AMPHIBIOUS BADAK TANK ANALYSIS

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By:

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- Education background:
  - B.Sc. in Mechanical Eng., Northeastern Univ., Boston, USA
  - S.M. in Mechanical Eng., Massachusetts Institute of Technology (MIT), Cambridge, USA
  - Sc.D in Mechanical Eng., MIT, Cambridge, USA
- Experiences:
  - Automotive Industry, USA ~ 14 years
  - Higher Education, Indonesia, since 2013

BADAK, PT. PINDAD

Current Specifications:
Weight = 14.1 Ton
Combat weight: 15,100 kg
Config: 6x6
Dim: LxWxH = 5.65 x 2.7 x 2.7 m

Crew: 3 persons
Range: 600 km
Speed: 80 km/h on high way
Diesel 6 Cyl, 340 HP Turbo Charger Intercooler

Overall Project: Amphibious Badak Project

Project Steps:

1. Determination of vehicle configuration
    - Number of personels, Loads, Vehicle configuration
2. Determination of components and total weight
    - Engine, Wheels, etc.
3. Determination of vehicle total center of gravity
4. Vehicle static floating attitude calculation and design
5. Vehicle static floating stability analysis
6. Dynamic analysis of vehicle water resistance characteristic
7. Propulsion analysis and design
8. Vehicle speed calculation
9. Vehicle water entry analysis (need entry specification)
10. Wave protection design
11. Cannon firing effect estimation on static vehicle
12. Cannon firing effect estimation on moving vehicle
13. Verification on scaled model test (in ITS)
    - Vehicle attitude, static stability, water entry, water resistance?
14. Prototyping and test (in Pindad)
    - Leaks, vehicle speed, wave protection, cannon firing?
15. Prototype improvements (in Pindad)

Design (AutoCAD) function:

- Weight estimate
- Location of center of gravity

CFD function:

- Vehicle static floating attitude calculation
- Vehicle static floating stability analysis
- Dynamic analysis of vehicle water resistance characteristic
- Propulsion analysis
- Vehicle water entry analysis
- Wave protection design
- Cannon firing effect estimation on static vehicle
- Cannon firing effect estimation on moving vehicle

Scaled model function:

- Verification on vehicle static floating attitude and stability
- Verification on vehicle water entry and wave protection

Prototype function:

- Leak study
- Verification on vehicle speed, etc.
- Improvements

Current Project: Amphibious Badak Analysis

Analysis Steps:

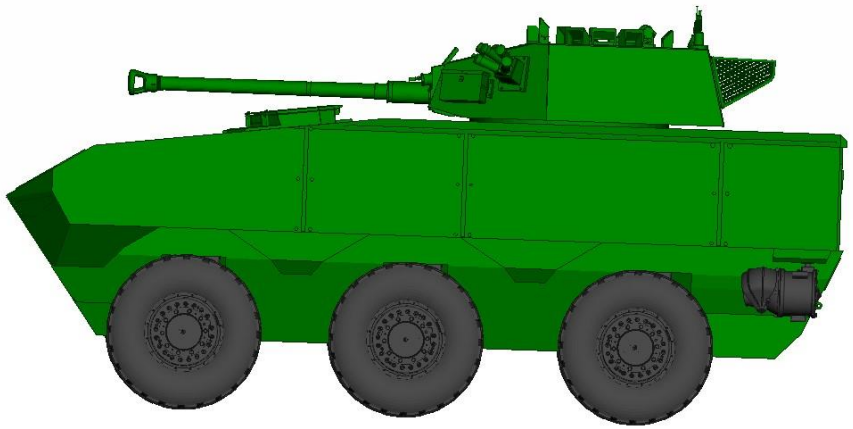
1. Determination of vehicle configuration
   - Number of personels, Loads, Vehicle configuration
2. Determination of components and total weight
   - Engine, Wheels, etc.
3. Determination of vehicle total center of gravity
4. Vehicle static floating attitude calculation and design
5. Vehicle static floating stability analysis
6. Dynamic analysis of vehicle water resistance characteristic

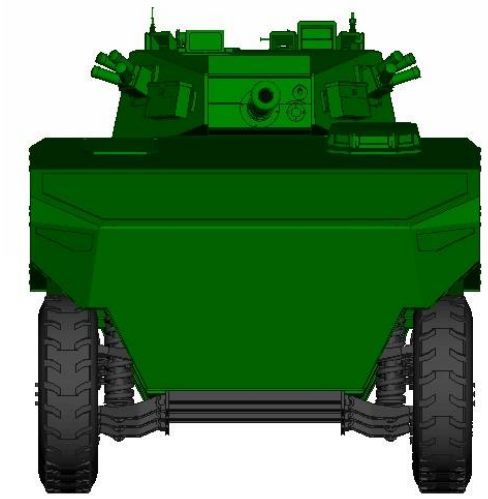
Step-step Simulasi CFD:

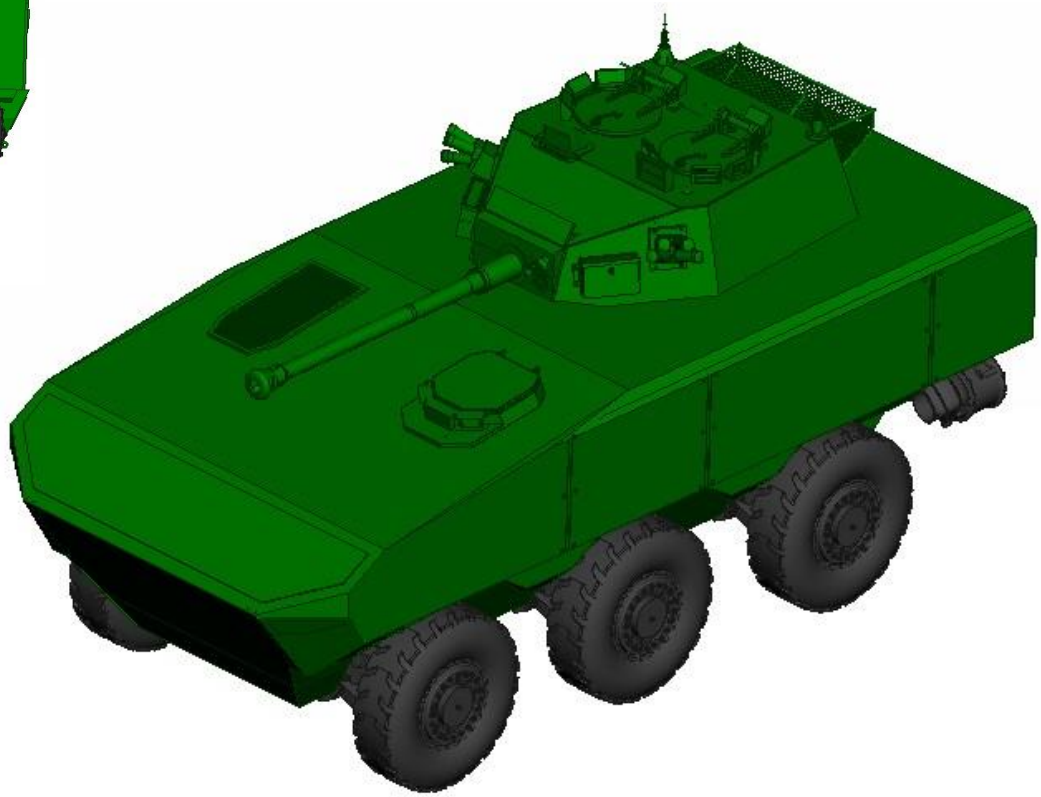
1. ***Persiapan geometry***
    - STL files
    - Tidak boleh bocor
    - Diposisikan Center of Gravity (CG) sebagai titik (0,0,0)
    - Diorientasikan sesuai dengan konfigurasi simulasi
2. ***Discretisasi***
    - Menggunakan SnappyHexMesh (otomatis)
    - Ukuran model sekitar 5 juta cell
    - Distribusi cell di optimalkan untuk pencapaian akurasi
3. ***Simulasi***
    - Menggunakan modul: LTSInterFoam
    - Test setup: gravitasi, data air dan udara, tinggi air
    - Simulasi setup: time step, pilihan method, dll.
    - Menggunakan server 24-core, 56 GB RAM, 10 TB HDisk
4. ***Post processing***
    - Menggunakan ParaView
    - Mendisplaykan geometry dan air di lihat dari sisi
    - Mengumpulkan data gaya-gaya hidrodinamik (arah x,y,z)
    - Mengumpulkan data momen hidrodinamik (arah x,y,z)

Persiapan Geometry

- STL files
- Tidak boleh bocor
- Diposisikan Center of Gravity (CG) sebagai titik (0,0,0)
- Diorientasikan sesuai dengan konfigurasi simulasi

