The Usage of Propeller Tunnels For Higher Efficiency and Lower Vibration

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Company Profile

- MILPER is established in 2011 as a Research and Development company in Istanbul.
- MILPER is located in Teknopark Istanbul which is the largest technology research area project of Turkey.
- MILPER’s main focus is design, development and production of propeller and associated propulsion systems for sea vehicles.
- Along with propeller and shaft systems, MILPER also works on design and acoustic analysis of exhaust silencers, which is another branch that needs advanced engineering and analysis backgrounds.
- MILPER also develops a propeller design software, which combines multiple propeller design jobs like series propeller design and wake adapted propeller design in one software package.

Company Profile

MILPER's mission is to be a leader propeller and shaft design company in Turkey, and to be a R&D center in Ship Building, Defense, Aerospace, Energy and Maritime sectors.

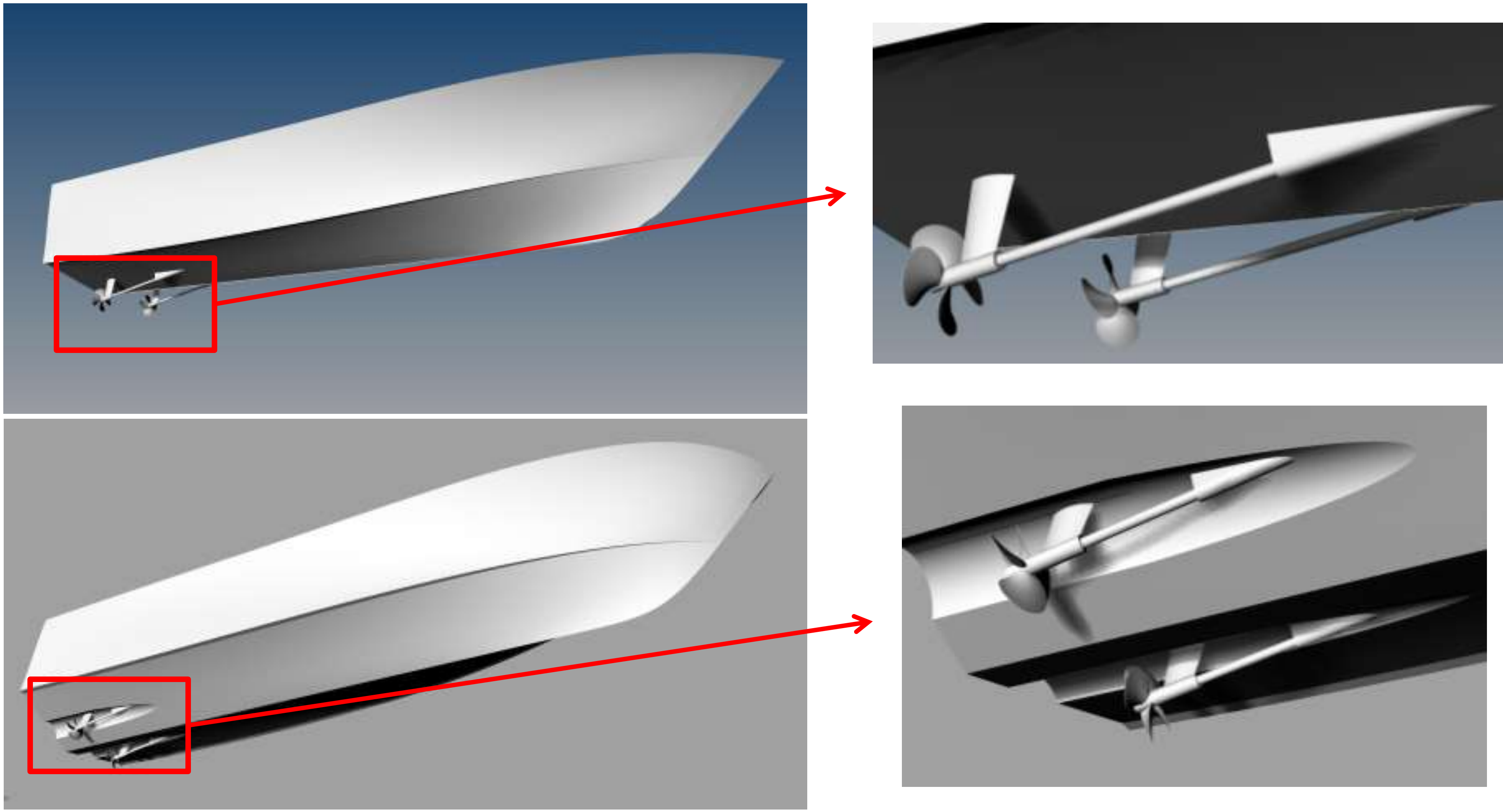
MILPER's vision is to be a pioneering company in design, analysis, optimization and project management using our advanced engineering and analysis capabilities, including computational fluid dynamics, structural, acoustic and vibrational analysis in Turkey and Europe.

