

ClassNK & Seatrade

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**Safe and Environment Friendly Hull Structures
with Newly Developed Highly Ductile Steel
and Collision Analysis**

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joint study by
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National Maritime Research Institute
Nippon Kaiji Kyokai (ClassNK)

Outline

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2. Highly Ductile Steel (HDS)
3. Objectives
4. Analysis Condition
5. FEA Results of Simulation 1 and 2
6. Class Notation
7. Conclusions

Background

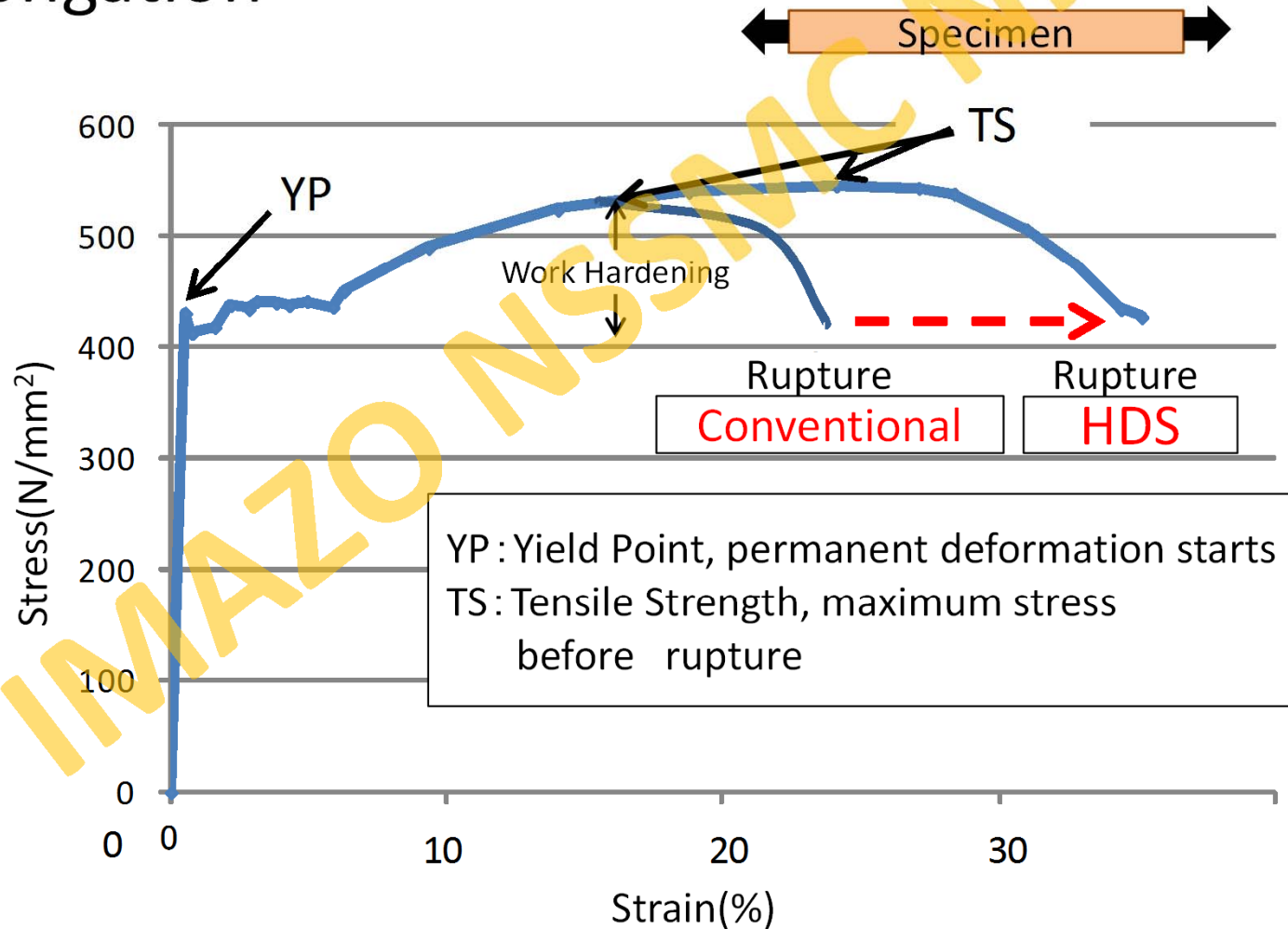
- Prevention of oil spill is one of important issues for maritime environment.
- D/H structure is effective to reduce risk of oil spill from tankers but is not sufficient to prevent oil spill accidents from tankers.
- Recently Highly Ductile Steel was newly developed by Nippon Steel and Sumitomo Metal and has been applied for actual ships to mitigate impact damages in collision.

Highly Ductile Steel (HDS)

- Comparing with the rule regulation of class or conventional steels,
 - Elongation : Larger than rule requirement
 - Strength, Toughness and Workability (*e.g.*, Weldability):
Same as conventional steels
- Comply with class rules and can be applied without change in structural design (with just substitute materials only).

Stress-Strain Curves

- Same yield and tensile strength with larger elongation



Advantage of HDS

- Because of the large elongation of steel itself and expansion of plastic area caused by large elongation itself, absorbed energy of hull in collision is increased largely.

- 1)Hollow depth is smaller than those in conventional steels applied.

⇒ Easy to repair

- 2)Hard to be pierced.