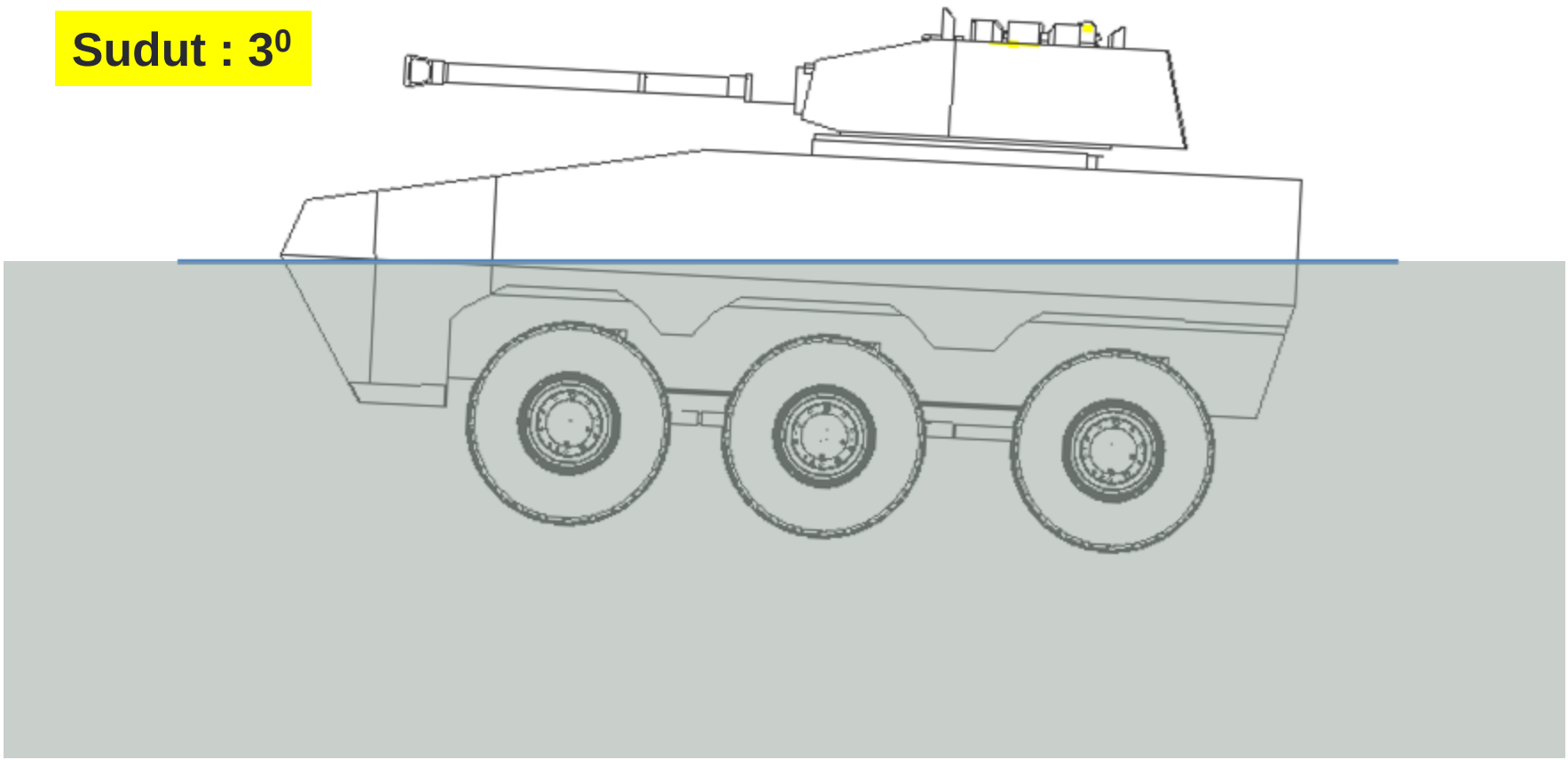




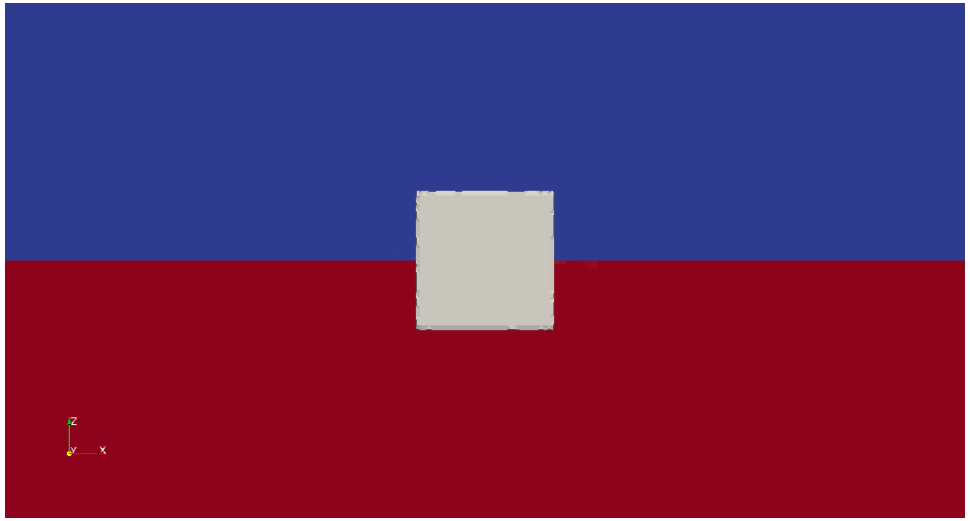


Water line yang diharapkan

Sudut : 3^0



CFD Simulation Validations



Hydrostatics Test:

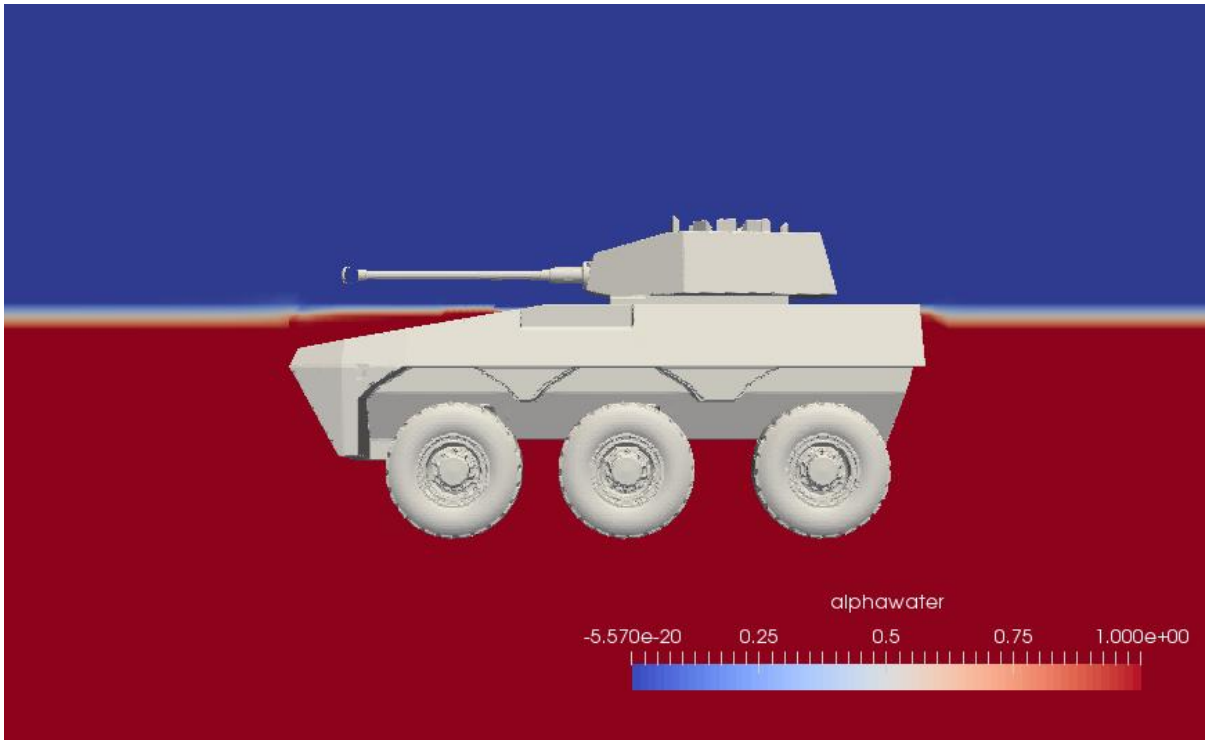
- Box 1m x 1m x 1m

- ***Fully submerge***
  - Theoretical force up: rho x g x Vol = 997 kg/m^3 x 9.81 m/s^2 x 1 = 9780 N
  - CFD: 9765 N
  - Error = 0.15%

- ***Half submerge***
  - Theoretical force up: 997 x 9.81 x 0.5 = 4890 N
  - CFD: 4888 N
  - Error = 0.04%

Badak Current Production Simulation Result

- ***Badak Current Production*** does NOT have enough bouyancy force to float on water.
- Weight = 15,100 kg x 9.81 = 148,131 N
- CFD simulation result, Bouyancy force = *142,199 N (for condition shown below)*

