"GLIDING WING"

VARIANT "SPALATO" - the super-high-speed vessel of the next generation

( preliminary solution )

Summary:

In the paper, some thinking has been given on needs and possibilities of modern super-high-speed vessel. This vessel is an original concept based on the optimum use of both media (air, water) using aerodynamic effects and the buoyancy force for flying and stabilisation of vessels and decreasing of the total resistance.

This idea refers to the preliminary design for variant "SPALATO", as a vessel from family "GLIDING WING", with the speed about 60 - 80 knots, without flying and landing possibilities on the sea surface, and without WIG (Wing-in-Ground) effect, for the beginning.

Key words: super-high speed vessel, flying-landing manoeuvre, soil effect, buoyancy force, profile raising, total resistance.

1. INTRODUCTION

A fast transportation of people and goods is a request which has been expressed today more that ever before. Railway, air and road transportations, which make 1/3 of the total world transport, have partly resolved this request by using modern high-speed passenger and cargo vehicles. However, the maritime traffic, which makes 2/3 in the world transportation, has not yet reached that level, although experts have worked for years on the plans of super-high-speed vessels. A policy of the maritime traffic should give a serious consideration to this fact, both for the coastal navigation and for the overseas one, because the maritime traffic in relation to the land-air traffic is still: the safest, the most attractive and finally the cheapest, which will be the case for a long time.

It is known that in Europe, the Far East and the USA several teams work on secret projects in order to plan and produce the vessel of the "new generation", i.e. "super-high-speed" vessel, which would meet the requirements of the modern time with its characteristics.

For such vessels, it is necessary to resolve:

- the question of drive for high speeds (80-100 knots)
- the application of modern materials and special technologies with the purpose of decreasing the vessel's own weight (like in the aircraft industry),
- the question of "new" ways of working out of elements, sub-assemblies, and assemblies,
- the application of improved classical means of connecting, and introducing the new ones,
- the question of automatization and stabilisation of the vessel for new maritime requirements,

- the question of providing maritime routes ("corridors") for the navigation of super-high-speed vessels, etc.

The system of hydroplane, in the case of "Gliding wing" will be used, i.a. gliding on the sea surface, with possible of a low altitude flight, without the classic "wing - span". But the WIG - effect would be use in the second phase of development of "Gliding wing", so variant "SPALATO", like idea project, will have "only" a speed about 60 - 80 knots, gliding on the sea surface.

The conventional shipbuilding has not resolved this so far because it has not been forced to, because it has not had any competition and the aircraft industry has been preoccupied with its own problems. All this requires, of course, significant investments.

Today, a typical form of fast vessels for mass transportation (Monostub, catamarans - SES, SWATH, WAVE-PIERCER, etc.) as shown in Figure 2 have the usual speeds:

- the buoyancy vessels..............30 - 35 knots, and 300 - 500 passengers,

- the hydrofoils vessels............40 - 45 knots, and 80 - 100 passengers and

  - the air - cushion vessels........45 - 50 knots, and 100 - 150 passengers.

Figure 1: Typical forms for the fast and high-speed vessels (2) (5)
- The classical form - pushing waves
- The form for gliding on waves
- The catamaran form
- The air-couchion form
- The hydrofoil form
- The wave-piercing form
- The form with stair-cause canals
- The Surface-Effect-Ship form
- The Smal Waterplane Twin Hull form
- The catamaran with amortizing superstructure form
- The catamaran of the new generation (flying vessels)
Of course, the conventional catamarans use buoyancy for support with a small amount of dynamic lift and can achieve speeds up to 40 knots, with good efficiency, but to go faster, hydrofoils and air-cushion system vessels are needed. For the speeds of 50 knots for the hydrofoils, cavitations become a major problem, but the air-cushion vessels work the best. Today’s hydrofoil and air-cushion vehicles are much more expensive than catamarans paying for unusual speed. They are built mostly of Al-alloys with conventional building techniques.

However, the science of the 3rd millennium has the historic mission to make, as soon as possible, the vessel which will overcome the previous ones regarding speed, form, applied technologies, quality and highly demanding world standards. The aircraft industry, with its great experience, can and must help in this respect.

This paper tries to present in a short view the idea of new super-high-speed vessel through, and a short preliminary plan of "GLIDING WING"-variant "SPALATO".

The idea for this project was born even in 1990 in the Aircraft Industry "Soko" Mostar (Bosnia and Herzegovina) by Faruk Dizdarevic, civil engineer of aircraft industry (now a refugee in the USA) and the author of this paper in the few variant, and was protected the following year.

