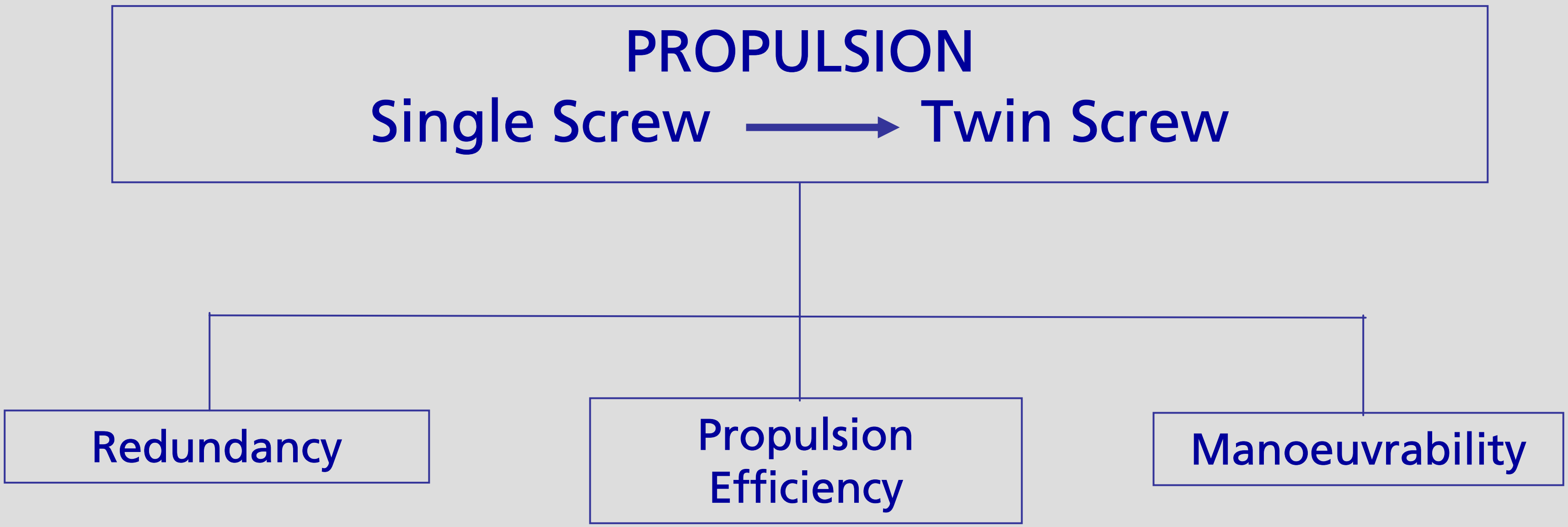
TWIN SCREW PROPULSION

Some Aspects of Propulsion Efficiency, Manoeuvrability in relation to Redundancy

October 2007



LNG Ships

Container Ships

Bulk Carriers

Tankers

Passenger Ships

PROPULSION EFFICIENCY

MANOEUVRABILITY

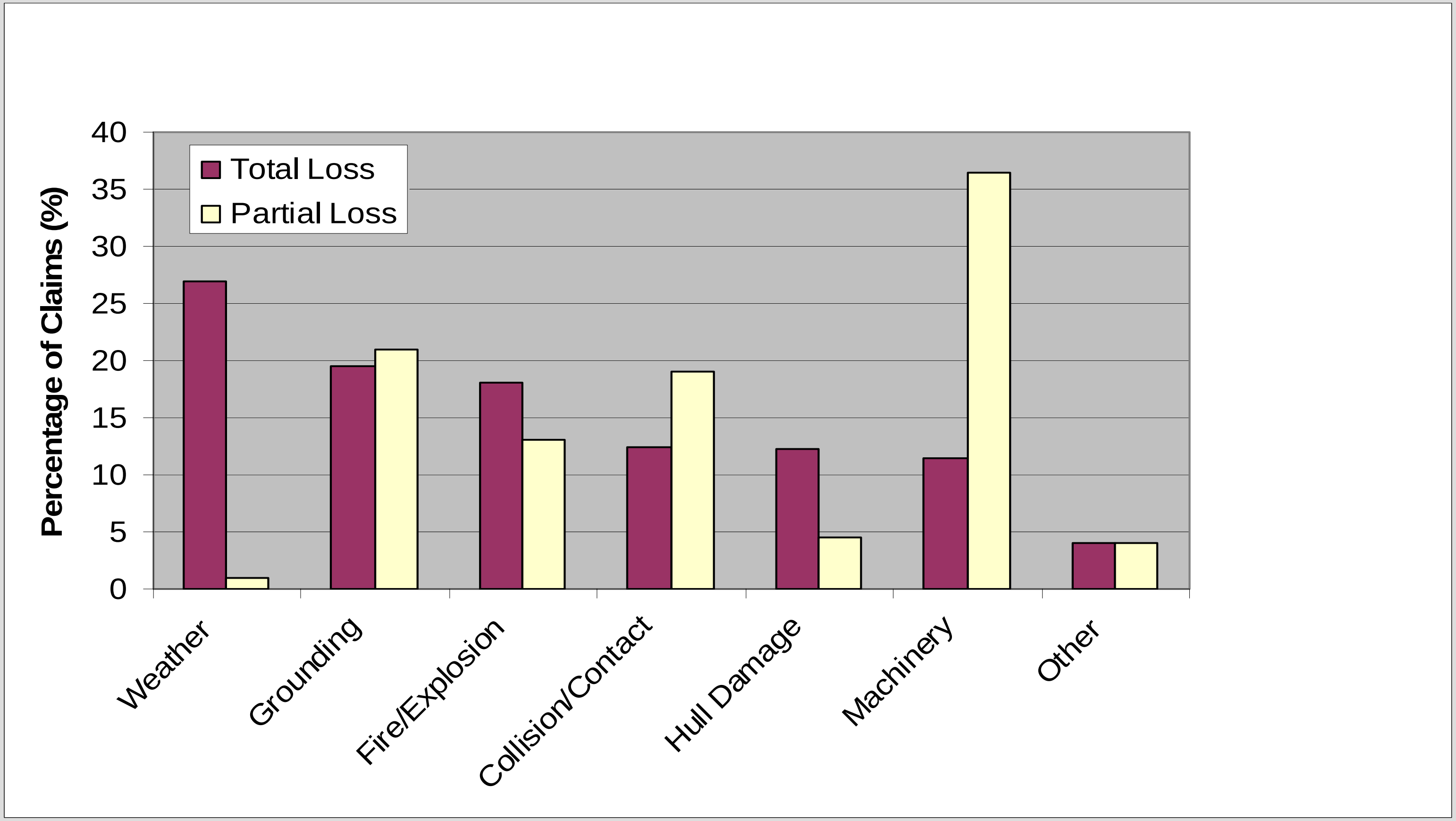
AVAILABILITY

All have implications for operating cost

Other issues: Environment, Legislation, Design, etc.

