- Required to measure speed through the water and relate this to resistance and when the craft is lifted onto the hydrofoil.

- Tow lines
  - Suitable tow lines to carry out the experiment, these should be very long to avoid the craft ending up in the stream of the motor current. (Micke)
- Test rig
- Dry suit, gloves, etc. (Micke)
- Towing boat (Jakob)
- Test protocol (Micke)
- Scale
- Camera
- Material

The test rig must be able to be built in a very short period of time and it is of the utmost importance that as simple materials as possible are used, i.e. easily processed.

- 18 mm plywood for wing profiles and strut.
  - Easily processed and cheap material
- Steel for structure to carry the hydrofoils and strut
- Floating body of foam-filled polyester plastic, (old surfboard)
- Various mounting material
- Paint to protect plywood

Construction

The craft's underwater body is rebuilt according to the results delivered in the analysis group's report, A13 - Pitch stability [1]. The experimental group also believes that a vertical wing should be placed above the stabilizer fin to provide increased stability in the yaw direction (figure 1). Another configuration is being tested, two up-angled wings to investigate if this can increase rolling stability.

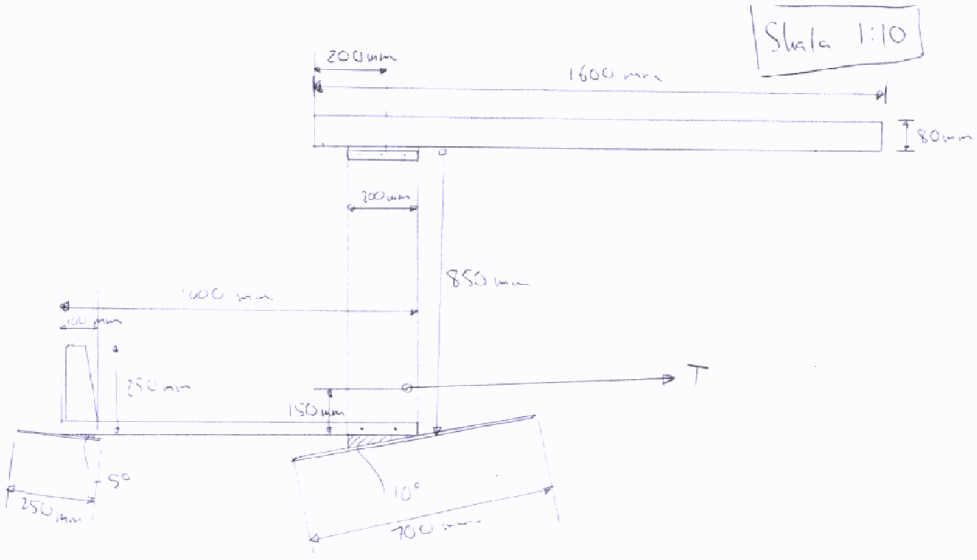


Figure 41. GA pre-test craft.

Safety

The safety of the user is of the utmost importance during testing. The craft must be able to be released immediately should something happen. This can be done by never attaching the towline to

the towboat. Handles or other fittings must be provided on the craft that enable the user to hold on. Life jackets and dry suits are mandatory.

Evaluation

The data in the form of subjective experiences and measured data must be delivered to the analysis group for evaluation. This must take place by October 22 at the latest. Test protocols must be completed and saved on Bilda. X7- Test protocol is on Bilda under experiment.

References

52. Bender, F: *A13 – Pitchstabilitet.* KTH 2008.
53. Razola, M: *X3 – Experimentprotokoll.* KTH 2008.

Appendix 1 - Checklist for Quality Assurance

The purpose of the list is to function as a structuring support for planning, writing and proofreading reports and as support for self-reflection. The list should be used for feedback from proofreaders. Evaluate each point with yes / no and sometimes with a grade of u, 3,4,5. Note that the completed checklist must be attached to each report!

General impression	Author Yes/No	Reviewer Yes/No
470. Are all elements of the problem addressed?	X	
471. Have the purpose and conditions been reported?	X	
472. Have relevant conclusions for the benefit of the project been drawn, reported and related to the objective?	X	
473. Is the purpose achieved?	X	
474. Is the report readable without access to task formulation, project instructions, etc. that you have received from teachers and supervisors?	X	
Technical content		
475. Have simplifications and assumptions been clearly stated and justified?	-	
476. Has the choice of solution methods been clearly reported and justified?	X	
477. Are calculations controlled and reasonably assessed?	-	
478. Are all used terms, variables, designations, abbreviations, etc., clearly defined and explained the first time they are used in the text?	X	
479. Are equations written as part of the running text, presented in separate lines and numbered?	-	
480. Can the technical reasoning be followed?	X	
481. Is there a difference between facts, statements and the author's opinion?	X	
482. Is there a realistic verification plan for the work in the report?	-	
483. Is there an acceptable follow-up of the verification plan?	-	
Presentation		
484. Is the report well structured with regard to section and chapter division, common thread and logical sequence as well as balance between different sections?	X	
485. Is the report provided with: appropriate title, date, author name, e-mail, eventual supervisor,summary/abstract, table of contents, reference list and page numbering 486. Is the report written in third person passive form? Are experiments described in imperfect, e.g."Drag tests were performed to verify…" while descriptions of analysis methodology and calculations are rewritten in the present, e.g. "Calculations show that the natural frequency…"?	X X	
487. Are figures and tables clear and informative, provided with figure / table text and clear numbering?numbered? Do all figures have units inscribed on all axes? Can figures be interpreted even after printing in black and white, and preferably after black and white copying?	X	

488. Are appropriate references made to figure, table and equation numbers in the text?	X	
489. Are appropriate references made to references in the reference list?	X	
490. Is the language cared for, free from spelling errors, sentence construction errors, special spellings, etc.?	X	
Other		
491. Has the report been written by you individually?	X	
492. The work has been carried out in collaboration with: _____	-	-
493. The report has been proofread by: _____		-
494. I believe that this report as a whole is worth rating (u, 3-5)		
495. The following is a reflection on how I believe that the work with this report and related projects relates to set learning goals (relevance of the work, which goals have been met, etc.):		-

Appendix 60 X7 Experiment report experiment 3

X7 - Experimentrapport

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In association with:
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Torvald Manners
Matthias Kennestad
Fredrik Bender

Course:	Marine design
Project:	Evolo
Date:	*20/11-2008*
Version number:	*1.0*
Supervised by:	-
Hours worked:	*2*
Reviewed by:	-

Summary

The following conclusions have been drawn from the experiment, these should be seen as recommendations and concerns in the further development work.

- The delta wing continues to give good results for the maneuverability of the Evolo
- Important with the right configuration in terms of angle conditions and distance between front and aft wing
- Considerably much better pitch direction stability with configuration according to [1]
- Compared to the straight wings, the delta configuration also provides smoother responses
- The rolling stability, or the inertia in the rolling direction, must be improved, the driver feels that it is like standing on a needle in this degree of freedom.
- The upward-angled, straight wings gave uncertain results, but were felt to be very difficult to handle. This can depend on both the configuration and build quality of the model.
- Ventilation of the main wing creates major problems as the driver's center of gravity is far forward, causing the craft to dive heavily.
- Larger vertical wing is recommended to increase yaw stability.

Suggestions for further development

In order to move forward with the development work, a new experiment should be carried out immediately with the goal of increasing the inertia in the rolling direction and making Evolo controllable for a longer period of time. By increasing the added water mass for the wings, the inertia should increase, for example this can be done by adding wing area far out in the transom direction. A floating body that is more similar to the final product should be designed, this to facilitate starting and driving. The driver finds it difficult to control the craft as it dips into the water. A possible investigation into the possibility of controlling the craft while standing should perhaps be initiated, the drivers feel that this can make the craft easier to handle.

Films from the experiments are available at www.bilda.kth.se. For construction details refer to [1], where drawings and test methods are presented.

Protocol

Driving 1

Driver: Mikael Razola Delta front: 10 degrees Delta aft: - 5 degrees

The Evolo felt much more stable in the pitch direction with the new configuration, the driver didn't have to move more than 10-20 centimeters back and forth to keep the balance in the pitch direction. The craft was, according to theory, completely self-righting up with the center of gravity located in front of the main wing. Finding this equilibrium was easy. The response in pitch direction was much smoother and the whole craft became more easily controlled. Evolo took off from the water at about 8 – 9 knots.

Driving 2

Driver: Matthias Kennestad

Delta front: 10 degrees
Delta aft: - 5 degrees

Successful test run, the driver quickly gains control of the Evolo and manages 30 – 40 seconds in flying mode, however control in lift-off was still difficult and the craft dips a bit during this time period. A much longer towline was used in this attempt and the craft became more stable as it ended

up further from the speedboat's stream. Unlike the previous experiment, this was controllable after all. The driver experienced some sideslip, that is, the craft moved sideways while driving. It may be because the vertical fin that should stabilize the craft in yaw was too small [1]. Here too, Evolo took off from the water at 8 – 9 knots.

Driving 3

Driver: Matthias Kennestad

Straight up angled: 10 degrees

Straight aft: -5 degrees

Very difficult to control configuration, the craft wants to lift diagonally backwards. Too much initial angle of attack on front wing, causing the floating body to lean into the water and chop as the craft dips. Less resistance than the delta configuration.

References

54. Razola, M: *X4 – Experimentunderlag.* KTH, Stockholm, 2008.

Appendix 61 X8 Experiment report experiment 4

X8 - Experimentrapport

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In association with:
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Mattias Kennestad
Fredrik Bender
Daniel Karlsson

Course:	Marine design
Project:	Evolo
Date:	*27/11-2008*
Version number:	*1.0*
Hours worked:	*2*
Reviewed by:	Mattias Kennestad

Trial set-up

The project's fourth attempt is called X8 and was carried out on 28/11 in the area around the large Värtan. During the experiment, windy weather prevailed with a westerly wind that in the gusts was probably over 10 m/s.

The test methodology itself looked largely the same as for X7 and X2 see [1] & [2]. The only difference was that this time no dynamometer was used as the "Micke-Metern[18]" used in previous attempts proved to be too small and gave unreliable results. However, a new configuration was used on the Evolo. Instead of the previous floating body, this time the front part from an old surfboard with a length of about 2 m and a width of 0.7 m was used.
The wing configuration was for the aft wing a delta wing with a cut nose and -5 degree angle of attack. The front one was a unique creation of a superposition between a delta wing and a regular straight wing with + 10 degree angle of attack. The choice of front wing was primarily based on an idea to keep the delta wing's softer lift curve but at the same time get increased stability in rolling direction with the straight wing. Figure 1 shows the wing configuration of this trial.



Figure 1. Evolo before attempt 4

Results

In total, approx. 20 runs were completed. All were filmed with a digital camera. From all these runs, half of the films have been selected as particularly interesting. These videos are uploaded on

[18] "Micke-Meter" - a hand-made dynamometer made of rubber cord. The name comes from the fact that it was not calibrated from the beginning and therefore the device was named after its proud inventor Mikael Razola. It probably won't lead to another Nobel Prize, but it was beautiful to watch.

Bilda under the folder X8- Experiment 4. As no changes to the configuration were made during the trial, no individual runs are commented on. Instead, a number of observations follow with reference to videos. These should be seen as recommendations and concerns in the continued development work:

- The new floating body provided considerable advantages. Above all, more buoyancy and a flatter bow meant that the driver could cope with dips into the water without falling. A good video that illustrates this is called "också länge.mov".
- An improvement in rolling stability was experienced by the driver.
- The steering works within a narrow range by the driver shifting his center of gravity, using his inertia and tilting the floating body. However, the majority of cases are such that the driver steers too much sideways and then the craft cannot right itself up. An interesting video that clearly illustrates the phenomenon is "styrning.mov"
- The flight time was consistently longer for all the trials and did not stop at a single "lucky run". A factor in this is probably that the Evolo is difficult to drive and Mattias is starting to learn. At the same time, increased pitch and course stability are important factors that made it easier.
- The resistance is very high. It took two breaks to be able to resist for a longer period of time.
- Ventilation of the supporting wing is still a major problem and causes many falls.
- An interesting film is "apan.mov" where the driver starts without holding on and sits far behind. Evolo then takes off much earlier and at a significantly lower speed, 4-5 knots compared to normally 8 knots.

Suggestions for further development

During experiment 1, trials were conducted with straight wings. At the time, this configuration was perceived as inferior and since then the emphasis has been on further developing the delta wing. In light of the fact that the most recent trials have provided important experiences (pitch, yaw, roll, etc.), these should be applied to a configuration with only straight wings. This trial should also be carried out with the possibility of measuring the resistance as this was judged to be far too high during this experiment. Likewise, the mountings to the wings must be improved with regard to screw holes so that quick changes are possible (delta to straight, other angles of attack, etc.). In this experiment we lost a lot of time by carelessly drilling a couple of holes that were not tested.

Another thing that should be evaluated is how the theory of pitch stability matches reality by varying the angles of attack on the wings. If stability is maintained with smaller angles, reduced resistance will be gained.

More test pilots must be used. It would also be interesting with a beginner to get an idea of the current level of difficulty linked to skill and experience.

Films from the experiments are available at www.bilda.kth.se. For construction details refer to [2], where drawings and test methods are presented.

References

55. Razola, M: X7 – Experimentrapport. KTH, Stockholm, 2008, unpublished
56. Razola, M: *X4 – Experimentunderlag.* KTH, Stockholm, 2008.

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General impression	Author Yes/No	Reviewer Yes/No
496. Are all elements of the problem addressed?		-
497. Have the purpose and conditions been reported?		Yes
498. Have relevant conclusions for the benefit of the project been drawn, reported and related to the objective?		Yes
499. Is the purpose achieved?		Yes
500. Is the report readable without access to task formulation, project instructions, etc. that you have received from teachers and supervisors?		Yes
Technical content		
501. Have simplifications and assumptions been clearly stated and justified?		-
502. Has the choice of solution methods been clearly reported and justified?		Yes
503. Are calculations controlled and reasonably assessed?		-
504. Are all used terms, variables, designations, abbreviations, etc., clearly defined and explained the first time they are used in the text?		Yes
505. Are equations written as part of the running text, presented in separate lines and numbered?		-
506. Can the technical reasoning be followed?		Yes
507. Is there a difference between facts, statements and the author's opinion?		Yes
508. Is there a realistic verification plan for the work in the report?		-
509. Is there an acceptable follow-up of the verification plan?		-
Presentation		
510. Is the report well structured with regard to section and chapter division, common thread and logical sequence as well as balance between different sections?		Yes
511. Is the report provided with: appropriate title, date, author name, e-mail, eventual supervisor, summary/abstract, table of contents, reference list and page numbering 512. Is the report written in third person passive form? Are experiments described in imperfect, e.g."Drag tests were performed to verify…" while descriptions of analysis methodology and calculations are rewritten in the present, e.g. "Calculations show that the natural frequency…"?		Yes Yes
513. Are figures and tables clear and informative, provided with figure / table text and clear numbering? numbered? Do all figures have units inscribed on all axes? Can figures be interpreted even after printing in black and white, and preferably after black and white copying?		Yes

514. Are appropriate references made to figure, table and equation numbers in the text?		Yes
515. Are appropriate references made to references in the reference list?		Yes
516. Is the language cared for, free from spelling errors, sentence construction errors, special spellings, etc.?		Yes
Other		
517. Has the report been written by you individually?		-
518. The work has been carried out in collaboration with: _____		-
519. The report has been proofread by: _____		-
520. I believe that this report as a whole is worth rating (u, 3-5)		-
521. The following is a reflection on how I believe that the work with this report and related projects relates to set learning goals (relevance of the work, which goals have been met, etc.):		-

X9 - Experiment report



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Course:	Marine design / Lightweight design
Project:	X9 - Experiment
Date:	*9/12-2008*
Version number:	*1.0*
Supervised by:	-
Hours worked:	*10*
Reviewed by:	-

Summary

- The resistance of the delta wings is about 30 percent greater than that of the straight ones, 700 [N] versus 500 [N]
- A longer strut was more difficult to control than a shorter one
- Delta wings still provide the best maneuverability
- If the straight wings are to be used, some form of automatic system is required to control the heave movement

Pictures and videos from the experiment are available at www.bilda.kth.se under Experiment – X9.

Problem formulation

The purpose of this experiment is to further evaluate the stability in heave, pitch and roll of the Evolo, as well as to do a resistance evaluation for straight wings versus delta wings.

Test rig

The same test rig was used as in experiment X8 [1], i.e. a surfboard as a floating body as this floating body was considered to make the Evolo significantly easier to control. A new, longer strut is tested in this experiment to investigate how this affects the maneuverability of the Evolo (Figure 1).



Figure 42. Test rig for experiment 5.

Results

Run 1 – Straight wings

During this trial, resistance measurements were performed for the Evolo from take-off to hydrofoil position. A number of runs to evaluate the maneuverability were also carried out, however these results confirmed the previous conclusions; that Evolo with straight wings becomes very difficult to control in heave direction. If this option is to be used, the experimental group believes that some form of automatic or manual control system must be used. Evolo took off with this configuration between

7 and 8 knots. This configuration had significantly less angles than previous tests with straight wings, as these tests showed that this was necessary for the floating body to have a favorable angle to the surface of the water, 0 degrees.

Run 2 – Delta wings

Resistance measurements were also carried out here, but measurements below 4 knots gave poor results and the resistance is interpolated here down to zero. What also proved difficult was getting reliable values in flying mode. The resistance varied greatly depending on the angle of attack, however, it was significantly greater than for the straight wings. Evolo took off with this configuration between 7.5 and 8.5 knots. In this test round, a smaller angle difference was chosen between the main wing and the stability wing, 10 degrees as opposed to experiment 3 when 15 degrees were used. However, the driver felt that this angle difference still provided sufficient pitch direction stability. However, what affected the stability was the fact that a longer strut was used, this made it more difficult to maneuver the Evolo.

Resistance

The drag measured during the trials is plotted against the speed, these plots confirm the earlier somewhat uncertain measurements which showed an increased resistance for the delta wings. What is also interesting to note is that the resistance in displacing mode differs very little, but at 5 knots the difference becomes significantly greater, i.e. where the wings make a significant contribution to lifting the floating body. The reason why the resistance is presented here as a smoothed curve is that, as previously noted, this resistance in flying mode was very difficult to obtain reliable values of. However, this can be expected to be less than the resistance measured just before the craft takes off. The maximum value of the resistance is measured at between 7 and 8 knots, i.e. exactly the speed at which the Evolo with these configurations takes off (figure 2).

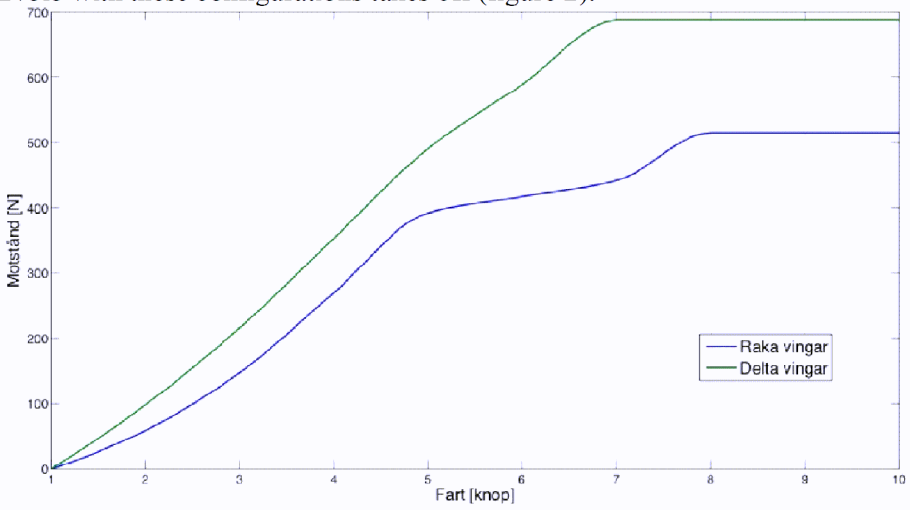


Figure 43. Resistance curve for Evolo.

These results show that the maximum resistance for the Evolo is about 29 percent greater with the delta wings, this means that the propulsive force from the engine must be at least 700 N, with no safety margin. For the straight wings this figure can be reduced to 500 N.

References

57. Manners, T: X8 – Experimentrapport. Marine Sytems, KTH, Stockholm, 2008.

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General impression	Author Yes/No	Reviewer Yes/No
522. Are all elements of the problem addressed?	Yes	
523. Have the purpose and conditions been reported?	Yes	
524. Have relevant conclusions for the benefit of the project been drawn, reported and related to the objective?	Yes	
525. Is the purpose achieved?	Yes	
526. Is the report readable without access to task formulation, project instructions, etc. that you have received from teachers and supervisors?	Yes	
Technical content		
527. Have simplifications and assumptions been clearly stated and justified?	Yes	
528. Has the choice of solution methods been clearly reported and justified?	Yes	
529. Are calculations controlled and reasonably assessed?	-	
530. Are all used terms, variables, designations, abbreviations, etc., clearly defined and explained the first time they are used in the text?	-	
531. Are equations written as part of the running text, presented in separate lines and numbered?	-	
532. Can the technical reasoning be followed?	Yes	
533. Is there a difference between facts, statements and the author's opinion?	Yes	
534. Is there a realistic verification plan for the work in the report?	-	
535. Is there an acceptable follow-up of the verification plan?	-	
Presentation		
536. Is the report well structured with regard to section and chapter division, common thread and logical sequence as well as balance between different sections?	Yes	
537. Is the report provided with: appropriate title, date, author name, e-mail, eventual supervisor,summary/abstract, table of contents, reference list and page numbering	Yes	
538. Is the report written in third person passive form? Are experiments described in imperfect, e.g. "Drag tests were performed to verify…" while descriptions of analysis methodology and calculations are rewritten in the present, e.g. "Calculations show that the natural frequency…"?	Yes	
539. Are figures and tables clear and informative, provided with figure / table text and clear numbering? numbered? Do all figures have units inscribed on all axes? Can figures be interpreted even after printing in black and white, and preferably after black	Yes	

and white copying?		
540. Are appropriate references made to figure, table and equation numbers in the text?	Yes	
541. Are appropriate references made to references in the reference list?	Yes	
542. Is the language cared for, free from spelling errors, sentence construction errors, special spellings, etc.?	Yes	
Other		
543. Has the report been written by you individually?	Yes	
544. The work has been carried out in collaboration with: _____		-
545. The report has been proofread by: _____		-
546. I believe that this report as a whole is worth rating (u, 3-5)	3	
547. The following is a reflection on how I believe that the work with this report and related projects relates to set learning goals (relevance of the work, which goals have been met, etc.):		-

Experiment X10



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Course:	Marine design
Project:	Evolo
Date:	*18/2-2009*
Version number:	*1.0*
Supervised by:	Jakob Kuttenkueler, Stefan Hallström
Hours worked:	*19*
Reviewed by:	

Summary

Experiment 10 is conducted to test a hydrofoil solution with no angle of attack on the aft hydrofoil, with a very large front hydrofoil and with the strut directly below the center of gravity. This is to reduce the resistance and be able to use an existing engine that has too little power for a smaller hydrofoil. The ergonomics of newly fitted handles are also evaluated.
The result is that the large hydrofoil breaks, but the resistance on the smaller hydrofoil is obtained less than previous experiments. The ergonomics are better with handles. However, controllability is worse.

Between planning and carrying out the experiment, new opportunities arise to buy a stronger engine. With this as a background and that the controllability is worse, it is suggested that the previous, most successful hydrofoil configuration be used, even though the resistance is greater.

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Dynamometer and wake problem 433
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Discussion 436
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Problem formulation

The towing test results in experiment X9 as well as the data on the Torqeedo motor available for the project show that the Evolo's resistance is too great to use that motor. To be able to use the motor, the resistance must be reduced and/or the maximum and lift speed must be reduced. This must be evaluated and determined through experimentation.

Experiment X10

In experiment X10, the same test craft used in experiment X9 shall be used with some modifications. Resistance is reduced with smaller angles of attack on the hydrofoil and that the center of gravity is moved to the aft to directly above the front hydrofoil. Maintenance of pitch stability thus gets a completely different solution than before. The lifting speed must be reduced by increasing the hydrofoil surface both in front and behind the hydrofoil according to TB 105 - hydrofoil and stay. Both the smaller wing that has been used in previous trials and the new, large wing have been sharpened at the front edges to investigate whether lift becomes greater with more favorable shedding for vortex formation. A new dynamometer will show the difference in resistance between the different hydrofoils, smaller angles and the effect of a sharper front edge.
In the experiment, ergonomics and control with newly installed handles will also be evaluated.

