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UNIVERSIDAD VERACRUZANA
FACULTAD DE INGENIERIA

TEAM ARCANGELLO PRESENTS
THE STUDENT PROJECT:

"ARCANGELLO IV"

Supported by:

UNIVERSIDAD VERACRUZANA
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1. HULL FORM DESIGN

1.1 HULL FORM DEFINITION

To define our submarine's form, we tested 2 new prototypes with different fish bodies which have a very good hydrodynamic performance and 1 more form of an already built submarine, the Arcangello 3 that participated in the 7th ISR.

The objective of testing the submarine Arcangello 3 is that, if it had a better performance than the other 2 new prototypes we wouldn't have the necessity of build a new hull, which would have meant a save of time and money.

1.3 DRAWING THE HULL FORM

To draw the hull form we used the software AutoCAD, there we paste an image of the fishes we selected, these fishes were a tuna fish and a wahoo fish.

We pasted an image of the fishes we selected on the background and then we started to plot the profile with polylines, that way we obtained the profile of the fish and then we refine the lines to have a very fine line as shown on fig. 1. And fig. 2

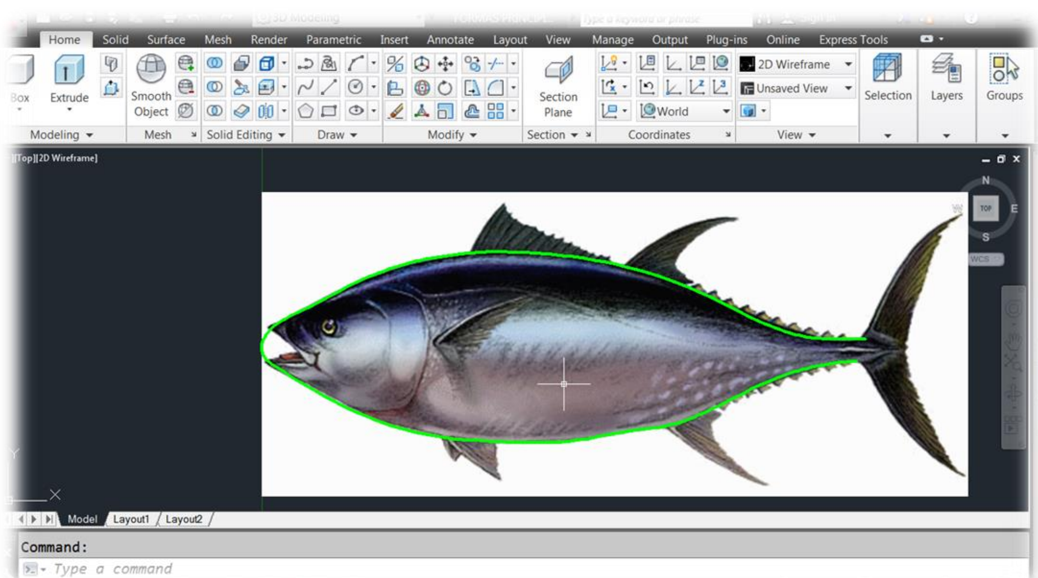

Fig.1 Plotting the profile.

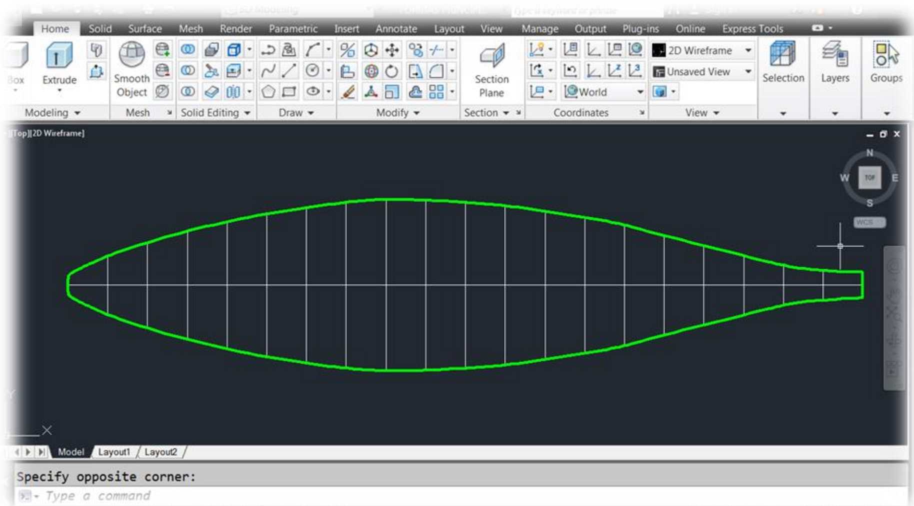

Fig.2 Refining the lines.