⇒ Decrease cargo/oil spill, escape sinking

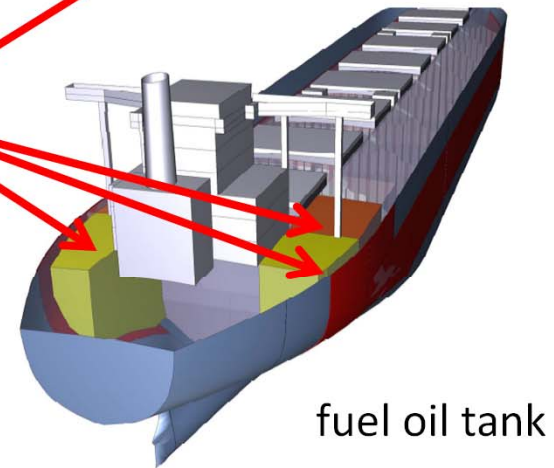
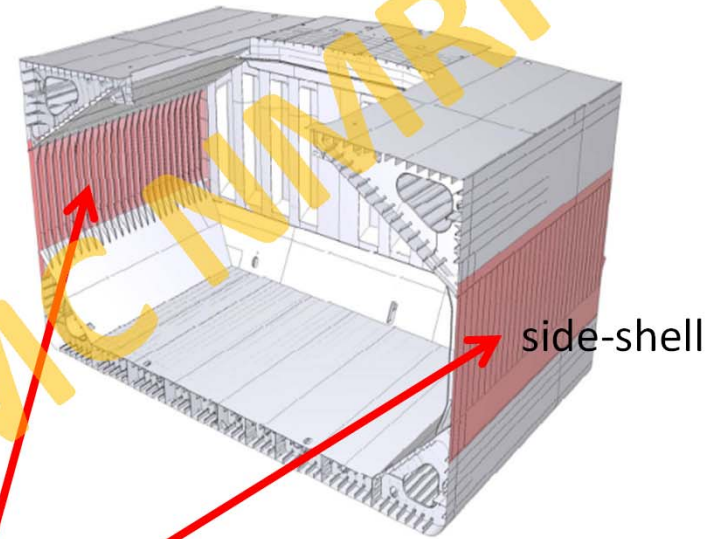
World First Application of HDS on actual ship

Bulk carrier (Mitsui O.S.K. Lines)
Sister Ship featuring the NSafe®-Hull



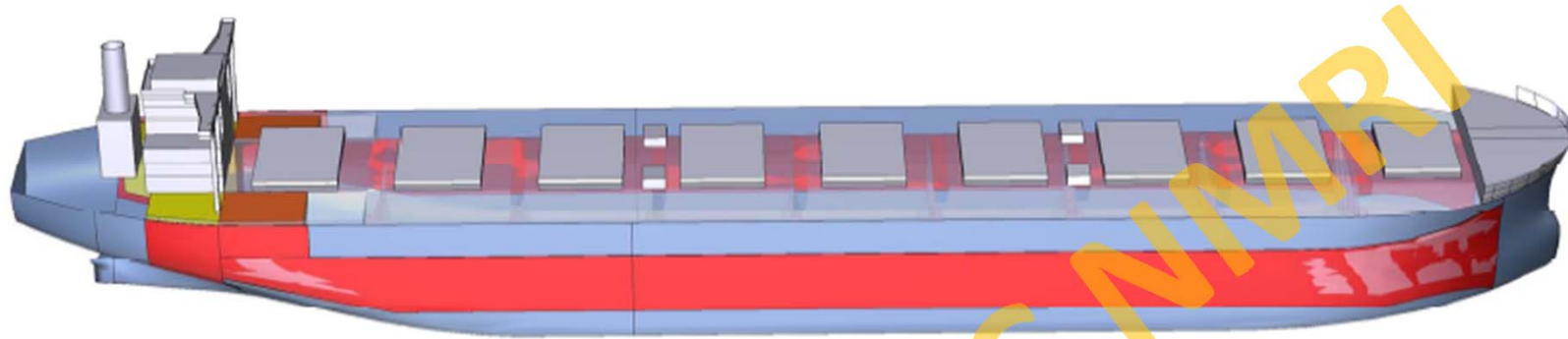
Built by Imabari Shipbuilding CO. Ltd.
Over 10 vessels will be HDS applied.

Loa	299.94 m	Highly ductile steel (HDS)
B	50m	
D	24.7 m	
DWT	206,600 ton	



Example of HDS
NSafe^(TM)-Hull (NSSMC)

Used Parts and Purpose of HDS



Part	Material Name	Purpose
Ship's side of cargo hold	<ul style="list-style-type: none"> ▪ Side shell ▪ Hold frame ▪ Side longitudinal stiffener 	<ul style="list-style-type: none"> ▪ Prevention for flood ▪ Protect for cargo ▪ Prevention for Mechanical damage (Grab damage)
Fuel oil tank (Top side tank)	<ul style="list-style-type: none"> ▪ Side shell ▪ Top side tank bottom plate ▪ Longitudinal bulkhead plate of fuel oil tank ▪ Side longitudinal stiffener 	<ul style="list-style-type: none"> ▪ Prevention for oil spill ▪ Prevention for Mechanical damage (Grab damage)
Fuel oil tank (Engine room)	<ul style="list-style-type: none"> ▪ Side shell ▪ Longitudinal bulkhead plate of fuel oil tank 	<ul style="list-style-type: none"> ▪ Prevention for oil spill

Objectives

1. Investigate effect of Highly Ductile Steel (HDS) material on the decreasing structural damage of the struck tanker.
By carrying out a series of Non-linear finite element analysis (NL-FEA)
2. Estimate Critical Striking Velocity ($V_{B,cr}$) :
Minimum striking ship speed to penetrate cargo oil tank (inner shell) in case of collision
 - Simulation 1 : Simple simulation / small deformation area
Collision angle : Vertical
Collision speed: 12knot
 - Simulation 2 : Practical, high accuracy, large deformation area
Collision angle : Oblique - vertical
Collision speed : 1-12(15)knot