What must be done in experiment X10 is therefore:

- Test zero angle on aft hydrofoil and strut on the center of the floating body
- Test larger hydrofoil front and aft
- Measure resistance difference between large and small hydrofoils
- Test ergonomics and control for handles
- Test several different angles on the hydrofoil front and aft and evaluate resistance and driving characteristics

Experimental plan

Dynamometer and wake problem

In order to make a new resistance measurement and compare with different angles of attack and hydrofoil, a new dynamometer must be acquired. It has also been observed in videos from previous experiments that the turbulence in the wake of the G-boat might affect the stability of the Evolo. Therefore, a device must be built that allows the Evolo to be driven alongside the G-boat's wake.

Weather and cold

Due to the season of the experiment (as soon as the ice condition permits from February onwards) there is a risk that the cold means that test drivers and experiment participants in the boat do not have as much endurance. In order to have time to evaluate everything within the framework of the experiment, a "double" experimental force is proposed where half can carry out experiments in the water and the rest can prepare things on land and warm up if necessary. It is a personnel-demanding option, but with it it is judged that all necessary attempts can be carried out in time. Then you can hopefully also have time to try several drivers to evaluate what, for example, the driver's weight has to do with it.

Experiment order

According to what is deemed most important for the project to investigate, the experiments are carried out in the following order:

- Driving with large hydrofoils and zero angle on the aft hydrofoil. 8 degree forward angle of attack.
- Driving as above with a smaller angle of attack at the front (5 degrees) and possibly a larger angle at the aft.
- If time permits, driving with other driver with most successful setting of those above.
- Driving with configuration according to experiment X8, with sharper edges on the hydrofoil.
- Driving according to X8 with smaller angles of attack.
- If time permits, driving with another driver.

Implementation

The experiment was supposed to be carried out on Thursday, February 5, but was canceled due to ice condition. The experiment was instead carried out on February 17 in ice-free water in Stockholm's southern archipelago. Participants were Mattias K, Erik J, Joacim W, Johan W, Jasmin S, Fredrik B, Anders L and Torvald M.
A different boat than the one used previously was used which did not allow the fitting of the device to remove the Evolo from the wake.
A newly acquired dynamometer was used to measure the resistance. It was mounted in the boat and the line from Evolo ran through a block at the other end of the dynamometer to the person holding on.
The runs that were done were filmed.

First, the large hydrofoil was tested with an angle of attack of 8 degrees in the front and 0 degrees in the aft. It could not be evaluated because breakdown, which is described in more detail under results.
After that, the smaller hydrofoil was used with 8 degrees in the front and 0 degrees in the aft. The angle of attack was then reduced to 5 degrees.
Resistance measurements were also made on only the towline and Evolo without hydrofoil and hydrofoil stays.

Results

Large hydrofoil

The large hydrofoil broke almost immediately just in front of the mount. The resistance that occurs when the mounting is so far back on such a large surface was a concern even before the experiment. A few attempts were made before the break on the wing was discovered, but no measurement values could be obtained except that the resistance was very large already at around 2-3 knots. This is probably due to the fact that the angle of attack became very large when the hydrofoil folded up during the break.

Resistance measurements

The measured resistances are reported in Figure 1. Figure 2 shows the same values but also shows for which values the Evolo was at flying speed. In order to distinguish them, not all individual measurement values are marked as in Figure 1. Figure 3 shows the curves after they have been fitted to third degree curves.

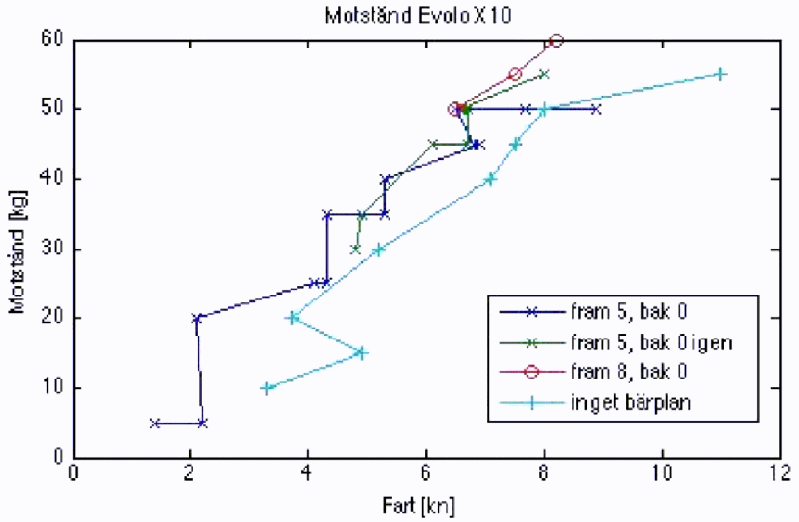


Figure 1. Measured resistances of Evolo with different hydrofoil angles.

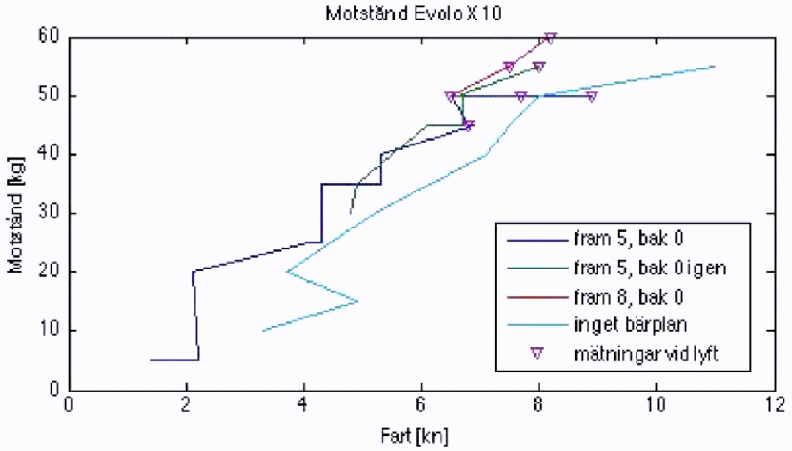


Figure 2. The same values as in Figure 1 but with markings on the measurement values that were recorded when Evolo had taken off.

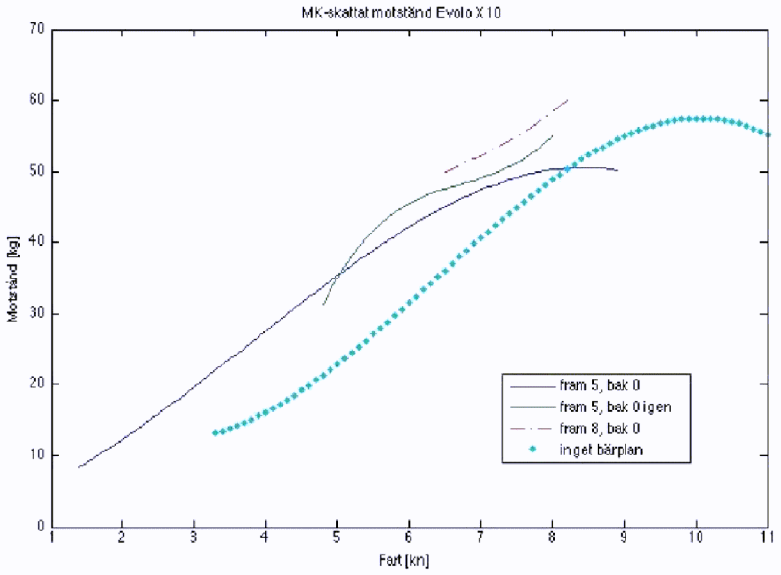


Figure 3. The results in a reasonable curve.

The measurement of the Evolo's resistance without the hydrofoil and stays cannot be seen as contributing to the total resistance as it was with the hydrofoil. This is because the floating position of the floating body changes because the lift from the hydrofoil disappears. It is also clearly visible on the videos from the experiment.
The resistance measurement of only the pull rope showed that the resistance is about 10-15 kg.
No noticeable differences were noticed or measured between how the hydrofoil looked before and when the edges were sanded sharp.

Moved forward strut

Moving the strut forward caused the stern of the floating body to take in the water for a longer time during the lift-off phase. Furthermore, the driver felt that it was more difficult to control the Evolo if he did not move slightly in front of the intended driving position.

Handle

The handle made it much easier to hold onto and control the Evolo.

Discussion

When carrying out the experiment, the project had won money from *KTH on the inside*, which meant that the focus had changed. We can now afford an engine that is strong enough to propel the Evolo with a smaller hydrofoil. This meant that it did not matter much that the large hydrofoil broke and no values could be measured from there.

The resistance with the smaller hydrofoil was measured behind another boat, with sharper edges and with a different dynamometer than before. All this means that the resistance readings are probably a little different from before. An important result from this experiment is the resistance of the towing rope. If you discount that, you end up with a resistance of around 40 kg at the Evolo's lifting speed, which gives

a lift-to-drag ratio of 3 (lifting force/resistance, calculated with 90 kg driver plus 28 kg Evolo) It should be compared with the lift-to-drag ratio 1.7 from the previous resistance measurement. Uncertainties exist, of course, with the gearing in the block at the dynamometer, the angle of the line from the block, other things in the extent of the line on the deck, etc.

One of the main aims of the experiment was to verify that it is possible to reduce resistance by having no angle of attack on the aft hydrofoil and to move the strut forward to directly below the center of gravity. Figure 1 shows that it probably affects resistance appreciably with small changes in angle of attack. However, it can be stated that it is more difficult to control Evolo with the new configuration. The driver still has to take up a position quite far forward, and the space ahead becomes smaller. The stern does not lift as easily because it ends up behind the strut. Of the runs that were filmed, only one can be said to represent a reasonably controlled flight. Compared to Experiment 8, controllability was much worse.

Conclusion

The resistance can be determined more closely because the towing line resistance was measured and another, probably more accurate, dynamometer was used. The lift-to-drag ratio, which from previous measurements can be read as 1.7, is instead obtained here as approx. 3. The new hydrofoil configuration with no angle of attack on the aft hydrofoil works and reduces resistance, but it makes the Evolo much harder to control.
Since a more powerful motor can be purchased compared to what the experiment was designed for and none of the runs were particularly controlled, it is suggested that the earlier, more successful configuration be used. This despite the fact that the resistance is greater.

References

58. Manners, T: *X8 – Experimentrapport.* Marine Systems, KTH, Stockholm, 2008.
59. Razola, M: *X9 – Experimentrapport.* Marine Systems, KTH, Stockholm, 2008.
60. Carlsson, D, Delin, P: *TB 105 - bärplan och stag.* Marine Systems, KTH, Stockholm, 2009.

Appendix 1 - Checklist for Quality Assurance

The purpose of the list is to function as a structuring support for planning, writing and proofreading reports and as support for self-reflection. The list should be used for feedback from proofreaders. Evaluate each point with yes / no and sometimes with a grade of u, 3,4,5. Note that the completed checklist must be attached to each report!

General impression	Author Yes/No	Reviewer Yes/No
548. Are all elements of the problem addressed?	Yes	
549. Have the purpose and conditions been reported?	Yes	
550. Have relevant conclusions for the benefit of the project been drawn, reported and related to the objective?	Yes	
551. Is the purpose achieved?	Yes	
552. Is the report readable without access to task formulation, project instructions, etc. that you have received from teachers and supervisors?	Yes	
Technical content		
553. Have simplifications and assumptions been clearly stated and justified?	Yes	
554. Has the choice of solution methods been clearly reported and justified?	Yes	
555. Are calculations controlled and reasonably assessed?	Yes	
556. Are all used terms, variables, designations, abbreviations, etc., clearly defined and explained the first time they are used in the text?	Yes	
557. Are equations written as part of the running text, presented in separate lines and numbered?	-	
558. Can the technical reasoning be followed?	Yes	
559. Is there a difference between facts, statements and the author's opinion?	Yes	
560. Is there a realistic verification plan for the work in the report?	-	
561. Is there an acceptable follow-up of the verification plan?	-	
Presentation		
562. Is the report well structured with regard to section and chapter division, common thread and logical sequence as well as balance between different sections?	Yes	
563. Is the report provided with: appropriate title, date, author name, e-mail, eventual supervisor,summary/abstract, table of contents, reference list and page numbering 564. Is the report written in third person passive form? Are experiments described in imperfect, e.g. "Drag tests were performed to verify…" while descriptions of analysis methodology and calculations are rewritten in the present, e.g. "Calculations show that the natural frequency…"?	Yes Yes	
565. Are figures and tables clear and informative, provided with figure / table text and clear numbering? numbered? Do all figures have units inscribed on all axes? Can figures be interpreted even after printing in black and white, and preferably after black	Yes	

and white copying?		
566. Are appropriate references made to figure, table and equation numbers in the text?	Yes	
567. Are appropriate references made to references in the reference list?	Yes	
568. Is the language cared for, free from spelling errors, sentence construction errors, special spellings, etc.?	Yes	
Other		
569. Has the report been written by you individually?	Yes	
570. The work has been carried out in collaboration with: _____	-	-
571. The report has been proofread by: _____		-
572. I believe that this report as a whole is worth rating (u, 3-5)	7	
573. The following is a reflection on how I believe that the work with this report and related projects relates to set learning goals (relevance of the work, which goals have been met, etc.):		-

X12 - Driving of Evolo without motor



MATTIAS KENNESTAD
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+46 709 229959

Course:	Marine design
Project:	Evolo
Date:	*14/4-2009*
Version number:	*0.1*
Supervised by:	Jakob and Stefan
Hours worked:	*4*
Reviewed by:	Erik Jerilgård

Introduction

In project Evolo's final stage, it seems that the motor is in danger of not being delivered in time to meet the deadline. In that case, changes will be made to the configuration and Evolo will be evaluated and validated as best as possible by being towed. This report describes how the Evolo should be able to be towed in a good way and how the mount should be designed.
The starting point will be, in part, the report from experiment X10 regarding getting the Evolo out of the towing boat's wake.

Towing device

The design of the towing device is divided into 2 parts:

- The mount of the tow line to the support on the Evolo
- Device for removing the Evolo from the towing boat's wake

The mount of the tow line to the support on the Evolo

During previous trials with the experimental craft, mounting points in the strut have been as far down as possible. This is to match the point of attack in the motor's power as much as possible. Then the tow line has worn against the front edge of the hydrofoil when the Evolo changes its pitch angle slightly. On the Evolo, it is not desirable for the tow line to risk destroying any part of the laminated hydrofoil because it takes significantly more time and money to manufacture the hydrofoil in carbon fiber than in plywood.
The mount should therefore be higher up than on the experimental craft, but preferably not mean that there will be a hole in the strut and it can be convenient to be able to move the mount if it turns out to be possible to lower it slightly.
Since motor power in the towing boat are enough and resistance thus does not need to be minimized, the device does not have to be particularly streamlined or smooth.

The suggestion is that a tensioning strap is wrapped around the strut in the simplest way and attached to the tow line. To prevent it from sliding up or down, a thin rubber mat is placed between the tensioning strap and the strut, and the tensioning strap is wrapped several times around the support.
If the resistance needs to be measured, the resistance of only the towline and mount can be measured first and then subtracted from the total resistance in the same way as in experiment X10.

Device for removing the Evolo from the wake

In experiment X10, the device mentioned there was not used because a different boat than the one intended was used. That device is suitable for use on the finished version of Evolo. The device is most clearly shown in Figure 1.

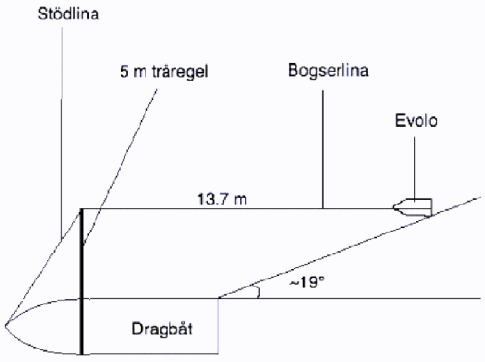


Figure 1. Anti-wake device.

The angle included in Figure 1 represents the propagation of the wave. There will be waves in front of this which are excited for about the stern but the turbulence from the propulsion of the towing boat is assumed to be significantly less that far out.
With a wooden ruler that moves the mount point 3 m outside the hull side, it is calculated to be approx. 13.7 m behind the stern wave. It is less than the tow line has been before but with a small turn you
can have an even longer tow line before the Evolo is in the worst waves.
The support line from the bow causes the wooden ruler to be loaded with a compressive load in the longitudinal direction instead of a bending load. At the far end of the wooden rule, a block is attached so that the tow line can be slackened in the same way as it has been done in previous attempts. A person can then stand by the wooden rule with a hold ready to let go if necessary.

Otherwise, mounts in the boat and the support line should be fixed with drill holes, extra clamps and general good seamanship.

References

61. M. Kennestad, Evolo - *Experiment X10*, Report, Unpubl. 2009.

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The purpose of the list is to function as a structuring support for planning, writing and proofreading reports and as support for self-reflection. The list should be used for feedback from proofreaders. Evaluate each point with yes / no and sometimes with a grade of u, 3,4,5. Note that the completed checklist must be attached to each report!

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581. Are calculations controlled and reasonably assessed?	-	
582. Are all used terms, variables, designations, abbreviations, etc., clearly defined and explained the first time they are used in the text?	Yes	
583. Are equations written as part of the running text, presented in separate lines and numbered?	-	
584. Can the technical reasoning be followed?	Yes	
585. Is there a difference between facts, statements and the author's opinion?	Yes	
Presentation		
586. Is the report well structured with regard to section and chapter division, common thread and logical sequence as well as balance between different sections?	Yes	
587. Is the report provided with: appropriate title, date, author name, e-mail, eventual supervisor,reference list and page numbering	Yes	
588. Is the report written in third person passive form? Are experiments described in imperfect, e.g. "Drag tests were performed to verify…" while descriptions of analysis methodology and calculations are rewritten in the present, e.g. "Calculations show that the natural frequency…"?	Yes	
589. Are figures and tables clear and informative, provided with figure / table text and clear numbering? Do all figures have units inscribed on all axes? Can figures be interpreted even after printing in black and white, and preferably after black and white copying?	Yes	
590. Are appropriate references made to figure, table and equation numbers in the text?	Yes	
591. Are appropriate references made to references in the reference list?	Yes	

592. Is the language cared for, free from spelling errors, sentence construction errors, special spellings, etc.?	Yes	
Other		
593. Has the report been written by you individually?	Yes	
594. The work has been carried out in collaboration with: _____	-	-
595. The report has been proofread by: Erik Jerilgård		-
596. I believe that this report as a whole is worth rating (u, 3-5)	5	
597. The following is a reflection on how I believe that the work with this report and related projects relates to set learning goals (relevance of the work, which goals have been met, etc.):		-

PR and Sponsor report Autumn 2008



FATIMA EKEKRANTZ
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In collaboration with
ANDERS LUNDELL
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Course:	Lightweight design/Marine design
Project:	Evolo
Date:	*2009-01-29.*
Version number:	*1.0*
Hours worked:	5 h
Reviewed by:	Torvald Manners

This report aims to describe how the sponsor group set up the work and which companies were contacted during the fall of 2008.
In order to realize the idea and the product Evolo, funding is required in the form of sponsors.

BACKGROUND

The courses Lightweight design and Marine design are part of the graduate engineering programs in Shipbuilding and Mechanical Engineering at KTH. The aim of the courses is to get the students to actively work to realize a product. Together with the course management, the students draw up a requirements specification, this year's challenge is a surfboard-like craft with an electric motor that, with the help of a hydrofoil, reaches a speed of about 15 knots. Part of the learning in the course involves the group organizing itself and assigning roles that lead to the various items being handled by the group participants in a satisfactory manner. One of these items is finance and under that falls the PR and sponsorship category.

A budget plan[1] was drawn up to estimate the costs that we felt could be incurred to have a seaworthy and fully functional craft in April 2009. From the beginning, the project had a pot consisting of SEK 20-25,000, provided by the course management. In addition to that amount, the idea is that sponsors should cover the coffers or that the students find an option solution to how the financing is to be solved.

SPONSORSHIP AND PR

During the fall semester, the sponsor group consisted of Fatima Ekekrantz and Anders Lundell, both students and course participants but with different orientations, which broadened the competence of the group.

The work was characterized at the start by a lot of brainstorming and information searching which formed the basis for the continued work. Newspapers and other media were contacted with the intention of trying to get them to write something about the work, the students or the product in order to be able to go ahead and seek out companies and demonstrate that there was media interest in the project. In general, we have received many positive comments from the media about the project, but still rejection of proposals for articles. The shortcoming on the part of the newspapers has consistently been that we have not yet had anything concrete/physical to show. But there is interest from several to return at a later stage of the project. The hope is that the media will become an easier partner after the turn of the year, as the project also has a little more to show in terms of design, which could generate some mass media focus.

An information sheet whose intention was to present the project group and above all the product Evolo was produced[2]. The idea behind this was that there would be something in writing that could be emailed/sent to companies after an initial contact had been made. In parallel with this work, the website began to take shape and all information would be gathered there so that you could continue to refer to .www.evolo.se The website was designed so that it would be possible to follow the project, partly through a photo/video gallery that was updated continuously but also that visitors could follow the work via the blog and read about what was going on in the project. The possibility now also exists for outsiders to comment on the project and the blog entries.

The sponsor search itself was divided into two categories; one referred to sponsors who could conceivably contribute money and the other referred to sponsors who could contribute equipment, products or other help. The idea with this was that focus would be placed on different parts in parallel with the progress of the other work in the group.

Since the project was in the start-up phase and decisions had not yet been made regarding which technical equipment might be needed, the focus was placed during the autumn semester on the companies that could conceivably contribute money. As this coincided with KTH's Armada labor market days, the companies that could find interest in the project in one way or another were selected. Before Armada, contact was made with the companies and the project was presented. The presentation also presented what we believed a collaboration could give the company in terms of connection to the education, KTH and the contact with students. In the same way also what we were interested in getting out of the collaboration.

One approach has also been to contact the companies that sponsored the GENA project last year. There were certain companies that were considered relatively safe cards as they have a fairly strong connection to KTH and the institution to which the project belongs, and that they have shown interest in previous years' projects.

In addition to the Armada companies and previous sponsors, the market was probed to find companies that could be thought to be interested in a collaboration in one way or another. We also reviewed the companies that might see the connection to our training as well as the companies that chose not to sponsor the previous year's project.

When companies were contacted, the sponsor group was careful to, somewhat depending on which company it concerned, put the focus and reason for sponsorship slightly differently. Some companies had been involved in the training in one way or another through, for example, guest lectures, presentations or other arrangements. In these cases, not only was the product emphasized, but also that the project was part of the students' learning and that it contributed to making the students mature and ready for working life. In other cases, the focus was on the product and its benefits.

KTH PÅ INSIDAN (KTH ON THE INSIDE)

KTH på insidan (KTH on the inside) (www.kthpainsidan.se) is a competition that KTH organizes with the intention of making the public aware of what is happening at KTH. Twelve projects are selected and will be available on the website for a period of time so that the public can vote for the three proposals they consider most interesting. A jury consisting of KTH staff will partially based on the voting select three projects that will be named winners. The projects receive SEK 75,000 each in addition to the fact that they will also have access to the PR/advertising agency that KTH has hired with the intention of being seen during the spring term. The idea is that the public should be able to follow the projects during the spring through blogs and other media until the final presentation in May 2009. Being one of the three winners would mean that the winnings received would more than cover the costs of the entire project. It also gives us a unique chance to show the public what we are doing within the project. The competition continues until 15 February 2009 and only then will the winners be announced.

PRODUCT SPECIFIC COMPANIES

From the project's point of view, there are some companies whose contributions would rather come in the form of products than from money. Examples of this are the electric motor, batteries, materials such as fiber and core, cabling, etc. Some companies are already closely linked to the education and the institution. This of course facilitates contact and ordering certain materials. The contacts also bring the opportunity to buy material at already favorable prices. This portion of potential sponsors has been deemed by the sponsorship team to be too product specific to be approached before the preliminary design is complete. This part is therefore intended to be taken care of during 2009.

RESULTS/CONCLUSION

The sponsorship work so far has mostly generated the basis for continued work. The part that was focused on during the autumn semester is perhaps the most difficult when it comes to getting companies to give away money without any real guarantees for what they can expect to get in return.

