박원규 교수

전산유체 실험실

연구실 소개

- 기계공학 관련 다양한 분야(기계, 항공, 조선 등)에서 열-유체 유동 현상을 CFD(Computational Fluid Dynamics)를 활용하여 이해·분석하고 여러 기업체, 연구소 등 각종 기관의 요구사항에 대하여 정확도 높은 유동 정보를 제공
- 상용프로그램(Ansys Fluent, STAR CCM+ 등) 및 인하우스(Inhouse) 자체개발 해석코드 활용
- 비압축성/압축성 다상유동 연구(캐비테이션, 자유표면, 수중폭발, 소화해석 등), 유체-고체 연성 6자유도 연구(고속 입수체 수중입수 6자유도 거동, 수직발사, 수평발사 등), 기타 산학연구경험(삼성전자, LG전자, 현대자동차 등) 다수 보유
- 에너지 기술인력양성사업에 선정
- 방위산업청과 국방과학연구소에서 지정한 수중운동체 특화연구센터에 참여
- 국내의 중형잠수함(장보고 III) 발사체계 위탁연구 사업 및 대한민국 차세대 전투기(KF-X) 위탁연구 사업 참여 중

주관심 연구분야

- 다상유동장 해석, 수중무기 유동 설계 및 해석
- 전산난류모델, 최적설계, 다중격자, 병렬연산
- 압축성(초음속)/비압축성 유동에 대한 연구
- 전산열유체역학
- 풍력 터빈 블레이드 설계 및 성능해석
- 부유식 해상풍력 시스템

구성원

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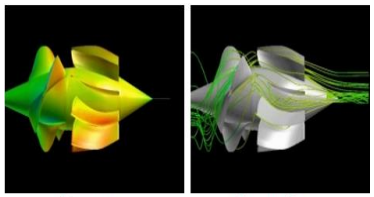
- 연구교수 : 1명
- Post.doc : 4명
- 박사과정 : 2명
- 석사과정 : 3명
- 학부연구생 : 1명

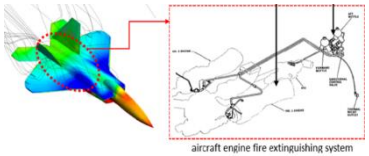
연구실 연락망

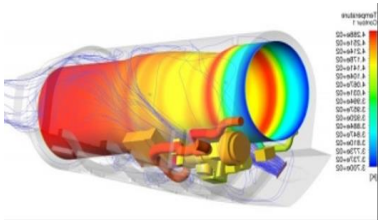
- 지도교수 : (051) 510-2457
- 실험실 : (051) 510-3064
- 홈페이지 : http://cfd.pusan.ac.kr

수륙양용탱크 waterjet 추진개발

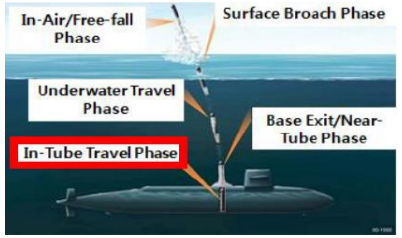


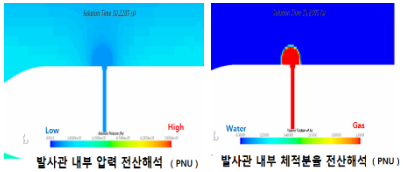
KF-X 차세대전투기 소화해석





장보고 III 수직발사체계 개발





발사관 내부 압력 전산해석 (PNU)

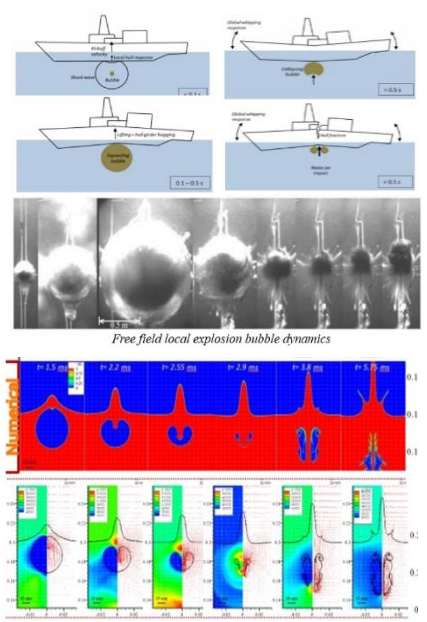
발사관 내부 체적분율 전산해석 (PNU)

주요 연구 수행 내용

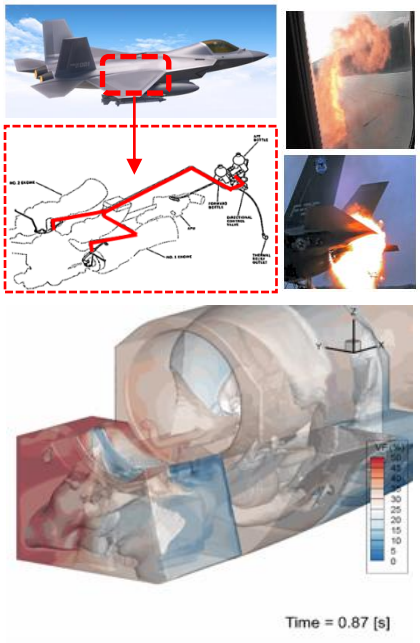
비압축성/압축성 다상유동 연구

- 수중 폭발 현상과 이에 의한 주위 물체(선박 등)의 충격/변형 관련 해석을 위한 고정도 전산해석 프로그램 개발 및 연구
- 차세대 전투기 엔진베이 화재시 소화를 위한 고온/고압 소화용기 및 배관 해석
- 초월공동(supercavitation) 현상을 이용한 차세대 초고속 어뢰 연구 개발
- 외란 및 받음각에 따른 초월공동 성장패턴 분석

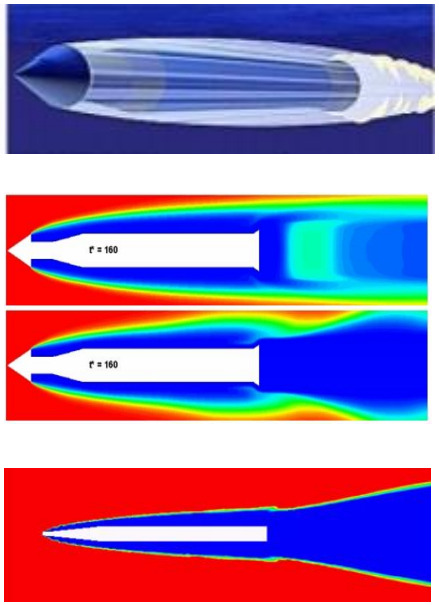
수중폭발에 의한 버블거동



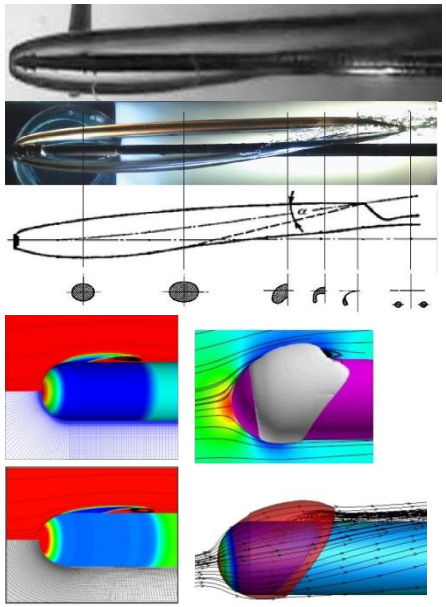
KF-X 전투기 소화장치 성능해석



초공동어뢰 다상유동 해석연구



외란/받음각에 따른 초월공동 전산해석

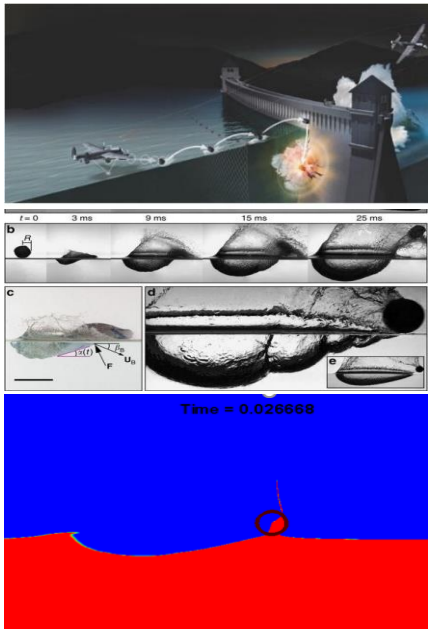


주요 연구 수행 내용

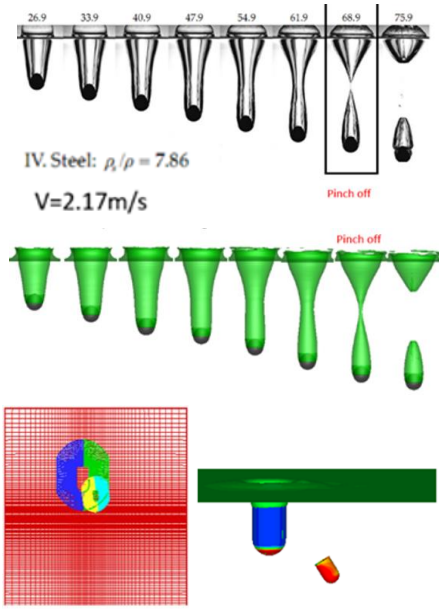
유체-고체 연성 6자유도 연구

- 도비(물수제비) 현상에 대한 전산해석
- 고속 입수체의 입수충격력 및 6자유도 입수거동 해석
- 이동 중첩 격자 시스템 구성을 통한 유체-고체 연성 해석
- 차세대 중형잠수함(장보고III) 수중발사체계(수직,수평) 전산해석

