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Monotricat®, Innovative Displacement Hull High Hydrodynamic Efficiency and Energy Recovery, Navigating at Speeds of Planing Hulls on Spray Self-produced

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Abstract: The need to have naval units ever faster pushed the ship design to design hull shapes with increasingly higher performance thanks to the use of lightweight materials such as aluminum, and more powerful engines, etc., but without substantially modifying the traditional forms of hull. The hull patented Monotricat high hydrodynamic efficiency and energy saving it represents an evolution of the traditional architectures of the hulls, as its shape is adapted to recover wave formation engendered from the bow and sprays associated with it so as to reduce the resistance to the benefit of the speed, and navigating in displacement at speeds of planing hulls with an efficiency of about 20%. The patented hull Monotricat represents the overcoming of distinction between displacement and planing hulls, because, unlike previous solutions, the hull conventionally called Monotricat is the first displacement hull that can navigate at both displacement and planning speeds, with a resistance curve almost straight, maintaining the characteristics of a displacement hull, since it combines the characteristics of displacement and planning hull. It presents an innovative architecture that could be defined as a hybrid between a monohull and catamaran, navigating on spray self-produced. The combination of these three types of naval hulls allows it to ensure: safety, comfort navigation, best seakeeping and maneuverability in restricted waters, stability, reduction of resistance to motion, cost management, regularity on the routes even in adverse weather-sea. These characteristics of the hull have been studied, tested and validated by leading research institutes and universities with more ameliorative results in each subsequent experimentation, reported in the present work, which demonstrated a greater hydrodynamic efficiency compared to conventional hulls of 20%.

Key words: Innovative naval hull, energy recovery, hydrodynamic efficiency, displacement hull, planing hull, spray self-produced, resistance curve straight line.

1. Introduction

This new architecture of naval hull, realized and internationally patented, born from 15 years of studies and research breaks all the conventional schemes as it consists of a thin and very immersed bow inserted in a catamaran having very thin hulls that delimit a central tunnel beneath the waterline, in which the wave engendered from the bow is conveyed associated with the formation of foam. Then, part of the kinetic energy of the wave is transformed into pressure energy with the result of obtaining a lifting of the stern, while the foam, interposed between the hull and the water, it breaks in good part the "boundary layer" getting a reduction of the viscous resistance. Therefore the reduction of the resistance is obtained through the recovery of the energy contained in the wave engendered from the bow and exploiting the spray associated with it, while with the increase of speed the hydrodynamic effect raises the bow compensating lifting stern. This reduction in resistance increases in proportion with the increase of speed is obtained therefore, the same result that, in a planing hull to get with the lifting part of the hull and, thus obtaining a reduction of viscous friction.

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Peculiarity of this hull is always navigating in displacement for it to produce the wave formation of the bow. Therefore the hull Monotricat can be defined as the first naval unit high hydrodynamic efficiency and energy recovery that navigates on a formation of spray self-produced as will be explained in the paragraph “Innovation”.

The purpose of this patented invention is to get boats that have: high efficiency, high navigation comfort, large load capacity, while ensuring increased safety / comfort / regularity of connections / excellent skills straightening / ability to evolve in narrow waters / cost operating in speed ranges which range from higher speeds applicable for displacement hulls at speeds typical for planing hulls while surfing the trim displacement, thus offer the market work boats, pleasure craft, passenger transport, coast patrol.

2. Innovation of New Architecture of Hull

The above is realized through an innovative architecture of naval hull completely out of all the conventional schemes, since it is properly of a hybrid between a conventional monohull, trimaran and catamaran. This hull consists of a bow deep V with an angle which gradually increases towards the stern of up to 180°; at the same time the bow reduces the immersion towards the stern. At the hull, are flanked by two side blades with the aim to capture and contain the wave formation created by the bow and the spray associated with it. Its distinguishing feature is the presence of a central tunnel under the waterline in the rear of the hull, while the front part, the hull has a bow V-shaped deep and thin. This architecture provides the hull excellent leadership skills, stability in the seakeeping in adverse weather conditions for the effect wave-piercing, and capacity to maneuver in tight areas.

Inside the tunnel is conveyed wave engendered by the bow with the formation of foam associated. Then, part of the kinetic energy of the bow wave captured under the hull is transformed into pressure energy with the result of obtaining a lifting of the stern section; simultaneously hydrodynamic thrust allows the bow to lift up and to maintain a structure that varies between 1 and 2 degrees approximately, while the foam, interposed between the hull and the water, it breaks in good part the “boundary layer” obtaining a reduction of viscous drag. These drivers allow the hull of not being sensitive to the movement of loads; for this reason the hull remains almost stable, so is called “mono-stab”. It can be said also that the hull Monotricat behaves as a hull ASV (Air Support Vessel) without the need to “pump” air under it. These phenomena are accentuated with increasing speed. It is therefore evident that the reduction of the resistance is obtained in proportion with the increase of the speed and whose resistance curve, will always be a nearly straight line.

