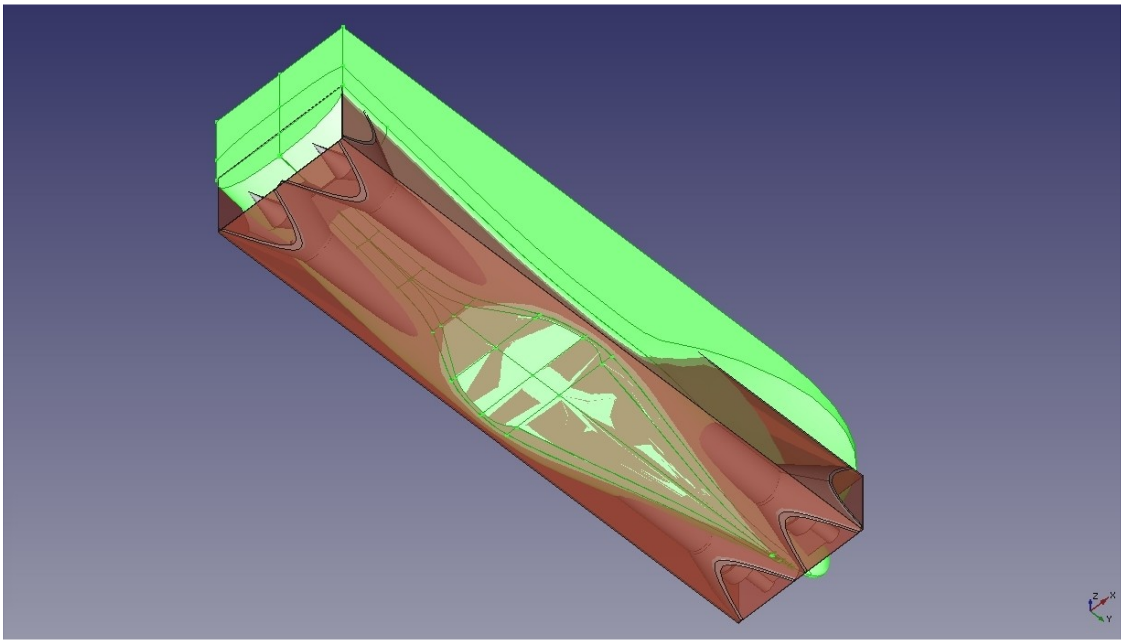

75% REDUCTION

in FUEL, CO_2 and NO_x

Inverse hull compared to the regular

The inverse hull is a known theoretical solution, but the practical problems of the water deceleration and friction have remained unsolved for many years. The keys to the 75% fuel consumption reduction are the recovery of the motion energy of the water jet which is pushed away by the propeller, the elimination of the front waves and the air injection into the internal channel.

The comparison is based on a 87 m long hull with bulbous bow. The largest wet cross section is 20 x 7 = 140 m^2. We calculated with 19,6 kn (10 m/s) ship velocity. Both design's waterlines and cross sections are the same. Fig. 1 shows the original hull.

