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The catamarans *George* and *Energa Solar*

Dariusz Duda,
Wojciech Litwin
Gdansk University of Technology

ABSTRACT

Since a few years students of the Faculty of Ocean Engineering and Ship Technology, Gdansk University of Technology , have designed and built untypical floating units. Until last year their efforts were focused mainly on leg-driven boats. The boats of interesting design have taken part in yearly competitions : the International Waterbike Regatta. Their advanced design made it possible to compete with the best boats from Croatia, Holland, Germany, Turkey and Italy. Recently the students have designed and built a solar-energy-driven boat. It is the catamaran Energa Solar which took part in a prestigious regatta : the Frisian Nuon Solar Challenge carried out in Holland in summer 2006.

Keywords: leg-driven boats, solar- energy - driven boats, renewable energy

INTRODUCTION

The Scientific Circle of Students *Korab* has acted for many years at the Faculty of Ocean Engineering and Ship Technology, Gdansk University of Technology, however presently an extraordinary activity was shown by the students associated in it.

The revival happened already in 2004 when a group of students attempted to design and build a leg-driven boat intended for taking part in the International Water-bike Regatta whose 6th edition had to be performed in Bremen in May 2005.

The RW-4 catamaran designed and built within a short time, made successively its debut : it was ranked sixth among 28 boats built by students from Croatia, Holland, Germany, Turkey and Italy. The success has motivated the team to an even greater effort. Basing on experience gained during the regatta it was decided to build an entirely new boat which could be able to compete for a place on podium. In the end of 2005 the Rector of Gdansk University of Technology obtained an official inquiry from the side of the organizers of the regattas of solar bikes, Frisian Nuon Solar Challenge, if somebody of the University would be interested in starting. The students of the Scientific Circle promptly declared their will to take part. However, as revealed clear in a short time, the task imposed on themselves, namely the building of two boats practically in parallel appeared difficult to be obtained, as the International Waterbike Regatta was scheduled for the end of May and the Frisian Nuon Solar Challenge – for the end of June, i.e. during examination session.

DESIGNING AND BUILDING THE CATAMARAN *GEORGE*

Debuting in 2005, the catamaran RW-4 was reliable and fast, and of excellent manoeuvrability due to its azimuthing propeller. Its main drawback was large weight resulting from the application of simple polyester composites (for hulls) and usual structural steel (for frame).

In designing the new boat, was taken into account the specificity of the regatta within the frame of which seven highly different competitions such as : sprint, slalom, acceleration test, forward-and-back sprint, long distance run, bollard pull test, are carried out.

Therefore mass reduction of the boat and achieving its possibly high speed even in expense of lowering its manoeuvrability were assumed design priorities.

The analysis of the competed structures revealed that each of them had important disadvantages. Therefore the team presented three different novel design concepts. It was decided to build a catamaran driven by a pulling azimuthing propeller placed fore. To limit number of mechanical gears and to unload the boat structure the crew members were assumed to occupy places along the hulls (Fig.1).

Fig.1. *The catamaran George .*

The team planned to single-handedly design and build the hulls but cost and time consumption of such undertaking forced it to drop out the plan. The model tests realized by Ship Design and Research Centre (the CTO) in Gdańsk (Fig. 2), demonstrated that the previously applied hulls of typical canoe form are of a low resistance at an assumed speed of motion. Hence it was decided to use a more modern canoe hull. Owing to the *Gemini* company which made available hull moulds the students unaidedly produced two laminated hulls.

Fig. 2. *Model tests carried out by the CTO .*

The designed structural frame was computationally controlled by using the Finite Element Method. Most troubles were associated with the highly loaded pipe connecting both hulls in the bow part of the catamaran. It transferred wave--generated loads and torque and bending due to azimuthing propeller thrust.

The connecting frame was built of a high-grade aluminium. All frame elements were carefully prepared by the students and welded together by the company *Aluminium Ltd* at *Wisła* shipyard.