Cause of Losses 1994 - 2003

(All ship types above 500GRT)



The Institute of London Underwriters

Redundancy

Requirements come into force for passenger ships on the 1st July 2010.

These require a safe haven to be provided for the passengers and the ability of the ship to be able to return to port or safe haven under its own power given that the casualty is less than certain defined limits

MSC 82/24 Regulation 21.

Casualty Threshold, safe return to port and safe areas.

- Establishes design criteria for a ship's safe return to port under its own propulsion after a casualty.
- It applies to passenger ships constructed on or after 1st July 2010 and having a length of 120 m or more or having 3 or more main vertical zones.
- Definition of casualty threshold in the context of fire includes:
  - Loss of space of origin up to the nearest "A" class boundaries, which may be part of the space of origin, if the space of origin is protected by a fixed fire extinguishing system.
  - Loss of the space of origin and adjacent spaces up to the nearest "A" class boundaries, which are not part of the space of origin.

Systems Required to be Operational

If the fire damage does not exceed the casualty threshold the following systems are required to remain operational in the remaining part of the ship not affected by the fire:

- Propulsion
- Steering and steering control systems
- Navigational systems
- Systems for fill, transfer and service of fuel oil
- Critical internal communication systems
- External communication systems
- Fire main and fixed fire-extinguishing systems
- Fire and smoke detection systems
- Bilge and ballast systems
- Power operated watertight and semi-watertight doors
- Systems for the support of safe areas
- Flooding detection systems
- Other systems vital to damage control efforts.

Twin Screw Ship Propulsive Efficiency

$$QPC = \eta_0 . \eta_H . \eta_r$$

$$\text{where } \eta_H = (1 - t)/(1 - w_T)$$

- Traditionally the view has been that while the propeller open water efficiency has been generally higher, the hull efficiency is lower than the equivalent single screw counterpart.
- The net effect is a tendency towards a lower quasi-propulsive coefficient for the equivalent twin screw ship.
- This view was based on traditional hull geometries for twin and single screw ships.
- Is it still correct for all/some modern hull forms?

Large Ship Design (Container and LNG Carriers)

- Both large LNG and container ships are draught constrained due to current port and river passage constraints.

- Single screw designs for large container ships can be satisfactorily executed up to 12500 teu (high cube) or around 13900 teu (standard). From Lloyd's Register studies this range can probably be extended up to around 14500 to 15000 teu.

- The constraints for the propulsion system are thrust density and, if a fixed pitch mono-block propeller is to be used, casting weight.

- Large LNG ships in the range 200000 to 260000 m^3 have already moved to twin screw propulsion due to the intractable hydrodynamic problems of single screw propulsion.

Twin Screw After Body Design

When compared to equivalent single screw ships, twin skeg hull forms, typically for larger LNG carriers, or other relatively large fast ships can be designed to give :

- A better model nominal wake field. This then has to be transformed into the ship's effective wake field in which the propeller operates.
- Improved propeller tip clearances.
- Improved model predictions of propulsive efficiency.

The true prediction of propulsion, cavitation and generated forces and moments depends upon scale effects and full scale correlation data.

Modern Twin Screw Hull Forms

- Model tests and time average Navier-Stokes based studies suggest that by careful design of the hull form some enhancement of the hull efficiency may be gained – typically in the case of LNG ships.

- Care has to be taken in these interpretations because of the scale effects which apply in the cases of these large ships and also due to the lack of quantitative correlation on a a wide sample of hull forms for CFD studies.

- Indeed, full scale data upon which to base these correlations is sparse.

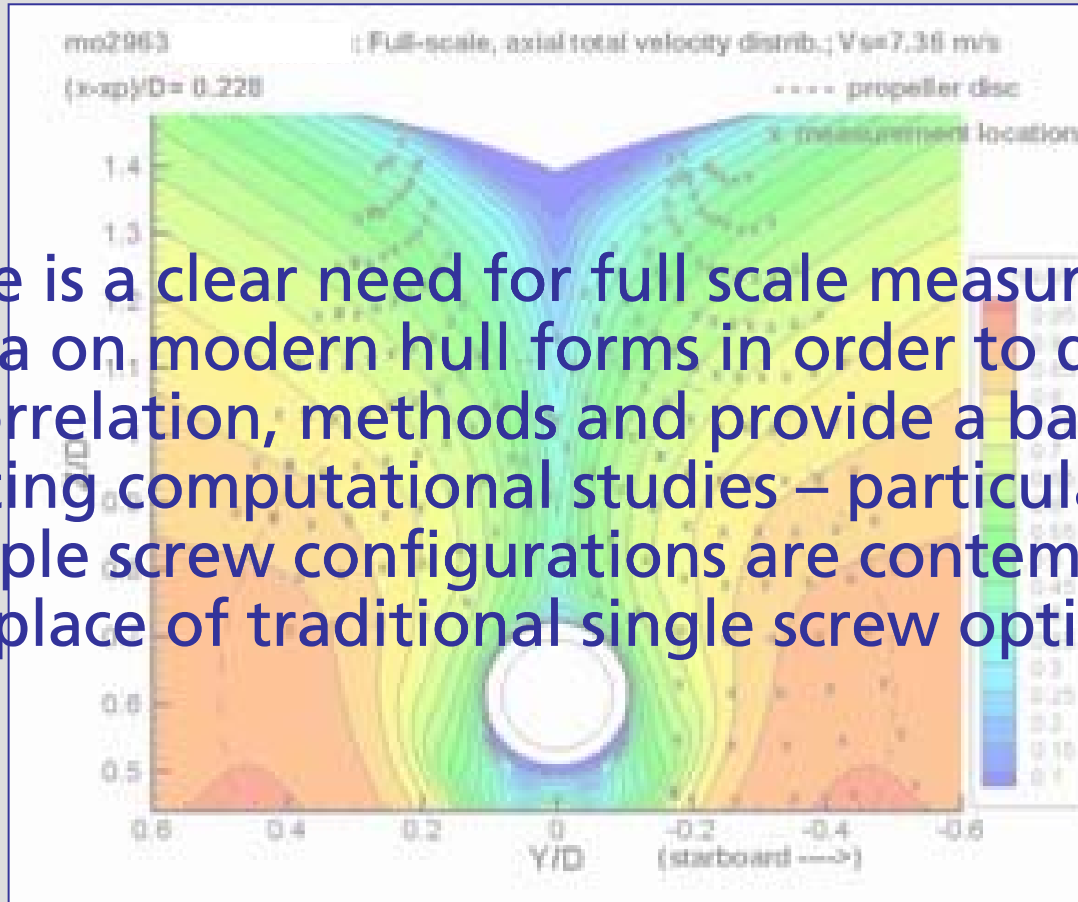
- Nevertheless, full scale measured data, model experiments and computational results have error bounds which must be carefully considered.