1.5 HULL FORM SELECTION

To choose the hull form we were going to build, we decided to do tests in the wind tunnel by building scale models of the new prototypes and also of the already existing submarine hull, the Arcangello 3.

We built the scale models with cardboard, polyurethane and paste. We selected these materials because this way we would ensure of having a lightweight and resistant model. We needed them to be lightweight because the wind tunnel sensors are very sensitive, so if we had done them too heavy, the sensors wouldn't have worked properly.

The manufacture of these models can be seen on figs. 3 thru 7.

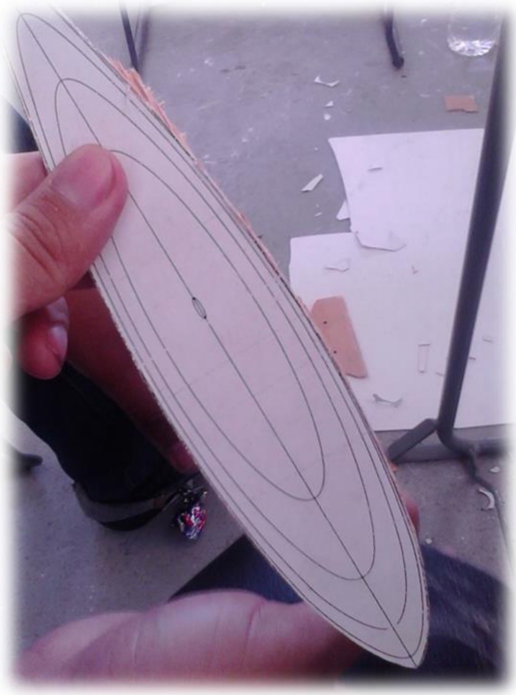

Fig.3 Main water plane.

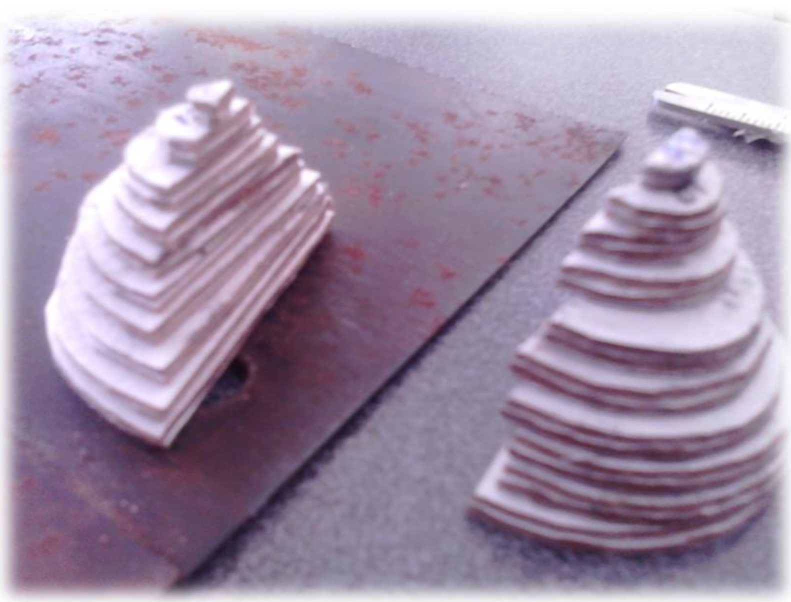

Fig.4 Cut of sections.

Fig.5 Putting the sections over the main water plane.

Fig.6 Adding polyurethane to the structure.

Fig.7 After taking off the excess of polyurethane, we obtained the scale models.

Once we had the models, we took them into the wind tunnel we have in the University to measure their drag force. The wind tunnel also measures other characteristics but as it is made for aerodynamic models and our model is hydrodynamic we just took in count this value, knowing that the density of the fluid is very different, but we conclude that the model with the minimum value of drag force in the wind tunnel would have the same results in an hydrodynamic tank, obviously with other numeric values.