The propulsion system was so designed as to reduce, as much as possible, torque in the azimuthing propeller vertical shaft. It is important since the torque interacts with the propeller rotation mechanism that may be troublesome for swain. For this reason the rotational speed of the first two stages of the reduction gear was increased up to the assumed rotational speed of the propeller. As demonstrated later during practical tests, the torque acting in the rotation mechanism was negligible and did not make any difficulty for swain during manoeuvres. The body of the intersecting-axis gear which operated under water, was modernized for two reasons. Its flange connection with the propeller column, provided for by its producer, was feasible but of large gabarites, that could detrimentally influence resistance to motion of the immersed part of propulsion system. Hence the reduction gear was disassembled and the upper connecting flange removed out of the body by machining. Then the propeller column was glued with the gear body. Additionally it was assessed that the propeller was to be moved away from the propeller column, hence the existing propeller shaft was replaced with a longer one and one sliding radial bearing was added.

The propeller, a crucial element of the boat, was produced by the CTO whose help appeared invaluable. The catamaran's design process took a few months, but its building and assembling – only four weeks.

First trials performed on *Motława* river showed that the catamaran's centre of gravity should be shifted aft as the boat was slightly trimmed by the head.

After some modernization work resulting from the trials the catamaran was finally completed one day before leaving for the regatta.

After traveling via Bohemia, Slovakia, Hungary, Serbia and Bulgaria the team finally reached Turkey. There after hard

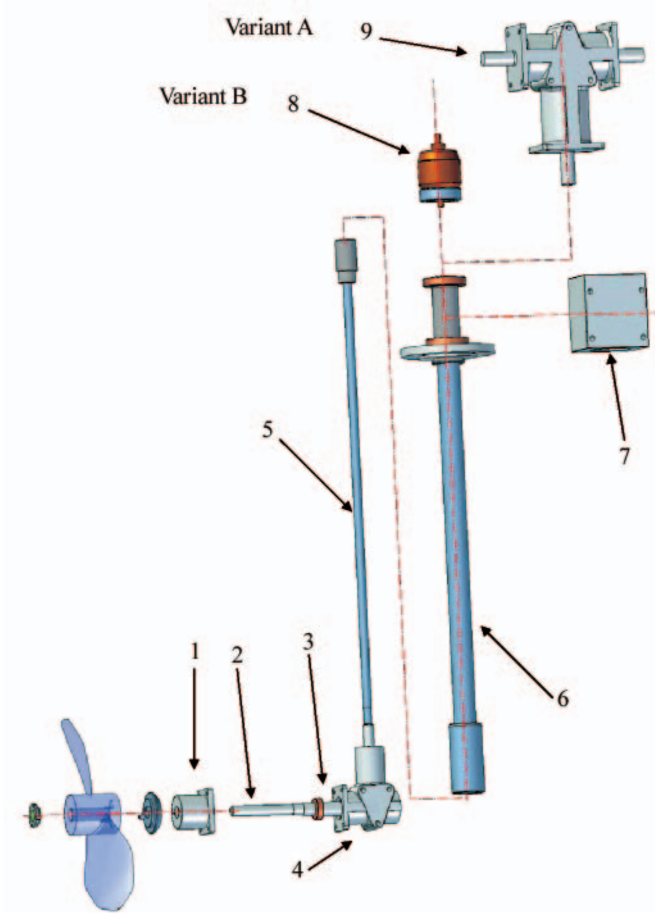

Fig. 3. *The simplified assembling drawing of the azimuthing propeller with vertical shaft;* ***Variant A*** *– for the catamaran George,* ***Variant B*** *– for the Energa Solar;* ***1*** *– seating of additional bearing supporting the shaft,* ***2*** *– the longer shaft made of stainless steel,* ***3*** *– additional sliding bearing supporting the shaft,* ***4*** *– modernized intersecting-axis reduction gear,* ***5*** *– vertical propulsion shaft,* ***6*** *– propeller column fitted with bearings and rotation mechanism flange, 7- rotation mechanism body,* ***8, 9*** *– propulsion engine.*

fighting it managed to win 1st place in general classification. The challenge cup founded 28 years ago by the German team, first time reached Poland.

The team will face hard work in the next year as the International Waterbike Regatta of 2007 has to be held in Gdańsk.