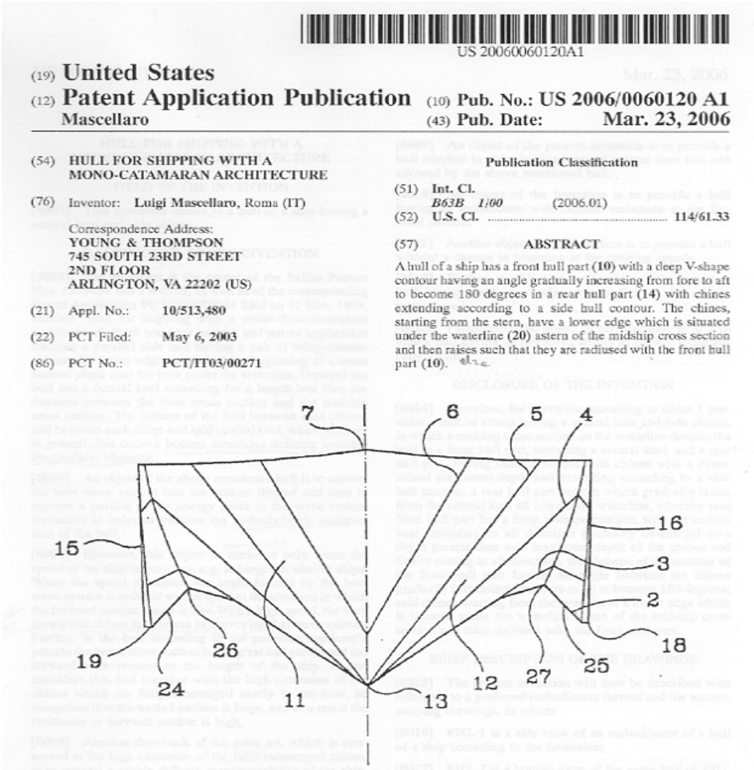
The hull Monotricat thus appears to be a hull very safe by virtue of its width (about + 20%). The bow thin type “wave piercing” makes it very comfortable even in adverse sea and weather conditions; is in fact able to deal with adverse sea conditions better than other hulls; recovery of wave formation associated with sprays make the hull Monotricat very efficient in both speed displacement that planing.

For such innovative features the Monotricat hull has been patented internationally in major countries of the world (besides the European countries, USA, Canada, China, Russia, Israel, Australia, etc.).

3. Methodology

3.1 Experimentation Performed

This new architecture of the hull has been repeatedly tested for 15 years both at leading research institutes and Italian and foreign university, with evidence in Towing Tank and testing CFD (Computational Fluid Dynamics) conducted with HPC (High Performance Computing), both with self-propelled models navigating long from 4 to 8 meters tested in open water (sea, lakes and rivers).



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(54) HULL FOR SHIPPING WITH A MONO-CATAMARAN ARCHITECTURE

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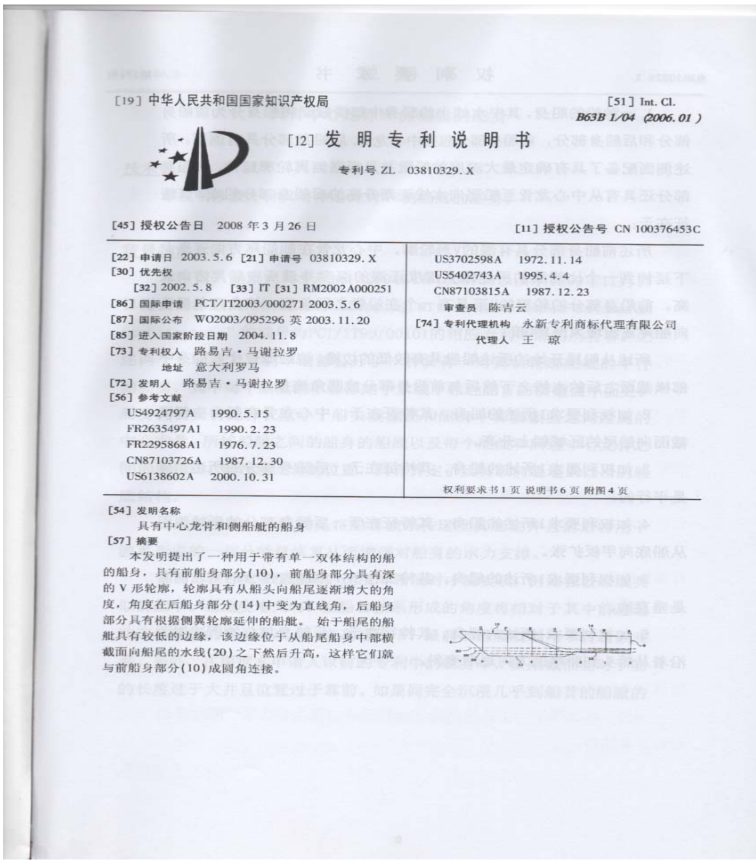
(57) ABSTRACT

A hull of a ship has a front hull part (10) with a deep V-shape contour having an angle gradually increasing from fore to aft to become 180 degrees in a rear hull part (14) with chines extending according to a side hull contour. The chines, starting from the stern, have a lower edge which is situated under the waterline (20) astern of the midship cross section and then raises such that they are radiused with the front hull part (10).

