
# Gemilerde Operasyonel Enerji Verimliliği

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Hidroteknik Yat Gemi ve Deniz Yapıları tasarım teknolojileri Ltd.

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HİDROTEKNİK
NAUTICAL DESIGN
& DEVELOPMENT

İstanbul ve Marmara, Ege, Akdeniz, Karadeniz Bölgeleri
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# Tanım

- Gemilerde Enerji Verimliliği Gereksinimi ?
- Operasyonal Enerji Verimliliği
  - Hız optimizasyonu
  - Trim Optimizasyonu
  - Pürüzlülük azaltımı
  - Sevk Sistem Optimizasyonu
- Gelecek Projeksiyonu


# Gereksinim

## Gemilerde Operasyonel Enerji Verimliliği

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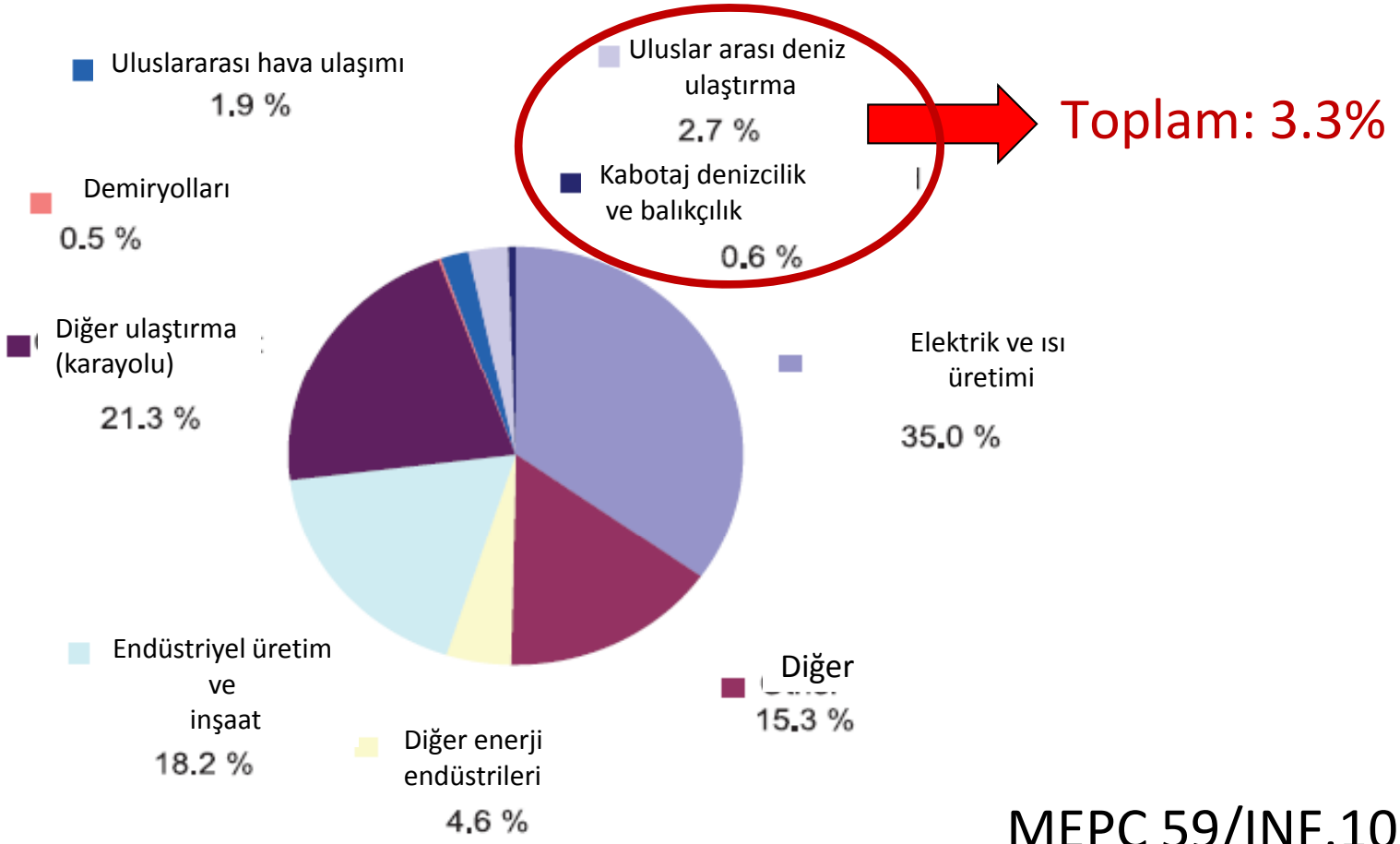
# İstanbuldan Manzaralar

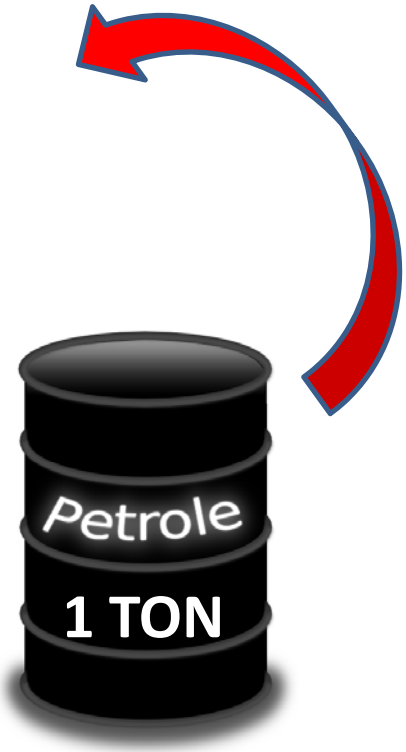

# CO2 Salınımlarının Dağılımı




MEPC 59/INF.10

# Yakıt CO2 ilişkisi






# Mevzuat

## Gemilerde Operasyonel Enerji Verimliliği

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# Denizcilik Sektörüne Yansıma

Yakıt kalitesi ile SOx emisyonlarının azaltımı

Yanma sistemleri ile NOx, emisyonlarının azaltımı

Enerji verimliliği tedbirleri ile $CO_2$ emisyonlarının azaltımı

# NOx

1. MARPOL Annex VI NOx Emission Limits

| Tier | Date | NOx Limit, g/kWh | | |
|---|---|---|---|---|
| | | n < 130 | 130 ≤ n < 2000 | n ≥ 2000 |
| Tier I | 2000 | 17.0 | $45 \cdot n^{-0.2}$ | 9.8 |
| Tier II | 2011 | 14.4 | $44 \cdot n^{-0.23}$ | 7.7 |
| Tier III | 2016† | 3.4 | $9 \cdot n^{-0.2}$ | 1.96 |
| † In NOx Emission Control Areas (Tier II standards apply outside ECAs). | | | | |

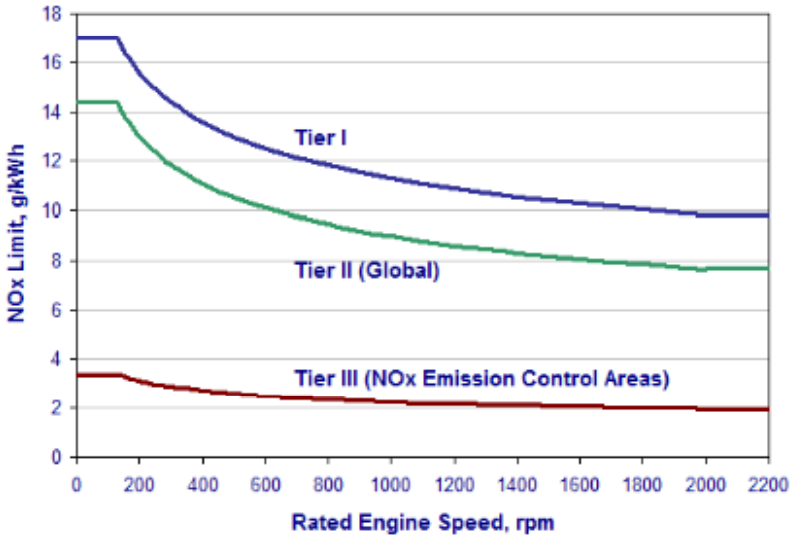



**Figure 1.** MARPOL Annex VI NOx Emission Limits

# SOx

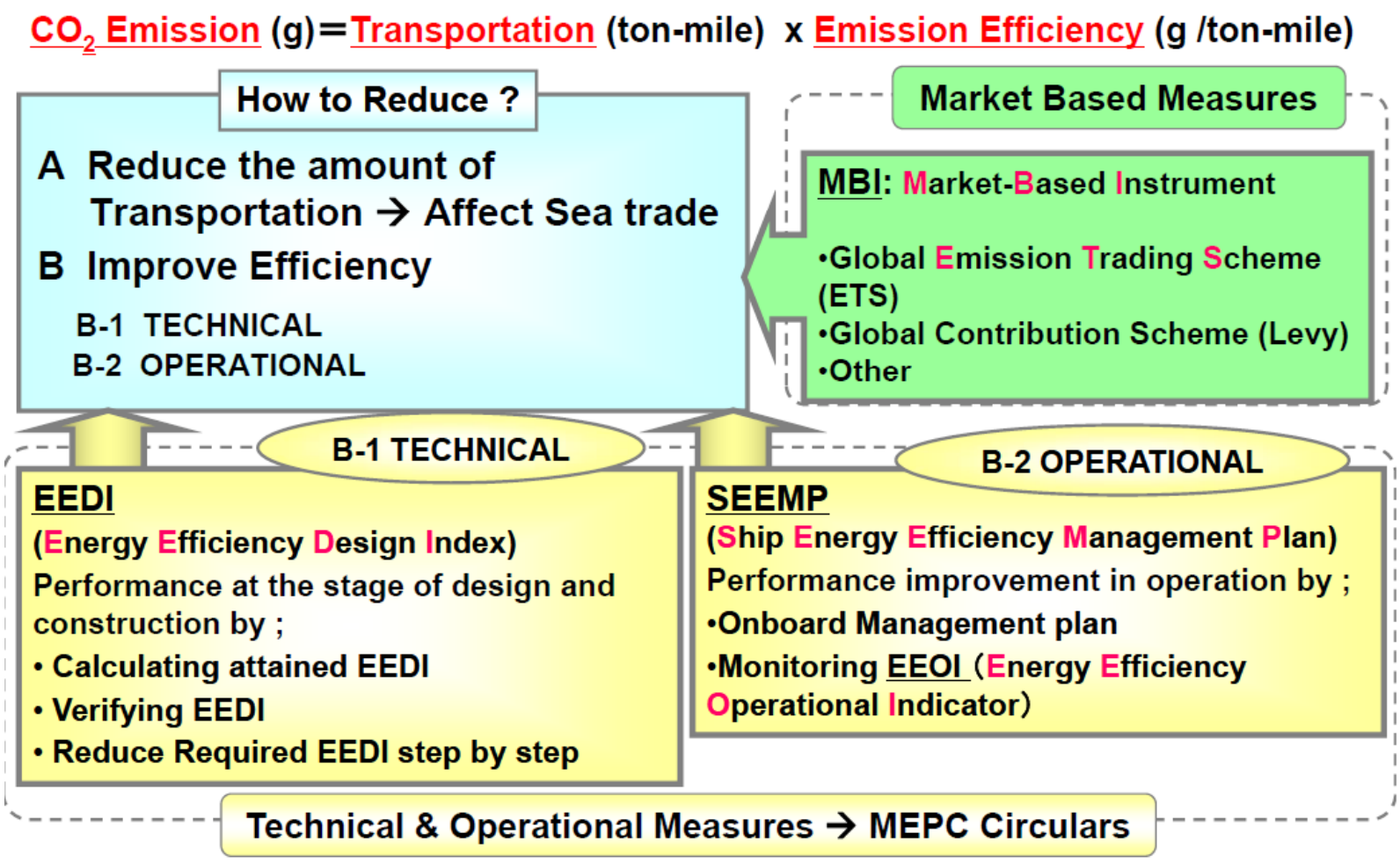
| Outside an ECA Established to Limit SOx and PM Emissions | Inside an ECA Established to Limit SOx and PM Emissions |
|---|---|
| 4.50% m/m prior to 1st January 2012 | 1.50% m/m prior to 1st July 2010 |
| 3.50% m/m on and after to 1st January 2012 | 1.00% m/m on and after to 1st July 2010 |
| 0.50% m/m on and after to 1st January 2020* | 0.10% m/m on and after to 1st January 2015 |

* To be implementation on current timeline subject to technical review (2018)

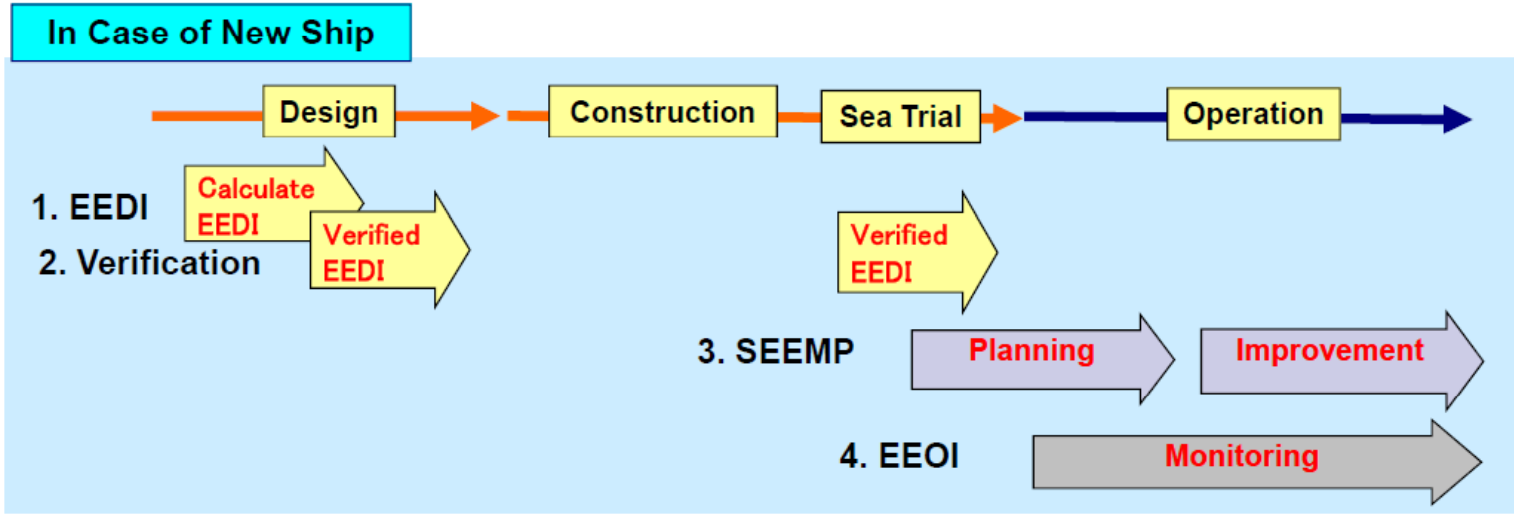
# Enerji Verimliliği ve Emisyon Kuralları

- IMO-MARPOL Ek VI (MEPC 62, Temmuz 2011)
- 400 GT dan büyük tüm gemiler için 1 Ocak 2013 (keel laying 1 Temmuz 2013, delivery 1 Temmuz 2015, conver 1 Ocak 2013) ten itibaren geçerli
  - Energy Efficiency Design Index (EEDI), yeni gemiler için zorunlu
  - The Ship Energy Efficiency Management Plan (SEEMP), mevcut gemiler zorunlu
  - Energy Efficiency Operational Indicator (EEOI), mevcut gemiler gönüllü
- Monitoring, Reporting and Verification -MRV