Scale Effects – *Particularly for larger ships*

Scaling problems apply to:

- The transformation of the nominal model to effective ship wake field.
    - ❑ Scale effects can be large particularly in the wake peak region. The propeller in-plane forces and moments with consequences for the shaft dynamic alignment.
    - ❑ The propeller behind efficiency.
    - ❑ Where large cavity volumes occur.
- The bubble dynamics of the cavitation.
    - ❑ Nuclei content.
    - ❑ Fourier analysis takes out the phenomenological detail.
    - ❑ Time series data is essential for proper analysis.
- Type of Cavitation:
    - ❑ Tip vortex cavitation.
    - ❑ Certain types of intermittent sheet cavitation.
    - ❑ Face cavitation.

Full Scale Data

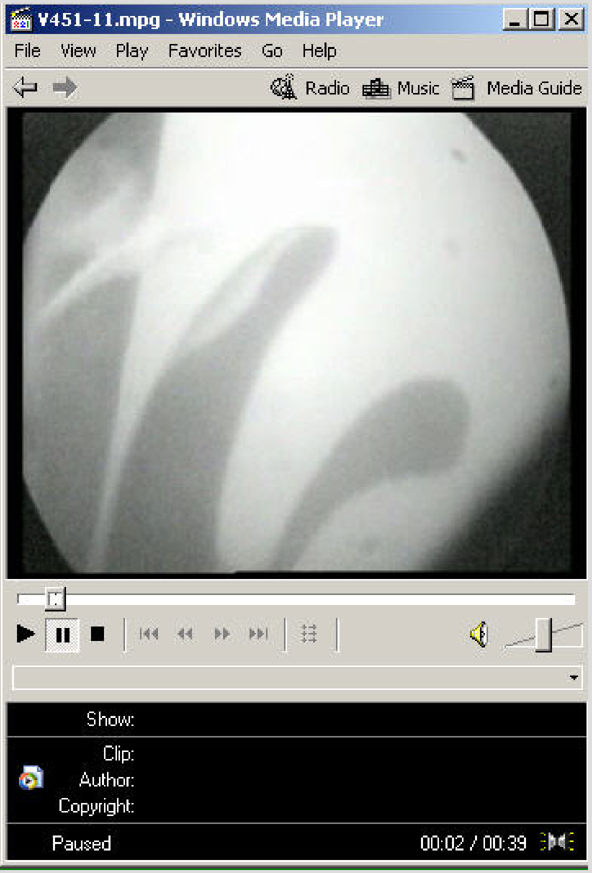


There is a clear need for full scale measured wake data on modern hull forms in order to develop correlation, methods and provide a basis for validating computational studies – particularly where multiple screw configurations are contemplated in place of traditional single screw options.