It has not been much done so far due to the war and financial shortages. A small information was done in the papers on The XIII Croatian shipbuilding symposium "SORTA 98" in Zadar - Croatia, and IX Congress "IMAM 2000." in Naples - Italy.

2. IN GENERAL

Taking into consideration that a vessel which would meet the requests of modern times with the aim of multi-purpose and super-fast connecting islands and littoral has not been designed, it is a time to offer the preliminary solution of the vessel which would have to meet the following requirements:

- to arrive at its destination in as short time as possible,
- to stay in ports as short as possible,
- to enable a safe and comfortable navigation at all sea and almost all weather conditions,
- to enable the multi-purpose use, i.e. to earn money even when it is not in the function of transporting passengers and/or goods,
- to have all necessary facilities for a pleasant stay of passengers during the navigation and outside of it,
- to have enough fuel, grease, drinkable and other water and supplies for the longest range,
- to enable the crew a safe and comfortable work,
- to be built in accordance to the good shipbuilding tradition, meeting the requirements of the classification societies, IMO-resolutions SOLAS-conventions and other regulations for the building of means of communication,
- to meet the standards of the environmental protection ("green vessel").
This means that the vessel must be conceived in accordance with the requirements of a passenger ship but that it can also serve, with small modifications, for the transport of cars, buses, heavy vehicles, containers and other packed load, at all sea conditions, that it must have a minimal own weight, without a robust and heavy propulsion arrangement, and that it must meet the requirements of speed above the so far one, i.e. it must have speed about 100 knots. This would be the vessel of "new generation".

This vessel have to be built of Al-alloys and other modern materials of various kinds of "sandwich" and honeycomb structures, while meeting the requirements of strength and applying modern technologies wherever possible.

Estimating that sixth generation of catamarans must have a completely new form and conception might meet these requirements, the "GLIDING WING" is the idea - project, capable to give the answer for more of previous questions.

3. THE BASIC IDEA OF THE PRELIMINARY DESIGN OF THE VESSEL "GLIDING WING"

"GLIDING WING" is the vessel of completely new, modern conception which offers a new, original functional profiling of the form and that of:

- the above-water part, completely outside of the reach of water,
- the immersed part, which provides the buoyancy of special profiling, and
- the new specific position of basic functional parts of the vessel, both mutual and in relation to the level of the water surface.

The basic idea during the conceiving of the vessel was to minimize the resistance of water and air for all the regimes of speed.

This enables a smaller consumption of fuel per kg/Nm of the transported useful load with simultaneous obtaining great super-speeds. Also, the requirement was set for as safe and comfortable navigation as possible in all atmospheric conditions and conditions of the sea and an optimum using of the effects of hydrostatics, hydrodynamics and aerodynamics in all the regimes of work.

"GLIDING WING" is the vessel composed of 6 main outside groups ( in the high level variant 12 bigger outside functional assemblies ), whose task is to enable the placement of useful load, equipment and installations, to provide optimum hydrostatic, hydrodynamic and aerodynamic effects, as well as needed firmness and stiffness of bearing construction:

1. - The above-water hull of the vessel (especially aerodynamically profiled)
2. - The under-water (immersing) part of the hull of the vessel (two or more especially hydrostatically, hydrodynamically and aerodynamically profiled submarines-skis),
3. - Vertical side pillars (at least 4 aerodydamically profiled supports- pillars)
4. Oblique front pillars (at least 2 aeroprofiled pillars)

5. The front upper and/or lower former-support (at least 1 aerodynamically and hydrodynamically profiled vertical support)

6. Rear lower former-support (at least 1 especially aerodynamically and hydrodynamically profiled vertical supporter)

7. Front revolving aerodynamic areas (stabilizers-rudders)

8. Rear lower revolving aerodynamic areas (stabilizers-rudders)

9. Rear upper revolving aerodynamic areas (stabilizers-rudders)

10. Supports of air propulsors (at least 2 aerodynamically profile supports)

11. The rear upper pillar (at least 1 aerodynamically profiled pillar)

12. Aerodynamical jackets of air propulsors (depending on the number of propulsors)

The main typical functional groups are shown in Figure 3:

Figure 3: The main bigger outside functional assemblies
3.1 THE ABOVE - WATER PART

The above-water part of the hull serves for the placement of useful load, crew, equipment and installations, but also for creating the additional force of buoyancy. It creates the additional force of buoyancy with the purpose of lowering the draught of the immersed part of the hull with the final result of decreasing hydrodynamical resistance, as shown in Figure 4.
This will enable the vessel, with the same power and consumption of fuel, to obtain a significantly greater speed compared with the so far solutions. Or, while moving with the same speeds, to obtain a smaller used power of engines, which means a smaller consumption of fuel. In such a concept of the vehicle, the air streaming of the construction is not a necessary evil, but it is used for bearing (maintaining on the set height) the vessel with useful load, together with hydrostatic and hydrodynamic components of the propulsion.