From the companies that have been contacted, it is noticeable that the current global crisis is very noticeable. Many have shown to be very interested in the project but for various reasons have not had the opportunity to contribute. In some cases due to difficulties in relating the project to the company's own operations, in other cases for the reason that the economy completely put an end to all forms of sponsorship.

The most common reasons why companies have refused so far have been;
- Difficulty relating the project to one's own business.
- Budget already laid out for the time the sponsorship concerns.
- The current economic situation puts a complete stop to all forms of sponsorship.
- The project is not extensive enough according to company policy.
- Evolo is not considered to be an interesting enough product.

However, the vast majority were interested and in one way or another wanted to receive further information about the project. When they then turned down a collaboration, the explanation was usually that the economic situation at the moment did not allow excesses in the budget.

To date, one company, KBT-gruppen AB (www.kbtgruppen.se), has shown an interest in sponsoring the project with a sum of SEK 5,000. Interest has also been shown from a former student in the same program, now employed at LUTAB, to assist with help and support, mainly in project planning. When the preliminary design was completed in December, there is a clearer idea of which products and materials may be needed to complete Evolo. The idea is that the next few days will be spent investigating the interest of the companies that can bring in products, and the hope is that that work will go more easily.

REFERENCES

1. A Lundell, F Ekekrantz, *Budgetplan*, KTH Stockholm 2008
2. F Ekekrantz, A Lundell *Evolo_mtrl*, KTH Stockholm 2008

APPENDIX 1.
LIST OF THE COMPANIES CONTACTED IN AUTUMN 2008
Companies that were contacted in connection with the sponsor search in autumn 2008
Comments and status can be found under the company name.

ABB AB
The company only wanted sponsorship applications via the website http://www.abb.se/cawp/seabb361/551157d7079fdffac125730e0046611c.aspx The application was submitted via email (2008-11-06). It could take a while to get a response...
Status: Answer has not yet been received

Accenture AB
Contact person: Sara Klingenborg
It took almost two weeks to get hold of the contact person due to business travel and illness.
Status: Not interested due to a complete stop for sponsorship.

Alfa Laval
Contact persons: Ulla Risberg, Marie Sommer Status: Not interested

ALSTOM Power Sweden AB
Status: Not interested

ALTRAN
There was no phone number available. Talked to staff who were in the booth at Armada.
Status: Not interested

Atlas Copco AB
Contact person: Leif Öhner
Initially, it was another contact who felt that he could not make that decision.
Status: Not interested

BAE Systems AB
Contact person: CEO Nicklas Friberg referred to Karin Frödeberg (HR) and/or Marinette Radebo (HR manager for all of BAE Systems). Met with Marinette and presented the project. BAE Systems is not really into watercrafts and therefore has no interest in watercrafts. Referred further to Saab Underwater Systems.
Status: Not interested

Cisco systems
The project was not considered to fit their profile.
Status: Not interested

Consat Engineering AB
The CEO referred to Filip Edström. They wanted more information and would review their budget.
Status: Not interested

Elkem
Norwegian company. Mail was sent with information but no reply has been received.
Status: No answer/Not interested

Epsilon Utvecklingscentrum Mälardalen AB
The company was not interested in sponsoring the project.
Status: Not interested

Ericsson AB
As you know, sponsors significantly larger watercrafts. They did not consider that project to be in their scope.
Status: Not interested

Etteplan
Contact person: Tobias Sigerstad. One of the companies that showed the greatest interest. As Lutab is part of Etteplan, he thought that the logo on the website needed to be updated. Lost interest when it turned out that the project would not be present at the boat fair in February 2009. Currently, the project group has tried to reach the contact person and sent an email with information about the competition KTH på insidan (KTH on the inside) in the hope of new interest, but no response has yet been received.
Status: No answer

FLIR Systems AB
Status: Not interested

Fortum
Could not currently sponsor the project.
Status: Not interested

HiQ Systems AB
Contact person: Anna Smedberg. Sent email and presented the project. The company sponsors larger projects.
Status: Not interested

HotSwap
Does not usually sponsor and in the current economic situation exceptions cannot be made.
Status: Not interested

Kbtgruppen ab
http://www.kbtgruppen.se/
Sweden's second largest company in cognitive behavioral therapy. The company offers development and work of change at all levels within organizations and companies as well as clinical operations.
Status: Interested. Contributes with SEK 5,000.

Metro
Presented the project and investigated the interest for a possible reportage, but the newspaper considered that as this was at the beginning of the project and design was not available, this was not interesting for them.
Status: Not interested, but this may be worth investigating once more.

Net Entertainment AB
Contact person: CEO Assistant Oscar Lundqvist. Were interested in appearing at KTH as they intended to hire 50 people in 2009. They wanted to be visible to the outside world and lost interest somewhat when it emerged that the project would not be exhibited at the 2009 boat fair. Have tried to reach the person in question to update about the competition KTH på insidan (KTH on the inside) but no answer has been received.
Status: No answer

Ny teknik
Contacted the editor-in-chief, who found the project interesting, however at that point in a much too early stage to write about.
Status: Interested, new contact should be made.

ORKLA AB
Norwegian company that cooperates with Elkem. Difficult to find Swedish information. Emailed with no response.
Status: No answer/Not interested

Praktiskt båtägande
Not interested, but another try is recommended
Status: Not interested, but this may be worth try once more.

Red Bull AB
Contact person: Jens Hedström. The company's policy is to sponsor competitions and major events. The project was considered too small for them to be interested. On the other hand, they are interested in offering the project members Red Bull and one more contact person at KTH: Clas Lundgren (+46 70 4195679) was recommended if the project wanted sponsors in the form of energy drinks.
Status: Interested. Sponsors in the form of an energy drink with no requirement for compensation

Reinertsen
Norwegian company that has shown interest in the education. Didn't really think the project was related to their business.
Status: Not interested

Rolls Royce Kristinehamn
Contact person: Anders Pettersson, Håkan Malmqvist (HR manager). Phone: +46 550 84168.
Contact Håkan during week 5. Unfortunately, the project is not within their scope.
Status: Not interested

SAAB Underwater Systems
A recommendation from BAE Systems. The company had no financial opportunity to sponsor at the present time.
Status: Not interested

SAS
The company was doubtful whether the project was in line with their business.
Status: Not interested

Scania
Contact person: Student Sponsor responsible - Therese Skoglund. Scania is one of the sponsors of the education. Had further contact with Johan Bringle, but finally got the answer that this year's economy was not suitable for outside sponsorship, but that the company would like to sponsor similar projects in the future.
Status: Not interested

Semcon AB
No possibility to sponsor at the moment.
Status: Not interested

Subsea 7
Presented the idea and got contact details for one more person, but the company felt that they could not sponsor at the moment.
Status: Not interested

Tele2 Sverige AB
The company sounded interested but had no opportunity to sponsor at the moment.
Status: Not interested

Tre.se
The company did not consider the project to be of sufficient magnitude to sponsor.
Status: Not interested

Vattenfall AB
Contact person: Robert Käck. Presented the project and emailed additional information.
No possibility to sponsor at the moment.
Status: Not interested

Wallenius
Contact person: Mikael Huss. Has been a sponsor on several occasions in similar courses. The contact person got in touch and advised that they could not sponsor this year's project due to the general financial situation and the relevance of the project. Also pointed out that this was sad as he himself has a great interest in our education.
Status: Not interested

ÅF
Currently had no opportunity to sponsor the project.
Status: Not interested

Östergrens elmotor
Possible electric motor manufacturer that has not yet been contacted. More data on the intended motor is required.

Torqeedo / Watski
Contact has been made with Torqeedo and main agent Watski regarding the project and the interest in the new more powerful Cruise 4.0 R motor. Have contact with the sales manager in Sweden, Magnus Sjögren, who has confirmed through the European sales manager that we will be connected with an engineer at Torqeedo in Germany. During week 5, several attempts were made to reach Magnus for more information, to no avail. This is probably due to the upcoming boat fair in Gothenburg.
Status: Processing contact.

Additional companies of interest that can be contacted;

Seaware
GVA
Vattenskoterspecialisterna
Michelin
SKF
XDIN
Fluke
Kimtech waterjet

Plan and status on PR



TORVALD MANNERS
FATIMA EKEKRANZ
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+46 704 856392

Course:	Marine design
Project:	Evolo
Date:	*2009-01-28.*
Version number:	*0.1*
Supervised by:	
Hours worked:	
Reviewed by:	

Plan for PR

During the autumn, some contact with the media took place. In general, the response has been weak, as the media want more concrete information to portray before they do anything. Now the product Evolo is starting to take shape and the PR issue ends up in a completely different focus, not least considering the need for sponsorship that the project has. This document is a PR implementation plan for the project. The idea is also that it should be updated as contacts are made.

Previous contacts

During the autumn, the media were contacted with the following results:
Fatima fill in...

Plan for the spring

Below is a description of the activities that are expected to be under the PR item.

Website

The website is our most important channel for informing ourselves about our progress in the project. It contains a blog with the goal of being updated at least once a week. Allocation to blog responsibilities takes place according to a separate list. On the website, we can also offer advertising space to our sponsors.

KTH på insidan (KTH on the inside)

At the time of writing, we are in the competition stage. At the time of writing, we are in the competition stage. It will bring great opportunities as well as a lot of obligations and maybe even some annoyances. Given the uncertainty, further planning is pending until the decision is made whether we will win or not.

A-media

A-media includes large daily newspapers, television and radio channels as well as trade journals with a larger circulation or a technical focus. Below is a compilation of potential A-media

Media	Time for contact	Comment/status:
SVD	final viewing	
DN	final display	
SVT –ABC	final display	
SVT - Hjärnkontoret	February	
SR –Radio Sthlm	final viewing	
Ny teknik	Construction and final viewing	
Praktiskt båtägande	During construction	
Båtnytt	final viewing	
Discovery	During construction	

B-media

B-media includes media with a smaller user base and a focus that does not necessarily focus on technology. Below is a compilation of potential B-media

2. See requirements spec. (www.bilda.kth.se)

Media	Time for contact	Comment/status:
Mitt i	As soon as possible	
Ingenjören	As soon as possible	
Lärarfackens tidning?	As soon as possible	
Utbildningsradion	As soon as possible	
TV4 teknik	As soon as possible	
Öppna kanalen	As soon as possible	
Stadsdelstidningar	As soon as possible	

Internet

The marketing that we can initiate ourselves is under this point. An example of this is Facebook where we already have a group. Other examples are forums with an area of interest that might be similar to Evolo's potential users.

Forum	**Comment**
Facebook	A group created on January 24 to gather votes for KTH på insidan. (KTH on the inside) Should then function as a support group regardless of the outcome of the jury's assessment.
www.Steffo.nu	
www.Surfsverige.se	Posted on January 24th by Jocke
www2.wakeboard.nu	Post initiated in September. Updated with link to our website 2009-01-28
www.foilforum.de	German forum for air chair geeks. Entry with reference to the website made 2009-01-28

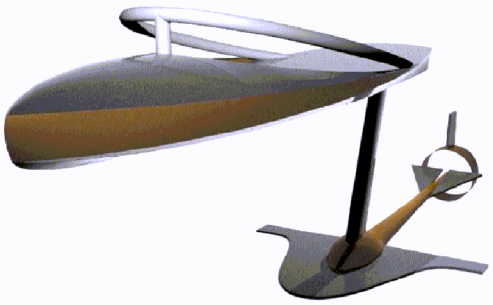
Media contact

Contacts with the media do not necessarily have to go through the PR manager. However, it is important to try to keep a united grip and that PR managers, i.e. Fatima or Torvald, are always informed. For contacts there is a template plus a description of the project adapted to the media. The description of the project is continuously updated to always depict the current status of Evolo.

2. See requirements spec. (www.bilda.kth.se)

2. See requirements spec. (www.bilda.kth.se)

Evolo is a modern water toy with an innovative design. The goal of the concept is to create a new way of playing on water, without disturbing fellow human beings and nature. We want to show that it is possible to minimize environmental impact and unnecessary noise and still have fun.



To reduce energy consumption, we have chosen to think in new ways and base Evolo on hydrofoil technology. By lifting the floating body and the driver above the surface of the water, resistance is reduced and thus also the amount of energy required for propulsion.

The electric motor is today the best option for reducing the environmental impact of a motorized craft and therefore an obvious choice. Placed below the surface of the water, the sound that reaches the driver and the surroundings is also dampened. Together with the elevated position of the driver, Evolo will create a unique feeling of silently flying forward at a low height above the surface of the water.



The Evolo project group, January 2009

Evolo is developed and designed by technologists at the Royal Institute of Technology in Stockholm (KTH). The project is part of the course Marine and Lightweight Design during the academic year 2008-2009, and is conducted by a total of 15 students who are all studying their fourth year on the Shipbuilding program and the Design and Product Development program respectively, with the specializations Marine Systems and Lightweight Constructions.

The idea behind this course is to give us technologists a good picture of how work can be carried out in project form and the engineer's role in this. It gives us technologists an opportunity to apply the knowledge we acquired during our education both theoretically and above all practically. In addition to the actual engineering work that the project involves, it also gives us the opportunity to meet the industry, working life and users face to face.

2. See requirements spec. (www.bilda.kth.se)

2. See requirements spec. (www.bilda.kth.se)

3098022.v1

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Evolo - Budget basis



ANDERS LUNDELL
FATIMA EKEKRANTZ
alunde@kth.se
+46 70 6071087

Course:	Marine design / Lightweight design - Evolo
Project:	Economy - Budget
Date:	*30/10-2008*
Version number:	*1.0*
Reviewed by:	*Joakim Westlund*

2. See requirements spec. (www.bilda.kth.se)

Budget plan

The purpose of this budget plan is to serve as a basis and orientation for the financial issues that may arise. Most of the costs reported are estimated values. The idea is to create a picture of where our costs are, what they come from, when they may occur and how we can manage them.

Costs

Table 1 below reports the costs that the project will entail. Most of these are estimated values based on estimates based on what we know today about our end product. The costs that will be prioritized are of course those that are directly linked to enabling Evolo to fly in May.

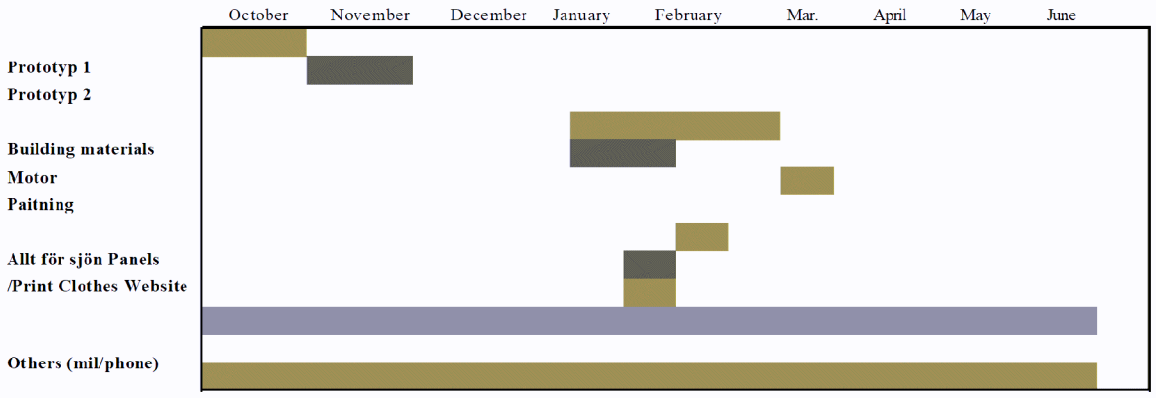
Motor	25,000 SEK
Batteries	20,000 SEK
Controls/electrical components	2,000 SEK
Core	3,000 SEK
Fiber	5,000 SEK
Matrix	2,000 SEK
Metal	1,000 SEK
Prototype 1	1,200 SEK
Prototype 2	1,000 SEK
Varnishing - painting	-
Allt för sjön	25,000 SEK
Panels/Print	1-2 000 SEK
Website	350 SEK
Profile clothes	3,500 SEK
Car compensation	18.70 SEK/10 km
Other costs (telephone etc.)	-
Total	*About 95 000 SEK*

The estimated sum of SEK 95,000 is hereby our guideline for the costs that must be covered.

2. See requirements spec. (www.bilda.kth.se)

When do the costs occur?

Many of the costs are related to specific dates or periods. For example, costs for materials fall at the end of January, while other costs such as the website and experiments arise already in the autumn and to some extent continuously. The diagram below illustrates this distribution.



What do we have today?

The project has about SEK 20,000 from KTH at its disposal. As can be seen above, these will not be enough to finish the project. The goal is for our excess costs to be covered with the help of sponsors. More about this will follow in future headings.

From last year's project, some components are available. At the time of writing, it is unclear whether these will suit our design. The components that may be of interest today are motors, materials and batteries. The uncertainty today lies partly in the uncertainty surrounding the need for power.

In addition to the components and materials available, there is a lot of information and contacts that are very valuable to follow up from the previous year. Under the following heading, it is reported what the previous project succeeded in securing in the form of sponsors and what these contributed.

2. See requirements spec. (www.bilda.kth.se)

Sponsors of previous projects

The following companies were sponsors of the previous year's project Gena:



2. See requirements spec. (www.bilda.kth.se)

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The table below shows what the respective companies contributed;

Wallenius Marine	25,000 SEK	Money
DNV	6,250 SEK	Money
Timbobryggan	5,000 SEK	Money
Marinshopen	Steering	Mikael Schriver
Captains	15,929 SEK	Torqueedo motor
ETP	43,769 SEK	Land motors
DIAB	15,000 SEK	Core material
Devold AMT (Carbon fiber)	11,500 SEK	Carbon fiber
Mastervolt	8,250 SEK	Batteries (lead)
Docksta varvet	16,000 SEK	Welding
Vägverket	25,000 SEK	Money
Rotera kullager AB	1,000 SEK	Discount on ball bearings
24 moto	1,810 SEK	Discount on wheels and brakes
Total: approx. SEK 175,000		

We intend to contact all sponsors who may be of interest to our project. Of greatest interest today are Wallenius Marine, DNV and Marinshopen who expressed great interest in the Gena project.

New potential sponsors

As Evolo's current status and market approach have not been determined at the time of writing, little time has yet been spent on investigating new potential sponsors. More about this will appear in the sponsor document. It is clear that due to the current economic situation, most of the investment will be directed towards larger companies with an interest in us as technologists.
The project already has its first sponsor, LUTAB, which has agreed to provide support in administrative matters in the form of consulting hours.

Handling

Most of the purchases that must be made in connection with construction and experiments will be made individually by the people involved. In order to supervise the project's expenses, any purchases must always be checked by the person in charge with the finance manager. Receipts for purchases must be collected in the project folder that is in the pool under the tab economy. Based on these receipts, money will then be paid back to the person or persons who paid for the purchase. In the event of major costs, purchases will of course be handled in direct connection with the sponsor and the finance manager.

2. See requirements spec. (www.bilda.kth.se)

Sponsor categories

Different sponsors can be divided as follows depending on their contribution to projects. The sum of the contributions given is based on the value of the components and/or money allocated to the project.

Main sponsor	>SEK 40,000
Gold -	>SEK 25,000
Silver -	>SEK 15,000
Bronze -	> SEK 5,000
Support -	< SEK 5,000

At our Evolo, we estimate that there will be at least an area corresponding to 0.4 square meters available for sponsor exposure. This is distributed according to the table below.

Main sponsor	40 x 50 cm
Gold -	20 x 35 cm
Silver -	15 x 25 cm
Bronze -	10 x 20 cm
Support -	5 x 10 cm

In the event that we succeed in obtaining sponsorship for profile clothing, all sponsors apart from the supporting sponsors will be entitled to a place there as well. Available surface on the jerseys will be similarly distributed according to the size of the contribution.

Exposure – Media

Båtliv

Båtnytt
Vi båtägare
Ny Teknik
SVD
DN

2. See requirements spec. (www.bilda.kth.se)

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Sponsor contacts - all companies on this list also exhibit at Armada

ABB AB
Have sent an application regarding sponsorship via email (6/11)
http://www.abb.sc/cawp/scabb361/551157d7079fdffac125730c0046611c.aspx

Accenture AB

For general questions contact: barbro.kearney@accenture.com
Sveavägen 25
Box 1331
111 83 Stockholm Phone: +46 8 451 30 00 Fax: +46 8 451 20 00
http://www.accenture.com/Countries/Sweden/Contact_Us/default.htm

Alfa Laval

http://local.alfalaval.com/sv-se/contact-us/sverige-adresser/Pages/default.aspx
Headquarters for sales and service
Alfa Laval Nordic AB Hans Stahles väg 7 147 80 Tumba
Phone: +46 8 530 656 00 Fax: +46 8 530 656 60
E-mail: info.se@alfalaval.com

ALSTOM Power Sweden AB

Press contact: Helena Karlsson

Phone: +46 11 884 85
http://www.se.alstom.com/home/contacts/28506.SV.php?languageId=SV&dir=/home/contacts/

ALTRAN
Altran Scandinavia AB
Parkvägen 2A
169 35 SOLNA
Sweden
Couldn't find a number, but you can leave a message via email…
http://www.altran.com/locations/sweden/?pays_id=27
http://www.altran.com/sweden/jobs/traffa-oss/kontakt/kontakt/

Atlas Copco AB
http://www.atlascopco.se/sesv/Aboutus/Contactus/
There are a few different departments…

2. See requirements spec. (www.bilda.kth.se)

Atlas Copco Compressor AB
Sales and service of compressors and generators
Postal Address: 131 82 Nacka
Visiting address: Marcusplatsen 1A, Nacka
Delivery address: Kummelbergets Industriområde, Snickarvägen 1 F,132 38 Saltsjö-Boo
- +46 8 743 90 00
- +46 8 644 25 45
- cpr.info@se.atlascopco.com

Atlas Copco CMT Sweden AB
Head office
Sales and service of mining and construction equipment
Postal Address: 105 23 Stockholm
Visiting address: Sickla Industriväg 3, 131 34 Nacka
- +46 8 743 92 30
- +46 8 743 92 46
- mcsinfo@se.atlascopco.com

Atlas Copco Tools Sverige
Sales and service of industrial tools and assembly equipment
Postal Address: 105 23 Stockholm
Visiting address: Sickla Industriväg 15, Nacka
Delivery address: Sickla Industriväg 11 B, 131 34 Nacka
- +46 8 743 95 00
- +46 8 743 93 75
- toolsinfo@se.atlascopco.com

BAE Systems AB

http://www.baesystems.com/Businesses/LandArmaments/Divisions/BAESystemsAB/index.htm

Linköping:
BAE Systems C-ITS
Repslagaregatan 6, SE-582 22
Phone: +46 13 24 09 80, fax: +46 13 24 09 99
Email: info.c-its@baesystems.se

Karlskoga /Bofors:
BAE Systems Bofors
SE-691 80, Sweden
Telephone: +46-586-733 000
E-mail: info.bofors@baesystems.se

Consat Engineering AB
You can find our Stockholm office at the address:
Consat Engineering AB

2. See requirements spec. (www.bilda.kth.se)

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2. See requirements spec. (www.bilda.kth.se)

Gårdsvägen 14 169 70 Solna
Phone: +46 8 5626 0500

Continental corporation???
http://www.conti-online.com/generator/www/com/en/continental/portal/general/home/index_en.html

Elkem
Norwegian page, there seems to be no Swedish page...