# Enerji Verimliliği ve Emisyon Regülasyonları



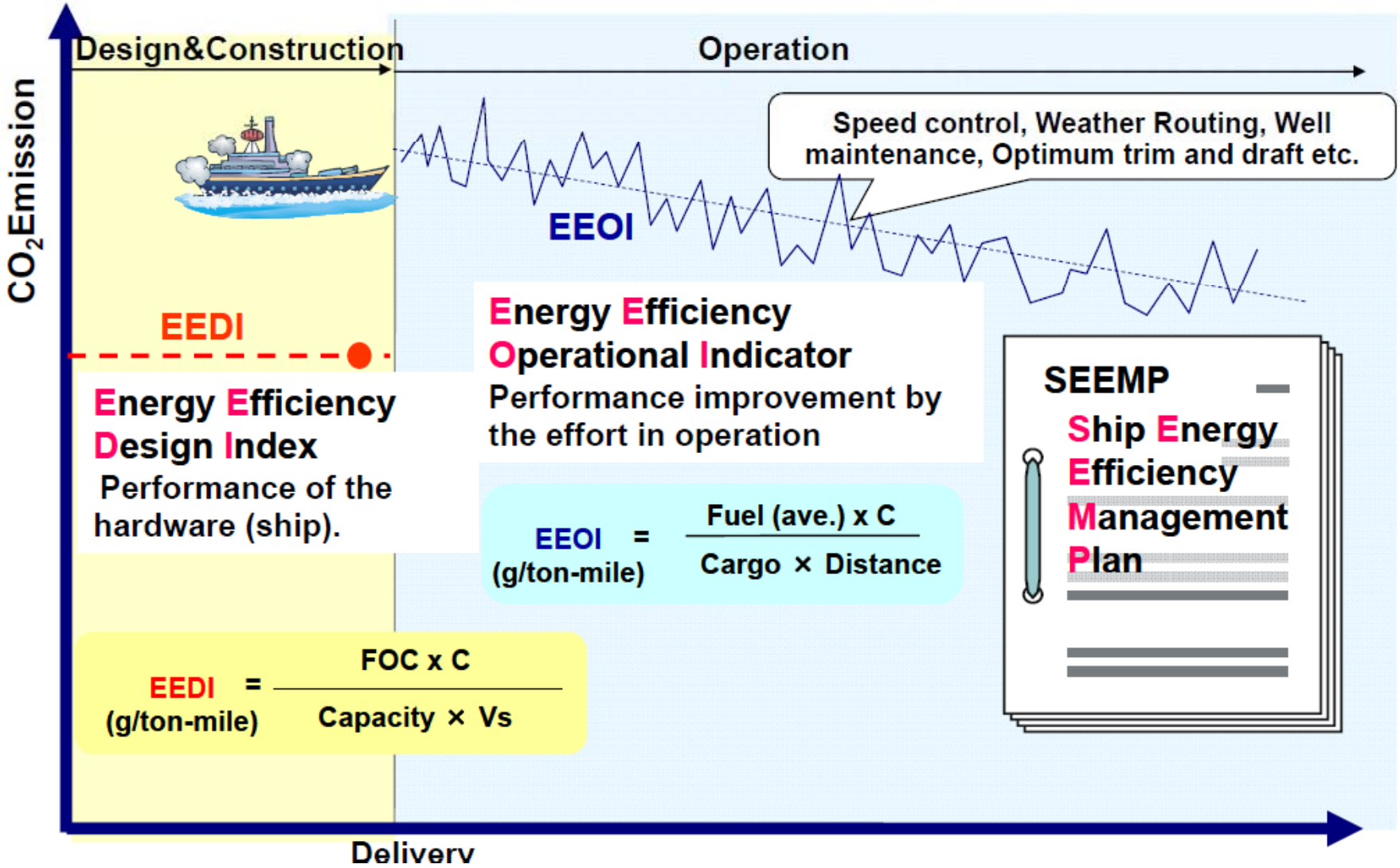
# Teknik ve Operasyonel Önlemler



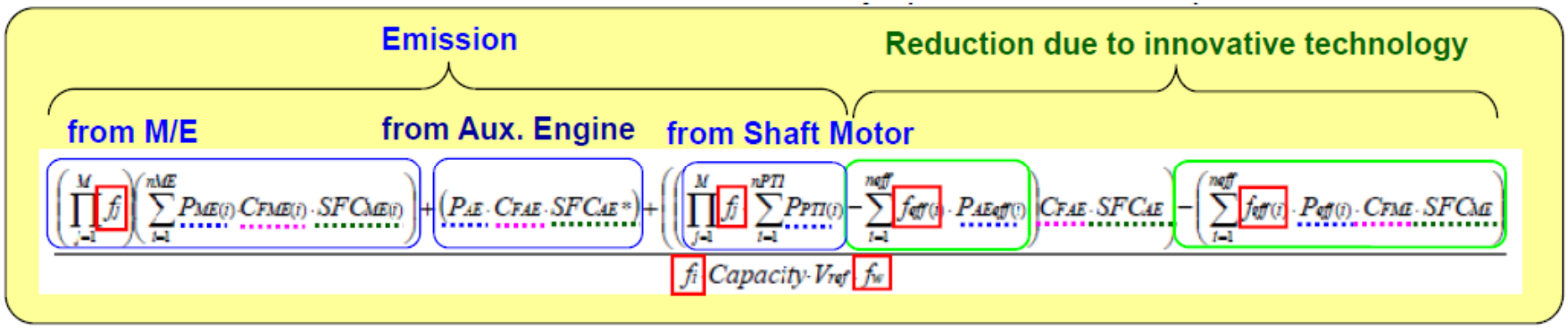

**Technical and operational measures ; developed in MEPC.59**

**→ Trial purposes or Voluntary Implementation**

1. **Interim Guidelines on the method of calculation of the EEDI (MEPC.1/Circ.681)**
2. **Interim Guidelines for voluntary verification of the EEDI (MEPC.1/Circ. 682)**
3. **Guidance for the development of a SEEMP (MEPC.1/Circ. 683)**
4. **Guidelines for voluntary use of the EEOI (MEPC.1/Circ.684)**


$CO_2$Emission
Design&Construction
Operation
Speed control, Weather Routing, Well maintenance, Optimum trim and draft etc.
EEOI
EEDI
Energy Efficiency Operational Indicator
Performance improvement by the effort in operation
Energy Efficiency Design Index
Performance of the hardware (ship).
EEOI (g/ton-mile) = Fuel (ave.) x C / Cargo × Distance
EEDI (g/ton-mile) = FOC x C / Capacity × Vs
SEEMP
Ship Energy Efficiency Management Plan
Delivery

# EEDI: Enerji Verimliliği Dizayn İndeksi




$$\frac{\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}{}^{*}\right) + \left(\left(\prod_{j=1}^{M} f_j \sum_{i=1}^{nPTI} P_{PTI(i)}\right) - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE} - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}\right)}{f_i \cdot Capacity \cdot V_{ref} \cdot f_w}$$

$P_{ME}, P_{AE}$ : Power of main and auxiliary engines

$P_{PTI}$ : Power consumption of each shaft motor

$P_{AEeff}$ : Main engine power reduction due to innovative mechanical energy efficient technology

$P_{eff}$ : Auxiliary power reduction due to innovative electrical energy efficient technology

$C_{FME}, C_{FAE}$ : non-dimensional conversion factor between fuel consumption and $CO_2$ emission based on carbon content. (Table given)

$SFC_{ME}, SFC_{AE}$ : certified specific fuel consumption of main and auxiliary engines

$fj$ : correction factor to account for ship specific design elements (for ice-class, table given)

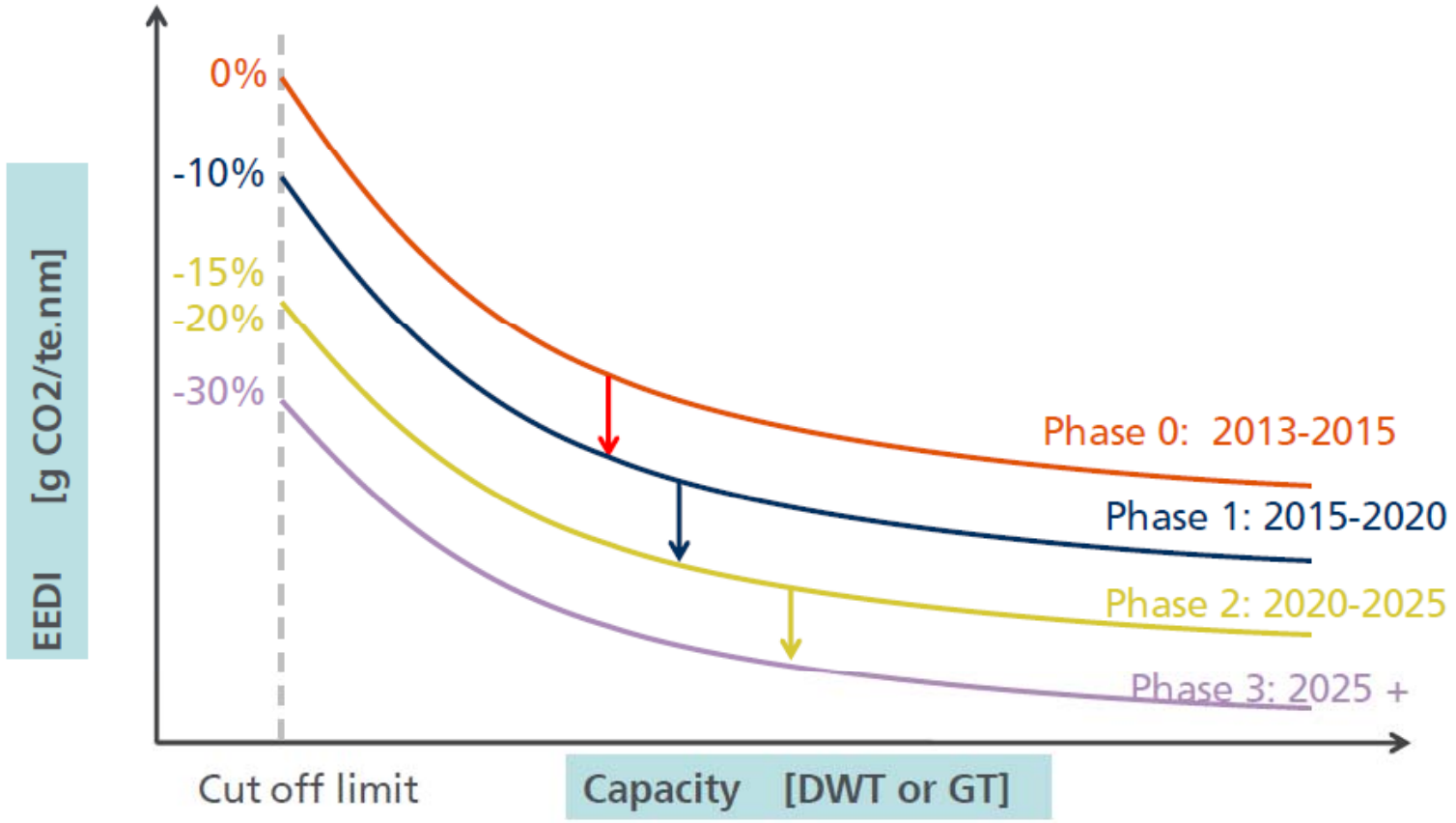
$fi$ : the capacity factor for any technical/regulatory limitation on capacity (for ice-class, table given)

$fw$ : non-dimensional coefficient indicating the decrease of speed in BF6. ( =1.0 )

$feff$ : availability factor of each innovative energy efficiency technology.(=1.0 for waste energy recovery system)

**Interim Guidelines for New Ships(MEPC.1/Circ.681)**

# EEDI nedir ?


0%
-10%
-15%
-20%
-30%
EEDI [g CO2/te.nm]
Phase 0: 2013-2015
Phase 1: 2015-2020
Phase 2: 2020-2025
Phase 3: 2025 +
Cut off limit
Capacity [DWT or GT]

# EEDI - EEOI

$$EEDI = \frac{b_e \cdot P_{installed} \cdot c_{Carbon}}{Capacity \cdot v_{ref}}$$

$$\mathrm{EEOI} = \frac{\mathrm{Fuel}_{consumed} \cdot c_{Carbon}}{\mathrm{Cargo}_{transported} \cdot \mathrm{Distance}_{sailed}}$$

# SEEMP

- 400 GT dan büyük tüm gemiler için 1 Ocak 2013 ten itibaren ilk havuzlama intermediate veya renewal survey ile geçerli
  - Klas sadece SEEMP nin gemide olduğunu kontrol eder. International Energy Efficiency Certificate (IEEC) sertifikası verir
  - PSC ise geçerli IEEC nin olduğunu kontrol eder.


# Trim Optimizasyonu

## Gemilerde Operasyonel Enerji Verimliliği

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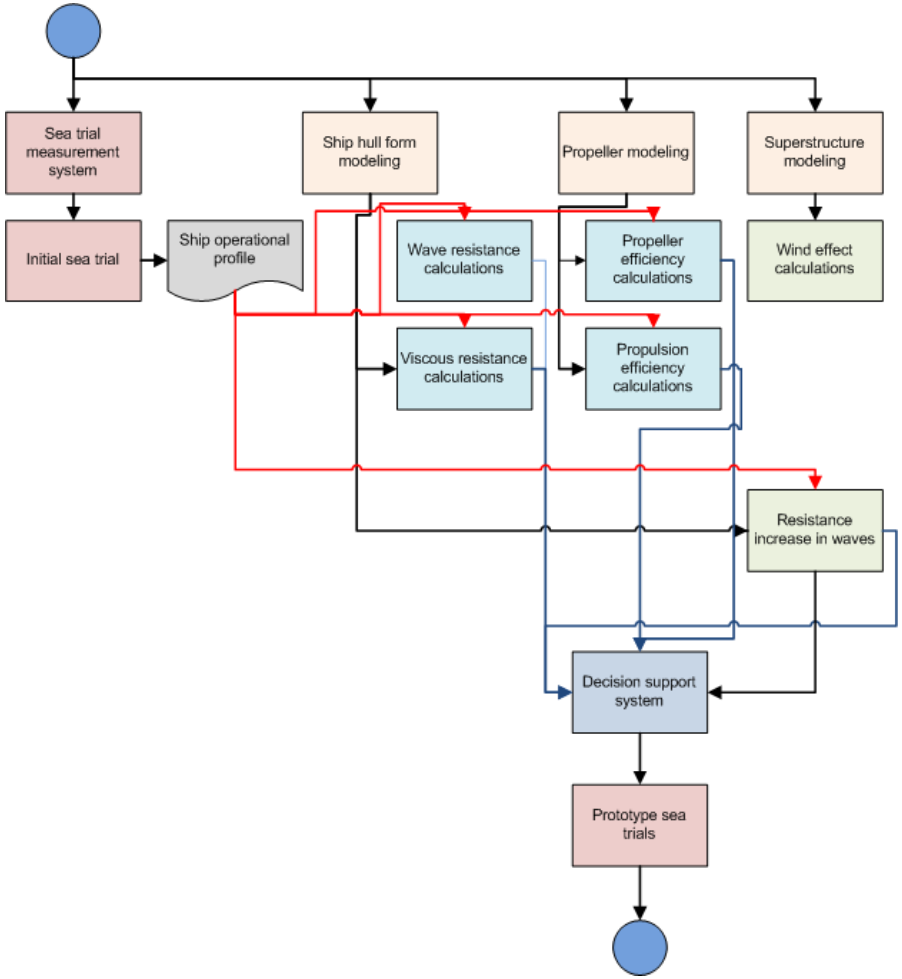
# SEEDS Trim Optimizasyonu Algoritması



# Trim Optimizasyonu

Trimin Gemi Direncine Etkisi

- Islak alan değişimi
- Dalga direncinde değişim

Trimin Sevk Verimine Etkisi

- Pervaneye gelen akış değişimi (iz)

Dalgalarda Direnç Artışı

- Dalgalarda direnç artış değişimi

# Trim Optimizasyonu
# Dalga direncinde değişim

- RoRo-Konteyner Gemileri
  - Dizayn draftından düşük draftlarda-düşük hızlarda

Gemi kıça trimli ise dalga direnci genel olarak azalır.

  - Dizayn draftından düşük draftlarda-yüksek hızlarda

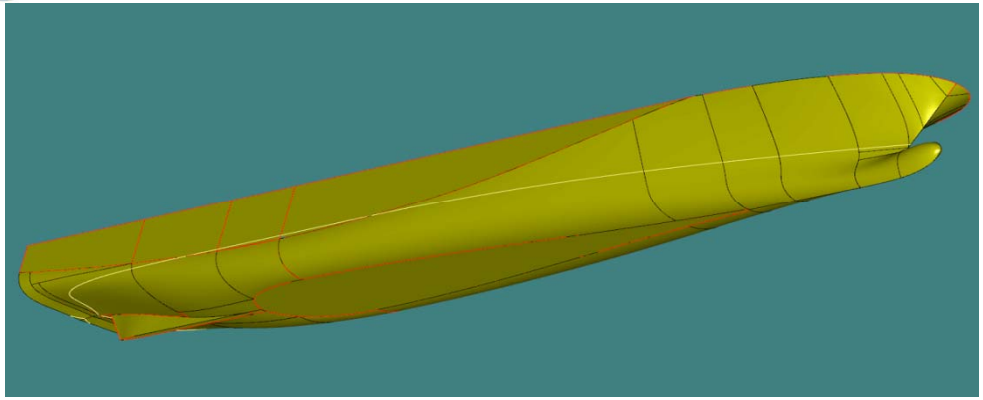
Gemi başa trimli ise dalga direnci genel olarak azalır.

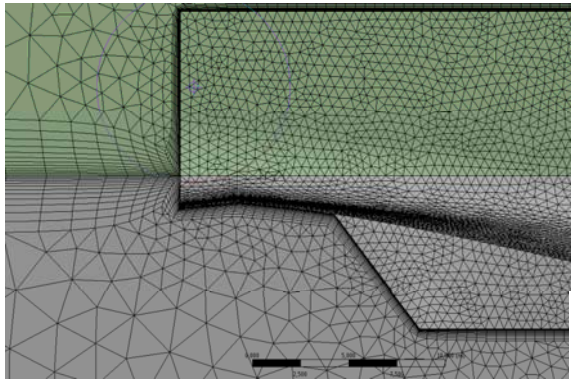
- RoRo-Konteyner Gemileri (Dizayn draftından yüksek draftlarda)

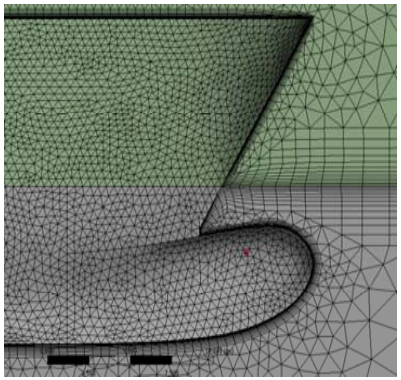
Gemi başa trimli ise dalga direnci genel olarak azalır.