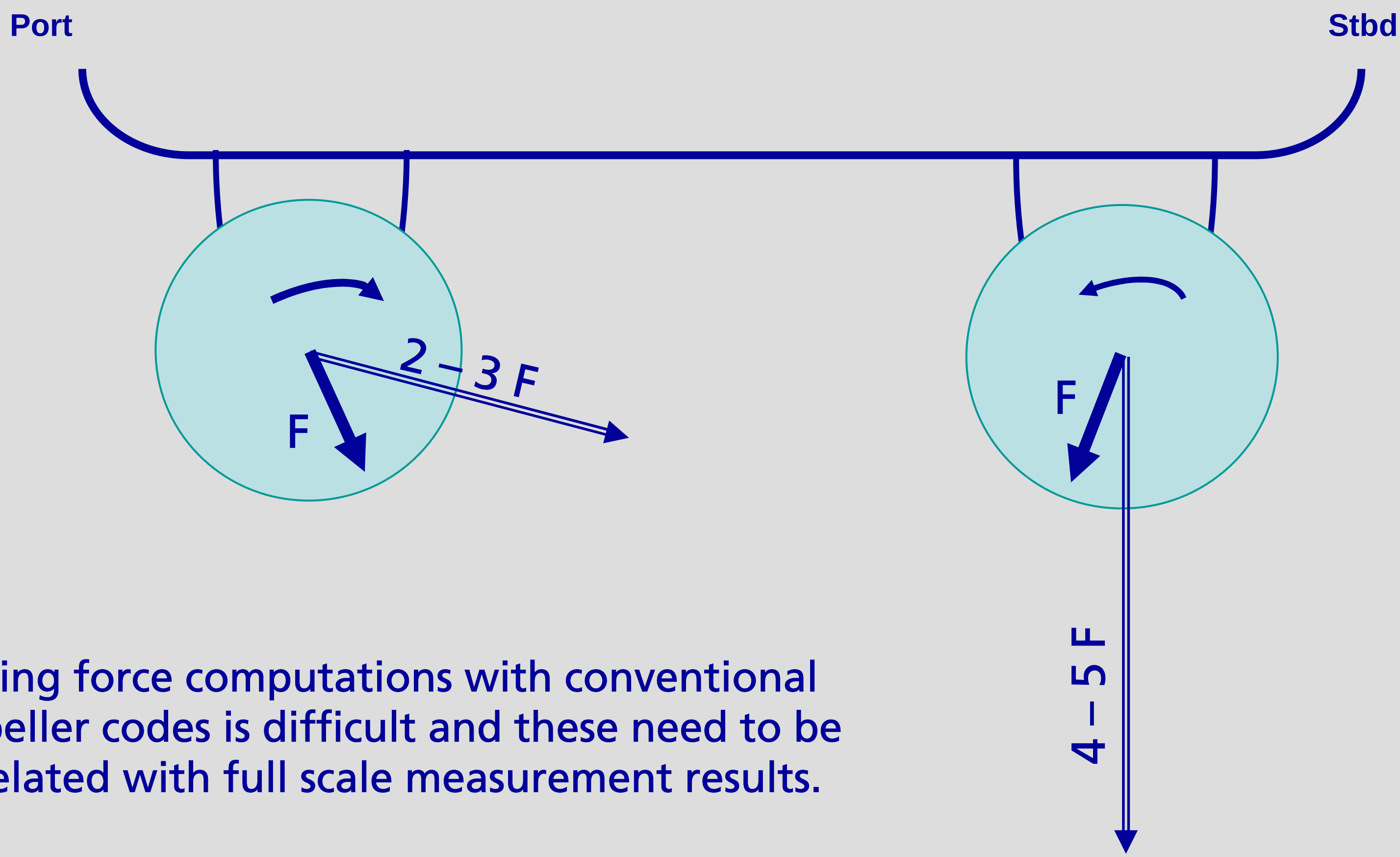
Propeller Cavitation Dynamics

- In the case of large, high powered single screw container ships the tip vortex structures are complex.
- Particularly this leads in many cases to the expansion of the tip vortex in subsequent turns of the helix – mostly towards the propeller.
- This causes difficulty in predicting radiated hull surface pressures: both from calculation and model testing.
- One of the key factors in the difficulties experienced is the scaling of the measured nominal model wake field.

Boroscope Technology



Bearing Forces During Turning



Bearing force computations with conventional propeller codes is difficult and these need to be correlated with full scale measurement results.

Hull Surface Pressures versus Propeller Efficiency

For equivalent ships:

When the thrust density is considered it is found to reduce in favour of the twin screw ship when compared to the single screw counterpart.

To maintain equivalent hull surface pressures between the single and twin screw versions of the ship and for an optimum propeller:

- The propeller diameter can be larger.
- The propeller rpm can be lower.
- The open water propeller efficiency will be higher.

Manoeuvrability

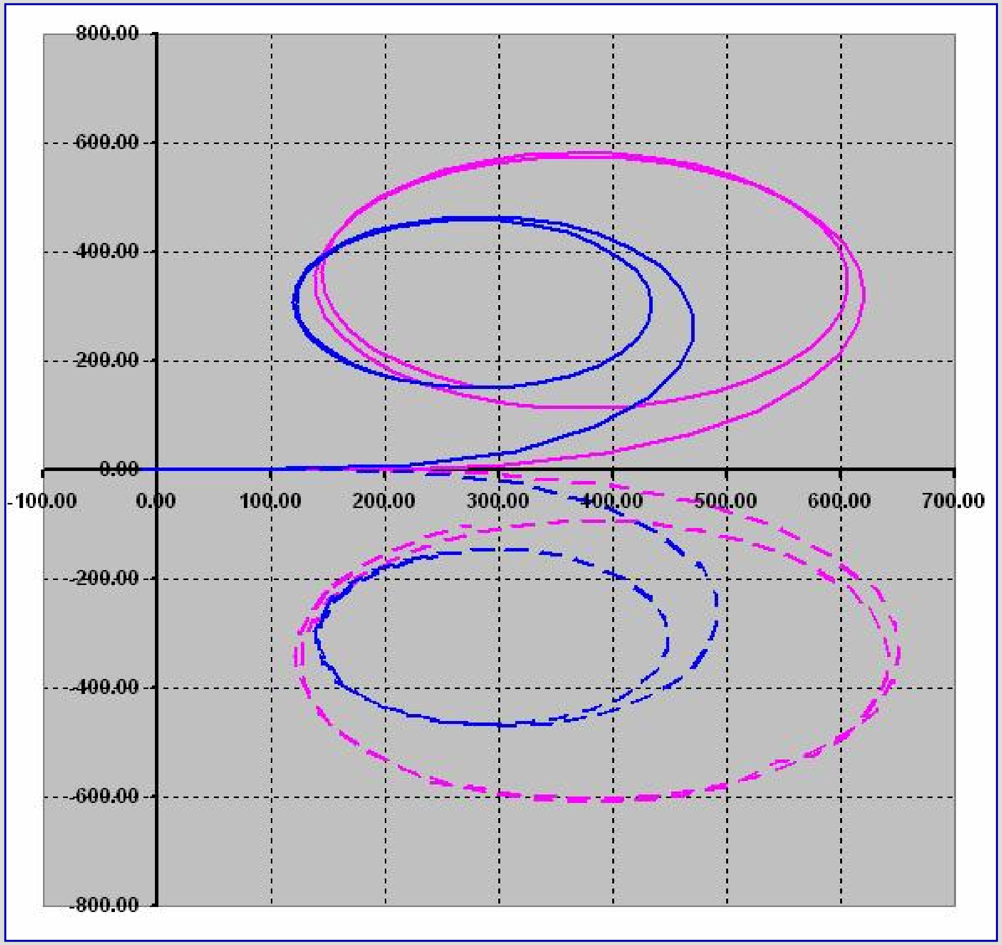
For single and twin screw ships similar options apply:

- Rudders – active and passive.
- Azimuthing thrusters.
- Podded propulsors.
- Hybrid propulsors – one conventional and one podded.

Clearly, when two manoeuvring devices are provided then the redundancy of the system is enhanced.

