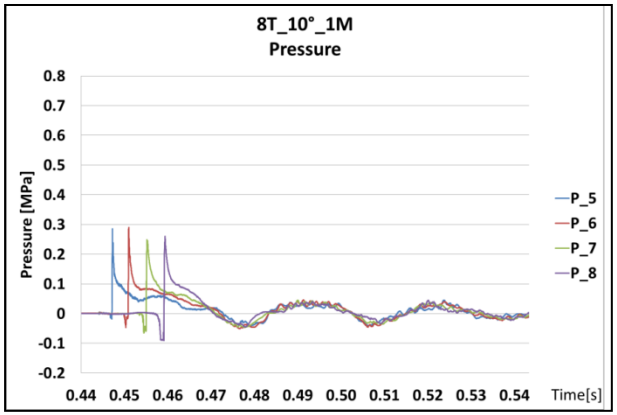


Max. Strain : 0.0008

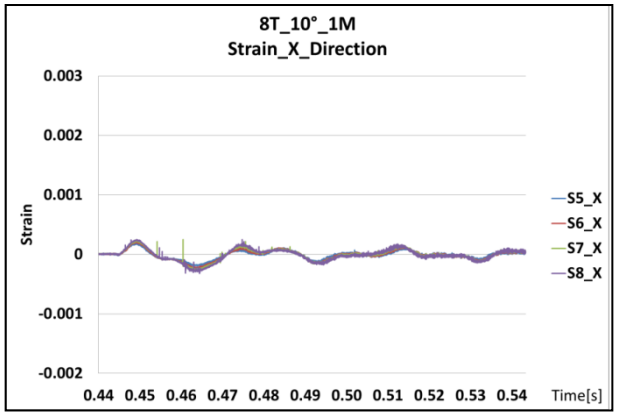


Max. Deflection : 5mm

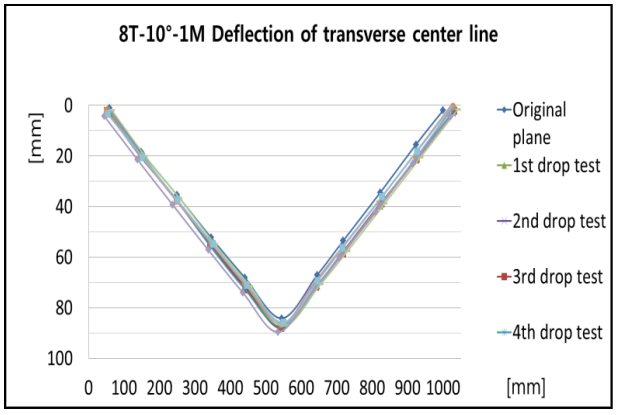
Experimental Results - 8T_10°



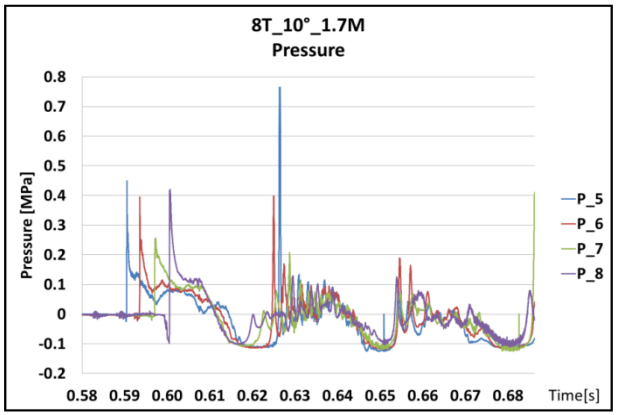
Max. Pressure : 0.29MPa



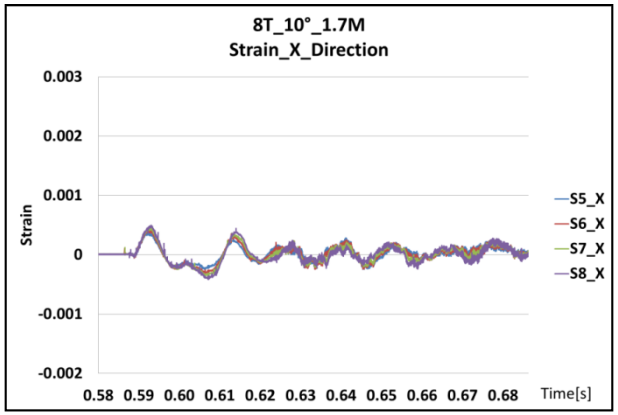
