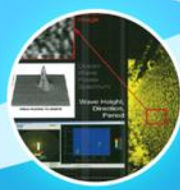
선박유체역학 관점에서의 친환경 해운 및 조선 전망
Environment-friendly shipping and shipbuilding prospects in terms of ship hydrodynamics

신 명 수 (Shin, Myung-Soo)

2018. 10. 18



한국해양과학기술원 부설 선박해양플랜트연구소
(Korea Research Institute of Ships & Ocean Engineering)

목 차

개 요

➢선박유체역학 관점에서의 친환경 해운 및 조선전망

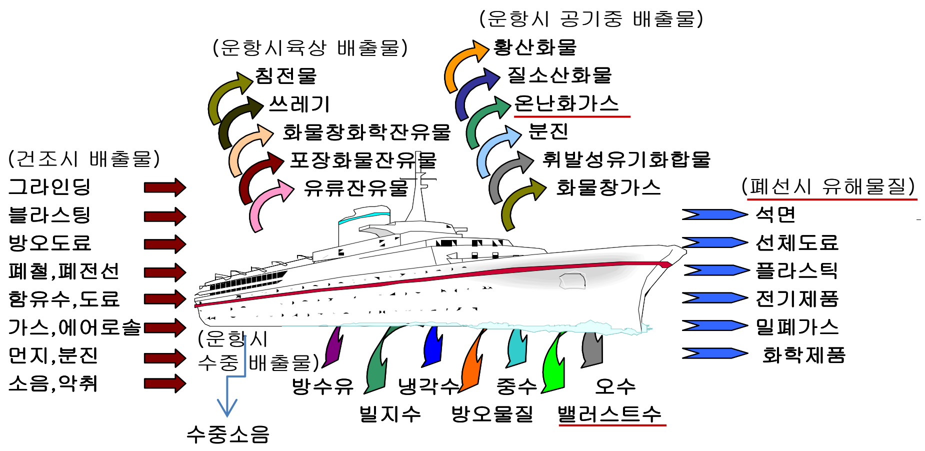
✓선박 저항, 추진, 소요 동력(DHP) 관점에서 논의 함.

➢신조선 EEDI

✓수송효율과 EEDI, 향후 동향에 대하여 논의함.

➢운항선 효율향상

✓운항선 효율 향상을 위한 향후 연구방향, 외국 연구결과에 대하여 논의함.



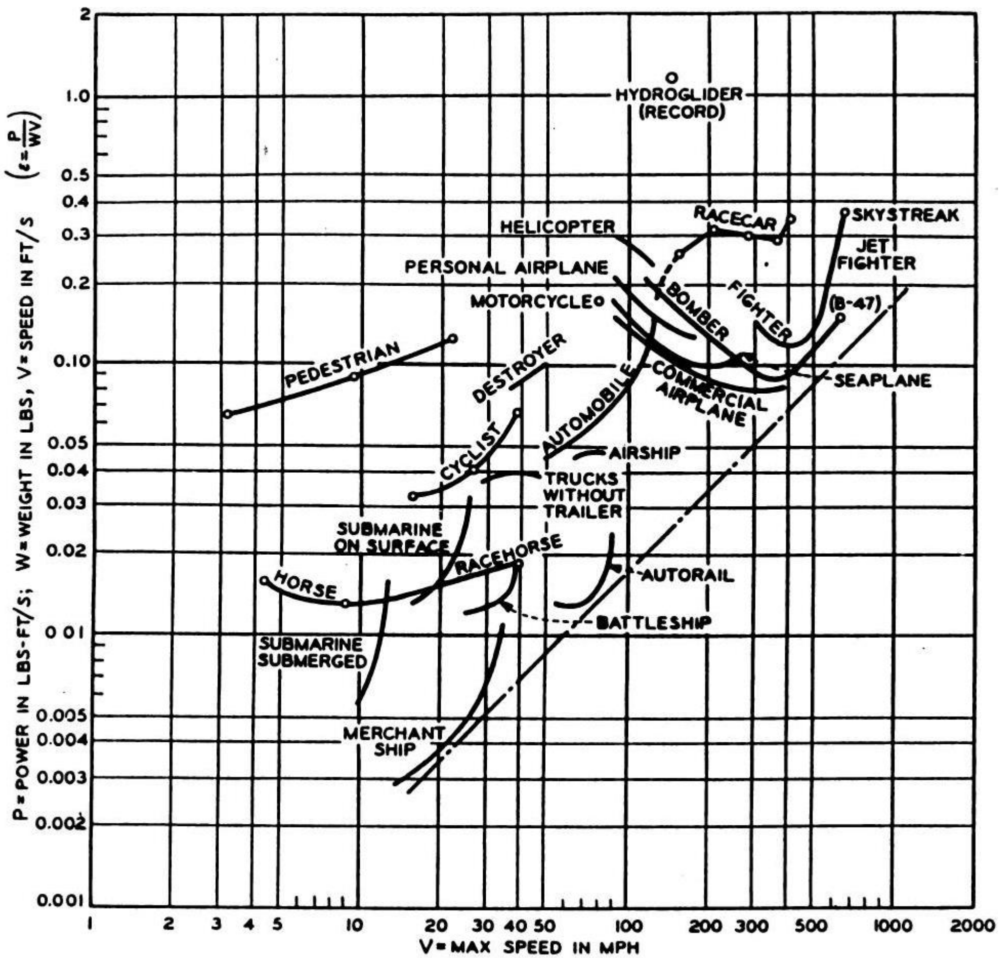
Source: Dr. E.C.Kim (2005)

선박유체역학 관점에서의 친환경 해운 및 조선 전망

신조선 EEDI

Von Karman – Gabrielli Diagram

$$\frac{Kw}{\Delta \cdot V} = \frac{Drag}{Weight}$$



- Gabrielli and G, von Karman T., `What price speed? Specific power required for propulsion of vehicles' Mech Eng., ASME, Vol 72, pp. 775–781, 1950
- 인류가 개발한 수송체의 수송효율을 그려보면, 최대치가 일정선에 접근함 (K-G Line)
- 같은 무게, 엔진조건에서 <u>수송체의 경쟁력은 속도</u>

1950년

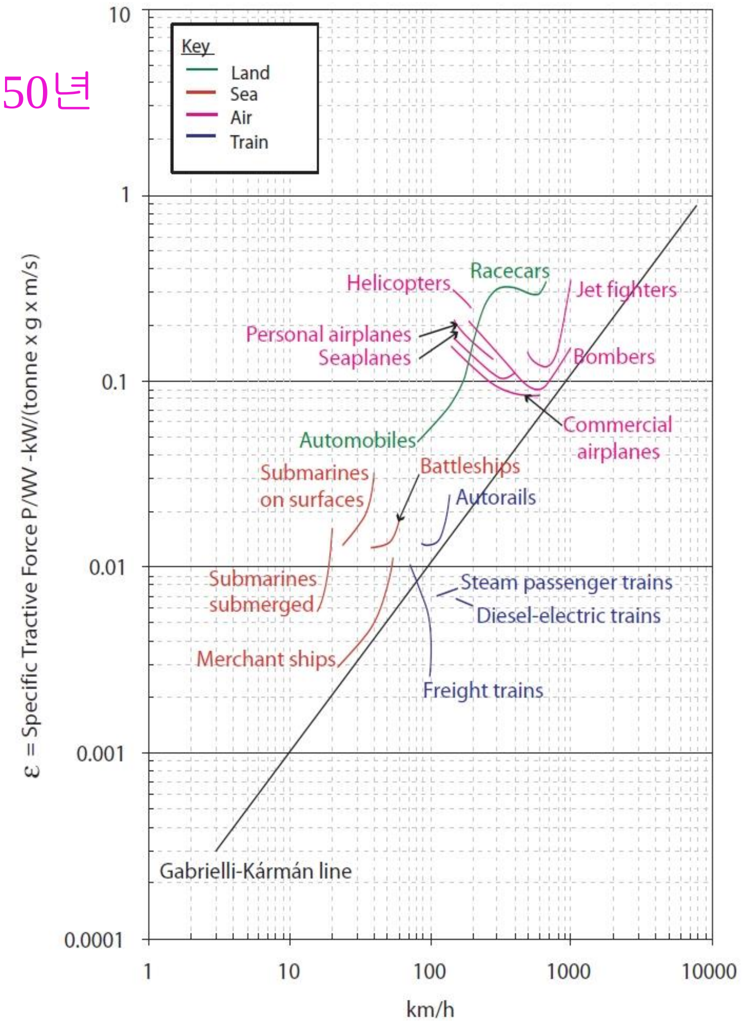


Figure 1

Specific resistance for various transport modes before 1950. The Gabrielli-Kármán (GK) line represents best performance.