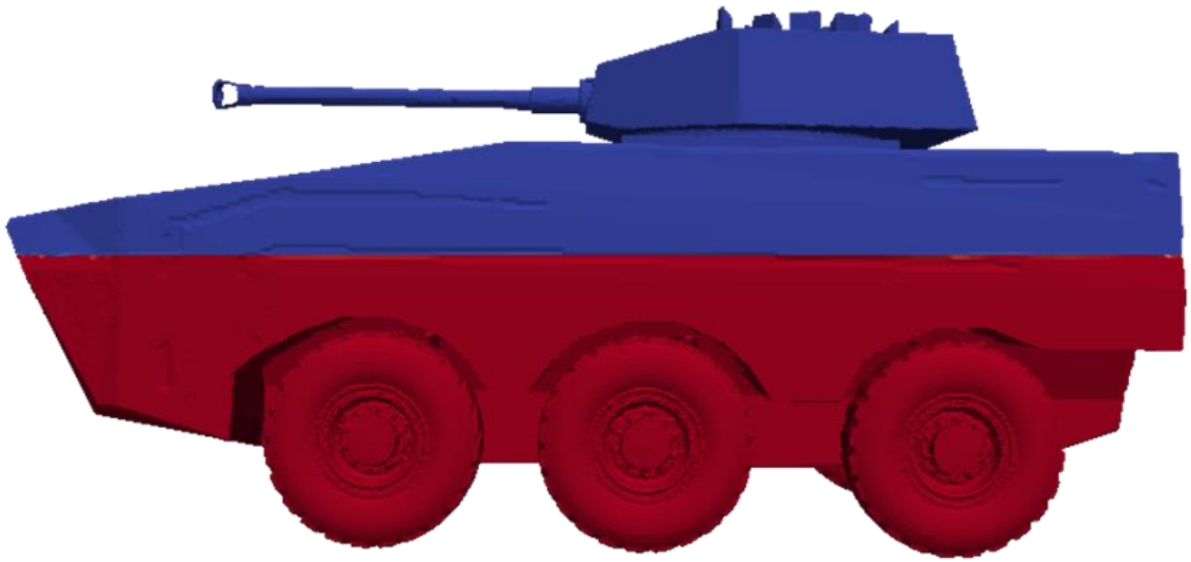


Simulation Iterations for Badak 2019 Design

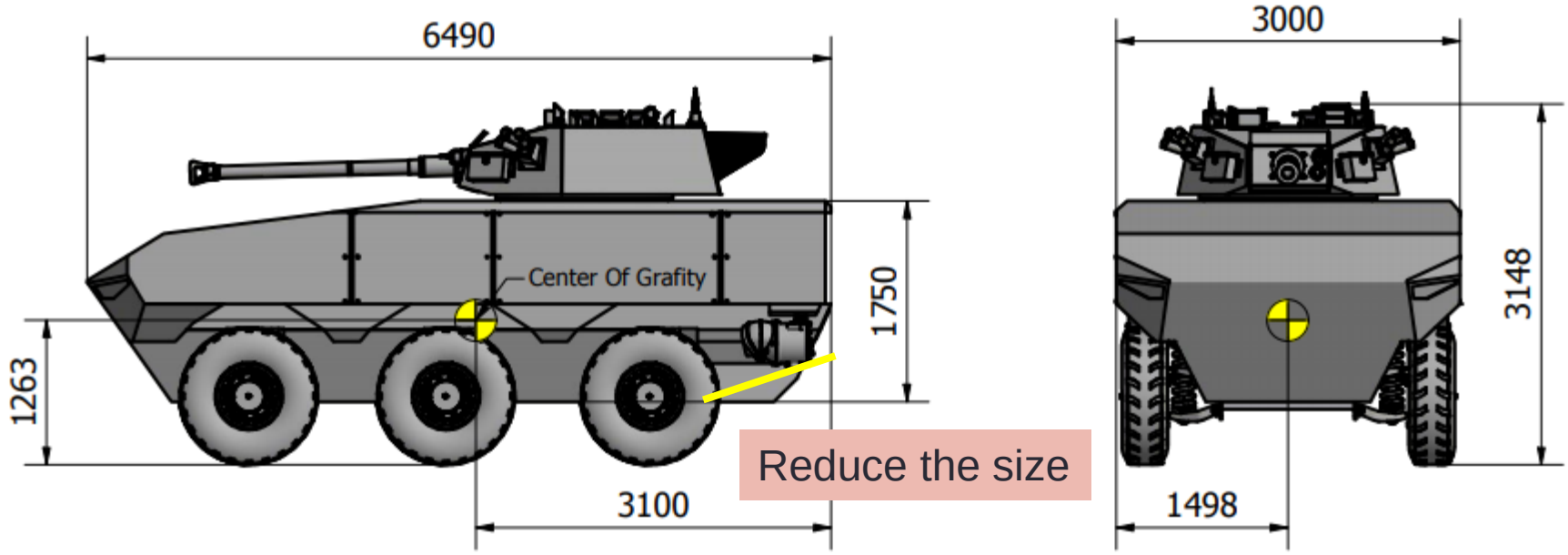
Iter #	Modification	Bouyancy Force	Delta force
	Weight of Badak	159,903 N	
0	Baseline (2019 Design)	123,707 N	36,196 N
1	Wider body by 30cm (15 cm each side)	130,319 N	increase ~7000
2	Longer body by 30cm (15 cm each side)	137,312 N	increase ~7000
3	Wheel well tighter	145,107 N	increase ~8000
4	Lower body floater	150,222 N	increase ~5000
5	Rear lower extension	151,456 N	increase ~1000
6	Front lower extension	155,764 N	increase ~4000
7	Extra large lower body floater	163,873 N	increase ~8000
8	Remove wider body because wider look ugly (back to original width)	155,720 N	decrease ~8000
9	Extra front lower extension	158,661N	increase ~3000
10	Extra volume at wheel well	159,135 N	increase ~500
20	Extra volume (10 iterations) at wheel well to balance Y and Z moments	160,134 N	increase ~1000

Conclusions from Badak 2019 Design Simulation Results :

- Badak Length needs to be 6.5 meter (iter #2,#5,#6,#9: worth of 15,000 N)
- Badak Width should be kept 3.0 meter
- Badak Height can change as needed.
- Lower body floater (iter #4,#5,#6,#7,#9: worth of 21,000 N)
- Tighter wheel well (iter #3,#10,#11-20:worth of 9,500 N)



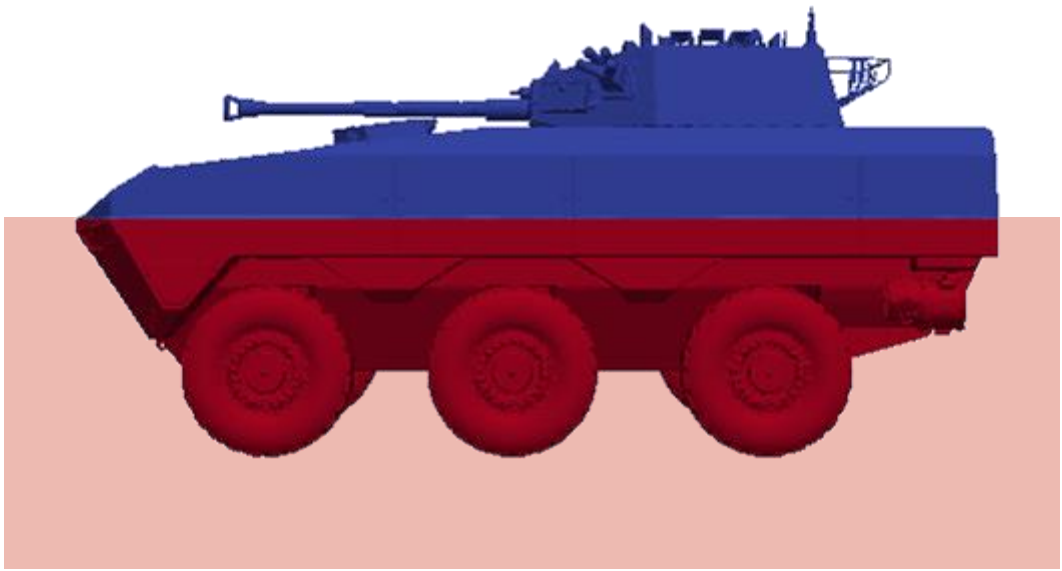
Dimensi of Badak 2020 Design



Mass = 16.300 kg

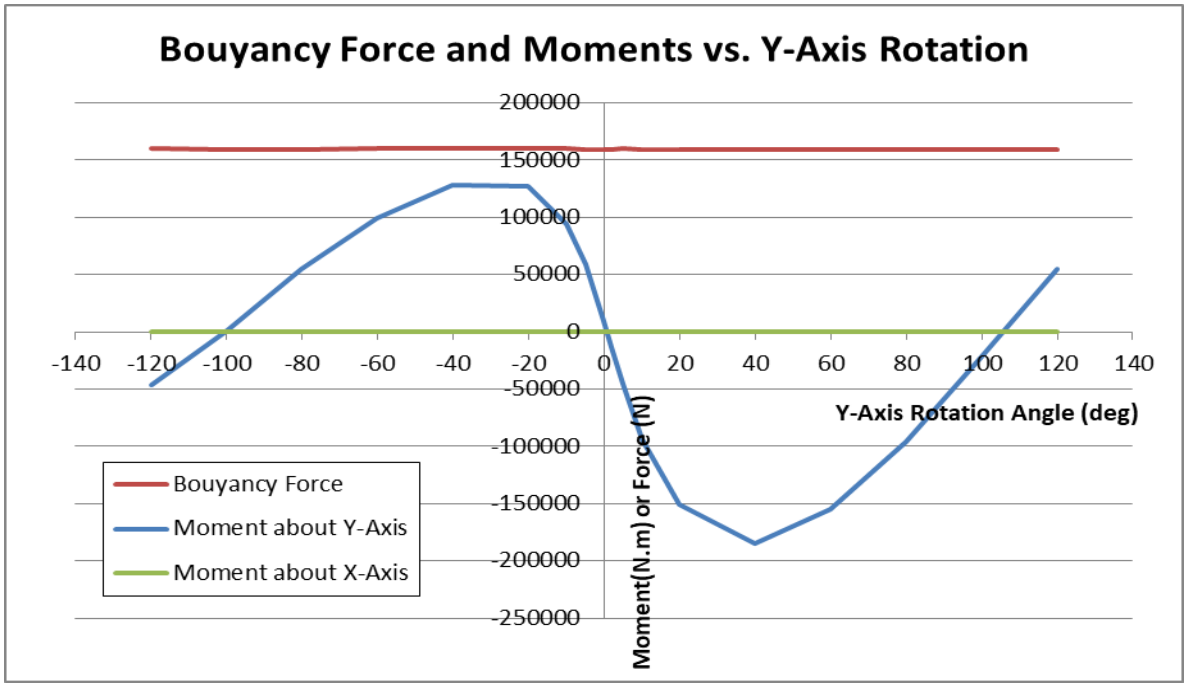
Hydrostatic Analysis for Badak 2020 Design

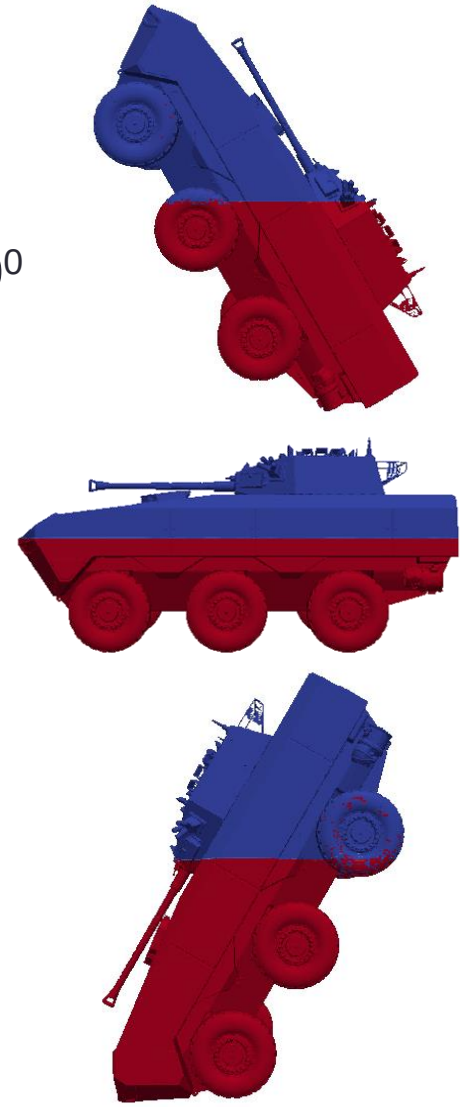
- Water height 0.4 meter from CG point of Badak.
- Badak mass 16,300 kg.
- Badak Weight 159,903 N.
- Bouyancy force from CFD simulation 159,702 N.
- Pitch angle in equilibrium position 1^0
- Expected Pitch angle 3^0
- No leakage on the body and turret.