Max. Strain : 0.0003



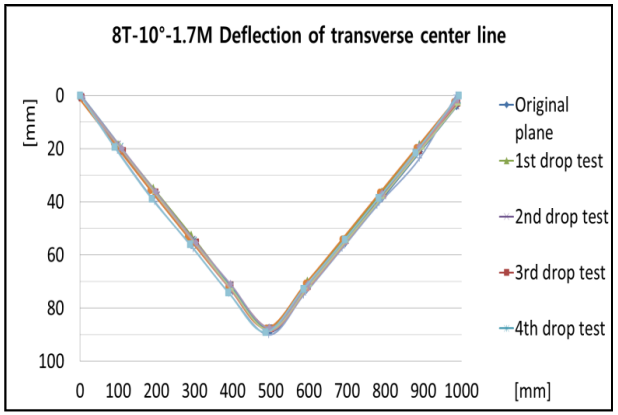
Max. Deflection : 2mm



Max. Pressure : 0.45MPa

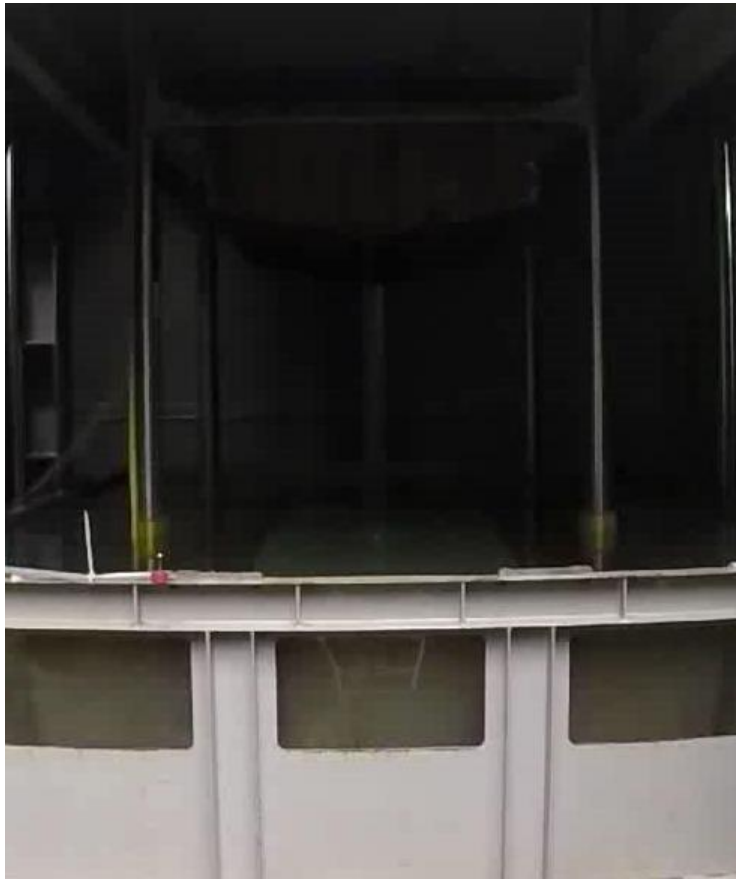


Max. Strain : 0.0005



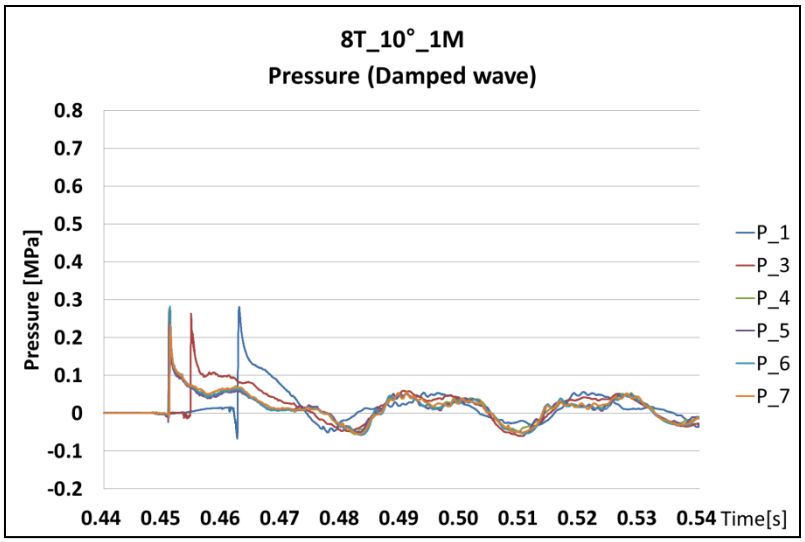
Max. Deflection : 4mm

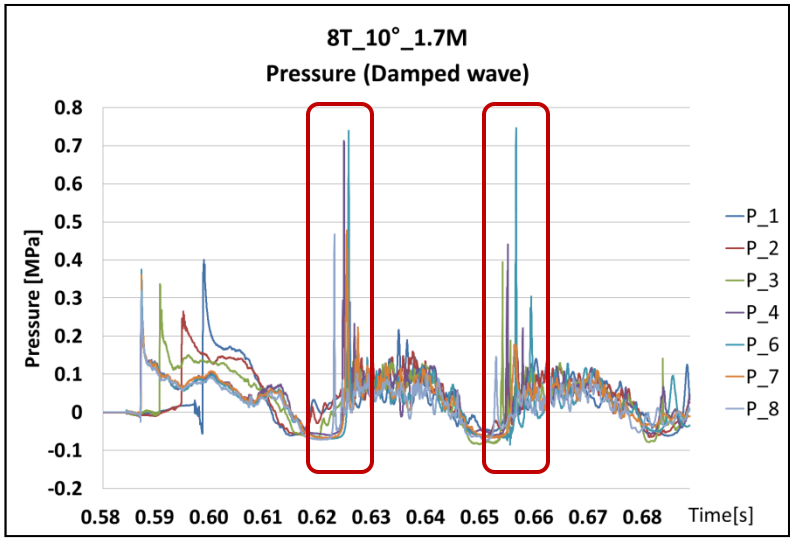
Experimental Results - 8T_10°_Damped Wave