# Trim Optimizasyonu-GEVKaDeS

# Form modellemesi







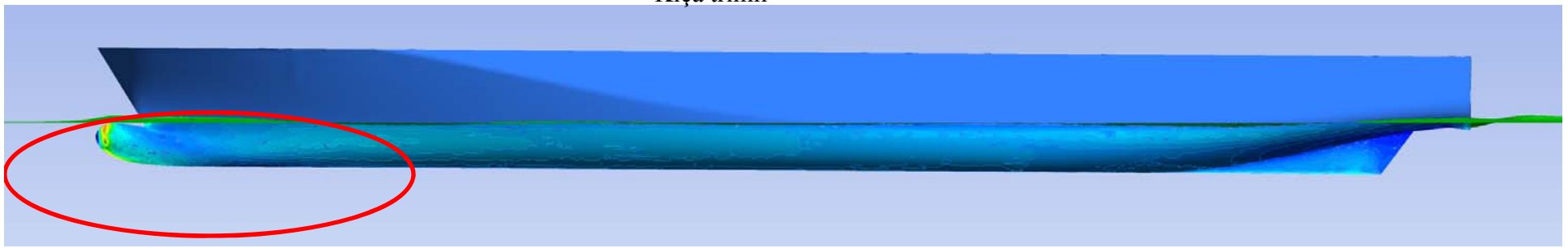
# Trim Optimizasyonu-GEVKaDeS
# Viskoz Direnç-Dalga Direnci

Baş dalgası

Başa trimli

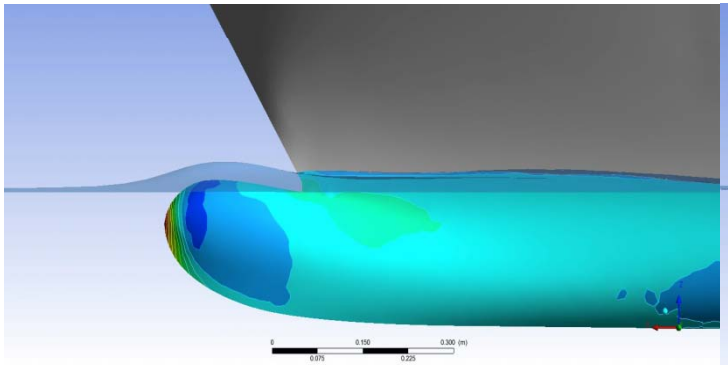
Ayna kıç akım

Kıça trimli

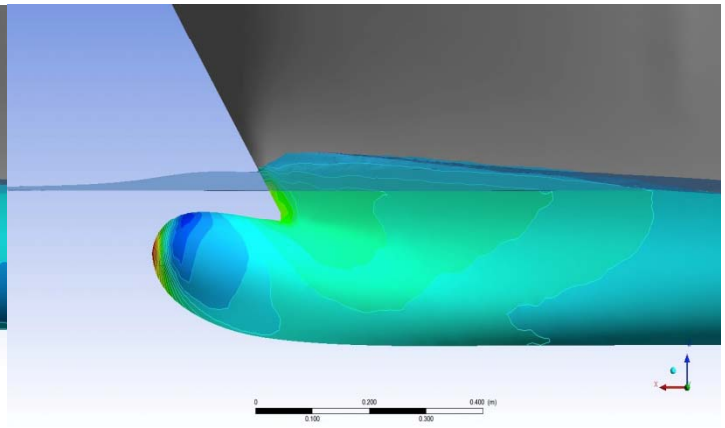


Basınç değişimi

# Trim Optimizasyonu-GEVKaDeS
# Viskoz Direnç-Dalga Direnci

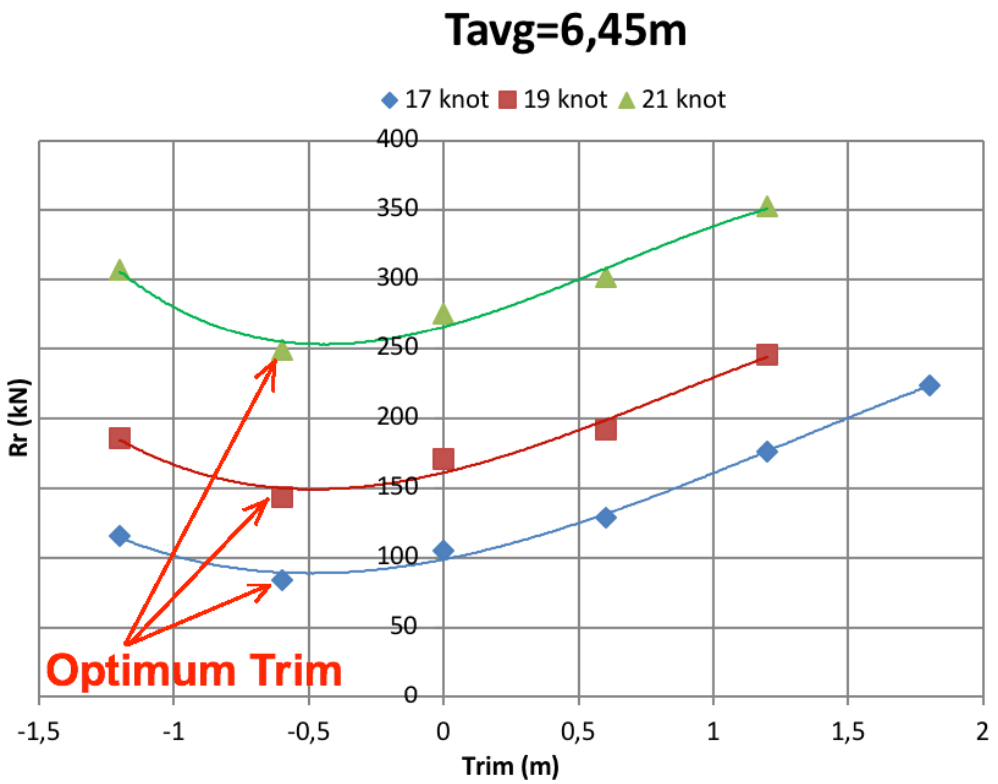


Normal yükleme koşulu



Optimize edilmiş trim

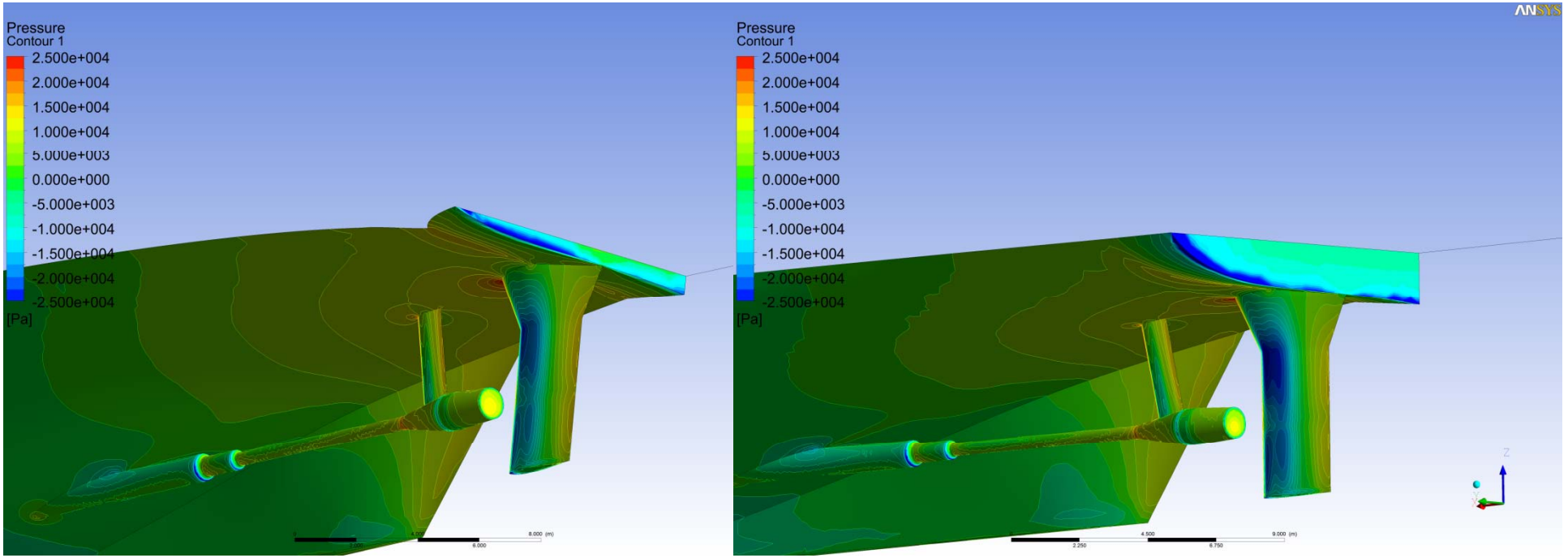
# Trim Optimizasyonu-GEVKaDeS
# Dalga Direnci



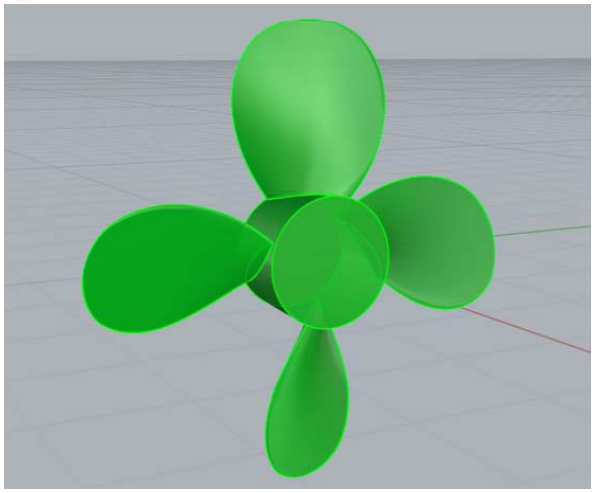
# Trim Optimizasyonu-GEVKaDeS
# Dalga Direnci

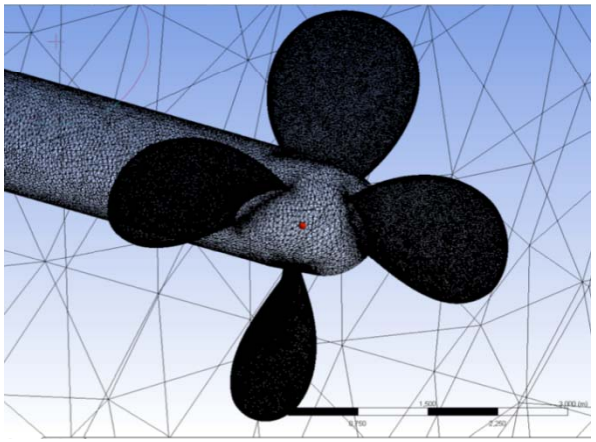
| | | Trim | | | | |
|---|---|---|---|---|---|---|
| | | -1.2 | -0.6 | 0 | 0.6 | 1.2 |
| Draught | 5 | 160 | 161 | 143 | 137 | 144 |
| | 5.5 | 165 | 145 | 137 | 142 | 160 |
| | 6 | 145 | 135 | 138 | 154 | 183 |
| | 6.5 | 162 | 162 | 175 | 200 | 239 |
| | 7 | 211 | 223 | 248 | 285 | 336 |

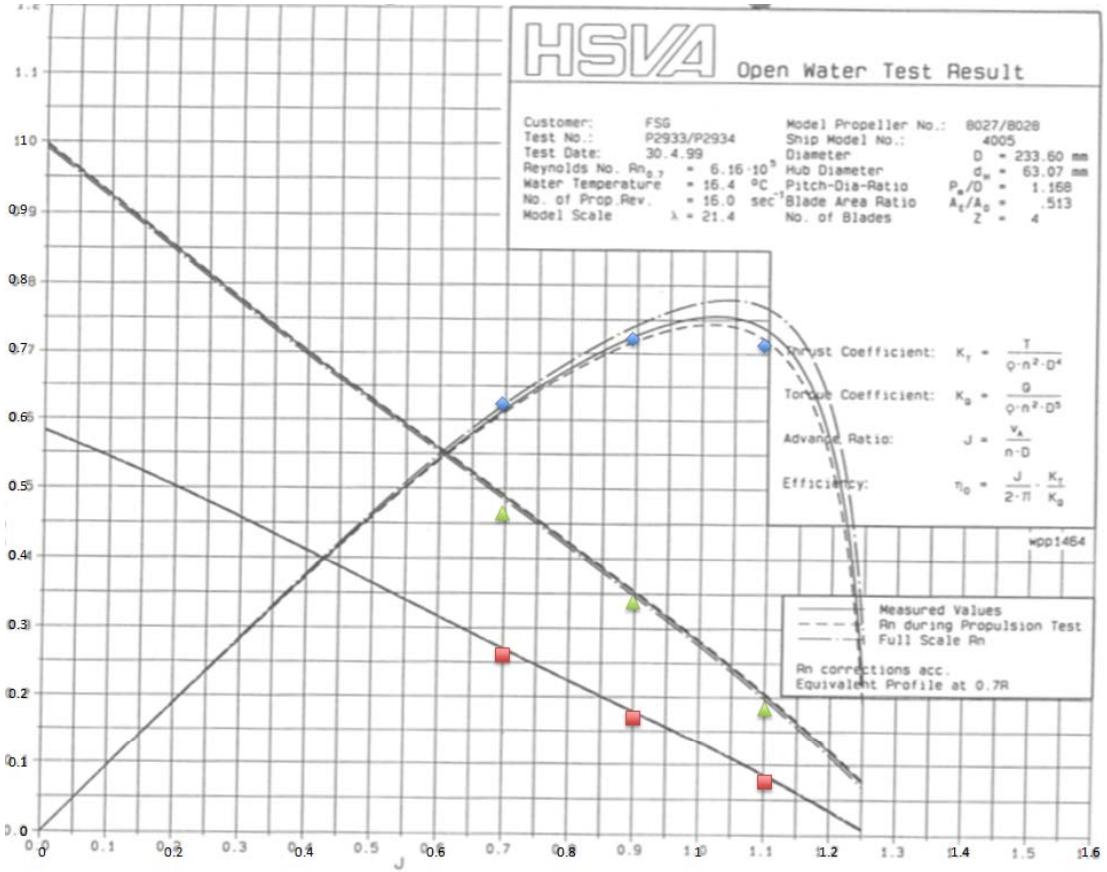
# Trim Optimizasyonu-GEVKaDeS
# Takıntı Direnci



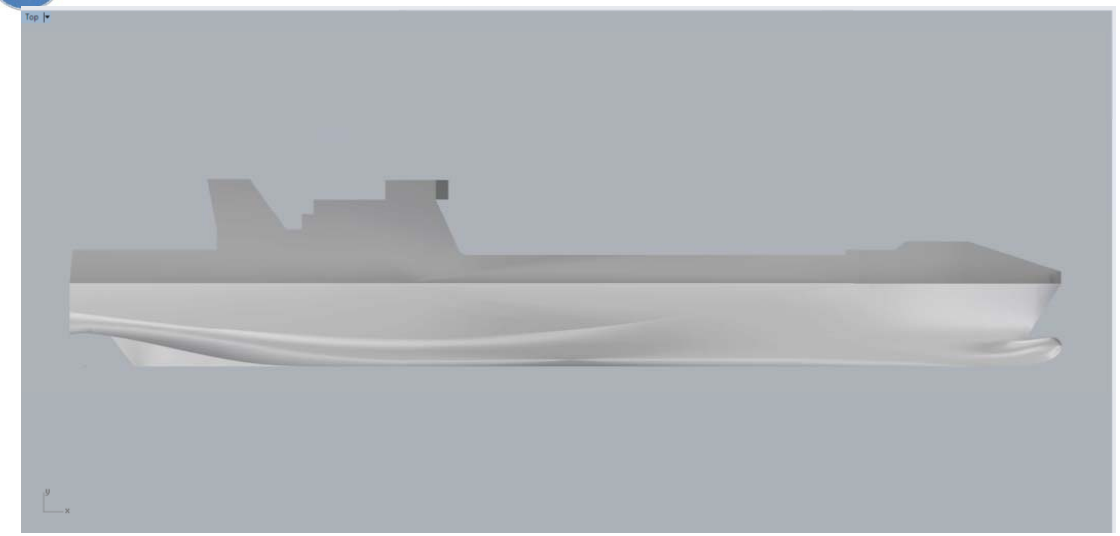

# Trim Optimizasyonu-GEVKaDeS
# Pervane Modellemesi

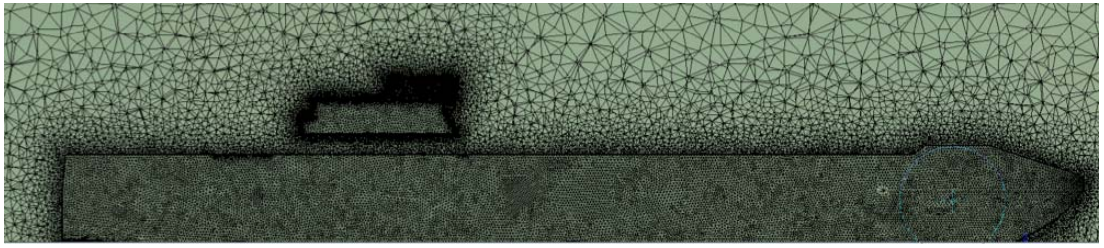


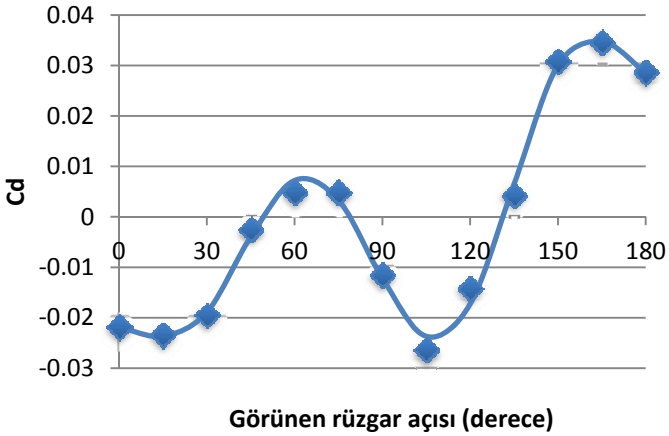




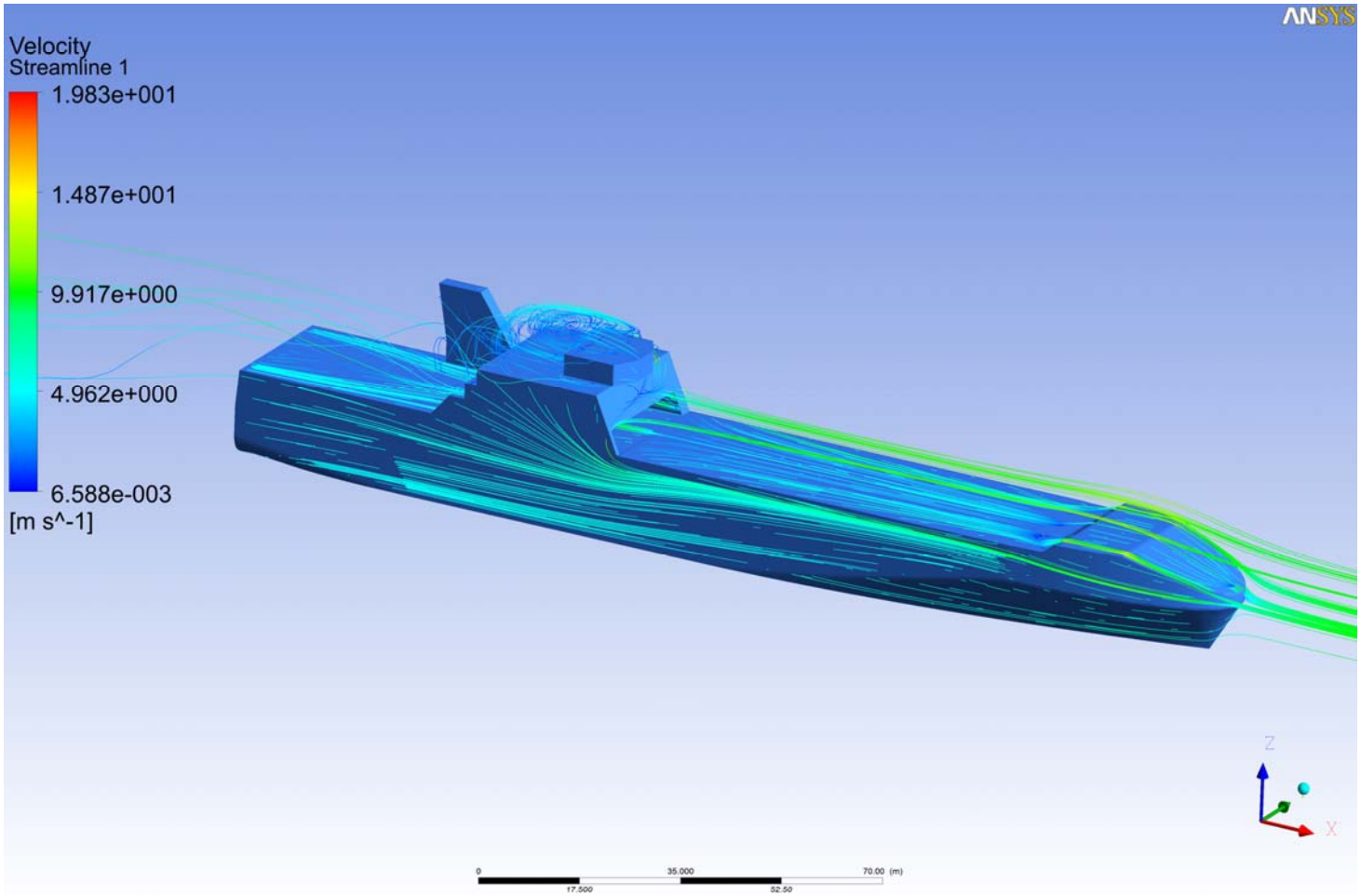
# Trim Optimizasyonu-GEVKaDeS
# Rüzgar Direnci



