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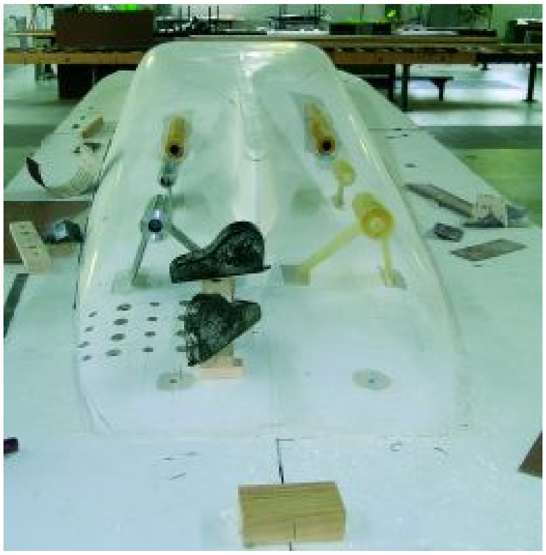
THE PROPELLER BEHIND THE HULL

effect of propeller shaft brackets and shafting line



Functioning and performance of a vessel's propeller is strongly influenced by non-uniformity of flow incidence, whose effects must be carefully calibrated to avoid jeopardising the efficiency of the propulsive system, comfort on board and the toughness of the structures. Non- uniformity of flow incidence in fact determines a variable distribution of the hydrodynamic load both radially and along the azimuth, giving rise to periodic fluctuations of thrust and torque values with consequent triggering of vibrations, noise, non-stationariness of thrust and stress on the structures. In these cases the wake released by the propeller is significantly affected by the reciprocal position between the blades and the current released upstream by the vessel's bottom, presenting perceptible alterations with regard to the axial-symmetrical morphology typical of propellers in uniform flow conditions. The vessel's bottom produces a perceptible distortion of flow incidence which, with twin propeller vessels, is particularly accentuated in the lee of the propeller shaft brackets and the shafting line. In fact with twin propeller hulls, due to the decentralised position of the propulsors, the flow tends to be little affected by the perturbation caused by the hull, with a nominal wake coefficient typically greater than 0.95. The main effect however is to be sought in the prop shaft brackets and the shafting line whose perturbation is manifested in the form of a lack of current speed and the development of turbulence.

The action exerted by a prop shaft bracket may be illustrated by means of the model of a wing surface of finite length struck by a current, with an angle of incidence linked to the local characteristics of the wake released by the after part of the hull (figure 1). The hydrodynamic action of the bracket is manifested in the form of unbalance of the field of pressure between the dorsal and ventral surfaces which determines on the one hand a slowing down of the current in the direction of movement, and on the other the diversion of flow towards the zone under pressure.

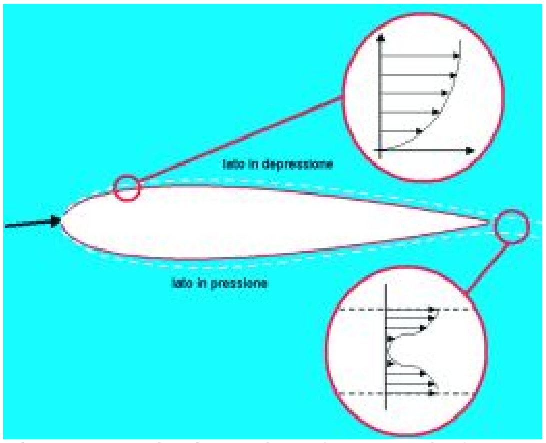


Figure 1. Hydrodynamics of a prop shaft bracket: flow around a load bearing profile

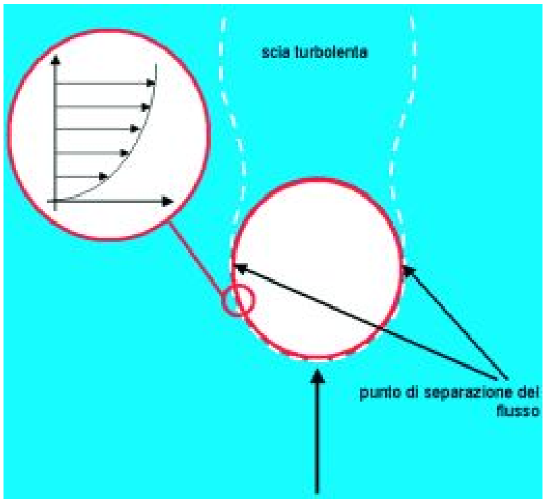


Figure 2. Hydrodynamics of the shafting line: flow around a cylinder in a uniform current