Ericsson AB
http://www.ericsson.com/ericsson/worldwide/sweden.shtml Company address:
TORSHAMNSGATAN 23, 164 83 STOCKHOLM Phone:+46 10 719 00 00
Fax:+46 8 18 40 85

Etteplan
Fannys väg 5
131 54 Nacka
Phone: +46 (0)8 562 989 20 Fax: +46 (0) 8 726 78 07
e-post inom Etteplan: fornamn.efternamn@etteplan.com
Contact persons:
Site manager
Tobias Sigerstad
+46 705 21 48 17

Mechanics/Technical information
Helen Eriksson
+46 732 74 18 08

Mechanics
Kristin Audell
+46 705 21 48 05

FLIR Systems AB (Market-leading suppliers of thermal imaging cameras)
www.flir.se
http://www.flirthermography.com/sweden/contact/

Contact: Tomas Jutebring and Tony Ohlsson
Adress: PO Box 3, Rinkebyvägen 19 SE-182 11 Danderyd SWEDEN
Phone: +46 8 753 2756 & 753 2713, switchboard: +46 (0)8753 25 00
Fax: + 46 8 755 07 52
Email: sales@flir.se

2. See requirements spec. (www.bilda.kth.se)

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Fortum
http://www.fortum.se/document.asp?path=19923;22344;22361;22315;22481;22327;21470
Huvudkontor för Sverige
Fortum
115 77 Stockholm
SWEDEN
Phone +46 8 671 70 00 (switchboard)
Fax +46 8 671 77 77
Visiting address:
Hangövägen 19
Communication, Sweden:
Ann Lindell Saeby (Communications Director)

HiQ Systems AB
(HiQ is a specialized consulting company in communication, software development and simulation. 2007 was a record year for HiQ! Revenue: MSEK 973,7. Net income: MSEK 182,3.)
http://www.hiq.se/HiQLMBreadFetchRightContent.aspx?id=631
HiQ International AB
BOX 7421
103 91 Stockholm
Visiting address: Mäster Samuelsgatan 17, 9tr
Phone: +46 8-588 90 000
Fax: +46 8-588 90 001
info@hiq.se

HotSwap
Let us tempt the engineer in you…
(HotSwap is an engineering consultancy company active in the life cycle of products) Main office
HotSwap AB
Landsvägen 39
SE-172 63 Sundbyberg Sweden
+46-8-478 7600 (voice)
+46-8-478 7699 (fax)
info@hotswap.eu
job@hotswap.eu

Net Entertainment AB (online gaming)
Net Entertainment NE AB
Birger Jarlsgatan 57B
SE 11356 Stockholm
+ 46 8 556 967 00
info@netent.com

ORKLA AB

2. See requirements spec. (www.bilda.kth.se)

Norwegian company that cooperates with Elkem. Difficult to find information for a Swedish contact...

Reinertsen
http://www.reinertsen.se/index.php?c=6&kat=Kontakt
Svärdvägen 29, 182 33 Danderyd Stockholm
Telefon +46 8 544 767 70 Telefax +46 8 768 30 60

Scania
http://www.scania.se/About_Scania/Contact_form/
Scania Head office:
Scania AB (publ)
151 87, Södertälje
Phone switch.: +46 8-553 81 000
Fax: +46 8-553 810 37

Semcon AB
http://www.semcon.se/sv/menu/24468/Adresser/-Countries-list-/Sverige/
Semcon Caran AB
Patentgatan 8
112 67 Stockholm
Phone: +46 8 562 906 00
Fax: +46 8 562 906 40
Semcon Informatic Services AB
Box 1099
164 25 KISTA
Visiting address: Kistagången 16, 7tr
Phone: +46 8-562 929 00
Fax: +46 8-793 91 40

Subsea 7
http://www.subsea7.com/subsea_cont_office_loc.php?loc=networknorway
Stavanger:
Phone: +57 51 83 71 00
Fax: +47 51 83 71 01

Tele2 Sverige AB
http://www.121.nu/onetoone/foretag/tele2-sverige-aktiebolag-7886
Visiting address:
Borgarfjordsgatan 16
164 40 Kista
Phone: +46 8-562 640 00
Fax: +46 8-562 642 06

Vattenfall AB
http://www.vattenfall.se/www/vf_se/vf_se/specialpages/kontakt_vattenfall/index.jsp
Phone: +46 8-739 50 00 (switch)

2. See requirements spec. (www.bilda.kth.se)

162 87 Stockholm
ÅF
http://www.af.se/templates/Page_34130.aspx ÅFs head office:
ÅF AB
Frösundaleden 2
SE-169 99 Stockholm
Switch: +46 10-505 00 00
Fax Reception: +46 10-505 00 10
Fax Corporate management: +46 8-653 56 13

2. See requirements spec. (www.bilda.kth.se)

3098022.v1

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WD086715

Maersk
http://media.maersk.com/en/Pages/MediaHomeNew.aspx Contact persons:
Peter Beck-Bang
Group Communication
+45 3363 3504
Other inquiries to Group Communication in Copenhagen, Denmark and media inquiries outside office hours should be directed to:
+45 3363 3363
Swedish department in Gothenburg
http://www.emfas.com/company/Maersk+Sverige+AB/Goeteborg/G71360487/R1000473/1
Mölndalsv. 24, Box 1115, 405 23 GOTHENBURG
+46 31-751 00 00

Praktiskt båtägande
http://www.praktisktbatagande.se/redaktionen/ Advertisement and market
Patrik Rehn, business ads: +46 8-692 66 34
patrik.rehn@praktisktbatagande.se

Ny teknik
http://www.nyteknik.se/ovrigt/redaktionen/
Lars Nilsson Editor in chief Phone: +46 8-796 66 19
E-mail: lars.nilsson@nyteknik.se Or the editor-in-chief:
Jan Huss Editor-in-Chief Telephone: +46 8-796 66 14
E-mail: jan.huss@nyteknik.se

Metro
http://www.metro.se/se/annonsera/ Advertise on metroteknik.se
Fekri Yousef Sales manager
fekri.yousef@metroteknik.se
Phone: +46 8-56 29 18 46

MJP
http://www.mjp.se/index.php?page_id=7&f=7
Per Ekblom Project Manager
per.ekblom@mjp.se
+46 295 24 42 55
+46 70 239 93 20

2. See requirements spec. (www.bilda.kth.se)

Seaware
http://www.seaware.se/Contact.aspx
+46 8 601 91 90
+46 8 601 91 91
info@seaware.se

GVA
http://www.gvac.se/
GVA Main Office, Gothenburg gva@gvac.se
Box 11450
SE-404 29 Göteborg, Sweden
Visiting address:
Östra Hamngatan 7 Phone: +46 31 10 67 00 Fax: +46 31 10 67 10

Epsilon Utvecklingscentrum Mälardalen AB
Telegrafg 8 A
16984 Stockholm
Sweden
Phone: +46 8 553 340 00 (switchboard) Ask for a finance manager if necessary
Economy: Catharina Wärngård
Fax : +46 8,553,340 99

Red Bull AB
Norrtullsgatan 6, 7tr
113 29 Stockholm
Phone: +46 8-739 50 00

Tre.se
Contact a seller call 020-333333
Lindhagensgatan 98
Box 30213
104 25 Stockholm
Telephone Switchboard: +46 763 33 33 33

Vattenskoterspecialisterna
Visiting address:
Fågelviksvägen 29A
145 03 Norsborg
Slagsta Industri Område
Postbox:

2. See requirements spec. (www.bilda.kth.se)

Box 30 86
Phone: +46 8 531 82 300
Mobil: +46 70 602 73 70

HDD Servo Motors AB
08-868780
Bandhagen Stockholm
Belongs to:
Stridsberg Powertrain AB
Phone: +46 (0)8-99 21 90

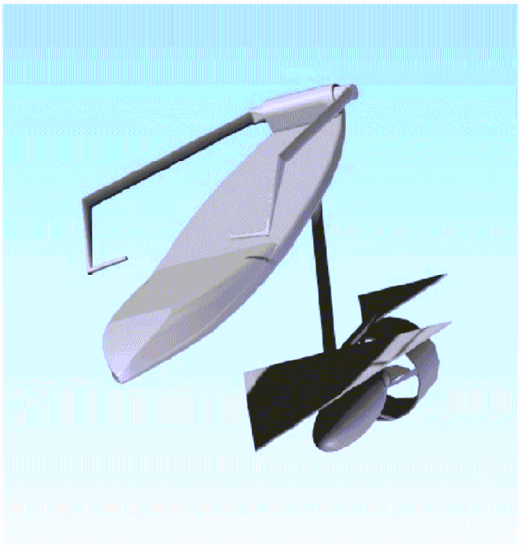
Cisco systems

2. See requirements spec. (www.bilda.kth.se)

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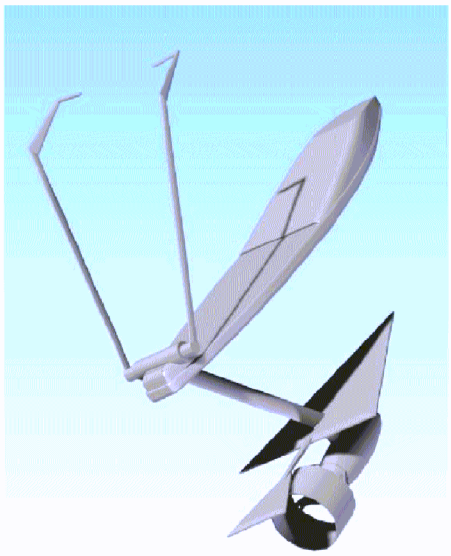
CONFIDENTIAL WD086718

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Evolo is developed and designed by technologists at the Royal Institute of Technology in Stockholm. The project is part of the course Marine and Lightweight Design during the academic year 2008-2009, and is conducted by a total of 15 students who are all studying their fourth year on the Shipbuilding program and the Design and Product Development program respectively, with the specializations Marine Systems and Lightweight Constructions.

The idea behind this course is to give us technologists a good picture of how work can be carried out in project form and the engineer's role in this. It gives us technologists an opportunity to apply the knowledge we acquired during our education both theoretically and above all practically. In addition to the actual engineering work that the project involves, it also gives us the opportunity to meet the industry, working life and users face to face.

www.evolo.se

2. See requirements spec. (www.bilda.kth.se)

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CONFIDENTIAL WD086719

2. See requirements spec. (www.bilda.kth.se)

A brief account of the student project's background, question and purpose, project goals, method and possible implementation (max two A4)

The student project is part of the design courses Lightweight Design and Marine Design, where a technical product is developed from idea to reality during the school year. The course is taught by technologists within Shipbuilding Technology and Design and Product Development with the specializations Light Structures and Marine Systems.

The purpose of the project is to give technologists a taste of what work groups might look like in working life. By working in project form and taking greater responsibility than is customary in regular courses, the motivation and desire to perform increases. This way of working is quite unusual in the courses given at KTH and experience shows that this way of learning is appreciated by both students and teachers. It becomes a more relaxed attitude where as a technologist you get to experience the feeling of being able to solve problems and tasks with the tools you actually already possess. Of course, supervisors are available to answer questions and act as a sounding board, but the major responsibility is taken by the individual technologist and the group as a whole. This in turn contributes to the group feeling that permeates the entire project. The participants feel a personal responsibility for the product to live up to the image and the requirements that they have jointly decided on, and this contributes to the high work ethic within the group.

The goal of the project is that after completing the course, the students should be able to work in project form in a way that makes their own and others' knowledge and efforts effectively utilized. They must be able to present technical work orally, in writing and graphically and also report on success and problem factors in the work. They must be able to handle technical problems from a systems perspective and effectively use available engineering methods and tools to practically realize their own technical ideas.
Furthermore, they must be able to effectively make estimates and describe their value and limitations, which are then used as a basis for decision-making, and make decisions based on interwoven knowledge in order to be able to attack complex and partly incompletely formulated problems. An important objective is that the students should finally be able to reflect on and evaluate both technical solutions and their own and others' work.

The method for reaching the goal is that the group organizes itself so that everyone gets a role that they can identify with and that contributes to feeling trust in the rest of the group as they themselves have been involved in creating the roles that exist.
The project includes regular scheduled meetings, work both individually and in small groups interspersed with a number of teaching elements, feedback and reflection exercises. In principle, the product is designed and constructed in the fall and manufactured and tested in the spring. The intention is for the participants to achieve the course objectives through the project work with support from parallel teaching and exercises.

The structure of the project is such that project planning, design and construction takes place during the autumn term and that the spring term continues with manufacturing, verification and evaluation of the project.
The arrangement is based on the students themselves running a project administration in the form of regular documented meetings where decisions are made, information is shared and work is delegated. The project includes technical work in the form of investigations and analysis carried out by individual project members or smaller groups, in consultation with supervisors. All work performed is presented to the remaining project members and outsiders during presentations and discussions. Joint teaching in the form of seminars and guest lectures takes place continuously during the course of the project, which also applies to evaluation of and reflection on one's own and others' work within

2. See requirements spec. (www.bilda.kth.se)

the project. During the autumn semester, project planning, design and construction take place, and the spring semester continues with manufacturing, verification and evaluation of the project.

Previous years' projects show that teaching conducted in project form is a good way to engage the students and to give them responsibility as this increases motivation so that they can make decisions and solve the questions that are posed. Each project given in this course is unique and has different conditions and layouts. Within this course, technologists have previously run projects such as GENA and Kaimaranen. These have generated a lot of publicity both in the media and among other students at KTH, which has led to them attracting a large crowd of outsiders.

This year's challenge is to develop a water toy on a hovercraft with a maximum speed of 15 knots where propulsion is made possible with the help of an electric motor.

A justification why the student project is suitable to represent KTH (½ A4)

Previous years' student projects within this course have proven to work as a good advertising pillar for KTH as design and innovation are always at the forefront. This year's craft is called Evolo and combines utility with fun as water toys meet environmental considerations in an innovative way. What distinguishes Evolo is that it is based on an hydrofoil solution and is propelled using an electric motor. With its futuristic design and the challenge of trying to ride, Evolo attracts young and old alike to take an interest in how it works and why.

An advantage of Evolo is that it is a spectator-friendly product and this can be exploited for PR purposes
to attract spectators and media to events where the product is displayed.

During the course of the project, continuous tests take place in the form of test drives and demonstrations, which primarily aim to give the project group technical feedback. These occasions can without major efforts be expanded to include events in the form of additional gimmicks that result in KTH as a whole taking up more space.

Evolo will be launched on April 25, 2009. The idea is that it will take place under mass media coverage and that it will function as a public attraction. Here, just as with planned test drives, there will be an opportunity for sponsors to get a space and advertise their products.

Description of the project group (age, gender, educational program, specific interests or competencies that distinguish the project group)

The project group consists of students from the civil engineering programs Shipbuilding Technology and Design and Product Development who are all studying in their final year at KTH with the specializations Light Constructions and Marine Systems. The project is part of the Lightweight Design and Marine Design courses. The project group consists of both women and men aged 22-30. Below, each participant is presented.

2. See requirements spec. (www.bilda.kth.se)

A justification from the student group about why we want to be part of this project
Our goal is to show in a playful and different way what can be developed with our knowledge. With Evolo, we give a preview of what tomorrow's water toys might look like.
We want to take part in the competition because we believe in our product and because we want to inspire others to dare to apply for our courses and specializations.

The idea of this project is to give us technologists a taste of what it is like to work in project form and to prepare us for what is expected of an engineer out in the working life. All participants in the project group have at some point come into contact with previous years' projects. Some have even chosen these specializations because they get to work in this way.

What makes this project unique for us is that it is the first time during our education at KTH that we have the opportunity to apply our knowledge that we have acquired, both practical and theoretical, and apply it to a product and then follow it through the entire process from idea to reality.

The course structure aims for us students to organize ourselves and assign different positions within the group in order to have a functioning organization in this way. This leads to everyone getting the opportunity to try out the role they are passionate about, which leads to great commitment.

Based on the requirements specification received, we as a project group have together developed a concept that we believe in. It is presented in its entirety on our website www.evolo.se he website acts as our face to the outside world and our progress is continuously updated there. It is also used as a forum where we present our sponsors. So we don't just deliver a finished product, but the idea is that you can continuously follow Evolo via the website and other media from idea to development, construction, analysis, manufacturing and finally verification.

We are actively looking for different ways to expose ourselves in the media and intend to ensure that Evolo is seen as much as possible during the development and production of the craft. Information is currently available on the website with links from the course website. There are also video clips on www.youtube.com where our experiments are shown. All participating students have a great interest and commitment for this project to be successful, not only that Evolo is functional at launch, but also that we as individuals gain experience that we can use in our further careers as engineers.

For many of us, the project is the beginning of the end of our studies at KTH and is similar in many ways to a degree project in project form. The chance to participate in a competition where we get the opportunity to show what we have created makes us more than motivated and ready for the challenge. We all want to do our utmost to ensure that in April 2009 we can present a finished product that we can be proud of; Evolo.

We see this project as a starting point into working life and hope that our project can be of interest to you.

2. See requirements spec. (www.bilda.kth.se)

Hydrofoil calculation



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Course:	Marine design
Project:	Hydrofoil
Date:	*30/10-2008*
Version number:	(<1 for working document, >1 for "finished" report)
Supervised by:	
Hours worked:	*5*
Reviewed by:	

2. See requirements spec. (www.bilda.kth.se)

Introduction

The purpose of this report is to give the reader an idea of which hydrofoil dimensions will be required to meet the set requirements (See Appendix 1). The technical investigation carried out in this report and the results that follow from it are not final. The design process of the hydrofoil is progressing, but the results from the technical investigation described here form the basis for the continued work. The study in this report only includes calculations on a straight hydrofoil wing.

Problem formulation

The purpose of the study is to analytically determine what dimensions will be required on a hydrofoil. The requirement placed on the hydrofoil is that a lifting force of 1700 N must be able to be generated in the speed range that is interesting. In this case, the speed range is from 0 knots up to 20 knots. To tackle the problem, a lifting speed must be adopted. Lifting speed means the speed at which the vehicle lifts up on the hydrofoil. After this speed has been assumed, the wing area required to achieve the given lifting force at the lifting speed can be calculated. To perform the calculation, assumptions are made regarding the lift coefficient, these assumptions are further described in the analysis. When the wing area is determined, a certain perception is created of what the hydrofoil should look like. However, a hydrofoil with a certain area can have many appearances, therefore a variable called aspect ratio is introduced. Aspect ratio is a relationship between the hydrofoil area and the wingspan. Since the area is determined, the wing span can now be varied to find the most suitable hydrofoil.

Analysis

The starting point for the problem is to employ a lifting speed for the craft. This speed is set to 6 knots. This assumption was made on the basis that the lifting speed wants to be kept as low as possible, because the faster the craft lifts up on the hydrofoil, the less power is required. Then the wing area is calculated using an equation to calculate the lifting force.[19] This equation is rewritten so that the wing area is calculated instead according to:

$$A = \frac{L}{0.5 \cdot \rho \cdot v^2 \cdot CL} \qquad (1).$$

Where L is the lift force of Newton, ρ is the density of water in kg/m^3, v is the speed of the craft in m/s and ^{CL} is the three-dimensional coefficient of lift. The value of the lift force is obtained from the requirements spec (See Appendix 1). According to the requirements, the craft must weigh a maximum of 70 kg and be able to carry a person weighing 100 kg, which leads to a total weight of 170 kg. This means that the hydrofoil must generate a lift force of approximately 1700 N. The density of water is approximately 1000 kg/m^3.
The speed had been assumed to be 6 knots, which corresponds to about 3 m/s. To determine the value of the lift coefficient, certain assumptions must be made. One of the assumptions made is that when lift speed, the maximum lift coefficient can be taken out, ie. the angle of attack is equal to the stable angle. The maximum lift coefficient of the wing is set to 1,5.[20] It is important to keep in mind that this coefficient is for the two-dimensional case. To convert the two-dimensional coefficient to a three-dimensional, it is used that the 3-D coefficient is about 90% of the 2-D coefficient.[21] This conversion can be done when the hydrofoil wing has an aspect ratio greater than 5. This gives a CL of 1.35. With all these values inserted in (1), the following is obtained:

$$A = \frac{1700}{0.5 \cdot 1000 \cdot 3^2 \cdot 1.35} = 0.24 m^2 \qquad (2).$$

Now that the area required to meet the lift requirement at 6 knots has been determined, use (1) again. This time to determine the CL required at each speed. As even a lift force as possible in the entire speed range is desirable, so the lift force is set constant. The speed varies between 6 and 30 knots, CL is calculated according to:

$$CL = \frac{L}{0.5 \cdot \rho \cdot v^2 \cdot A} \qquad (3).$$

A good way to compare different hydrofoils is to calculate the resistance that the hydrofoil generates.[22] This resistance is calculated according to:

$$D = 0.5 \cdot \rho \cdot v^2 \cdot A \cdot CD \qquad (4).$$

[19] J.Kuttenkeuler. Segling så funkar det. s.44.
[20] J.Kuttenkeuler, Segling så funkar det, s.56-64.
[21] John D.Andersson. Aircraft performance.
[22] J.Kuttenkeuler, Segling så funkar det, s.43

In this equation, everything is known except CD, which is the three-dimensional coefficient of resistance. This coefficient consists of two parts according to:

$$CD = CD_0 + CD_i \quad (5).$$

CD_0 is a drag coefficient that refers to the wing area, this coefficient is set to 0.05.[23] CD_i is called the lift generated drag coefficient. This occurs due to the overcurrent that occurs at the wingtips. The overflow contributes to the total resistance and is directly linked to the generation of lift force, hence the name. By calculating the coefficient of lift, the CD_i can then be calculated.[24] This is done according to:

$$CD_i = \frac{CL^2}{\pi \cdot e \cdot AR} \quad (6).$$

Where e is the "span efficiency factor" that can be assumed to be 0.85.[25] AR, the wing aspect ratio is calculated according to:

$$AR = \frac{b^2}{A} \quad (7).$$

Where b is the wing span of the hydrofoil and A is the wing area of the hydrofoil. Now b is varied to calculate the resistance for different ARs but for the same A, the A determined earlier. The wingspan varies between 0.4 m and 2 m. The drag was calculated for the different wingspans according to (4) and plotted against the craft's speed. The result is reported in Figure 1.

[23] J.Kuttenkeuler. Segling så funkar det. s.49
[24] ibid.s.46
[25] John D.Andersson. Aircraft performance.

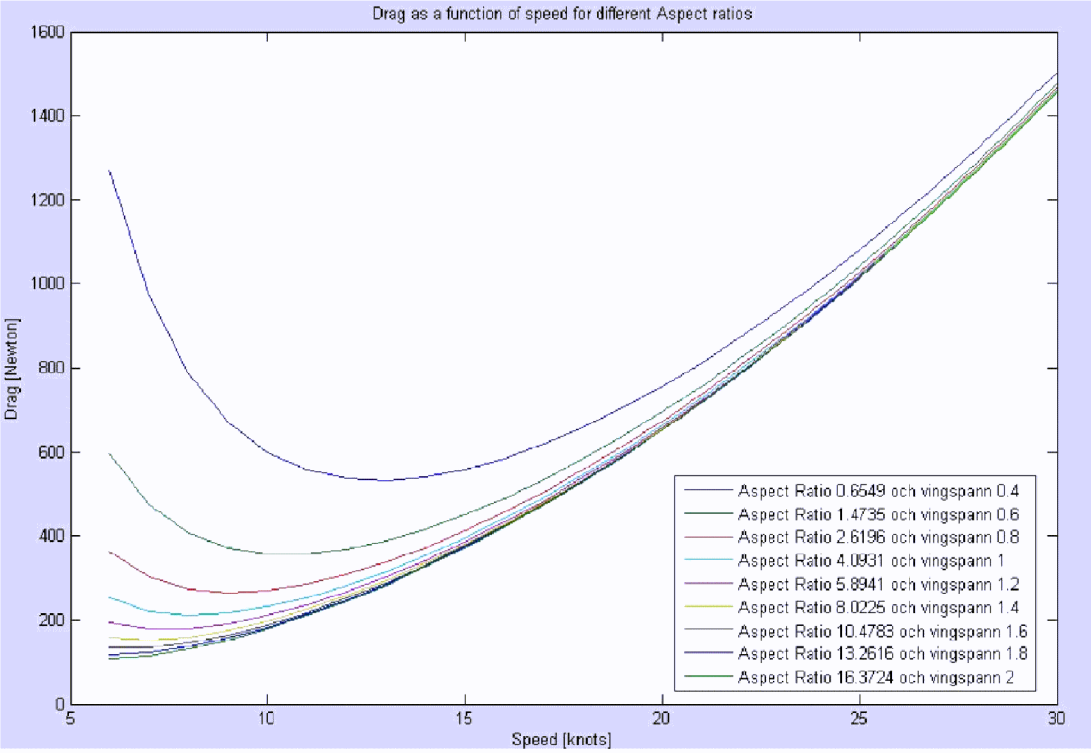


Figure 18. The resistance of the different hydrofoil plotted against the speed.

If the plot is considered, it is noted that a high aspect ratio gives less resistance. But the 5 wings with the highest aspect ratio do not differ much at all. This means that virtually any of these could be chosen as a hydrofoil from a resistance point of view. However, since the hydrofoil is to be applied to a water toy, demands are made on both strength but also on the product being easy to move, if this is considered, the hydrofoil with the lowest aspect ratio of the 5 would be most suitable.