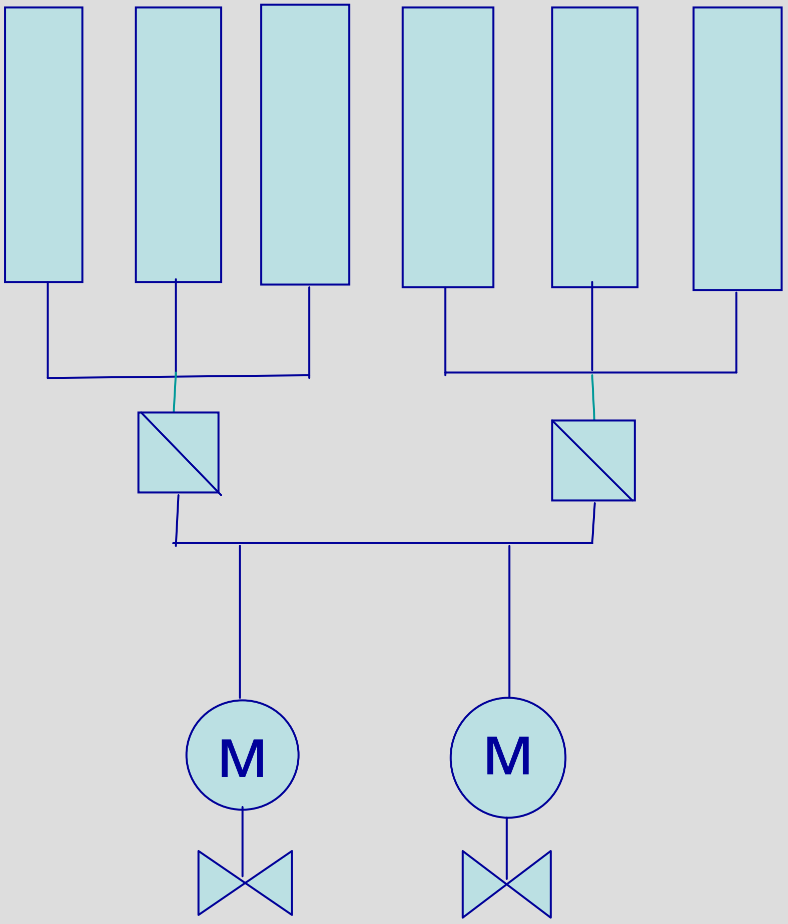
Comparison between Rudders and Podded Propulsors

Two sister ships, one fitted with conventional passive rudders (mauve lines) and the other with twin podded propulsors (blue lines)

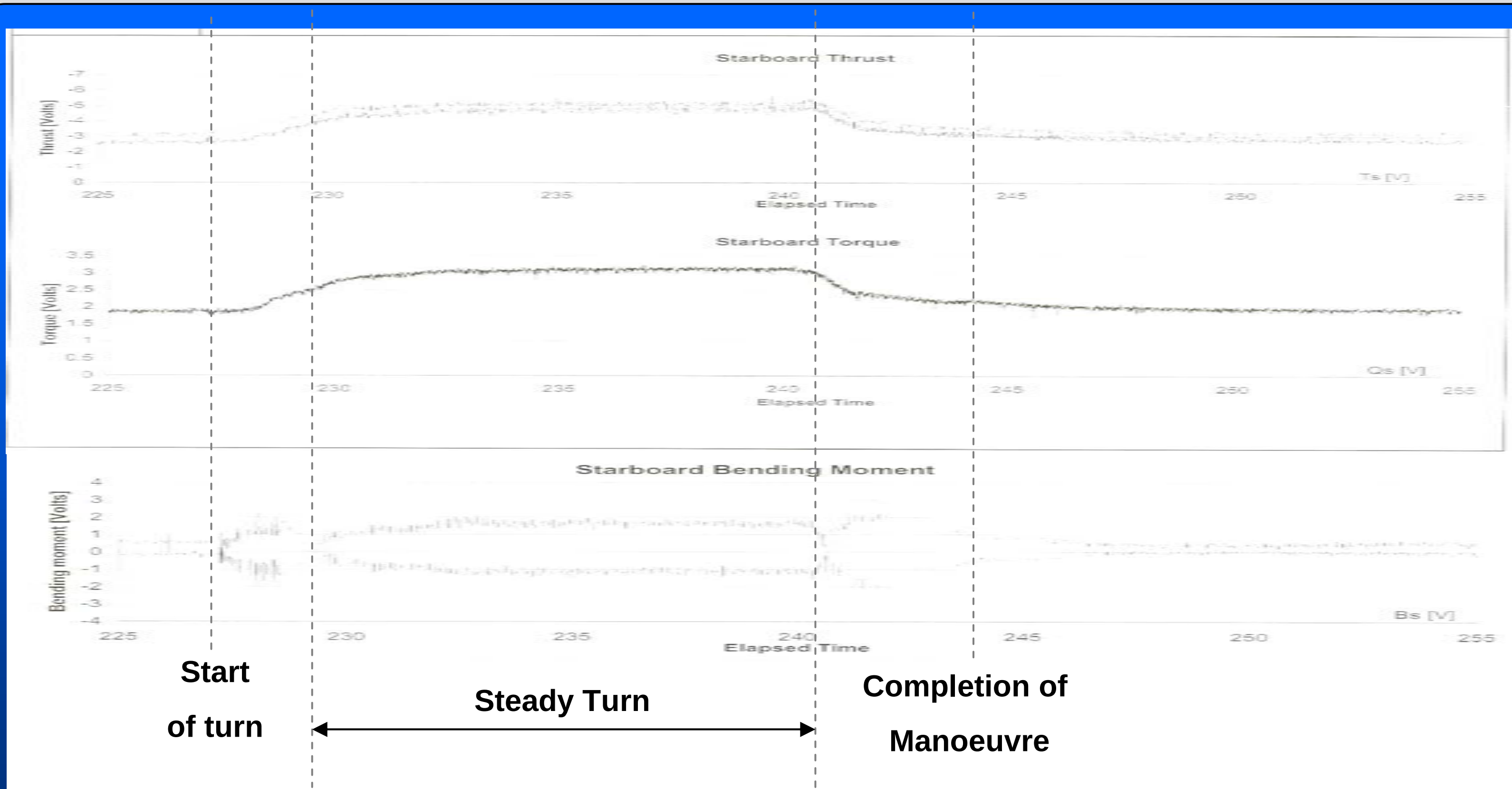


Podded Propulsion, Diesel or Dual Fuel Electric Propulsion

- Enhanced maintainability.
- Minimised consequences should a failure occur – assuming the control system is satisfactory.
- Energy conversion losses are likely to be higher.
- There is the ability to run the diesel generators at close to optimum performance in cases where variability of load is required.
- Increased capital cost.
- Gas engines prefer steady loadings.