2004년

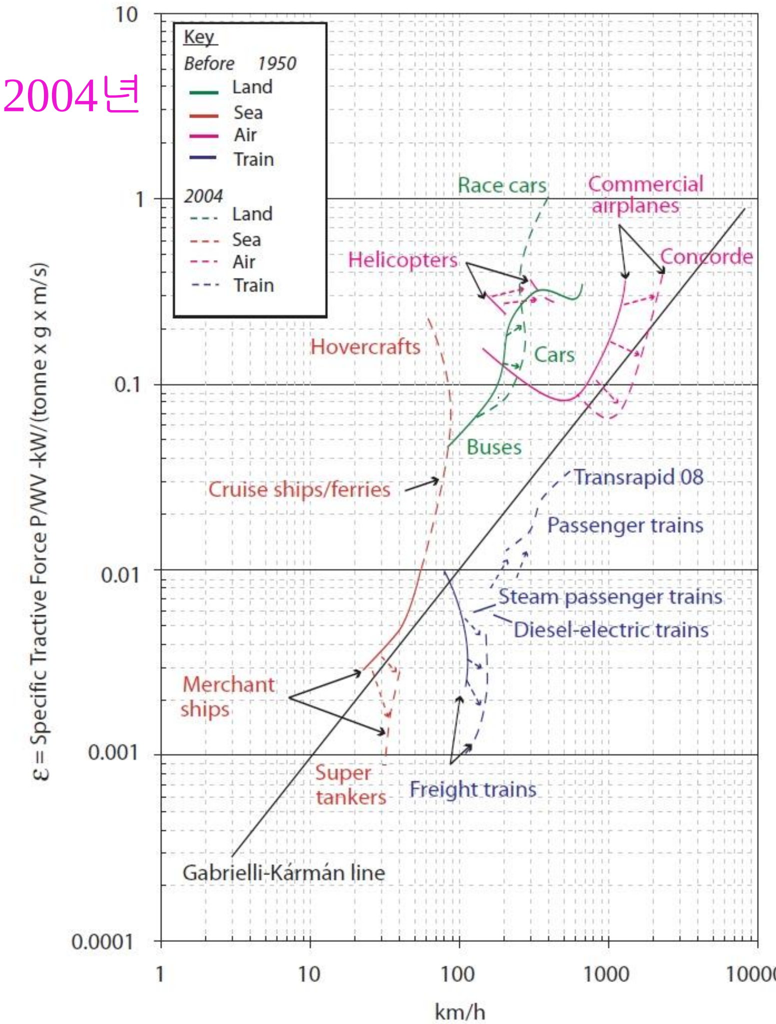


Figure 2

Updated specific resistance of various transport modes (with exception of military vehicles) over the last 54 years. The data lines for sea, land and air transport have moved below the original GK line (movement illustrated by arrows), which illustrates considerable performance improvement in all kinds of transport.

➢ Yong, J., Smith, R., Hatano, L. and Hillmansen, S. (2005) what price speed – revised, Ingenia 22, March 46-51

수송효율과 EEDI

- ➢ $\mathrm{EEDI} = \mathrm{SFC} \times C_F \times$ 수송효율

- ➢ 수송효율 $= \dfrac{\mathrm{Drag}}{\mathrm{Weight}} = \dfrac{R_T}{\Delta} = \dfrac{R_T \cdot V}{\Delta \cdot V} = \dfrac{Kw}{\Delta \cdot V}$

- ➢ $\mathrm{EEDI} = \mathrm{SFC} \times C_F \times \dfrac{Kw}{\Delta \cdot V} \left(= \dfrac{R_T}{\Delta} \propto \dfrac{C_T \cdot V^2}{Ls}\right)$
  - ✓SFC : Specific Fuel Consumption rate of Engine (g/Kwh)
  - ✓C_F : Non-Dimensional Conversion Factor (t-CO2/t-Fuel, 선박용 벙커유 3.1144)

- ➢ EEDI는 특정 수송효율(저항/배수량비)로 운항하는 선박으로부터 발생되는 GHG양이며, 단위는 g-CO_2/ton·mile (SFC와 같음. g/Kw·h)

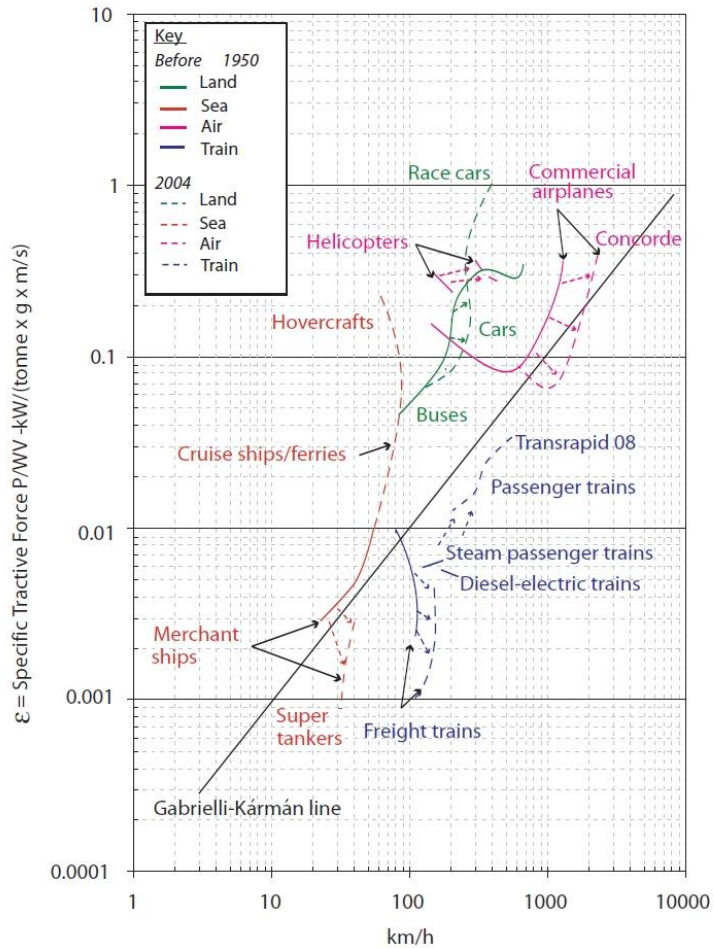


Figure 2
Updated specific resistance of various transport modes (with exception of military vehicles) over the last 54 years. The data lines for sea, land and air transport have moved below the original GK line (movement illustrated by arrows), which illustrates considerable performance improvement in all kinds of transport.

수송효율, EEDI, EEOI

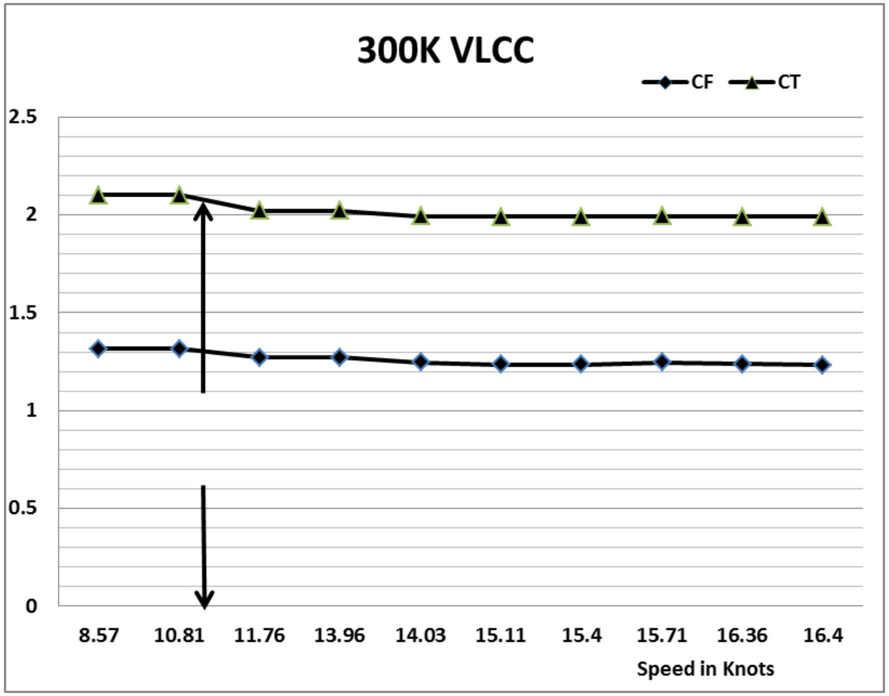
- $\text{EEDI} = \text{SFC} \times C_F \times \frac{\text{Kw}}{\Delta \cdot V} \left(= \frac{R_T}{\Delta} \propto \frac{C_T \cdot V^2}{Ls}\right)$
  - ✓저항에 비례, 배수량에 반비례
  - ✓전저항계수 (C_T)에 비례
  - ✓v^2에 비례
  - ✓L_S(Length Scale)에 반비례