Conclusion

Based on the calculations and assumptions made, the author has come to the conclusion that a hydrofoil with dimensions according to Table 1 would be most suitable if the craft is equipped with a straight hydrofoil.

Wingspan [m]	1.2
Chord [m]	0.2
Aspect Ratio	5.9

Table 2. Results from the technical investigation

It is also notable that the result was an hydrofoil with an Aspect Ratio greater than 5, which was one of the prerequisites for one of the assumptions.

References

62. Kuttenkeuler, J: *Segling så funkar det.* Department of Marine Systems, KTH, Stockholm, 2008.
63. Andersson, John D: *Aircraft performance.*

Appendix 1

Requirements specification version 0.1 The craft shall:

- Be a playful means of transport.
- Be electrically powered with an effect of approx. 3 KW.
- Be able to transport an adult of 100 kg.
- Have a cruising speed of 15 knots.
- Use a hydrofoil solution at cruising speed.
- Be able to float and balance in a stationary position with with passengers.
- Performed in a controlled manner.
- Mainly steered with center of gravity shift.
- Be ready to drive within the schedule, ie. on 25/3 -09.
- Cope with moisture and the Swedish spring and summer climate as well as cope with stresses from the motor, i.e. heat and vibration.
- Have protection around the propeller and dead man's switch.
- Follow current requirements for noise and environmental impact according to SJÖFS 2005:4.
- Can be performed at cruising speed for a minimum of 40 minutes.
- Be able to be transported with a B driving license on land.
- Produced within financial and time budget, ie. SEK 20,000 plus possible sponsorship money and 8,000 hours.
- Do not weigh more than 70 kg.

Motor options

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Date:	*24/11-2008*
Version number:	*1.0*
Supervised by:	
Hours worked:	5 h
Reviewed by:	Markus Norberg

Introduction

Several options are available to power the Evolo. Among these are easier and more difficult options, i.e. more or less time-consuming solutions. The two most obvious ways to approach this are either to start from a finished product, such as an electric outboard motor, or to build the motor system ourselves. There are both pros and cons to these two options. This report aims to compile the information search that has been done regarding engine options as well as provide a recommendation as to how the analysis can proceed.

Problem statement

Based on previous analysis according to *A14 – Power requirement, M.Norberg [1*], the power requirement varies depending on the wing configuration and design of the floating body. These calculations are still under analysis and we will therefore look here at a wide range of possible engines, both with more and less power than required by *A14*. In the analysis made, it appears that the power required to drive the craft forward amounts to around 800 - 1000 Watts from the propeller. In connection with this, a thrust force of approximately 500 Newtons. Furthermore, the craft must be able to achieve a top speed of around 15 knots, something that may prove to be of great importance in the choice of motor system. The required thrust force is expected to be around 50kg. These figures naturally depend on how optimized the floating and the underwater body are.

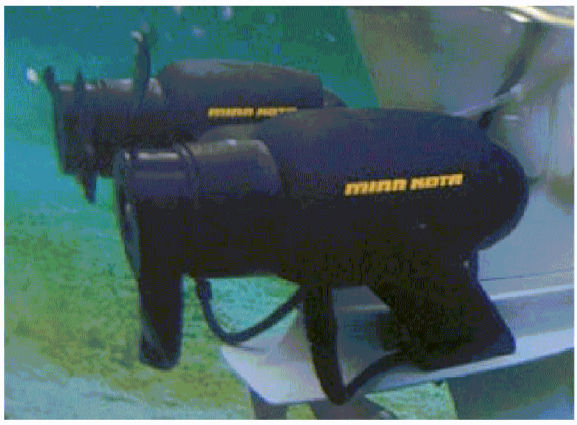
Option 1 – Finished System

There are several options on the market today in terms of ready-made electric motor concepts for marine use. The method would be to source a product that matches the data produced in terms of power requirements and thrust for the Evolo, then remove the excess parts to build the motor and electrical system into the Evolo's design. The following options can be seen as reasonable for our purpose;

Minn Kota, MK160/ÆM

Figure 1. *Minn Kota, MK160/EM*

Minn Kota provides several different variants of so-called trolling motors. Of which a model with sufficient thrust, the MK160/EM may be of interest. This model is a type of dual motor arrangement intended to be mounted on the rig of an existing



outboard motor. In this moment, no exact values of this motor's power have been found.

The obvious weakness of this option is that the manufacturer himself states that most boats only reach a speed of around 4.3 knots with their engines. What is not clear is whether it is due to the choice of propeller or limitations in the motor.

Torqeedo Cruise 2.0/4.0 R

Figure 2. *Torqeedo Cruise 2.0*

Torqeedo claims not only to deliver the most powerful electric outboard on the market, but also the most efficient. The Cruise models shall correspond to 6 and 9 horsepower respectively. Table 1 below shows data for the smaller Cruise 2.0 *[2][4]*.

Torqeedo		Cruise 2.0
Effect in		*2000 W*
Effect out		*900 W*
Maximum efficiency		*45 %*



Max RPM		*920 rpm*
Static thrust kf		*55*

Table 1. *Data for Torqeedo Cruise 2.0*

The weakness still lies in the fact that regardless of the thrust that a Torqeedo produces, there is no indication that the propeller is effective above 5-6 knots. According to the information that has been found, it does not matter much whether the craft is a dinghy or a small sailboat [4], *see Figure 3*.

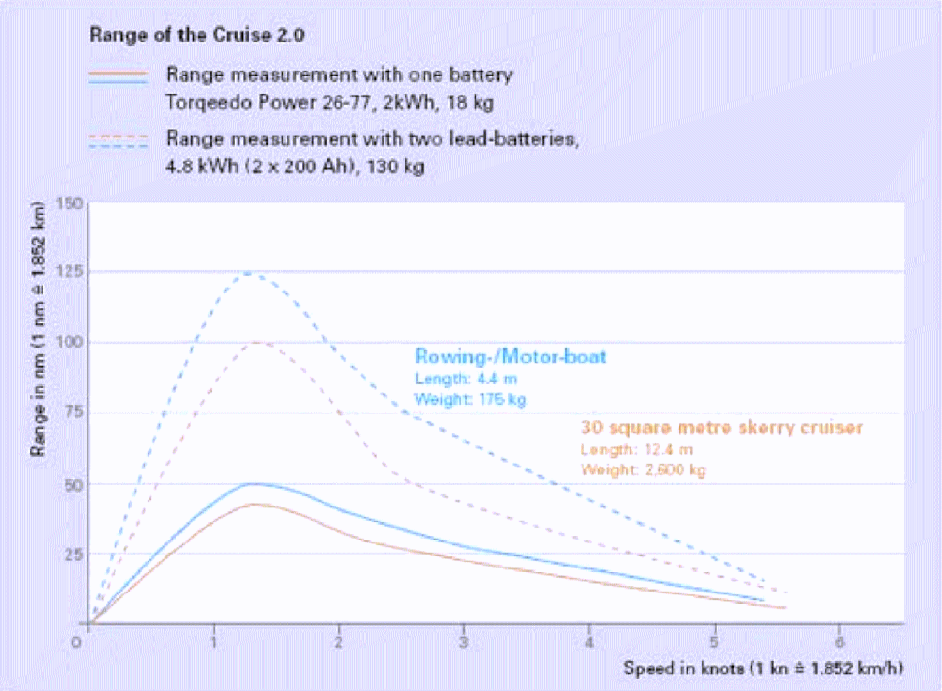


Figure 3. *Range for torqeedo cruise, two different load cases.*

The figure shows range as a function of speed. The two different boats are a dinghy and a sailboat with a considerable difference in weight. The efficiency of the motor (incl. the propeller) can be assumed to be greatest around the top of the curve. We then see that closer to 6 knots the curves for both boats converge. My interpretation of this is that the efficiency of these speeds is so low that the type of boat is of no great importance, but that the limitation here lies in the motor/propeller. To circumvent this, it is necessary to change the propeller, which requires a deeper analysis of the entire system. RPM and thus gear ratio are also included in this analysis.

A Torqeedo Cruise 2.0 is available today from last year's project. Unfortunately, it is still unclear what we are allowed to do with it. Today it is owned by Captain's and is only on loan to KTH.

Option 2.

The other option is to construct a motor system from scratch. This requires a motor, control device, controls, suitable cables and more. The problem with choosing a propeller will be the same regardless of whether we choose option 1 or 2. For this option, an interesting motor has been found so far.

Hacker Brushless A100 *[5]*

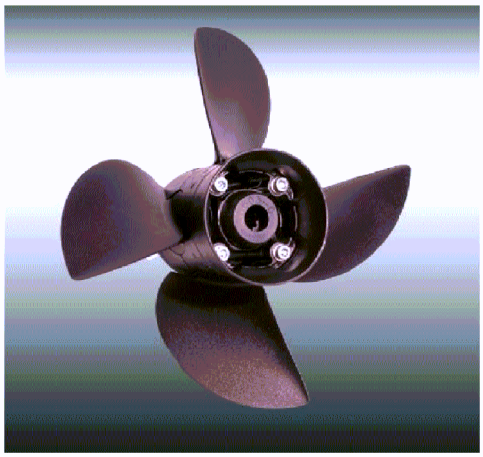
Hacker builds brushless motors primarily intended for model aircraft. This model is said to be equivalent to an 80cc internal combustion motor and weighs only 2.5 kilos. More precise data has not been found at this point. The difficulty with which electric motor is chosen is that the entire system must be built from scratch.

- Other options that include more industrial electric motors are difficult to apply due to high weight in relation to the power they deliver.

Conclusion and recommendation

In whichever case one is chosen, it is clear that further analysis must be done regarding the propeller. If we choose to start with the Torqeedon, we have the problem that it probably won't propel the Evolo faster than 5-6 knots, which means that the Evolo takes off just fine before the speed stagnates. The conclusion is therefore that regardless of which type of engine is chosen, a more detailed analysis must be made regarding which type of propeller can conceivably work in combination with possible motors. Several aspects like downshift and other parameters have to be weighed into this.
An alternative that has been found and may be interesting is ProPulse [3], see Figure 4. The company manufactures propellers with adjustable plastic blades. It is important to investigate whether any model can be mounted on, for example, Torqeedon and what this would mean. Would a propeller change mean that the power and torque from the motor would still be enough to produce enough thrust while giving us a higher speed? In that case, torqeedon is preferable as everything is available in this one. Otherwise, we have the situation where a complete engine system has to be dimensioned and assembled.

Figure 4. *Propulse 4901*



References

1. A14 – M.Norberg, Motståndsberäkningar
2. www.torqeedo.com - 2008-11-24
3. www.propulse.se - 2008-11-24
4. www.greenboatsupply.com/products.html - 2008-11-24
5. www.hackerbrushless.com - 2008-11-24

Motor control



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Date:	*01/12-2008*
Version number:	*1.0*
Reviewed by:	Erik Jerilgård

Summary

Since most industrial and marine motors on the market, eg Torqeedo, are asynchronous motors, there is a need to summarize their function and control in order to be able to decide how the Evolo should be propelled and controlled. Since the motor control of asynchronous motors is of a control technology type and that the skills required to manufacture an own system are not available in the project today, it is strongly recommended to purchase an already completed system, adapted to the motor that is finally chosen for Evolo.

Induction motor

Unlike a direct current motor where a variation of the input voltage directly controls the speed of the motor, an asynchronous motor is a type of alternating current motor. It is unique in that it lacks directly connected parts and carbon brushes, making the motor very robust, reliable and durable. The asynchronous motor works by the input current going to the stator in the motor, whose winding in cooperation with the input AC voltage produces a rotating magnetic field that sweeps over the rotor. This induces a new current in the rotor and the interaction between them will cause the rotor to rotate. For this to work, there must be a speed difference between the rotating magnetic field and the speed of the rotor. Without this difference, they would not move relative to each other and then no currents would be generated. This is the reason for the name asychron motor[1]. The motor is controlled by varying the frequency of the input voltage by varying a control voltage to a control system, a so-called inverter or pulse modeler[2], indicates which speed or torque is desired, whereupon the control system regulates the strength and frequency of the input voltage in response. An example of such a connection is shown in Figure 1 where the motor, control box, voltage source, key and feedback system are shown. Control of asynchronous motors was a major problem before the development of reliable control systems.

Use in Evolo

Since almost all motors now on the market are of the asynchronous type, it will not be possible to avoid using one, and it is an asynchronous motor that is now being investigated in the project, *Torqeedo Cruise 2.0*.

Due to the complexity of motor control of asynchronous motors, it is strongly recommended to use the motor manufacturer's own control system. This is because these are already specially made and adapted precisely for the motor in question and that we do not have the skills required in the project to make our own system. However, most systems can be modified externally, such as the placement of controls. This should provide sufficient adaptation to our area of use without sacrificing the desired functionality of the system.

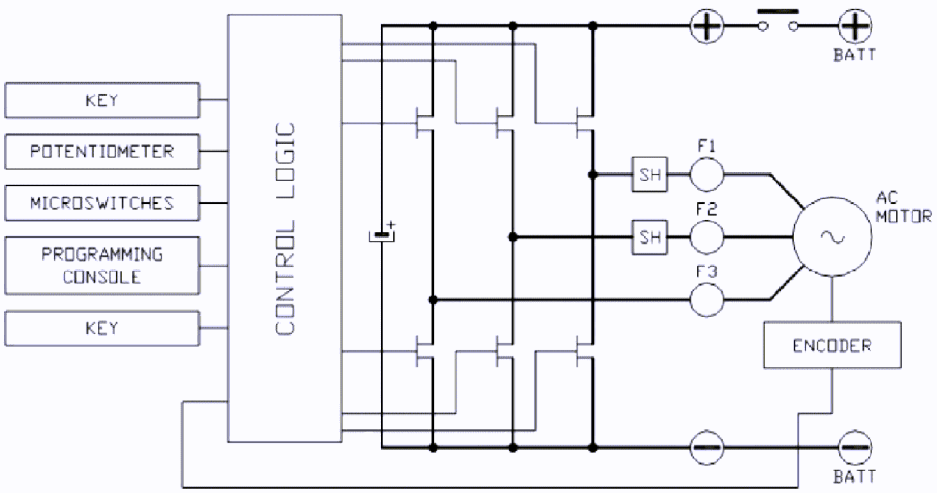


Figure 1. Example of connection of asynchronous motor with control system

References

Ex)
64. The function of indiktion motors, Wikipedia 2008.
http://en.wikipedia.org/wiki/Induction_motor
65. Handbok drivning och automatisering. Sigbi System AB. 2008. http://www.sigbi.se/

R-11 Production plan



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MARKUS NORBERG
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MIRJAM FÜRTH

Course:	Marine design / Lightweight design
Project:	Evolo
Date:	*5/2-2009*
Version number:	*1.0*
Hours worked:	*10*
Reviewed by:	*Jasmin Satari Far*

Production plan

A Gannt schedule of the construction period is presented in Appendix 1. Below is a clarification of the Gannt schedule.

Test

The test that should be carried out before the actual production starts, this to ensure manufacturing methods are:

Vacuum injection

Purpose: Investigate what conditions we have and what values we can expect from the manufacturing method. Small-scale test.
Status: Carried out. Report TB 104 vi_drag_resultat deals with this.

Sandwich Production

Purpose: A vacuum injection where the focus is on understanding how the set-up should take place as the experience is relatively little in this regard. Tests will be made regarding bending stiffness. Large scale test. Possibly inhibitor tests will be done if deemed necessary.

Status: Scheduled week 9

Mountings

Purpose: Practically test which mountings are most suitable. A full-scale mounting is built and then loaded.
Status: Scheduled week 9

Manufacturing

Floating body

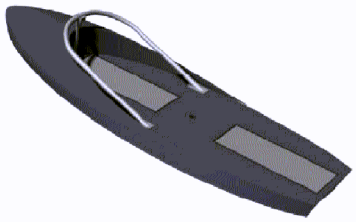


Figure. 1. Illustration of the floating body

The floating body consists of sandwich composite with Diviny cell core and carbon fiber layers. Batteries
must be able to be accommodated in the construction and be easily accessible.

Method of manufacture: Sandwich (carbon fiber/vinyl ester and diviny cell core)

Estimated time: 1 week Status: Planned week 10 Number of people: 3

Strut

The strut consists of a load-bearing steel shaft in a carbon fiber composite profile. Estimated weight 2.95 kg.

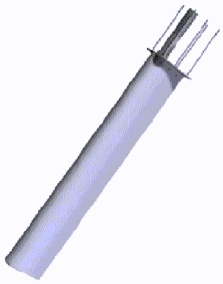


Figure. 2. Illustration of the strut

Method of manufacture: Sandwich (carbon fiber/vinyl ester and diviny cell core) The recommendation is to use a $[+45\ -45]_s$ laminate in a suitable thickness to handle both bending and torque, see report TB106 Strut.

Estimated time: 1 week
Status: Planned week 9
Number of people: 2

Stay

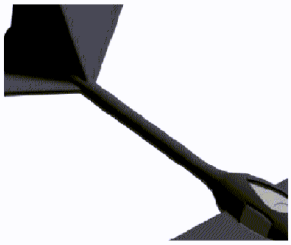


Figure. 3. Illustration of the stay

Method of manufacture: The length of the stay is set to 0.75 m. Metal rings (washers) must be cast into the mold to avoid cracking. In addition, holes in the mold must be left around the center of the motor because the cooling to the motor is there. To prevent excessive forces from arising and the fibers to be broken, aluminum plates must be cast into the mold around the motor's cooling part.

Estimated time: 1 week Status: Planned week 12 Number of people: 2

Wings/Hydrofoil

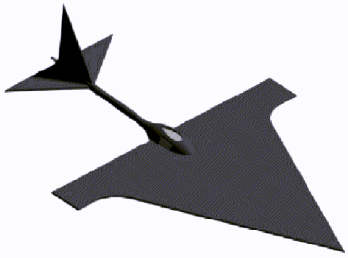


Figure. 4. Illustration of the hydrofoils

Wings consist of a forward and aft hydrofoil. These are to be manufactured in sandwich composite with Divinycell core and carbon fiber layers. It has not been decided whether wing components will be manufactured in advance to test tensile/bending tests as material consumption is limited. An assumption is made in such cases that the mechanical properties of the fabricated wings are at least tangential to the existing plywood wings.

Method of manufacture: Sandwich (carbon fiber/vinyl ester and diviny cell core)

Estimated time: 2 weeks

Status: Planned week 12

Number of people: 2

Propeller



Figure. 5. Illustration of the propeller

If a propeller is manufactured, it must consist of carbon fiber.

Method of manufacture: The manufacturing process is that a thin piece of sheet metal is bent and shaped into the desired shape. The carbon fiber is then applied by hand laying, see report TB 113 manufacturing plan/manufacturing propellers.

Estimated time: 2 weeks
Status: Planned week 9
Number of people: 2

Handle/Rail



Figure. 6. Illustration of the handle

The handles must be manufactured in aluminum as manufacturing in carbon fiber was considered too complicated.

Method of manufacture: A suitable aluminum pipe is procured and bent to the desired shape.

Estimated time: 1 week
Status: Planned week 9
Number of people: 2

Mountings

In order for the various components to be linked together, functioning mountings are needed between them. The various mounting options available are reported in report TB 102 Mounting plan.
Method of manufacture: In order to determine exactly how the mountings are to be manufactured, tests must be carried out.

Estimated time: 3 weeks
Status: Planned week 9
Number of people: 2

Assembling

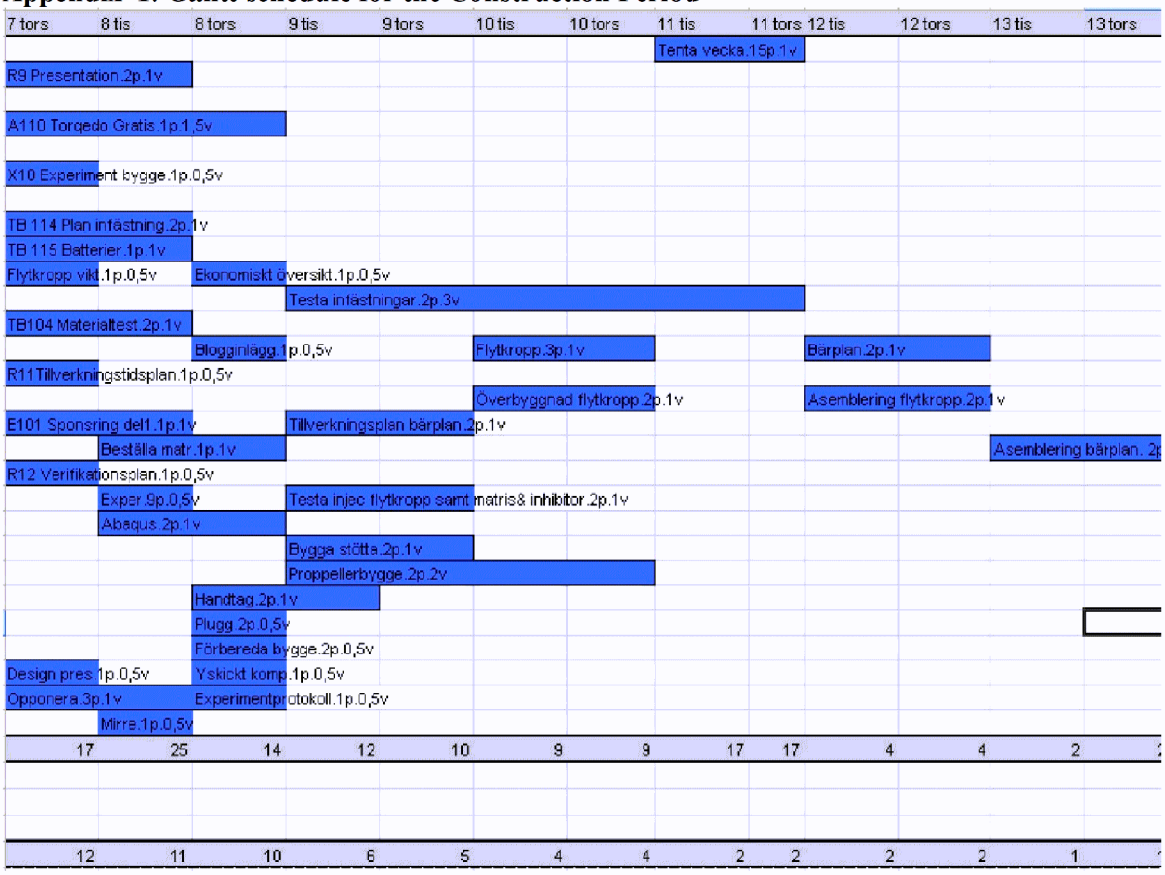
Assembly means assembly of all components. Since the components are not built at the same time, they will be assembled individually and then make a final assembly. This means that this activity takes place during almost the entire construction.

Estimated time: 3-4 weeks
Status: Planned week 11
Number of people: 2

References

1. N.Wolter, F.Ekekrantz, *Rapport TB 104 vi_drag_resultat*
2. M.Razola, *TB106 Stötta*
3. M.Razola, *TB 113 tillverkningsplan/tillverkning*
4. N.Wolter, E.Jerilgård, *TB 102 Infästning plan*

Appendix 1. Gantt schedule for the Construction Period



Verification plan Evolo



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Course:	Marine design
Project:	Evolo
Date:	*26/1-2009*
Version number:	*1.0*
Supervised by:	Jakob Kuttenkeuler and Stefan Hallström
Hours worked:	*16*
Reviewed by:	Mirjam Fürth

Summary

This is a plan for the verification of Evolo. The verification is divided into different areas and a timetable shows when the respective area and sub-areas should be verified according to the plan. Each area has a responsible person who will verify the area and report in a verification report for the entire project. However, it is the project's verification manager who has the overall responsibility that the verification is reported.
Many things can contribute to the failure of the verification schedule. These are, for example, delivery times, extra work due to labour intensive motor options, delayed experiments due to the ice condition and strength tests on fastenings that take time.

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Introduction

Verification means answering whether set requirements have been met. In the Evolo project, there are many requirements to be verified, partly those that are directly stated in the requirements specification, but also indirect requirements and sub-requirements that must be verified before the project can proceed.
The verification of Evolo has been divided into different areas that cover all the requirements from the activities that exist and from the requirements specification. The areas that the verification has been divided into are

- Material
- Durability
- Hydrofoil Design/Stability
- Motor and battery choice
- Ergonomics
- Performance:
- Safety
- Weight

Each area is reported further down in the verification plan with sub-areas and activities.
Manufacturing is an area that is closely related to the verification areas but is addressed in the manufacturing plan. Another area that needs to be verified is the finances of the project, but this is also not addressed in the verification plan. It is natural that the finances and budget are verified on an ongoing basis by the project's finance manager.