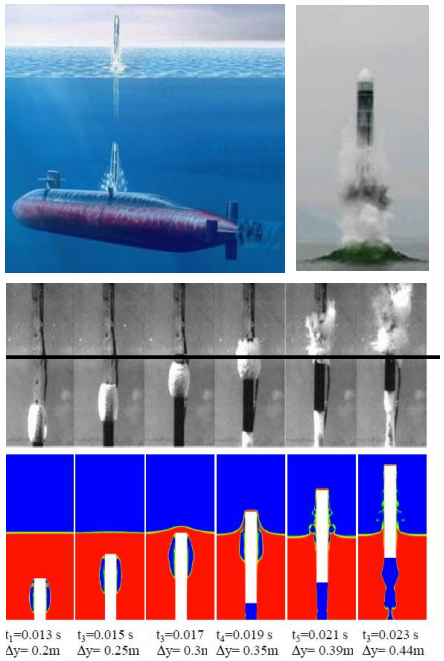
도비(rIcochet) 현상 전산해석



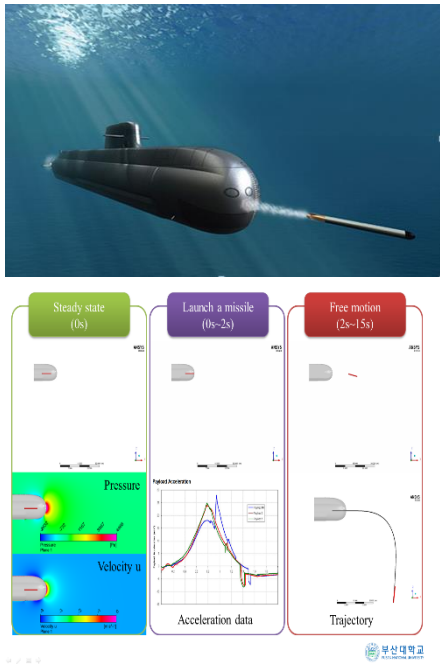
고속 입수체 입수충격력 전산해석



수직무장발사 공동붕괴 안정성 해석



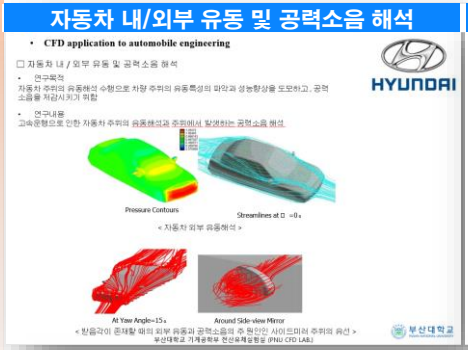
장보고III 수중발사체계 전산해석

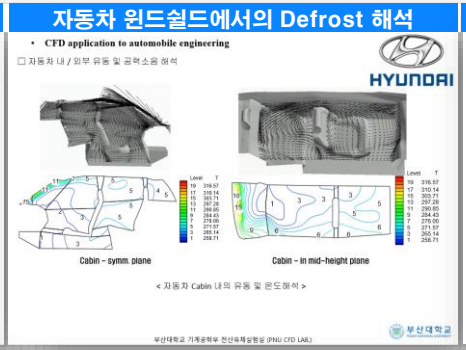


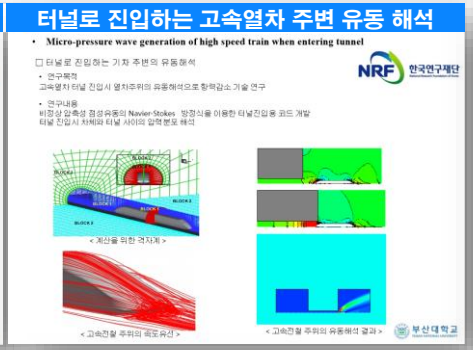
주요 연구 수행 내용

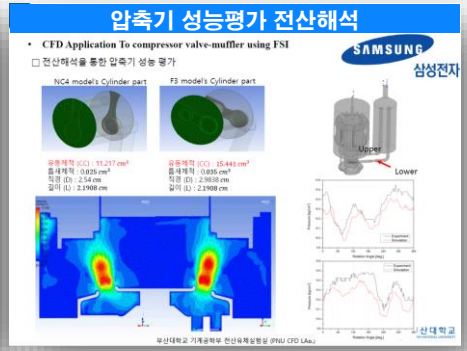
기타 산학연구수행 내용

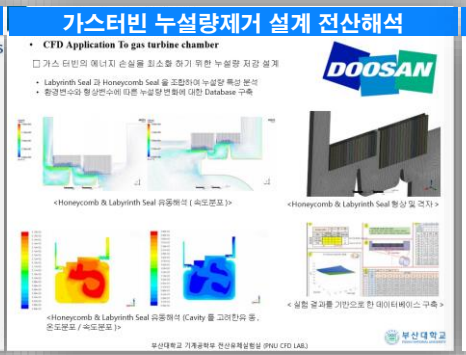
- 자동차 형상 특징에 따른 유동소음 해석 및 전면 유리 서리 해석을 통한 안정성 연구
- 터널로 진입하는 고속열차 주변 유동해석 연구
- 2원연성(two-way FSI) 해석을 통한 압축기 밸브 거동 전산해석 연구
- 냉장고 및 전자레인지 등 내부 열전달 해석을 통한 성능 개선 연구
- 가스터빈 누설량제거 설계 전산해석 연구
- Etc.











전산유체 실험실

졸업생 취업 현황

▪ 박사학위 (Ph.D) 졸업자 :

– 총 15명 (~2022.02)

- 국방과학연구소, ADD
- LG 전자
- 한국가스공사
- 효성 굿스프링스
- 부산대학교 Post-doctor, 연구교수
- 부산대학교 풍력발전미래기술센터

▪ 석사학위 (Master) 졸업자 :

– 총 85명 (~2022.02)

- LG 계열사 (전자 , 화학 , 디스플레이 , Hitach),
- 삼성 계열사 (전자 , 중공업)
- 현대 계열사 (자동차 , 중공업 , 미포조선 , 제철)
- 한국중부발전
- 대우조선해양(DSME)
- 효성중공업
- 한국델파이
- 볼보코리아
- 한국항공우주산업(KAI)
- 넥센타이어
- 안철수연구소
- etc.

전산유체 실험실

지도교수 이력

박원규 교수 (Park Warn Gyu) 에너지 시스템 전공

Computational Fluid Dynamics Lab. 전산유체실험실

학력

- Georgia Institute Technologe 박사 (1993)
- KAIST 석사 (1983)
- 부산대학교 학사 (1981)

주요 경력

- 부울과총 지역연합회 부회장(2019 - 현재)
- 부산대학교 기계공학부 학부장 (2013 - 2019)
- 한국전산유체공학회 학회장 (2017)
- 부산대학교 지방대학특성화사업단(CK-1) 단장 (2014 - 2019)
- 수중운동체 특화연구센터(UVRC) 제2실 연구실장 (2003-2014)
- 미국 퍼듀대학교 방문교수 (2006 - 2008)
- 일본 동경대학교 초빙교수 (2000 - 2001)
- 한국과학기술연구원(KIST) 연구원 (1983 - 1988)

박원규 교수(E-mail : wgpark@pusan.ac.kr)
실험실 연락처 : 051-510-3064

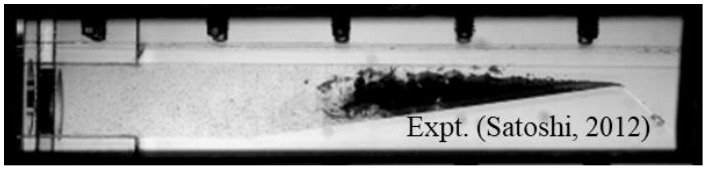
전산유체 실험실

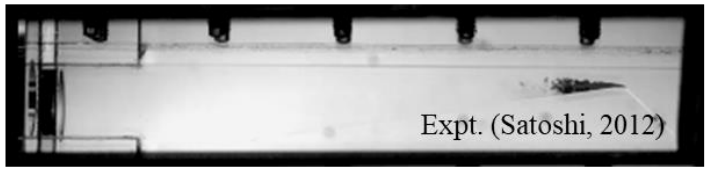
APPENDIX

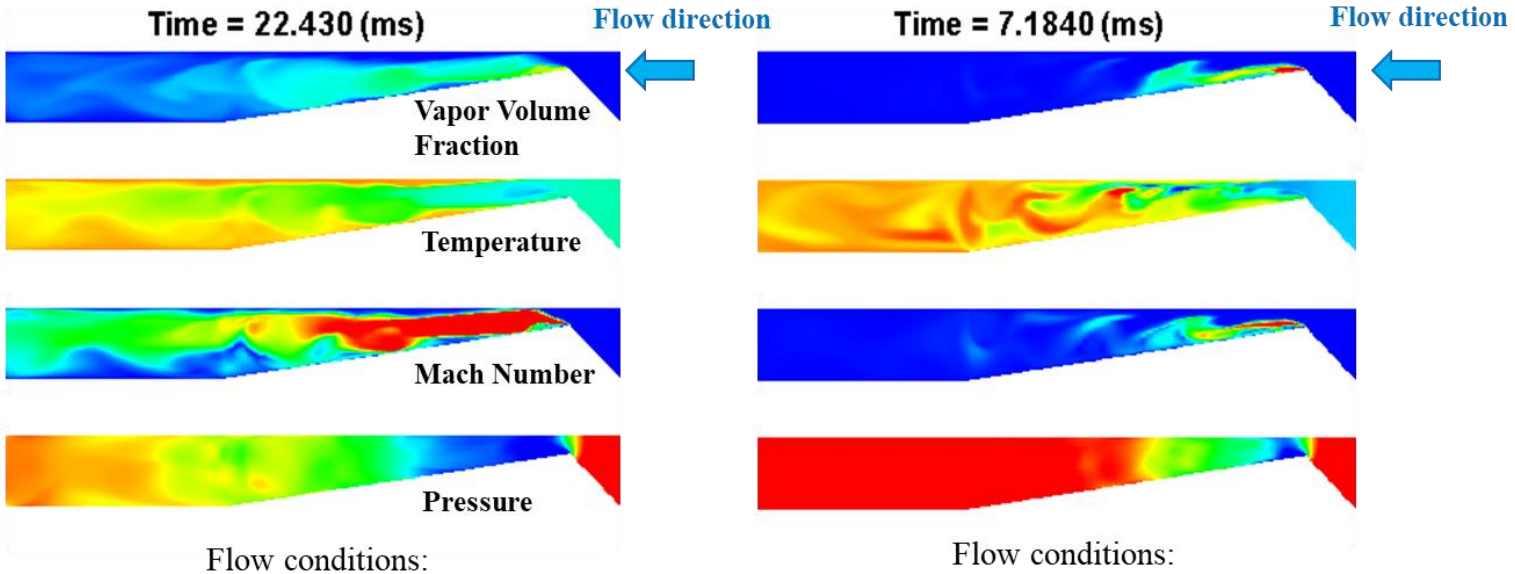
전산유체 실험실

연구 분야 - 전산유체역학(CFD)

비압축성/압축성 다상유동 연구_Nozzle Cavitation







Flow conditions:

p_{outlet}=94.5 kPa ($\sigma_{outlet} \approx 14.9$) U_{inlet}=3.5 m/s (Min~0.01) T_{inlet}= 27°C

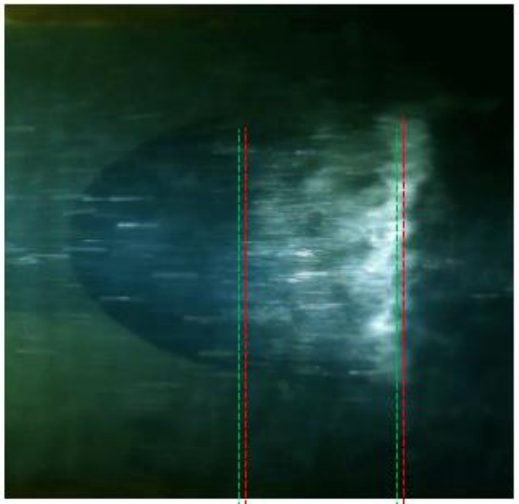
Flow conditions:

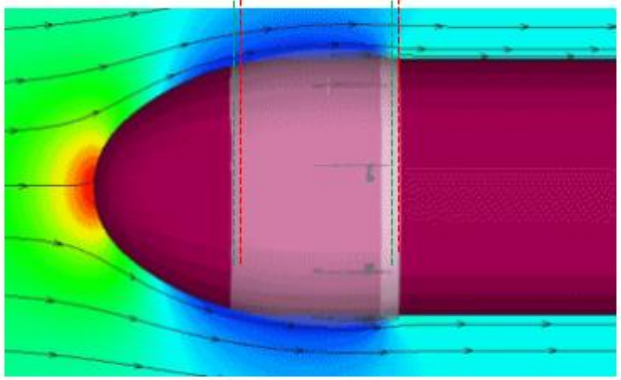
p_{outlet}=124 kPa ($\sigma_{outlet} \approx 19.8$) U_{inlet}=3.5 m/s T_{inlet}= 27°C

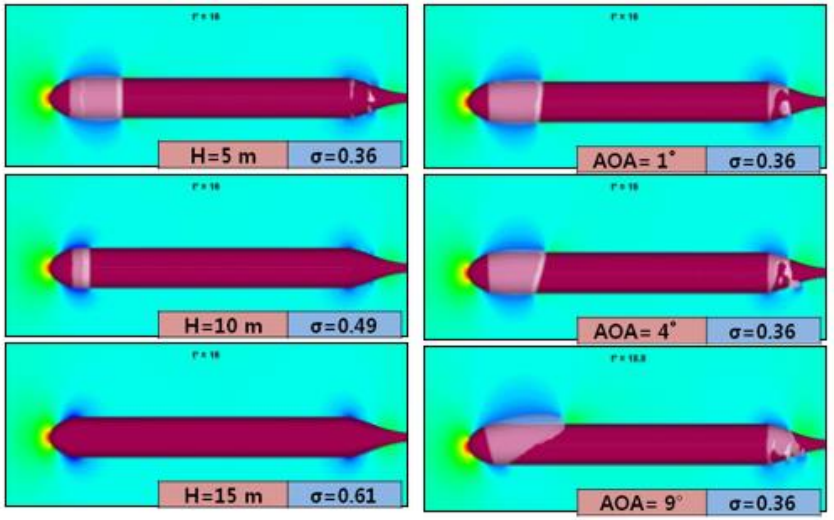
전산유체 실험실

연구 분야 - 전산유체역학(CFD)

비압축성/압축성 다상유동 연구_Natural Cavitation: 범상어(wire-guided)







▪ Depth : 5 , 10 , 15 m

(Fixed AOA=0°, V=55knot)

▪ AOA : 0°~ 9°

(Fixed H=5m , V=55knot)

--- PNU

--- Experiment (KRISO's)

	Start of L/D (mean)	End of L/D(mean)	Length(mean)
PNU	0.561	1.153	0.592
Experiment	0.613 ± 0.05	1.276±0.01	0.663