FEA Analysis

Simulation 1

Vertical Collision

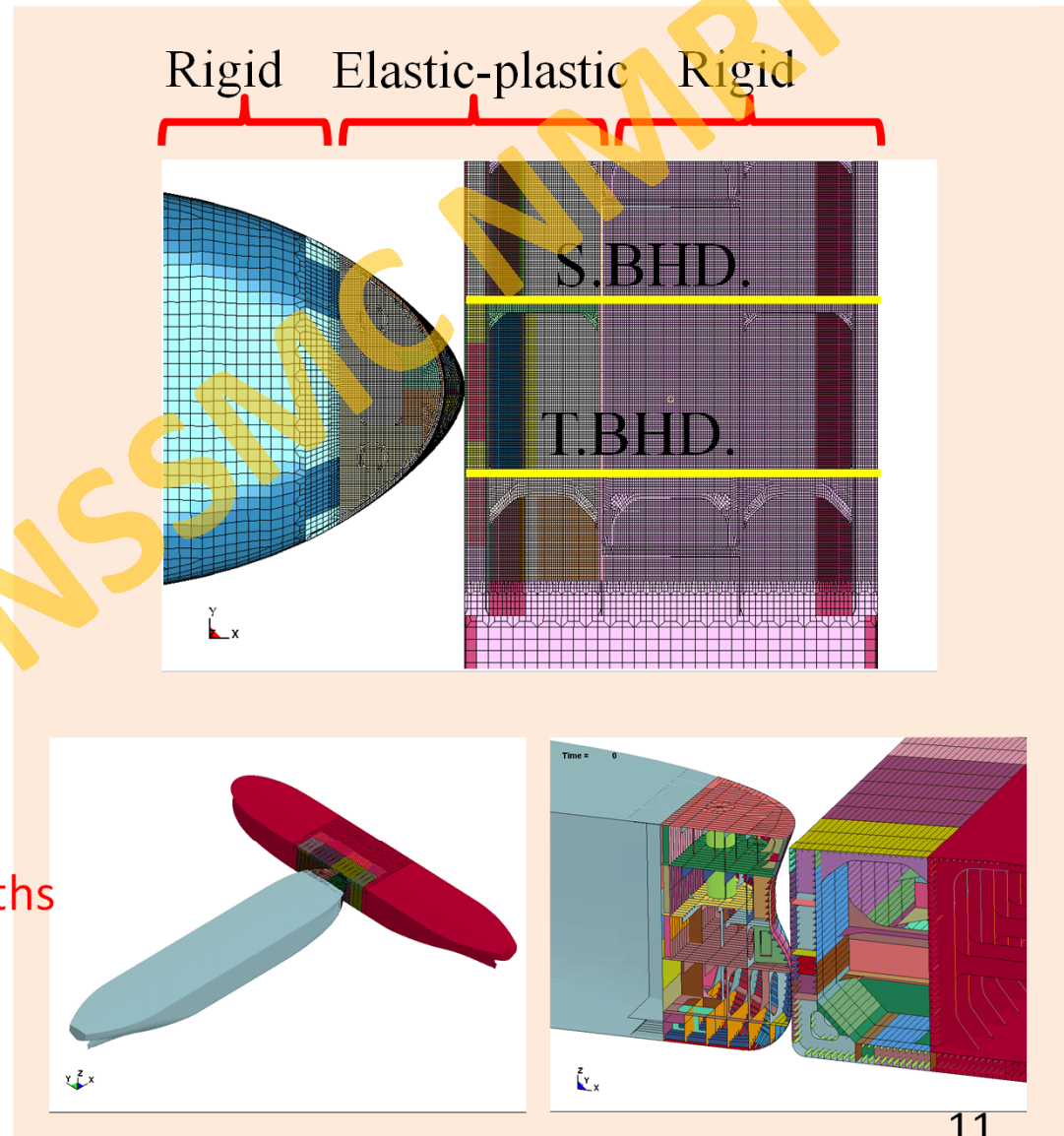
(Simple simulation)

IMAZO A/S SMC NMRI

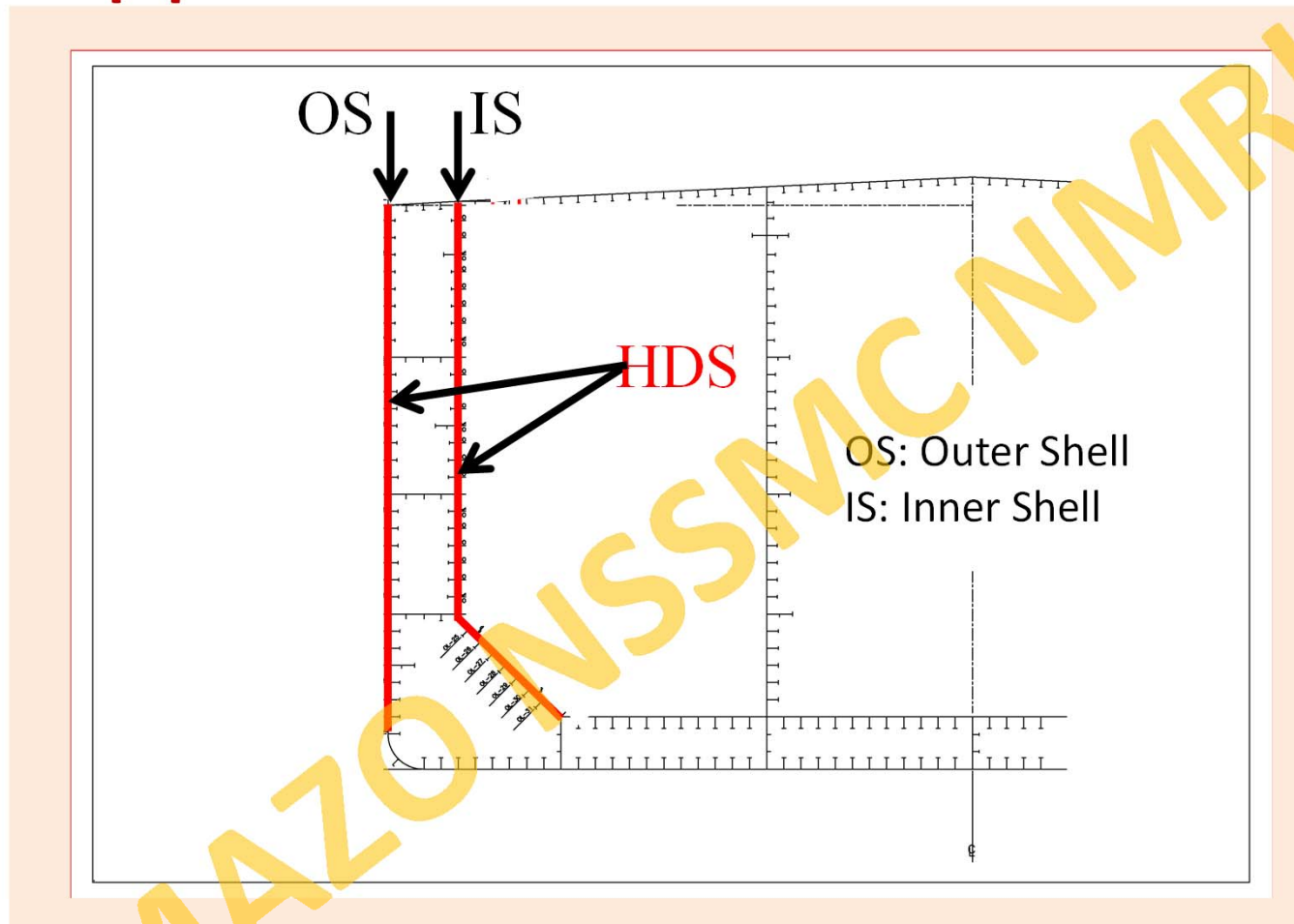
Collision conditions

Simulation 1

- VLCC collides with the midship part of another VLCC
- Both ships fully loaded
- Collision speed
striking (VB) = 12 knot
struck (VA) = still
- Collision angle $\theta=90$ deg.
- Motion of struck ship
: Considered
- Deformation area
: 1hold length ,1/3widths