Patent Usa



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[54] 发明名称
具有中心龙骨和侧船舭的船身
[57] 摘要
本发明提出了一种用于带有单一双体结构的船的船身，具有前船身部分(10)，前船身部分具有深的 V 形轮廓，轮廓具有从船头向船尾逐渐增大的角度，角度在后船身部分(14)中变为直线角，后船身部分具有根据侧翼轮廓延伸的船舭。始于船尾的船舭具有较低的边缘，该边缘位于从船尾船身中部横截面向船尾的水线(20)之下然后升高，这样它们就与前船身部分(10)成圆角连接。

Patent China

Monotricat hull in Towing Tank Rome (2011)

The experimentation carried out so far has produced excellent results every ameliorative, widely tested and certified at the Towing Tank of Rome INSEAN CNR and at the Towing Tank at the University of Trieste. The simulations in C.F.D. technology HPC (High Performance Computing), made it possible to confirm the evidence in Towing Tank simulating phenomena insist that under this new hull. Studies in C.F.D. were conducted at the University of Stockholm - Dip. HPC in 2014 where it was possible to compare the results in CFD with those obtained in Towing Tank on the the 2010 model, and then was reached to achieve scalability between tests in CFD and previous results in Towing Tank, demonstrating that there are under this hull phenomena that occur under it and allowing it to be so efficient. At this point it was possible to continue the optimization of the hull in CFD at an Italian research center, getting a model optimized hull with related performances, and simulations in reaching a speed of 3.4 FNV, while the so-called resistance curve results to be almost a straight line.

The experimentation has had as their object the numerical evaluation relating to a vessel 24 meters long and 7.45 meters wide, displacing 60/70/80/90 tons, with the purpose of verification for a wide spectrum of use.

The experimental study has been previously performed with models navigators self-propelled variable length between 5 and 8 meters. (These models are still available for demonstration in open water.)

In detail, the studies and experiments carried out so far have been:

3.2 Test in Towing Tank and Test in Open Water

Institute Towing Tank I.N.S.E.A.N. C.N.R. of Rome (2000/2004):

October 2000 Towing Tank INSEAN ROME Hull C2414 (Fig. 1)

October 2004 Towing Tank INSEAN Bolsena Lake Hull C2479

Department of Naval Engineering of the University of Trieste (2008) directed by Prof. Igor Zotti, who personally tested the hull and has exhibited in the report to Congress Sea-Med 2012 “Evolutions and trends in the development of modern hydrodynamic fast hulls” (Zotti and Agrusta, 2012):

December 2008 Department naval UNITS Hull C412-08 (Fig. 2)

In Fig. 2 is highlighted in the hull C 412-08 the resistance curve resulting by tests in Towing Tank at the University of Trieste, which show along the abscissa axis the speed of the tested model (meters per second) and along the ordinate axis the resistance in Newton, where RTM is the total scale resistance model and RFM model is the frictional resistance.

Institute Towing Tank I.N.S.E.A.N. C.N.R. of Rome (2010, 2011):