Stability Analysis for Badak 2020 Design

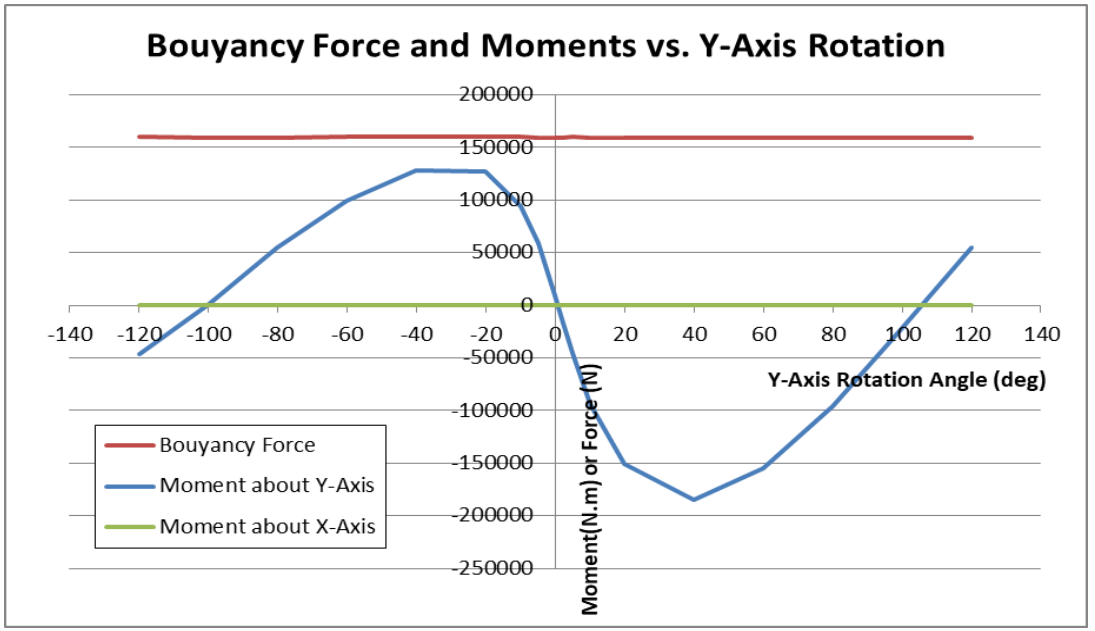
- Moments and force as a function of Y-axis rotation
- Bouyancy force consistent, around 160 kN
- Moment in X-axis is negligible
- Moment in Y-axis show range of stability -100^0 to +100^0
- Max. Abs. moment 128.000 N.m and 180.000 N.m

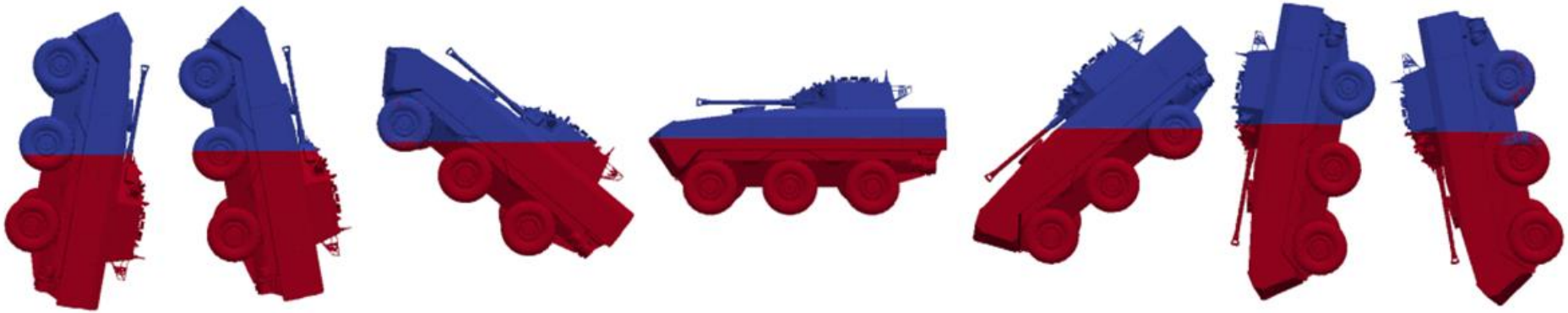




Stability Analysis for Badak 2020 Design

- Moment in Y-axis show range of stability -100^0 to +100^0
- Maximum absolute moment 128.000 N.m for negative rotation and 180.000 N.m for positive rotation.
- No leakage assumption.

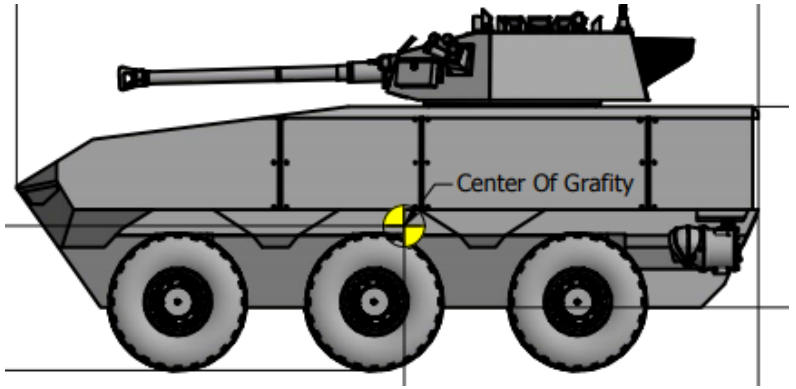


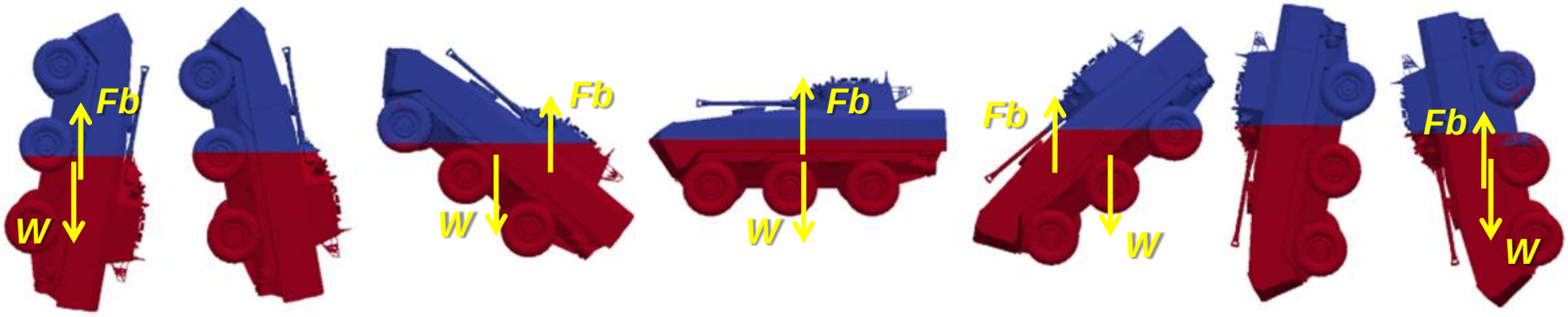


+100^0 +80^0 +40^0 0^0 -40^0 -80^0 -100^0

Stability Analysis for Badak 2020 Design

- Moment in Y-axis show range of stability -100^0 to $+100^0$
- Maximum absolute moment 128.000 N.m for negative rotation and 180.000 N.m for positive rotation.
- No leakage assumption.

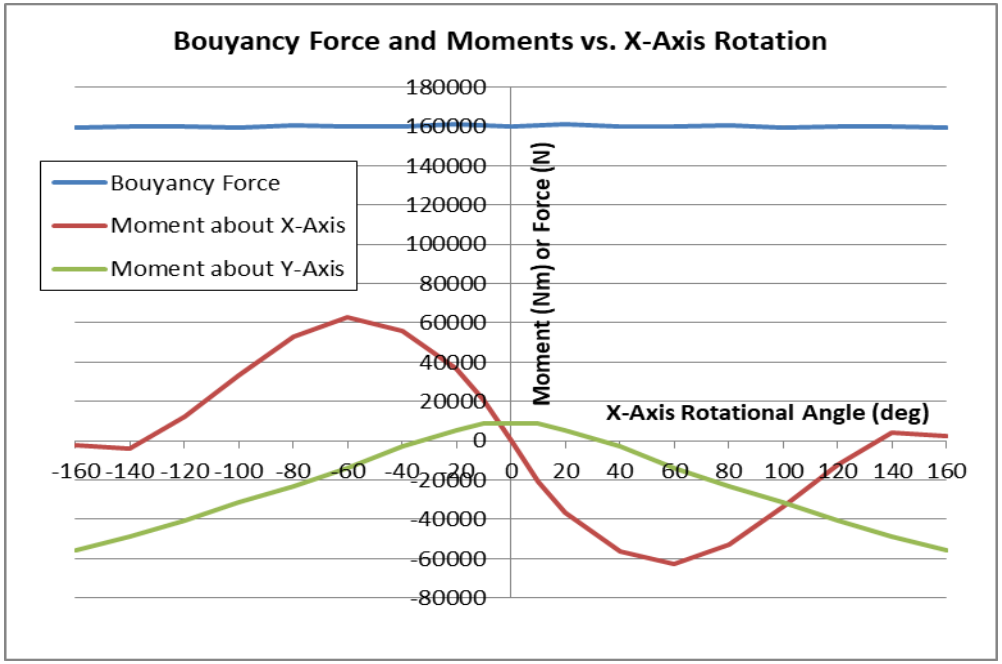


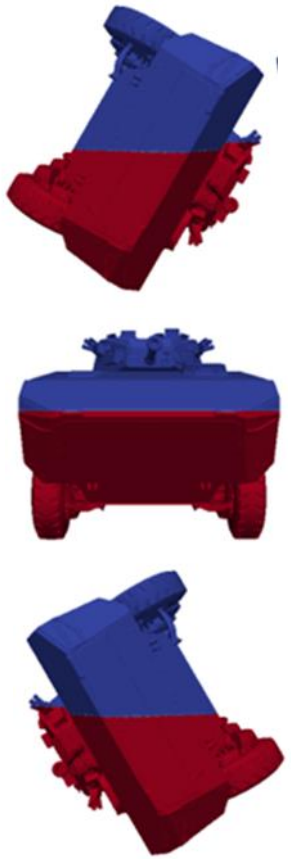


$+100^0$ $+80^0$ $+40^0$ 0^0 -40^0 -80^0 -100^0

Stability Analysis for Badak 2020 Design

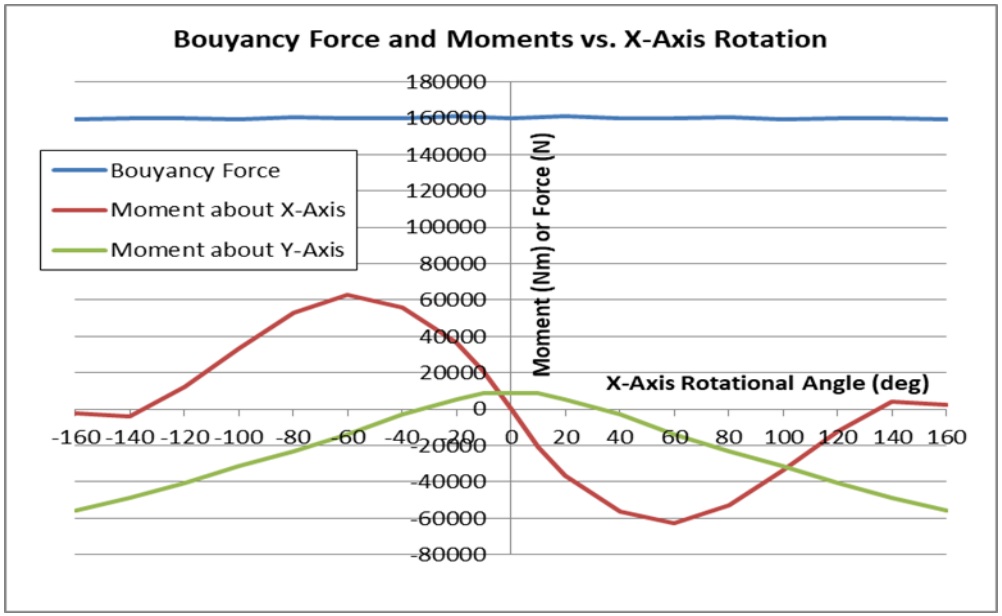
- Moments and force as a function of X-axis rotation
- Bouyancy force consistent, around 160 kN
- Moment in X-axis show range of stability -130^0 to +130^0
- Maximum absolute moment 60.000 N.m
- Moment in Y-axis is within 5^0 rotation in Y-axis