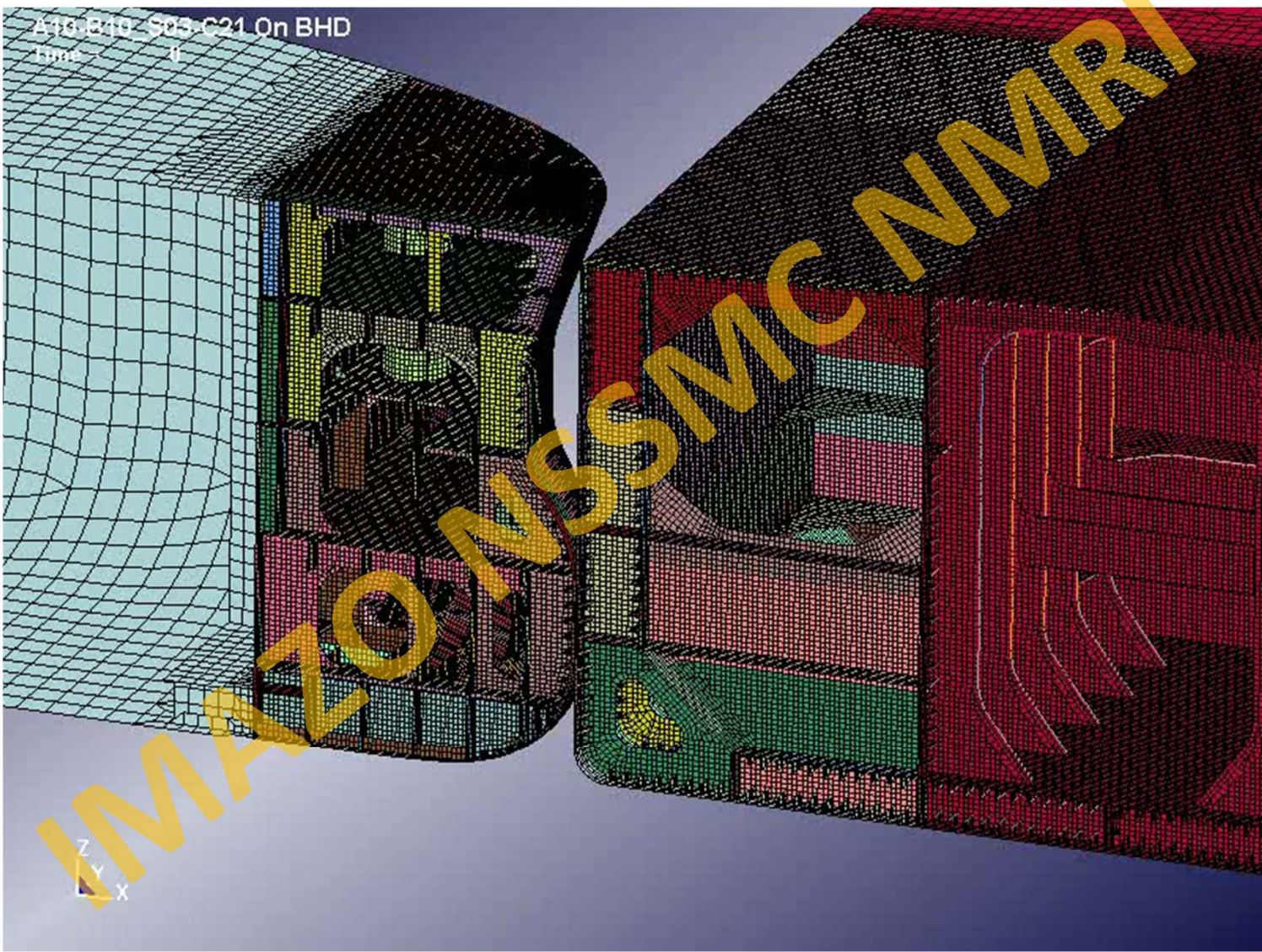


Application members of HDS



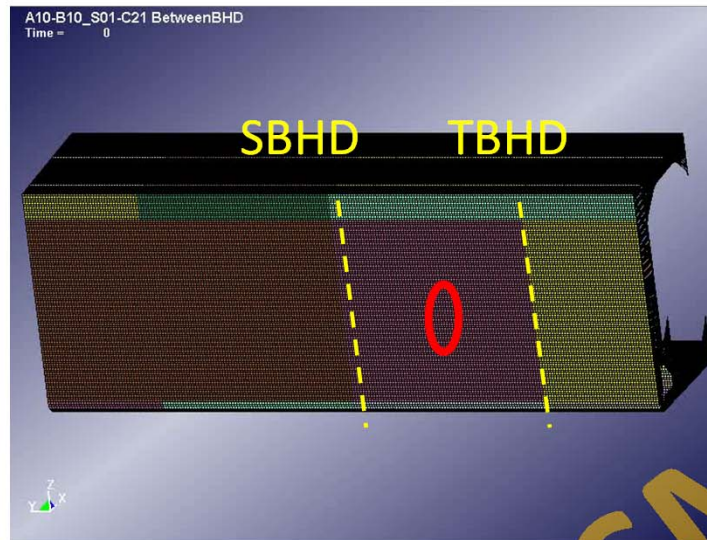
- HDS is only applied to OS and IS of the struck ship.
- Analysis conditions other than material are same.