- EEDI, EEOI
  - ✓EEDI 분자, 분모에 t(time)를 곱하면
  - ✓$\text{EEDI} = \text{SFC} \times C_F \times \frac{\text{Kw} \cdot t}{\Delta \cdot V \cdot t}$

$$= C_F \times \frac{\text{FC (mass of consumed fuel)}}{\Delta \cdot D}$$

$$= \text{EEOI}$$

  - ✓<u>EEOI는 특정시간 동안의 EEDI평균</u>



$R_T = \frac{1}{2} \rho s v^2 \bullet C_T$

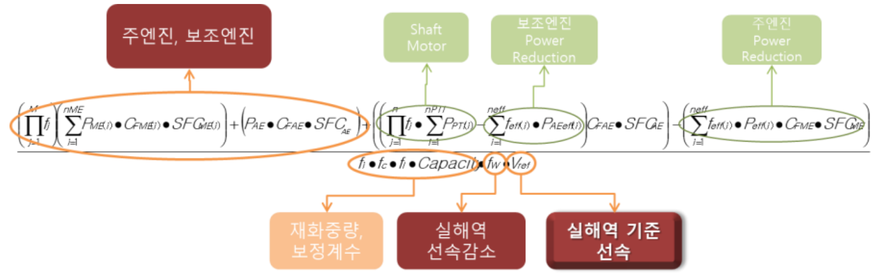
$\text{Kw} = R_T \bullet v$

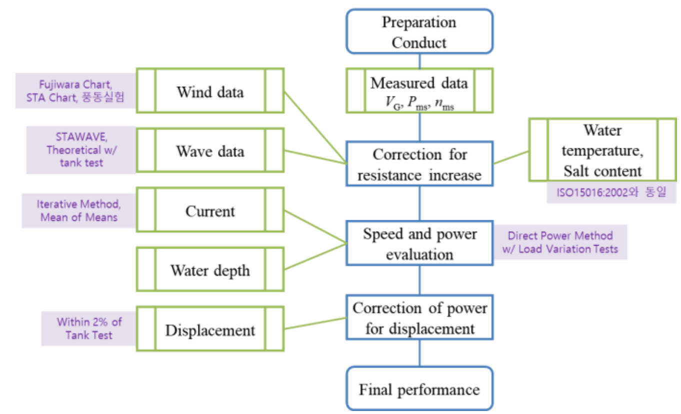
S : wetted surface area

C_T : 전저항계수 ($C_F + C_R$)

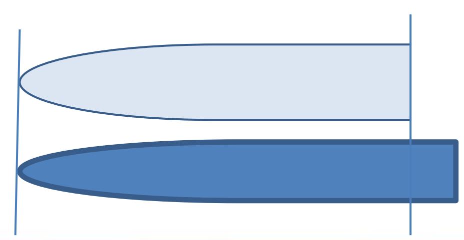
EEDI를 낮추기 위한 향후 동향

- **선형개발, 고효율 추진기 개발**
  - ✓높은 기준선속(Vref) 달성
- **선박 주요목 변화**
  - ✓길이 늘리고, 폭 줄이며, Cb (Block Coefficient)낮춤
    - 침수표면적이 증가하는 바, 한계 있음.
  - ✓경하중량 증가로 신조선 가격 상승
- EEDI가 V^2에 비례 하는바, **<u>기준 선속의 저속화</u>**
  - ✓최소추진출력 제한 조건과 상충





기준선속 (ISO15016:2015 Flow Chart)



선박유체역학 관점에서의 친환경 해운 및 조선 전망

운항선 운항 효율 향상

상가 전후 성능분석 (PBCF장착)

➢ Application of low friction Anti-Fouling paint and Propeller Boss Cap Fin(PBCF)

<Arrival Condition>

<Blasting & Painting>

<PBCF>

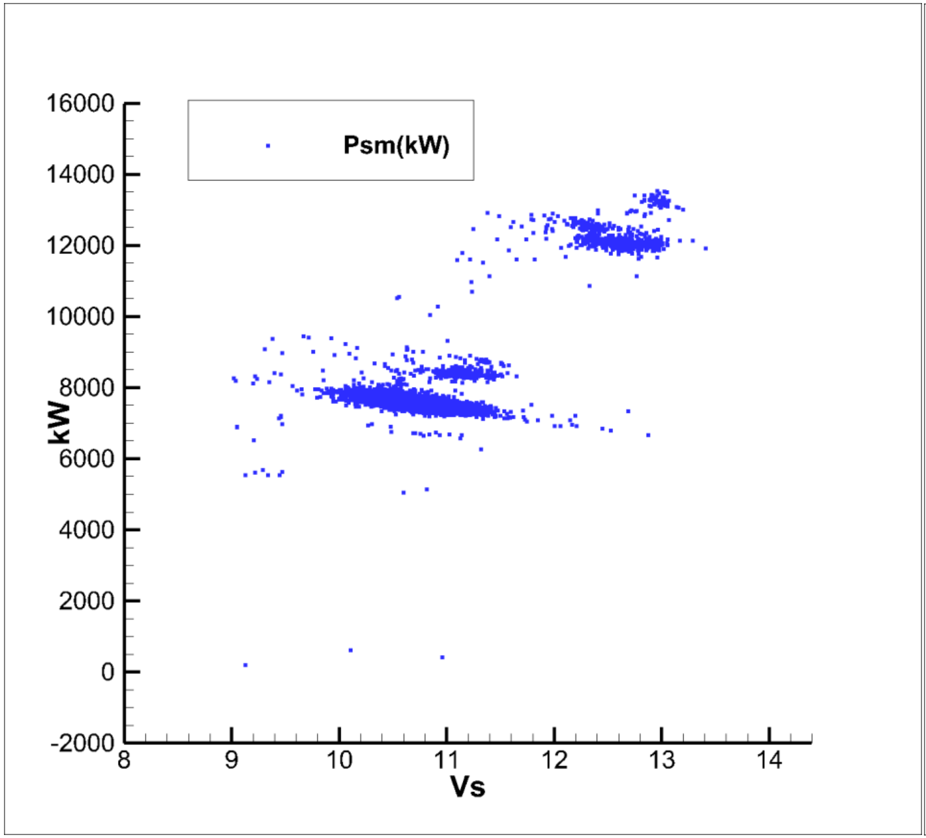
상가 전후 성능분석 (PBCF장착)