DESIGNING AND BUILDING THE CATAMARAN *ENERGA SOLAR*

To be carefully acquainted with the rules was the first step in preparation of the team, made just after submitting its participation in the regatta. The regulations of over twenty pages were very extensive and detailed. It imposed values of maximum dimensions of the boat, its mass and number of crew members, as well as it even determined the minimum weight (mass) of each crew member amounting to 70 kg.

The regatta organizers established three separate classes of boats :

- ★ The Class A – for one-person boats having solar cells of less than 100 kg mass and 6 m length at most
- ★ The Class B – for two-person boats having solar cells of less than 150 kg mass and 8 m length at most
- ★ The Open Class –for boats of 8 m length at most, without any other limitations.

As Dutch partners suggested that the Class A would have the greatest number of competitors it was decided to build an one-person boat complying with relevant requirements for that class.

The team faced difficulties in gaining financial support for building the boat. As in the case of the catamaran *George* it was the Rector of Gdansk University of Technology and the Head of the Faculty of Ocean Engineering and Ship Technology who financially supported the building of the boat. However it was crucial to find a strategic sponsor. Ultimately, the company *Energa S.A.* accepted position of the main sponsor.

To take part in the regatta it was necessary to fulfill a few conditions. The regatta's organizer required a.o. to submit the boat's technical plans and schematic diagram of electric network. The team was concerned about if crew safety is the only thing of this request or perhaps also the gaining of experience on the basis of the submitted designs.

It was important that the company *Sharp* declared to equip each team with the same number of identical solar cells. They were only lent and had to be returned after the regatta. However this way all the teams had the identical energy sources, that - in the conditions of limited funds - was crucial and helpful in getting even to each other. The energy source for the A-class boats consisted of six panels whose total power output could be up to 600 W depending on solar operation.

The regatta's organizers allowed to store the produced energy in electric batteries of the capacity limited to about 40 Ah at 24V voltage. No charging them from land was allowed and only solar radiation had to be used.

The organizers attached high importance to safety issues therefore each boat had to be fitted with a fire extinguisher, water draining pump, emergency electric „death man switch" etc.

The planned route of the regatta run along canals of Holland. It was divided into six stages and its total length reached 230 km. In designing the boat it had to be remembered that the boat must be durable and reliable enough to cope with several day trip in variable ambient conditions.

As in the case of the catamaran *George*, the boat's concept was discussed for a relatively long time. It was sure that an azimuthing propeller will be applied. The team has already gained some experience concerning the boats of similar mass and propulsion power. Hence, knowing advantages of the catamaran concept and necessity of fitting six cell panels of a mass close to that of the boat itself, the team was convinced that the twin-hull unit should be chosen. The problem was to get appropriate hulls as the firm which already accepted the building order withdrew from it in the last moment. The hull of the canoe used up to that moment appeared to short and its displacement insufficient. In this situation 6 m hulls of one of typical sailing catamarans was chosen. The order for two such GRP hulls was placed with one of their producers. To limit their weight thickness of laminate was kept at minimum and original heavy decks were removed. As prompt delivery of the hulls was not possible it was also not possible to finally design and build the frame, without which to determine location of centre of buoyancy necessary for arranging solar cell panels and position of swain, was impossible.

Two months before the regatta the delay connected with building the frame and hulls, increased since it was necessary to focus the team's effort on the water bike because the starting date of the International Waterbike Regatta was nearer and nearer.

As late as in the end of May the work upon the solar - energy - driven catamaran started again when only four weeks remained to the date of departure for taking part in the regatta. The approaching examination session made the situation even worse as the students had less and less time to build the boat. Nevertheless the frame and hulls were completed on schedule.

An azimuthing propeller was used to drive the catamaran. From the very beginning of designing process of the boat two different design solutions were considered (Fig. 1 and 2). It was possible either to place the electric motor within an underwater pod and apply direct propulsion or to drive the propeller through an intersecting-axis reduction gear and vertical shaft and to place the motor over the propeller's column. Tests of the electric motor on a special test stand showed that to apply a rotational speed reduction gear would be more favorable. Unfortunately the directly driven azimuthing propeller was already ready to use and its modernization was rather impossible. Time was running and funds lacking. Therefore elements of the propeller with vertical shaft was promptly ordered and an intersecting -axis gear able to reduce rotational speed in half, was purchased.