FEA Results

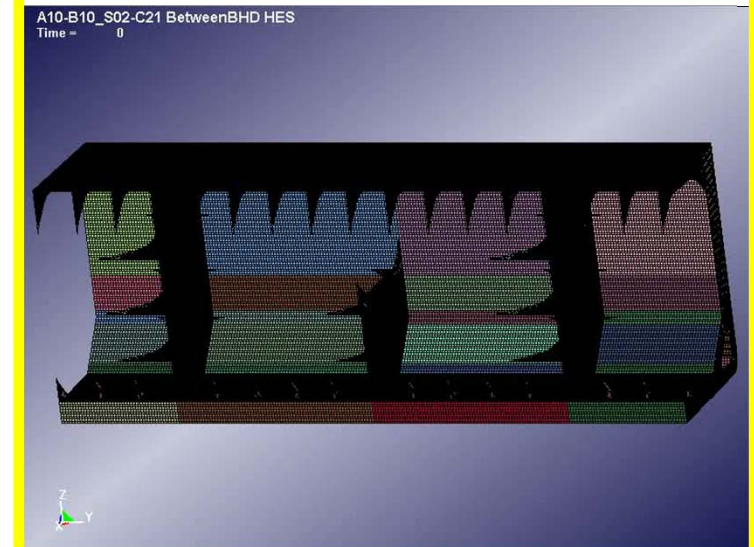


Results of FEA

Outer Shell



Inner Shell



Conventional

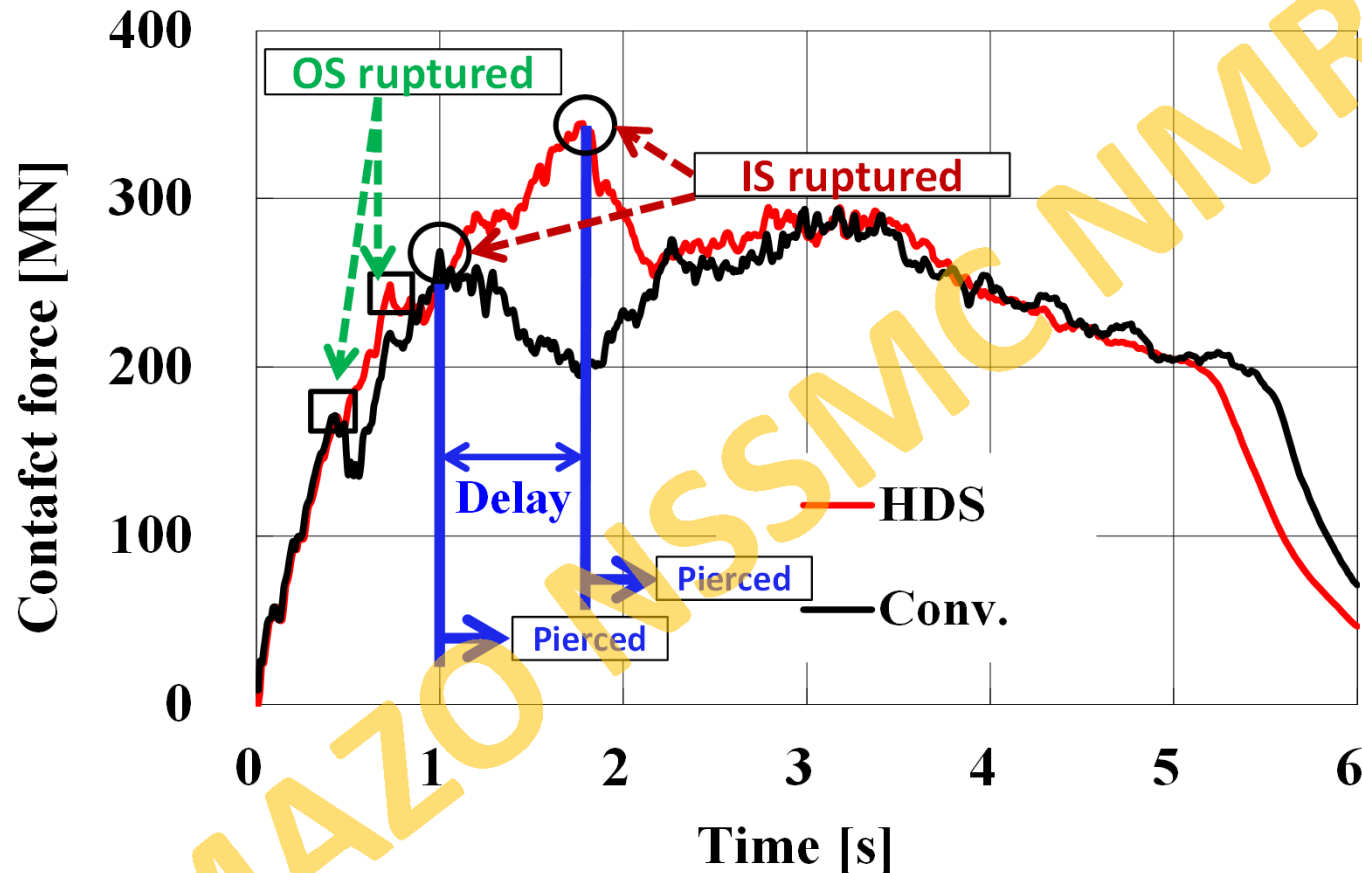
Trupture:0.87

HDS

Trupture:1.81

Comparison of histories of contact force

VB=12kt, Bet. T.BHD. (C21)