Introduction

- In this study; a specified motor yacht hull and a propeller is analyzed without tunnel and with tunnel geometry by using CFD solver.

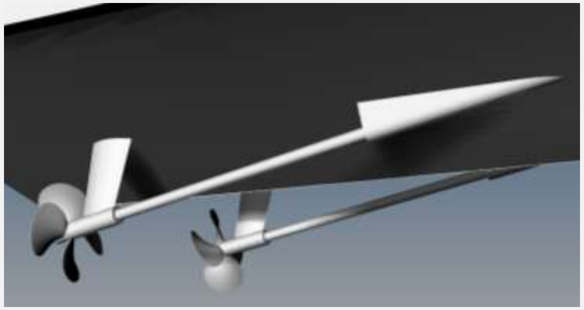
- Propeller induced vibrations and efficiencies are compared for each conditions in order to determine the advantages of the propeller tunnels.

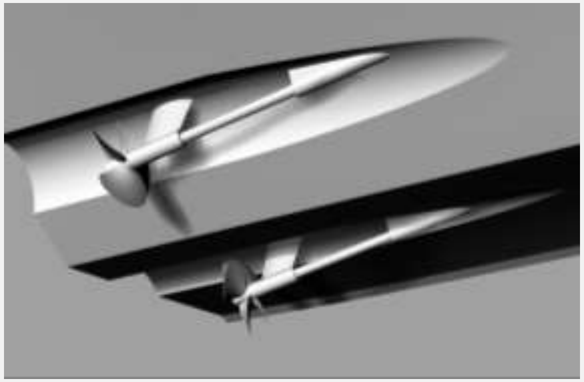
Propeller Tunnels



Why Propeller Tunnels ?

- Reducing the total draft of the boat
- Reduction in shaft angle
- Larger diameters become available
- Small tip clearence leads to reduced tip losses
- Reduced blade load vibration
- Reduced blade-rate hull pressures
- Increased propulsive efficiency





Advantages of Propeller Tunnels

- Appendages increases the total draft of the vessel so increased draft creates operational disadvantages for the vessel. In some cases propeller diameter reduction is a solution in order to reduce total draft of the boat. But this method leads to lower propulsive efficiency and limitations cause non optimum conditions.

- Propeller tunnel usage causes buoyancy loss for the hull therefore total draft increases. On the other hand, propeller tunnel brings flexibility to reduce the shaft angle. In short, shallow draft may be provided even though hull draft increases.

- Propeller tunnel usage provides efficiency increase for most of the cases due to the shrouding effect of the propeller tunnels. Especially shallow partial tunnels lead to reduction in propeller induced vibrations. In order to reduce propeller induced vibrations for conventional propeller installations, propeller tip – hull clearance should be increased; however increased clearance brings increment in total draft.

Experimental Results

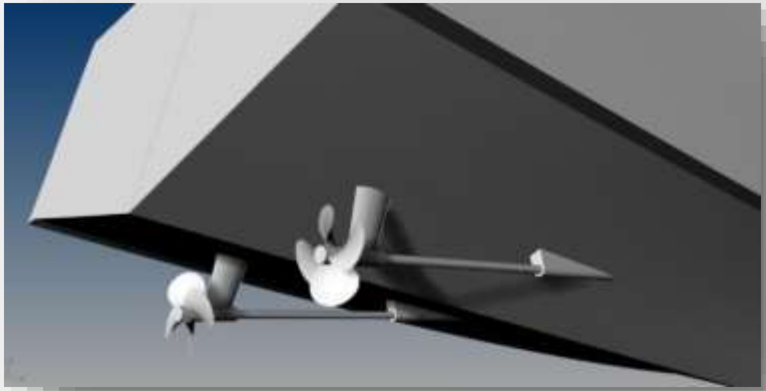
- According to the experimental results,

  Propeller tunnels does not bring a negative effect on propeller efficiency. Moreover, an optimum tunnel - propeller design increase efficiency. Small tip clearance, for an optimum tunnel-propeller design, generates higher efficiency than open-water. Reduced clearance provides the propeller to operate with increased efficiency by the help of reduced tip losses.