Stability Analysis for Badak 2020 Design

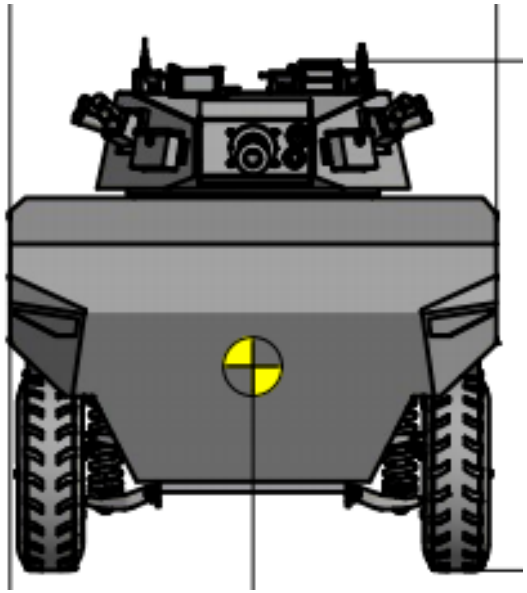
- Moment in X-axis show range of stability -130^0 to +130^0
- Maximum absolute moment 60.000 N.m
- No leakage assumption.

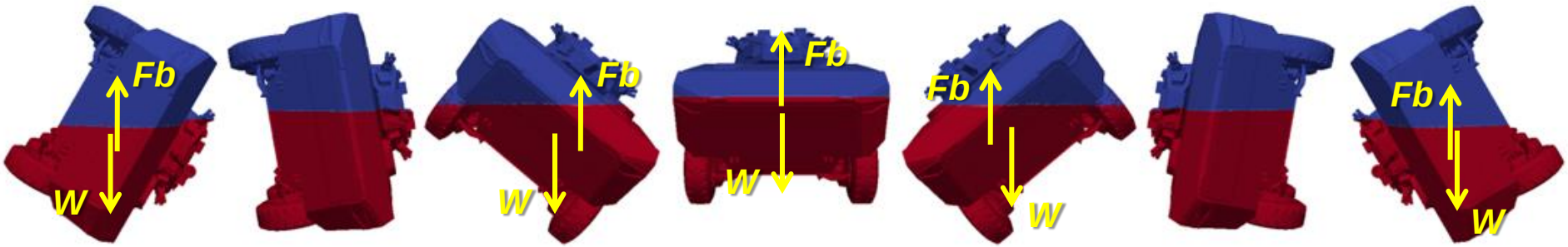


+120^0 +80^0 +40^0 0^0 -40^0 -80^0 -120^0

Stability Analysis for Badak 2020 Design

- Moment in X-axis show range of stability -130^0 to $+130^0$
- Maximum absolute moment 60.000 N.m
- No leakage assumption.

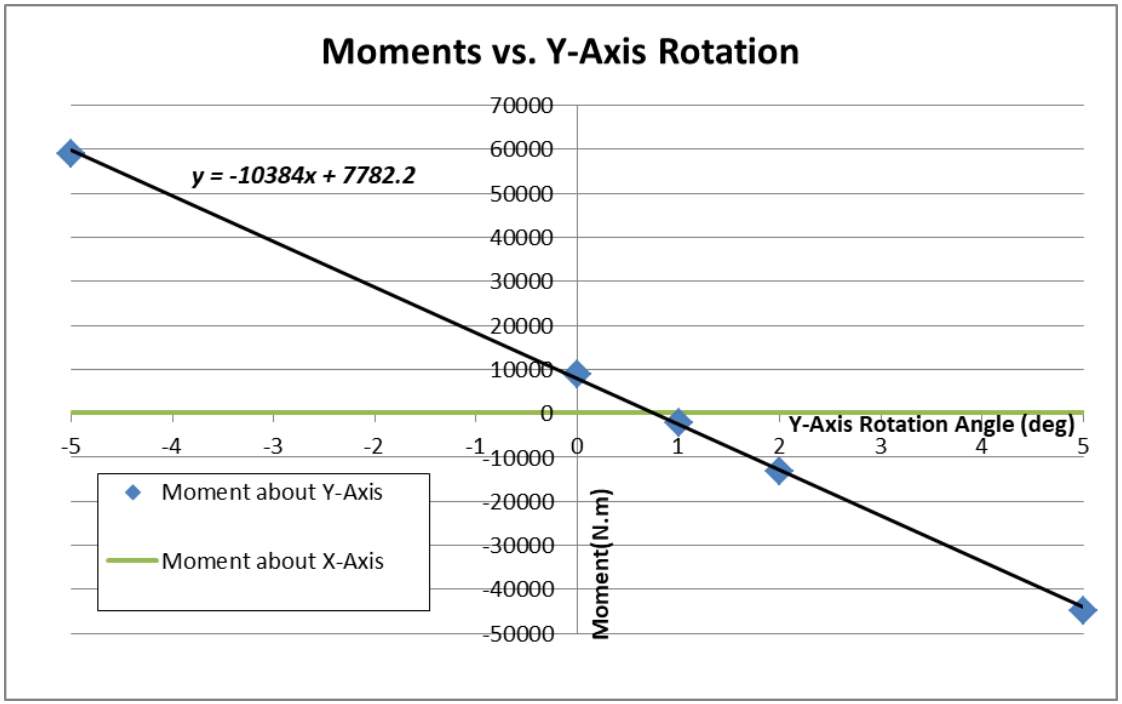


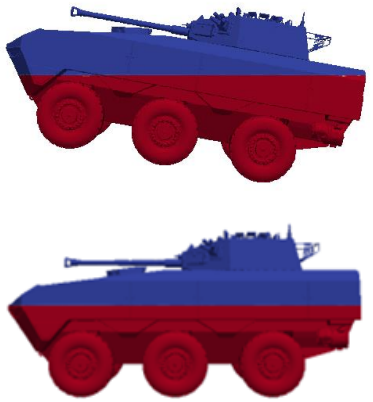


$+120^0$ $+80^0$ $+40^0$ 0^0 -40^0 -80^0 -120^0

Stability Analysis for Badak 2020 Design

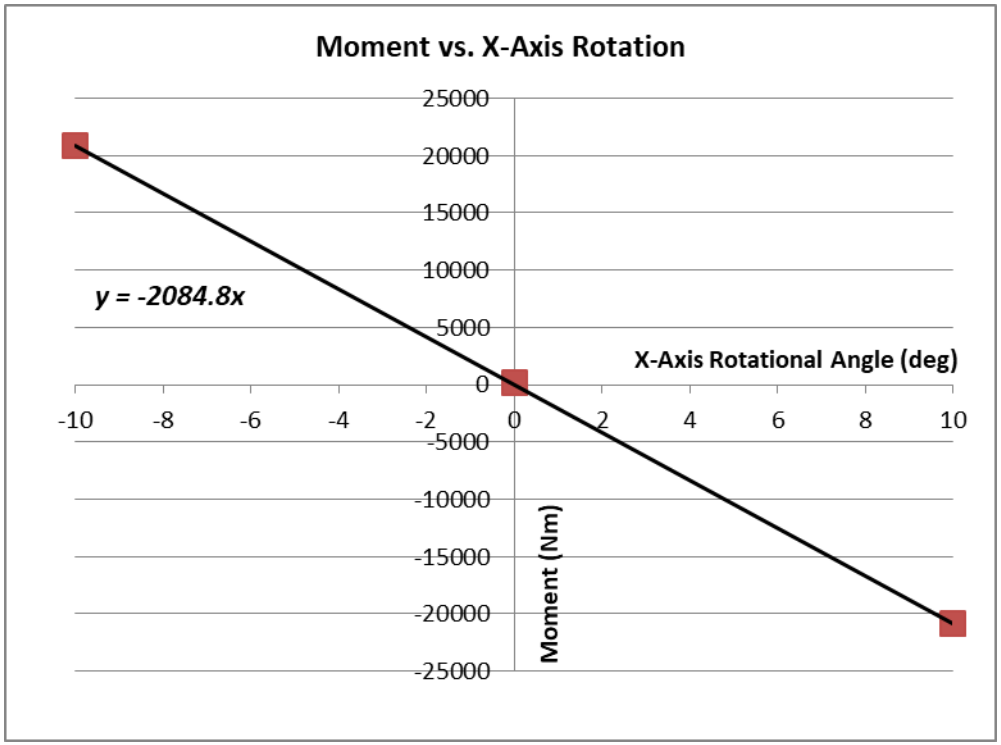
- Sensitivity curve in Y-axis rotation around equilibrium.
- Moments as a function of Y-axis rotation.
- Equilibrium at Pitch angle of 1^0
- Moment in Y-axis sensitivity is10.484 N per degree rotation.