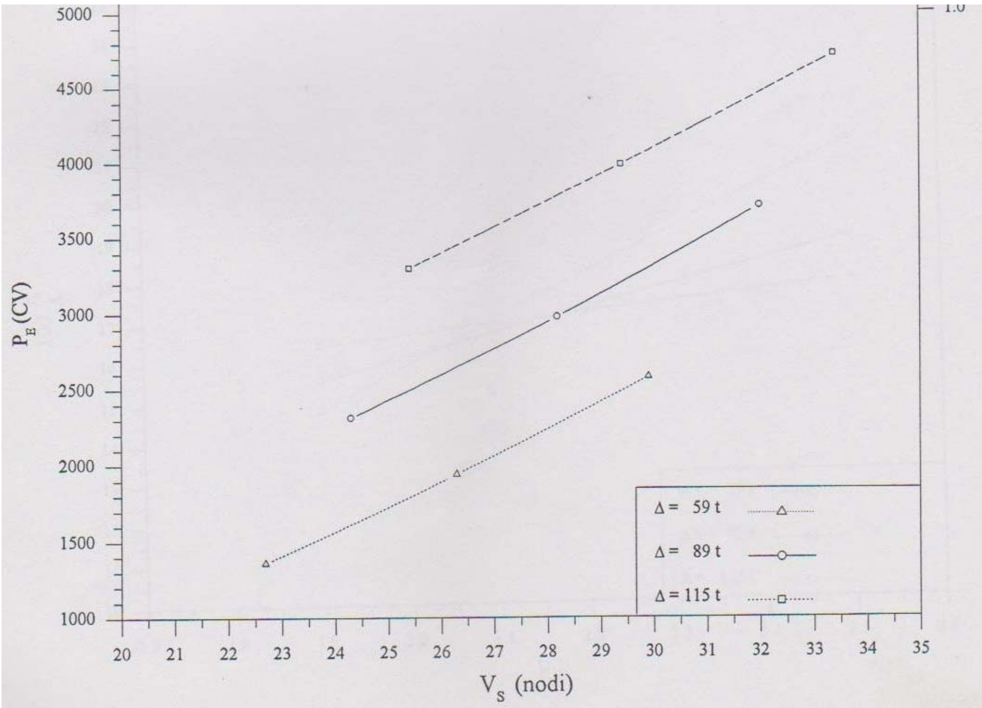


Fig. 1 Resistance curve Towing Tank INSEAN CNR, Rome, 2000.

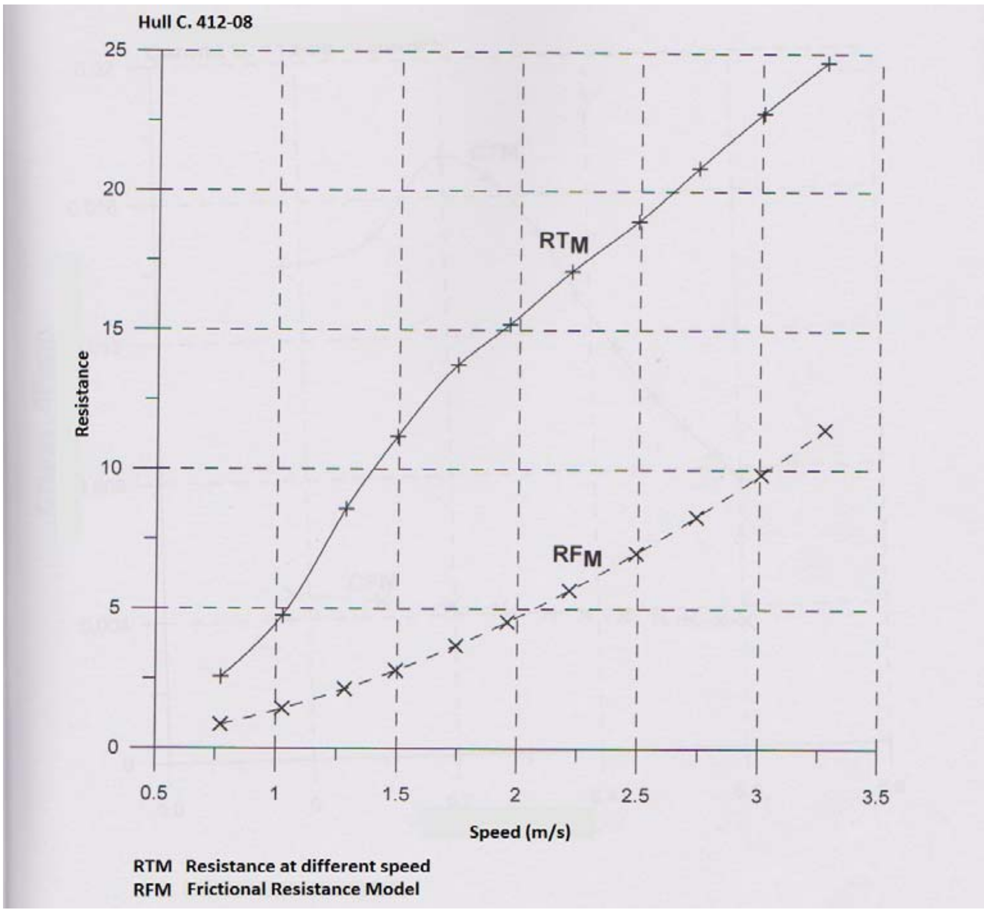


Fig. 2 Resistance curve Towing Tank University of Trieste, 2008.

August 2010-2011 Hull 2565 (where it was certified that a hull of 24 meters 70 tons displacing is able to reach 20 knots with a maximum of 1,600 Cv), while for the same vessel at 60 tonnes must be a power of 1,450 Cv on a performance engine estimated at 50%.

Tests on open water with self-propelled vessel at Bolsena Lake by Studio of Engineering and Consulting Naval Boghi & Partners, 2005 (Fig. 5), and other tests at sea and rivers (Fiumicino, Sabaudia) (2002-2009).