Propeller – Hull Clearance

- By the usage of the propeller pockets which are shallow tunnels, propeller induced vibrations become lower.

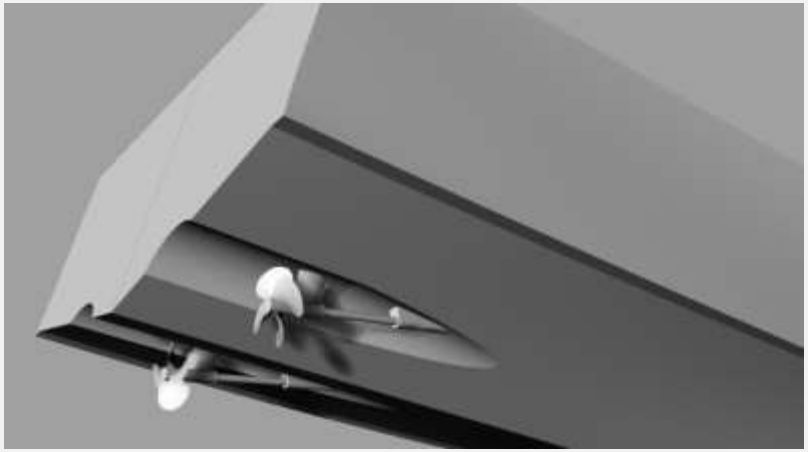
On conventional installations without tunnels, minimum clearance should be minimum 15 percent of the propeller diameter between the propeller tip and the hull; otherwise excessive vibration will occur. But tunnel usage gives flexibility to reduce the clearance to 5 percent and with an optimum design nearly zero clearance is possible without vibration.