➢ After dry-docking : Application of Propeller Boss Cap Fin

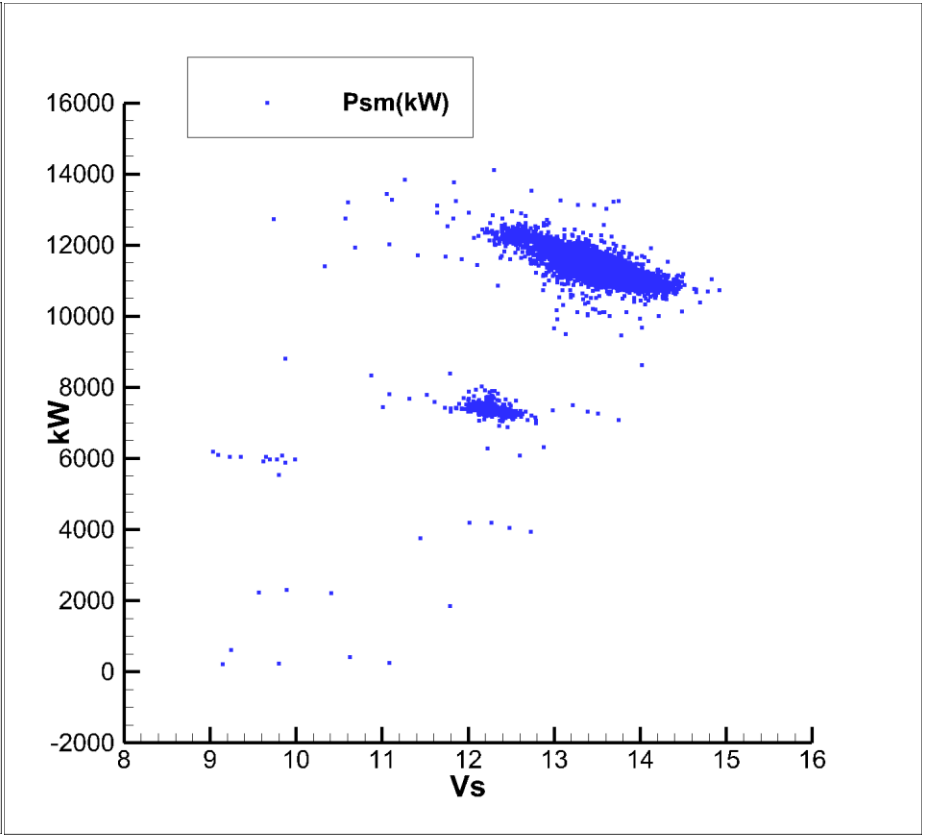
Speed-Power Analysis

Measured Speed-Power

- ➢ Before dry-docking



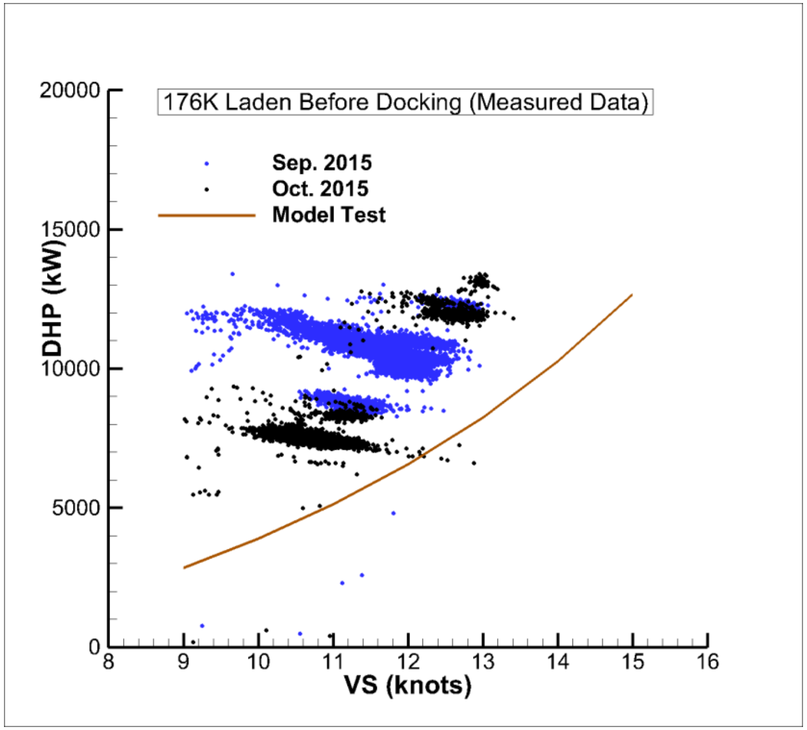
- ➢ After dry-docking



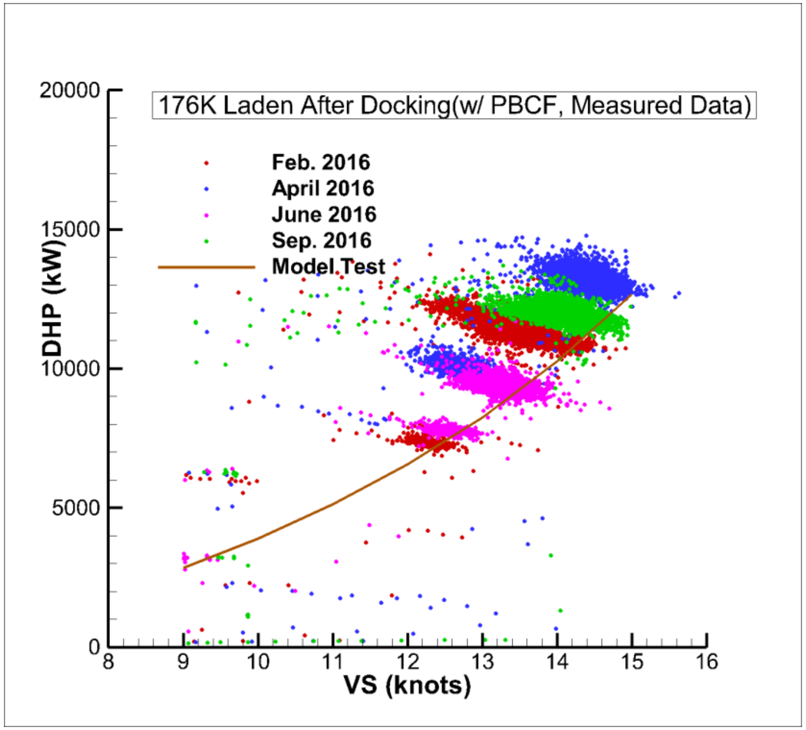
Speed-Power Analysis

Speed-Power Curve (before filtering)

➢ Before dry-docking



➢ After dry-docking



Speed-Power Analysis

➢ Analysis Outline

✓ Analysis was carried out laden condition only

- Australia → South Korea
- One LEG Sailing time : 15 days

✓ Using 2 LEGs data before dry-docking, 4 LEGs data after dry-docking

✓ Analysis was carried out based on speed trial data analysis method (ISO15016:2015)

➢ Input data

✓ Ship data

- Main Dimension such as L_{OA}, B, L_{PP}, C_B.....
- Towing tank test result such as t, w, ηR, ηD.....

✓ Measured data from operating ship such as V_G, V_S, n_{ms}, P_{Sms}, Ψ, V_{WR}.....

- Data Frequency : 2 min.
- The number of data collected by one LEG : 8,000~10,000

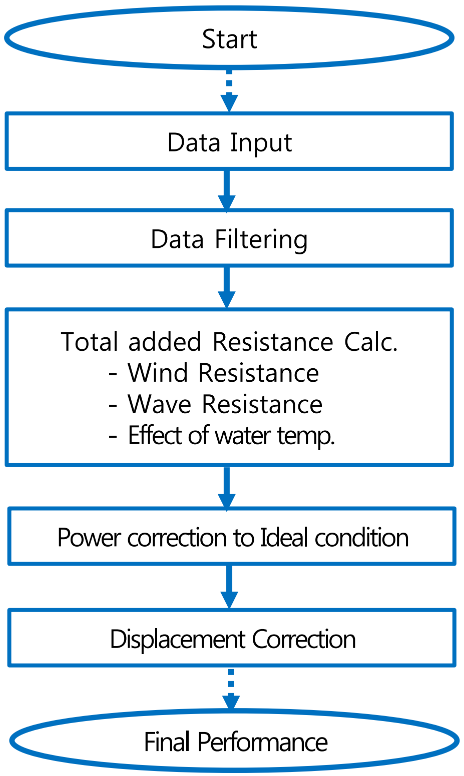
✓ Weather data from NOAA such as $H_{W1/3}$, D_W, T_W.....