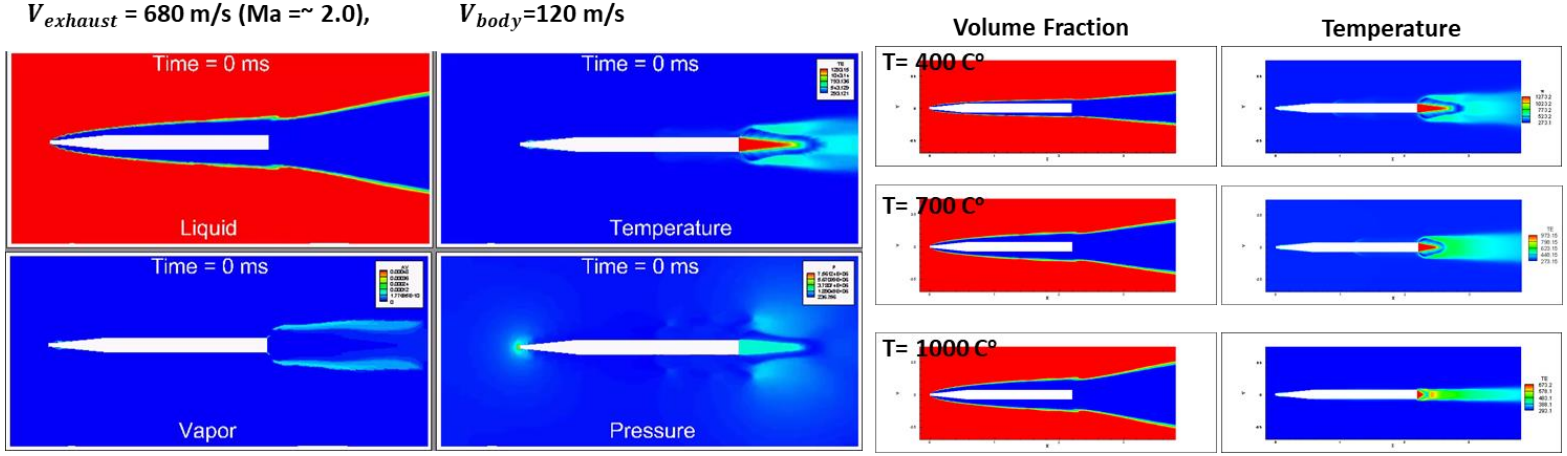
전산유체 실험실

연구 분야 – 전산유체역학(CFD)

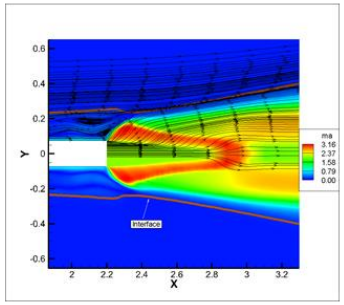
비압축성/압축성 다상유동 연구_Supercavitating Torpedo: hot gas exhaust/ventilation

$F_{thrust} = \dot{m}(V_{jet} - V_{body}), \quad \dot{m} = 10kg/s$

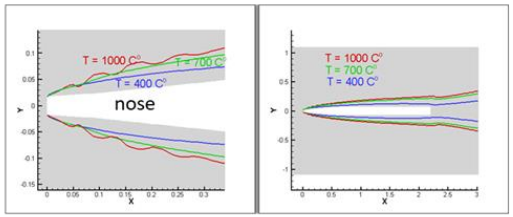
$V_{exhaust}$ = 680 m/s (Ma =~ 2.0), V_{body}=120 m/s



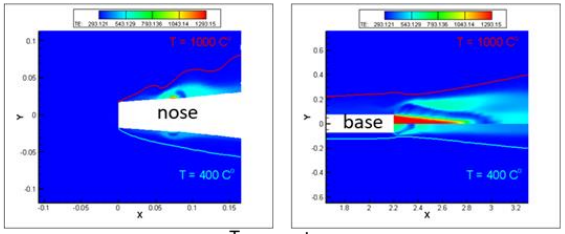
Hot gas supercavitating flow around a Shkval-shape projectile



Mach number, streamline and interface



Interfacial profiles

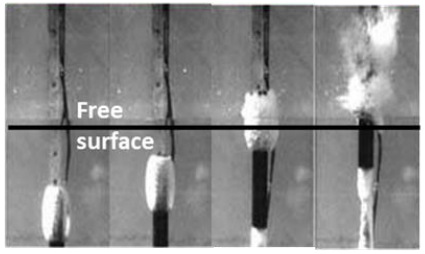


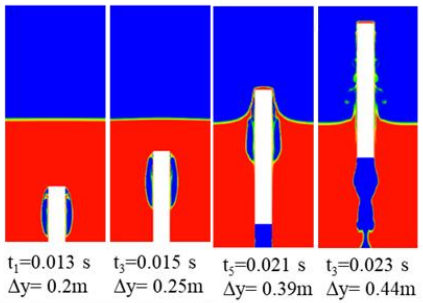
Temperature

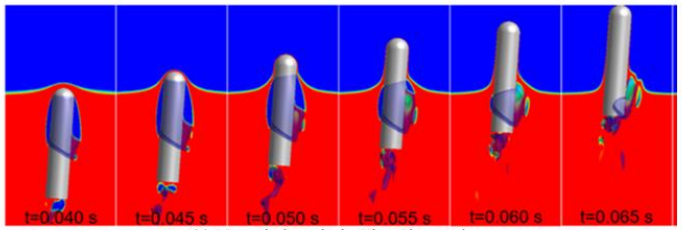
전산유체 실험실

연구 분야 - 전산유체역학(CFD)

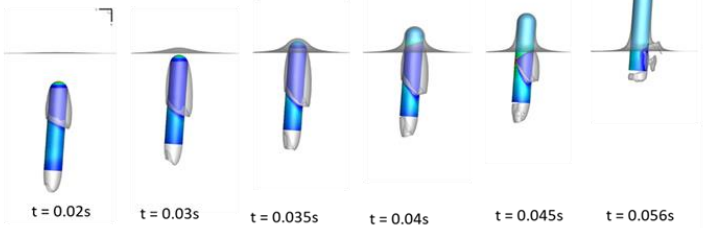
비압축성/압축성 다상유동 연구_잠수함 수직발사(SLBM): cold launch/hot launch



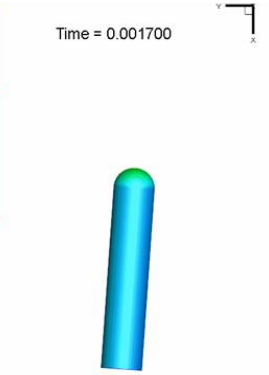




(a) Numerical results by Ying'Chen at al.
Journal of Fluids Engineering, Vol. 142 / 011403-1



(b) Numerical result by PNU

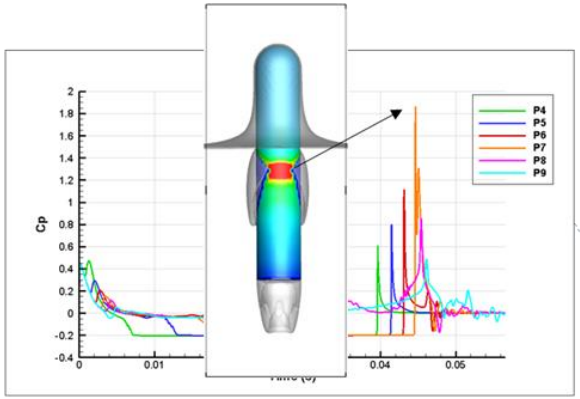


Chu et al., 2010, Numerical simulation of water-exit of a cylinder with cavities, 9th Int. Conference on Hydrodynamics, Oct. 11-15, 2010 Shanghai, China

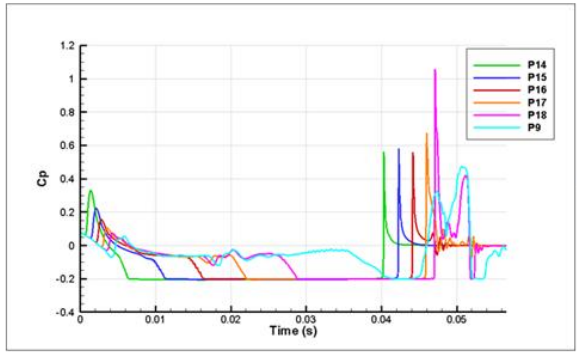
전산유체 실험실

연구 분야 - 전산유체역학(CFD)

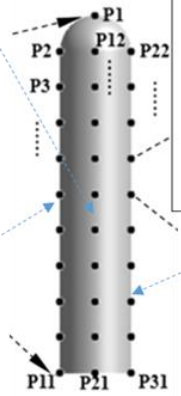
비압축성/압축성 다상유동 연구_잠수함 수직발사(SLBM): cold launch/hot launch