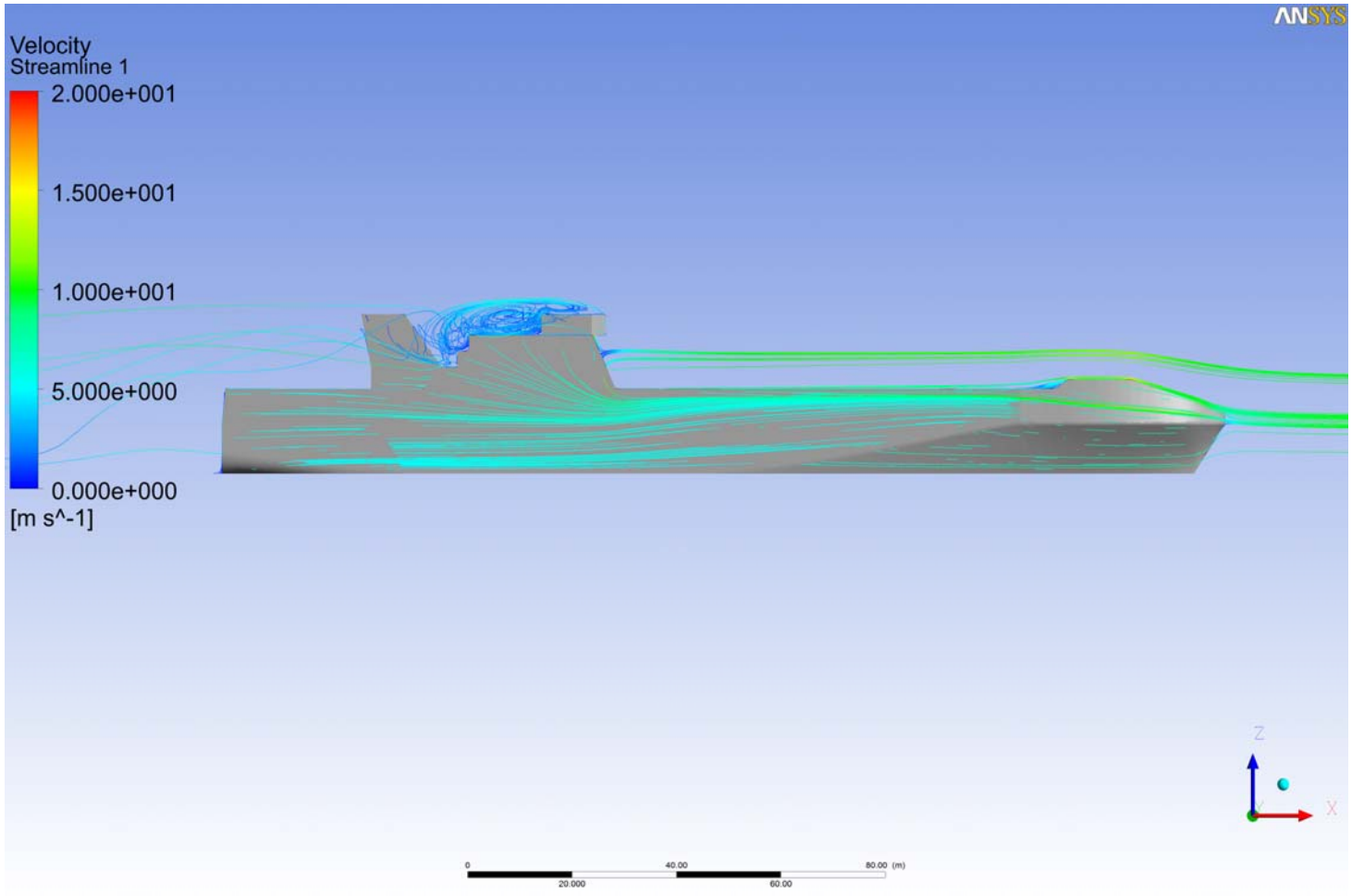




# Trim Optimizasyonu-GEVKaDeS
# Rüzgar Direnci



# Trim Optimizasyonu-GEVKaDeS
# Rüzgar Direnci



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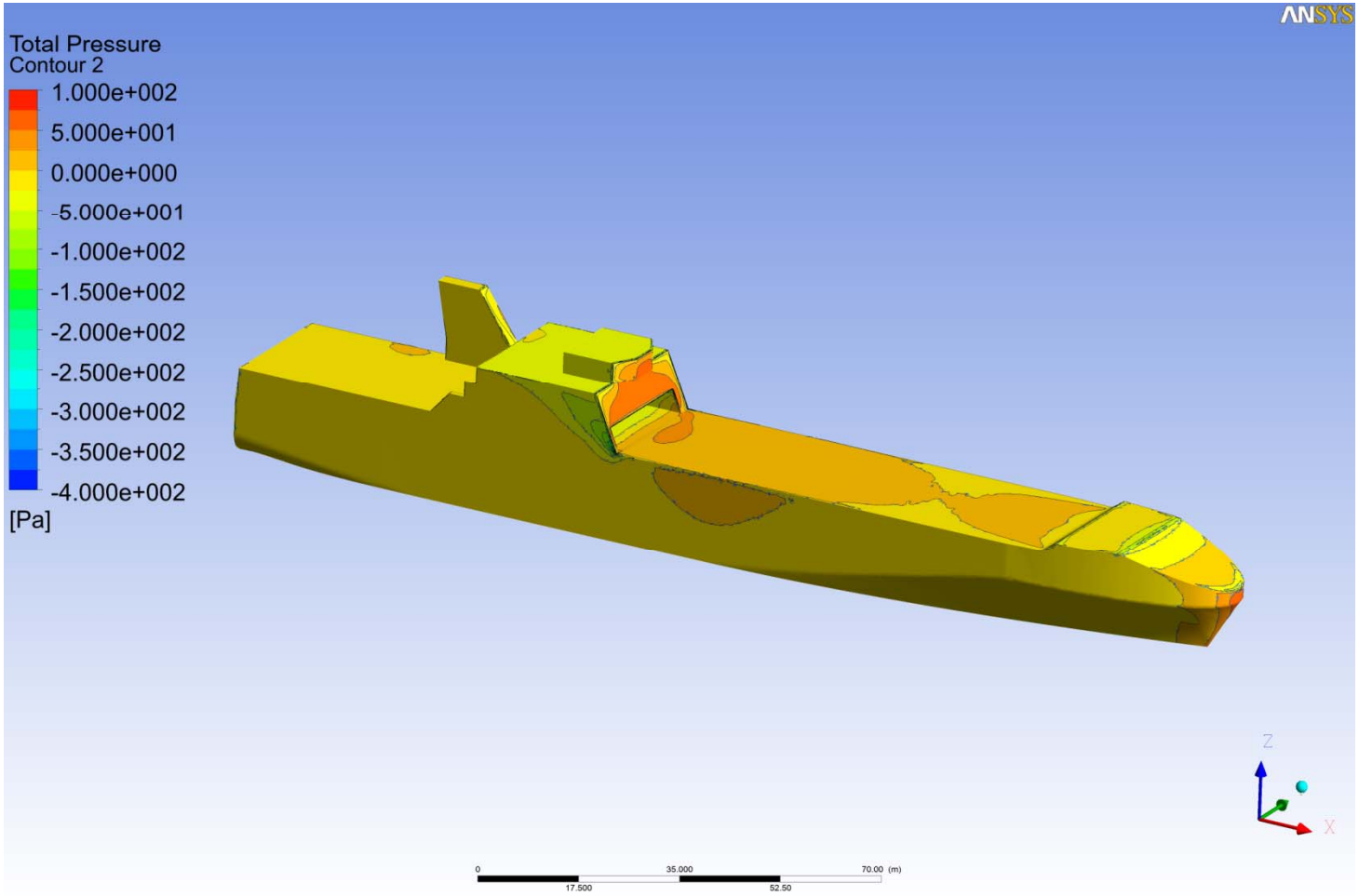

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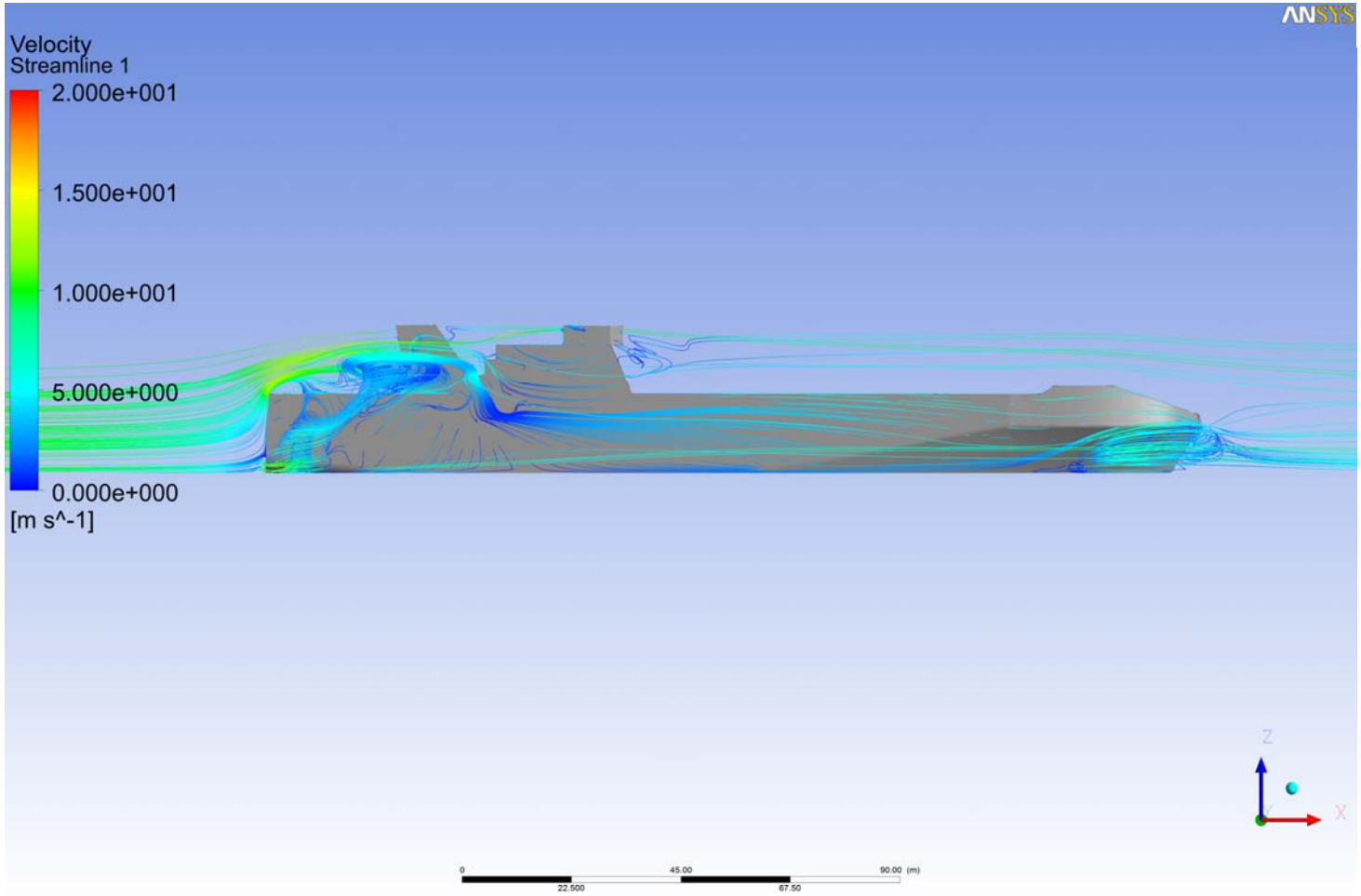
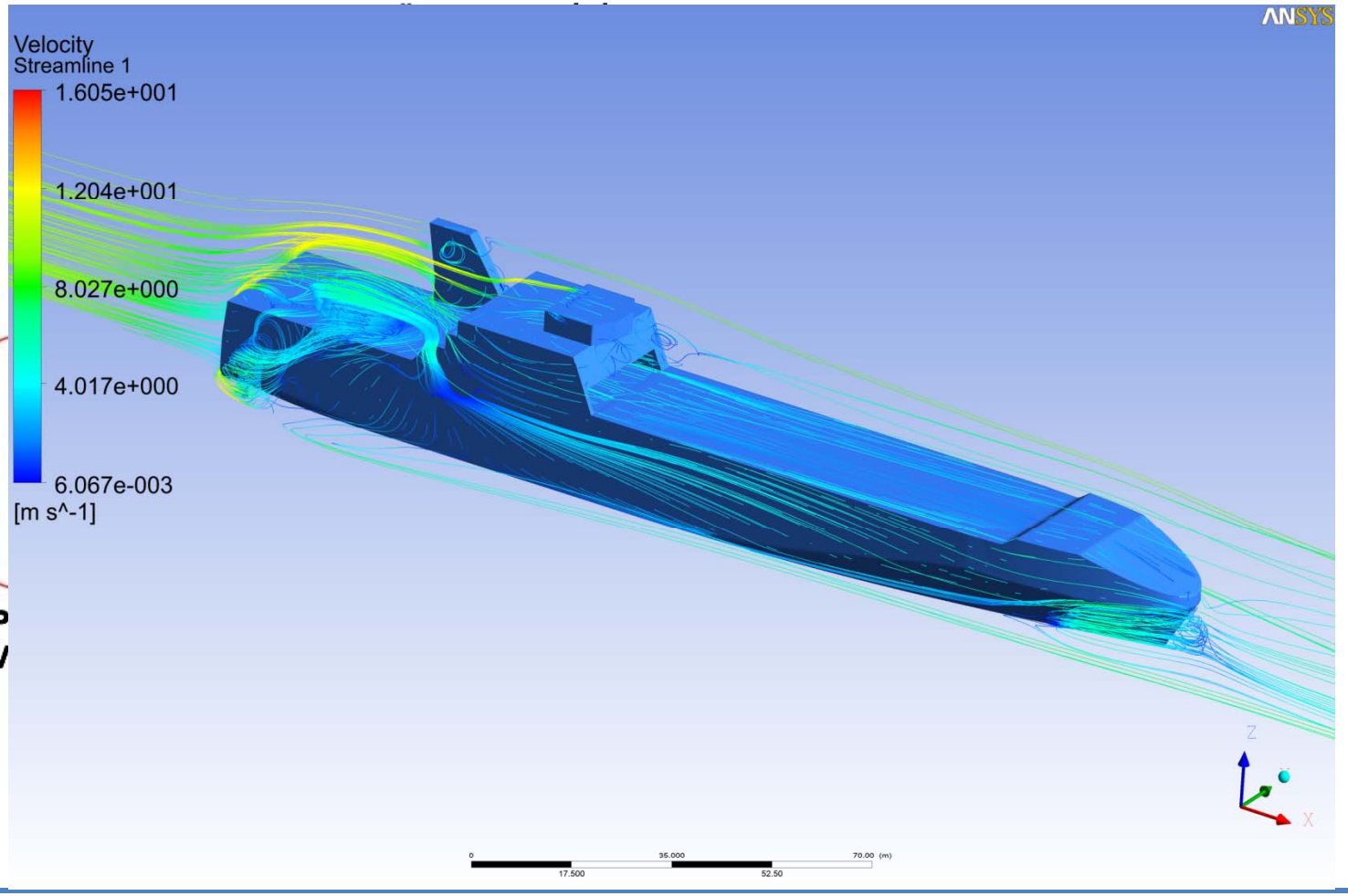
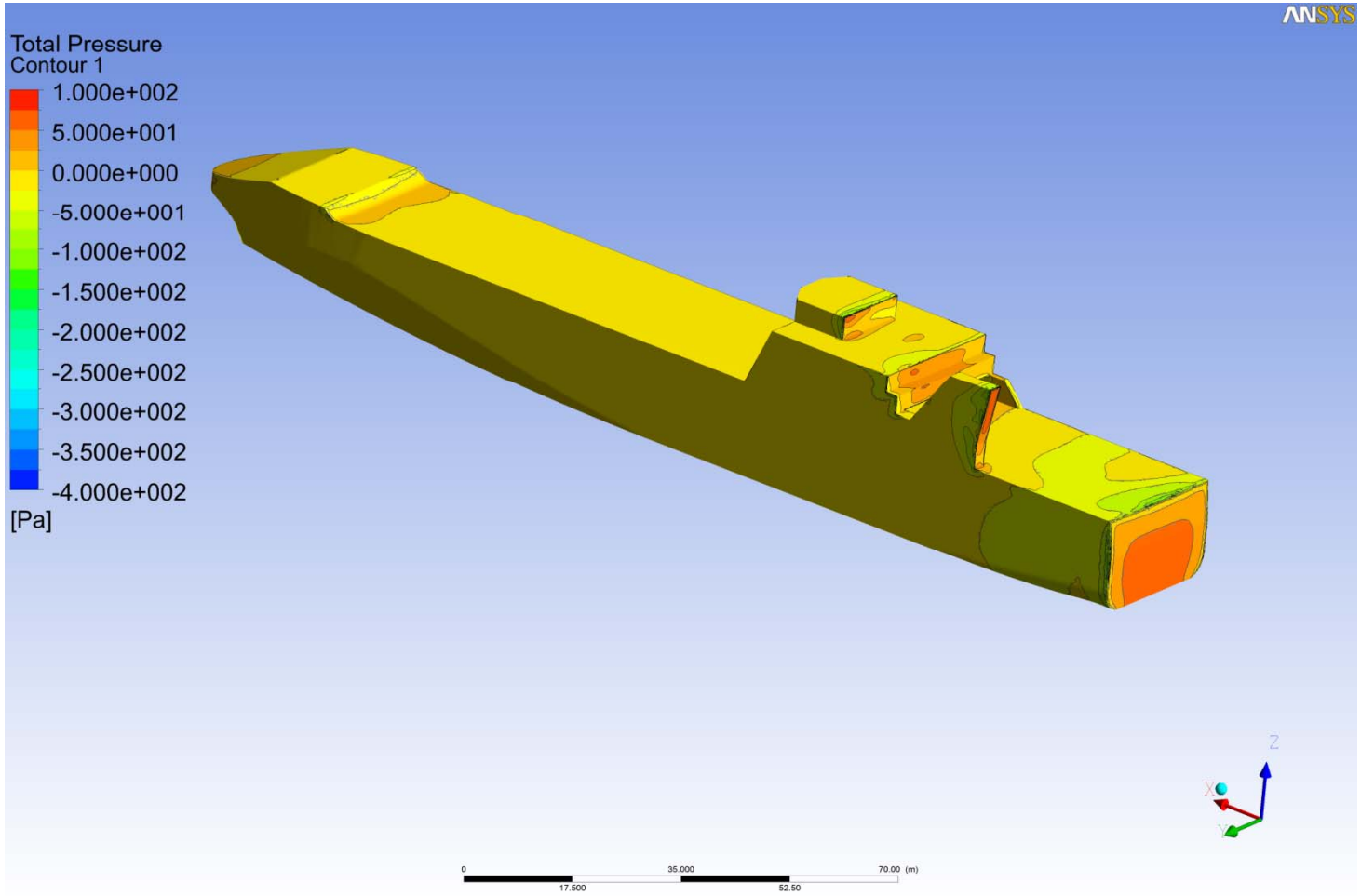
# Rüzgar Direnci



