Supplementary information to the manuscript

Forensic seismology for an underwater explosion vis- à-vis the ROKS Cheonan Sinking

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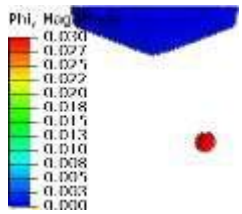
Bubble Shape Modeling by Boundary Element Method (BEM) for the ROKS Cheonan Sinking in the case of 136 kg TNT (LCM)[1-4,14] and 250 kg TNT (torpedo)[2-4,14]

a. Bubble shape evolution near a ship hull with 136 kg TNT depth at a depth of 8 m and 3 m portside. b. Bubble shape evolution near the ship with 250 kg TNT at a depth of 9 m and 3 m portside. c. Bubble shape evolution near the ship hull with a charge of 136kg TNT at a depth of 8 m and 5 m portside. The bubble pulsing period is 1.030 s which is close to the observed bubble pulse period (0.998 s). d. Bubble shape evolution near the ship hull with a charge of 250 kg TNT at a depth of 9 m and 5 m portside. The bubble pulsing period is 1.172 s in this case.

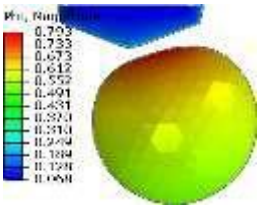
The bubble simulation results are as follows:

The post-detonation bubble expands and achieves its maximum volume at t=0.500 s and the bubble impinges the hull generating a toroidal bubble at 0.932 s before starting its collapsing phase. At the same time a bubble jet impact penetrates the bubble at t=1.007 s with vortex ring (130-170 m/s), finally reaching a bubble pulse at t=1.030 s, At t=1.030 s the bubble achieves its minimum volume and ends its first pulsing period.

a



(1) *t*=0.000s



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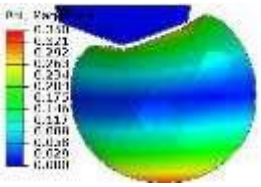

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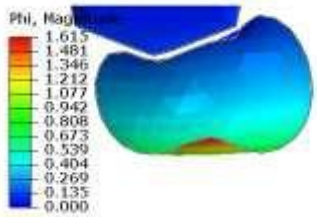

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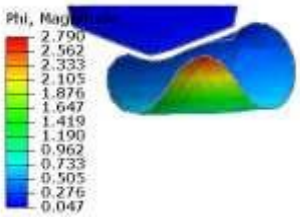

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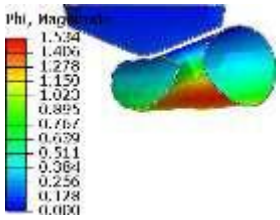

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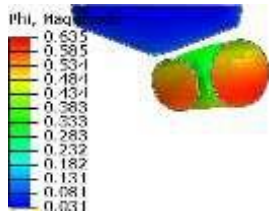

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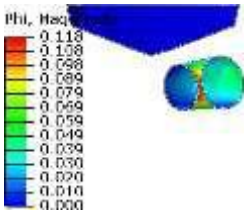

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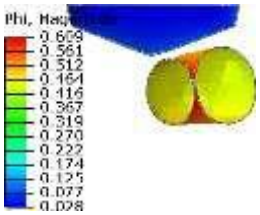
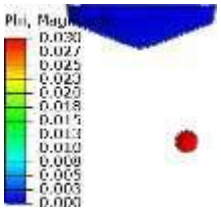


(9) *t*=1.140s

b



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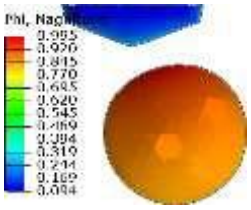
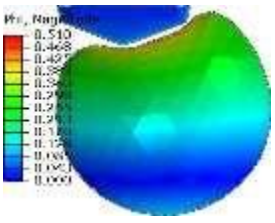


(2) *t*=0.110s



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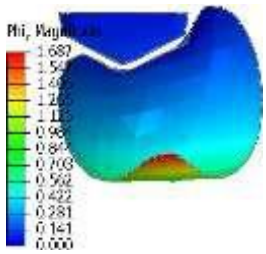

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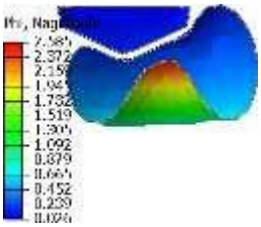

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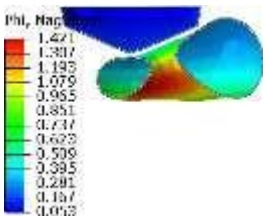

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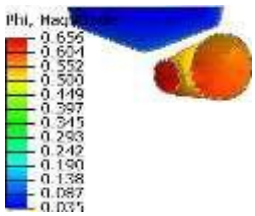

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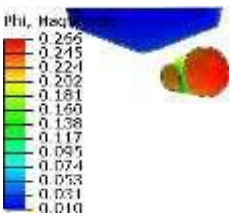