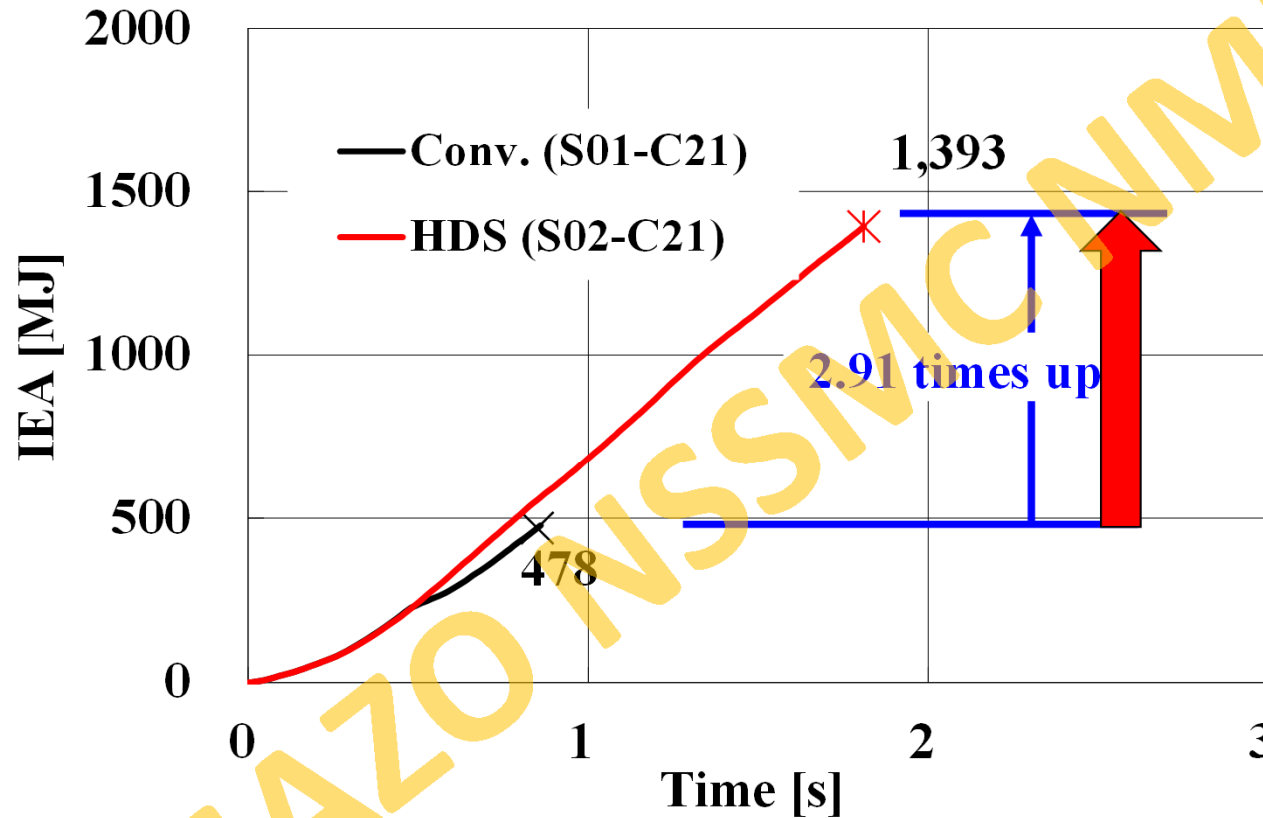
Black: Conventional, Red: HDS

Contact force significantly decrease after IS rupture.

Due to application of HDS, delay of IS rupture can be seen
($T_{rupture}$; 0.87s \rightarrow 1.81s, 2 times later).

Effect of HDS on Energy absorption

Bet. BHD.

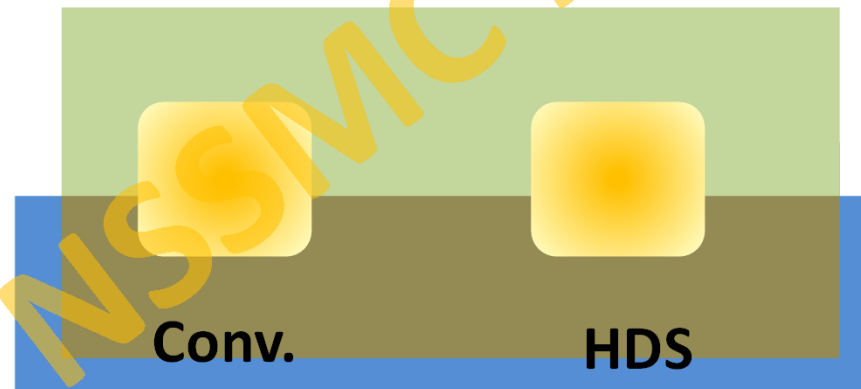


Energy absorption by the struck ship until oil tank (inner shell) rupture becomes 3 times larger than that of conv.

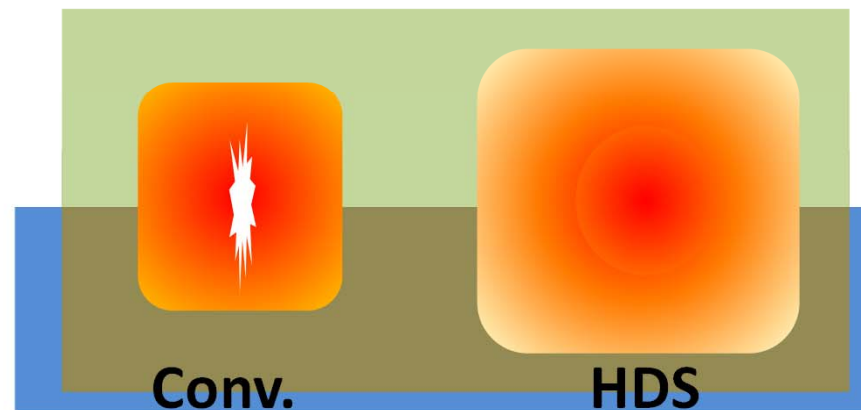
Conceptual drawing of deformation

Large elongation of steel and expansion of plastic area increase energy absorption of hull in collision.
Hull structures HDS applied is hard to be pierced.