A picture of these trials can be seen on fig.8

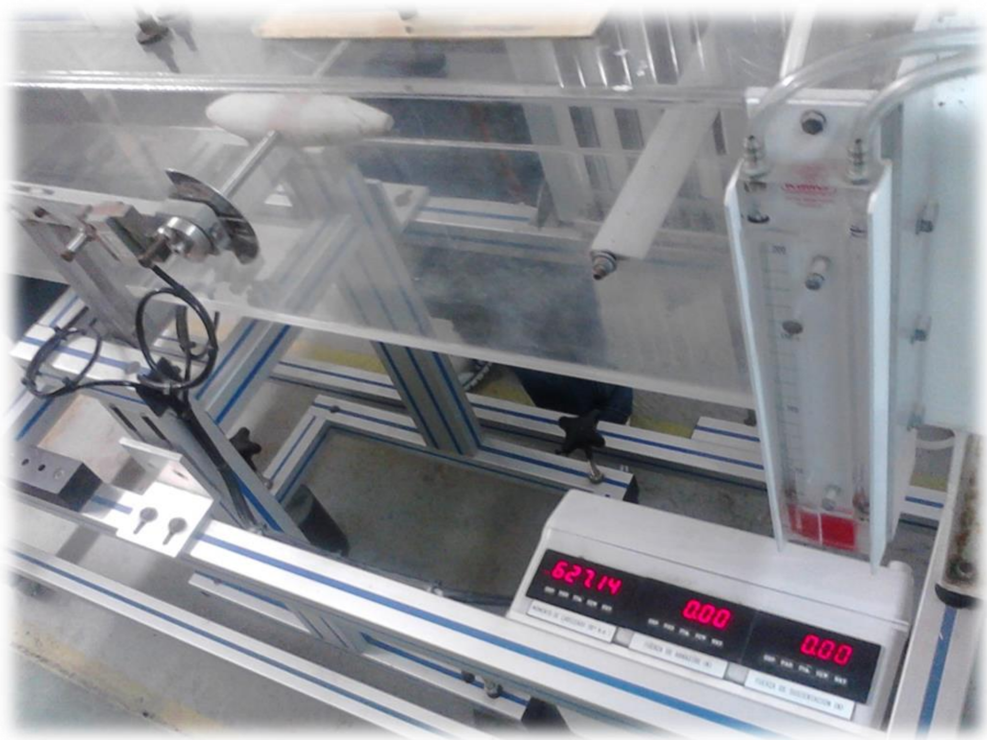

Fig.8 Running one model trial.

The outcomes were the following:

Velocity (RPM)	1500	1750	2000	2250	2500	2750
Prototype	**DRAG FORCE (N)**					
1	0.01	0.01	0.02	0.02	0.03	0.04
2	0.01	0.02	0.02	0.02	0.02	0.03
Arcangello 3	0.01	0.02	0.04	0.04	0.04	0.06

With these results, we conclude that the best model to be built would be the prototype model number 2, the one with the tuna fish form.

1.7 MAIN DIMENSIONS

To define the main dimensions of our submarine we took in count the comfort of the pilot and most important the space to pedal. The last submarines of our University have had a length of 3 m. and a maximum average diameter of about 0.60 m. With this information we decided to maintain the 3 m. length but modify the diameter, because based on the experience of the past competitors of our University, they have told us they had some problems with the space to pedal.

So we decided to choose a bigger diameter based on the length of the cranks of the pedals and the diameter we needed to do a complete revolution.

That's how we choose for our submarine a maximum diameter of 0.75 m. So with this diameter we ensure we won't have problems with the pedaling. What we sacrificed with this is an increase of the wetted surface; normally the past submarines had a wetted surface of about 4 m². And now we have a 4.56 m² of wetted surface, so this means an increase on the frictional resistance.

1.9 GENERAL ARRANGEMENT

We made a very basic general arrangement of our submarine, and taking in count a person of about 1.70 m. tall, that is the average height of the tallest team members whom possibly will be capable of powering the submarine. Fig.9