# Trim Optimizasyonu-GEVKaDeS
# Rüzgar Direnci



# Trim Optimizasyonu-GEVKaDeS
# Rüzgar Direnci



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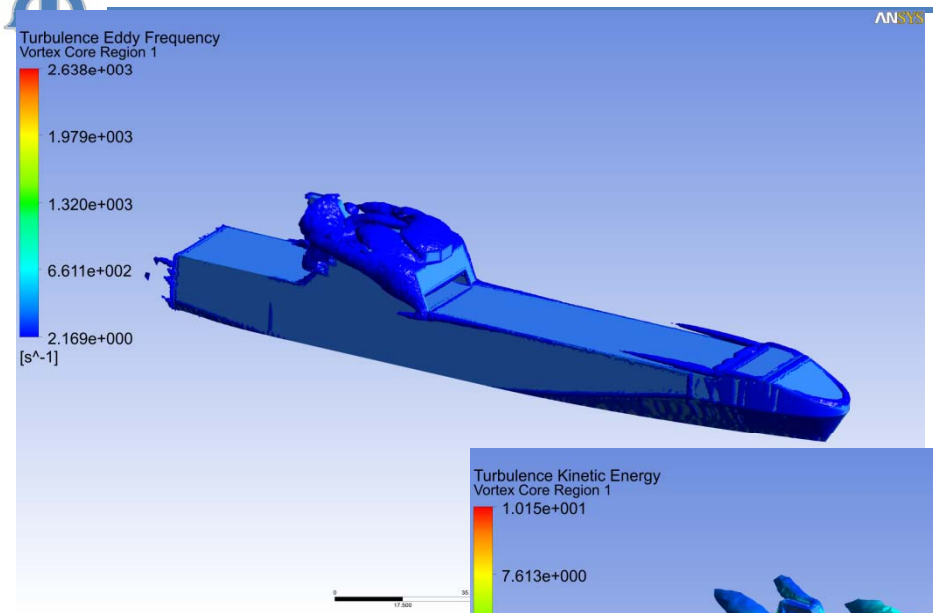
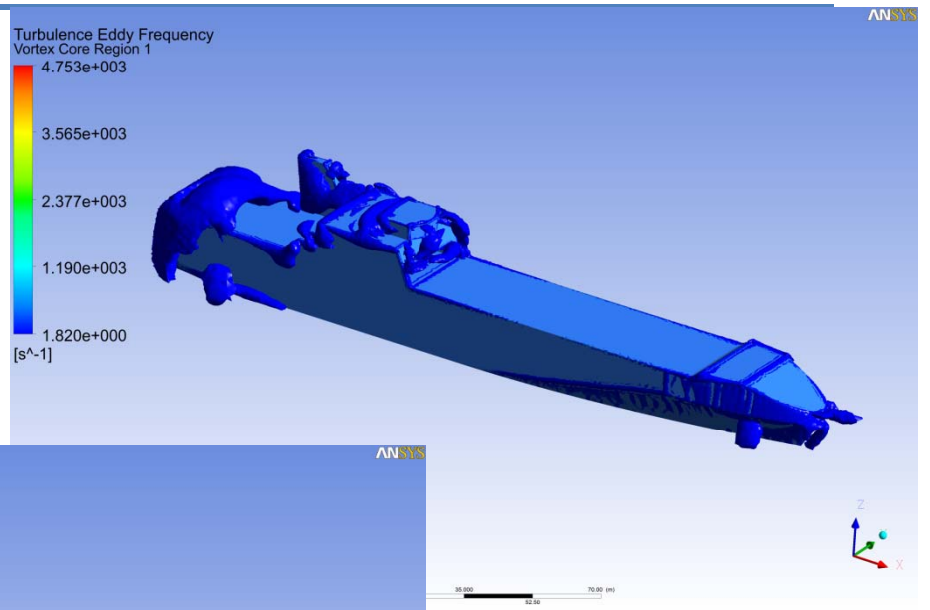
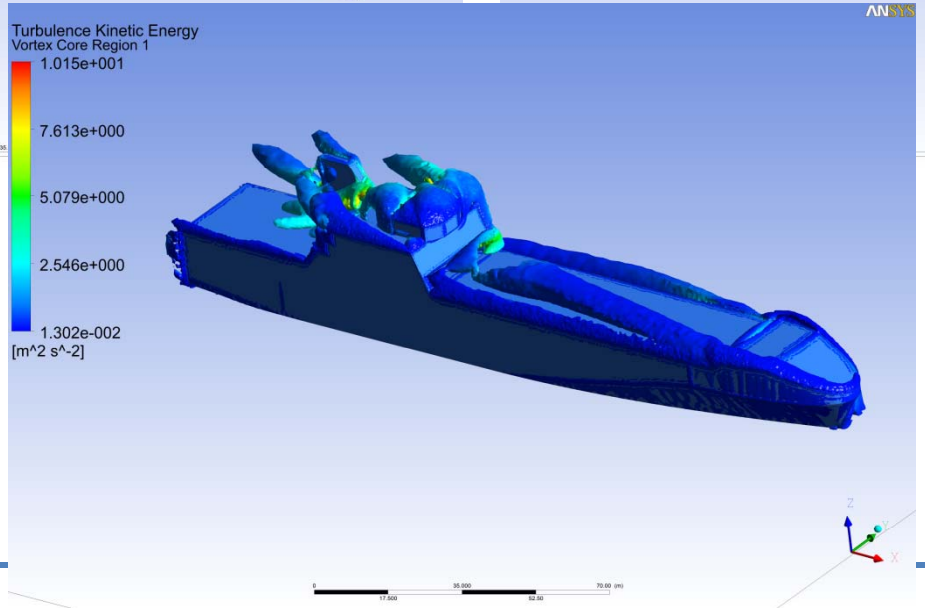
# Rüzgar Direnci

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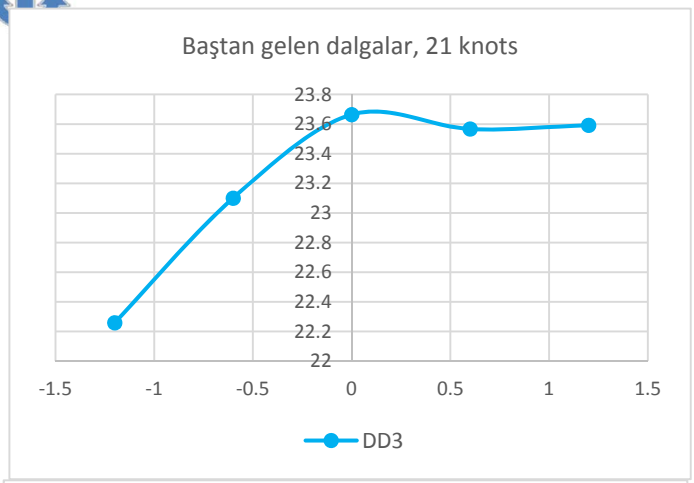
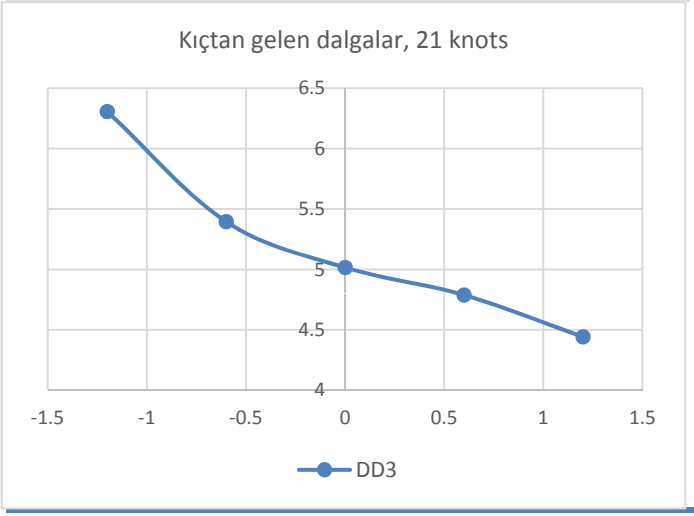
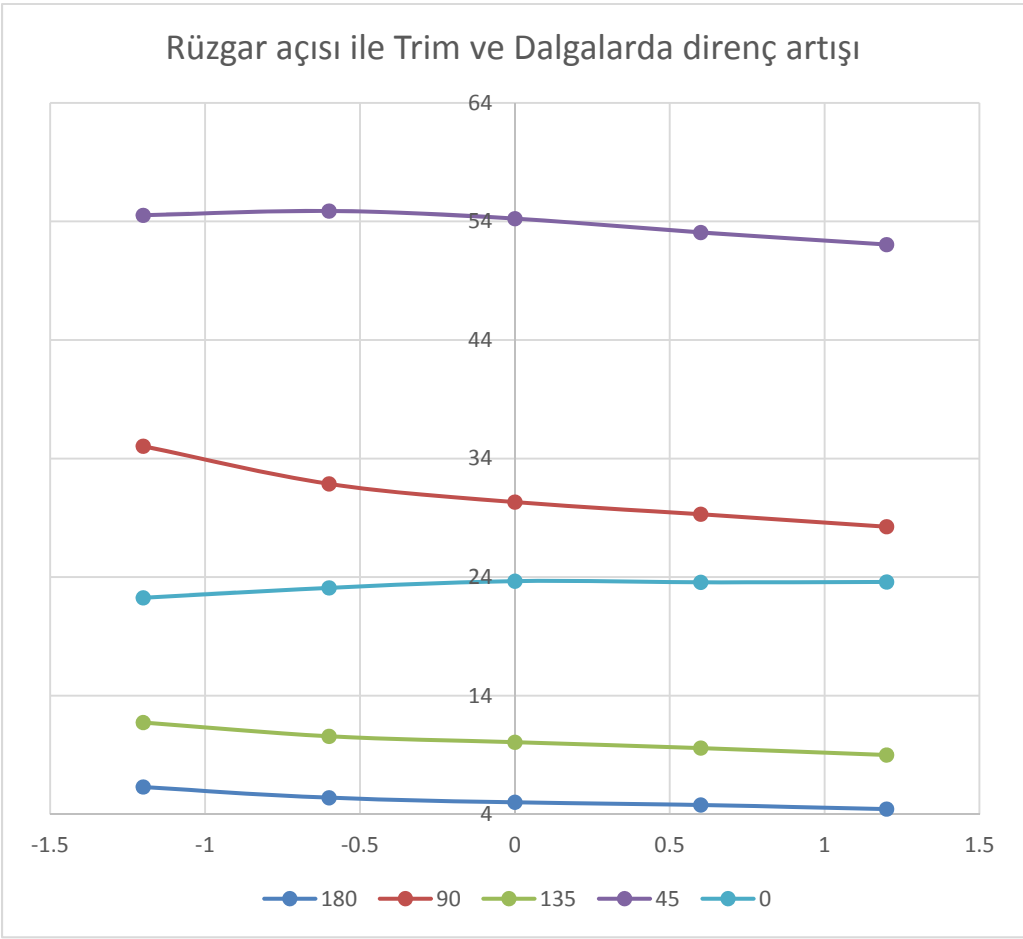
# Trim Optimizasyonu-GEVKaDeS
# Dalgalarda Direnç Artışı