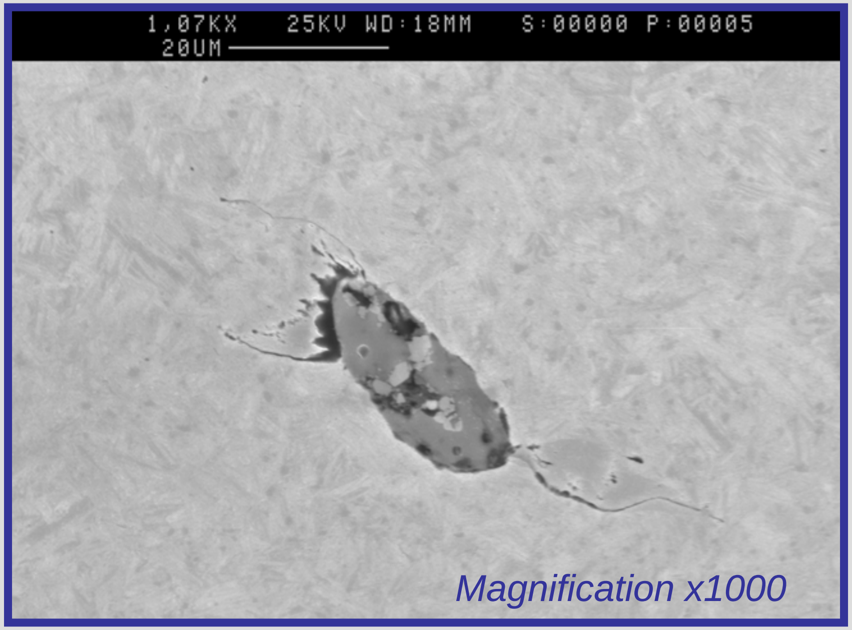
Hydrodynamic Loadings During Turning Circle Trials



Podded Propulsors: Typical Bearing Failure Morphology

Crack Initiation

- **Cracks mostly initiate after the first few significant loading cycles.**
- **They mostly initiate from hard inclusions – oxide or complex types.**
- **Whether a crack then propagates or not depends on subsequent loading cycles.**



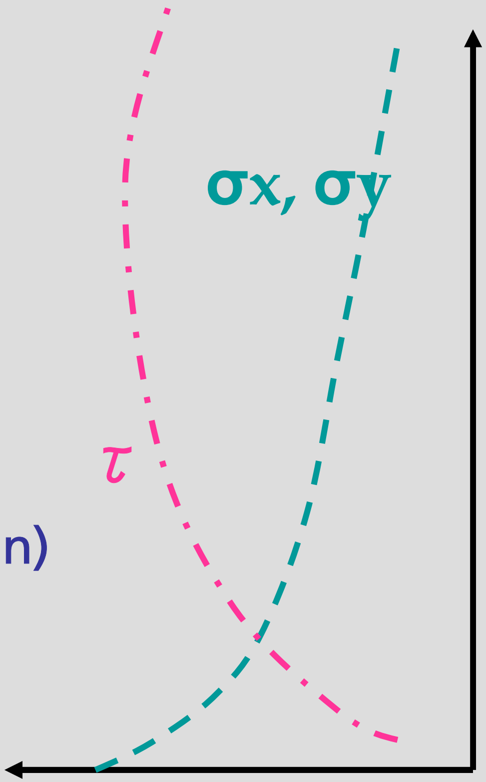
Magnification x1000

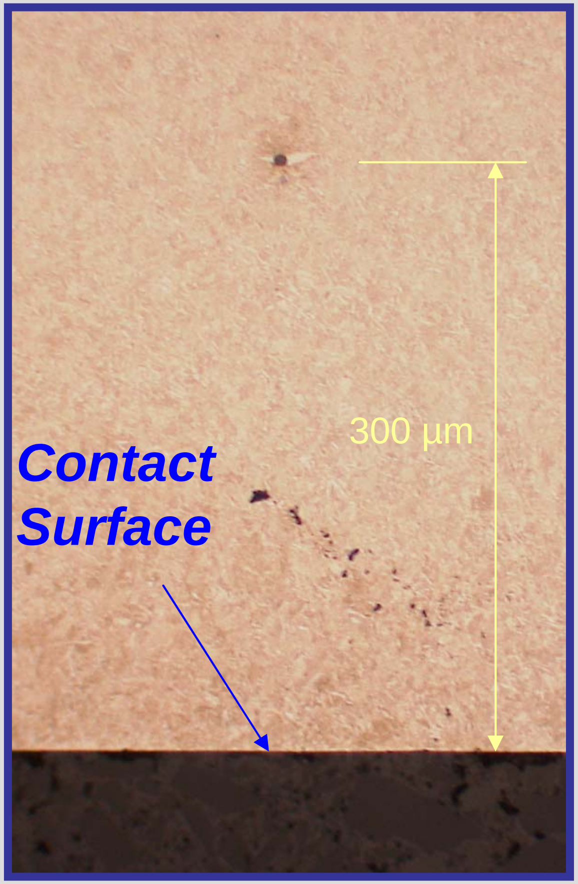
- **This begs the question of sea trial procedures being conducted to the prescribed requirements of conventional propulsion systems rather than using an *Equivalence Principle*.**

Significance of Defect Location

Not all material defects initiate butterflies.

The Hertzian shear stress τ is cyclic (tension/compression) while σ_x and σ_y fluctuate between zero and some compressive level.