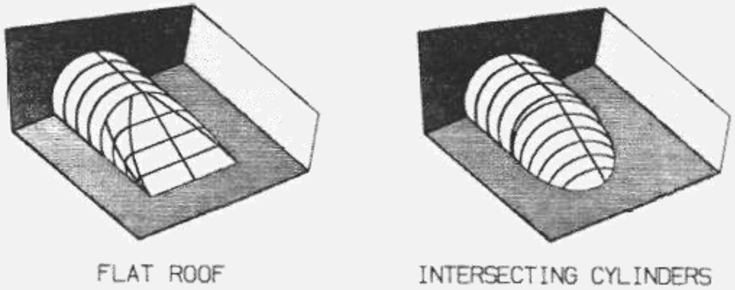


Tunnel Hull Geometry Samples

Tunnel Geometry

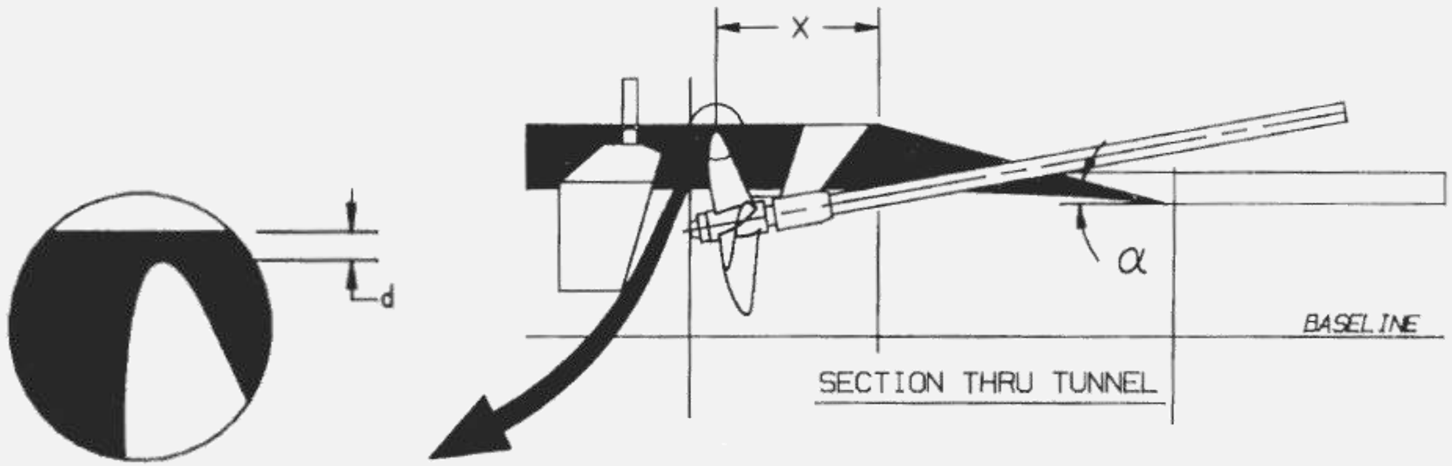
- In conventional layout, hull form directly effects the nominal wake coming through the propeller zone. But boats which have propeller tunnels, nominal wake is mostly specified by the tunnel geometry. Propeller tunnel geometry have significant influence not only on suction side of the propeller. Tunnel length at the aft side of the propeller effects the wake of the vessel.





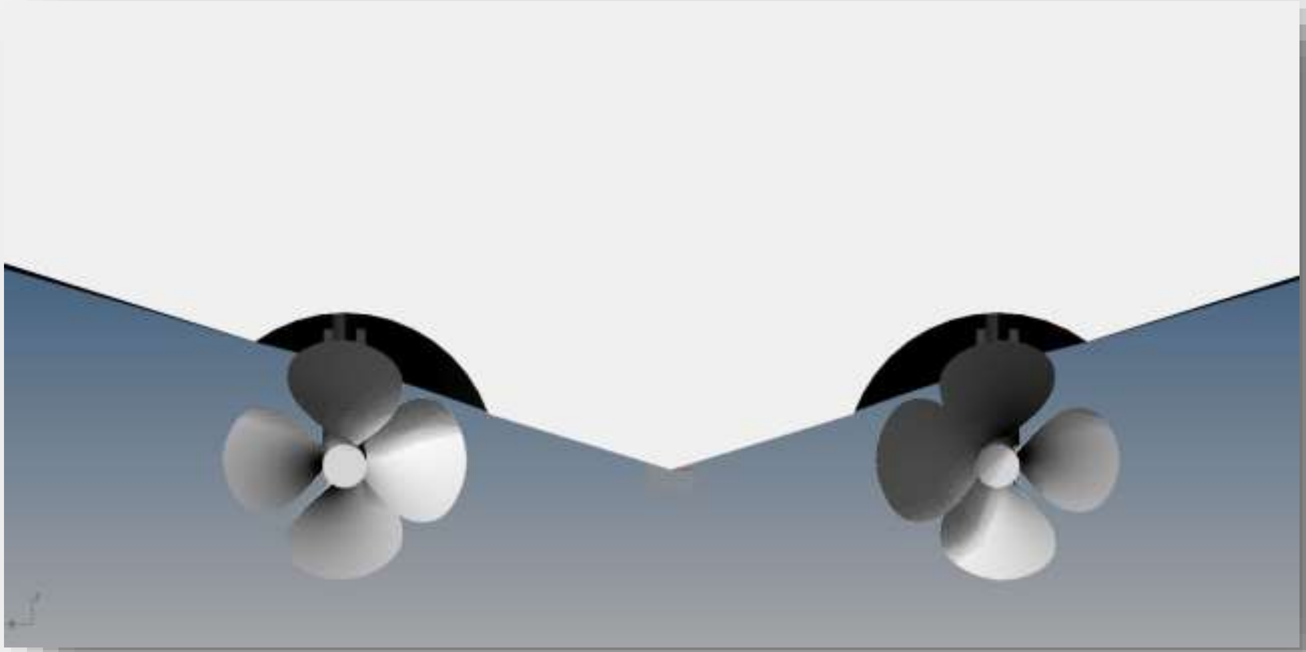
Tunnel Geometry

- Tunnel entrance region should not be longer than required dimensions. This condition causes loss in buoyancy and also increase in draft. Most critical condition is the angle of the entrance zone. Angle between the tunnel entrance the hull buttock at that section should not be more than 15 degrees. Also, diameter of the entrance zone should not have larger diameter than the propeller zone.