Responsible persons and reporting

There is a responsible person for each verification area who is usually the same person who has the overall responsibility for the corresponding area in the other project activities. A large part of the verification takes place according to the project's schedule and is considered complete when each activity is reported to the project's report compilation on Bilda. In order to compile the verification work, a verification report will also be posted in which each area manager must summarize the verification. The verification report must be completed at each time specified in the verification schedule. Each summary must be concise but clearly report that each activity has been verified, i.e. that the result meets the set requirements. In its simplest form, the summary can refer to a clear report of a trial or experiment. The reason why the verification of each activity is not reported under the respective activity is that so few activities so far have their own verification plan.
The person who has overall responsibility for ensuring that all areas and sub-areas are verified and that the verification report is filled in is the project's verification manager.

Verification methods

The methods that can be used for verification are primarily trials and experiments such as tensile tests, engine experiments or full-scale experiments, but can also be, for example, analysis in Matlab with parameter values from manufacturing or experiments. The description of each area below shows in most cases how the verification should be done or at least an approach is made to give suggestions for a method. Each area manager can of course assess for himself which method is suitable,

especially for cases that are not described in more detail due to a lack of information at the moment.

Verification areas

Material

The sub-areas to be verified regarding materials are

- Carbon fiber laminate
- Sandwich test
- Stiffness on the hydrofoil

The verification of materials has already begun in the form of tensile tests of carbon fiber laminates. A segment of the floating body must be built to verify that the sandwich construction meets the requirements and the manufacturing method can be verified. The section needs to be large enough for the manufacturing process to function as on the finished craft. This should be verified before construction of the floating body begins.
Stiffness of the airframe should be verified so that it is not less than that of the test craft. However, in consultation with the material manager, the assessment is made that no special tests for this need to be carried out.

Durability

The sub-areas to be verified regarding durability are

- Mountings
  - Floating body - strut
  - Motor – hydrofoil
- The floating body beam
- The strut
- Hydrofoil stay

The mountings should be tested to the greatest extent possible by having a corresponding fastening manufactured and loaded with the loads for which the respective mount must be dimensioned.
The floating body beam can hopefully be tested with the section of the floating body described above under the heading *Materials* above. However, much information can be obtained from analysis in CAD and FEM programs.
The strength requirements of the strut are described in the report on the production of the strut.

Hydrofoil Design/Stability

The sub-areas to be verified regarding hydrofoil design/stability are

- Hydrofoil angles
- Resistance
- Floating position and transverse stability
- Eigenfrequencies on hydrofoil
- Controllability
  - Center of gravity/moment of inertia in yaw direction
  - Length of the strut

The hydrofoil design has been tried out during the autumn but no trials or experiments have been done on the design that Evolo has in the final design. This is because it is designed analytically to reduce drag and not through experimentation. Angles and principle of stability must be verified by experiment. The resistance must also be verified by experiment.
Floating position and transverse stability apply to stationary and speed with the floating body in the water. They must be evaluated against the requirements specification when Evolo is finished.
Eigenfrequencies on the hydrofoil refers to whether it would be the case that the hydrofoil acquires an eigenfrequency that can be excited at normal speed and negatively affect the Evolo's drivability and performance. It can be verified by FEM analysis of the hydrofoil but ultimately it must be verified by experiment with the finished product.
Controllability here means the extent to which Evolo can be controlled. It is difficult to verify any results because it is not possible to measure how well the requirements are met. However, some parameters that can be taken into account to verify controllability are center of gravity and turning moment and the length of the strut.

The verification of hydrofoil design and stability is divided into two different periods in time. The first concerns experiments with the experimental craft towed behind a boat. The other refers to the finished product or something that is largely finished and can be driven with its own motor. Several of the sub-areas under hydrofoil design and stability must therefore be verified in two steps.

Motor and battery choice

The sub-areas to be verified regarding motor and battery choice are

- Motor performance
- Battery performance
- Possible installation of an electric motor

Once a motor can be delivered, it must be verified that it has the characteristics required to get the Evolo to take off with the chosen hydrofoil design. This is done through engine experiments and possibly analytically with specifications on the motor.
Battery performance is similarly verified in connection with engine experiments or by measuring the battery and analyzing the batteries' specifications.
In the final design, there were a few different motor options suggested to Evolo. If an option not initially adapted to drive a propeller in water is chosen, the motor must be built into some kind of watertight housing. Construction of such must be verified, both in terms of strength and resistance contribution to the craft but also in terms of function such as cooling and that it holds tight.

Ergonomics

The sub-areas to be verified regarding ergonomics are

- Handles and controls for different drivers
- Handling on land, ease of use

Ergonomics are difficult to evaluate in the same way as the driving experience or controllability. However, the ergonomics can be evaluated against the requirement specification and how drivers of different sizes experience Evolo.

This verification is divided into two periods in the same way as the verification of the hydrofoil design, i.e. the verification takes place in two stages.

Safety

The sub-areas to be verified regarding safety are

- Dead man's switch
- Propeller nozzle/cover
- Risk of hydrofoil piercing

In addition to the safety details mentioned in the requirements specification, i.e. dead man's switch and protection against the propeller, it should also be verified that the safety of all operations is high and that recommendations from the safety analysis that was done in the autumn are followed. It is mainly the person who is responsible for the execution of various experiments who should also think extra about safety. However, all project members should consider their own safety and that of others.
Hydrofoil piercing refers to being injured by a pointed hydrofoil or other dangerous parts of the Evolo.

Performance

The sub-areas to be verified regarding performance are

- Lifting speed
- Maximum speed
- Propeller
- Environment according to requirement specification
  - Wet etc
  - Heat, vibration
  - Noise
  - Transportability

Evolo's performance is the final verification of how the project has succeeded in meeting set requirements. The verification of performance must take place with experiments at the end of the project when the finished product exists. Of course, the fulfillment of the performance requirements is an important part of the goal of the project and thus they are kept in mind during every activity up to the verification.
The performance of Evolo is quite well defined in the requirements specification and is thus verified against it. The propeller is a part that is not in the requirement specification but its performance should be verified to ensure the best possible performance of the Evolo with the motor used.

Weight

The weight of the Evolo must be verified according to the requirement specification. In terms of weight, it is important that every part of Evolo strives to minimize weight in design and manufacture. When Evolo is finished, it is not possible to correct the weight to a very large extent without major, costly and time-consuming interventions.

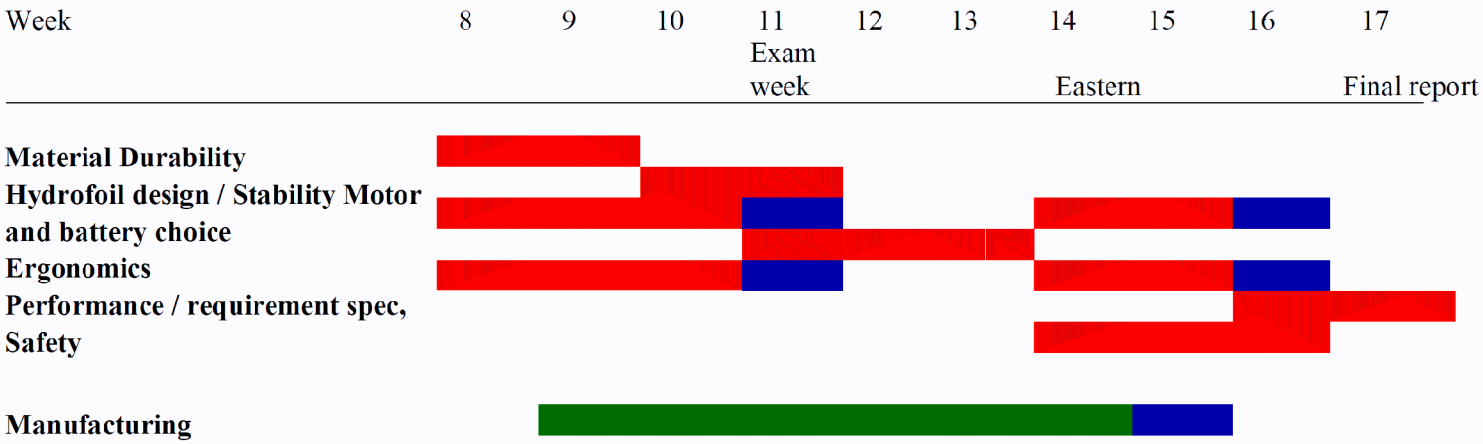
Timetable for verification

The verification plan applies to the period between week 8 and week 17 when the final report must be ready for approval, i.e. February 16 to April 24. The requirement specification states that the goal was to have a finished product by March 25, but that date should be postponed.
The timetable is presented in Table 1. It is an orientation that will likely need to be changed over time. However, there is a relatively large time span in each area to be verified.

Whether or not the schedule is kept depends on several factors that can cause problems. For example, the delivery time for materials or motors and batteries can be very long in this context, especially considering that nothing has currently been ordered.
Another problem is that, for example, mountings to be built for verification before being built on the final product can be complicated and time-consuming so that it should be considered to settle for an analytical verification. If there is also time-consuming additional work in the form of a waterproof housing for the engine having to be built, there can be major delays.
The airfoil design, which is not yet tried, may need more experiments to verify it. Then it depends on how the ice condition is, whether it takes time to verify it.

Table 1. Timetable for verification of Evolo. Manufacturing is listed at the bottom to be able to compare. The blue (dark in black and white) fields are "reserve weeks".

Timetable for verification of Evolo



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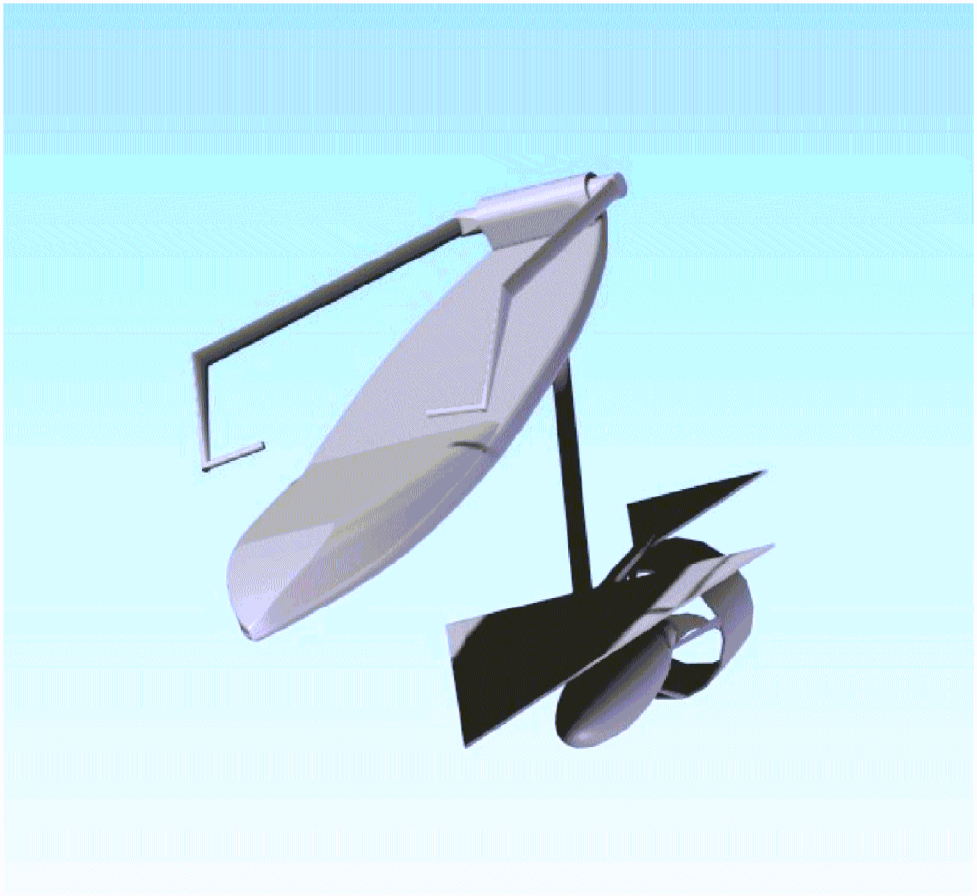
Appendix 1 - Checklist for Quality Assurance

The purpose of the list is to function as a structuring support for planning, writing and proofreading reports and as support for self-reflection. The list should be used for feedback from proofreaders. Evaluate each point with yes / no and sometimes with a grade of u, 3,4,5. Note that the completed checklist must be attached to each report!

General impression	Author Yes/No	Reviewer Yes/No
598. Are all elements of the problem addressed?	Yes	Yes
599. Have the purpose and conditions been reported?	Yes	Yes
600. Have relevant conclusions for the benefit of the project been drawn, reported and related to the objective?	Yes	Yes
601. Is the purpose achieved?	Yes	Yes
602. Is the report readable without access to task formulation, project instructions, etc. that you have received from teachers and supervisors?	Yes	Yes
Technical content		
603. Have simplifications and assumptions been clearly stated and justified?	-	-
604. Has the choice of solution methods been clearly reported and justified?	Yes	Yes
605. Are calculations controlled and reasonably assessed?	-	-
606. Are all used terms, variables, designations, abbreviations, etc., clearly defined and explained the first time they are used in the text?	-	-
607. Are equations written as part of the running text, presented in separate lines and numbered?	-	-
608. Can the technical reasoning be followed?	-	-
609. Is there a difference between facts, statements and the author's opinion?	Yes	Yes
610. Is there a realistic verification plan for the work in the report?	Yes	Yes
611. Is there an acceptable follow-up of the verification plan?	-	-
Presentation		
612. Is the report well structured with regard to section and chapter division, common thread and logical sequence as well as balance between different sections?	Yes	Yes
613. Is the report provided with: appropriate title, date, author name, e-mail, eventual supervisor,summary/abstract, table of contents, reference list and page numbering	Yes	Yes
614. Is the report written in third person passive form? Are experiments described in imperfect, e.g. "Drag tests were performed to verify…" while descriptions of analysis methodology and calculations are rewritten in the present, e.g. "Calculations show that the natural frequency…"?	Yes	Yes
615. Are figures and tables clear and informative, provided with figure / table text and clear numbering? numbered? Do all figures have units inscribed on all axes? Can figures be	Yes	Yes

interpreted even after printing in black and white, and preferably after black and white copying?		
616. Are appropriate references made to figure, table and equation numbers in the text?	Yes	Yes
617. Are appropriate references made to references in the reference list?	Yes	Yes
618. Is the language cared for, free from spelling errors, sentence construction errors, special spellings, etc.?	Yes	Yes
Other		
619. Has the report been written by you individually?	Yes	-
620. The work has been carried out in collaboration with: _____		-
621. The report has been proofread by: Mirjam Fürth		-
622. I believe that this report as a whole is worth rating (u, 3-5)	6	
623. The following is a reflection on how I believe that the work with this report and related projects relates to set learning goals (relevance of the work, which goals have been met, etc.):		-

Conceptual Design
Evolo



Written by:
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Project:	Evolo
Date:	*22-10-2008.*
Version:	*2*

Introduction

The purpose of this report is to provide an insight into the work of developing Evolo. The project group's goals and vision of what the end product should look like are reported and evidence for this is reported to the extent that it has been investigated.

For two weeks before the start of the project, a concept study was carried out where possible design concepts were investigated. A concept design was selected taking into account the most important attributes that attract customers of water sports and the requirements specification of the projects. The components and form of the selected concept are presented in more details in this report.

Evolo

Evolo is a Latin name meaning fly away, escape or rush. Evolo is an electrically powered composite craft that lifts on a hydrofoil at a speed of about 6 knots.

The most important attributes that Evolo should express are [1]:

- Playfulness
- Speed
- Challenge for the user (with endless possibilities to develop)
- Safety (dead man's switch and propeller protection)

Evolo has been divided into four main parts; floating body, underwater body, propulsion and material.

Floating body

According to the requirements specification, the craft must be able to float and balance in a stationary position with the driver and be able to be steered by means of a center of gravity shift. Surveys regarding the target group show that close contact with the water and physical exertion are among the general features that water sports practitioners appreciate. A floating body in the form of a surfboard is easy to associate with these properties and the shape of Evolo's floating body has therefore been chosen to resemble a surfboard.

Evolo's floating body is not 100% designed, but it is clear that it must have a volume displacement of 0.17 m^3 [4]. From tests performed on October 18, 2008 in Saltsjöbaden, several instructive conclusions were drawn about the floating body [3]. Driving position was examined and a kneeling driving position was established as the easiest way to handle Evolo. However, the conceptual design offers two different driving positions; kneeling and standing, as the goal with Evolo is that it should be a challenge to drive, and provide a large space for personal development.

The tests also revealed the need to be able to move the driver's center of gravity quickly. This has meant that the Evolo has been given an upper body with a large surface to facilitate the driver's movements. The surface will also be provided in a suitable place with a soft material as the testers experienced pain in the knees after sitting on the tested model. Requests for a floating body that can be lowered into the water while driving without causing too much resistance were expressed, whereupon

Evolo was provided with a slightly larger upper body in the bow with streamlined lines. This is so that Evolo can accelerate more easily and be allowed to "bounce up" if the user presses the bow into the water during use. A slightly larger volume is also required for other reasons such as containing batteries and electronics. The vision is that this volume should also be able to contain a waterproof storage compartment, a clear LCD screen with information about speed, battery level, depth, position, etc., and lanterns.

Evolo is equipped with handles to facilitate controlled driver movement. The experiment has shown that in order to be able to turn the craft around the vertical axis, the driver needs to use fixed points to hold on, which is why the craft is equipped with two handles, one on each side.
These handles have two positions; raised (Figure 36) so that you can stand on the craft and hold on and lowerd (
Figure 37) so that you can sit on your knees. The handles have controls for the engine and dead man's switch. For even greater freedom, you should be able to remove the stays for the handles completely and disconnect the handles, which can then regulate the motor wirelessly.

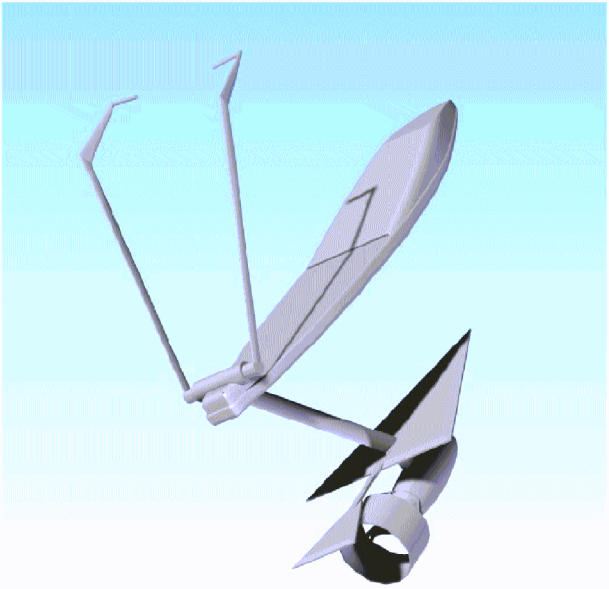


Figure 44: Evolo with raised handles

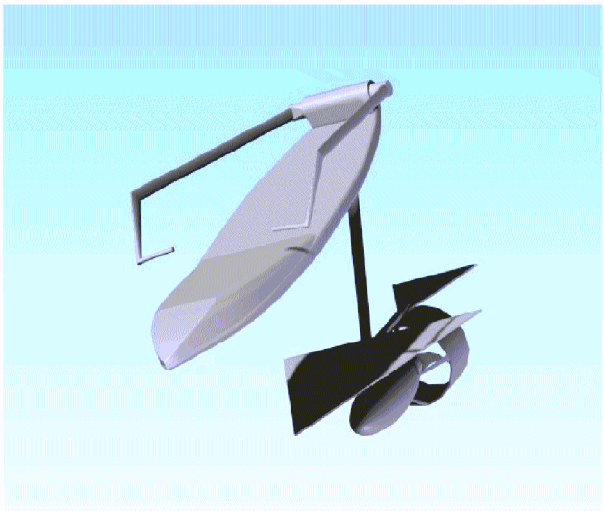


Figure 45. Evolo with lowered handles

Underwater body

The investigation of the design of the hydrofoils has been done in two stages, partly analytically and partly experimentally, and it has been realized early on that two wings are probably required, of which a main wing and a stability wing. Calculations of the main wing have been performed on two different types of wings and have included resistance, size, design and angle of attack. The two investigated types are straight wings and delta-shaped wings. From a resistance point of view, it has been chosen that a straight hydrofoil constitutes the least propulsion resistance. However, the delta wing has analytically proven to be capable of larger angles of attack and that it does not respond as quickly to a disturbance of the angle of attack as the straight wing, which is why the analytical investigation shows that a delta wing is preferable.

Also during the experiment, it was observed that a delta-shaped wing gave increased control and meant that Evolo became less sensitive to small disturbances, so a delta-shaped main wing was chosen for the conceptual design.

According to the analysis, the wings made for the experiment would lift the craft at a speed of about 6 knots This agreed very well with the experiment, which is rumored that the analytical calculations made on the wings that refer to angles of attack and dimensions do not seem to be too far from reality. However, the size and relative position of the wing can not yet be determined exactly as engine power and drag resistance have not yet been determined.

The stabilizing rear wing was experienced during the experiment not to add as much stability as desired, but a certain positive difference was observed with a stability wing slightly inclined forward, regardless of whether it was a straight stability wing or a delta-shaped one.
The stability wing is therefore included in the conceptual design until further investigation has been carried out. See Figure 38 below.



Figure 46: Design of hydrofoil

In order to be able to get the desired stability and turning properties on the Evolo, it must be possible for the user to replace the stability wing. This should e.g. can be adapted to driving style, knowledge and different wave conditions (weather conditions). It is conceivable that a more experienced driver can choose a more fast-swinging craft, while a beginner can choose a slightly more course-stable craft.

The hydrofoil is mounted on the board with a simple stay. The reason for this is to have less resistance in the water, lower weight and a simpler and cheaper manufacturing process. With a simple stay, the Evolo also gets a lighter and smoother expression, and it is angled and tilted forward to give a more aggressive look. The stay has to some extent been analyzed analytically and as a result has been designed as a wing to facilitate its steering and contribute to as little propulsion resistance as possible. During model building, however, the significance of the thickness of the strut was observed. The first strut that was built was perceived as far too sensitive to the torques around the vertical axis that could occur, which is why a much more powerful support was constructed. The lessons are included in the conceptual design and a thicker strut is used unless a material with significantly stronger torsional rigidity can be found. The strut must be able to fold forward during transport and travel in shallow water. [3], [4]

Propulsion

According to the requirements specification, the vehicle must be electrically powered in order to be environmentally friendly, quiet and relatively power-efficient. The advantages of an electric motor are many, including that it easily meets the requirements for noise and environmental impact, and that it has no requirements for exhaust pipes and chimneys and that it is thus relatively easy to use underwater. The motor is

currently located in the load-bearing hydrofoil (see

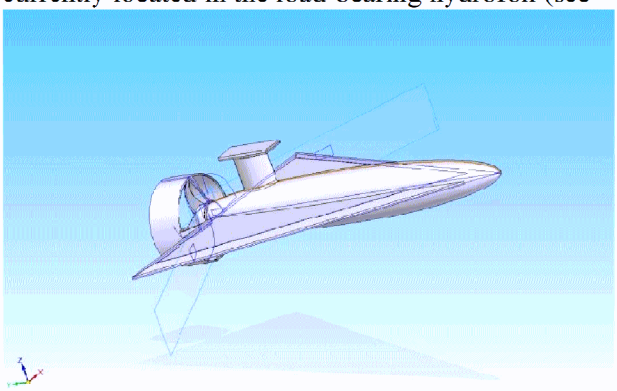


Figure 39) for two reasons. First, the depth and number of components increase if the motor is placed under the wings, and if it is placed over the wings, the number of components increases while the height at which the craft can lift out of the water is reduced. Secondly, the motors front can form the wing for which means that its tip does not become sharp and dangerous to hit if you end up in the water. However, it remains to be investigated how this placement disturbs the flow to the wings and how the installation of the stability wing could look like.