The form of the above-water solution of the hull at sea positioning is shown in the Figure 5

The problem of "induced resistance" has been especially analyzed. In other words, a great curve of the aeroprofile creates a great possibility of the secondary, i.e. vertical air-streaming by the flanks of the hull because of a great difference in pressures on the upper and lower parts of the profile. Therefore, the flanks are especially profiled (Figure 6) and technologically easily executable. In other words, special formers ("spoilers") are envisaged on the flanks which top the outside aerodynamic outline of the hull, and that from the head of the upper and lower part of the profile. In this way, the flank bordering is created which prevents the secondary flank air-streaming from the lower to the upper part of the hull profile.

The form of flank areas is evolving by the length of the hull and dimensioned in such a way as to provide as great as possible longitudinal air-streaming by the flanks. The advantages of thus profiled hulls are:

- a minimized air resistance,

- the creation of a significant buoyancy force by air, whose size grows with the square of the speed of the vessel's movement.

It is possible to significantly rationalize the construction by the application of bearing scale bark and honeycomb panels, as well as the materials of a high specific load capacity, by the application of honey-comb decks, as well as transversal and longitudinal partitions.
The "spoilers" will be used for the reason of induced resistance instead of the classic half-wings, as is shown in Figure 6.

![Figure 6: The above-water solution with the side "spoilers"](image)

3.2 THE IMMERSED PARTS

The immersed parts of the hull serve for the placement of the auxiliary propulsion group, equipment, installations and ballast, but also for creating the hydrostatic and hydrodynamic buoyancy force necessary for maintaining the vessel on the "assigned draught" or on the height "Z" in relation to the water surface, in the correlation with the aerodynamic forces of buoyancy. They have a special significance in providing the transversal stability due to a great mutual span by the breadth of the vessel. This temporarily or permanently immersed part of the hull has special hydrodynamic and aerodynamic profiles, and in accordance with this it is called "submarines" or "skis".

Such a demanding functional form, as well as the specific conditions of exploitation in water, have initiated their special profiles, according to the Figure 7a; 7b.

In one part the transversal cross-section is close to the circle (when the skis are significantly immersed in water) due to the least washed by surface for the set displacement. In such a way the resistance of friction is also minimized. Along the submarines-skis the profile of the transversal cross-section is evolvingly changeable, forming "the fig-form" of the frames. Frontally the profile is narrower, and there is B/H<1, with the position of the greatest depth of the profile by height on H/2. In the rear is B/H>1, and the position of the greatest breadth is under H/2 in order to obtain levelled bottom, which enables a more quality effect of gliding at great speeds.

Symmetrical and continuously rounded lines of the profile of the transversal cross-section intersect in the symmetry plane. They create sharp edges on the top and on the bottom, which ensure a small resistance of the form even when submarines-skis are set obliquely and when they move both through air and water. A sharp and strengthened bottom, especially in the front, provides a great stiffness and prevents possible damages for the cases of collision with hard objects on water, at greater speeds. The front end terminates sharply, under the angle of 20°, with the position of the top at about H/2. This corresponds to the position of the greatest depth of the profile of the cross-section at the front end. The rear end terminates also with a significant
narrowing with a small exit radius whose middle is under H/2, but also at the height of the greatest thickness of the profile of the transversal cross-section on the rear end. For the case of damaging of the bottom, the skis are vertically partitioned into the upper and lower watertight chambers (something like a double bottom), but also into transversal and longitudinal bulkheads. In this space, the ballast is envisaged with the purpose of adjusting the longitudinal centre of gravity, and of providing the "oblique" position of the vessel at small speeds, and while embarking and disembarking in ports.

Figure 7a. : Special "fig - form" of skis (immersed parts) of "Gliding wing"
Figure 7b. : Waterlines and frames shapes (immersed parts) of "Gliding wing"

Other functional parts have specific tasks and they are mainly in the function of providing firmness, manoeuvrability and decreasing the total resistance.

3.3 THE PROPULSION GROUP

The propulsion group is envisaged with two separate propulsion systems:

- the main propulsive system, and
- the auxiliary propulsion system.