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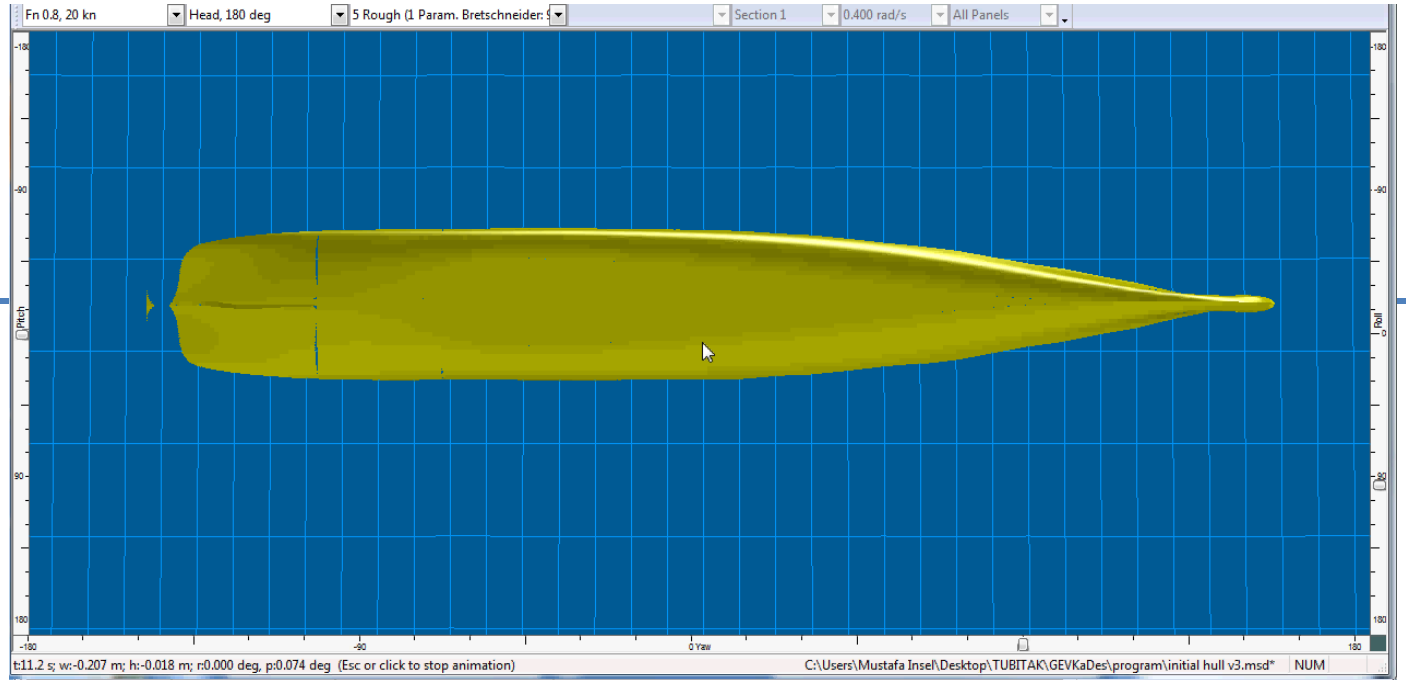
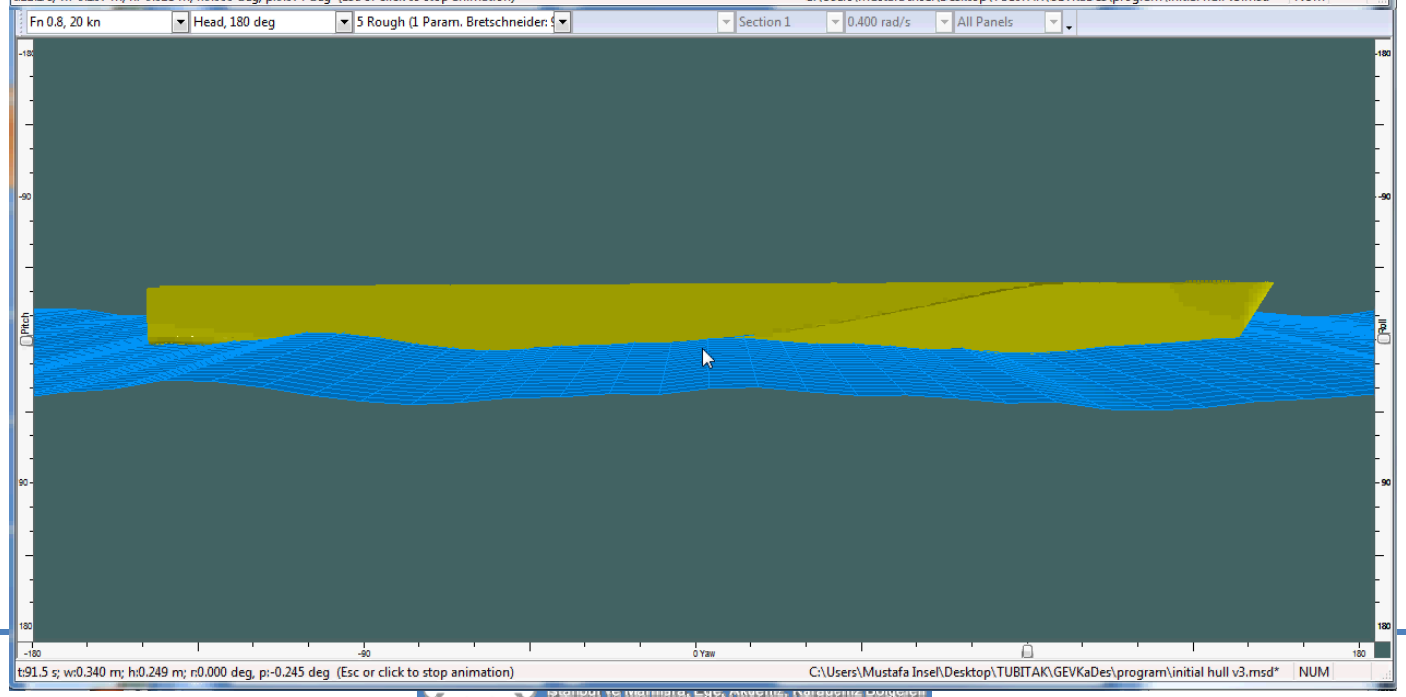
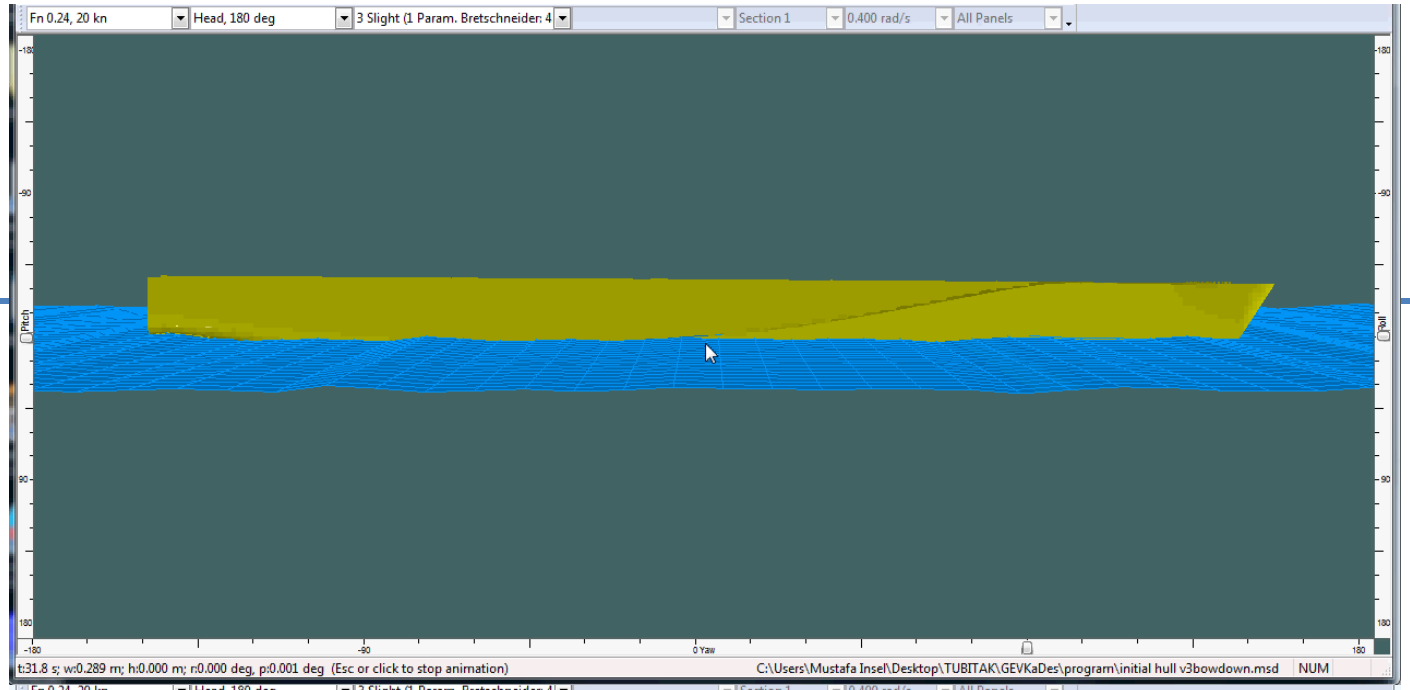
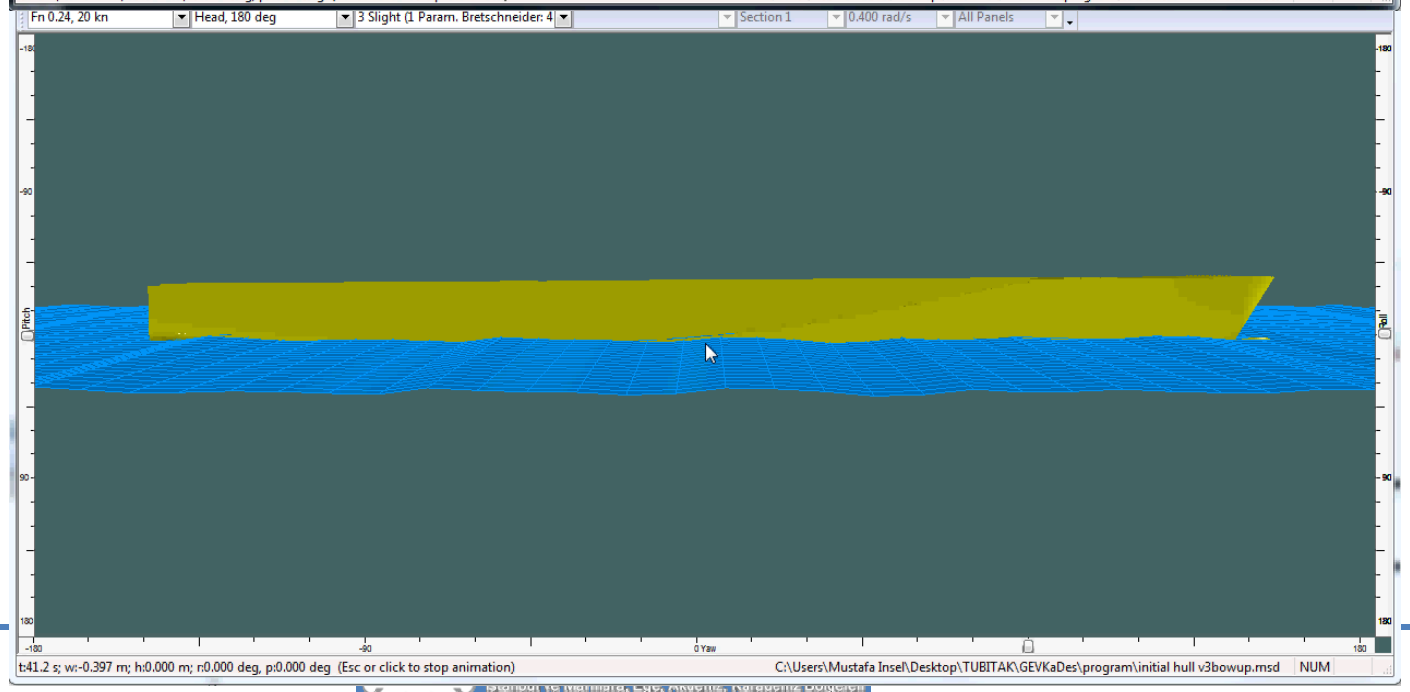
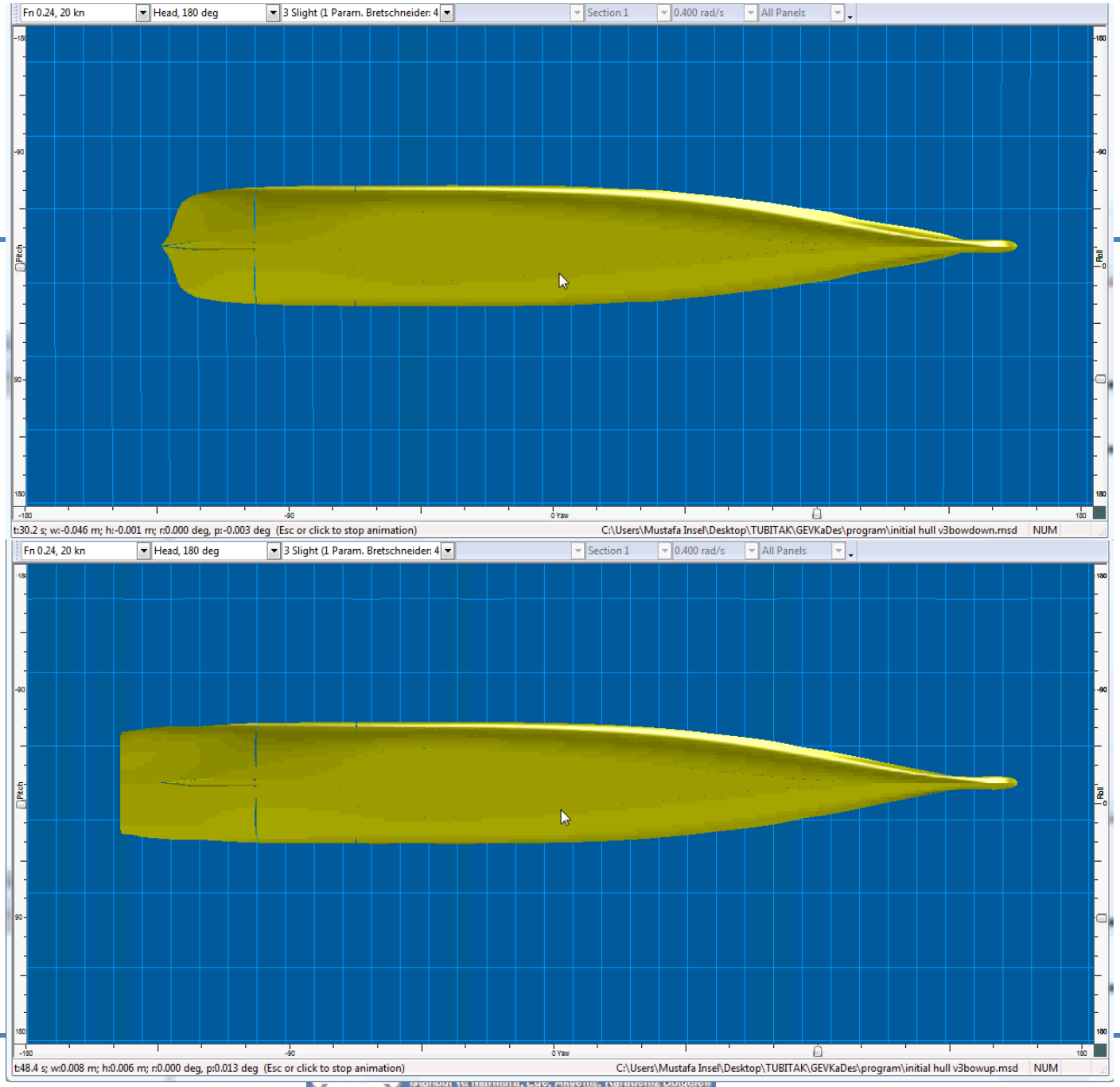


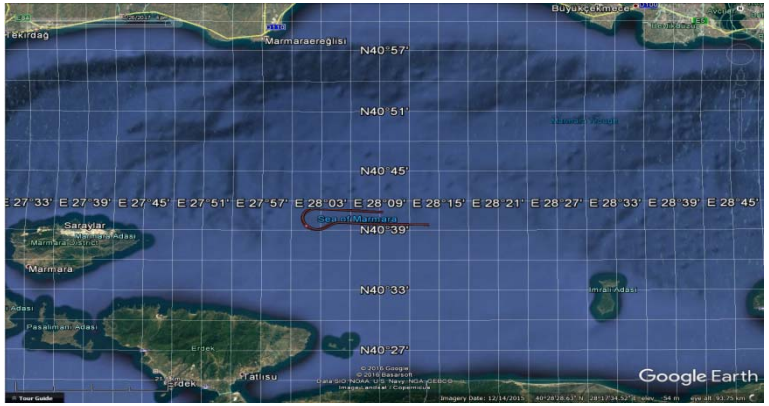




# Seyir Verileri







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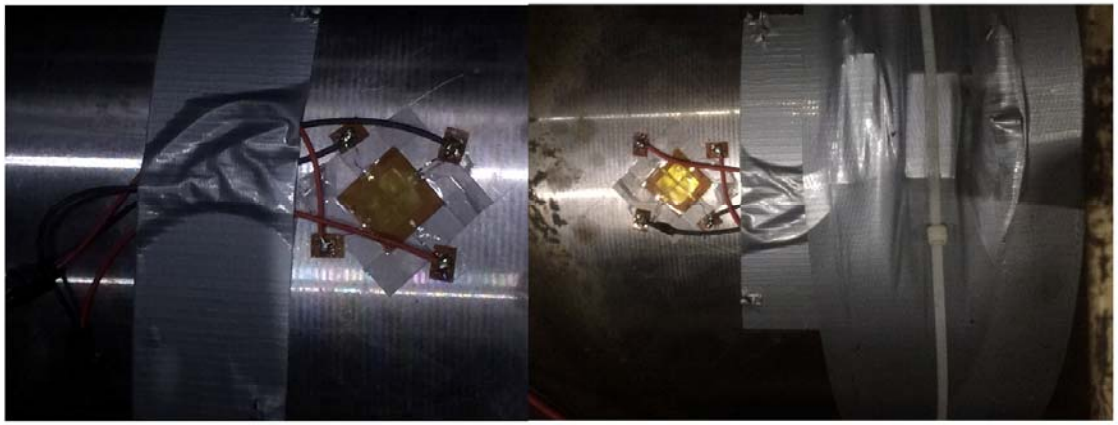
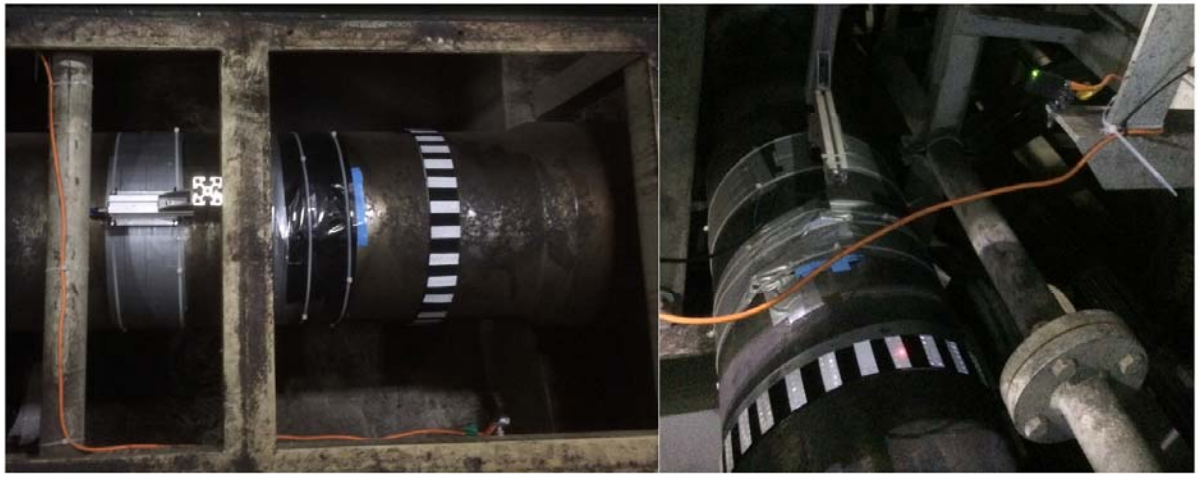
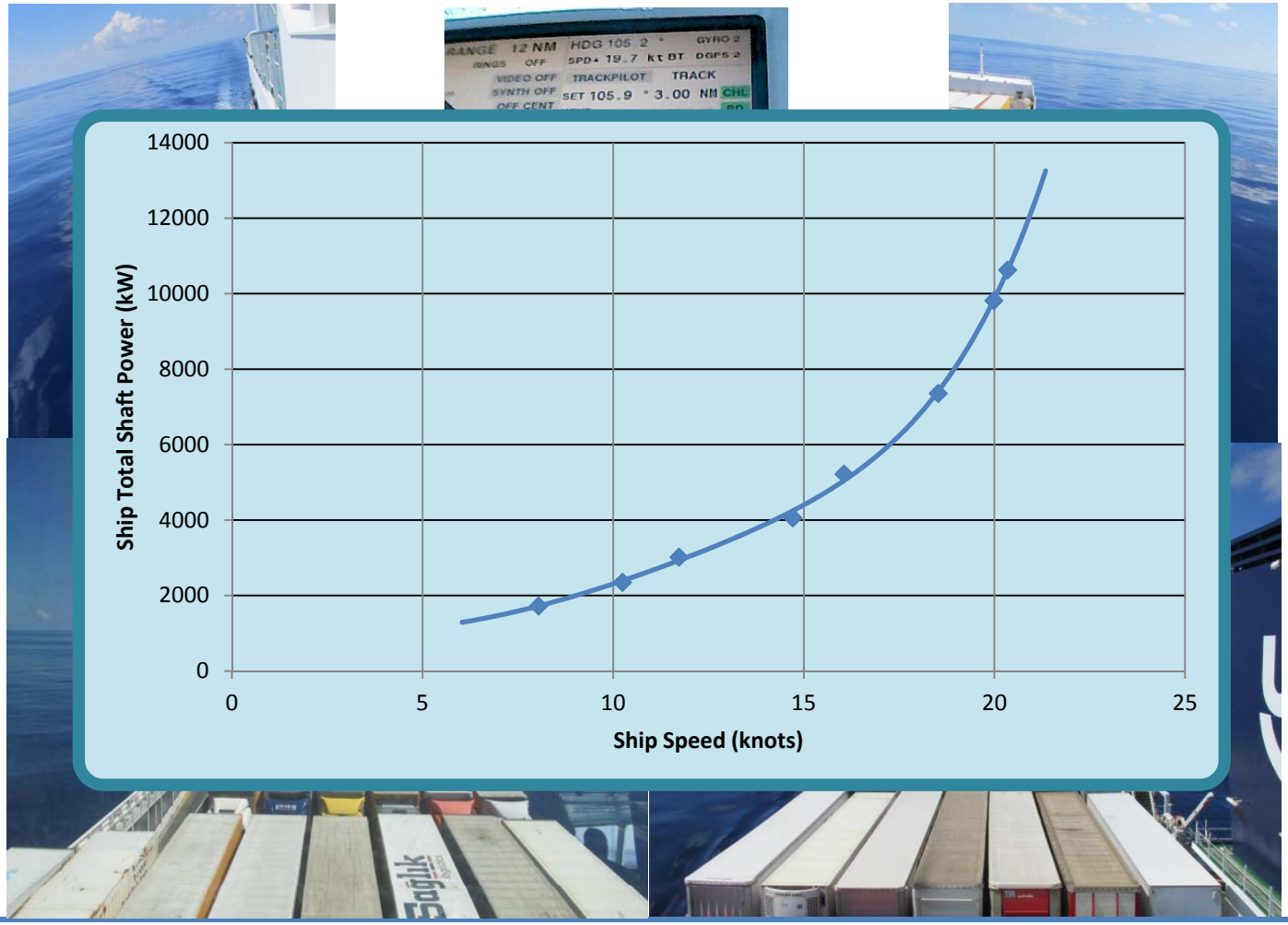