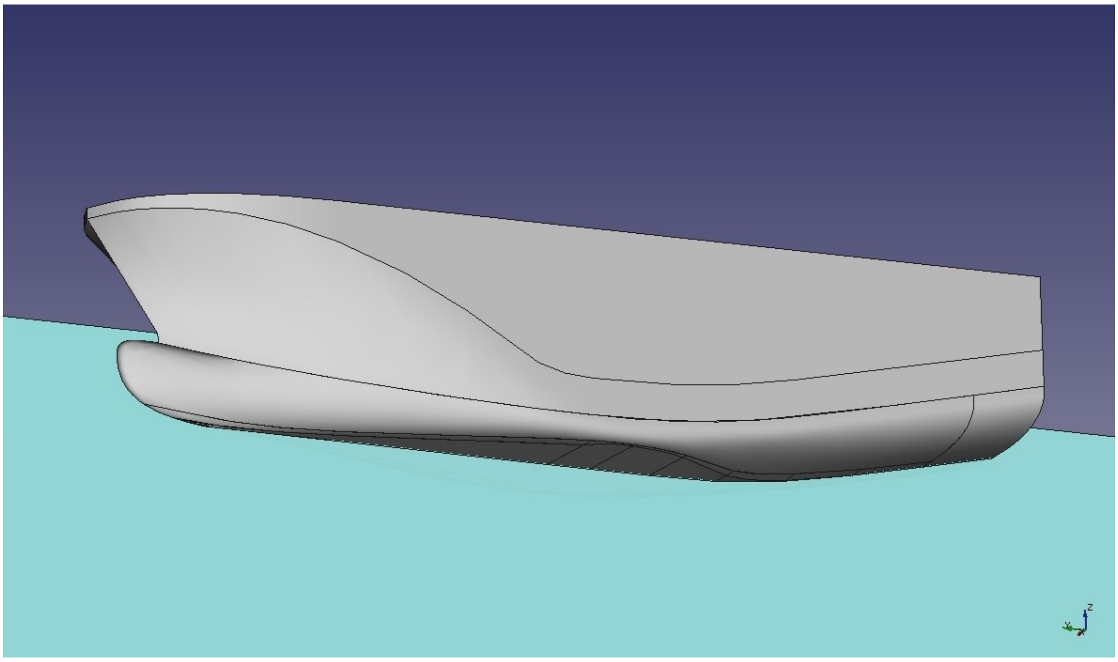

Fig. 1. Original hull

The inverse system is showed on Fig. 2. It has double channels with symmetric layout.

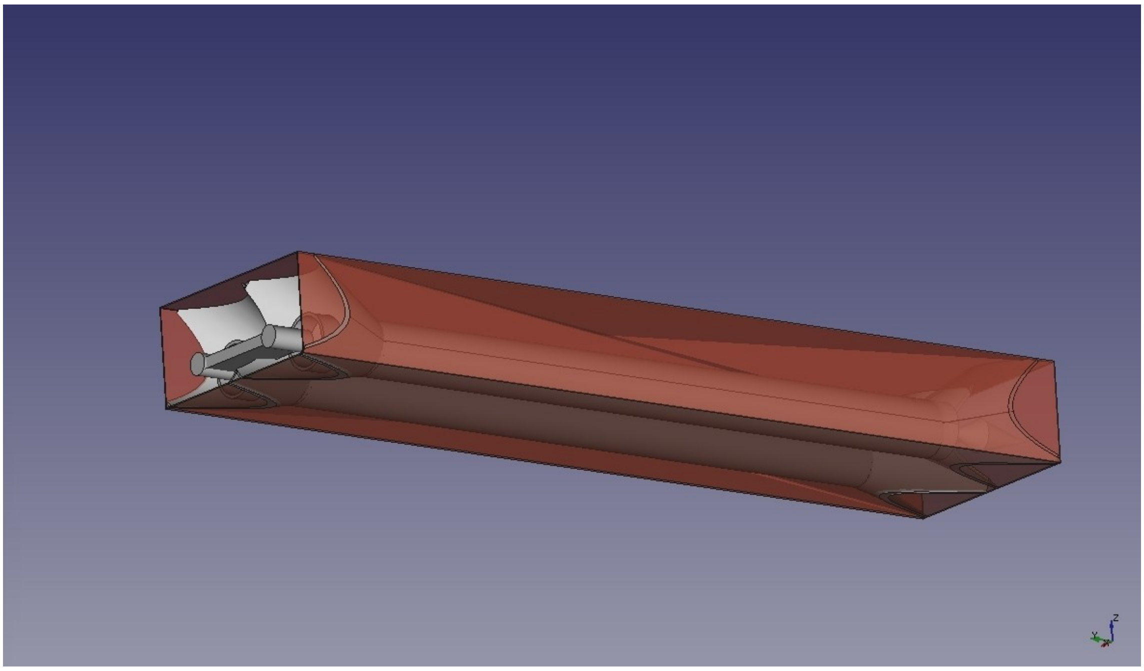

Fig. 2. Inverse system

The inverse system has some parts which increase and other parts which decrease the BRT of the ship. In our design the result/difference is compensated to zero. There are two water channels along the hull, but there is additional volume outside of the original hull. The geometry, location and number of the channels are flexible. The present inverse system consists of the outer box with parallel outer walls and 87 x 20 x 7 m dimensions, the channel with confuser cone, diffuser cone and pipe with 5 m diameter, the propulsion at the bow and a special deflector in the diffuser. The deflector system in the diffuser ensures the recovery of the motion energy of the water beam. It looks like a water jet propulsion system completed with a diffuser and deflector system. The result is shown on Fig.3. Propellers are located in the confusers at the bow.