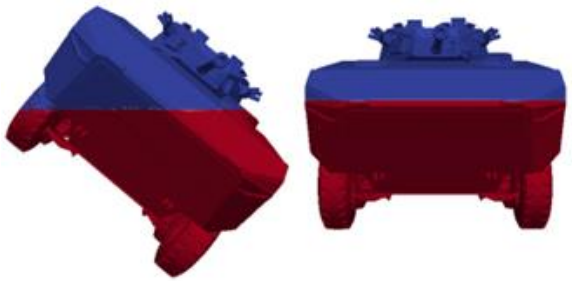




Stability Analysis for Badak 2020 Design

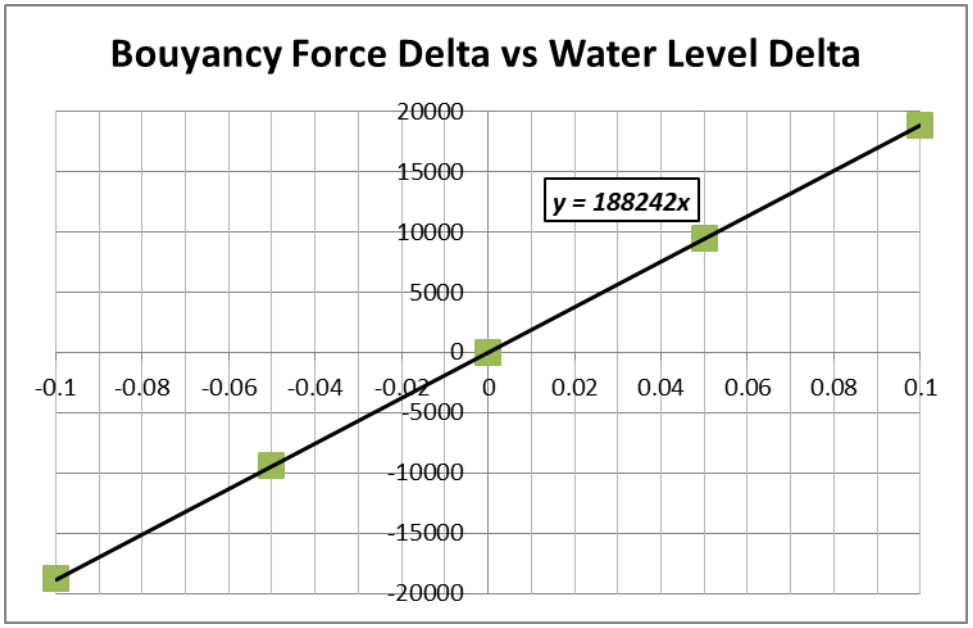
- Sensitivity curve in X-axis rotation around equilibrium.
- Moments as a function of X-axis rotation.
- Equilibrium at Rolling angle of 0^0
- Moment in X-axis sensitivity is 2.085 N per degree rotation.

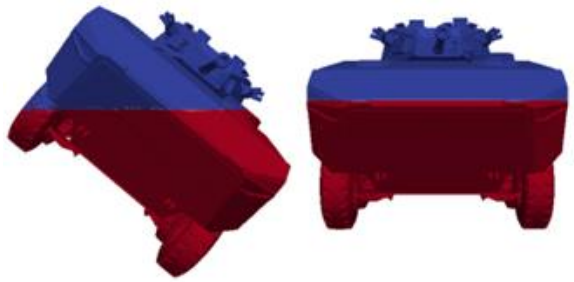




Stability Analysis for Badak 2020 Design

- Sensitivity curve in water height change around equilibrium
- Bouyancy force as a function of water height change
- Equilibrium at water height of 0.4 m higher than CG.
- Bouyancy force sensitivity is 1.882 N per cm water height change.

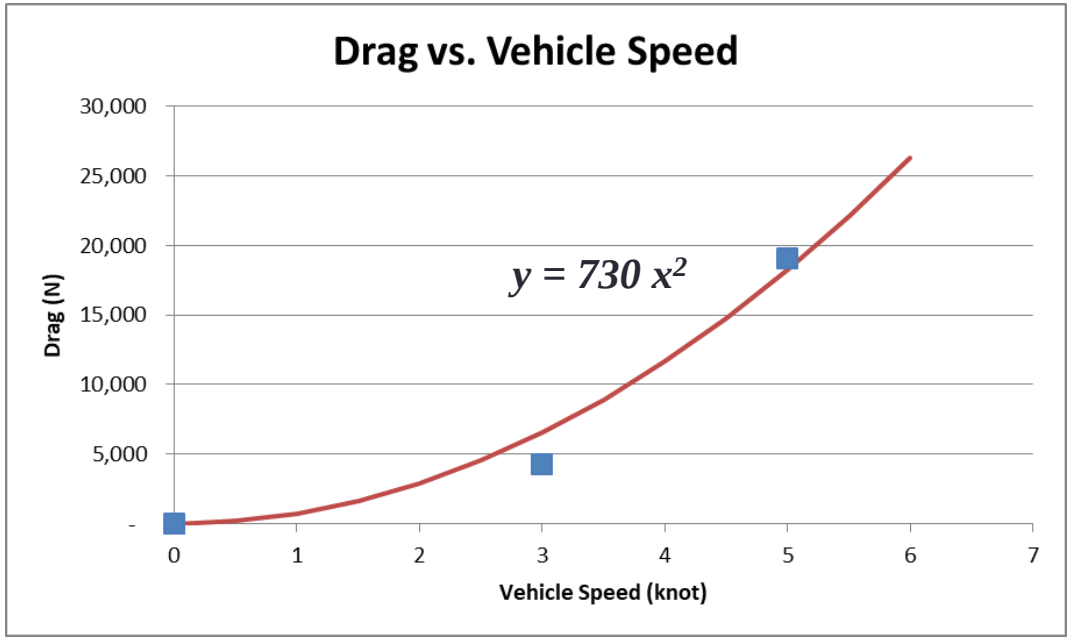




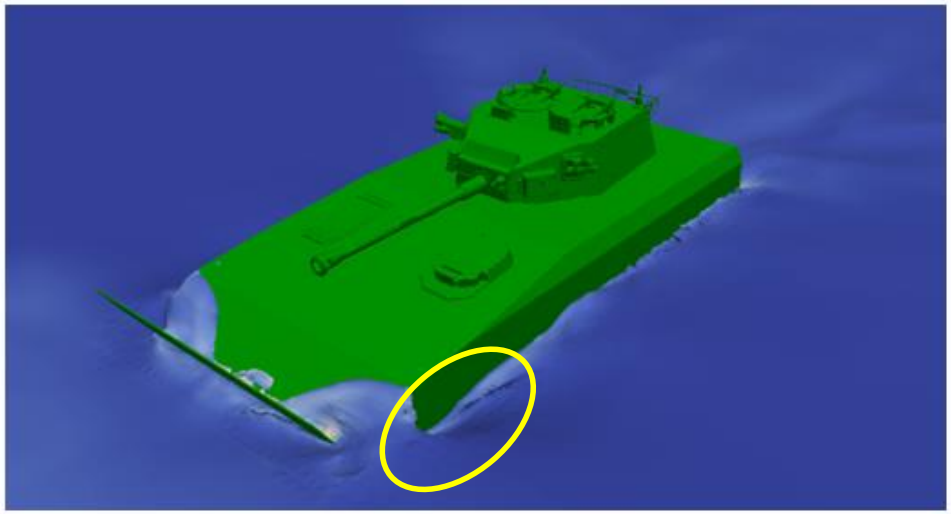
Hydrodynamic Analysis for Badak 2020 Design

Simulation Results for Badak 2020 Design								
Badak Weight : 159.903 N								
Floating Position : 1 degree								
Velocity (knot)	Water Height	Drag	Bouyancy Force	Pitch Moment	Water Height	Drag	Bouyancy Force	Pitch Moment
0	0.4	13	159,651	-2127	0.400	13	159,651	-2127
3	0.4	5,540	149,700	1400	0.454	4,260	162,700	-3700
5	0.4	19,600	140,090	8700	0.505	19,100	156,800	18200

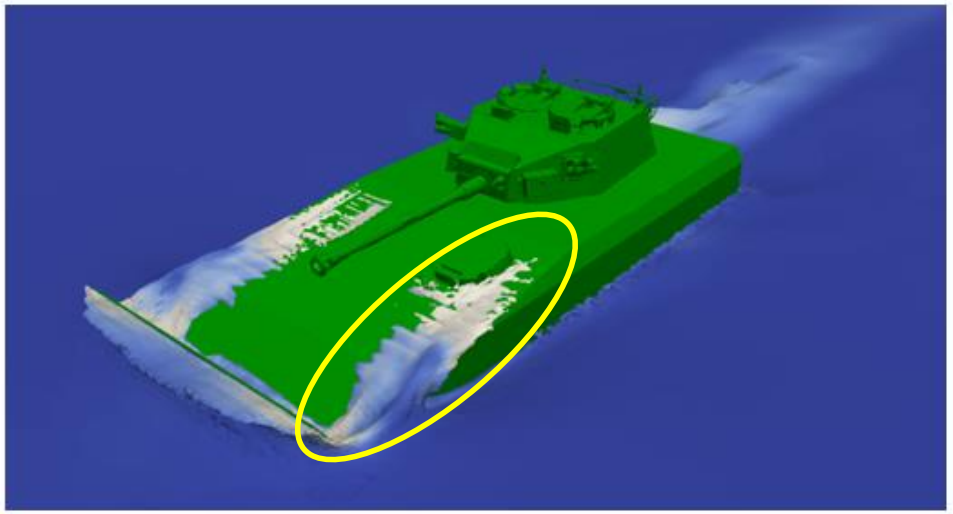
- Vehicle speeds: 0, 3, 5 knots
- Almost consistent bouyancy force around 160 kN.
- Different water heights, 3knot give 5cm lower and 5knot give 10cm lower.
- Characteristic drag curve.
- Pitch moment.