Early in the project, the possibility of using electric water jet drive was studied, but the lack of such motors of the current size on the market meant that the idea was dropped and ordinary propeller operation was chosen. According to the requirements specification, there must be a protection for the propeller, which is why a propeller nozzle is used, but the effects of this remain to be investigated. The motor and propeller are dimensioned only approximately on the basis of existing motors and propellers in the current size class. Something that also remains to be investigated, but which is a wish in the vision is that you can momentarily take extra power out of the motor to be able to jump with the craft, for example.



Figure 47: Motor placement

Material

In terms of material on the craft, the weight, the mechanical properties and resistance to moisture are of great importance. Since weight is perhaps most important for this vehicle, the specific E-module as well as the specific strength are important parameters, which is why carbon fiber is a suitable material [5]. High strength and rigidity enable the use of less materials, ie fewer layers of fiber. However, it should be borne in mind that a thin composite layer has poor impact resistance and is therefore sensitive to point forces. This can be solved by using a more impact-resistant material where point forces are likely to occur, e.g. aramid fibers, or use more layers of fiber in these locations. You can also use different types of fibers in the same place in alternating layers.

Together with carbon fiber, a suitable matrix must be used, the most important task of which in this case will be protection against moisture, but it should also have good mechanical properties. A matrix of thermosetting plastic generally has better resistance to the external environment, better mechanical properties and is more practical in manufacture than a thermoplastic. Epoxy and vinyl ester together with carbon fiber are well-proven matrices and with good mechanical properties. However, epoxy is very allergenic in the uncured state and should therefore be avoided.
To save weight, a sandwich solution may also be relevant, especially for the floating body. A possible choice of core is a foam core of a polymeric material that can be made resistant to moisture. As we will not be making large series, vacuum injection is a suitable manufacturing method that also enables more complicated shapes. Another current manufacturing method is hand-laying.

A carbon fiber / vinyl ester composite material is a suitable material system for Evolo. It has good mechanical properties, good resistance to moisture and fits into the "image" that wants to be conveyed with Evolo. These materials are relatively readily available and equipment for manufacturing by means of vacuum injection is also available.

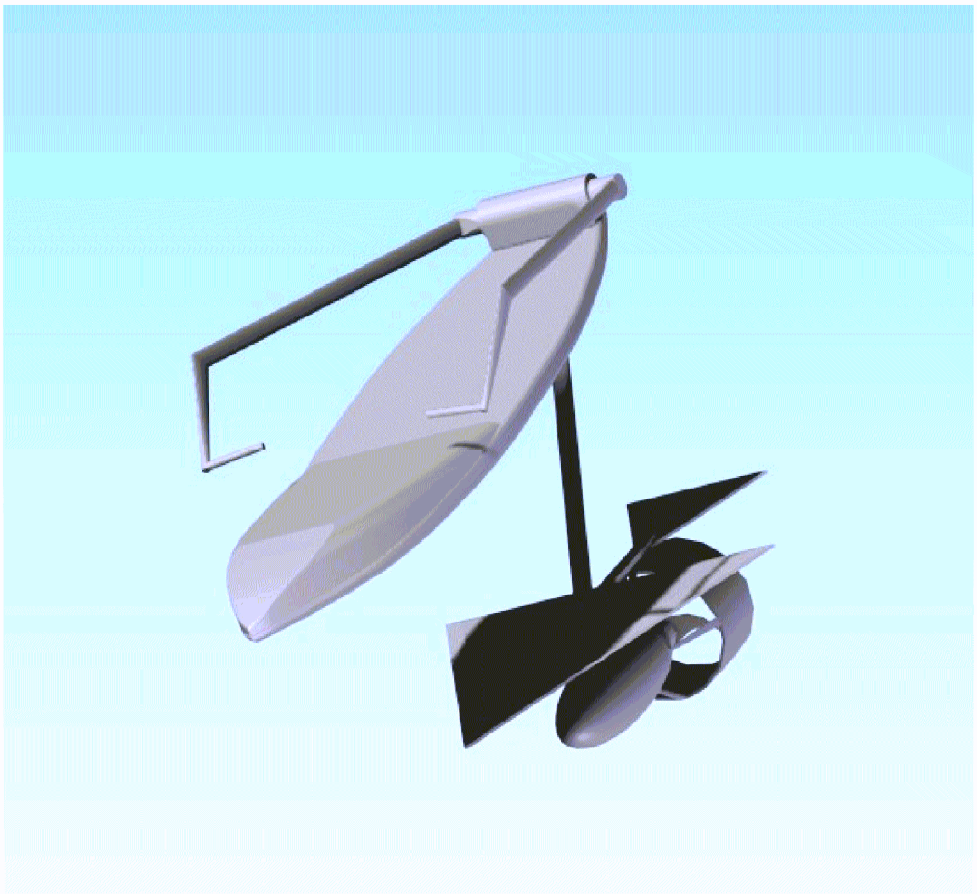
Conclusion

The Evolo craft has been roughly defined and a vision of what it could be has been established. Many basic parts that the project group had poor insight into have been clarified, cutting-edge knowledge has been developed within the group and the goal, to actually be able to build the craft, is in sight. Of course, there is still a lot to investigate for the project to succeed and priority in the project's third phase Preliminary Design, which begins with this submission, is on propulsion, stability and to some extent strength.

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7. M. Norberg: *A1-Bärplan*, Evolo, KTH, 2008
8. B.T.Åström, *Manufacturing of Polymer Composites.*

Conceptual Design
Evolo



Written

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Drawings by:
NILS WOLTER
JOHAN VESTIN

Course: Marine design / Lightweight design

Project:	Evolo
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The tests also revealed the need to be able to move the driver's center of gravity quickly. This has meant that the Evolo has been given an upper body with a large surface to facilitate the driver's movements. The surface will also be provided in a suitable place with a soft material as the testers experienced pain in the knees after sitting on the tested model. Requests for a floating body that can be lowered into the water while driving without causing too much resistance were expressed, whereupon Evolo was provided with a slightly larger upper body in the bow with streamlined lines. This is so that Evolo can accelerate more easily and be allowed to "bounce up" if the user presses the bow into the water during use. A slightly larger volume is also required for other reasons such as containing batteries and electronics. The vision is that this volume should also be able to contain a waterproof storage compartment, a clear LCD screen with information about speed, battery level, depth, position, etc., and lanterns.

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These handles have two positions; raised (Figure 36) so that you can stand on the craft and hold on and lowerd (
Figure 37) so that you can sit on your knees. The handles have controls for the engine and dead man's switch. For even greater freedom, you should be able to remove the stays for the handles completely and disconnect the handles, which can then regulate the motor wirelessly.

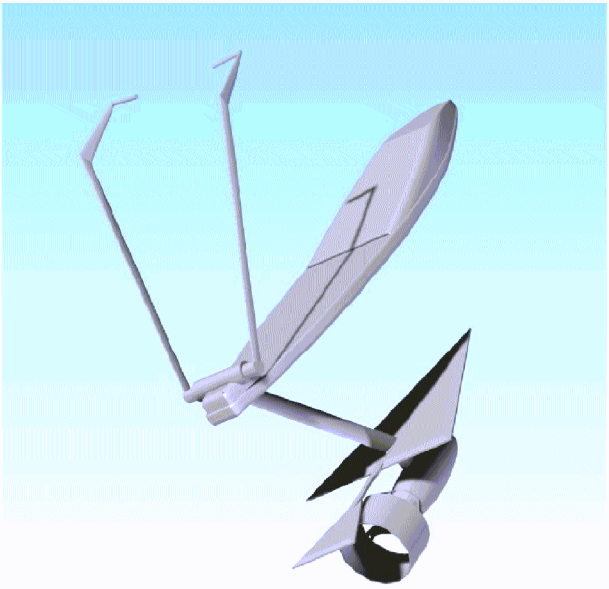


Figure 48. Evolo with raised handles

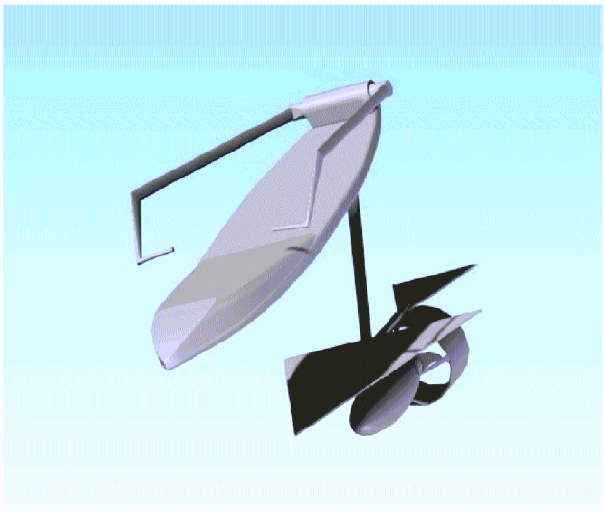


Figure 49: Evolo with lowered handles

Underwater body

The investigation of the design of the hydrofoils has been done in two stages, partly analytically and partly experimentally, and it has been realized early on that two wings are probably required, of which a main wing and a stability wing. Calculations of the main wing have been performed on two different types of wings and have included resistance, size, design and angle of attack. The two investigated types are straight wings and delta-shaped wings. From a resistance point of view, it has been chosen that a straight hydrofoil constitutes the least propulsion resistance. However, the delta wing has analytically proven to be capable of larger angles of attack and that it does not respond as quickly to a disturbance of the angle of attack as the straight wing, which is why the analytical investigation shows that a delta wing is preferable.

Also during the experiment, it was observed that a delta-shaped wing gave increased control and meant that Evolo became less sensitive to small disturbances, so a delta-shaped main wing was chosen for the conceptual design.

According to the analysis, the wings made for the experiment would lift the craft at a speed of about 6 knots This agreed very well with the experiment, which is rumored that the analytical calculations made on the wings that refer to angles of attack and dimensions do not seem to be too far from reality. However, the size and relative position of the wing can not yet be determined exactly as engine power and drag resistance have not yet been determined.

The stabilizing rear wing was experienced during the experiment not to add as much stability as desired, but a certain positive difference was observed with a stability wing slightly inclined forward, regardless of whether it was a straight stability wing or a delta-shaped one.
The stability wing is therefore included in the conceptual design until further investigation has been carried out. See Figure 38 below.



Figure 50. Design of hydrofoil

In order to be able to get the desired stability and turning properties on the Evolo, it must be possible for the user to replace the stability wing. This should e.g. can be adapted to driving style, knowledge and different wave conditions (weather conditions). It is conceivable that a more experienced driver can choose a more fast-swinging craft, while a beginner can choose a slightly more course-stable craft.

The hydrofoil is mounted on the board with a simple stay. The reason for this is to have less resistance in the water, lower weight and a simpler and cheaper manufacturing process. With a simple stay, the Evolo also gets a lighter and smoother expression, and it is angled and tilted forward to give a more aggressive look. The stay has to some extent been analyzed analytically and as a result has been designed as a wing to facilitate its steering and contribute to as little propulsion resistance as possible. During model building, however, the significance of the thickness of the strut was observed. The first strut that was built was perceived as far too sensitive to the torques around the vertical axis that could occur, which is why a much more powerful support was constructed. The lessons are included in the conceptual design and a thicker strut is used unless a material with significantly stronger torsional rigidity can be found. The strut must be able to fold forward during transport and travel in shallow water. [3], [4]

Propulsion

According to the requirements specification, the vehicle must be electrically powered in order to be environmentally friendly, quiet and relatively power-efficient. The advantages of an electric motor are many, including that it easily meets the requirements for noise and environmental impact, and that it has no requirements for exhaust pipes and chimneys and that it is thus relatively easy to use underwater. The motor is

currently located in the load-bearing hydrofoil (see

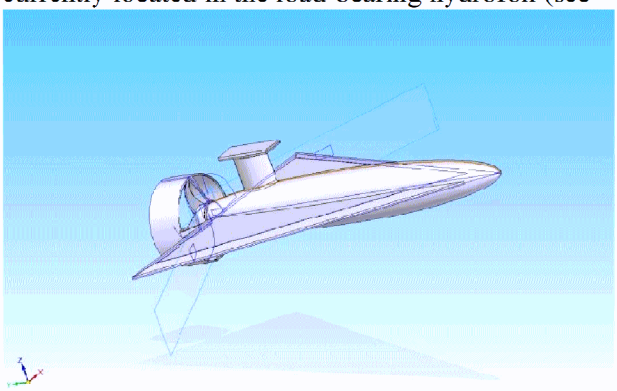


Figure 39) for two reasons. First, the depth and number of components increase if the motor is placed under the wings, and if it is placed over the wings, the number of components increases while the height at which the craft can lift out of the water is reduced. Secondly, the motors front can form the wing for which means that its tip does not become sharp and dangerous to hit if you end up in the water. However, it remains to be investigated how this placement disturbs the flow to the wings and how the installation of the stability wing could look like.

Early in the project, the possibility of using electric water jet drive was studied, but the lack of such motors of the current size on the market meant that the idea was dropped and ordinary propeller operation was chosen. According to the requirements specification, there must be a protection for the propeller, which is why a propeller nozzle is used, but the effects of this remain to be investigated. The motor and propeller are dimensioned only approximately on the basis of existing motors and propellers in the current size class. Something that also remains to be investigated, but which is a wish in the vision is that you can momentarily take extra power out of the motor to be able to jump with the craft, for example.



Figure 51. Motor placement

Material

In terms of material on the craft, the weight, the mechanical properties and resistance to moisture are of great importance. Since weight is perhaps most important for this vehicle, the specific E-module as well as the specific strength are important parameters, which is why carbon fiber is a suitable material [5]. High strength and rigidity enable the use of less materials, ie fewer layers of fiber. However, it should be borne in mind that a thin composite layer has poor impact resistance and is therefore sensitive to point forces. This can be solved by using a more impact-resistant material where point forces are likely to occur, e.g. aramid fibers, or use more layers of fiber in these locations. You can also use different types of fibers in the same place in alternating layers.

Together with carbon fiber, a suitable matrix must be used, the most important task of which in this case will be protection against moisture, but it should also have good mechanical properties. A matrix of thermosetting plastic generally has better resistance to the external environment, better mechanical properties and is more practical in manufacture than a thermoplastic. Epoxy and vinyl ester together with carbon fiber are well-proven matrices and with good mechanical properties. However, epoxy is very allergenic in the uncured state and should therefore be avoided.
To save weight, a sandwich solution may also be relevant, especially for the floating body. A possible choice of core is a foam core of a polymeric material that can be made resistant to moisture. As we will not be making large series, vacuum injection is a suitable manufacturing method that also enables more complicated shapes. Another current manufacturing method is hand-laying.

A carbon fiber / vinyl ester composite material is a suitable material system for Evolo. It has good mechanical properties, good resistance to moisture and fits into the "image" that wants to be conveyed with Evolo. These materials are relatively readily available and equipment for manufacturing by means of vacuum injection is also available.

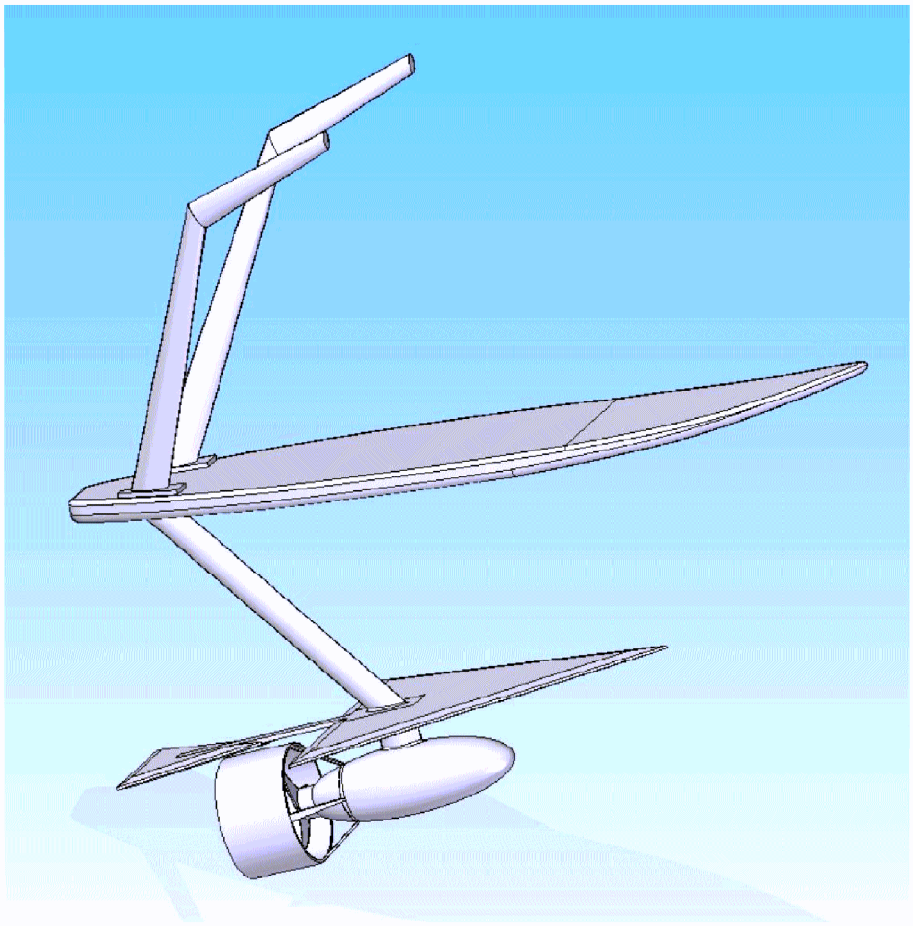
Conclusion

The Evolo craft has been roughly defined and a vision of what it could be has been established. Many basic parts that the project group had poor insight into have been clarified, cutting-edge knowledge has been developed within the group and the goal, to actually be able to build the craft, is in sight. Of course, there is still a lot to investigate for the project to succeed and priority in the project's third phase Preliminary Design, which begins with this submission, is on propulsion, stability and to some extent strength.

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Preliminary design
Evolo



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Background

The purpose of this report is to give an idea of the main factors that have been taken into account in the design of the Evolo.
For two weeks before the start of the project, a concept study was carried out where possible design concepts were investigated. Taking into account the most important attributes that attract customers of water sports and the project's requirement specification, a concept design was selected that will be developed during the course.
The components and form of the selected concept are presented in more details in this report.

Evolo

Evolo is Latin and means fly away, escape, rush.
Evolo is an electrically powered composite craft that is lightweight and environmentally friendly. The craft must also use an hydrofoil solution at cruising speed.

The most important attributes that Evolo should express are:

- Playfulness
- Speed
- Challenge for the user (with endless possibilities to develop)
- Safety (dead man's switch and propeller protection)

Evolo has been divided into four main parts; Shape, hydrofoil, propulsion and material.

Form

According to the requirements specification, the craft must be able to float and balance in a stationary position with the driver and be able to be steered by means of a center of gravity shift. Previous
research has shown that close contact with the water and physical effort are among the general traits that make the craft successful among the target group of similar
watercraft. Craft in the form of a surfboard seems to be able to fulfill many of these requirements. In simple terms, surfboards can be divided into four different types based on their shape and size[1]:

- Longboards (Malibu)
- Fish
- Funboards

- Shortboards

Evolo is equipped with a shortboard-like surfboard (see figure 1). The board is adapted for the intermediate to advanced surfer. The size is determined so that the craft will not be too large and clumsy, nor too small so that it becomes difficult to balance, especially in the case of a hydrofoil. The drift nose is pointed for good maneuvering and hydrodynamics and it is angled upwards so as not to cut into the waves below the surface of the water.
To be able to steer in the desired way, the driver has the option to stand or sit and lean in the desired direction.

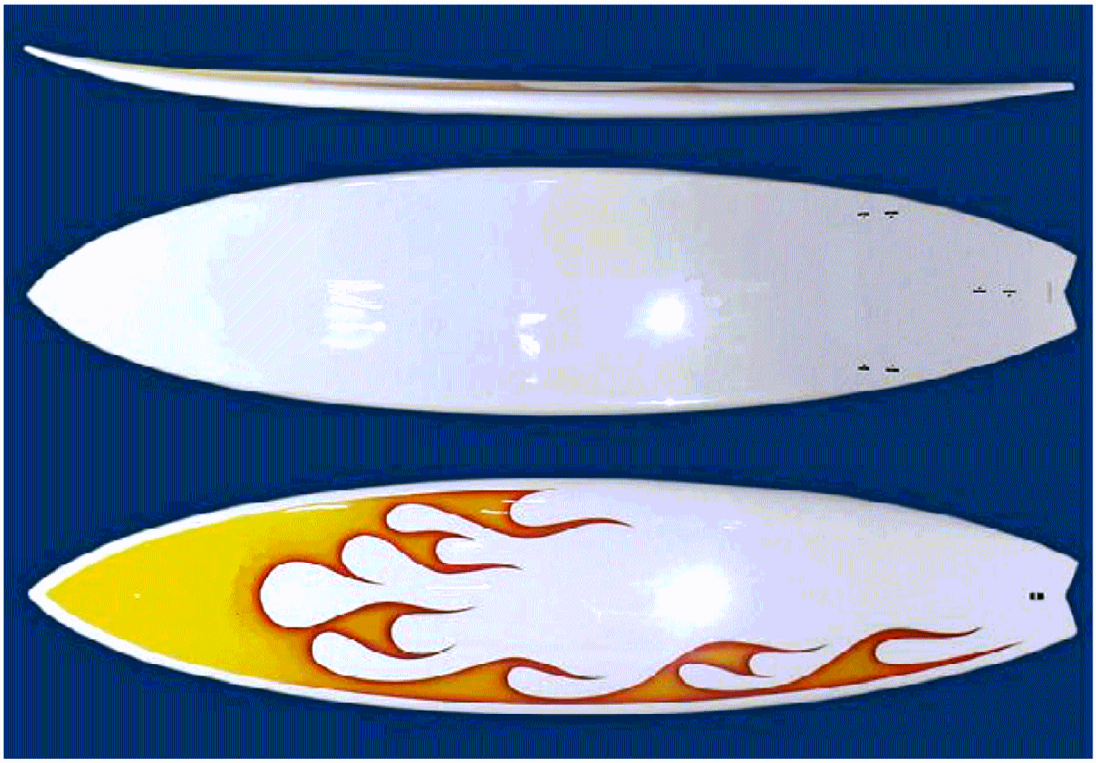


Figure 1. Shortboard[2]

In order to more easily maintain the balance on the board and to be able to turn more easily, the craft has two handles that extend from the board, behind the driver to the hands. In order for the structure to look simple while retaining the sense of freedom, nothing but the handles have been provided.

Hydrofoil

In order to be able to equip Evolo with an hydrofoil, some analytical and experimental research has been carried out. According to these studies, it has been possible to calculate suitable wing areas on the airfoil that make the craft achieve the desired lifting force at the speed range of interest, which in this case is between 0 to 20 knots[3].

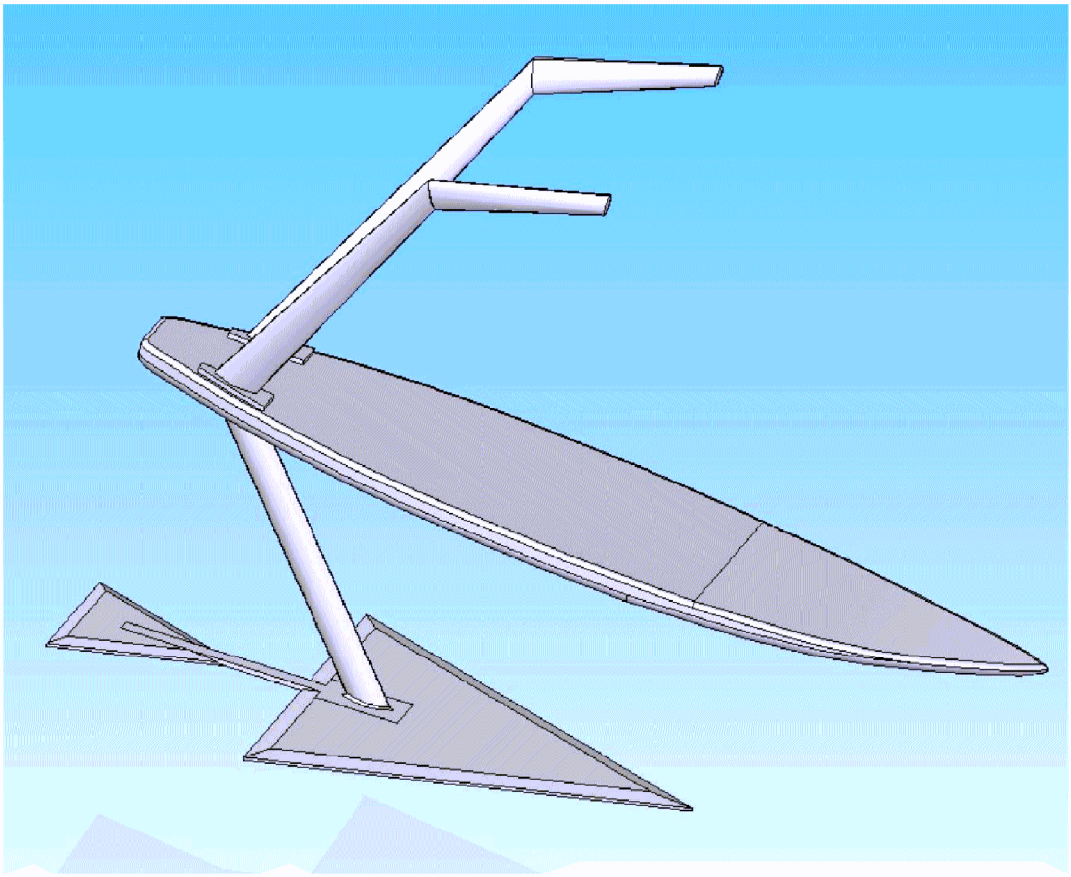


Figure 52. Evolo equipped with hydrofoil and handle

In order to find the best suitable hydrofoil solution for the craft, the relationship between the wing area and the wingspan has been investigated.
The result of these studies is an hydrofoil solution with two wings. This solution helps the craft to increase stability and provides a larger support surface.