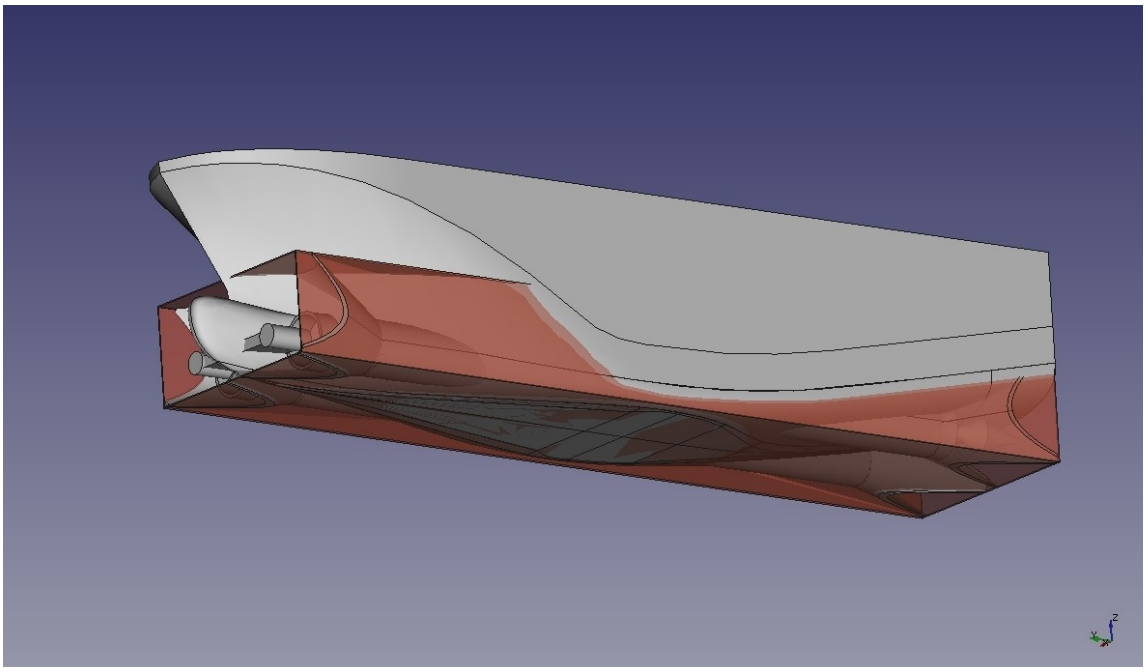

Fig. 3. Completed Inverse hull.

The inverse system doesn’t need a bulb, but we didn’t change the original stem. We calculated with motionless water surface, but in waving water the original bow works as usual.

Difference between the inverse system and the regular hull

INVERSE SYSTEM	REGULAR HULL
The power dissipation, caused by the water transport: P= 0 kW. In detail: **No accelerated water transport** before and surrounding the bow. There is no energy dissipation at the bow. All the accelerated water flows into the internal channel as it is known in a Venturi – type channel. We calculate it as a closed pipe system. **The power loss of the front resistance = 0 kW.** **No depression is caused at the stern.**	**The power dissipation caused, by the water transport: P= 14 330 kW.** In detail: **The bow pushes away all the water** from the largest cross section of the hull. The bow is 30 m long (wet surface is 31,6 m long). The average vertical velocity of the water at the bow surface is v= 10 m/s *10/31.6=3.2 m/s. The hull moves V= 2*31.6 m *7 m *3.2 m/s) = 1416 m^3/s water away. **The power dissipation** of the front resistance = 1416 *3.2^2 /2= **7 250 kW.** (The gravity is excluded) **The depression at the stern**, which is caused by the stern geometry and the propulsion: The average depression is 0.05 bar (about 0.5 m deflection at the stern. Augment of resistance and thrust deduction are included.) **The Power dissipation P=7 080 kW.**
All friction power dissipation P= 10 325 kW. In detail: The wet surface causes **friction loss.** The outside surface: A= 87 m*(7 m+20 m+7 m) = 2 958 m^2. The velocity = 10 m/s. The outside friction loss: **P= 2 225 kW**. (Calculated at: www.druckverlust.de) The internal friction loss: The internal average cross section: A= 2*5^2*3,14/4 m^2 = 39 m^2. We apply both atmospheric and pressurized air injections. They cause 50% density and dynamic viscosity reduction at the wall and increase the stagnation pressure in the diffuser. The internal friction loss: **P= 8 100 kW**.	**All friction power dissipation P= 2 151 kW** In detail: The wet surface causes **friction loss.** The surface: A_1=57 m*(7m +20 m + 7 m)=1 938 m^2. A_2=31,6 m*(7m +10 m + 7 m)= 758 m^2. A= A_1+A_2 = 2 696 m^2. The average parallel water speed is 10.3 m/s. It causes: **P= 2 151 kW** power dissipation. (Calculated at: www.druckverlust.de and https://marine.man.eu/docs/librariesprovider6/propeller-aftship/basic-principles-of-propulsion.pdf?sfvrsn=0) Air resistance is neglected with both hulls.