Small deformation
(Low speed collision)



Large deformation
(High speed collision)



FEA Analysis

Simulation 2

Oblique - Vertical Collision

(Practical and high accuracy simulation)

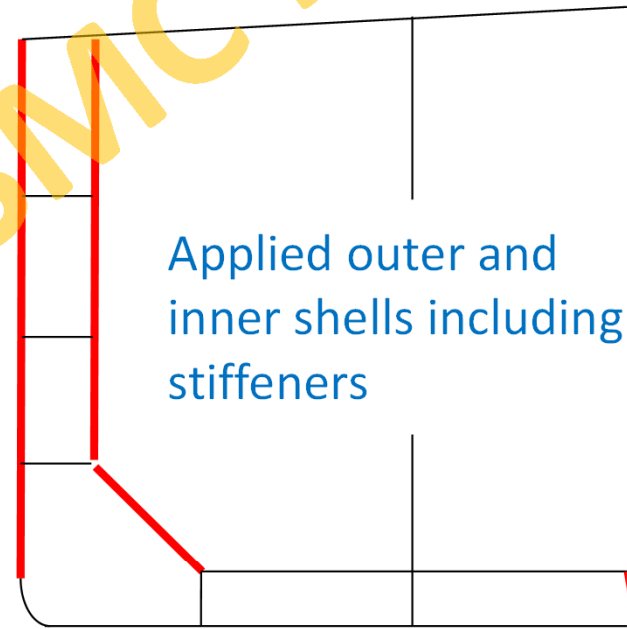
IMAZO NSSMC NMRI

Application members of HDS

Full application



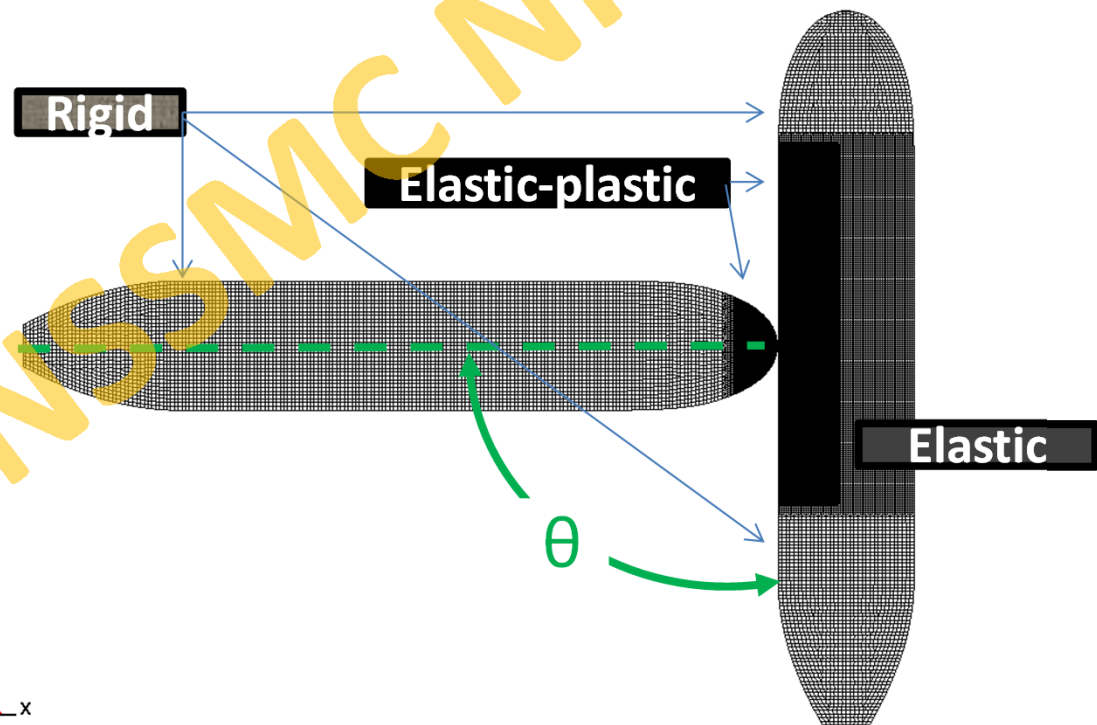
Partial application



Collision conditions

Simulation 2

- VLCC collides with the midship part of another VLCC
- Both ships fully loaded
- Collision speed
striking (VB) = 1-12(15) knot
struck (VA) = still
- Collision angle $\theta = 60-150$ deg.
- Motion of struck ship
: **Considered**
- Deformation area
: **3hold \times 1/2width**



Collision velocity and angle

Full applied

Velocity θ	15	12
60		
75		
90		
105		
120		
135		
150		

Partial applied

Velocity θ	15	12
60		
75		
90		
105		
120		
135		
150		

Simulated

Not applied

Velocity θ	15	12	10	9	8	7	6	5	4	3	2	1
60												
75												
90												
105												
120												
135												
150												

Critical Striking Velocity ($V_{B,cr}$)

Critical Striking Velocity ($V_{B,cr}$) :

Minimum striking ship speed to penetrate cargo oil tank (inner shell) in case of collision

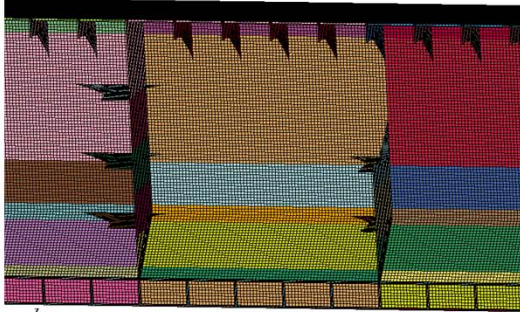
Kinetic energy of striking ship =

Kinetic energy after collision + angular momentum + $E_{s,cr}$

$E_{s,cr}$: Absorbed Energy by the time of cargo oil tank rupture.

Collision Movies of Simulation2

A13-B10 B02-C122 A90 V12kt HES-FULL
Time = 0



Full-applied, 90deg.
(B02-C122)

A13-B10 B05-C126 A90 V12kt HES-HALF
Time = 0



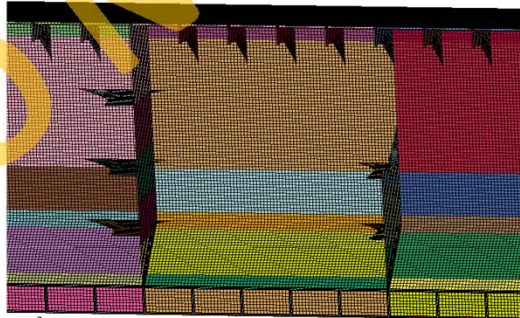
Partial-applied, 90deg.
(B05-C126)