# Toulon-Istanbul Speed Trials



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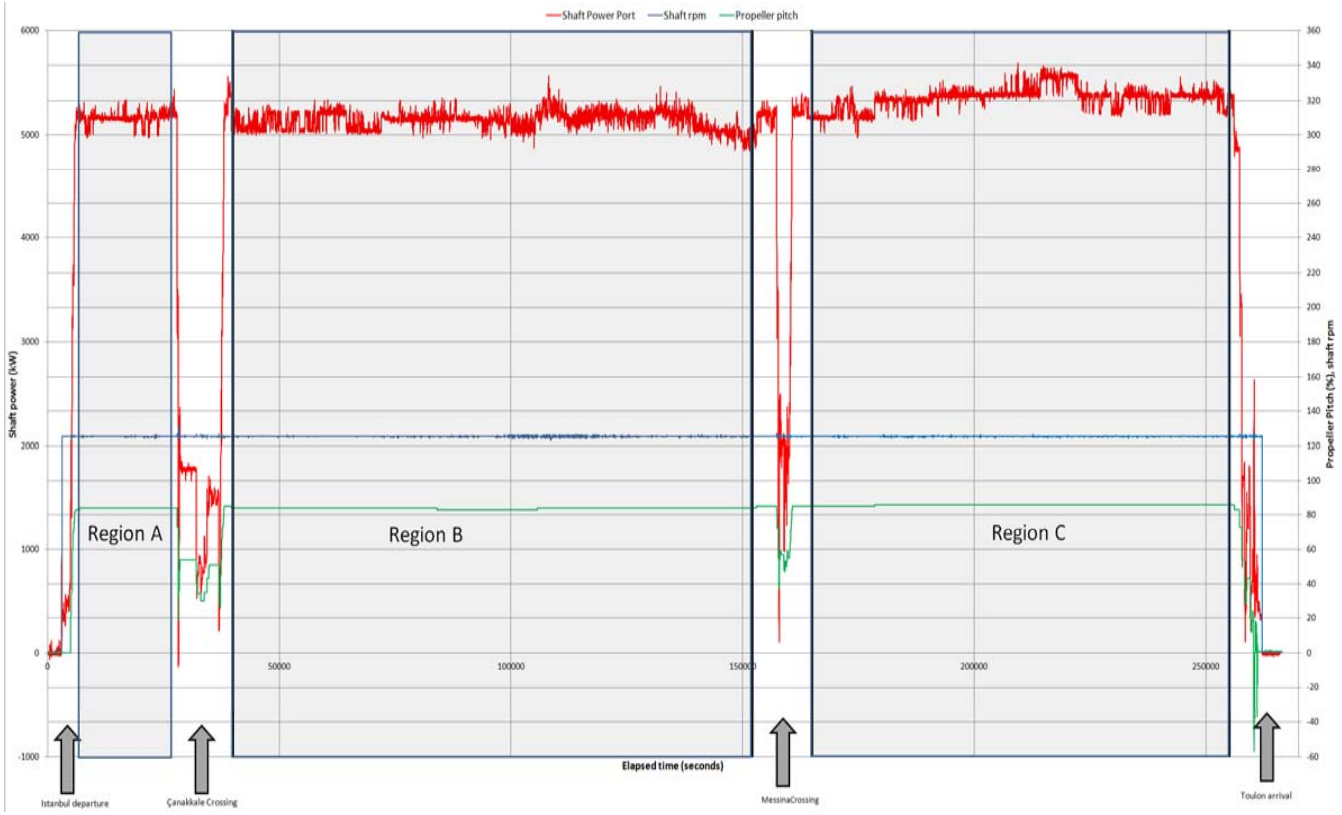
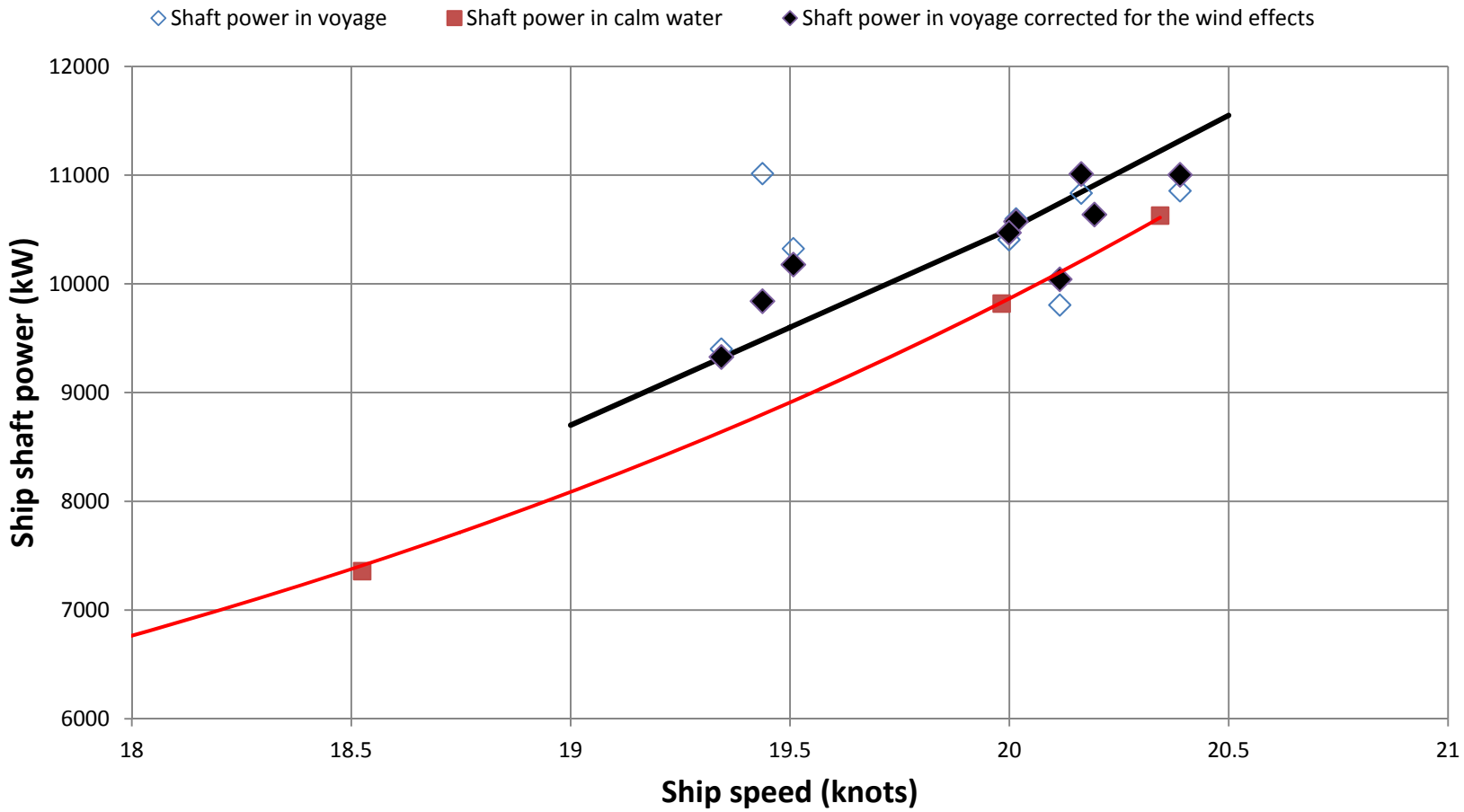
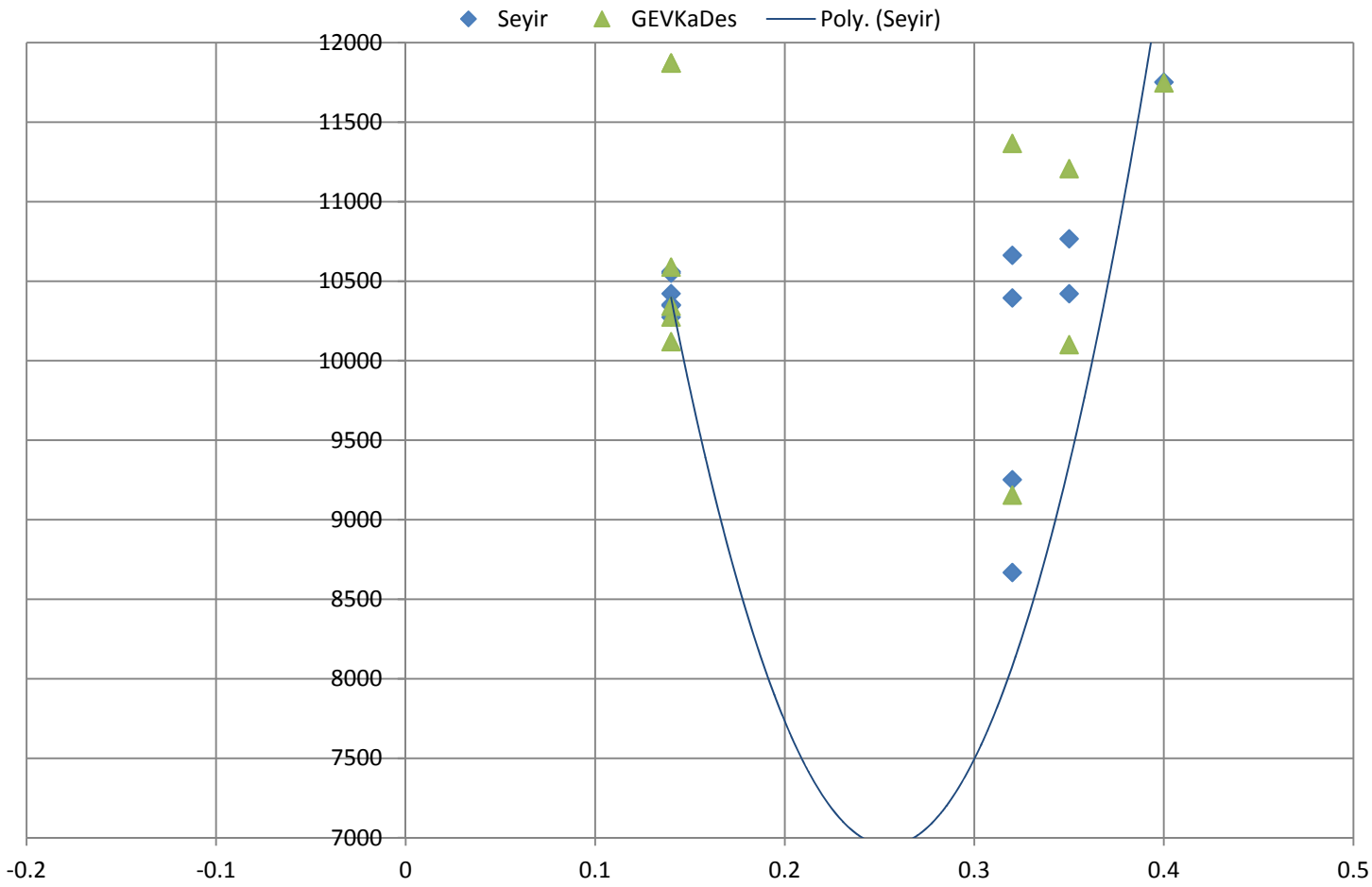
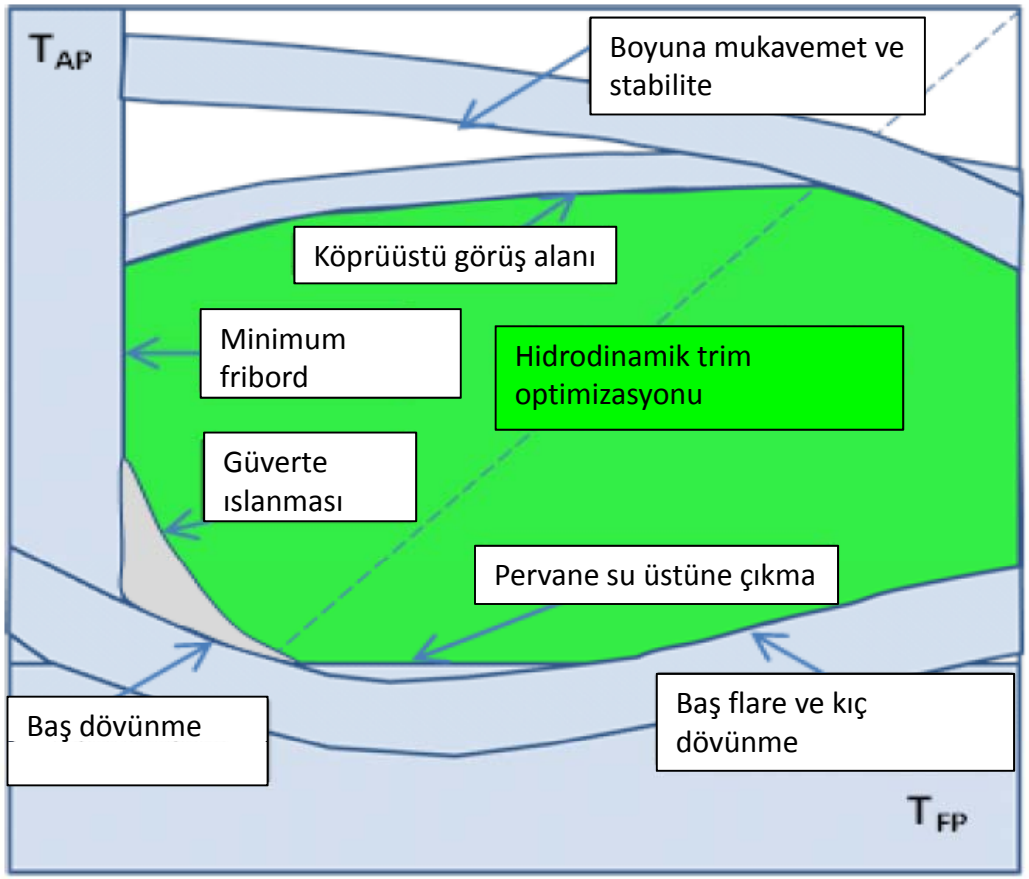


# Gerçek Deniz Koşulları




Seyir
GEVKaDes
Poly. (Seyir)
12000
11500
11000
10500
10000
9500
9000
8500
8000
7500
7000
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

# Trim Kısıtları



# İşletim Yaklaşımları

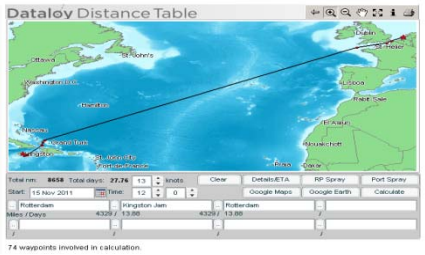




Figure 5.2.2: Wind direction probability (0: North, 90: East, 180: South, 270: West)

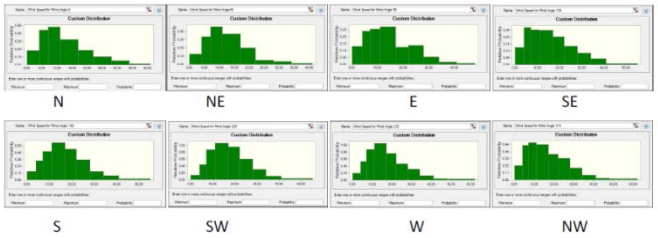



Figure 5.2.3: Wind speed representation with wind direction

Figure 5.3.3: Wave height probability distributions for each wind speed for Western Europe


# Bakım-Tutum-Modernizasyon

## Gemilerde Operasyonel Enerji Verimliliği

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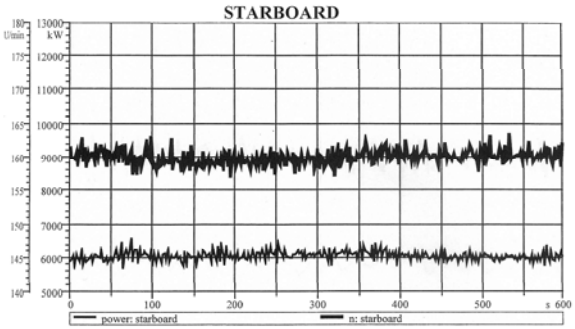
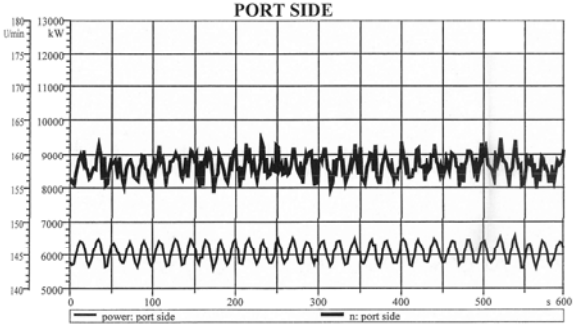
# Şaft güç ölçümü

$$P_S = 2\pi Qn$$

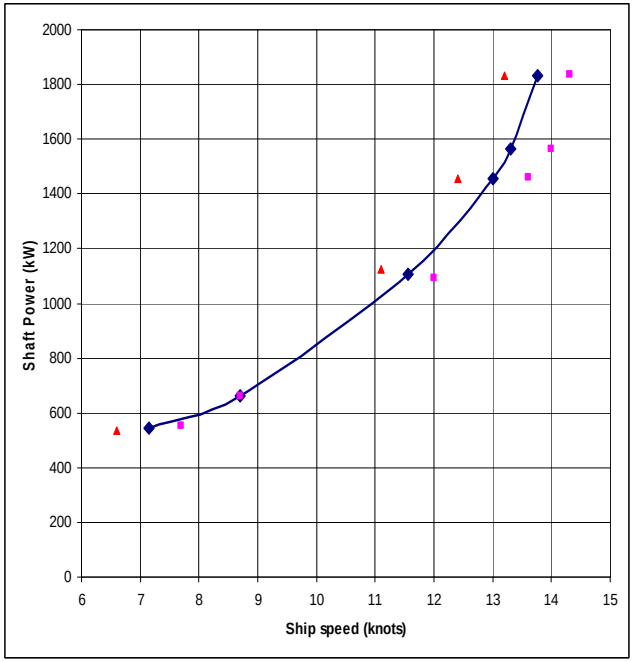
***$P_S$***: Shaft power
**Q**: Shaft torque moment
***n***: Shaft rate of revolution




| Mean Values | starboard | port side |
|---|---|---|
| power [kW]..... | 6054 | 6077 |
| r. p. m. [U/min]..... | 160,0 | 158,2 |