➢ Filtering

✓ 2 min. interval data

✓ Extract only steady state data

- Wave incident angle (STAWAVE II)
- DHP by torque sensor
- Rudder Angle
- Speed Log Variation

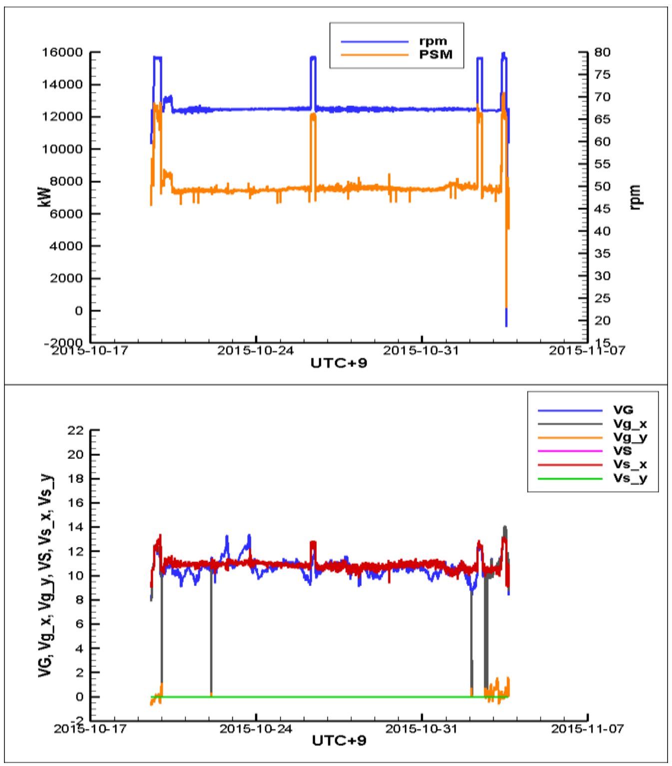


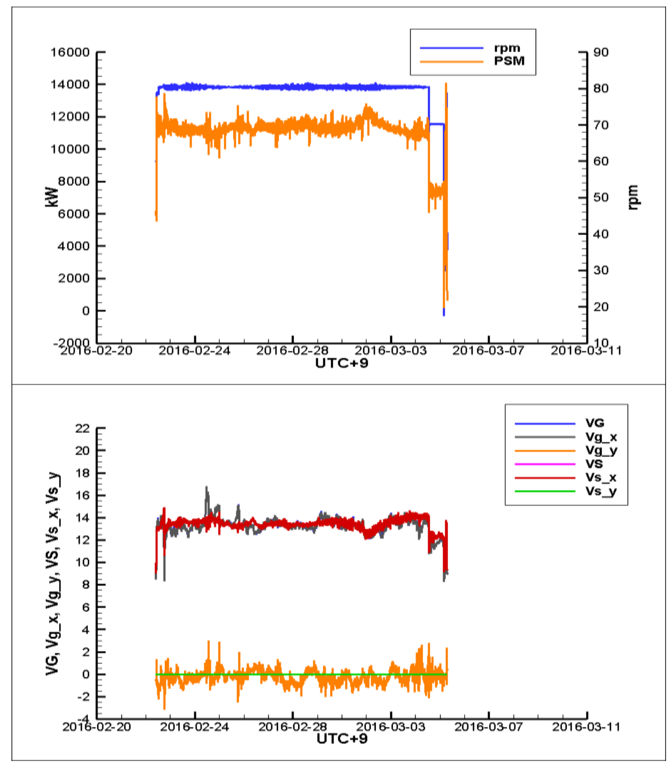
<Analysis Procedure>

Speed-Power Analysis

Measured data Verification

- Before dry-docking
  - ✓Laden Condition
  - ✓Full Load (67rpm, 7,000kW)
- After dry-docking
  - ✓Laden Condition
  - ✓Full Load (80rpm, 11,000kW)