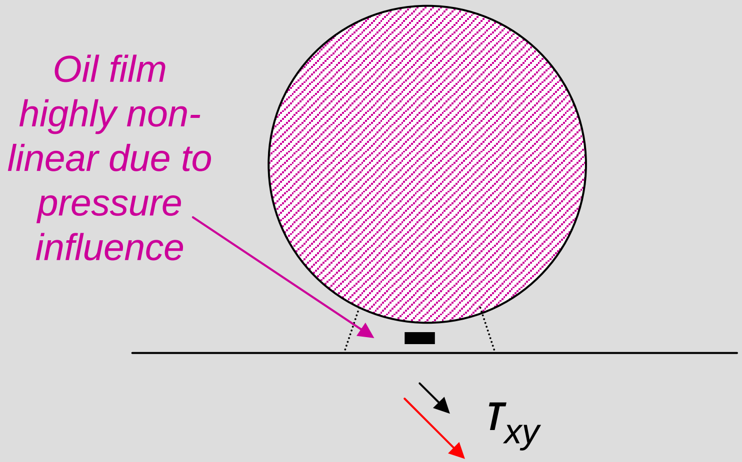
The Influence of Debris

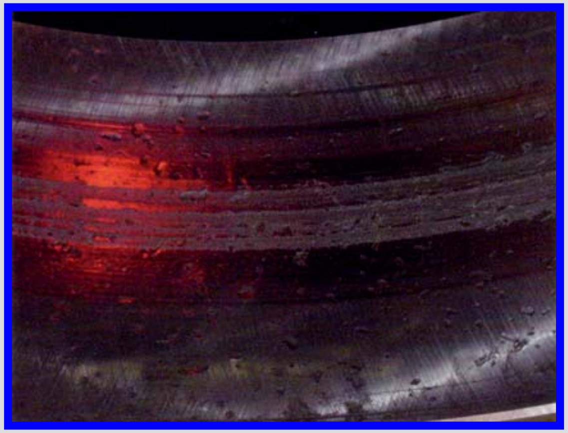
i. **If significant debris is entrained in the oil this can have two effects – both detrimental to bearing life:**

ii. **If it can pass through the oil film between the rolling element and the raceway then it will modify the pressure field significantly and hence increase the Hertzian stress distribution.**

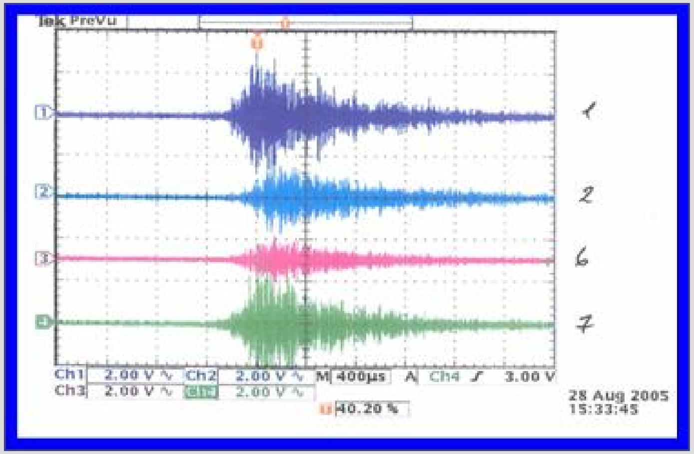
iii. **If it causes an indentation then it will, in addition, introduce a local residual stress field into the material.**

iv. **Oil quality is important:**
   - **NAS 6 is minimum level.**
   - **NAS 4 is preferred.**