Due to the envisaged great speeds in service and a possible phenomenon of cavitation at the water jet, the main propulsion system would consist of air propulsors and that with free or directed propellers. Taking into consideration the planned speed of 100 knots, and by a suitable choice of the aerodynamic profile of the armour (protection), it is possible to obtain a greater total exploitation coefficient at the directed propeller than at the free one.

Also, the noise and vibrations are decreased in this way, and there is the possibility of building in "movable deflectors" (rudders) for directing the air jet behind the propeller, which enables the governing of the vessel by direction. Two main propulsors are envisaged on the flank ends of the rear part of the hull.
The engines for driving the main propulsors would be ship's classical diesel engines or turbo-axial ones. Diesel engines are more suitable regarding a safer running, thermal loading and lesser consumption, but they are heavy and big in dimensions. On the other hand, turbo-axial engines are much lighter and smaller in dimensions, with a quite high level of exploitation. Their quite high resources have already been achieved by the application of modern materials resistant to high temperatures. They are much more expensive than the diesel engines but we consider that their price will decrease as this propulsion represents the future for such kind of the vessel.

The auxiliary propulsion system would be placed in submarines-skis and it will represent the combination of the diesel and turbo-axial engine with the water jet. It will be much weaker than the main propulsion system and it would serve for entering ports and manoeuvring in them, for the navigation near the coast, for easy cruising (v = 25 - 35 knots), the reason being the decrease of the noise and a better manoeuvrability enabled by the water jet. In case of need they are used for governing the vessel by the fore and at greater speeds.

3.4 THE MAIN EXPLOITATION CHARACTERISTICS

The main exploitation characteristics of this vessel would be:

- the development of significantly greater speeds with the same propulsion power and with the same load capacity of the useful cargo in relation to the existing vessels which move on water,

- a far better comfort while navigating (smaller rolling and vibrations) while driving on waves in relation to the vessels of classical construction and the same weight category, which increases with the increase of speed,

- due to the minimizing of the resistance at all speeds, and especially at greater ones, the consumption of fuel per kg/Nm of the passed distance (transported load) is significantly smaller than it is the case with the existing smaller than it is the case with the existing high-speed vessels, and even some aircrafts, - the manoeuvrability of this vessel by all axes and in all the regimes of navigation is exceptional,

- the general safety of the vessel, passengers and load during the navigation is very significant due to a higher degree of unsinkability, and smaller chances for fire and other damages,

- the possibility of a quicker embarkation-disembarkation of cargo and passengers is great, which is significant for using the vessel in shorter distances,

- the possible application of modern technologies (honey-comb and "sandwich" panels), which enables designing of multi-purpose solutions of the interior; these solutions can change effectively and quickly while in service regarding a new assignment of the vessel, without intervening on the bearing structure.

The inside arrangement of the small passenger variant is shown in Figure 8.
5. THE BASIC TECHNOLOGICAL, ECOLOGICAL AND PASSENGER COMFORT AIM

The main technological aim of these preliminary plans is the application of modern technologies and the development of new ones (on the basis of the known aircraft ones) in planning and execution of a new vessel for the transport of passengers and goods by the water routes. It should have high characteristics that have not been realized so far. These refer to the achieving of great voyage speeds (~ 100 knots) with a significantly less consumption of energy and a much greater comfort "at high waves" in relation to the existing solutions of high-speed vessels. Of course, "GLIDING WING" requires a years-long work on the final project and much greater investments. But Croatian shipbuilding have a chance to go easily in research and development of this project, together with Aircraft Industry "SOKO" - Mostar, because that more experience and resources are saved after the war in Bosnia and Herzegovina.

The vessel would be executed in accordance with IMO-resolutions, SOLAS-conventions, and other international standards, as well as with all the requests of a good shipbuilding and aircraft tradition. A special attention is paid to:

- the safety and comfort of passengers and crew during and outside of the navigation,
- the safe embarkation-disembarkation,
- fire protection
- air-conditioning and ventilation,
- automatic and manual control, regulation and stability,
- health and safe working conditions in the engine room, wheelhouse and other premises,
- the good stability at all the regimes of the sea and wind, and of a sudden diversion from the course,
- the decrease of the noise in the spaces of passengers and crew,
- the safe anchoring, mooring and the navigation "in towing",
- the two-degree propulsion regarding the avoidance of the noise in the populated environment,
- the quality enclosure and unsinkability for the case of an accident,
- the sufficient number of life-saving devices and water and food reserves,
- the impossibility of emptying fuel, grease and faeces tanks on the high seas,
- the application of new technologies and materials, as well as constructive solutions with the purpose of a quality execution and a prolonged lifespan.