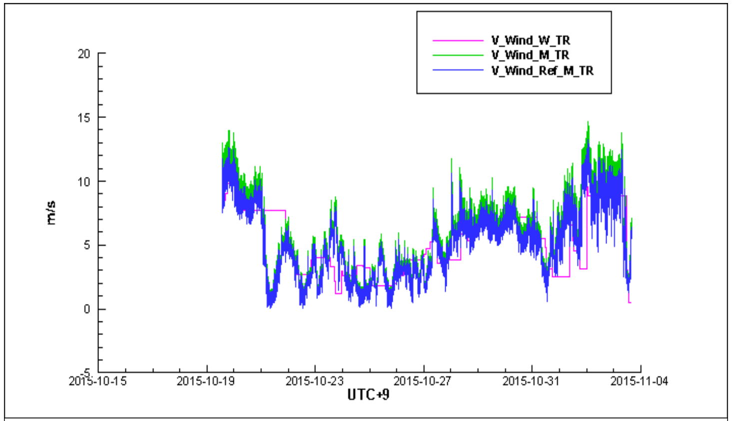


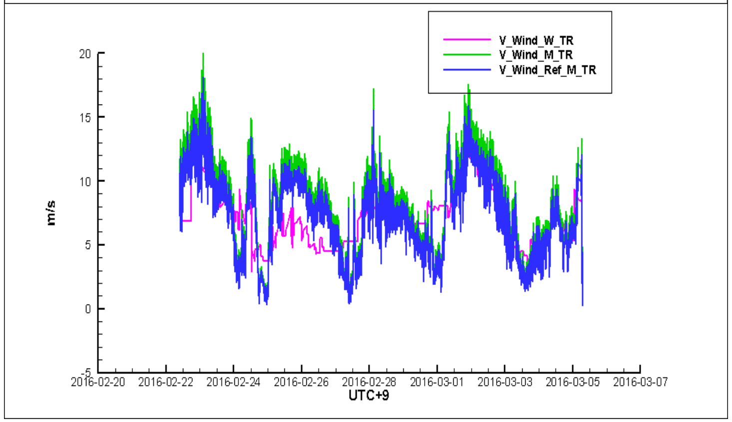


Speed-Power Analysis

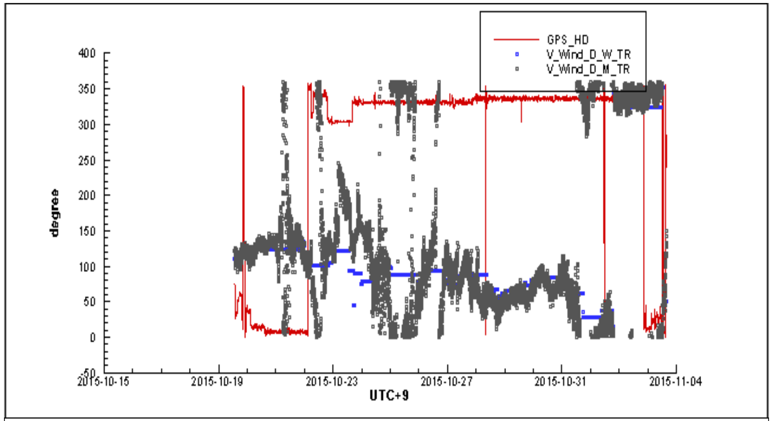
Comparison with Measured & Weather Data

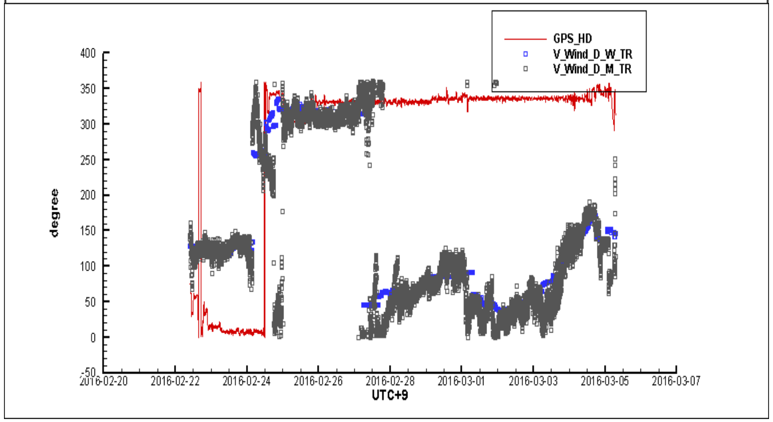
- True wind velocity





- True wind direction



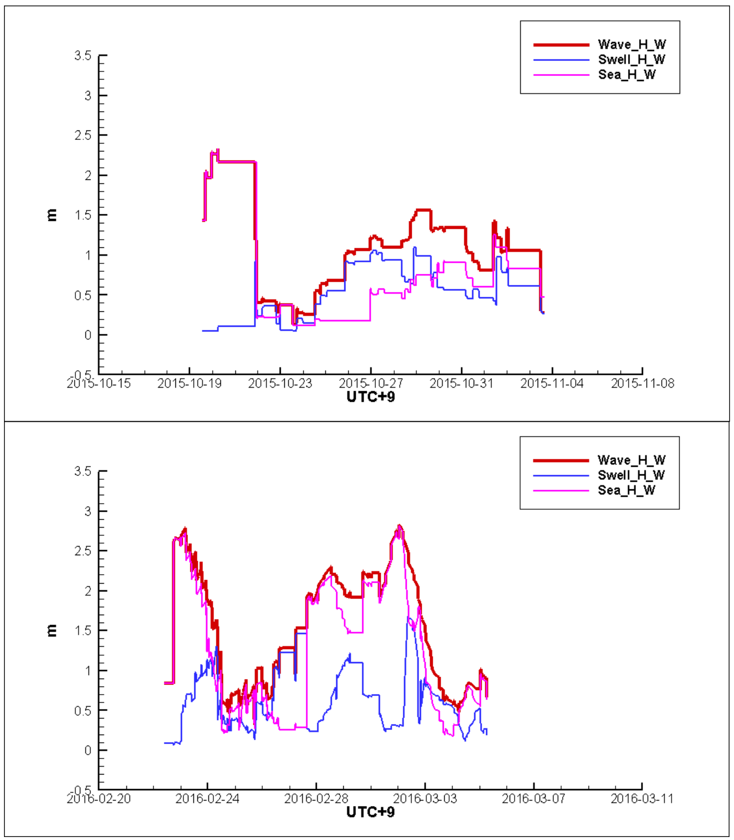


❖ Measured data and Weather data are in good agreement

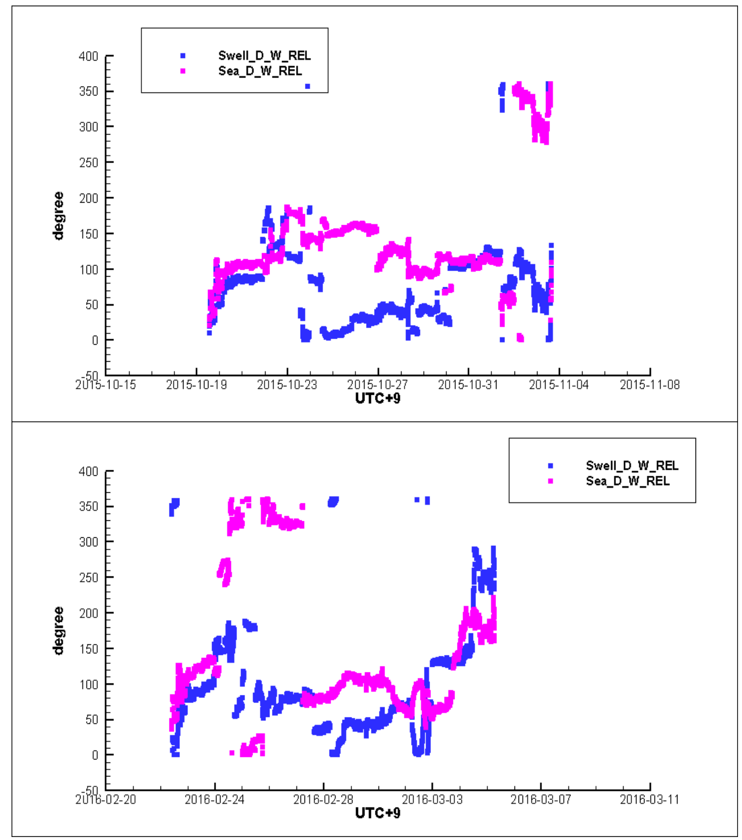
Speed-Power Analysis

Wave data - Weather data

- Wave height



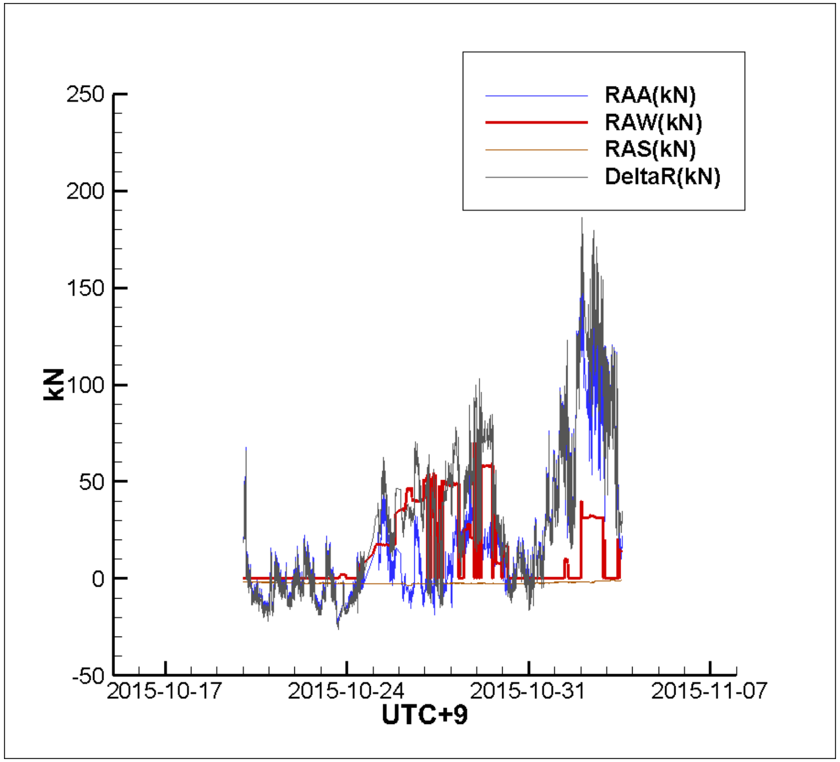
- Wave direction



❖ NOAA weather data was used for analysis of added resistance, with sea wave and swell separated using STAWAVE-2 method

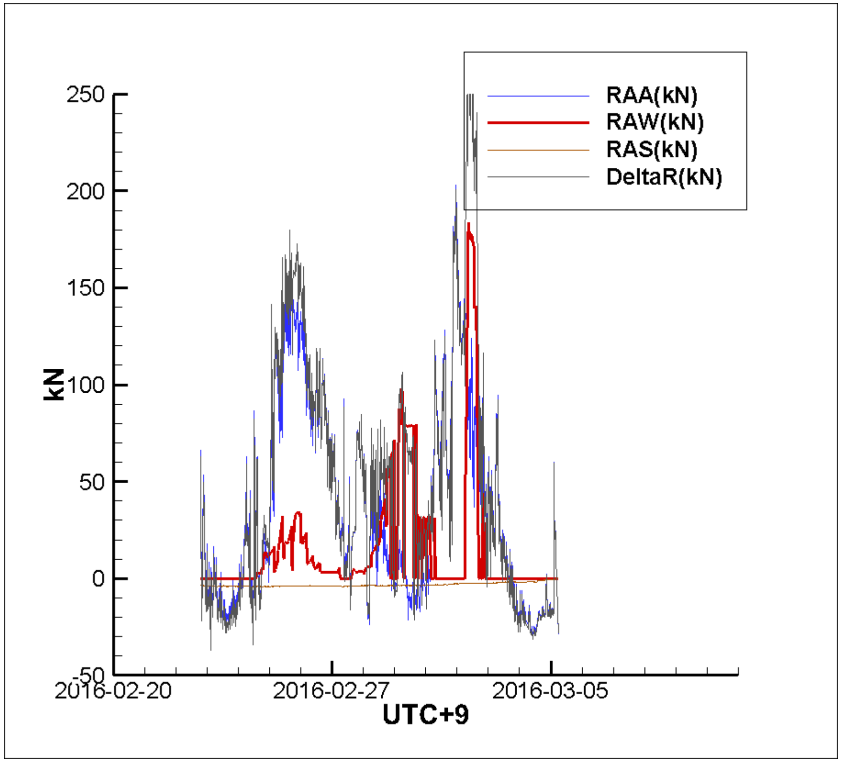
Speed-Power Analysis

➢ **Before dry-docking**



Added Resistance (kN)