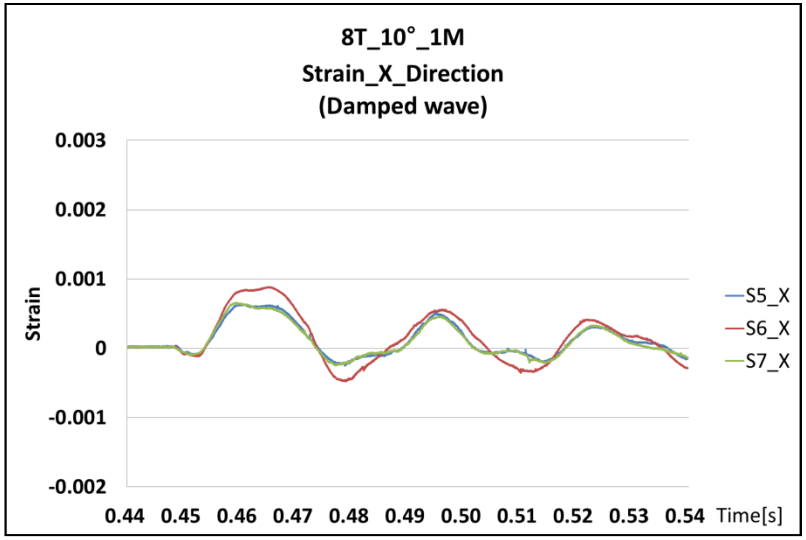


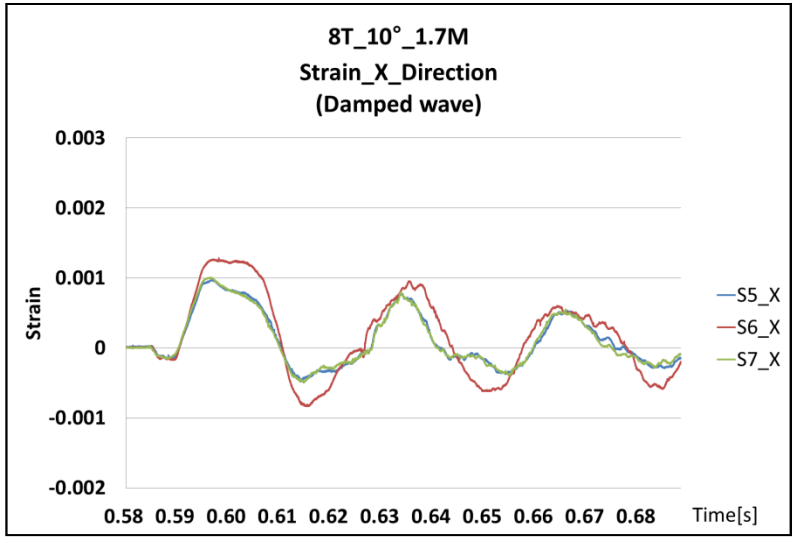
- Steel - Dead-rise angle 10°, Drop height : 1.7m

Experimental Results - 8T_10°_Pressure and Strain (Damped Wave)