5. THE PRELIMINARY GENERAL ARRANGEMENT OF VARIANT "SPALATO"

Variant "SPALATO", presented on Figures 9a, 9b, 9c was born like idea for needs of high-speed Split - Ancona transport, in the other words, to assure, by the first fast vessel in family "Gliding wing", trans-Adriatic transport, with optimal speed 60 - 80 knots. This first vessel from family "Gliding wing" will not use the WIG-effect, and its speed will be smaller than the others, and the aim of the first vessel is to build it with new materials and special technologies.

Possibilities:

1. Lav./gal.  (max. 27x20 = 540 pax.) 20 abreast/30”
2. Lng. 6x3 cars 6x3 Corr.+Lav/gal. 8 cabins
3. or 8x2 cars or Restaurant or Recreat. Area or Lng.
4. or 120 pax. or 40 pax.

Figure 9a: The side view of "Spalato" high-speed vessel

Figure 9b: The top view of "Spalato" high-speed vessel

Figure 9c: The frontal view of "Spalato" high-speed vessel
The hull - above water part, would be assymetrical aeroprofile of the positive curve (NACA type SI 53009 or SI 64009) with insignificant deviations in the fore part in order to better use the internal area.

The hull - imersed parts, would be special hydrodinamic and aerodynamic profiles "submarines - skis", with the main tasks to create a significant hydrostatic buoyancy at small speeds, and at the great speeds a significant hydrostatic thrust in the regimes of gliding, with simultaneously minimizing hydrodynamic and aerodynamic resistance ( forms and frictional ) as shown in Figures 7a and 7b.

The submarines - skis have to ensure:

- a mild deflection of water particles while air-streaming around the skis at all heights "Z" and at various longitudinal inclinations, which results in a minimum fore wave and insignificant aft whirls in all the regimes of the navigation, so that they minimize the resistance which they have caused, and

- the creation of a significant force of the hydrodynamic thrust (buoyancy) by the levelled bottom on the after end and in the middle of the profile, while a mild and gradual expansion of the cross-section prevents rough and sharp blows, and the unpleasant vibrations at bigger waves. The evolving profiles of the rear end of the skis (gradual narrowing) contributes to this decreasing.

The problem of "induced resistance" would be solved by special spoilers, as presented on Figure 6. The height of flank spoilers changes reasonably by the height of the hull, while the greatest height is set at the place where there is the greatest disturbance if flow lines during air streaming of the aeroprofile.

Other functional parts have specific tasks and they are mainly in the function of providing firmness, manoeuvrability and decreasing the total resistance.

The preliminary idea design shows the three possibilities:

1. the maximum places for cars, (52 cars + 540 to 580 pax.)
2. the maximum places for passengers, (36 cars + 700 pax.) and
3. the cruise variant (Excursion), (no cars, 72 pax + 36 cabins).

as snows Figure 9a.

The propulsion group is envisaged with main engine (diesel or turbo - axial) with the water - jet.

The main innovative basis of this vessel would be:

- a completely new concept (mechanics of the vessel) with the effect of the optimum use of both medias (water, air),

- the original hydrodynamic form of the immersed part of the hull,

- new design and technological solutions for the bearing construction of the vessel, which moves on water by the application of modern materials of high mechanical characteristics, modern methods of connecting, which enables a light construction of a great load capacity,

- the providing of natural directed stability of the vessel by all axes, with the various possibilities of the application of aerodynamics, together with hydrostatics and hydrodynamics, as well as with the computer
support and servo-commands, which enable quick responses to the outside impulses with the purpose of the stabilization the vessel.

6. CONCLUSION

The classical concept of slow ships, with the application of conventional shipbuilding technologies, will not win the race with new trends, as these old technologies are seriously "shaken" even at middle displacements (to 300 dwt). Only the vessels of new generation, like presented "GLIDING WING", in near future can provide demanding characteristics which will prevail in the 21th century. It is especially the case with great voyage speeds and a great and safe stability, a comfortable navigation, and the mass, cheap and fast transportation, on the basis of which requests this project are founded. This is especially valid for partly closed seas, as the Mediterranean and its constituent parts.

The variant "SPALATO" have to be first step in the production of high - speed vessels in new croatian shipbuilding possibilities, but in colaborration with aircraft industry "SOKO"- Mostar in Bosnia and Herzegovina, which production resources is not in efficient use till 1992 year.

The Republic of Croatia and its shipbuilding science has founded the scientific project "Croatian Shipbuilding 2000". and this idea - project is accepted, but is not started jet. The beginning of the realization exspect the financial sources within this scientific project.