3.3 C.F.D. Studies

University of Stockholm (Sweden) (2014) as part of the European program PRACE SHAPE for innovation with the aim of promote cooperation and technology transfer between research and industry, where the MONOTRICAT SMEs, holder of the international patent Monotricat®, participated with other 9 innovative European SMEs. The hull Monotricat was studied with simulation software Open FOAM (system open source CFD). The results obtained with the CFD OpenFOAM are substantially superimposable to those obtained with the tests in Towing Tank.

Simulation in C.F.D. carried out in an Italian research center (2015) with the aim to optimize the hull, simulating speeds up to 42 knots for a hull of 24 meters and 70 tons displacing (model Towing Tank INSEAN CNR 2010), obtaining a resistance curve almost rectilinear (Figs. 3 and 4). Tests performed: Change in weight distribution; test very high speed.

In the last test in CFD (Italy) has been performed a simulation of variation of trim. In particular, tests have been carried out specifically for moving the center of gravity and precisely: simulation with the hull at bow up of + 0.5° and simulation with the hull at bow down of -0.5°, without a significant difference in performance.

From the results of the simulations in C.F.D. at the Italian research center on optimized model obtained by varying the initial static trim, it is interesting to observe how the curves of dynamic trim absolutely not affected the change the center of gravity because the measured values are always roughly the same with the only addition of the initial static trim. Often, in fact, on traditional hulls, a small variation of the initial static trim can result in a large and amplified variation of dynamic trim, sometimes such as to significantly alter the conditions of motion of the hull (Fig. 4).

“Original Hull - v0” comes from tests conducted in Towing Tank INSEAN CNR in Rome in 2010.

“Modified Hull - v5” is a modification done in CFD (test in Italy by NavalHead).

Fig. 3 Self-propelled model hull navigating on Bolsena Lake (speed 22-24 knots).

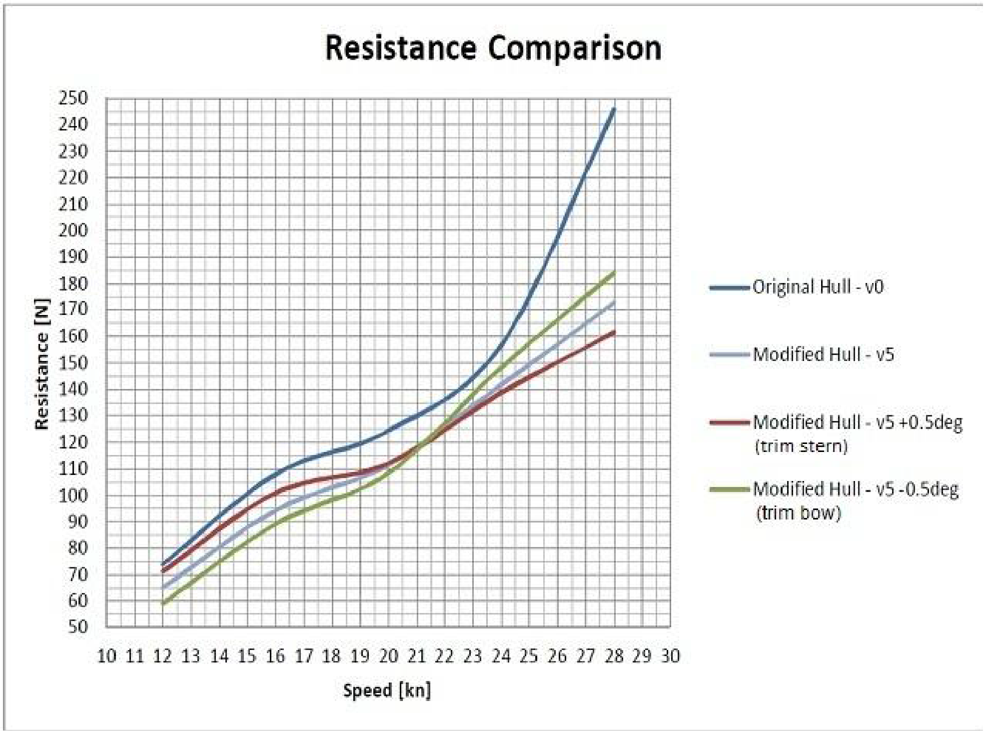


Fig. 4 Variations in trim, 2015.