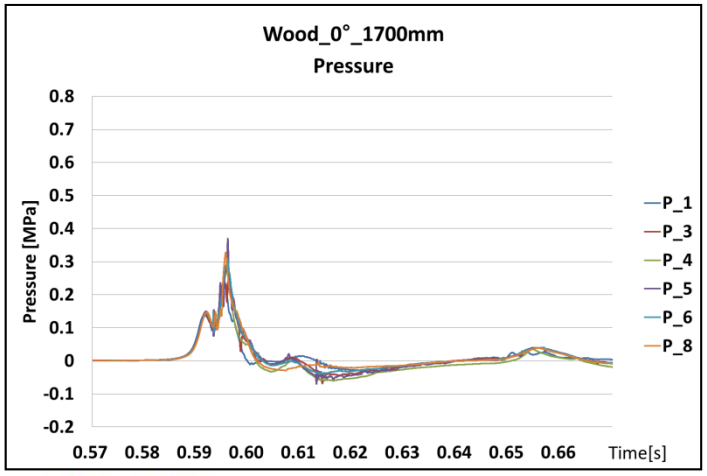


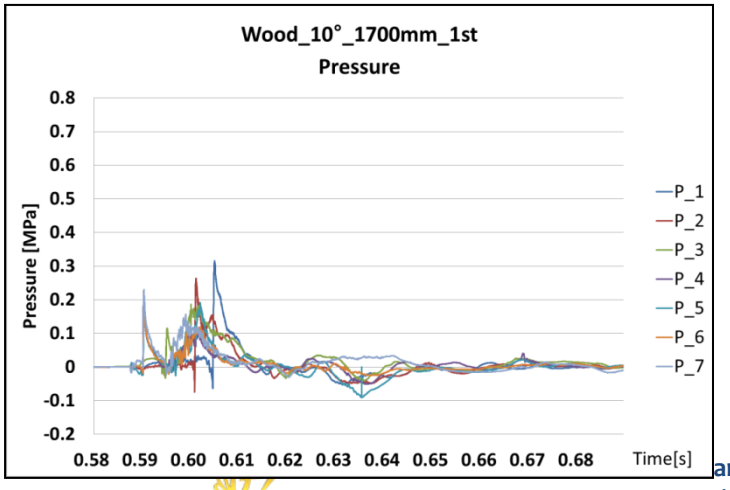






Experimental Results (Wood)

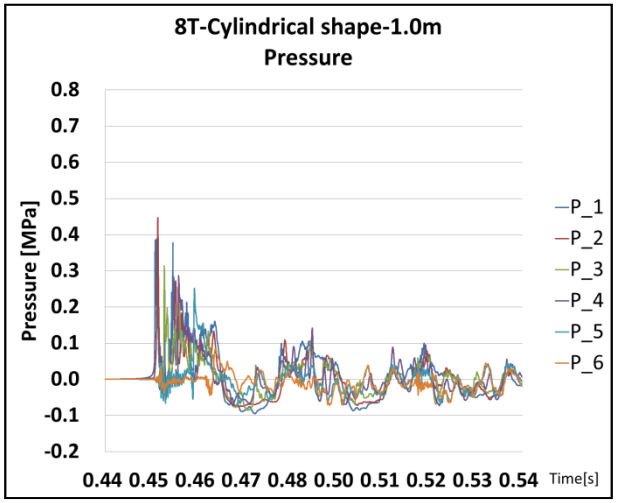




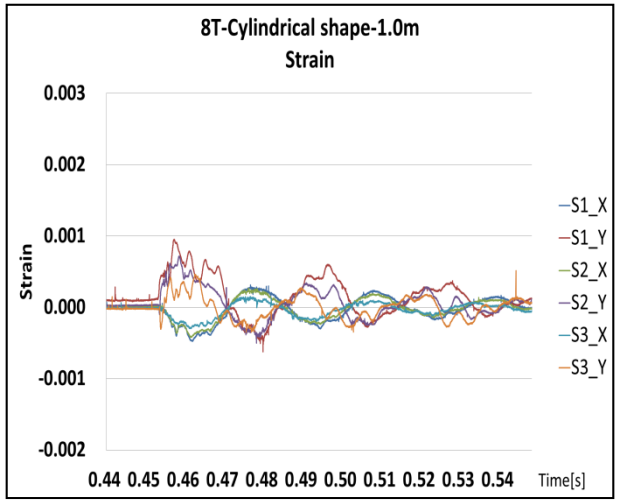
Free wet drop test (Steel_Cylindrical shape in UOU Slamming Tank)

- Steel – Cylindrical shape, Drop height : 1m
- Steel – Cylindrical shape, Drop height : 1.7m

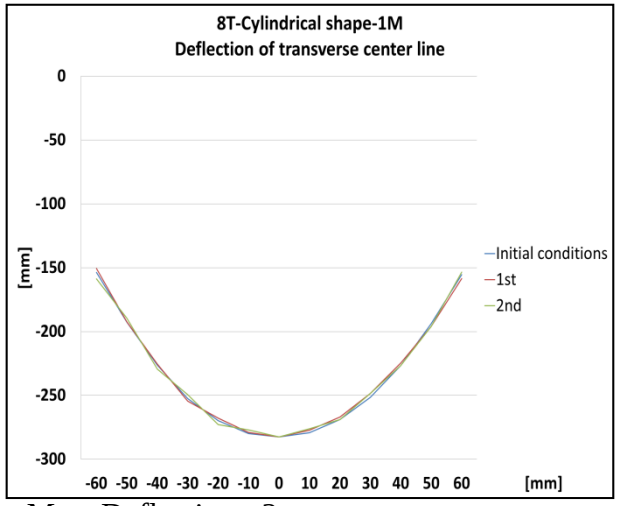
Free wet drop test (Steel_Cylindrical shape in UOU Slamming Tank)