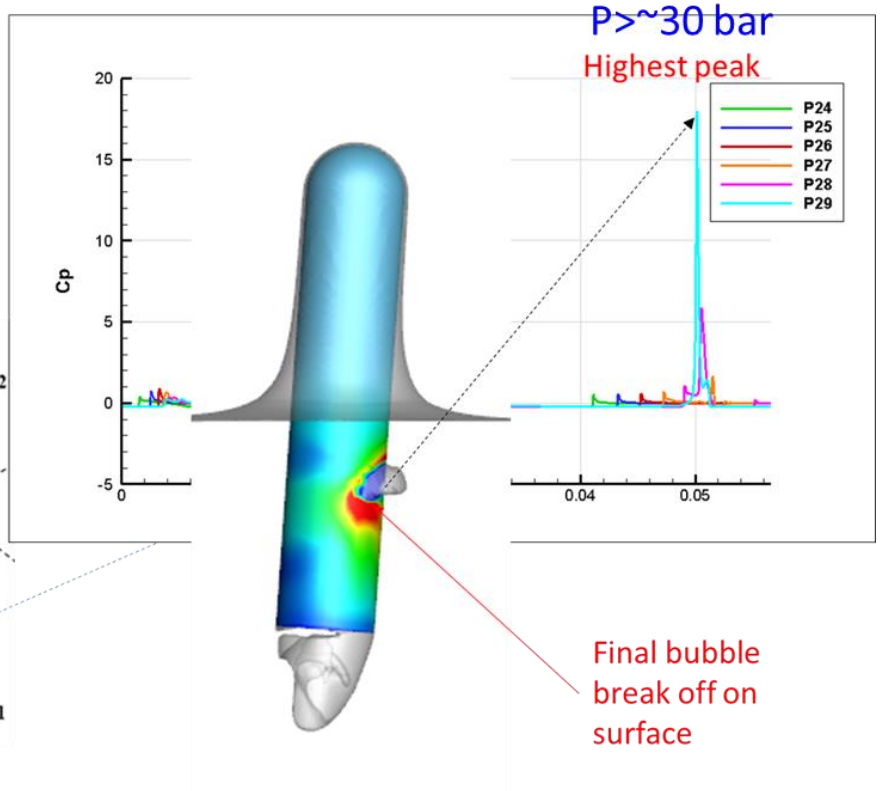


(a) Pressure peaks caused by the cavity break-off on the left surface



(b) Pressure peaks caused by the cavity break-off on the middle surface



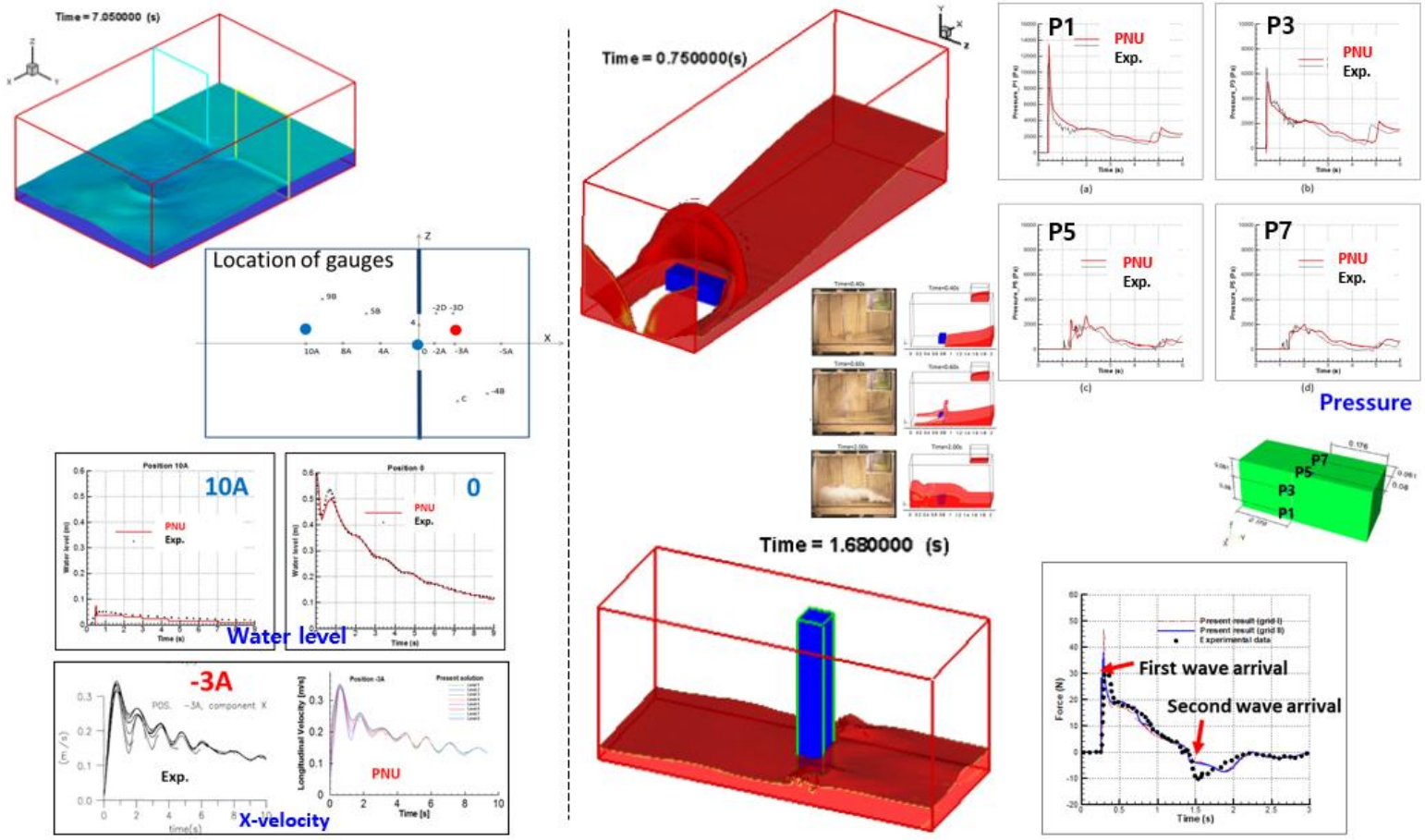


(c) Pressure peaks caused by the cavity break-off on the right surface

전산유체 실험실

연구 분야 - 전산유체역학(CFD)

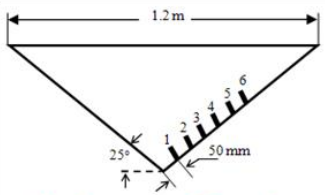
VOF(Volume of Fraction)_자유 표면 해석



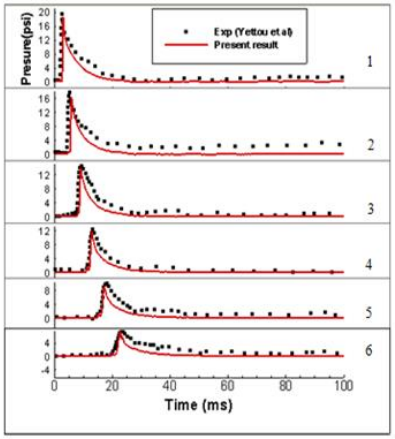
전산유체 실험실

연구 분야 - 전산유체역학(CFD)

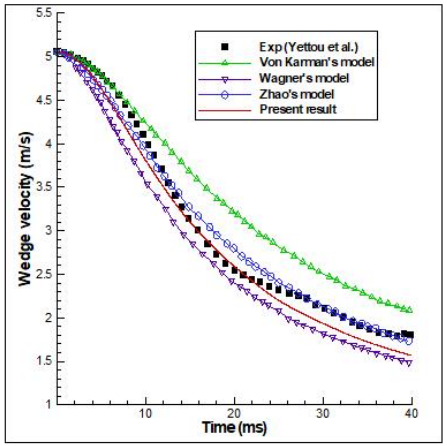
VOF(Volume of Fraction)_입수 충격력 해석



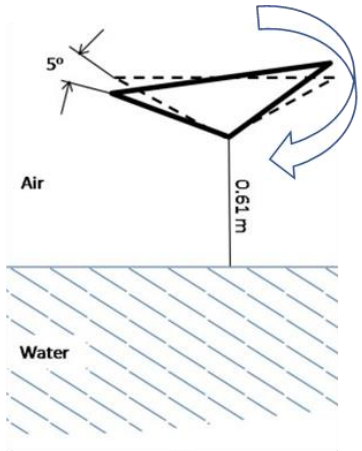
Six Pressure Transducers

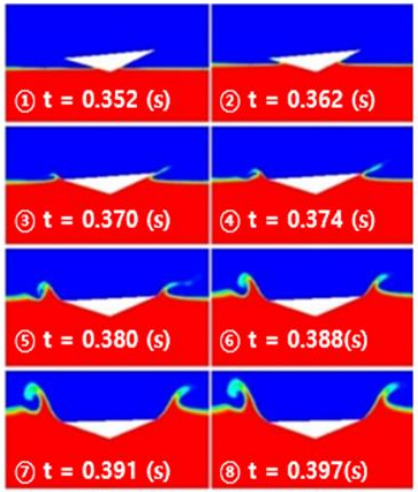


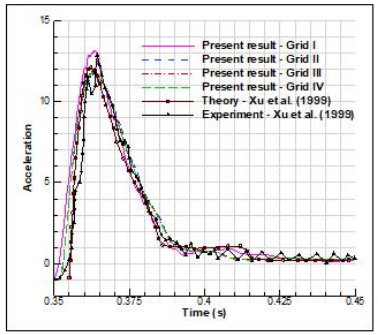
Pressures
at the six points



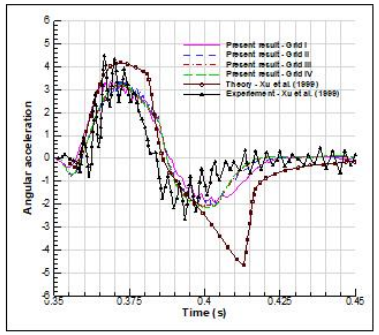
Velocity







Vertical Acceleration



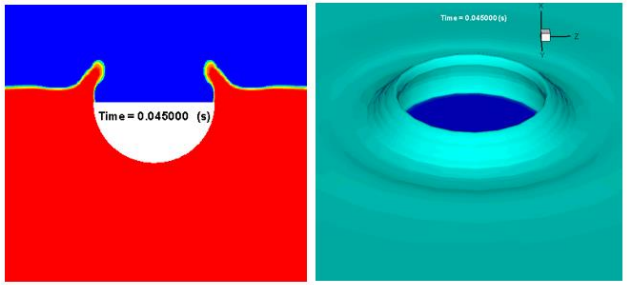
Angular Acceleration

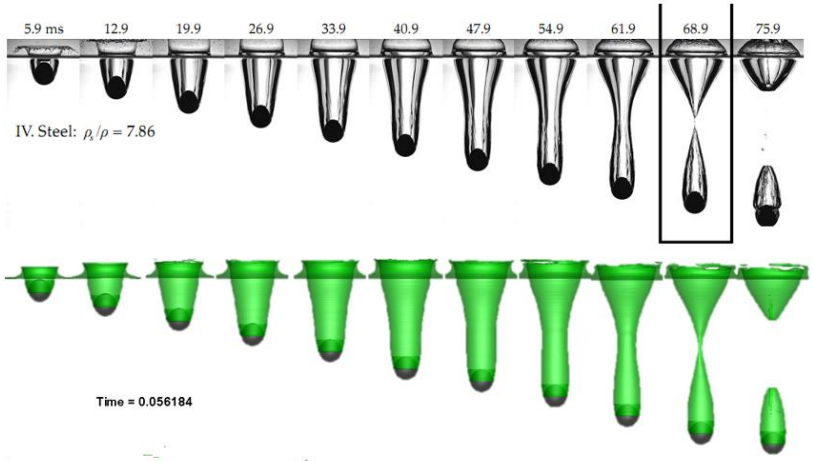
전산유체 실험실

연구 분야 - 전산유체역학(CFD)

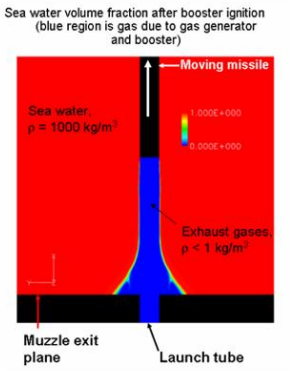
6DOF&Ricochet

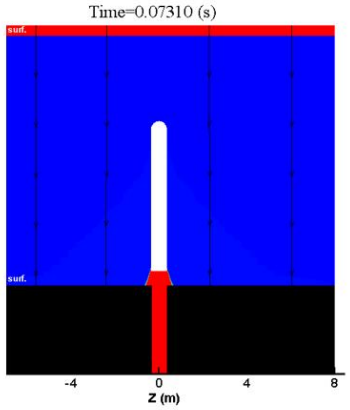
- 수중입수 해석

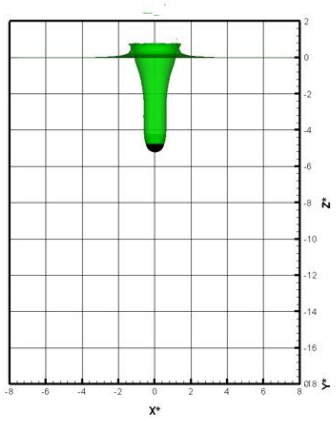


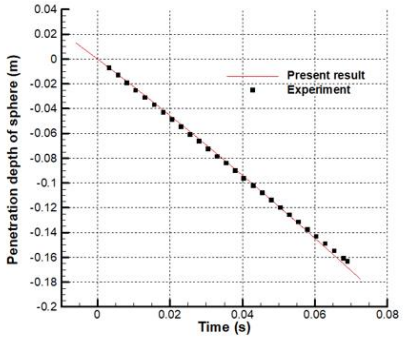


- 수직발사 해석





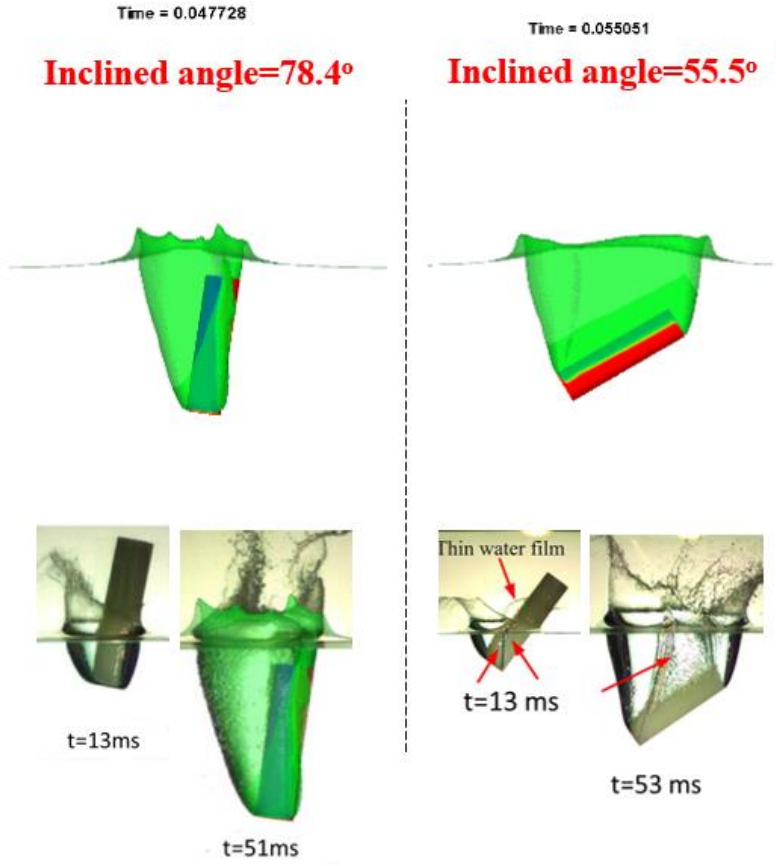




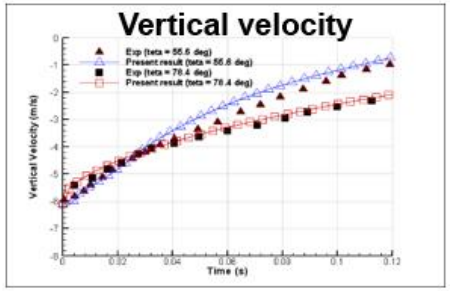
전산유체 실험실

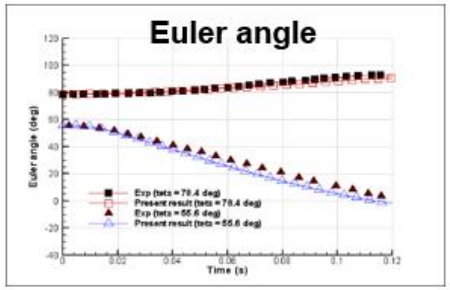
연구 분야 - 전산유체역학(CFD)