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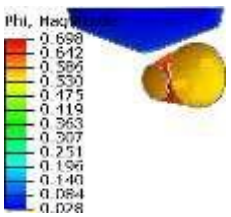
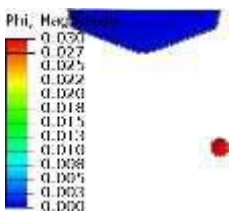


(9) *t*=1.220s

c



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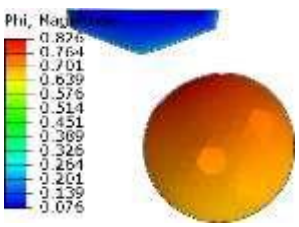

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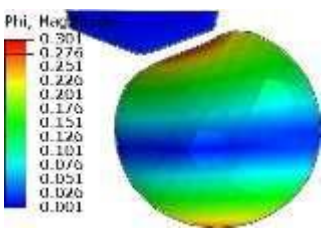

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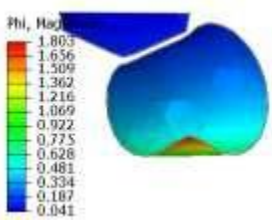

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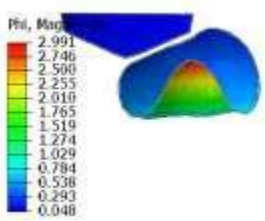

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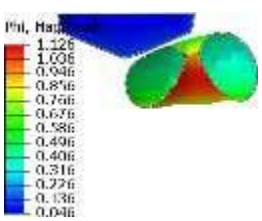

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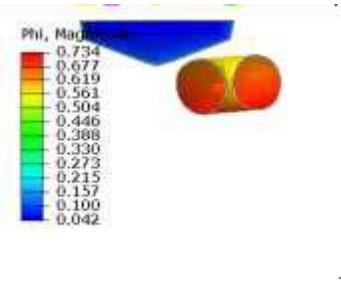

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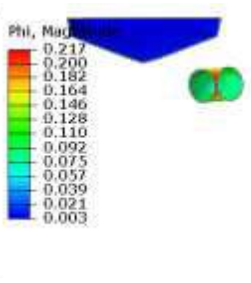

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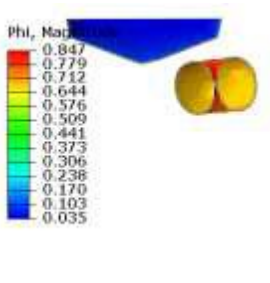
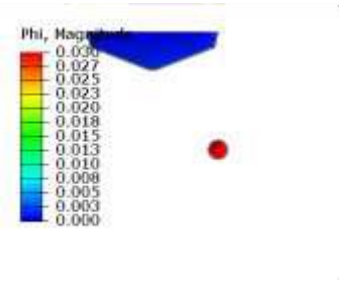


(9) *t*=1.122s

d



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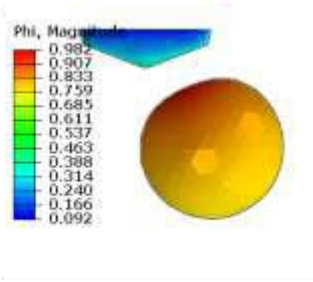

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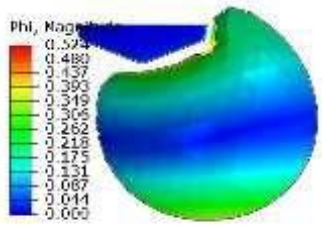

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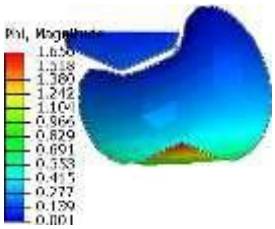

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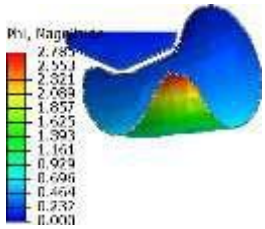

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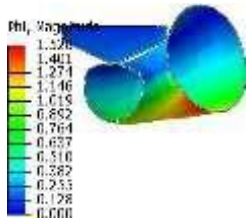

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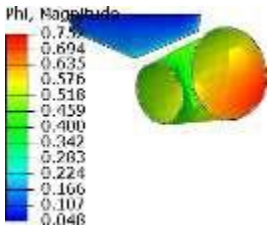

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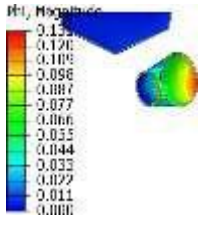

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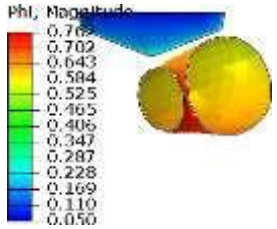

(9) t = 1.286s