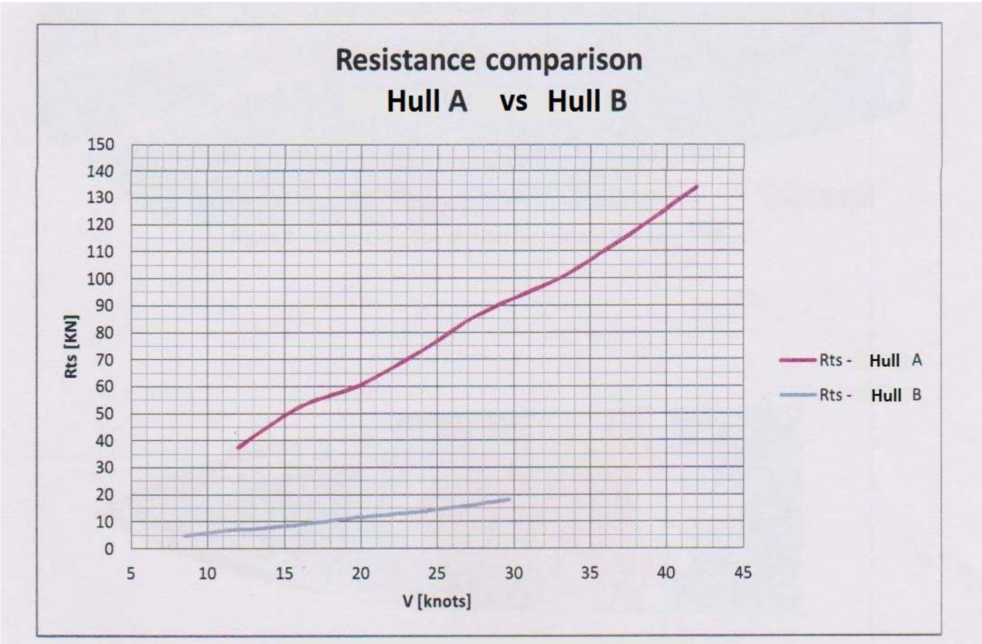


Fig. 5 Resistance curve C.F.D., 2015: Comparison resistance at different speed between Hull A length 24 meters and Hull B lenghth 12 meters.

"Modified Hull - v5 + 0.5 degrees (trim stern)", "Modified Hull - v5 - 0.5 degrees (trim bow)." This is CFD simulations starting from different trims of the hull.

It was also performed with excellent results, a simulation at high speed up to a Fn of 1.38 (Fig. 5).

4. Results

The hull patented Monotricat®, was then tested at leading research institutes and university Italian and foreign, to verify its peculiarity of being a displacement hull that navigates at speeds typical for planing hulls, thanks to the reduction of the viscous resistance between the water and the bottom of the hull which is obtained by exploiting the foam associated with the wave formation engendered from the bow and conveying it below the hull breaking the boundary layer on part of the surface of the hull with the result of significantly reduce the frictional resistance. For this reason it is comparable to a hull ASV without the need to "pump" air under it.

All experiments performed in Towing Tank have embraced a speed range up to a Fn equal to 1, while the so-called resistance curve results to be almost a straight line. Has been found in tests that actually the kinetic energy of the bow wave captured under the hull is transformed into pressure energy, causing the lifting of the aft section which is compensated with the hydrodynamic lift the bow of the hull allowing to maintain a trim that varies between 1 and a maximum of about 2 degrees, thanks to these forces which support the hull, whereby the hull Monotricat was also found to be not very sensitive to the displacement of the load (mono-stab).

A demonstration of the distribution of the "spray" we present photos taken in Towing Tank INSEAN CNR of Rome showing their distribution at different speed (Figs. 6 and 7).

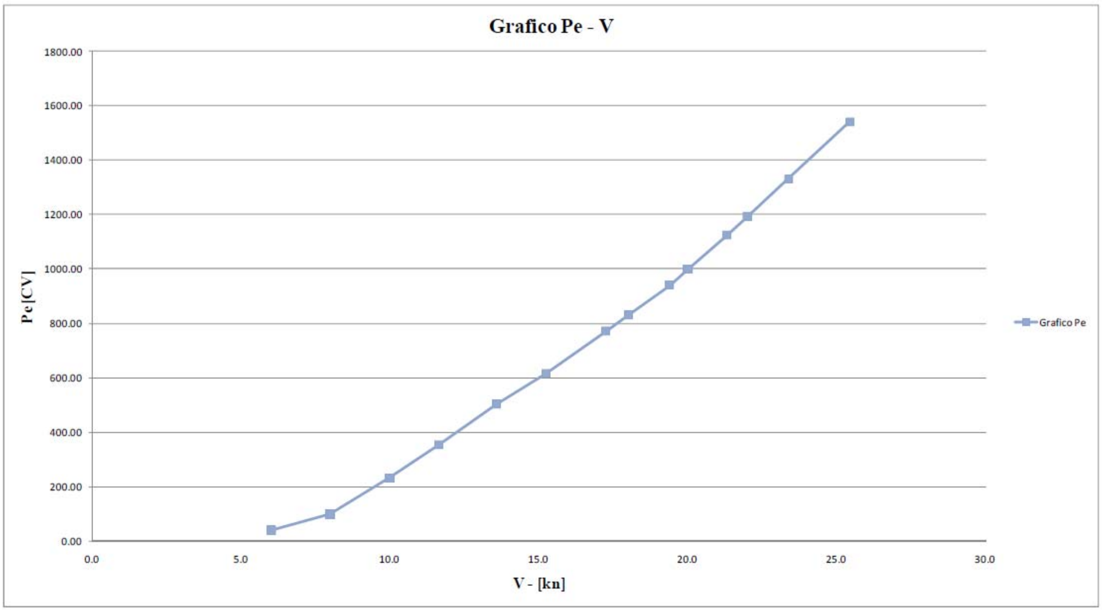
The summation of these prerogatives Hull Monotricat make a hull suitable to navigate with unusual efficiency at all operating speeds that are required; also important the little influence the movements of the provision of cargoes on board, such that one can define a hull "mono-stab".