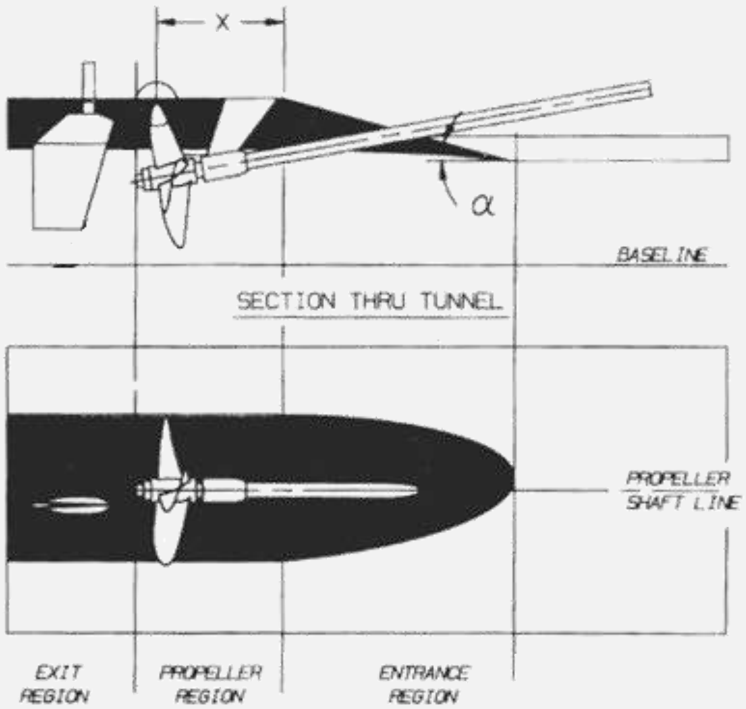
Tunnel Geometry

- Tunnel center and propeller center must be concentric in order to provide a constant clearance between hull and propeller blade tips. Also tunnel longitudinal axis should be parallel to the waterline.



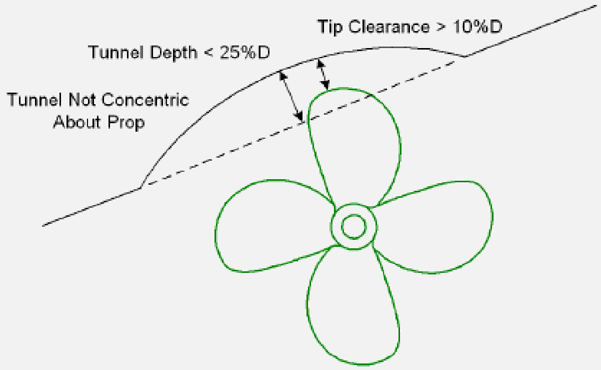
Tunnel Geometry

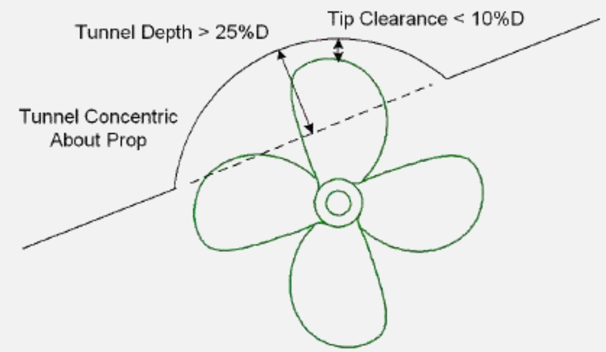
- For higher propulsion efficiency, one of the main point is tunnel geometry around propeller zone. Location of the propeller and entrance of the tunnel become critical for hydrodynamic characteristics. Tunnel geometry accelerates the flow and lower the pressure. Therefore tunnel entrance zone should be close to the propeller zone.



Tunnel Geometry

- Tunnel hull forms which have a very low propeller – hull clearance may have higher propulsive efficiency than open water efficiency. Because this configuration reduces the propeller tip losses and provides a proper wake.
- For the vessels which have propeller tunnels, propeller rate pressures have more uniform distribution.
- It is possible to make an arrangement that propeller tip and hull clearance have a dimension close to zero. Avoiding mechanical interaction, propellers which have 5% d/D clearance provides higher efficiency.