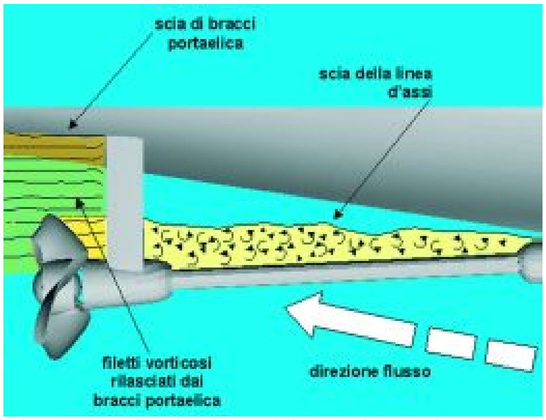


Figure 3. Distribution of the wake of the prop shaft and the brackets in a twin propeller vessel

The braking action is in particular linked to two effects, the first of a potential nature due to resistance of form, the second of a viscous nature linked to the presence of the boundary layer. The deviating action exerted on the flow may be easily interpreted, by means of the third law of dynamics, as the effect of a force equal and opposed to lift which will tend to rotate the current in the direction of the surface under pressure. The extent of this action is therefore linked to the intensity of lift force, so it will augment with increase in hydrodynamic incidence of the bracket (through the lift coefficient), with increase of dynamic pressure of flow incidence , and naturally with increase of the wetted surface. In the case of prop shaft brackets this force is often utilised to produce a component of flow counter-rotating with regard to the propeller, which brings about an increase in blade hydrodynamic load, counterbalancing the lack of dynamic pressure induced by the hull wake. This effect is very similar to the one that leads to adoption of asymmetric stern shapes in single propeller vessels where conformation of the construction lines in the submerged part, above and below the shafting line, forces the flow counter-propeller, minimising the effects of non-uniformity of the blade load during rotation . Slowing down of flow in the direction of movement is distributed along an area of finite thickness whose amplitude, for small values of hydrodynamic incidence, is roughly one order of magnitude less than the maximum thickness of the profile itself. On the increase of incidence the opposing pressure gradient causes detachment of the boundary layer, which is associated with a considerable thickening of the wake and a fall in bracket performances (hydrodynamic stall).

The hydrodynamic behaviour of the shafting line may be described by means of the hydrodynamic model of a cylinder immersed in a fluid current (figure 2). Contrarily to what was seen for a body with profiled section, in the case of a bluff-body, with hydrodynamic characteristics similar to those of a shafting line, the flow does not

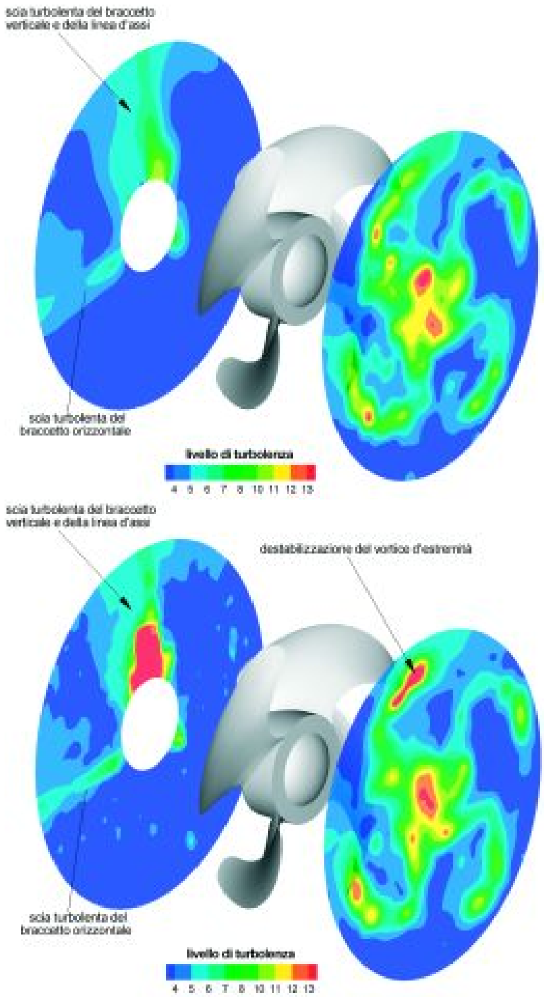


Figure 4. Effect of prop shaft bracket orientation on distribution of the turbulent wake upstream and downstream of a propeller. Top figure: configuration with brackets at geometric incidence nil (configuration 1). Bottom figure: configuration with brackets in counter rotation with regard to the propulsor (configuration 2).