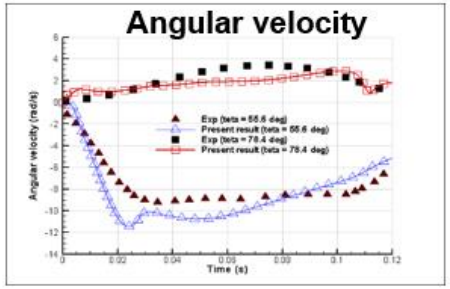
6DOF&Ricochet_입수 충격력 해석



D=50mm
L=200mm
U_{entry}=6.1m/s
m=0.35kg
ρ = 902 kg/m^3







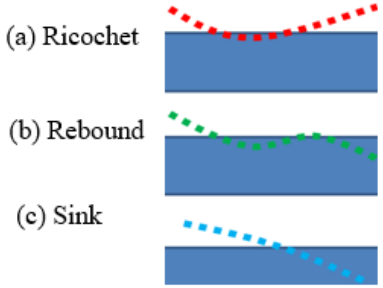
전산유체 실험실

연구 분야 - 전산유체역학(CFD)

6DOF&Ricochet_Ricochet(skipping) of high speed objects

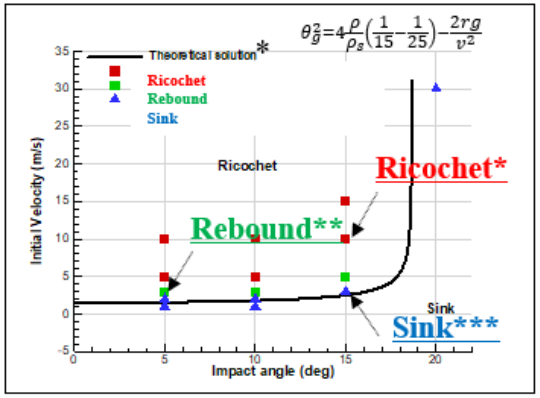
Sphere

- D = 25.4 mm
- Density ratio =1.0
- M=8.58 g

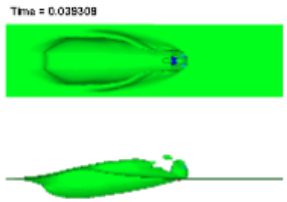


Trajectory possibilities upon water entry body

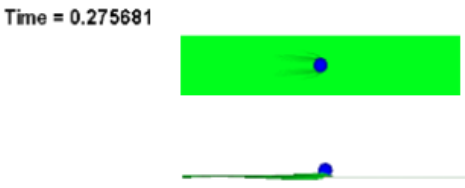
$(\rho_{sphere} / \rho_{water} = 1.0)$



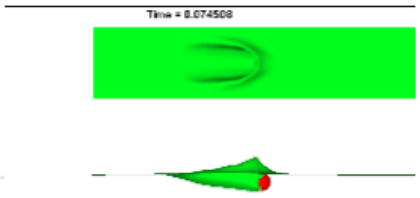
Ricochet, rebounding, and non-ricochet behaviors
Diameter of sphere = 0.025 m



Ricochet*
V = 10m/s
θ= 15°



Rebound**
V = 3m/s
θ= 5°



Sink***
V = 3m/s
θ= 15°

전산유체 실험실

연구 분야 - 전산유체역학(CFD)

Full Fluids Equation_Shock and Bubble Interaction

Air / Helium bubble system

Air

$$\begin{cases} \rho_a = 1.29\ \mathrm{kg/m^3}, u_a = 0\ \mathrm{m/s}, p_a = 10^5\ \mathrm{Pa} \\ \gamma_a = 1.4, \quad \pi_a = 0\ \mathrm{Pa} \end{cases}$$

Helium

$$\begin{cases} \rho_H = 0.167, \quad u_H = 0, \quad p_H = 10^5\ \mathrm{Pa} \\ \gamma_H = 1.67, \quad \pi_H = 0\ \mathrm{Pa} \end{cases}$$

Air / Nitrogen bubble system

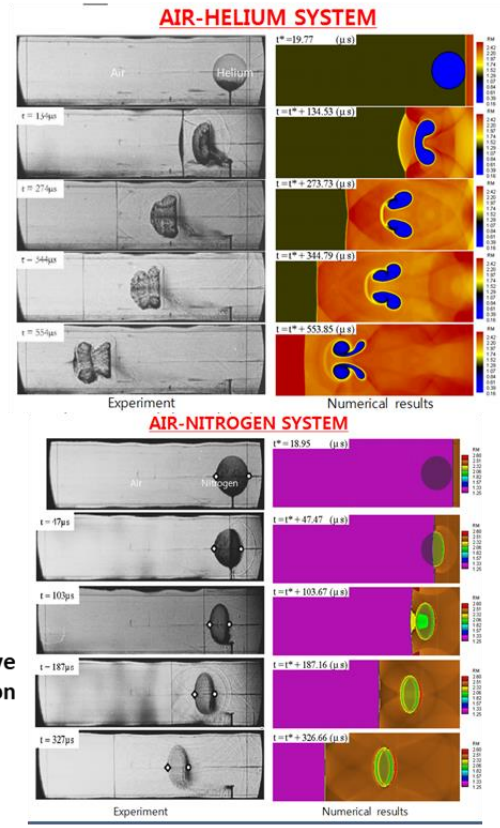
Air

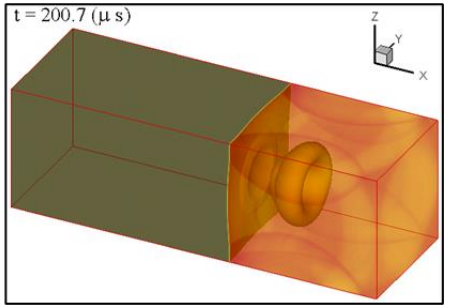
$$\begin{cases} \rho_a = 1.29\ \mathrm{kg/m^3}, u_a = 0\ \mathrm{m/s}, p_a = 10^5\ \mathrm{Pa} \\ \gamma_a = 1.4, \quad \pi_a = 0\ \mathrm{Pa} \end{cases}$$

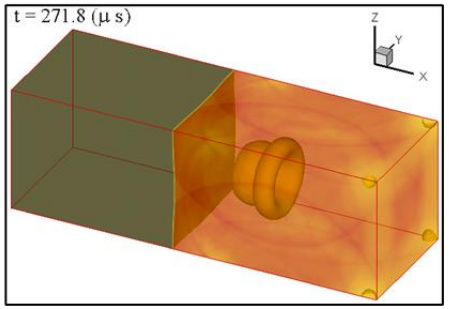
Nitrogen

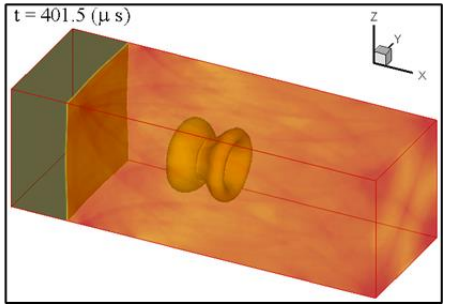
$$\begin{cases} \rho_N = 1.25\ \mathrm{kg/m^3}, \quad u_N = 0, \quad p_N = 10^5\ \mathrm{Pa} \\ \gamma_N = 1.4, \quad \pi_N = 0\ \mathrm{Pa} \end{cases}$$

Shock Wave Propagation









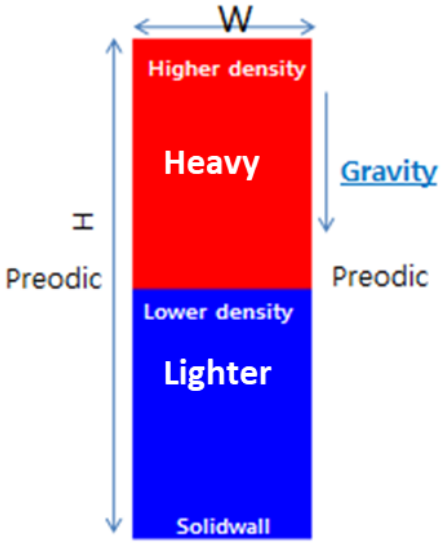
전산유체 실험실

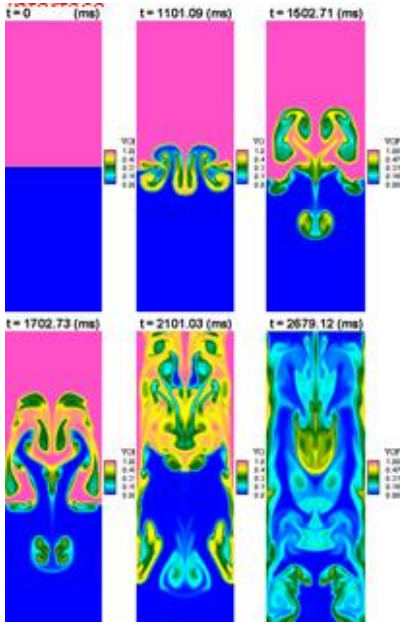
연구 분야 - 전산유체역학(CFD)