Propeller Factors

- Propeller tunnels lead to reduction in shaft angle and total draft. Tunnel geometry and propeller location in the tunnel depend on the design and there are important points such as inflow velocity, pressure and angle.
- Propeller blade tip – hull clearance brings both hydrostatic and hydrodynamic advantages. Lower clearance brings possibility to reduce the tunnel diameter; smaller tunnel diameter increases the shrouding effect and leads to top speed increment.

Dynamic Factors

- Number of propeller blades also an important selection for the vessels that have propeller tunnels. In order to minimize the torsional resonance, determining the number of blades of the propeller regarding the engine RPM range is one of the main points of this selection. For reducing the vertical blade rate forces, if one blade enter the tunnel than another blade should not leave the tunnel at the same time.

CFD Background

- In many areas computational fluid dynamics is a very important and useful method to solve complex problems as well as marine applications. It is mostly used for determining hull resistance, propeller performance, pressure and velocity distribution of flow around hull. By using this tool, it is possible to find out effects of any appendage on hull or any change on hull form.
- According to the problem characteristics, different turbulence models can be useful in order to reach the minimum error margin.
- In short, computational fluid dynamics equations satisfy:
  - ✓ Conservation of fluid mass
  - ✓ Rate of change in momentum of the fluid particles are equal to the sum of the forces acting on
  - ✓ The change in energy input to the particles is equal to the heat or work.

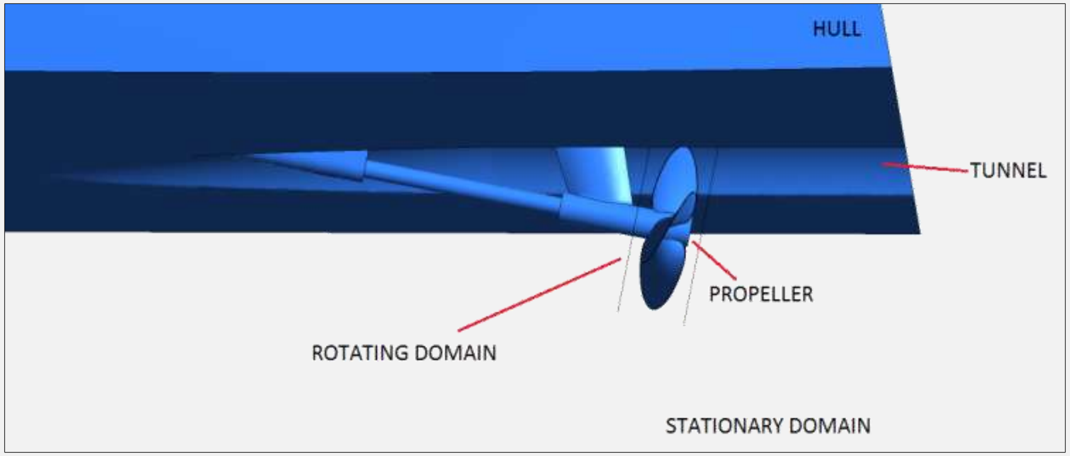
Geometry Informations

- Fluid analysis is carried out for hull and propeller geometry together. Design parameters of hull and propeller geometries are shown in table.

Propeller		Hull	
Blade Number (Z)	4	L_{OA}	24 m
Propeller Diameter (D)	720 mm	L_{WL}	19 m
EAR	0.85	B	5.16 m
Average Pitch Ratio (P/D)	1.05	T	1.05 m
Revolution (n)	900 RPM	D	3.65 m
Rake	0	Design Speed (V_s)	22 Knots
Skewness	0	Displacement	45000 kgs