These experiences demonstrated that the hull Monotricat while navigating in displacement, is able to reach speeds typical of planing boats, while the so-called resistance curve actually represents as a straight line.

Prof. Igor Zotti, Director of the Department of Naval Engineering, University of Trieste, having been tested hull Monotricat in Towing Tank in Trieste, has counted it among the modern fast hulls mentioning it in the report to Congress Sea-Med of Messina in 2012 (Agrusta, Zotti, 2012).

Fig. 6 Spray hull Test towing Δ 70t - speed 18 knots, Towing Tank INSEAN CNR Rome, 2010.

Fig. 7 Spray hull Test towing Δ 70t - speed 24 knots, Towing Tank INSEAN CNR Rome, 2010.



Resistance curve Model Trieste 2008

Table 1 Comparison between.

“SHUTTLE 28”- Shipyard FERRETTI (Source: Magazine “BARCHE”[“BOATS”], May 2015 - page 92) and “MONOTRICAT” Innovative Hull (Source: Towing Tank INSEAN C.N.R., 2010-2011)		
	SHUTTLE 28 - Shipyard FERRETTI	MONOTRICAT
LENGTH	28.31 meters	28 meters
WIDTH	7 meters	8.77 meters
DISPLACEMENT MAX	106 tons	114 Ton
ENGINES	2 x 1,200 hp Man	2 x 1,200 hp Man
SPEED max	15.4 knots	19.5 knots
Range at cruising speed	640 Nm	810 Nm

Table 2 Geometric characteristics of the tested hull Monotricat.

MONOTRICAT Hull				Displacement: 70t	
$L_{OS}/\nabla^{1/3}$	5.59	L_{OS}/B_{WL}	3.14	C_B	0.227
$B_{WL}/\nabla^{1/3}$	1.78	B_{WL}/T_M	4.02	C_P	--
$T_M/\nabla^{1/3}$	0.443	$S_S/\nabla^{2/3}$	9.78	C_M	--

5. Conclusions

The hull Monotricat is characterized by high hydrodynamic efficiency and economy of operation, since, as already described, the recovery of the kinetic energy with its conveyance and containment below the hull, causes a lifting of the stern area offset by a lifting dynamics of the forward area, while the spray, proportionally to the speed, reduce the viscous friction obtaining therefore not a classical curve of the resistance but a straight line. The presence of these sprays has been documented by a video recording made at the University of Trieste by Prof. Igor Zotti who called the hull Monotricat a boat type ACS “Air Cavity Ship” but without the need to pump air below it as in ACS.

As an example of the efficiency of this new architecture of naval hull, it represents the difference between Monotricat hull and one hull of a famous shipyard in the world (28 Shuttle of the shipyard Ferretti, world leader in the production of cabin cruising), where the hull Monotricat which results superior in all parameters considered by absolute evidence :

Comparison between:

SHUTTLE 28 Shipyard FERRETTI (Source: Magazine BARCHE, May 2015 page 92) and MONOTRICAT Hull (Source: Towing Tank INSEAN CNR 2010-2011): see Table 1.

Unfortunately I did not come into possession of technical data relative hulls air cavity or vessel hulls under which fed pressurized air. The experience on the model of self-propelled 7.3 meters proved to be no problem about the suction of the spray/thrusters to time, as seen from the photos taken in towing tank in Rome, the sprays are confined just below the surface of the hull. The confirmation of when asserted, is documented by the experimental curves in towing tank of the resistance in relation to the variation of the speed. This shows that, as soon as trigger those phenomena with the production of spray (approximately one FNV equal to 0.4). The resistance, with increasing velocity, which increases proportionally to it are not perceived then the so-called “ramp” for the displacement hulls as well as the hump and the next ramp for planing hulls.

The lifting of the stern area is offset by an equal hydrodynamic lift the bow, which demonstrates how much pressure there is below this bottom. It can be said that this hull while sailing in displacement, “glides on the wave created by himself” with the result of being able to avoid the use of stabilizing fins whose use would be required only for the function “0 speed”. The values resulting from the experience in Towing Tank do not take into account the optimization of the hull made in CFD in 2014 (Italy), by virtue of which, the speed would be much greater than 19.5 knots, plausibly tending towards 22 knots.