➢ **After dry-docking**



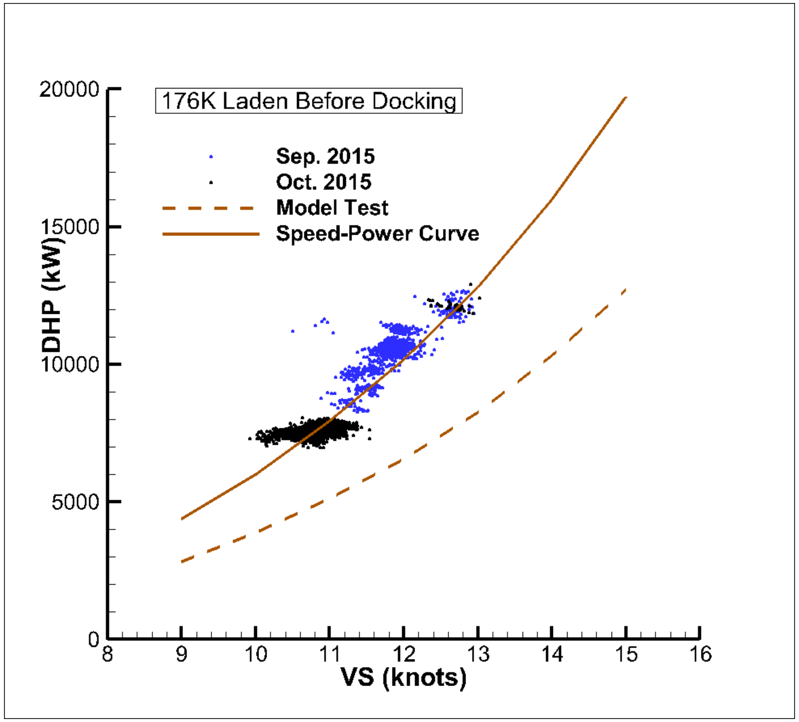
Added Resistance (kN)

➢ The main portion of resistance is the wind resistance

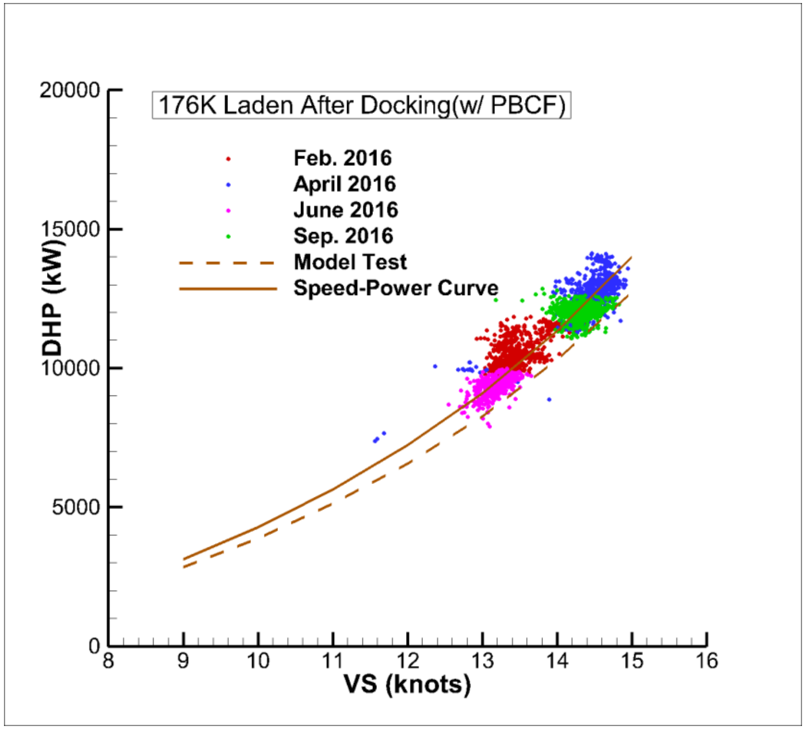
➢ RAW = 0 for waves with incident angle exceeding ±45 (restriction of STAWAVE-2 method)

Speed-Power Analysis

- **Before dry-docking**



- **After dry-docking**



- 상가 후의 선속-동력 성능은 약 23% 향상된 것으로 판명됨.
- 페인트 선정, ESD장착을 위한 **항목별 BCA정밀 분석이 중요**
  - ✓선체 Blasting, 도색
  - ✓프로펠러 Cleaning
  - ✓PBCF

외국 동향

➢ Extensive Full-Scale Measurement on Propeller Performance of 14000 TEU Container Ship, JMU, MTI, Furuno Electric, Japan, Hullpic 2018, pp27

✓Furuno사와 협동으로 새로운 장비인 MLDS(Multi-Layered Doppler Sonar)를 이용하여 프로펠러주위 유동장의 직접 계측 시도.

✓유동장이 안정된 상태에서 10분간, 수차례 계측하였음. 결과를 CFD결과와 비교함.
- 센서와 6미터 이내의 범위는 CFD결과와 잘 일치함.
- 센서와 3미터 이내는 편차가 5%이내임.

✓모형시험결과로부터 실선반류(wake)는 실험식으로 추정함
- <u>현재의 기술로 계측 불가, 실선 저항추진성능 추정의 가장 큰 걸림돌임</u>.

✓운항선의 저항추진 성능추정을 위해서는 매우 중요한 기술임.

Fig.2: NYK 14,000 TEU series container ship

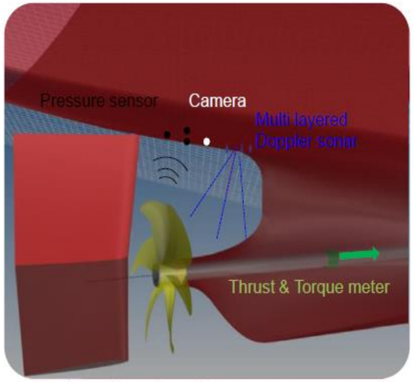
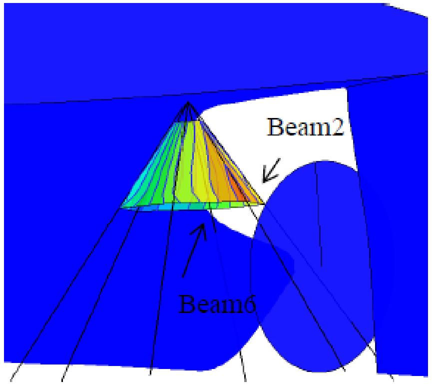
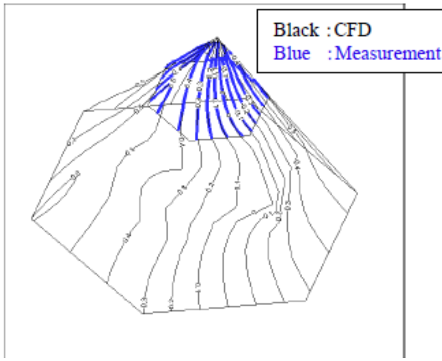


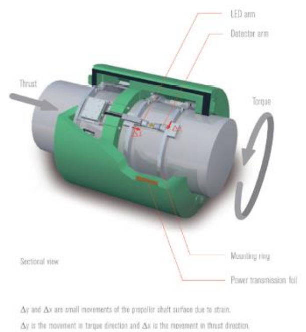
Fig.1: Illustration of the measurement system

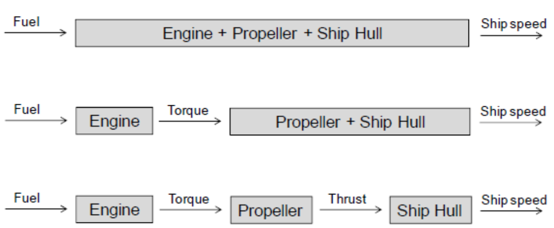


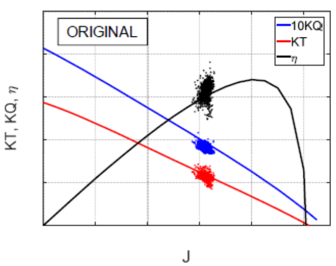


외국 동향

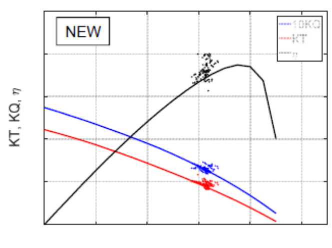
- ➢ Measuring the Full-Scale Performance of a Propeller and Bulbous Bow Retrofit via Propeller Thrust Measurements, VAF Instruments, Netherlands, HULLPIC2017, pp132
  - ✓ 실선 프로펠러 추력 계측으로, 선체 저항증가, 프로펠러 추진효율 분리하여 해석 가능함.
  - ✓ 운항중인 대형 컨테이너선에 프로펠러 설계 및 교체, boulbous bow 개조 수행하였음.
    - 프로펠러 교체에 의한 효과는 10%이상, Boulbous Bow개조효과는 5% 미만임.
    - 프로펠러 교체에 의한 최적 rpm세팅으로 엔진효율 약 5%향상 가능
  - ✓<u>저속운항중인 컨테이너선은 프로펠러 교체가 효과적임</u>
  - ✓추력계측에 의한 고정도 저항추진 성능 분석 가능함.