In order to get the desired turn-carrying characteristics, the Evolo has the option of replacing the aft wing. This should e.g. can be adapted to driving style, knowledge and different wave conditions (weather conditions).
With the help of the aft wing, you can increase or decrease the degree of difficulty of driving so that a more experienced rider gets a more fast-swinging craft, while a beginner gets a slightly more course stability craft.
The hydrofoil is mounted on the board with a simple stay. The reason for this is to have less resistance in the water, lower weight and a simpler and cheaper manufacturing process. With a simple step, the Evolo seems to look lighter and smoother. The step is angled and canted forward to give a more aggressive look.

Driving

According to the requirement specification, the craft must be environmentally friendly, quiet and "relatively low-impact". In order to meet these requirements, Evolo is equipped with an electric motor. The advantage of the electric motor is that it has no exhaust gases, can more easily meet the requirements for noise and environmental impact well.
The motor is located under the supporting hydrofoil wing. This will to some extent disrupt the flow to the hydrofoil, something that is currently being studied.
It is also relevant to investigate which motor and batteries should be used, as well as where these could be placed.

Material

When it comes to materials on the craft, the weight, the mechanical properties and resistance to the environment (e.g. moisture) are of great importance. Since weight is perhaps most important for this vehicle, the specific E-module as well as the specific strength are important parameters. The diagram (figure 3-4) below shows a comparison of different current materials. It can be concluded that carbon fiber is the best choice of material in our case. The disadvantages of carbon fiber are that it is expensive and has relatively poor impact resistance, i.e. it is sensitive to point forces. This can be solved by using a more impact-resistant material where point forces are likely to occur, e.g. aramid fibers. You can also use different types of fibers in the same place in alternating layers.

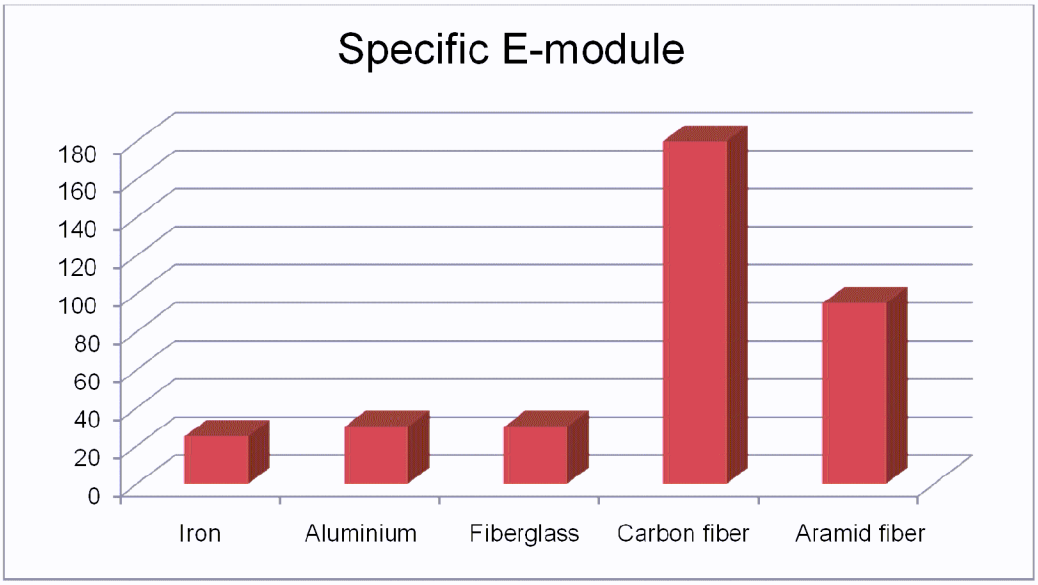


Figure 3. The specific E-module [4]

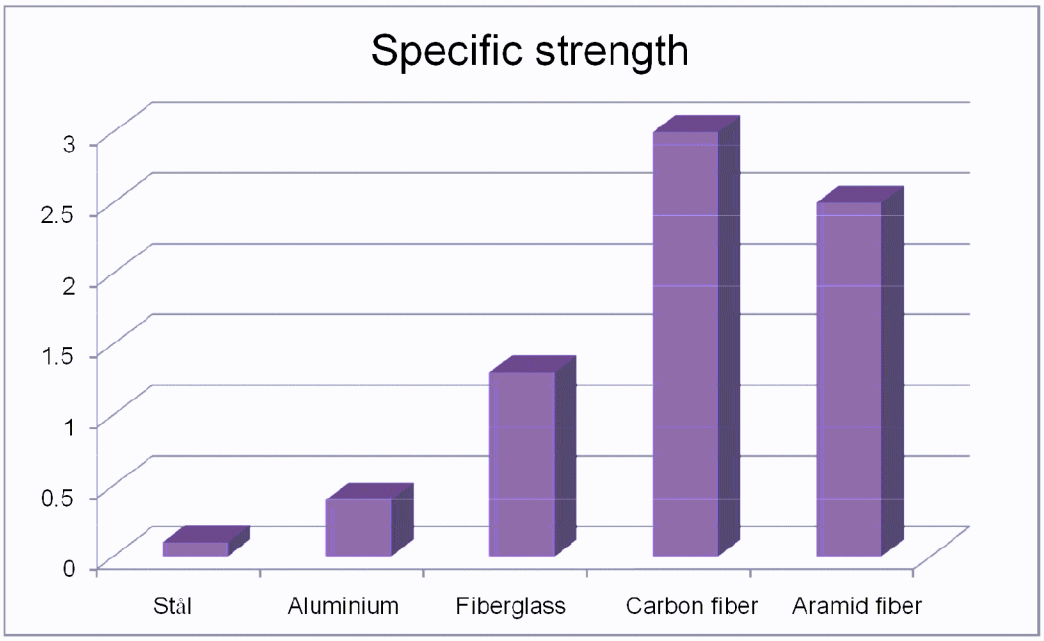


Figure 3. Breaking stress [5]

Along with carbon fiber, a suitable matrix must be used, possible matrices are presented in Figure 5. In our case, the matrix's most important task will be protection against moisture. It should also have good mechanical properties. A matrix of thermosetting plastic generally has

better resistance to the external environment, better mechanical properties and is more practical in manufacture than a thermoplastic. Epoxy, together with carbon fiber, is a well-proven matrix and thus relevant for our craft.

	Unsaturated polyester	**Epoxy**	**Polypropylene**
ρ[kg/m^3]	1.200	1.150	900
E [GPa]	3.2	3.5	1.5
σ [Mpa]	60	75	35
ε [%]	1-5	1.5-8	100-600
T_g/T_m [^{o}C]	70	165-175	170
η [Pa s]	0.2-1	0.75-1	10-100

Figure 5. Properties of three most common matrices [6]

To save weight, a sandwich solution may also be relevant, especially for the board. A possible choice of core is a foam core of a polymeric material that can be made resistant to moisture. As we will not be making large series, vacuum injection is a suitable manufacturing method that also enables more complicated shapes.

The conclusion regarding the choice of material

A carbon fiber/epoxy composite material is the most suitable material system. However, the impact resistance is a problem. The core of the board should be a lighter material. The possibility of obtaining these materials and manufacturing the composite is considered high. The next step on the material front is to find out how many layers of each material will be needed, direction of laying and volume fraction fiber/matrix.

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6. B.T.Åström, Manufacturing of Polymer Composites.

Final design



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Summary

Evolo is a new type of watercraft that travels on a hydrofoil and is intended for one person. It is powered by an electric motor and is controlled only by means of center of gravity movement. Evolo's final design is presented in Reference source not found..

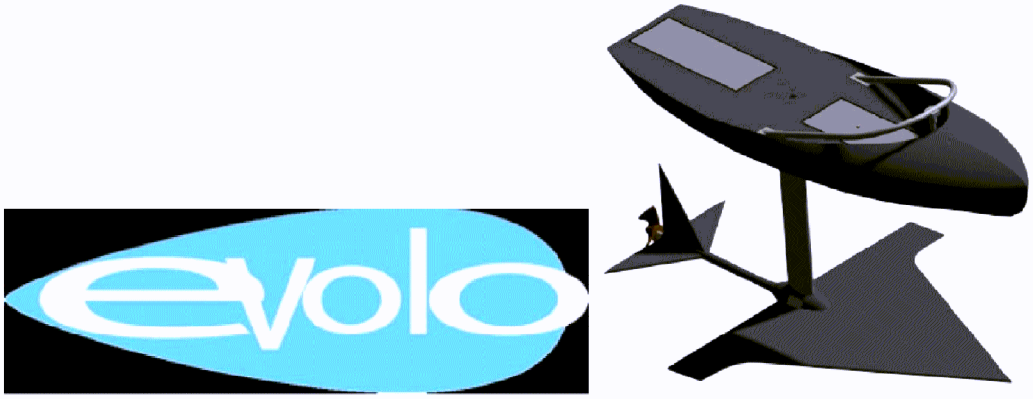


Figure. 7. Evolo's logo and the final design

A general arrangement for Evolo is shown in Reference source not found. The quantities defined in the figure are reported in Reference source not found.

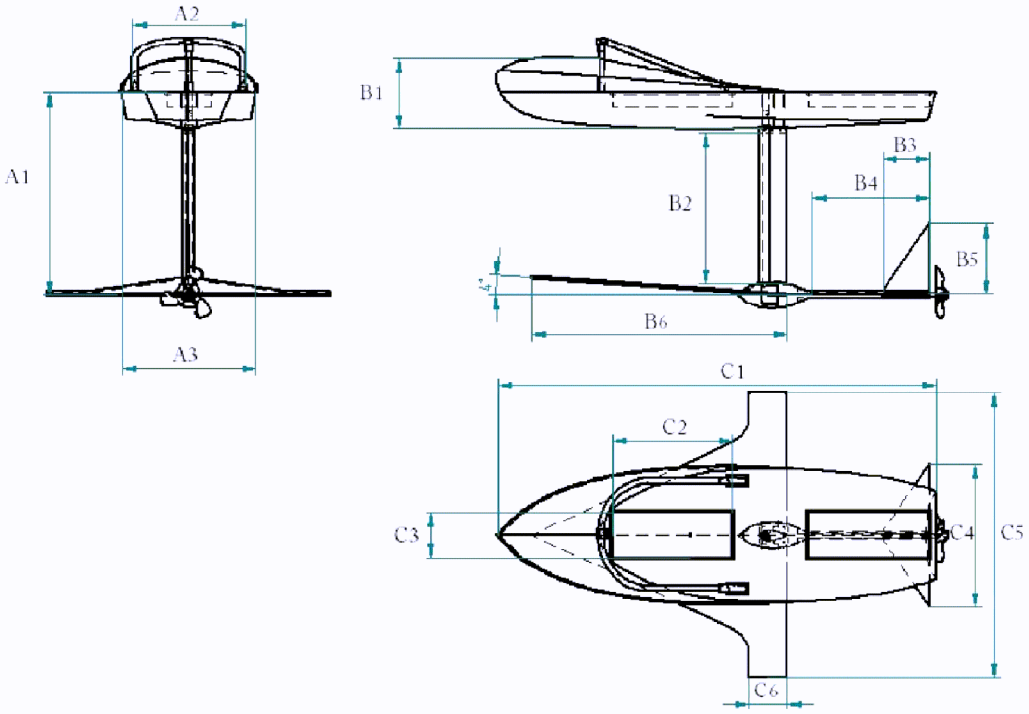


Figure. 8. General arrangement of Evolo

Table 1. 1. Measurements of quantities from the general arrangement

Parameter	Size (mm)
A1	1065
A2	598
A3	701
B1	367
B2	800
B3	241
B4	615
B5	369
B6	1367
C1	2313
C2	636
C3	237
C4	750
C5	1500
C6	200

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Introduction

Evolo is a modern water toy with an exciting design, the product is aimed at young active people see Appendix 1. The goal of the concept is to create a new way of playing on water, without disturbing the environment. The ambition is to show that it is possible to minimize environmental impact and unnecessary noise and still have fun. In order for the energy consumption not to be too great, Evolo is based on hydrofoil technology. By lifting the floating body and the driver above the surface of the water, resistance is reduced and thus also the amount of energy required for propulsion. An electric motor is today the best option for reducing environmental impact. Placed below the surface of the water, the sound that reaches the driver and the surroundings is also dampened. The development of the product is carried out in project form, i.a. according to the project plan drawn up by management, see Appendix 3. The requirements that the project aims to achieve are defined in the requirements specification in Appendix 4. Those of these requirements that the project may have problems meeting are requirement 3.3; that the craft must reach a speed of over 15 knots. To achieve that requirement, probably requirement 3.2; that the craft must be able to transport a person weighing 100 kg is not met.

Conclusion

Hydrofoil/underwater body

The hydrofoil according to the preliminary design would work if a larger motor than the one available can be obtained. If a larger motor is not available, the alternative is to enlarge the hydrofoil in order to reduce the angles of attack. This leads to a reduced resistance at the lower speeds. The negative of this is that the maximum speed will be lowered, plus the craft will be more cumbersome to handle on land. The electric motor must be integrated into the front hydrofoil, then a shaft must be mounted behind the aft hydrofoil where the propeller is located. The shaft must run in a watertight shell. An image of underwater body is shown in Figure. 9.



Figure. 9. Illustration of Evolo's underwater body

Detailed investigations that include the hydrofoil and the underwater body are reported in Appendices 5-12, 15, 16, 25, 38.

Strut

The strut is the part that connects the floating body and the hydrofoil. It has the shape of a wing to reduce the resistance but also to increase the course stability. The support also has steel pipes that run inside the wing profile with the purpose of absorbing forces and torques. However, the iron bar cannot take up all the forces and torques, and the wing profile must also be load-bearing. A figure of the strut is shown in Reference source not found..

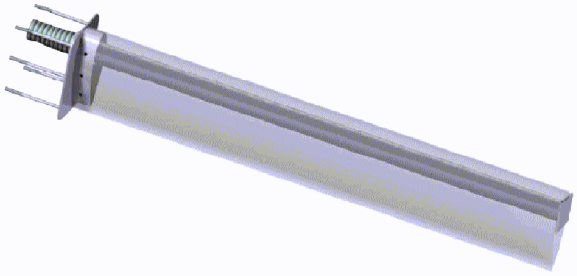


Figure. 10. Illustration of Evolo's strut

Detailed investigations that include the strut and its mountings are reported in Appendices 7, 9, 12, 22, 23, 26, 39.

Floating body

The design of the floating body is inspired by a Riva boat, Reference source not found.

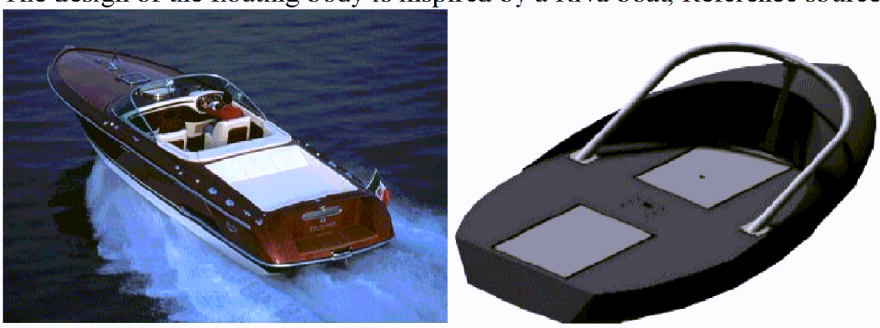


Figure. 11. Shows Evolo's floating body and the source of inspiration

The floating body has sufficient volume to be able to stay afloat with the driver. It should also have room for batteries. The space for the batteries must be accessible by the driver, which is why hatches are designed for access. The floating body is intended to be manufactured in carbon fiber according to the sandwich principle, however, the superstructure does not have to be in carbon fiber. A figure of the floating body is shown in Reference source not found..



Figure. 12 Illustration of Evolo's floating body

Detailed investigations involving the floating body are reported in Appendices 9-11, 15, 16, 19, 20, 34, 35, 40.

Manufacturing/materials

Sandwich construction has been used as much as possible to minimize the weight of the craft. The surface layer will consist of carbon fiber and vinyl ester and the core material will most certainly be Divinycell. The decision to use carbon fiber is based, among other things, on its good mechanical properties and that it has a higher specific E-modulus than fiberglass. The craft's material weight is thereby halved compared to fiberglass.
Vinyl ester is a thermosetting plastic and is used because it has good resistance and that it can withstand moisture. Epoxy would have been preferable but could not be used due to health risks.

The manufacturing method has mainly consisted of vacuum injection. Possibly hand laying will be used if some components have advanced structures or shapes. To ensure the mechanical properties of the materials, both tensile tests and bending tests are performed. All manufacturing and testing is carried out in lightweight Structures premises at KTH. Detailed investigations of Manufacturing/Materials are reported in Appendices 21, 36, 37.

Handle/steering handle

The handles on the Evolo are designed for a kneeling driver's position. Its appearance is described in Reference source not found. The handles are supposed to be built in aluminum. Detailed investigations involving the handle are reported in Appendices 18, 20, 33, 35,



Figure. 13. Illustration of Evolo's handle

A controller must be applied to the handles. This gives the driver an opportunity to regulate the RPM. The design of the control unit is shown in Reference source not found.

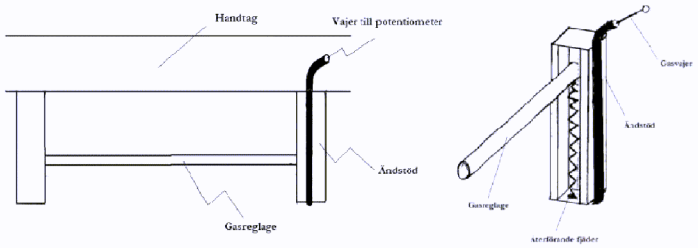


Figure. 14. Illustration of Evolo's control system

Detailed investigations involving the control system are reported in Appendices 17, 28, 29, 35,

Propulsion

Motor

Finding a motor that meets the requirements was easier said than done. The project has at its disposal a Torqedo motor that has a rated power of 2 kW, which gives an output power of 0.9 kW. According to experiments and analytical calculations, the wing configuration from the preliminary design requires an output power of 1.8-2 kW. Thus, there are two options.

- Find a larger motor that meets the requirements for power and speed.
- Change wing configuration and weight optimization to reduce drag, leading to larger hydrofoil and smaller angles of attack.

Detailed investigations that include motors are reported in Appendices 13, 14, 17, 27, 30.

Batteries

In order to be able to drive the Evolo's electric motor, batteries are needed. The project has available 8 series-connected batteries of 3.2 volts, this gives a total of 24 volts. But in order to fulfill the requirements set by the motor, a battery of 48 volts is needed. This means that additional batteries must be procured via purchase or sponsorship. Detailed investigations involving the batteries are reported in Appendices 29.40,

Propeller

To deliver the necessary propulsive power, a propeller is needed that is efficient enough and is not too large. With the motors that are on the market and the speeds they deliver, there are two options.

- Gear the motor so that a higher rpm is obtained.
- Make our own propeller that meets the requirements.

Reversing the motor requires a gear that can handle size and torque requirements. Making your own propeller requires a manufacturing method that is feasible. Detailed investigations involving the propellers are reported in Appendices 8, 14, 24.

Economy

PR/Sponsors

The focus of the sponsorship has until now mostly been on financial support as the materials needed were not determined. This has resulted in a company (Kbtgruppen ab) sponsoring with SEK 5,000 and Red Bull sponsoring with energy drink. The most common reasons why companies have refused so far have been;

- Budget already laid out for the time the sponsorship concerns.
- The current economic situation puts a complete stop to all forms of sponsorship.
- Evolo is not considered to be an interesting enough product.
- The project is not extensive enough according to company policy.

Now that the materials needed have crystallized, companies must be contacted again with a view to material sponsorship. Now that the materials needed have crystallized, companies must be contacted again with a view to material sponsorship. In addition, a website has also been set up (www.evolo.se) , which gives the public an opportunity to follow the progress of the project in the form of pictures, texts and videos. The website also has a blog that is updated daily. In order to spread interest in Evolo, information has also been posted on various marine forums. This has shown that interest in Evolo is great outside the country. A group has also been started on Facebook, which is steadily increasing in membership.

KTH på insidan (KTH on the inside)

The project is also included in a competition called KTH på insidan (KTH on the inside). This competition means that three projects run at KTH are selected and followed during the spring of 2009. These are the projects that best reflect what it means to be an engineer and how the work is done. It is a committee that decides which projects best fit that description, but the public can also

have their say by voting for the project they consider most interesting via the website www.kthpainsidan.se. The winning projects receive help from KTH in the form of financial support (SEK 75,000) but also with being visible to the outside world. This has resulted in a massive effort to spread the Evolo project to the public in order to get votes. If Evolo were to be chosen as one of the three, a large part of the budget would be solved. The budget is presented in Appendix 2.

Discussion

One of the biggest challenges in the project is making decisions based on limited information. It is also one of the most common challenges engineers face in working life. This report may seem to hover around the goal, a final design. This is because more information is needed to make informed decisions. However, there will always be a need for more documentation, regardless of how much information the project has. Which means that decisions have been made where the basis is summarized in the following points. There are basically three different design choices.

Torqeedo 2.0 and a larger wing

Advantages

- That the project has access to the motor, which makes the solution safe.
- The project has access to batteries.
- Much of the existing system is built around the Torqeedo Motor.
- The motor includes all the parts we need.

Disadvantages

- It is unclear how much the motor system may be changed, for the configuration of the strut, the cable tube must be extended.
- Untested wing (calculated theoretically only).
- The Evolo must be pulled up onto the hydrofoil with the help of a boat.
- A propeller must be built/purchased or the motor must be upgraded.

Torqeedo 4.0 and a smaller wing

Advantages

- Much of the existing system is built around the Torqeedo Motor.
- The motor contains all the necessary parts.
- The smaller and tested wing can be used.

Disadvantages

- Unclear if the project can get/afford the motor
- New battery pack must be purchased
- The motor requires 48 V, which may mean that the floating body must be modified
- A propeller must be built/purchased or the motor must be upgraded.

Own engine solution and smaller wing

Advantages

- The smaller and tested wing can be used.
- An existing propeller can be used.
- There are medium-priced solutions that are ready for purchase
- There are cheap solutions

Disadvantages

- It is unclear whether solutions at the affordable price can be delivered.
- The whole system must be built by the project team, which is difficult
- A watertight motor housing must be built
- The motor requires 48 V, which may mean that the floating body must be modified

With this as a basis, the project management chooses the configuration with the larger hydrofoil presented in this report and Torqedo 2.0. This is because it is considered to be the safe choice. As Evolo cannot start construction yet because more material tests and testing of manufacturing methods are needed, the project has a little more time to investigate the other possibilities. These would enable Evolo itself to reach the hydrofoil speed and also have no experiment due to ice performed and therefore it is also not certain that the larger wing works in practice.