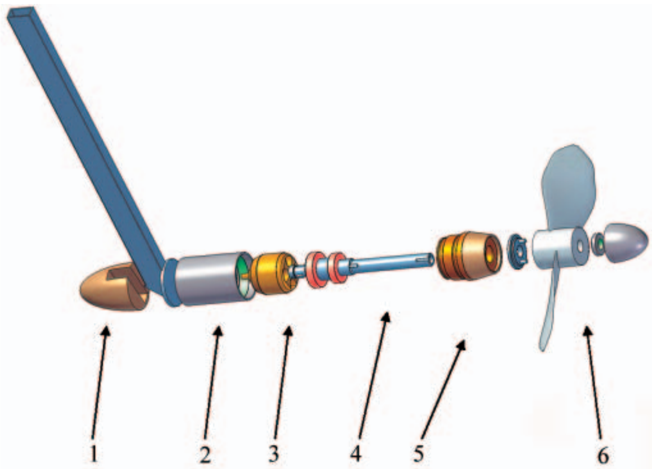

Fig. 4. *The simplified assembling drawing of the azimuthing propeller with the electric motor placed in the pod;* ***1*** *– fairwater,* ***2*** *– motor's seating,* ***3*** *– driving motor,* ***4*** *– stainless steel shaft with pair of bearings,* ***5*** *– second part of the propeller's pod with the seating of rolling bearings,* ***6*** *- propeller .*

To reduce the propeller's resistance to motion the reduction gear was subjected to the modernizations already proved in the propulsion system of the catamaran *George* (Fig. 1), i.e. the flange connecting the pod with propeller's column was removed and the propeller itself shifted away from the reduction gear.

Fig. 5. *The catamran Energa Solar .*

To drive the propeller a non-typical three-phase electric motor fitted with permanent magnets containing neodymium, was used. Owing to its relatively large diameter and a large density of magnetic field generated by the permanent magnets it produced a relatively large torque. In spite of its small mass of 680 g its output power reached almost 2kW. Results of tests performed on a special test stand showed that the motor operated correctly within the assumed range of its rotational speed. It was assumed that during the regatta the motor has to operate on the power level of 500 – 700 W. Unfortunately, during the tests some troubles associated with the motor's controller overheating, appeared. The controller fed from DC source (accumulator battery) produced three-phase alternate current feeding the motor. Its efficiency was relatively high reaching even about 90%. In effect large amount of heat was emitted. Due to compact design of the controller, heat exchange was difficult and resulting increase of temperature triggered the thermal cut-out to operate until the temperature drops enough. Because of lack of time it was not possible to order another controller. Hence the previously purchased controller was subjected to modernization work. The controller's circuit plate packets were divided into three separate segments and glued onto a radiator fitted with a fan (Fig. 6). The solution appeared effective and turned out to be correct during the regatta.

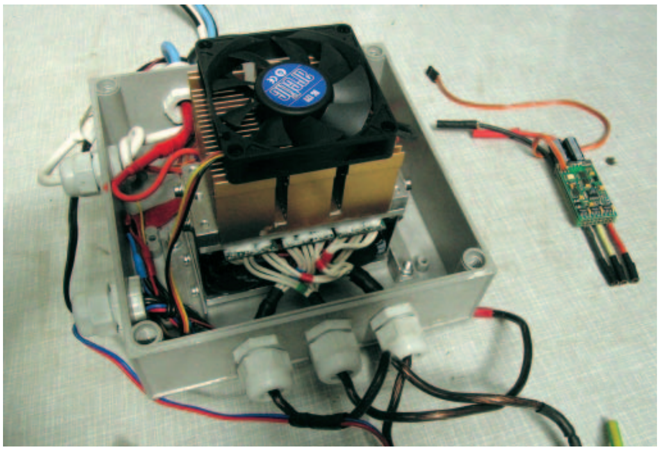

Fig. 6. *The DC/AC controller; on the left, inside casing - its modernized version, on the right – its original version before modernization .*