Full Fluids Equation Solver

- Rayleigh-Taylor Instability

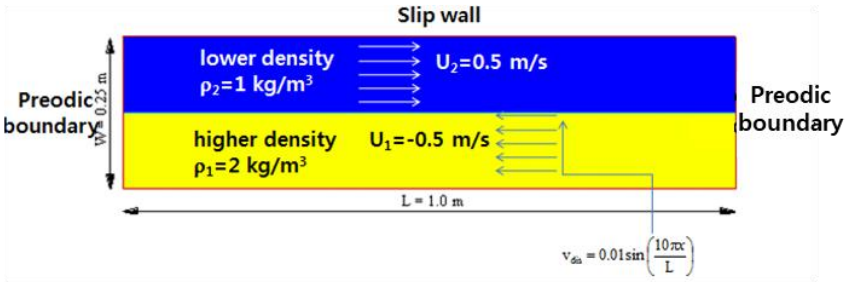
: $\rho_2/\rho_1=2.0$

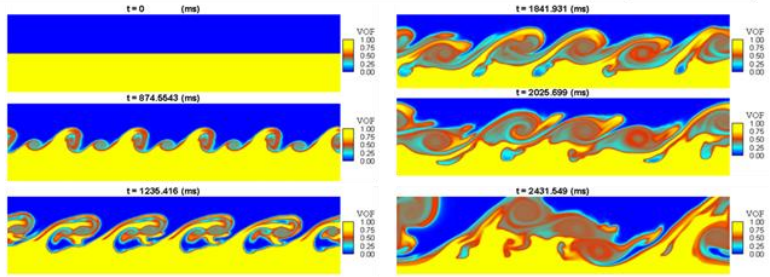




- Kelvin-Helmholtz Instability

: $\rho_2/\rho_1=1/2$ & $U_1 = -U_2$

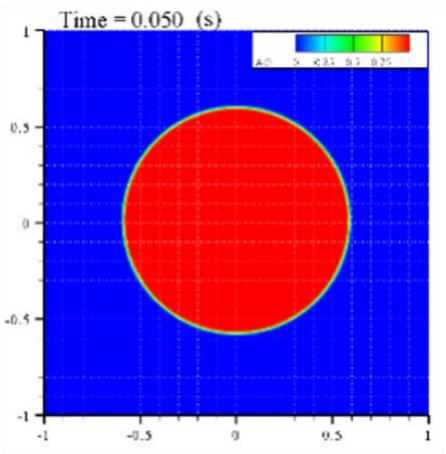


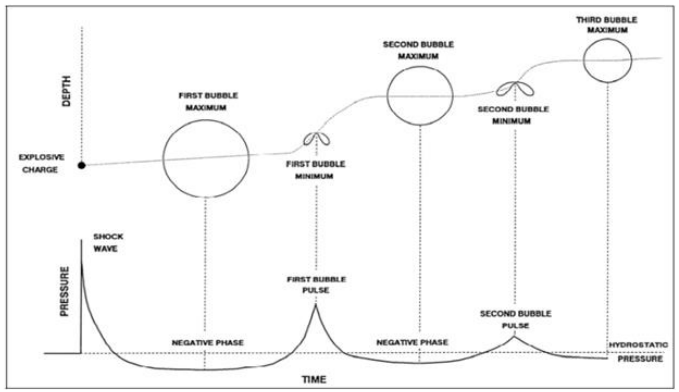


전산유체 실험실

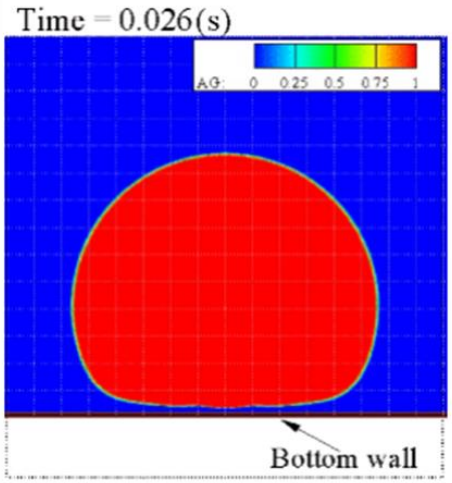
연구 분야 – 전산유체역학(CFD)

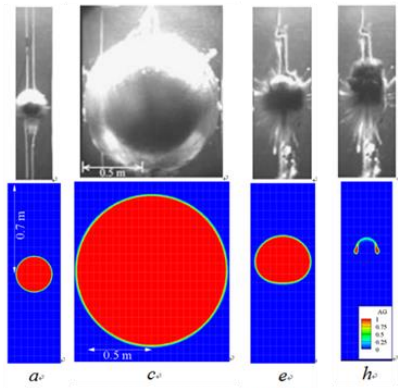
Underwater Explosion(UNDEX) under free field and near wall conditions



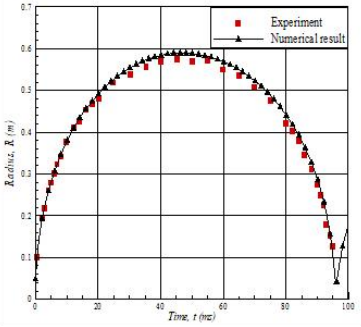


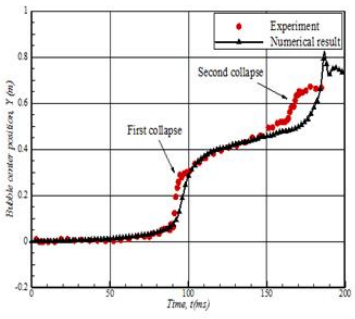
Schematic view of UNDEX phenomenon



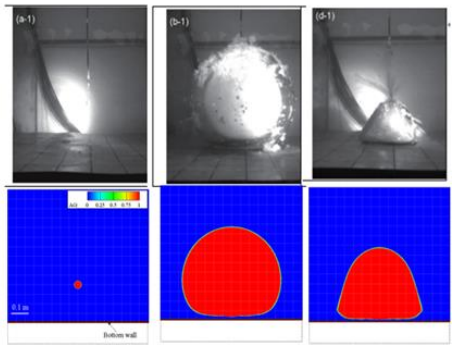


<Free field condition>





<Comparison of bubble radius and bubble center position>

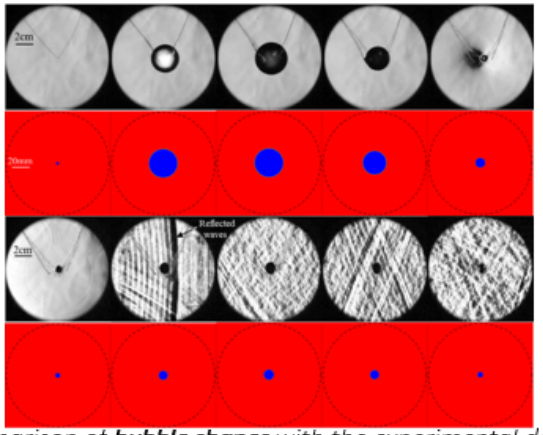


<Near wall condition>

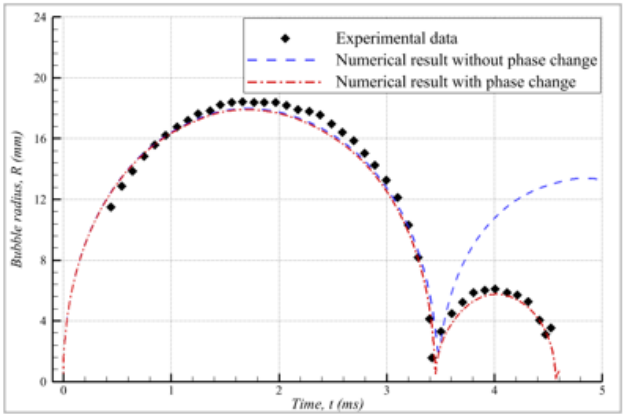
전산유체 실험실

연구 분야 – 전산유체역학(CFD)

Bubble collapsing with heat and mass transfer effects

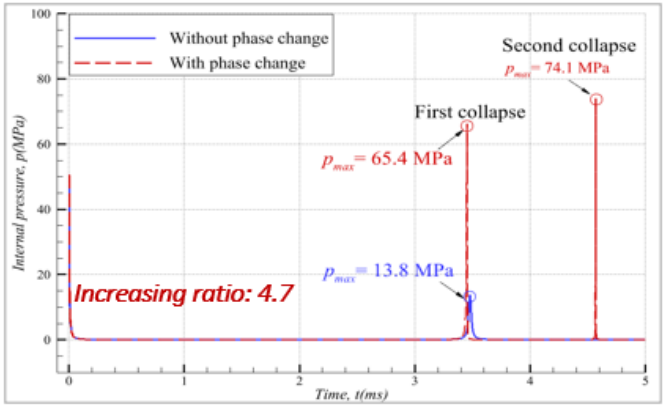


<Comparison of **bubble shapes** with the experimental data>

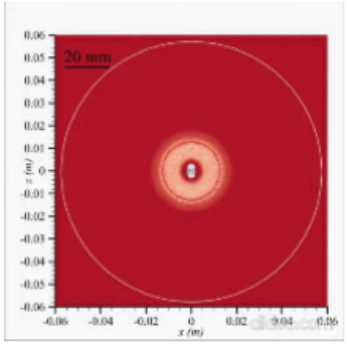


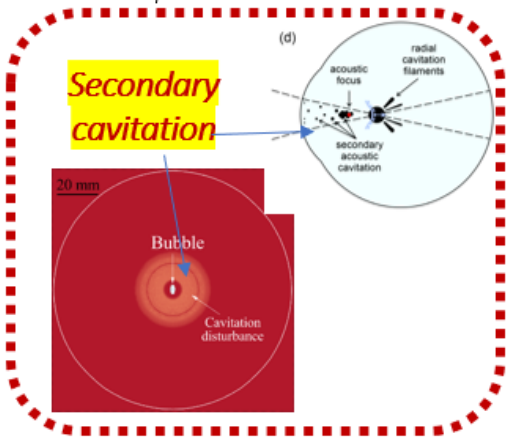
<Validation of **bubble radius** with the experiment>

Eye surgery



<Numerical animation>



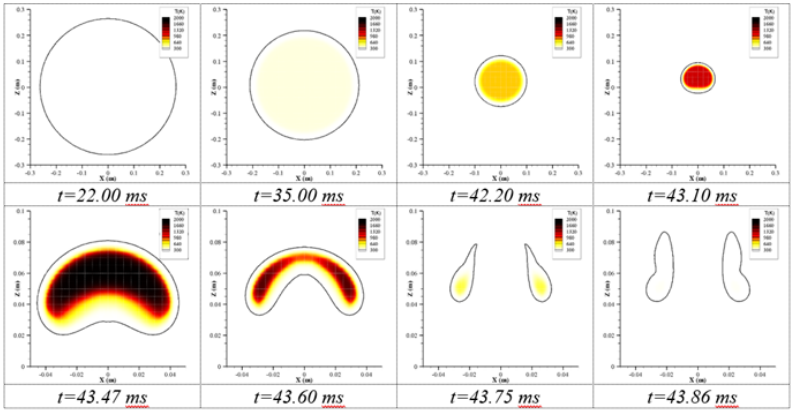


<**Peak pressure** can occur at the second collapse stage with the **secondary cavitation** generation>

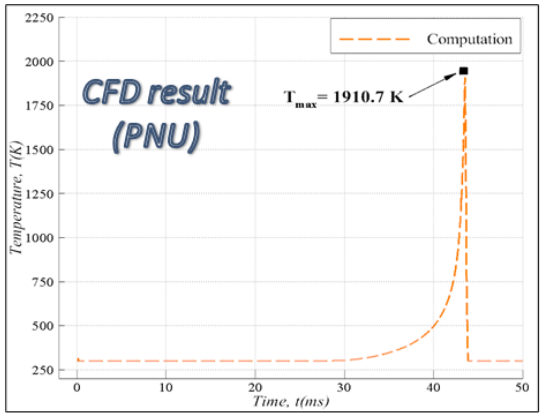
전산유체 실험실

연구 분야 – 전산유체역학(CFD)

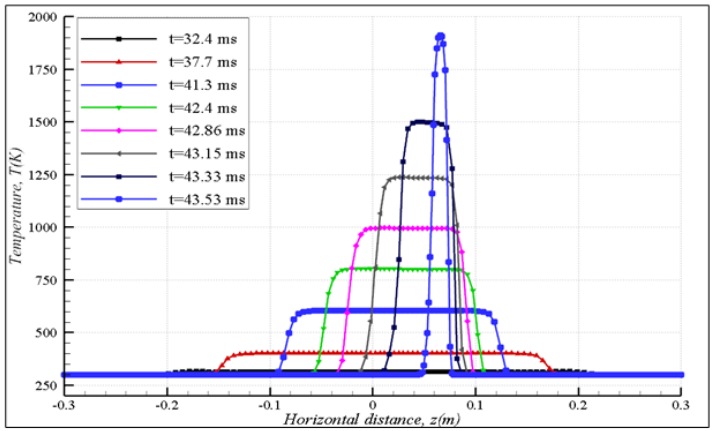
Underwater Explosion(UNDEX) with thermodynamics effects



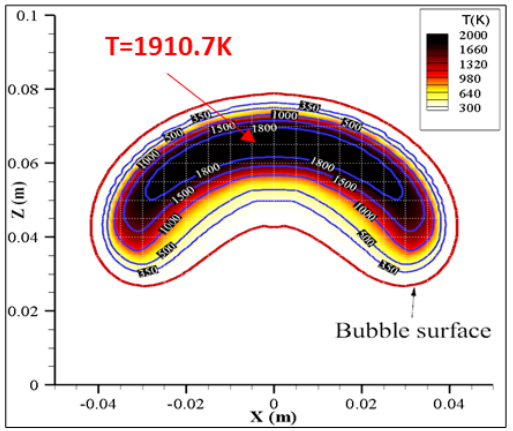
<Evolution process of the temperature field >