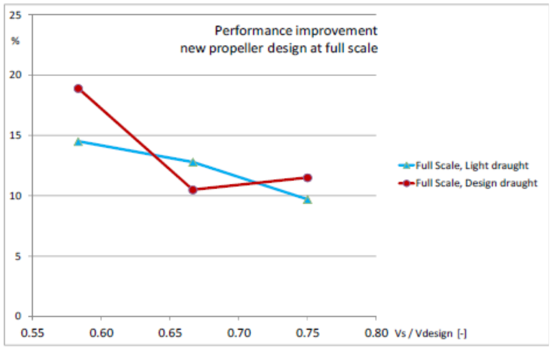




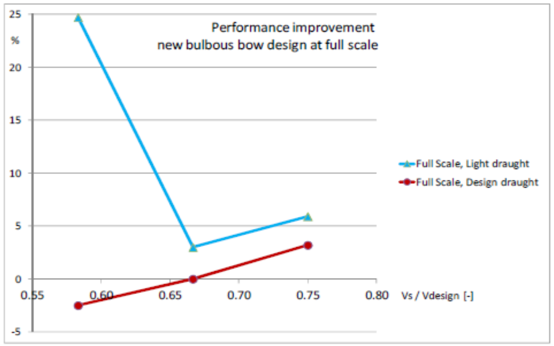
Original propeller, before retrofit
Design draught conditions



New propeller, after retrofit
Design draught conditions



New Propeller



New Bulbous Bow

외국 동향

➢ Quantification of Changes in Propeller Performance – Method Validation, Jotun, Norway, HULLPIC 2018, pp285

- ✓ 290,000 DWT Ore Carrier
- ✓ 프로펠러 3개월 간격 세척, 27개월 결과
- ✓ 27개월 동안 프로펠러 성능 변화 거의 없음.
- ✓ 적은 예산으로 연료절감 가능, 많은 조사가 필요함.
  - <u>정기적인 프로펠러 세척 만으로 큰 효과를 볼 수 있음.</u>

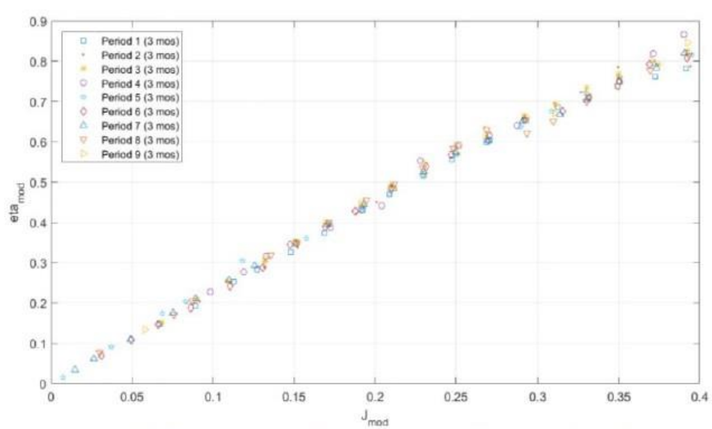


Fig.4: Modified propeller efficiency over consecutive 3-month periods

Table III: Variation in η_{mod} from the mean

Period	1	2	3	4	5	6	7	8	9
Diff. in integral value	-2.1%	0.1%	0.5%	1.2%	-0.1%	-0.3%	-0.4%	0.07%	1.4%

프로펠러 정기 세척

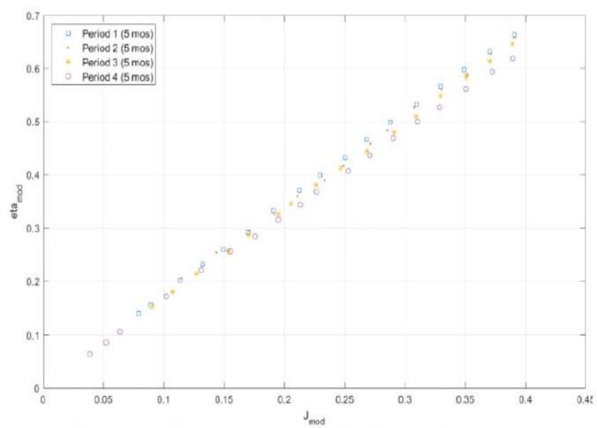


Fig.2: Modified propeller efficiency as function of modified advance number over 4 consecutive periods (length of each period – 5 months)

Table I: Difference between the areas under each of the fitted curves

Period	Difference in integral value [%]
1	0 (period 1 is taken as reference)
2	-1.1%
3	-3.6%
4	-6.4%

프로펠러 세척하지 않은 경우

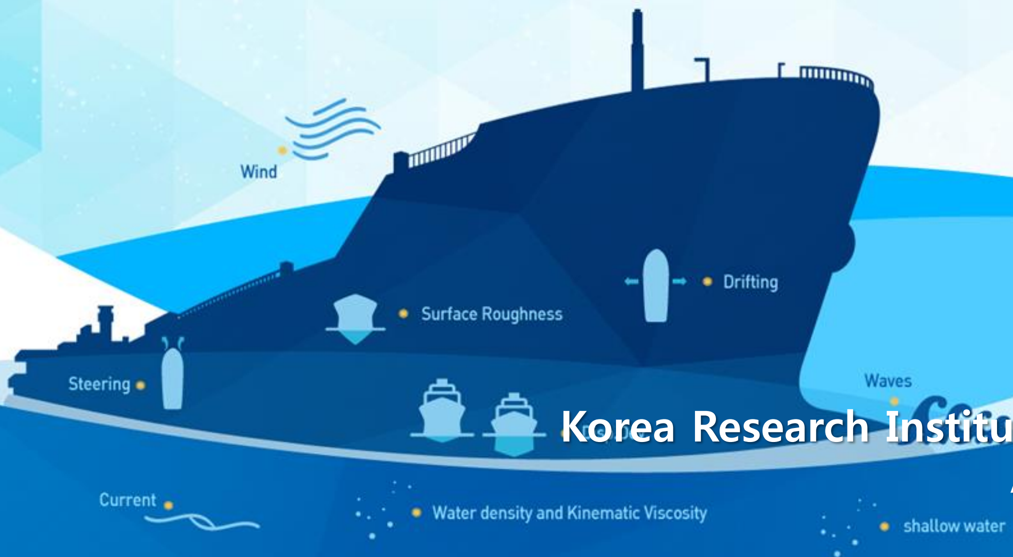
선박유체역학 관점에서의 친환경 해운 및 조선 전망

결 론

결 론

- 신조선 EEDI향상을 위한 전망은 다음과 같음
  - ✓수송효율 향상을 위한 ESD, 선형개발, 추진기 개발을 지속적으로 수행 됨.
  - ✓EEDI는 V^2에 비례하는 바, 운항속도는 저속화 될 것으로 전망됨.
    - EEDI, EEOI는 기본적으로 같은 개념의 변수임.
  - ✓길이가 늘어나는 등, 기본 사양의 변화가 예상되며, 신조가 가격상승으로 연결됨.
- 운항선 효율향상을 위한 전망은 다음과 같음.
  - ✓상가 전후 성능분석, 선체, 프로펠러, ESD등의 항목별 정밀분석 필요
  - ✓프로펠러 주위 유동장 계측이 앞으로의 과제임.
  - ✓추력계측으로 선체, 프로펠러 성능 분리하여 해석 가능
  - ✓저속 운항중인 컨테이너선은 프로펠러 교체가 효과적 임.
  - ✓정기적인 프로펠러 세척만으로 큰 효과를 볼 수 있음.

Thank You



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