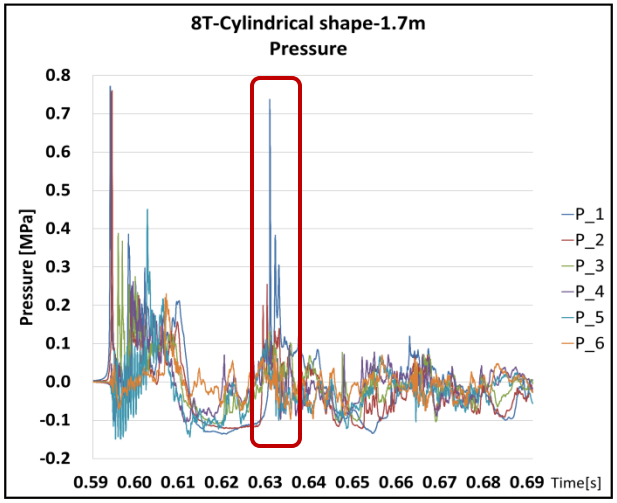
Max. Pressure : 0.45MPa



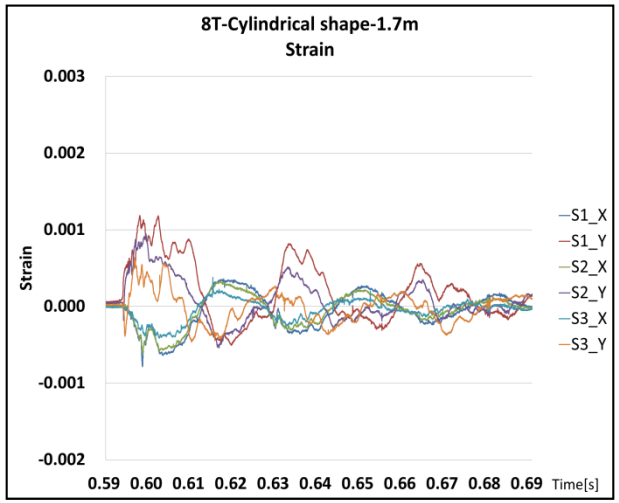
Max. Strain : 0.0009



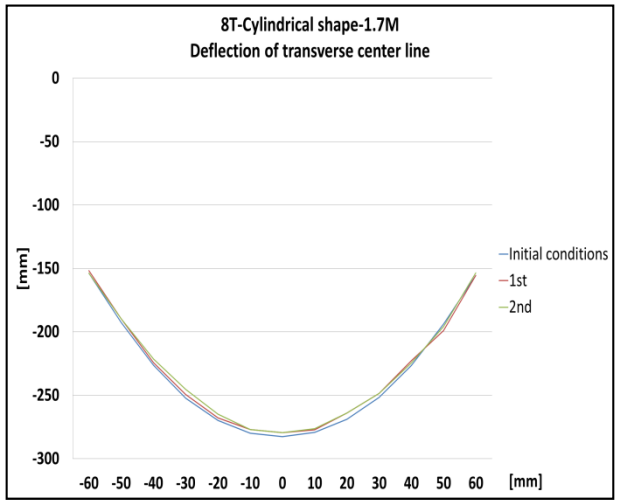
Max. Deflection : 2mm



Max. Pressure : 0.78MPa



Max. Strain : 0.0012

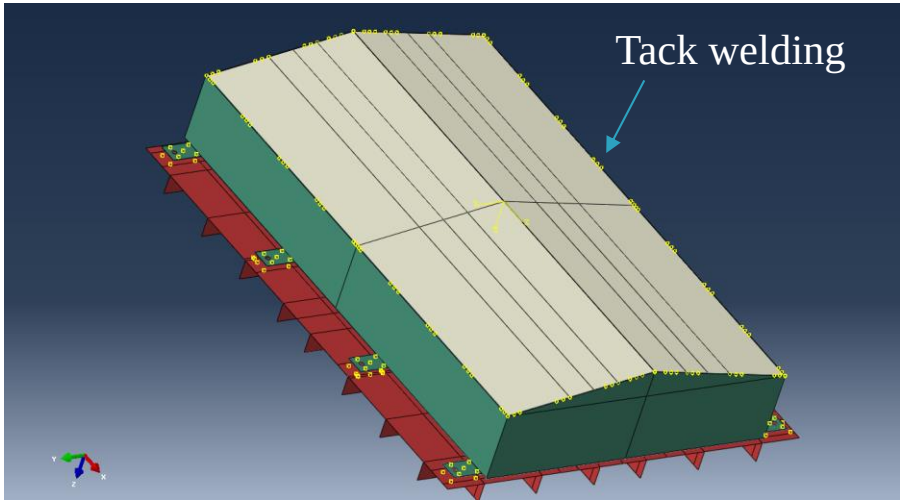


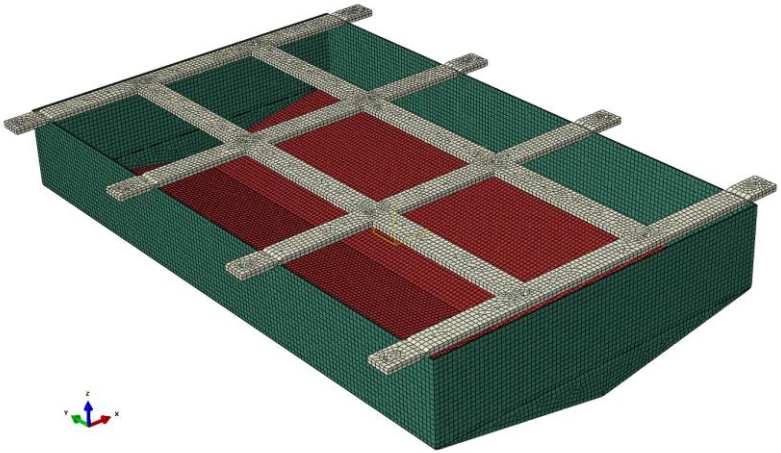
Max. Deflection : 4mm

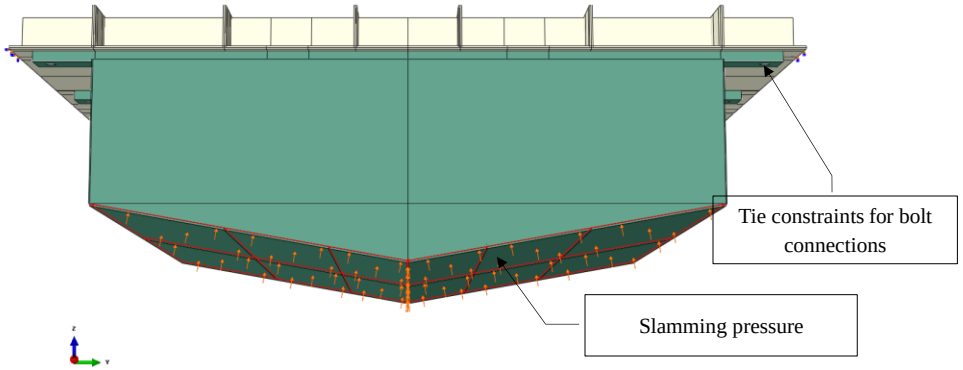
Numerical analysis