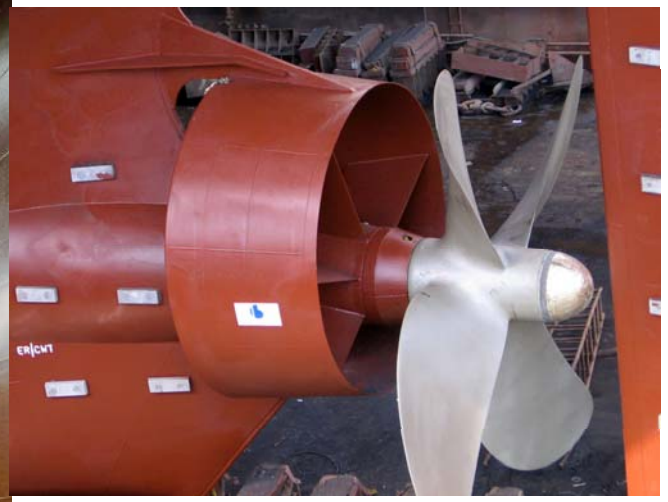
Run No. 9



# Sevk verimi arttırıcı önlemler

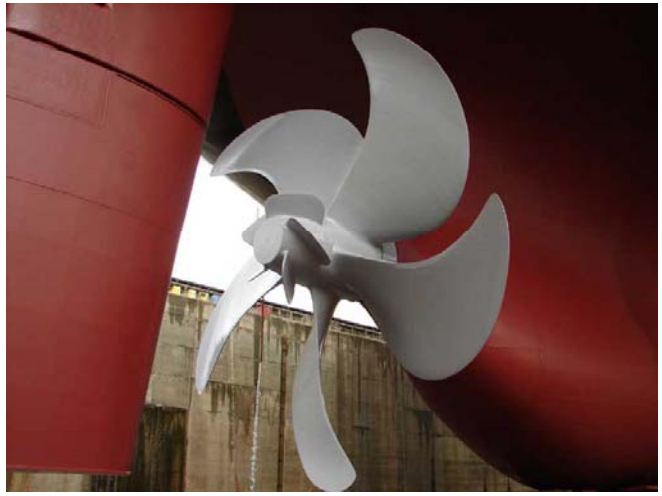
Propeller Cap Turbine

Simplified compensating Nozzle

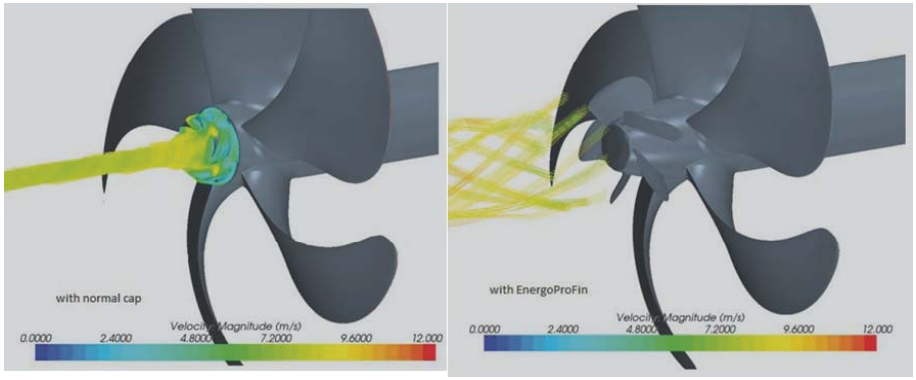


Mewis duct

# Sevk verimi arttırıcı önlemler

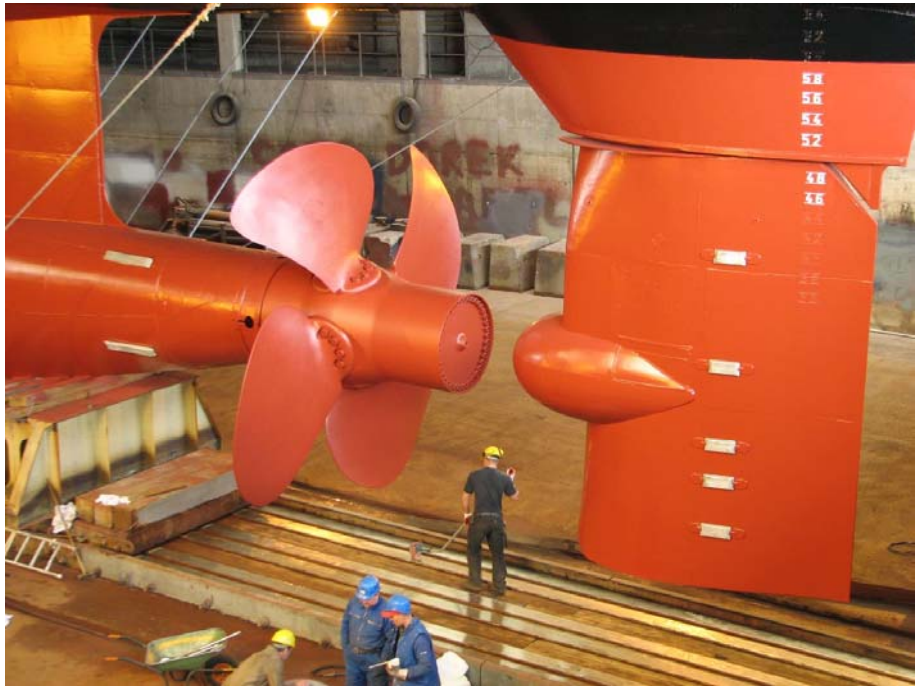


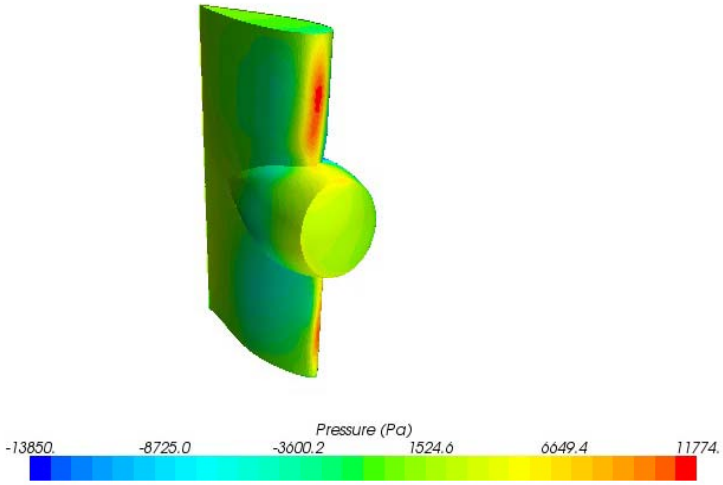
Twisted Fin




Boss cap

# Sevk verimi arttırıcı önlemler



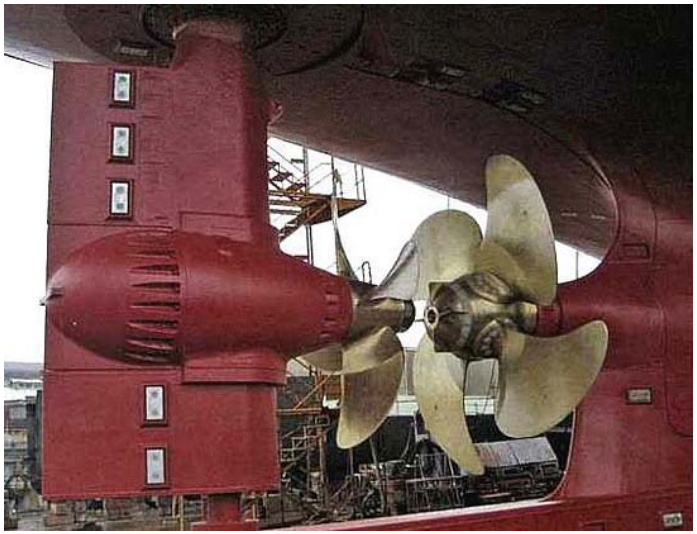


# Pervane Değişimi

KAPPEL

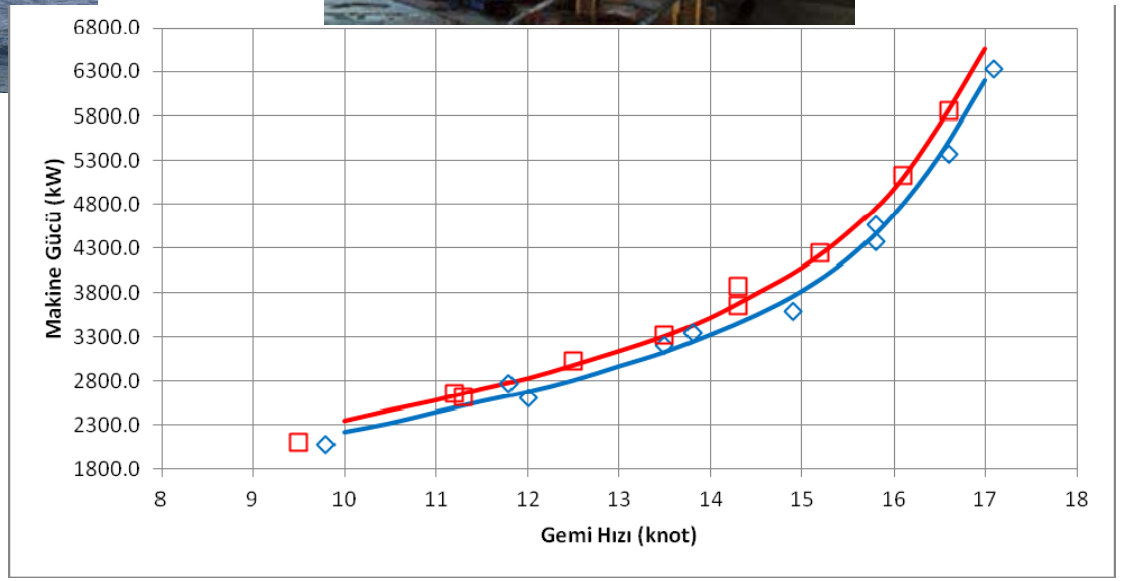
CLT

CONTRAROTATING

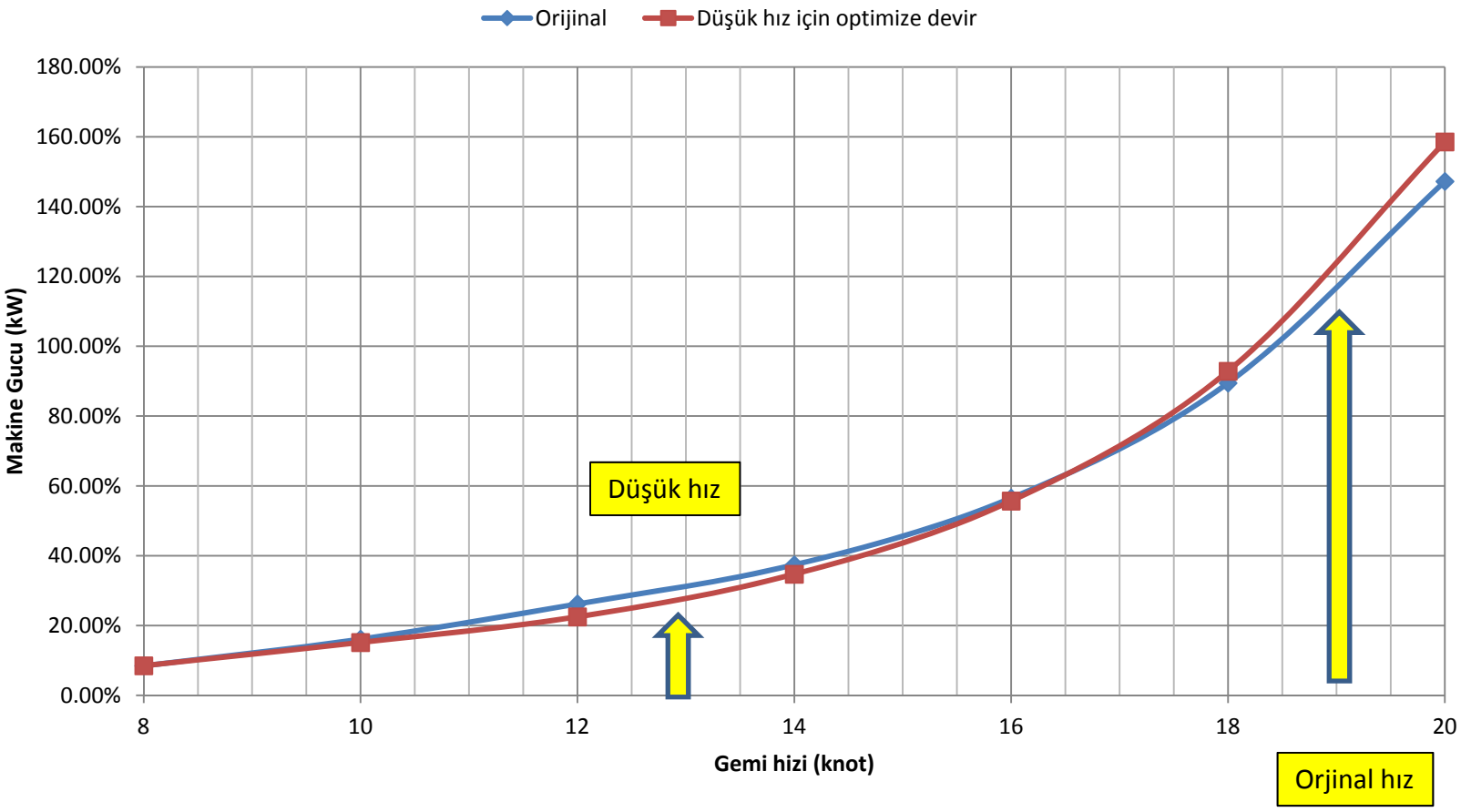


# Boya etkisi


ARKAS


6800.0
6300.0
5800.0
5300.0
4800.0
4300.0
3800.0
3300.0
2800.0
2300.0
1800.0
Makine Gücü (kW)
8
9
10
11
12
13
14
15
16
17
18
Gemi Hızı (knot)

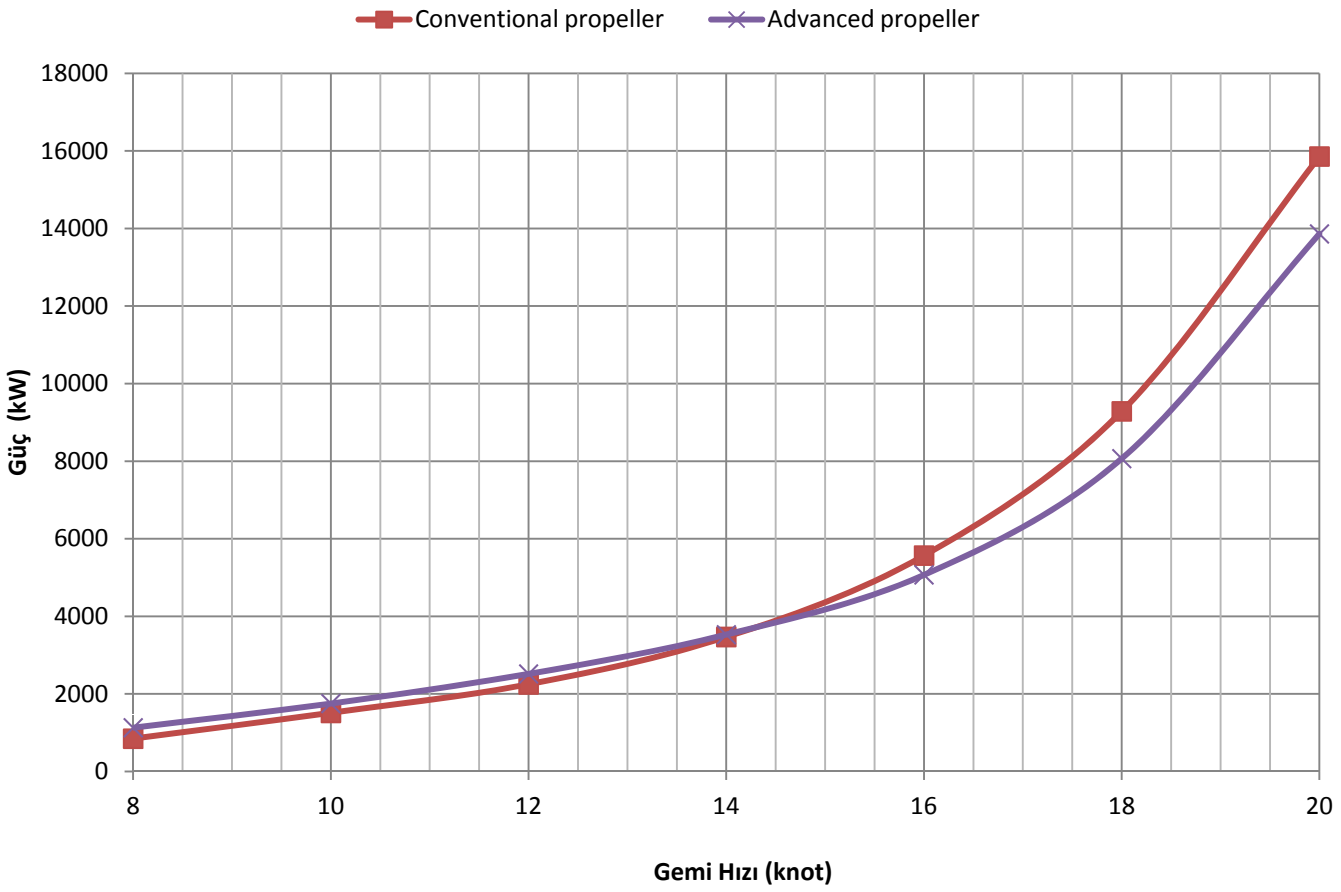
# Pervane devir etkisi



# Pervane Değişimi

KAPPEL

CLT



# Yüksek Verimli Pervane

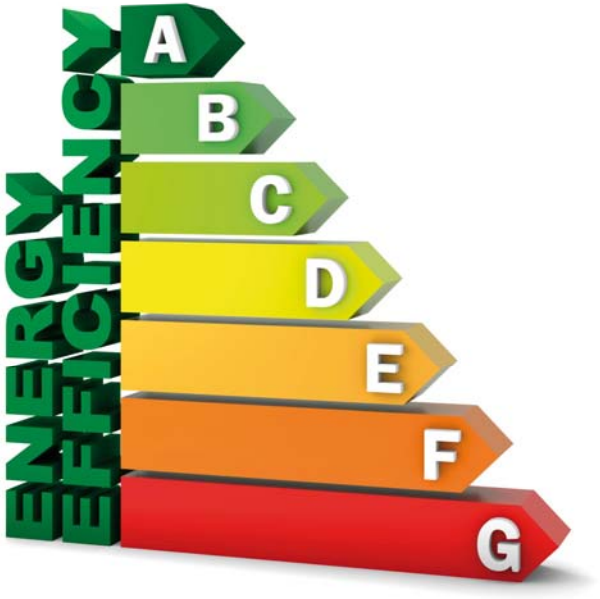
# Teşekkürler

Bu çalışmaların hazırlanmasında yardımlarından dolayı

- U.N. Roro
- ARKAS denizcilik ve nakliyat AŞ.

ye teşekkür ederiz

# Teşekkürler




Mustafa Insel : minsel@hidro-teknik.net