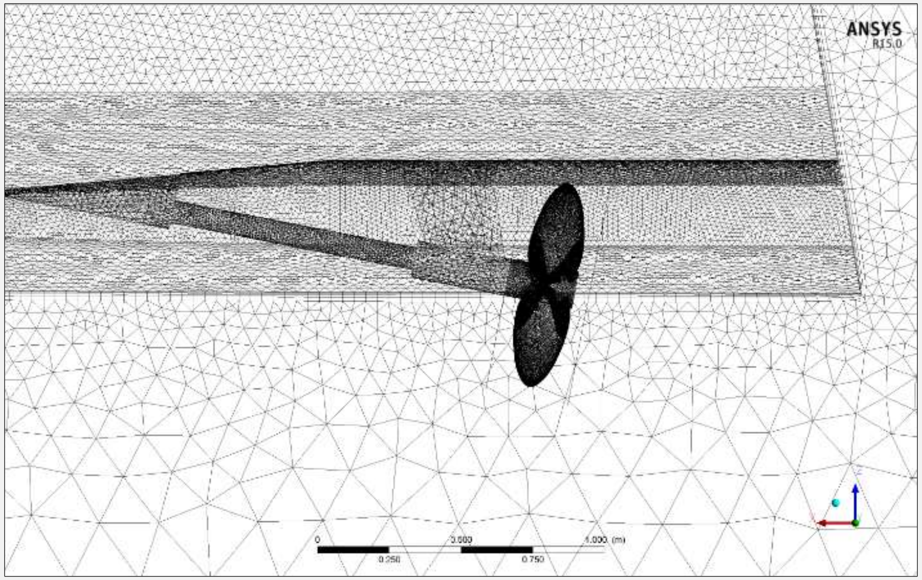
Geometry Informations

- Two different hull geometries are analyzed and influence of hull shape on propeller efficiency are evaluated. One of the hull geometry includes shaft, propeller and P bracket, second hull configuration involved a tunnel inside hull geometry, shaft and propeller with P bracket. Thus effect of tunnel geometry is examined



Mesh Generation

- Unstructured mesh (tetra mesh) is preferred as a grid generation for this study and mesh quality criteria values are provided. Skewness, aspect ratio and orthogonal quality are examined and these values are shown in table.

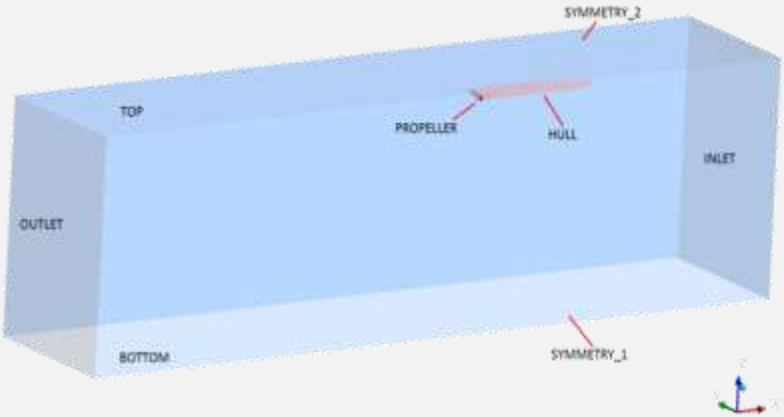


	With Tunnel	Without Tunnel
Number of Elements	7.523.045	7.612.893
Number of Nodes	2.697.003	2.585.022
Skewness	0.90	0.93
Orthogonal Quality	0.10	0.11
Aspect Ratio	149.7	66.291

Solver Setup

- After mesh generation, setup and boundary conditions are defined in pre-processing. In this study, type of fluid is defined as water with 1025 [kg/m^3] density value and turbulence model is selected as K-ω SST.

Turbulence Model	k-ω, SST
Type of Fluid	Water, 1025 [kg/m^3]
Revolution	900 [rpm]
Inlet	22 [knot]
Outlet	Pressure value is 0 [Pa]
Blade (Wall)	Propeller blade is described no slip wall and rotating velocity is 0 [rpm]
Hull (Wall)	Hull is described no slip wall
Symmetry	Exterior surface of domain is described symmetry.