<Evolution of the maximum temperature>



< Gas temperature along the axis of symmetry for the collapse>

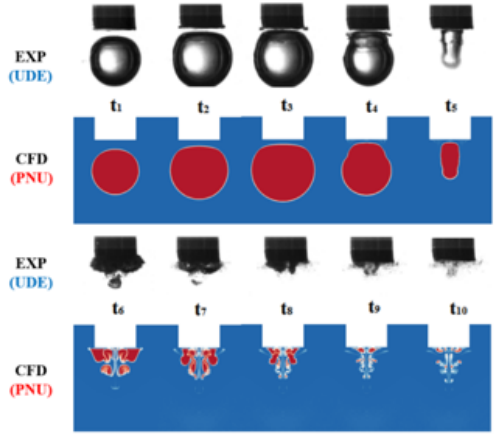


<Maximum temperature stage>

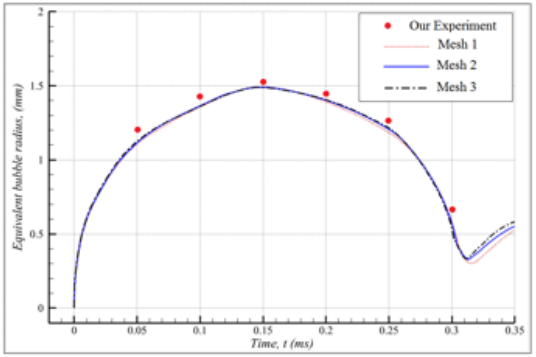
전산유체 실험실

연구 분야 – 전산유체역학(CFD)

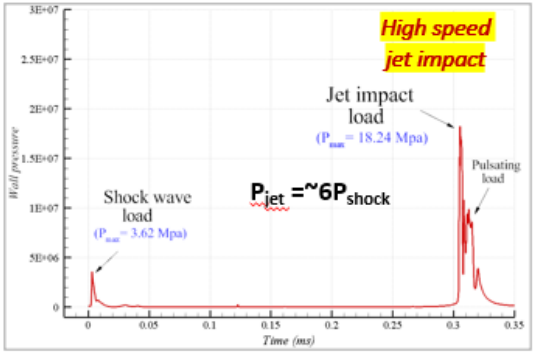
Bubble collapsing near a cylindrical rod



<Comparison with the experiment>

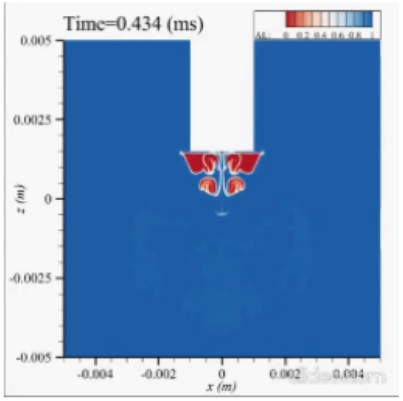


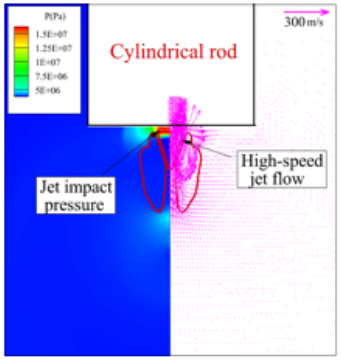
<Equivalent bubble radius with the experiment>



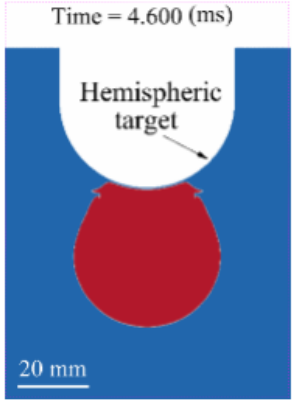
<High speed jet impact to the wall >

<Numerical animation>





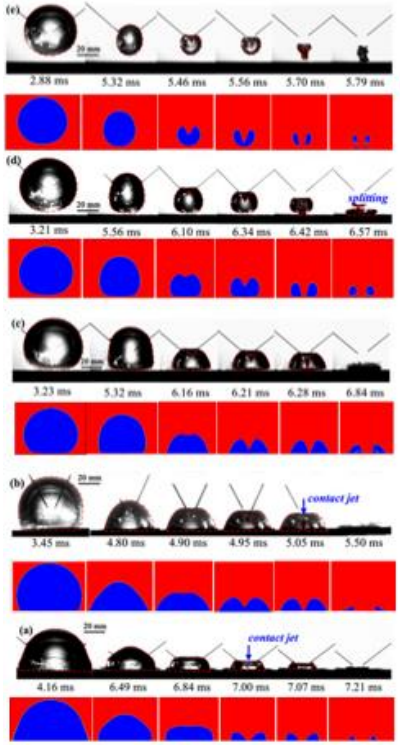
- Cancer treatment
- Renal stone treatment
- Drug delivery



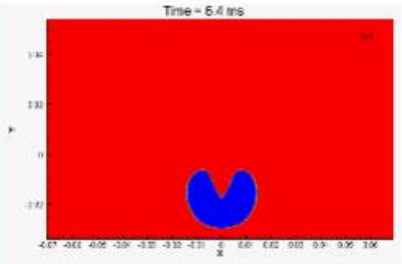
전산유체 실험실

연구 분야 – 전산유체역학(CFD)

Bubble collapsing near wall

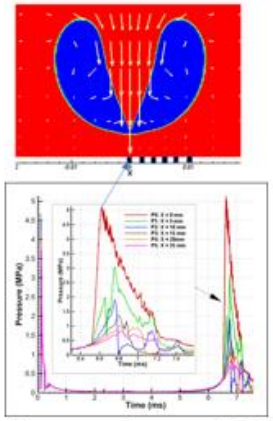


Bubble near wall with standoff distances: $\gamma = \frac{d}{R} =$ 1.09, 0.91, 0.71, 0.51, 0.31

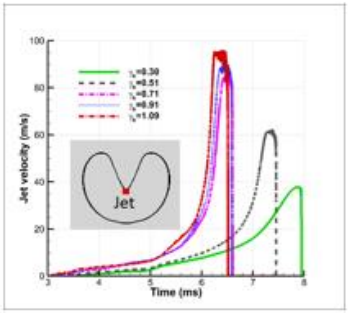


$V_{M-jet} \cong 100 m/s$

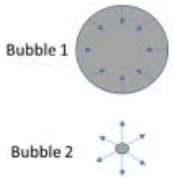
Bubble near wall with standoff distances: $\gamma = 1.09$



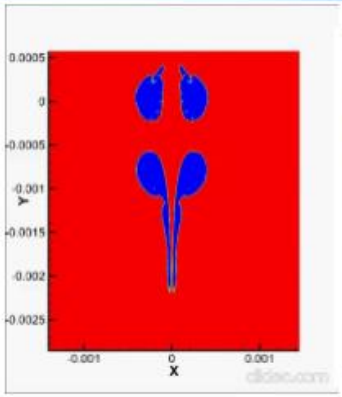
The case of $\gamma_b = 1.09$.



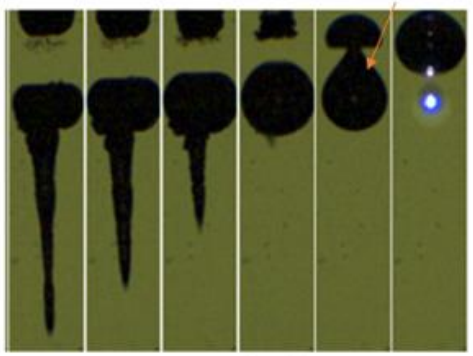
Jet Velocity in difference cases



Sketch of initial double bubbles



$V_{M-jet} \cong 320 m/s$

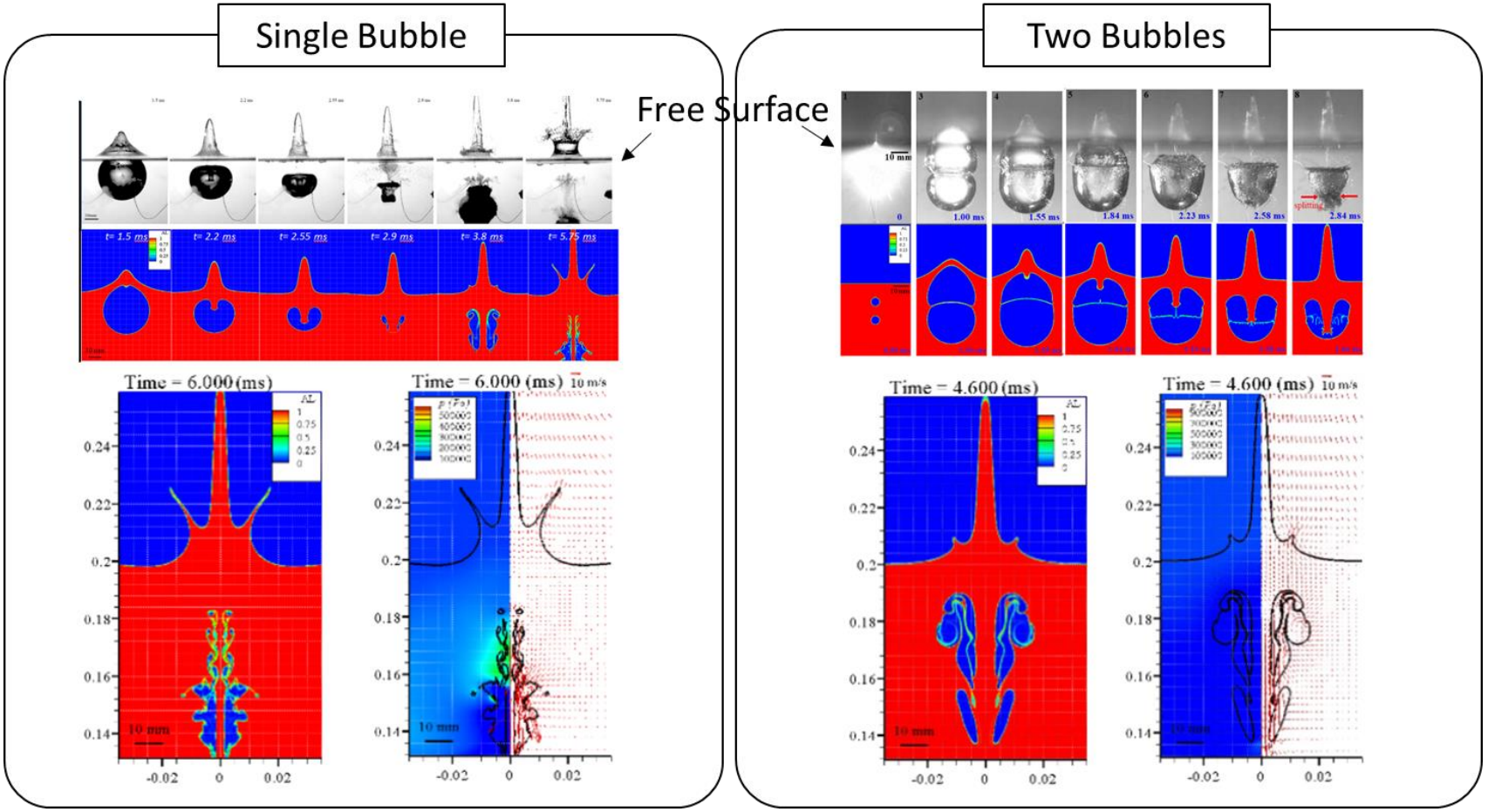


University of California

전산유체 실험실

연구 분야 – 전산유체역학(CFD)

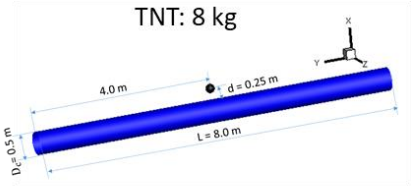
Evolution of bubble shape near a free surface(with splash)

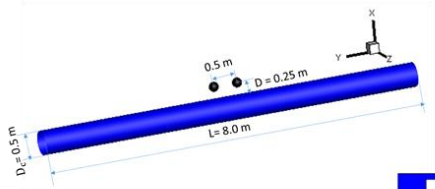


전산유체 실험실

연구 분야 - 전산유체역학(CFD)

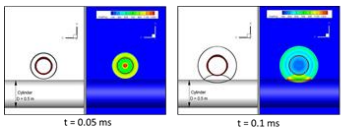
Underwater Explosion(UNDEX)_Shock wave propagation near cylinder

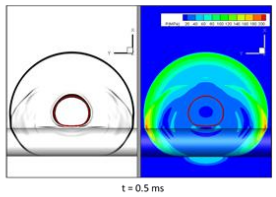




Pressures on top of the cylinder at positions shown the figure

underwater explosion near a cylinder

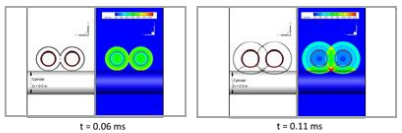


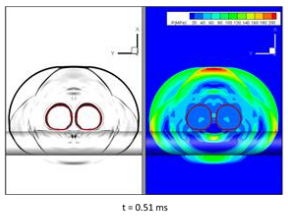


Patterns of Schlieren-type

Pressure

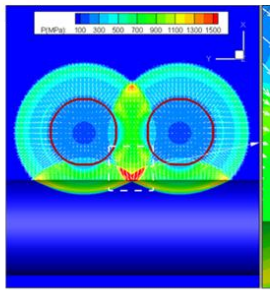
double underwater explosion

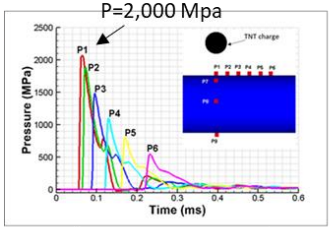




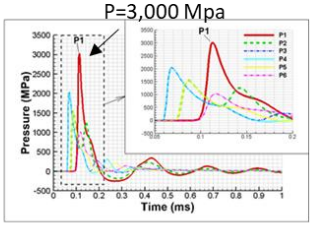
Patterns of Schlieren-type

Pressure





Single bubble



Two bubbles

Maximum pressure load on the cylinder increases 1.5 times than single bubble

Shock wave propagation

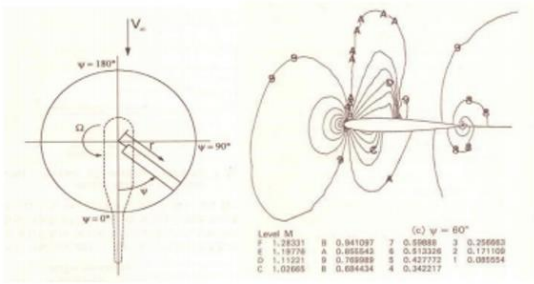
Benchmarked by Los Alamos National Lab. and NC state Univ.