The new architecture of the naval hull Monotricat encloses in a single hull the fundamental characteristics that have always required a great naval unit, namely:

- Ability to navigate in a wide speed range (from displacement speed to planing speed);
- Poor sensitivity to the displacement of the load;
- Security: as it results to be much wider than the traditional hulls, thus able to offer a “platform stability”;
- Comfort navigation: the bow thin can be define a hull Wave Piercing;
- Cost management: the Towing Tank tests have shown that just a power of 1,600 Cv to reach a speed of 20 knots for a vessel of 24 meters and displacement of 70 tons; or a power of 1,450 Cv for a displacement of 60 tonnes (considering the propeller efficiency equal to 50%);
- Regularity of movements: the bow wave-piercing and an unusual width allow deal more easily weather conditions adverse sea, unlike equal naval units.

The MONOTRICAT Hull is distinguished from other types of hulls for:

Safety-Comfort-Regularity of Navigation-Economy

Security:

Effect platform (stability)

L/B ratio = from 3 to 3.6 → high transverse stability and large spaces on board more of over 20% compared to other naval units of equal lenghth;

Simultaneous effect of self-righting

Comfort:

Forms of bow wave-piercing → comfort in navigation at sea with waves

Effect MonoStab → maintaining trim sea adverse weather conditions: the trim constant at all speeds, practically horizontal, that does not vary in dependence on the speed variation) and which makes it unnecessary to install regulators trim (flaps);

Regularity of Navigation:

Higher speeds even in difficult meteorological conditions adverse sea

Economy:

interposition of the foam between the hull and the water → reduction of viscous drag

→ effect ACS: Air Cavity System

→ power and lower operating costs

6. Advantages Achieved

Reduction of the wave formation: the wave formation engendered ahead with the associated spray is conveyed under the hull;

Increased load capacity: at same lenghth, this hull has a greater width, and therefore great roominess interior and exterior;

Outstanding lateral stability; Greater width (effect platform);

Increased maneuverability in restricted areas: the bow especially deep allow tight turns;

Less draft: The particular shape that resembles a catamaran with the bottom resting on the water and with greatly reduced side hulls creates a “effect platform”;

Improving the efficiency of the engines due to the water flow accelerated;

Exceeding the limitations typical of displacement hulls (the curve of the resistance appears to be a straight line);

Economy, environmental friendliness and cost reduction management: the comparison of the experimental data with equal naval units on the market shows a real energy saving of about 20%;

Wide possibility of using different engines depending on the application, with the possibility of using green technologies and renewable energy sources with lower CO_2 emissions and less pollution;

Less interior space to be allocated to the engines, and then still more available space;

High load capacity (one of the models of size m.7,3 x m 2,4 was declared fit to carry 13 people); excellent ability to self-righting;

High efficiency hydrodynamic: having a resistance curve almost straight, because of the recovery of the kinetic energy contained in the bow wave and associated spray, its new forms allow a hull of 24 meters to navigate between 10 and 40 knots, with the comfort of navigation and the typical plan of a displacement boat, without the use of excessive power, and thus with motorization and reduced costs of purchasing and running.

Versatility: maintaining a high hydrodynamic efficiency for a wide speed range more extended compared to a conventional hull (resistance curve almost straight) since it is more efficient both in displacement boats that of planing boats.

Ability to diversify the exterior design: The versatility and the spacious interiors typical hull Monotricat enable design of a variety of solutions with regard to the exterior design: with endless possibilities to diversify the concept exterior design according to the specific needs and the owner’s tastes.

The large possibilities of design and spatial organization that lends itself innovative hull Monotricat for more space on board internal and external compared to other types, makes possible various and diverse arrangements with various solutions for: ferries, yachts, fast boats, coast guard patrol boats, merchant shipping, freight, etc., depending on the specific requirements of use.

Reduction of the costs of purchase and management, as the hull Monotricat to its conformation may be produced in equal volumes, with a considerable saving of money and time with respect to any other vessel or vessel for the greater simplicity of construction in all its phases, offering the most remarkable interior volumes for the same performance.

The study of this new hull has developed over time and through tests in Towing Tank (INSEAN CNR Rome, University of Trieste) and CFD (Computational Fluid Dynamics, in Italy and at in Stockholm University) and with the construction of dozens of boats length from 5 to 8 meters, tested in open water and restricted waters, and tested both at sea and lake, towed or self-propelled.

The hull, designed to date for length up to 50 meters, is proposed for technology transfer, licensing, sale or transfer of the patent international shipyards and shipowners (passenger ferry) or the industries concerned.

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Monotricat hull shape