1. Finite element modelling of tested models

   - Using shell elements
   - Mesh / plate thickness =1.88
   - Fully fixed at upper supporting frame







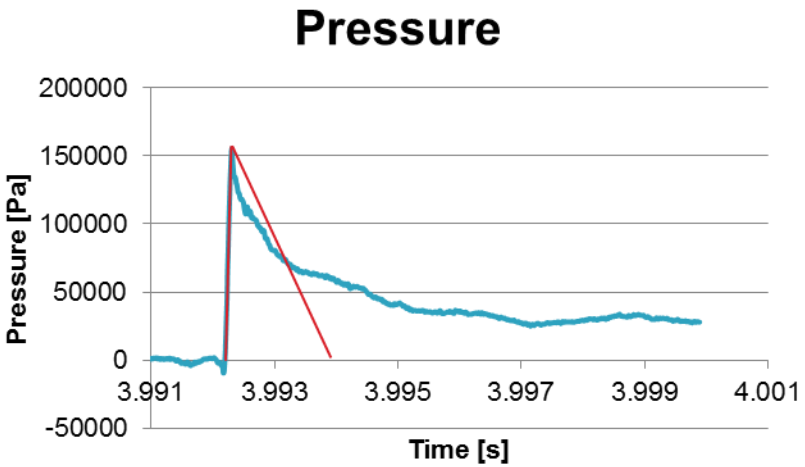
School of Naval Architecture & Ocean Engineering
University of Ulsan

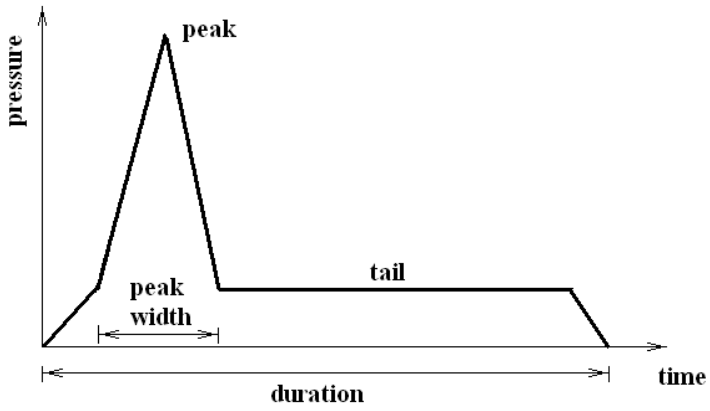
Numerical analysis

2. Simplified impulsive pressure shape : Triangular shape

Three presentative parameters:

- Peak pressure
- Rising time
- Decaying time





Process of simplified slamming pressure history

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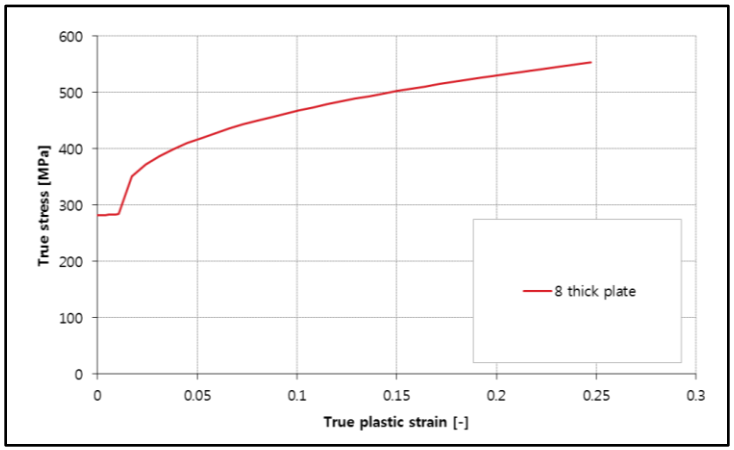
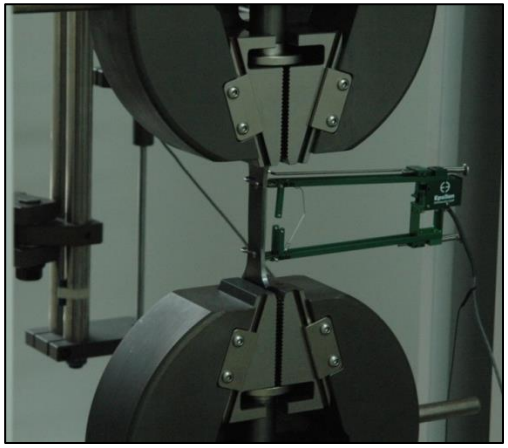
Numerical analysis

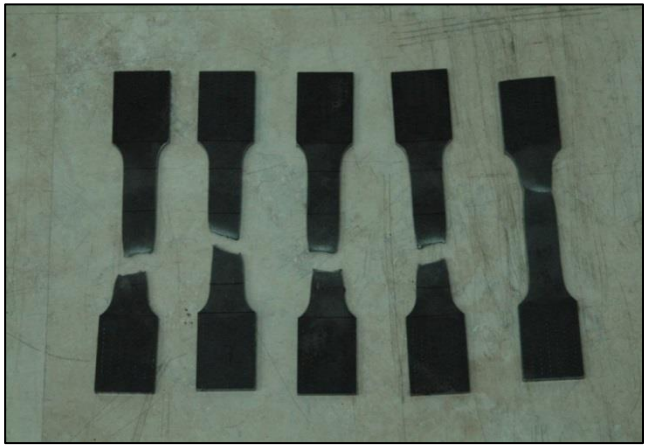
3. Material property definition

- Strain hardening: Use tensile test data
- Strain rate hardening: Cowper-Symonds Eq. (D=40.4 & q=5)

$$\sigma_{YD} = \sigma_Y \left[1 + \left(\frac{\dot{\varepsilon}_p}{D} \right)^{\frac{1}{q}} \right]$$







Thickness		Yield stress	Ultimate strength	Ultimate strain
Nominal [mm]	Actual [mm]	[MPa]	[MPa]	[-]
8	7.84	280.8	433.2	0.2151

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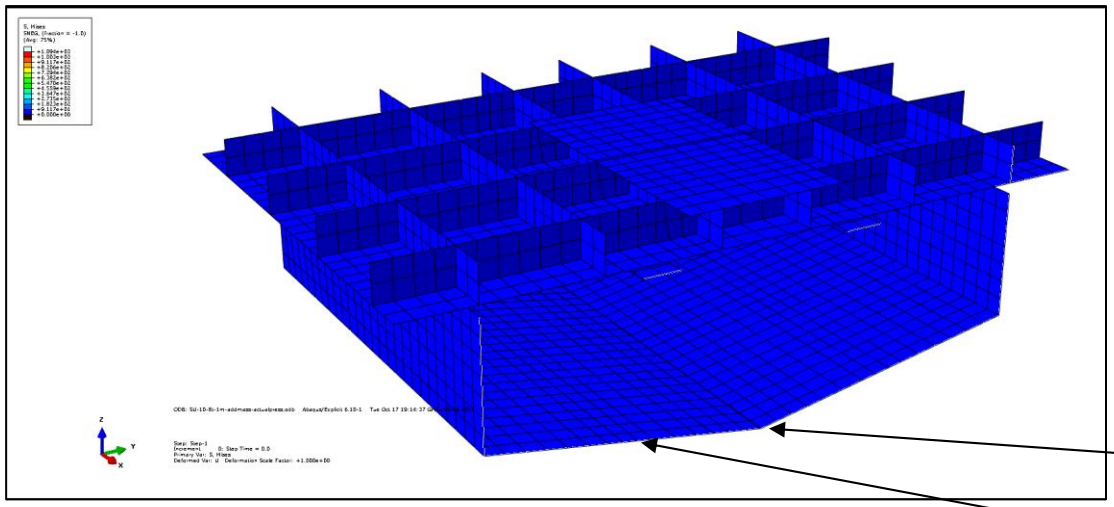
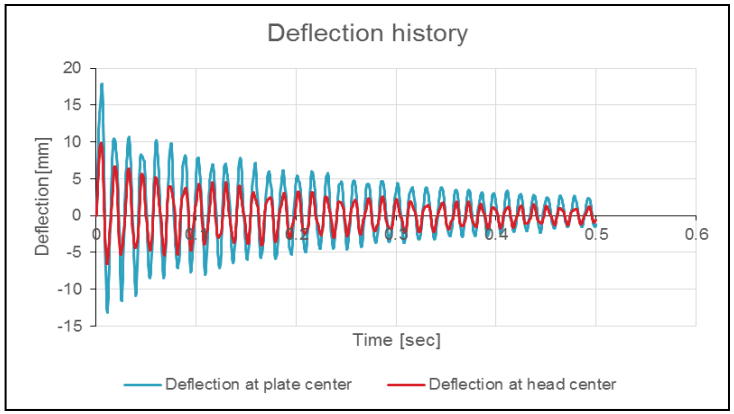
Numerical analysis results