A13-B10 B09b-C116e A90 V12kt Conventional
Time = 0



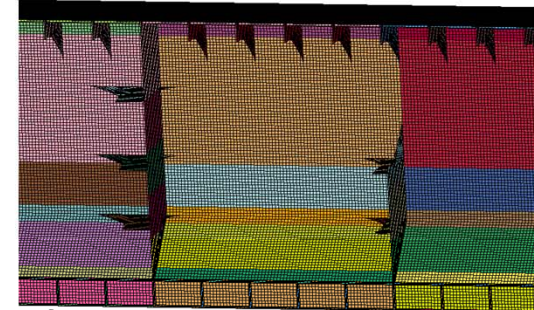
Conventional, 90deg
(B09b-C116e)

A13-B10 C130 A135 V12kt Conventional
Time = 0



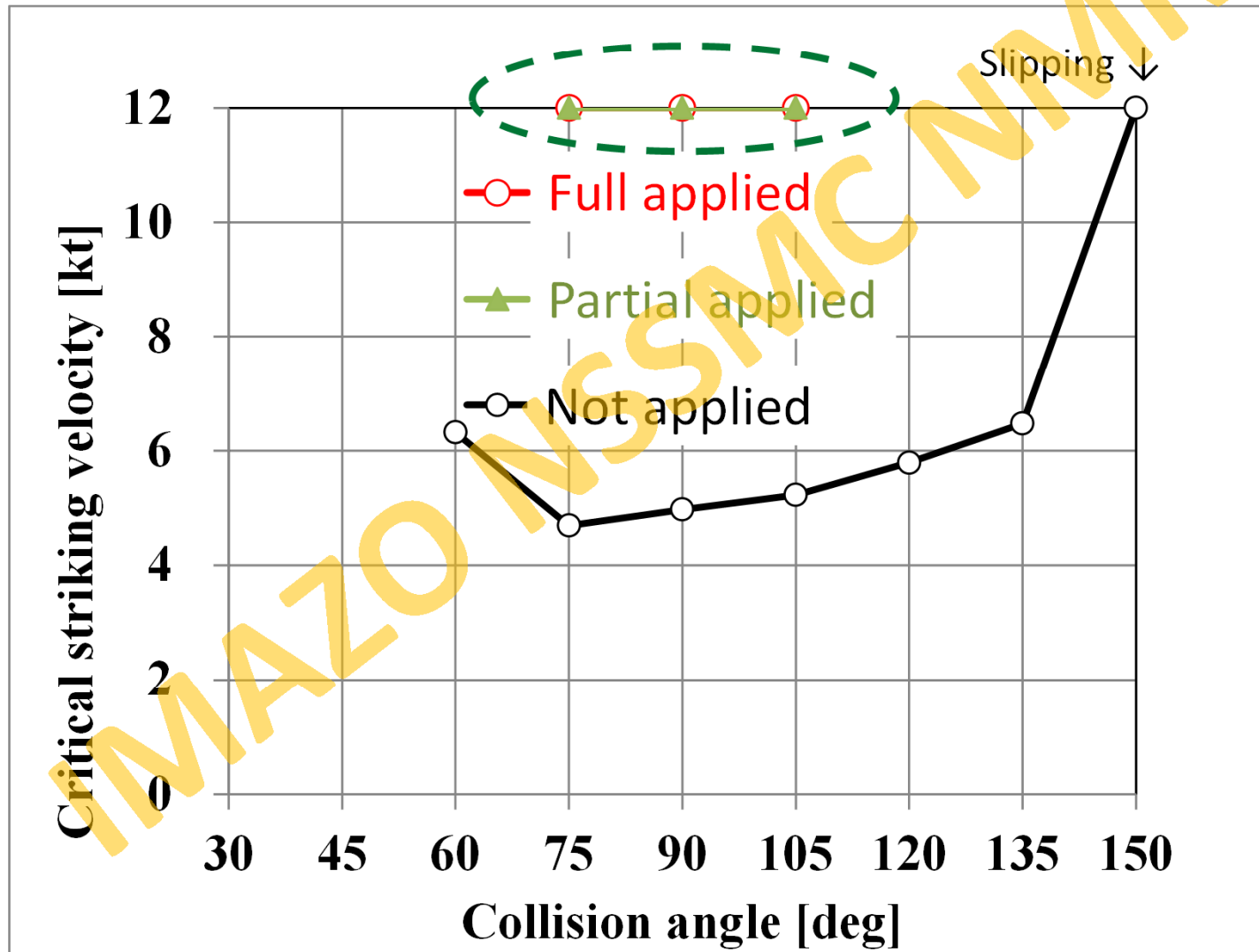
Conventional, 135deg.
(C130)

A13-B10 C151 A150 V12kt Conventional
Time = 0



Conventional, 150deg.
(C151)

Critical Striking Velocity



ClassNK Notation and Descriptive Note

ClassNK Notation

“Hull Protection by Highly Ductile Steel” (HP-HDS)

Notation is assigned to ships using ClassNK approved HDS effectively to increase the energy absorbed by the hull in the case of collision or grounding.

Descriptive Note

Specifies the grades and application areas of the HDS used.

e.g. : KA32-HD XX applied to side shell plate and side longitudinal
within Fr. XX-XX (or No. X-X WBT)

Material grade of HDS

Approved HDS is indicated by “HD XX”

“XX” shows the increased percentage of elongation of HDS against the rule required minimum specified elongation of the corresponding normal steel.

e.g. : KA32-HD50 for $15 < t \leq 20$

KA32-HD50 is Highly Ductile Steel with minimum specified elongation 27%, where the minimum specified elongation of KA32 is 18%.

($18 \times 1.5 = 27$)

Conclusions(1)

- HDS is developed by Nippon Steel & Sumitomo. HDS possess larger elongation.
- HDS can increase energy absorption of hull structures in collision about 3 times larger than that of ordinary steel.
- HDS is applied on the actual ships already by Imabari Shipbuilding to prevent/mitigate cargo and fuel oil spill.

Conclusions(2)

- Advantages of HDS are

- 1)Hollow depth is smaller than the hull conventional steel applied.

⇒ Easy to repair

- 2)Hard to be pierced by striking ship

⇒ Decrease cargo spill, escape sinking

- Imabari Shipbuilding will apply HDS as standard for safety of ships and global environment conservation.

Thank you for your attention



ClassNK
R&D PROJECT

This technology was developed with the support of ClassNK as part of the ClassNK Joint R&D for Industry Program.