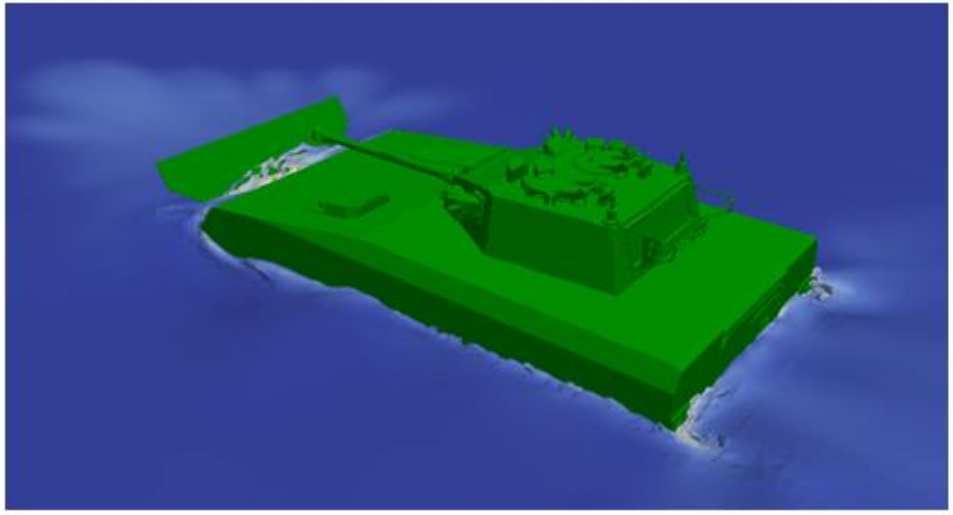
Hydrodynamic Analysis for Badak 2020 Design