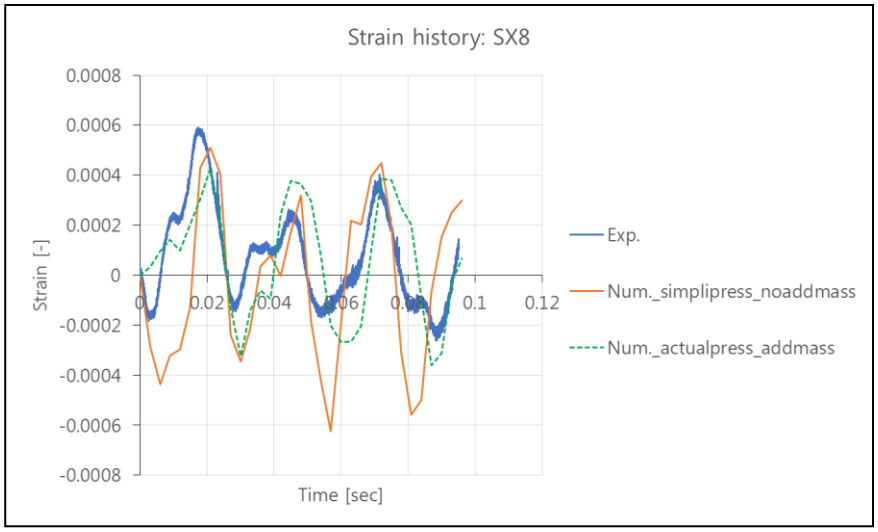
4. Deflection: SU-10-8T-1.7m

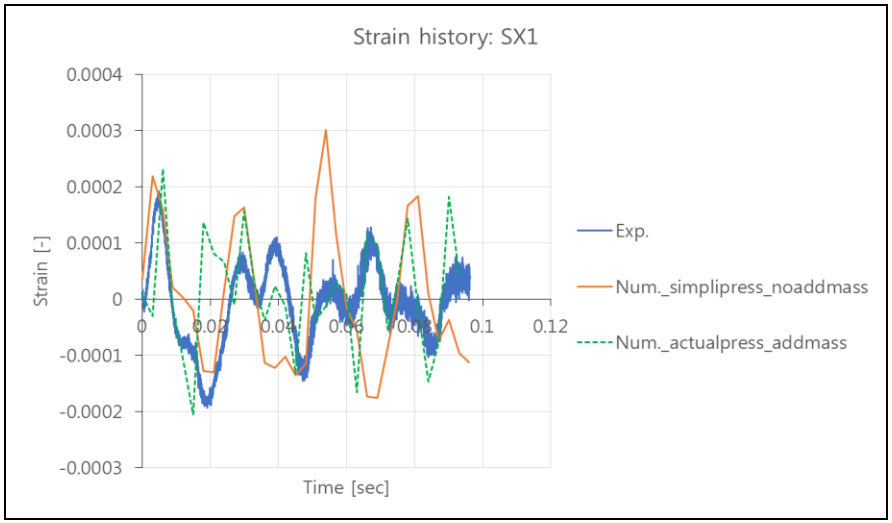




Head center

Plate center





Discussions & Future work

1. The slamming load characteristics were investigated through experiments with numerical analysis.

2. In case of dead-rise angle 0°, the slamming pressure value is smaller than dead-rise angles 3° and 10° due to the air effect.

3. Air effect comes from the elastic effect, so the model size is made bigger that can be applied to the actual design.

4. The same air effect occurred at dead-rise angle 0°.

5. Pressure increase is directly proportional to the increase of drop height, weight and thickness.

6. It was confirmed that several peak pressures were generated in one drop at dead-rise angle 10° and cylindrical shape models.

7. The largest slamming pressure was observed in the cylindrical shape model.

8. Considering the slamming load in the elastic region, it was taken into consideration that several slamming loads are applied to a single wave load rather than a single pressure value.

9. Further study is necessary to improve its accuracy and reliability, and additional experiments under the same test conditions are required for the uncertainty.

THANK YOU

ACKNOWLEDGMENTS

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