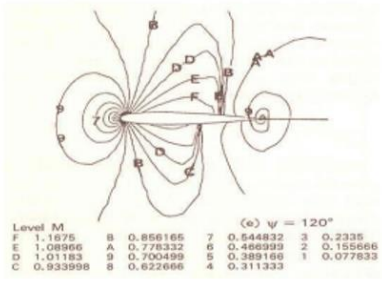
전산유체 실험실

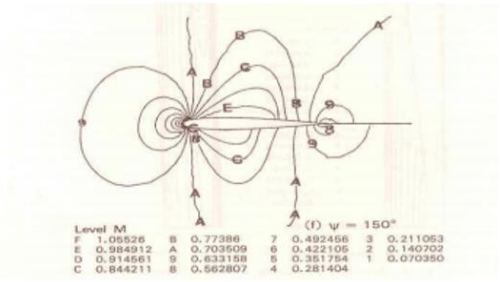
연구 분야 – 전산유체역학(CFD)

국책과제_헬리콥터 로터 및 폭격기 프로펠러 익형 해석(국방부)

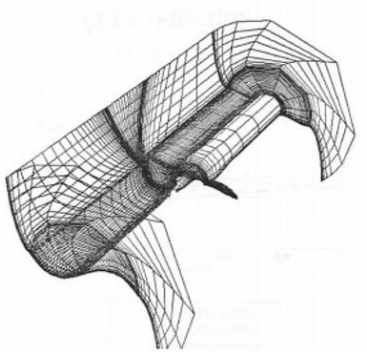
- 헬리콥터 로터 해석

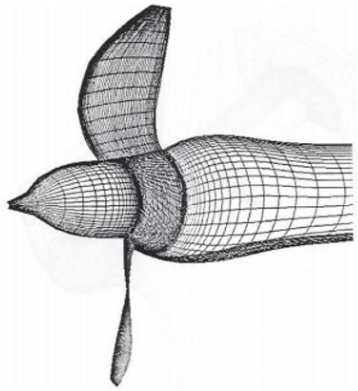


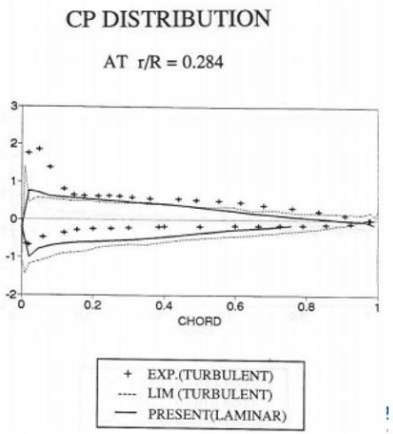




- 폭격기 프로펠러 익형 해석



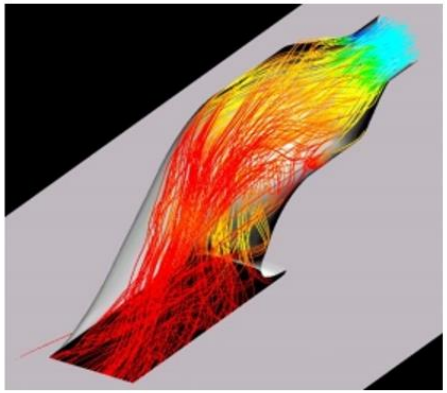


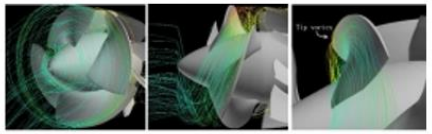


전산유체 실험실

연구 분야 - 전산유체역학(CFD)

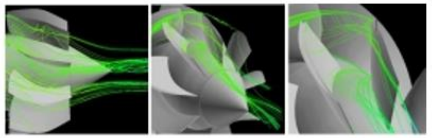
국책과제_장갑차용 수상추진시스템 개발(과학기술부)





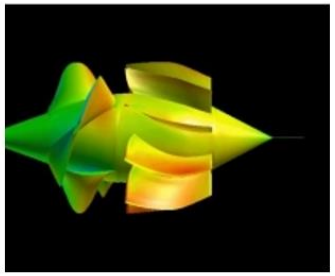
Front oblique view | Side view | Near the rotor blade

Streamlines past the rotor of waterjet

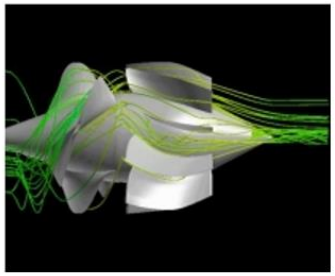


Front oblique view | Side view | Near the rotor blade

Streamlines past the stator of waterjet



Pressure

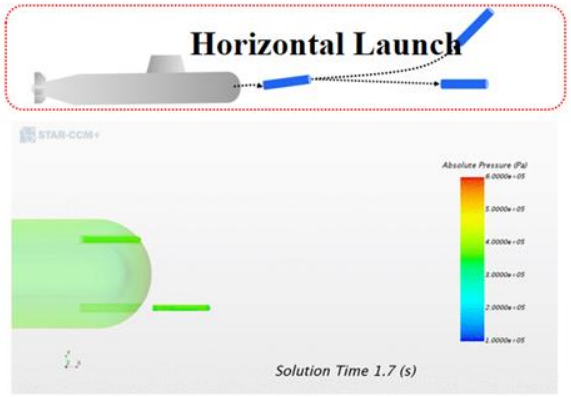


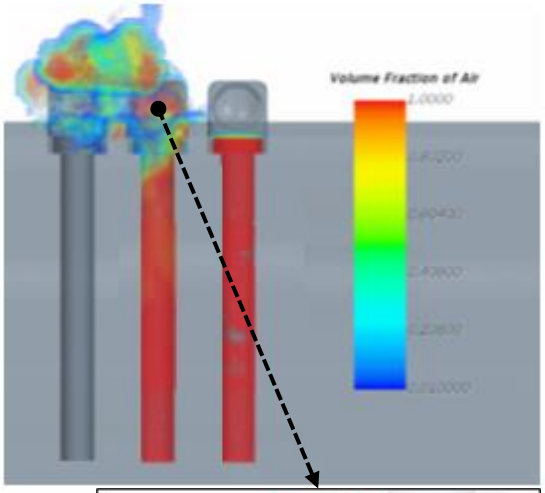
Streamline

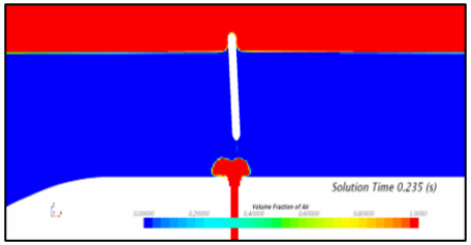
전산유체 실험실

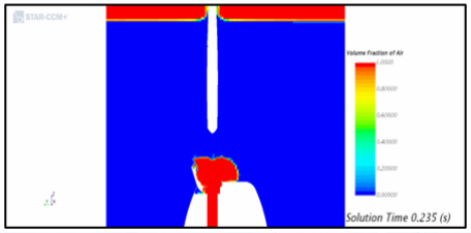
연구 분야 - 전산유체역학(CFD)

국책과제(진행중)_장보고-III Batch-II 체계 개발 위탁 연구(방위사업청)

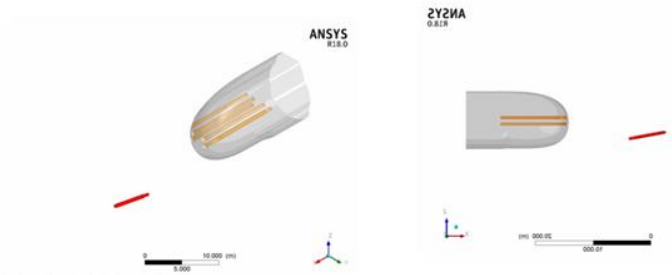


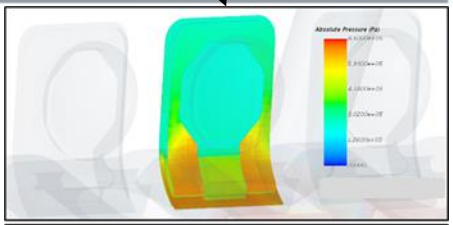


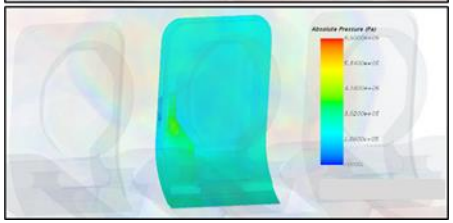


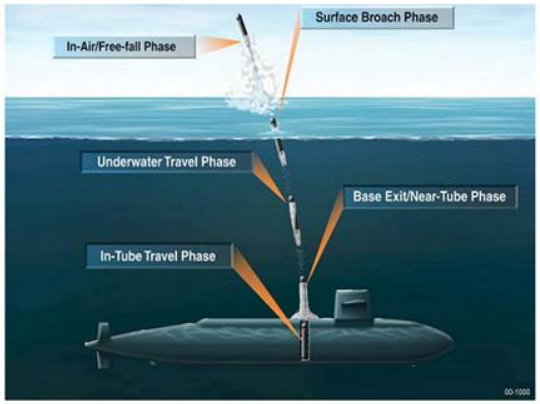


- Negative buoyancy









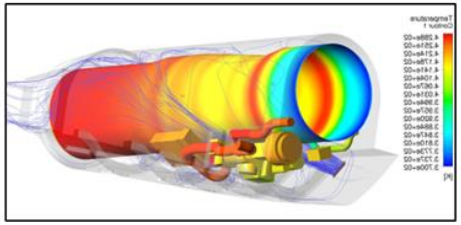
전산유체 실험실

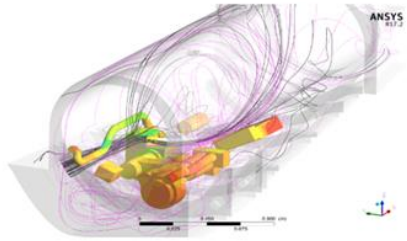
연구 분야 - 전산유체역학(CFD)

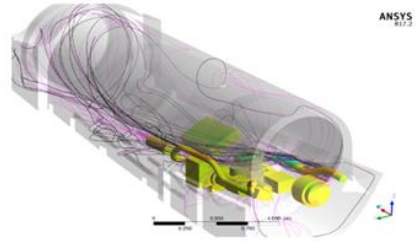
국책과제(진행중)_KF-X 소화장치 성능해석 및 시험 용역(방위사업청)

Engine Bay CFD Simulation

Hot Component Cooling







< 지상 이륙 상태 F-35 엔진 화재 >

< 항공기 엔진 화재 사고 >

Fire Extinguishing