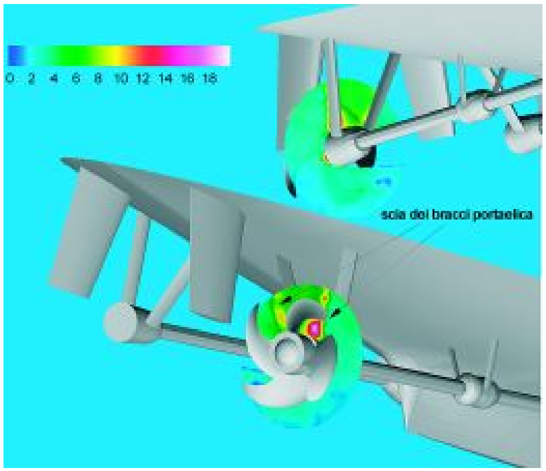


Figure 5. Distribution of turbulent wake in the zone between propulsor and prop shaft brackets

succeed in adhering to the body but tends to separate fairly rapidly, releasing a turbulent wake characterised by notable loss of speed and a thickness of the same order of magnitude as the diameter of the body. The vortex shedding that takes place on the shafting line creates a wake of alternate vortexes which produces forces of resistance and lift on the body that are variable in time with a well defined frequency, independently of the fact that the hull is moving at a constant speed.

The wake of the prop shaft brackets and the shafting line constitute peaks of discontinuity of the velocity field whose effect increases if not suitably dimensioned from the hydrodynamic viewpoint. On this matter, figure 4 shows the states of the turbulence field of a twin propeller vessel regarding two configurations of brackets with geometrical incidence nil (configuration 1: figure 4, left) and in counter rotation with regard to the propulsor (configuration 2: figure 4, right). The measurements were taken at the Circulation Canal of the National Institute for Naval Architecture Studies and Experiments with a Laser Doppler anemometric system. The distribution of turbulent intensity supplies information very useful for evaluating the functioning conditions of the propeller and the effects due to interaction with the wake of the hull and its appendages.

Turbulence is in fact an important indicator of propulsor efficiency inasmuch as it represents that portion of energy transferred from the propeller to the flow which gets "lost" since it does not contribute actively to the development of thrust. In this sense the zones in which the highest values of turbulent intensity are encountered constitute potential sources of noise and the triggering of cavitation due to the processes, activated by turbulence, of generation and destabilisation of bubbles. The turbulent wake of the prop shaft brackets and the shafting line in particular constitutes the main source of triggering processes destabilising the propeller wake. Returning to the example of figure 4, this behaviour is especially evident in the vertical bracket of configuration 2 (figure 4, right) which causes a perceptible increase in turbulence levels of the blade extremity vortexes each time they pass downstream of the bracket itself.

This perturbation is propagated in the form of noise and of vibrations on the counter, consequently disturbing comfort on board. Moreover, as noted above, the turbulent wake of the bracket gives rise to cavitation phenomena on the propeller which increase the already mentioned hydro- acoustic effects and vibrations; and, of course, erosive type phenomena on the propulsor blades. The choice of adjustment for prop shaft brackets is generally implemented through self-propulsion trials in Testing Tanks, seeking an orientation that minimises the thrust required of the propulsor for a given speed. This approach, based on the measurement of a global magnitude (thrust, precisely), takes account only of aspects connected with propulsion, actually neglecting all implications of a hydro-acoustic and structural type with regard to the hull itself. So in this sense the idea of orienting the brackets in such a way as to generate a counter-propeller flow must be considered with the "noise" created by the wake and its interaction with the propulsor, whose effects augment with the increase of incidence. On this subject, the backup of non intrusive diagnostic techniques (Laser Doppler anemometry, PIV anemometry , measurement of pressures brought to bear on the counter, measurement of cavitating surface with image processing techniques etc.) is a powerful instrument for monitoring the characteristics of wake around the propeller in terms of average and turbulent flow and judging the "noise" produced by interaction of the propulsor with the wake of the hull and its appendages. Availability of these techniques supplies the designer with a series of information useful for improving vessel performance in terms of both propulsion and comfort. This information should therefore form an integral part of the design process.

Note: Dynamic pressure is given by the half product of the density of the fluid means multiplied by the velocity squared of the undisturbed current.

See also: "The propeller shaft bracket" by A. Sinisi, Superyacht, January 2005.
"Anemometric flow measurements for underwater applications" by M. Felli, Superyacht, September 2004