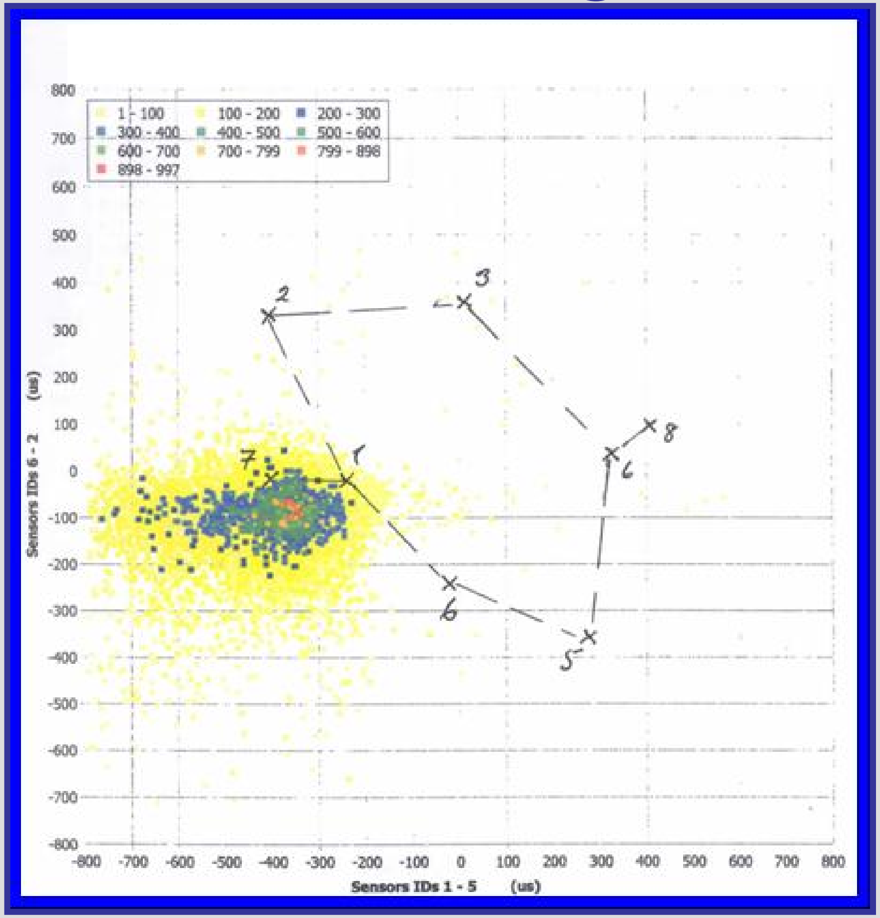




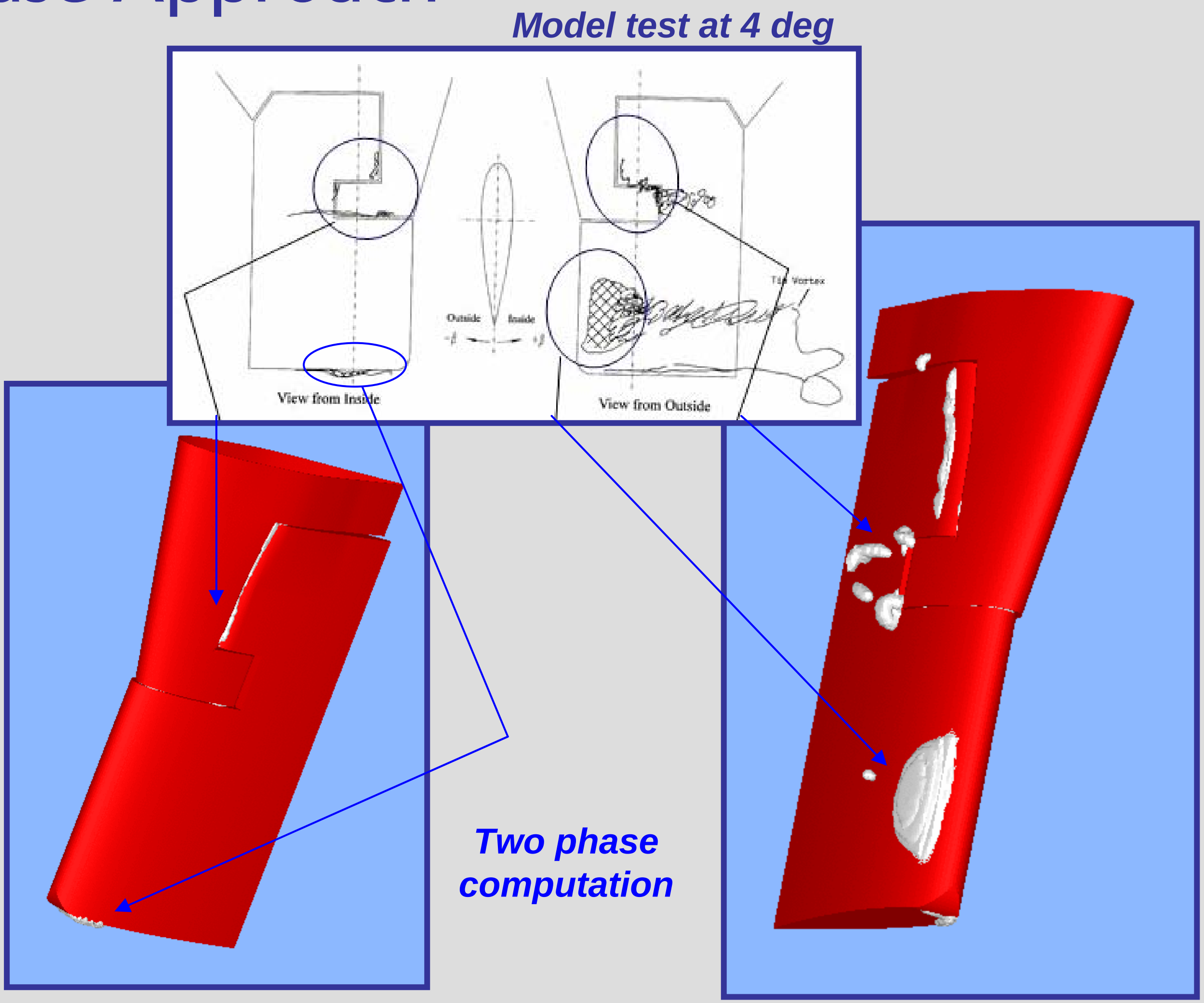
Typical Acoustic Emission Signatures from Podded Propulsors – Condition Monitoring



- **Acoustic emission capabilities offer the potential for active crack location.**
- **Care is needed in the selection of the appropriate equipment.**

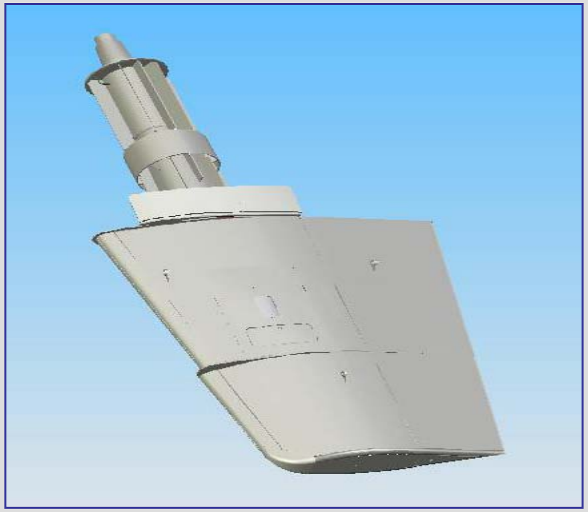


Two Phase Approach



Twisted Rudders

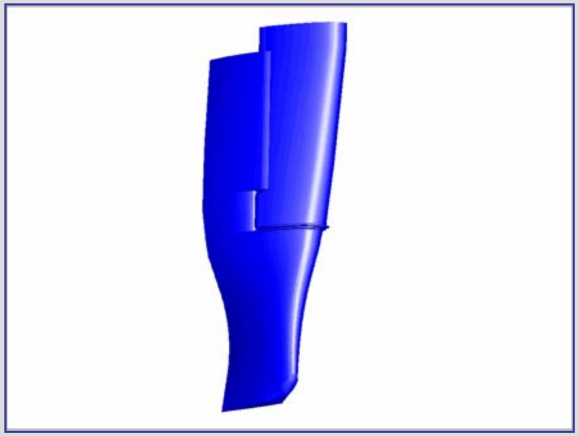
Two principal types of twisted rudder exist:



i. **The uniform angle above and below a fixed location on the rudder, commonly in line with propeller shaft axis, with flat plate connecting both parts of the rudder.**

ii. **A rudder with a continuously varying leading edge angle. This also sometimes extends to the trailing edge.**

iii. **Some appendage efficiency enhancement can be derived from twisted rudders.**



LIFE MATTERS

SHIP EFFICIENCY

by STG