Solution and Results

- At the end of the analysis thrust and torque values of the propeller are evaluated and pressure distribution on blade and hull surface is examined. The pressure distribution on propeller and hull is evinced in Figure

Propeller Properties

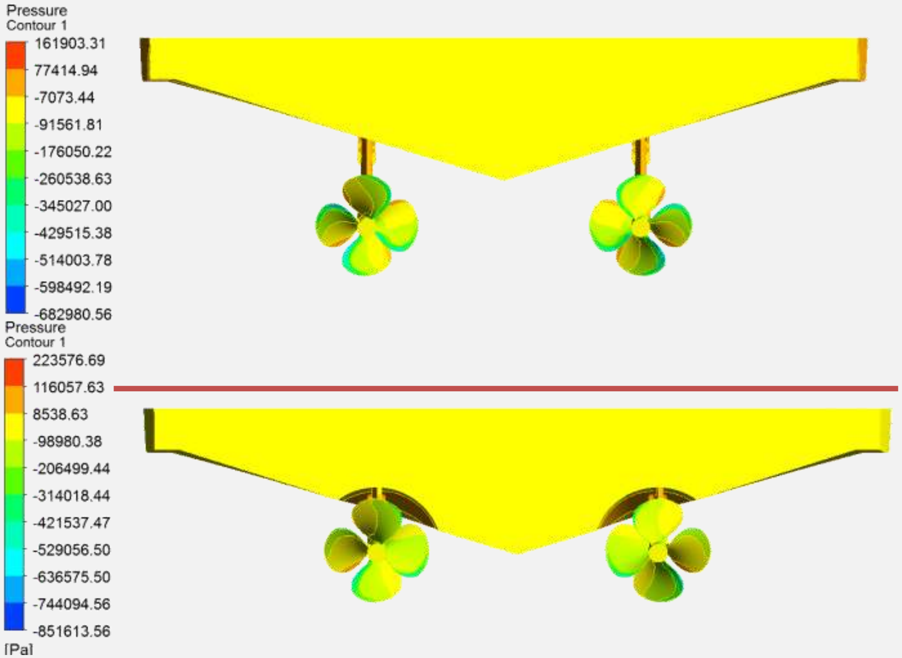
	Without Tunnel	With Tunnel
Diameter [m]	0,72	0,72
Speed [m/s]	11,300	11,300
Rotation [rpm]	900	900
Rotation [s^{-1}]	15	15
J [-]	1,046	1,046
Thrust [N]	40700	50842
Torque [Nm]	13612	15923

Solution and Results

	Without Tunnel	With Tunnel
K_T	0.65731	0.81963
K_Q	0.30478	0.35652
$10K_Q$	3.048	3.565
Efficiency	36%	38%

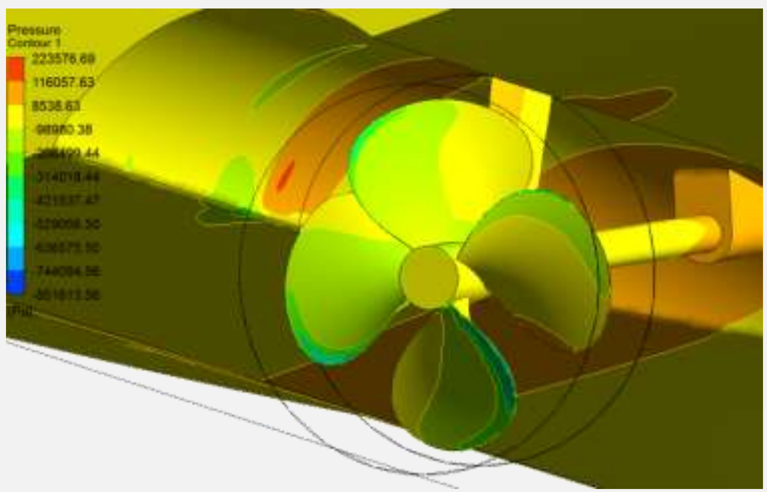
Conclusion

- Computational fluid dynamics solutions that examine propeller – hull interactions indicate that propeller induced pressure effects on hull have significant influence on vibration.



Conclusion

- The uniform pressure distribution in the axis of the tunnel provides lower vibrational effects on the vessel .On the other hand, on the conventional hull form, every blade pass near the hull creates pressure drop. Every pressure drop effect increases vibrational effects on the non-tunnel hull geometries.



Conclusion

- Advantages of the tunnel applications and decreased propeller – hull tip clearance are:

  Reduced circumferential blade load vibration, reduced blade-rate hull pressures, increased propulsive efficiency and reduced shaft torsional loads, but on the other hand more critical relationship occurs between blade number and tunnel shape.

Future Works

- Focusing on propeller induced hull pressures
- Determining blade induced hull forces
- Propeller induced hull vibration analysis

Thank you.

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