Propulsive efficiency with motion energy recovery by the diffuser: η = 96% **Thrust power** delivered by the propeller to water: P=10 325/0.96=**10 755 kW** **COMPARISON of the INVERSE and REGULAR HULL:** Power rate =10755/43371=0.248 **THE POWER REDUCTION = 75.2%**	**Propulsive efficiency: η = 38%** (loss of trust is included) **Thrust power** delivered by the propeller to water: P=(14 330 + 2 151)/0.38 **= 43 371 kW** Reference: https://marine.man.eu/docs/librariesprovider6/propeller-aftship/basic-principles-of-propulsion.pdf?sfvrsn=0
The steering is the same as the double-jet propulsion. The high speed water – in the channel – is usable for cross/side-jet to generate side-propulsion/bow thruster. The inverse ship propulsion works in reverse direction also.	**The steering** is as usual.
The traction force is 1.5 - 2 times higher than it would be with a same diameter propeller at the stern.	**The traction force:** depends on the propeller diameter.
The stop distance of the inverse ship **is 2-6 times shorter** than the regular because of the larger form factor of the front or bow – with stopped propeller. C_F =1.2 for 140 m^2 cross section.	**The stop distance:** With stopped propeller C_F =0.2 for 140m^2 cross section.
A narrow channel or shallow water causes less difficulty. There is no influence if the water depth is more than 2 times the ship draught.	**A narrow channel or shallow** water causes difficulty in moving aftwars. There is no influence if the water depth is more than 10 times the ship draught.
The inverse ship causes less trouble with the **seabed and the properties** of the ports. The ships can go closer to each other without danger.	The motion energy of the propelled water can have harmful effects as far as several times the ships' length.

We have solved most of the problems with a special deflector system and tested the models with CFD modeling and a small model in a real lab-test channel. The simulated model of the inverse system with conical deflector in the diffuser and with 10 m/s initial water speed is on Fig. 4.

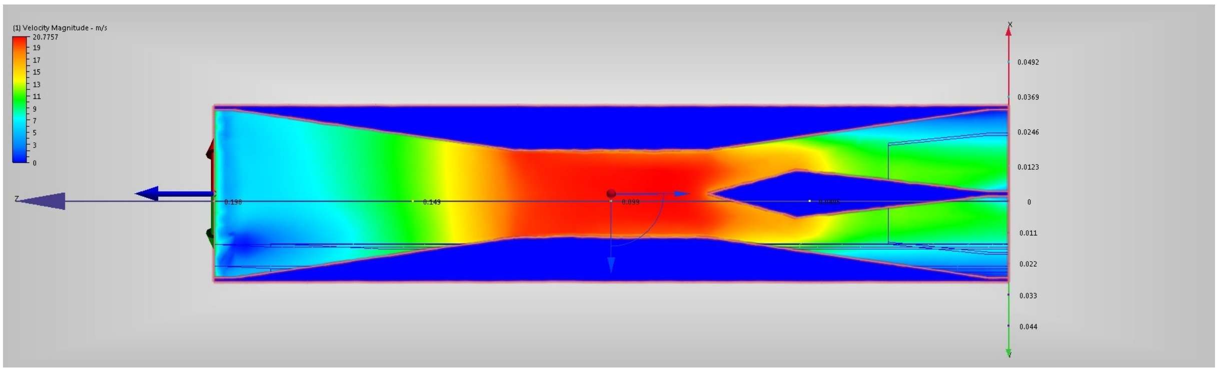

Fig. 4. Conical diffuser and deflector

The simulated model of the inverse system with twisted deflectors in the diffuser is on Fig. 5.