One of the prerequisites for taking part in the regatta was to submit to the organizers the electric network documentation for careful review in advance the regatta. Necessity of such control has been demonstrated by fires broken out on two boats as a result of overloading the electric network. The electric network of the catamaran was based on two 12V gel batteries connected in series. Each of them was placed in another hull. Left from the swain post a box containing all electric and electronic devices, was located (Fig. 3), except of the motor's controller which was placed near the driving motor. Initially it was planned that in the case of propulsion system's failure the fast switching from 24 V to 12 V voltage in the electric network, would be possible. Such option could make it possible to install a typical overboard motor used for propelling small boats. However tests carried out in the model basin of the CTO demonstrated that the catamaran's speed fitted with a 300W outboard motor would be very low, hence the concept has been abandoned.

To drive the boat a special propeller designed and manufactured by the CTO was applied.

In the course of the catamaran's manufacturing efforts were undertaken to reduce its weight as much as possible. In spite of that its mass was exceeded by almost 15 kg. It was expected that the regatta organizers would penalize the team with penalty minutes, but they came to the conclusion that the

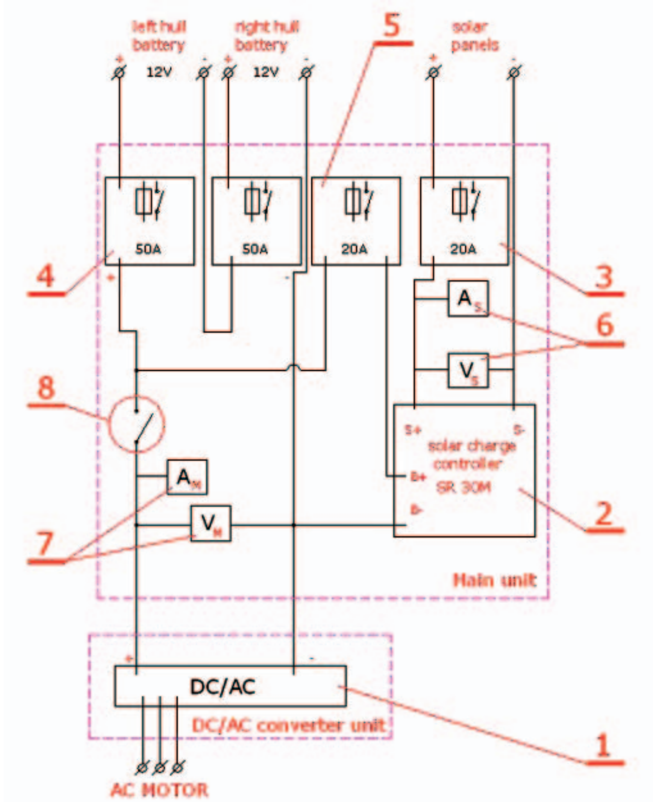

Fig. 7. *Schematic diagram of the electric network of the catamaran Energa Solar; **1** – module of AC/DC controller; **2** – controller charging accumulators, **3** – cut-out in solar cells circuit, **4** – cut-out in circuit of accumulators, **5** – cut-out in feeding circuit, **6** – power measurement system of solar cells, **7** – power measurement system of motor, **8** – safety cut-out switch .*

overweight would make harm to the team itself and no penalty was finally given.

A week before the regatta the boat was two times practically tested. Results of the tests appeared positive : the boat was fast and responsive. It was given the name of *Energa Solar*.

The preparations were continued till the day of departure. Despite some troubles the team succeeded in being in time for the regatta. The boat, after thorough technical control, was approved for taking part in the regatta.

Six days of the race were full of dramatic events. What's most important the team succeeded in finishing the race in spite of some technical problems. Unfortunately the organizers punished the team for introducing the changes to the electric system. The penalty wrote off chance of winning a place on podium and finally the team was ranked seventh among 14 boats of A class.

CONTACT WITH THE AUTHORS

Wojciech Litwin, Ph. D.
Dariusz Duda, Ms. C.
Faculty of Ocean Engineering
and Ship Technology
Gdansk University of Technology
Narutowicza 11/12
80-952 Gdansk, POLAND
e-mail : wlitwin@pg.gda.pl
e-mail : dadu@pg.gda.pl