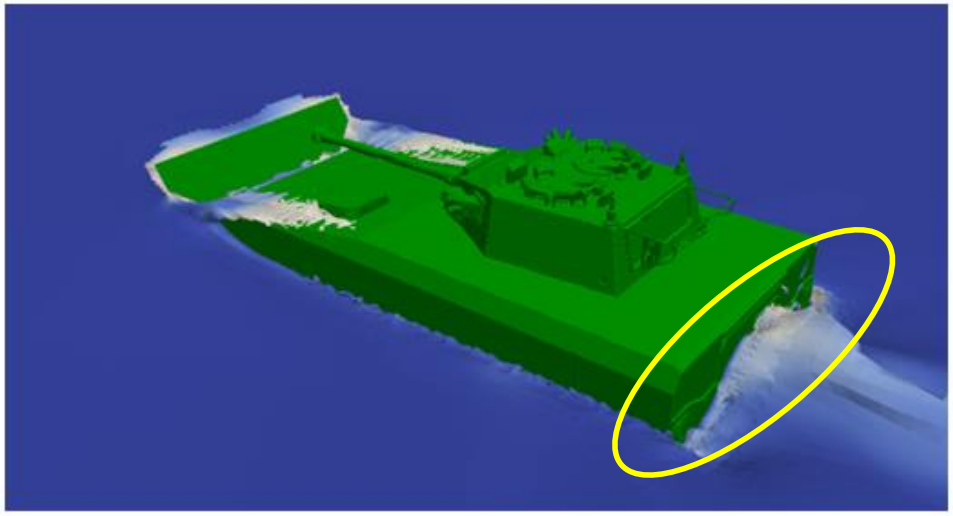


Vehicle speed of 3 knot

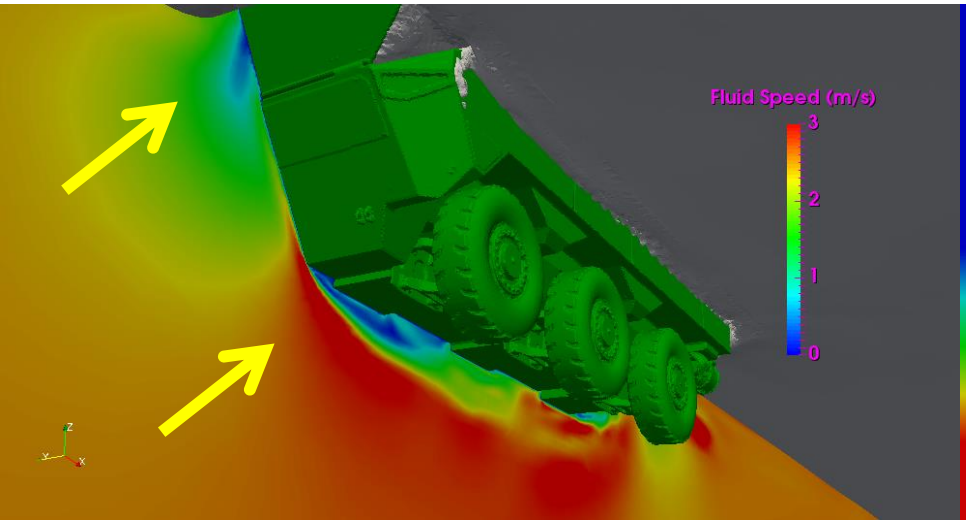


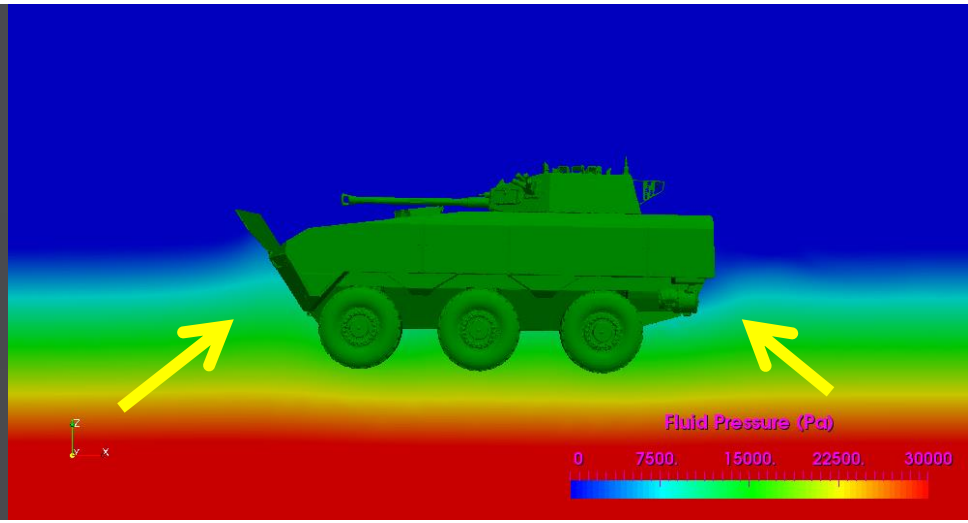
Vehicle speed of 5 knot

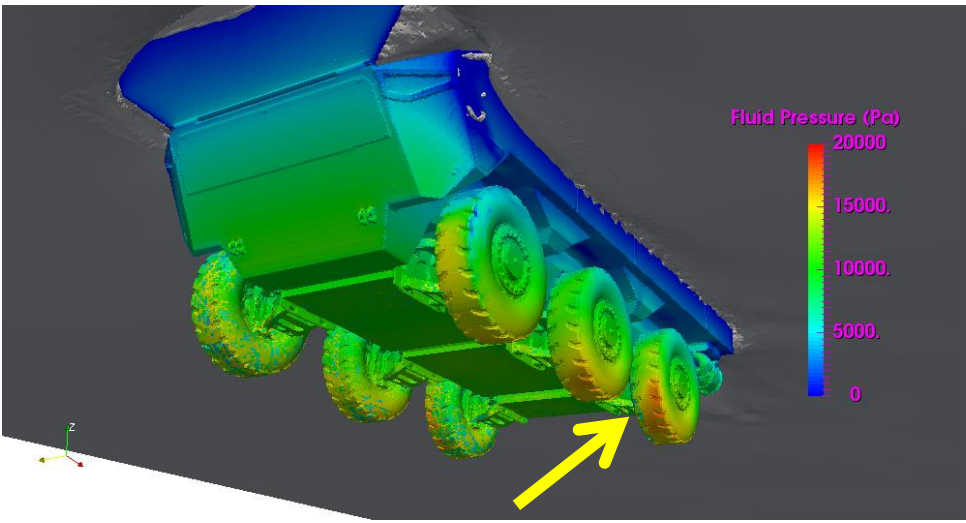


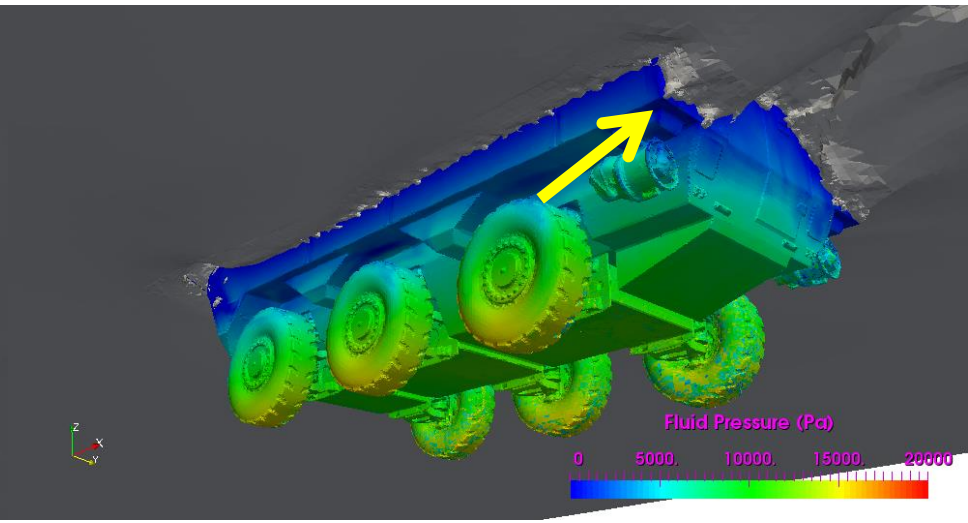


Hydrodynamic Analysis for Badak 2020 Design

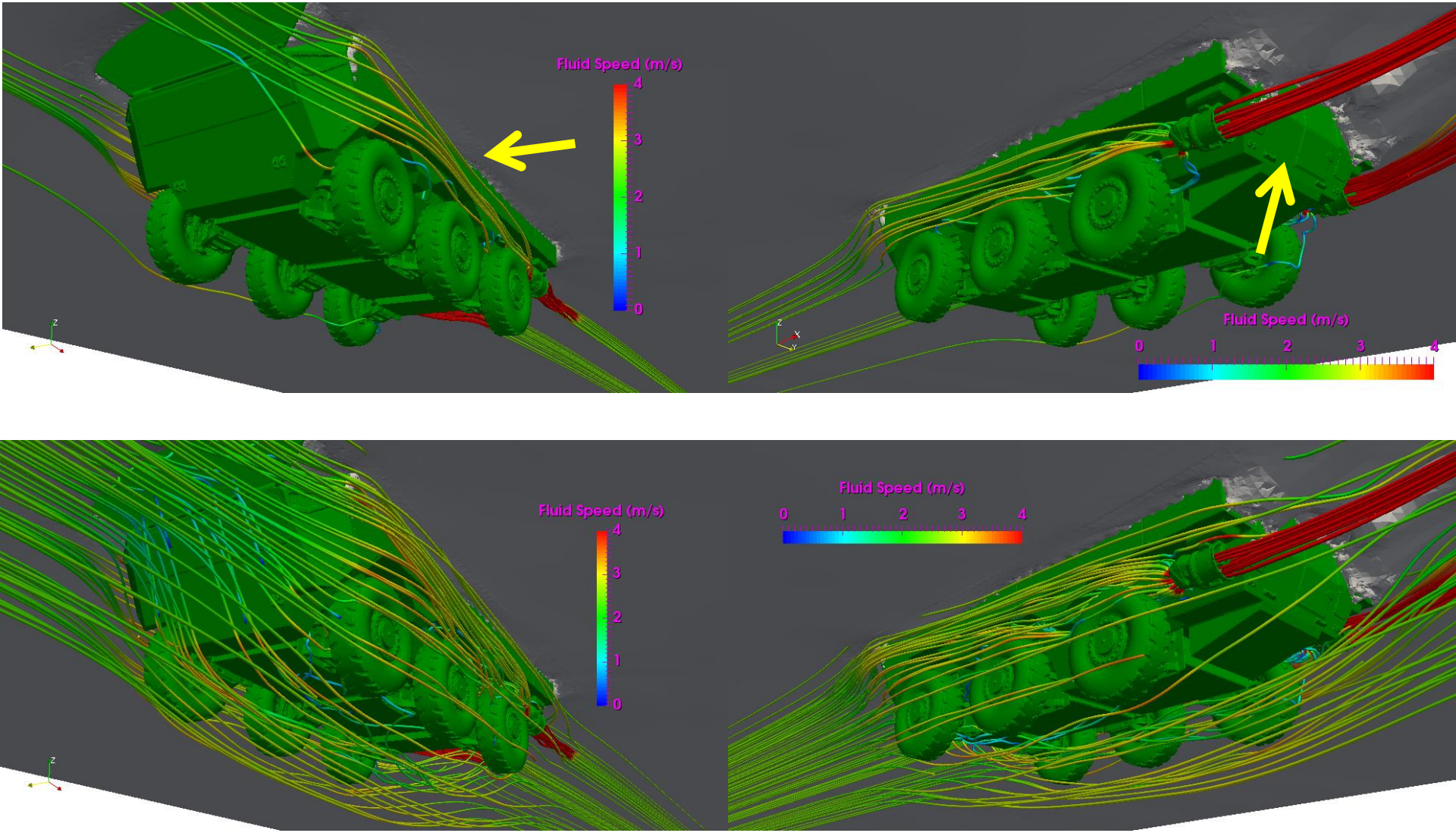








Hydrodynamic Analysis for Badak 2020 Design



Hydrodynamic Analysis for Badak 2020 Design

Conclusions:

- Badak 2020 design has a good size of body to generate enough bouyancy force with reasonable water height.
- Water height at equilibrium for static vehicle is 40cm above the vehicle CG point.
- Pitch angle at the equilibrium for static vehicle is 1^0 , when the vehicle moves at 5 knot, the vehicle equilibrium pitch angle is around 3^0.
- Vehicle wave protector deflects water coming from the front effectively, however it needs to be widened to protect the vehicle better.
- Manhole for the vehicle driver and hole for engine air intake need to be protected better from water intrusion.
- Water height to the vehicle is 5cm higher when vehicle moves at 3 knot and 10cm higher at 5 knot.

Hydrodynamic Analysis for Badak 2020 Design

Conclusions:

- Assuming there is no leakages in Body and Turret:
- Stability range for the vehicle in Y-axis rotation is -100^0 to $+100^0$
- Stability range for the vehicle in X-axis rotation is -130^0 to $+130^0$
- Maximum perturbation moment in negative Y-axis is 128.000 N.m, and in positive Y-axis is 180.000 N.m
- Maximum perturbation moment in X-axis is 60.000 N.m.
- Moment sensitivity around the equilibrium position in Y-axis direction is 10.384 N.m per degree of rotation.
- Moment sensitivity around the equilibrium position in X-axis direction is 2.085 N.m per degree of rotation.
- Bouyancy force sensitivity around the equilibrium position is 1.884 N per cm of water height change.

Hydrodynamic Analysis for Badak 2020 Design

Recommendations:

- Rear most floater under the vehicle body need to be reduced its size.
- Vehicle wave protector needs to be widened to protect manhole and engine air intake hole.
- Air intake hole should be protected with taller structure.
- If needed, cannon should be fired only to front direction.


Other amphibious vehicle attitude
H637


Other amphibious vehicle attitude


Other amphibious Bulky Body
MARINIR
1514
INDONESIA
1


Other amphibious Bulky Body
MARINIR
www.antaranews.com

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Assignment Letter/Surat Tugas

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Dena Hendriana, B.Sc., S.M., Sc.D

Activity Assignment | ***Penugasan Kegiatan***

Dean of the Faculty of Engineering and Information Technology

Dekan Fakultas Teknik dan Teknologi Informasi

In consideration of:

His appointment as the Dean of the Faculty of Engineering and Information Technology under agreement no. SK/017/Y-SGU/VIII/2018

Mengingat:

Pengangkatannya sebagai Dekan Fakultas Teknik dan Teknologi Informasi di bawah perjanjian no. SK/017/Y-SGU/VIII/2018

Herewith permits to | ***Dengan ini menugaskan kepada***

Name/*Nama:* Dena Hendriana, B.Sc., S.M., Sc.D

Position/*Jabatan:* Head of Master of Mechanical Engineering Department/ Kepala Program Studi Magister Teknik Mesin

Faculty/*Fakultas*: Engineering and Information Technology/ Teknik dan Teknologi Informasi.

To follow on the activity below: | *Untuk mengikuti kegiatan berikut ini:*

No	Activity / *Kegiatan*	Organizer / *Penyelenggara*	Day & Date / *Hari & Tanggal*	Venue / Tempat
1.	Penelitian Tank badak menjadi amphibus bekerja sama dengan PT. Pindad	Swiss German University	January 2021 – December 2021	Prominance Office Tower. Swiss German University

The Appointed shall accomplish the task in responsible ways in line with the related guidelines and other regulation given by SGU.

Pihak yang bersangkutan harus melaksanakan tugas dan tanggung jawab sebaik-baiknya, sesuai dengan petunjuk dan peraturan dari SGU.

Assignor / *Pemberi Ijin:*

Dr. Maulahikmah Galinium, S.Kom., M.Sc
Dean of Faculty Engineering and Information Technology
Dekan Fakultas Teknik dan Teknologi Informatika

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SWISS GERMAN UNIVERSITY

LAPORAN

PENELITIAN MODIFIKASI TANK BADAK MENJADI AMPHIBIUS

BEKERJA SAMA DENGAN PT. PINDAD

Dena Hendriana, B.Sc., S.M., Sc.D – Team Leader
Keysha Zakri (PT. Pindad) – Team Member
Martin (PT. Pindad) – Team Member

MASTER OF MECHANICAL ENGINEERING

2021

Swiss German University
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Judul Penelitian	: Penelitian Modifikasi Tank Badak menjadi Amphibious Bekerja Sama dengan PT. Pindad
Nama Team Leader	: Dena Hendriana, B.Sc., S.M., Sc.D
Research Center/Dept.	: Master of Mechanical Engineering
E-mail	: dena.hendriana@sgu.ac.id
Mobile phone	: 081213715844
Masa program	: Januari – Desember 2021 (12 bulan)
Keterangan Aktifitas	: PT. Pindad akan mengembangkan produk Tank Badak untuk menjadi Amphibious yang bisa bergerak di darat dan di perairan. Kegiatan penelitian ini di minta oleh PT. Pindad untuk melakukan analisa hydrostatics dan hydrodynamics untuk Tank Badak untuk bisa mengambang dengan stabil dan dapat bergerak di permukaan danau. Bekerja sama dengan team desain dari PT. Pindad, bentuk dan volume tank Badak yang mampu menjadi Amphibious dengan memenuhi kriteria dari hasil analisa hydrostatics dan hydrodynamics dapat dilakukan. Kegiatan ini merupakan kegiatan pengabdian masyarakat dari Swiss German University yang memanfaatkan keilmuan akademik dari hydrostatics dan hydrodynamics untuk kebutuhan masyarakat yang disini adalah dari pihak Industri yaitu PT. Pindad. Hasil dari penelitian ini tidak dipublikasikan dikarenakan kerahasiaan dari produk PT. Pindad.

Alam Sutera, Tangerang
Date: November 2021

Dena Hendriana, B.Sc., S.M., Sc.D
NIK: 11211528

AMPHIBIOUS BADAK TANK ANALYSIS

Summary Report on: April 2021

By:

Dr. Dena Hendriana

Swiss German University

Dr. Dena Hendriana

Swiss German University

Head of Master of Mechanical Engineering

- Education background:
  - B.Sc. in Mechanical Eng., Northeastern Univ., Boston, USA
  - S.M. in Mechanical Eng., Massachusetts Institute of Technology (MIT), Cambridge, USA
  - Sc.D in Mechanical Eng., MIT, Cambridge, USA
- Experiences:
  - Automotive Industry, USA ~ 14 years
  - Higher Education, Indonesia, since 2013

BADAK, PT. PINDAD

Current Specifications:
Weight = 14.1 Ton
Combat weight: 15,100 kg
Config: 6x6
Dim: LxWxH = 5.65 x 2.7 x 2.7 m

Crew: 3 persons
Range: 600 km
Speed: 80 km/h on high way
Diesel 6 Cyl, 340 HP Turbo Charger Intercooler

Overall Project: Amphibious Badak Project

Project Steps:

1. Determination of vehicle configuration
    - Number of personels, Loads, Vehicle configuration
2. Determination of components and total weight
    - Engine, Wheels, etc.
3. Determination of vehicle total center of gravity
4. Vehicle static floating attitude calculation and design
5. Vehicle static floating stability analysis
6. Dynamic analysis of vehicle water resistance characteristic
7. Propulsion analysis and design
8. Vehicle speed calculation
9. Vehicle water entry analysis (need entry specification)
10. Wave protection design
11. Cannon firing effect estimation on static vehicle
12. Cannon firing effect estimation on moving vehicle
13. Verification on scaled model test (in ITS)
    - Vehicle attitude, static stability, water entry, water resistance?
14. Prototyping and test (in Pindad)
    - Leaks, vehicle speed, wave protection, cannon firing?
15. Prototype improvements (in Pindad)

Design (AutoCAD) function:

- Weight estimate
- Location of center of gravity

CFD function:

- Vehicle static floating attitude calculation
- Vehicle static floating stability analysis
- Dynamic analysis of vehicle water resistance characteristic
- Propulsion analysis
- Vehicle water entry analysis
- Wave protection design
- Cannon firing effect estimation on static vehicle
- Cannon firing effect estimation on moving vehicle

Scaled model function:

- Verification on vehicle static floating attitude and stability
- Verification on vehicle water entry and wave protection

Prototype function:

- Leak study
- Verification on vehicle speed, etc.
- Improvements

Current Project: Amphibious Badak Analysis

Analysis Steps:

1. Determination of vehicle configuration
   - Number of personels, Loads, Vehicle configuration
2. Determination of components and total weight
   - Engine, Wheels, etc.
3. Determination of vehicle total center of gravity
4. Vehicle static floating attitude calculation and design
5. Vehicle static floating stability analysis
6. Dynamic analysis of vehicle water resistance characteristic