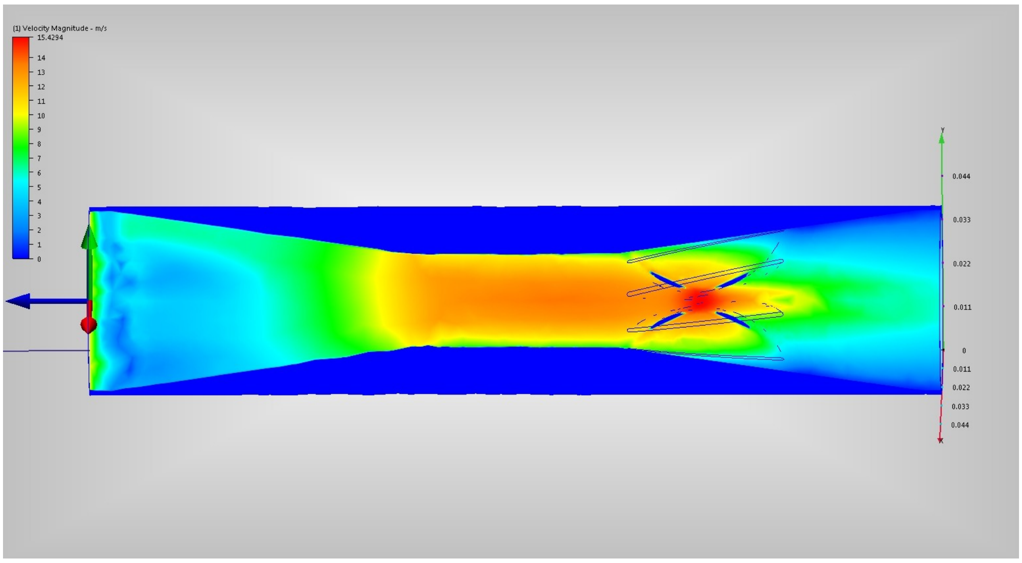

Fig. 5. Twisted deflectors

The deceleration process in the diffuser needs a deflector to avoid the uncontrolled shocks and swirls. For more details visit our website: www.magaimotor.magai.eu/inverse_ship.php
There is an example of a limited solution on Fig. 5.

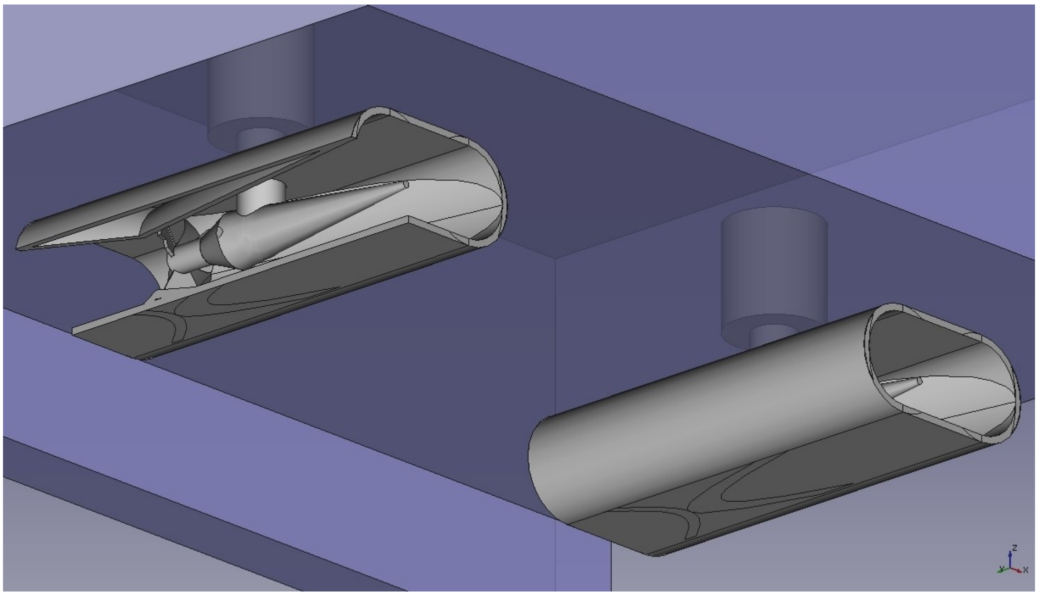

Fig. 5. Thrusters are mounted at the stern of the ship

There are 2 thrusters mounted on steerable gondolas. The fuel consumption reduction is 30-50% only but this marine propulsion is easy to fix on a regular hull.

The ship has regular friction and wave resistance at the bow, but the recovery of the motion energy behind the propeller can reduce the fuel and power need while having the same thrust. The air injection is applicable in this case as well.

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