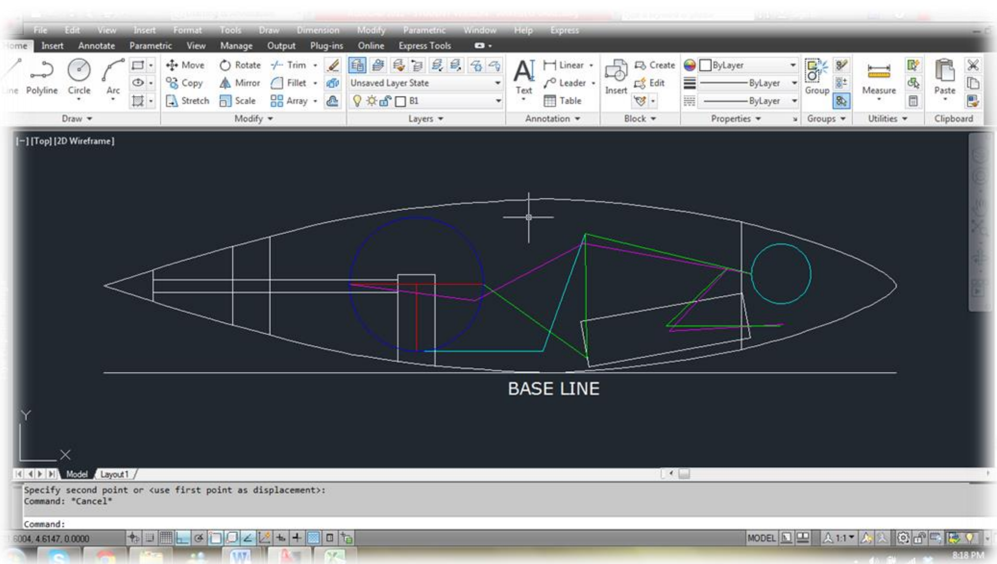

Fig.9 Basic general arrangement.

2. HULL RESISTANCE, EFFECTIVE POWER AND THRUST FORCE CALCULATION

2.1 HULL RESISTANCE CALCULATION

To calculate the submarine resistance we just took in count the frictional resistance, because it's the only form of resistance it will experience for the reason that it will be submerged. We calculate the frictional resistance with the ITTC's friction line and taking in count the hydrodynamic tank conditions, the most important, the temperature of the water and knowing that is fresh water.

We made an Excel chart to tabulate the results of the frictional resistance at different velocities. We made it from 1 knot to 10 knots, highlighting the 8 knots velocity that it's our goal for this 12th ISR.

Results can be seen in fig.10, taking in count that the values for density and kinematic density are for fresh water at 10˚C.

V (knots)	Wetted Surface (m^2)	ρ (kg/m^3)	ν (m^2/s)	Rn	Cf	Rf (N)
1	4.56	999.6	1.31E-06	1298367.28	0.00443	2.669
2	4.56	999.6	1.31E-06	2596734.56	0.00385	9.270
3	4.56	999.6	1.31E-06	3895101.84	0.00356	19.287
4	4.56	999.6	1.31E-06	5193469.13	0.00337	32.495
5	4.56	999.6	1.31E-06	6491836.41	0.00324	48.750
6	4.56	999.6	1.31E-06	7790203.69	0.00313	67.945
7	4.56	999.6	1.31E-06	9088570.97	0.00305	90.000
8	4.56	999.6	1.31E-06	10386938.25	0.00298	114.849
9	4.56	999.6	1.31E-06	11685305.53	0.00292	142.437
10	4.56	999.6	1.31E-06	12983672.81	0.00287	172.715

Fig.10 Total resistance at different speeds.

2.3 EFFECTIVE POWER CALCULATION

Having the value of the resistance that we will experience, we calculated the effective power, that is the power we need to generate to beat this resistance and move the submarine at the desirable speed. We used the basic formula:

$$Pe=Rt*V$$

Where:

Pe= Effective Power.
Rt= Total Resistance.
V= Submarine Speed.

The results can be seen in the chart of fig.11.

V (Kn)	Rf (N)	Pe (W)
1	2.669	1.372
2	9.270	9.529
3	19.287	29.741
4	32.495	66.810
5	48.750	125.286
6	67.945	209.543
7	90.000	323.822
8	114.849	472.261
9	142.437	658.912
10	172.715	887.754

Fig.11 Effective Power at different speeds.

2.5 THRUST FORCE CALCULATION

Having this, we could calculate the thrust we need our submarine's propeller need to generate to obtain the desirable speed. Results can be seen in the chart of fig. 12. We used the basic formula:

T=Rt/(1-t)

Where:
T= Thrust
Rt=Total Resistance
(1-t)=Thrust deduction fraction
* "t" was estimated to be equal to 0.20

V (Kn)	Rf (N)	Pe (W)	T (N)
1	2.669	1.372	3.336
2	9.270	9.529	11.587
3	19.287	29.741	24.109
4	32.495	66.810	40.619
5	48.750	125.286	60.937
6	67.945	209.543	84.931
7	90.000	323.822	112.501
8	114.849	472.261	143.562
9	142.437	658.912	178.046
10	172.715	887.754	215.893

Fig.12 Thrust force calculation.

3.TRANSMISSION SYSTEM

For the transmission system we took in count the fact that the power produced by a human being underwater is about 1/8 hp at 50 rpm, so we decided to use 2 bevel gears with a 3:1 relation to convert our 50 rpm into 150 rpm, to increase our rotational speed. We choose two carbon steel gears because the other contestants of our university had problems with gears made of other materials, so we don't want to have the same problems.

The crank of the pedals will be 0.27 m long and will be joint to the main gear and will move the second gear, and the second gear will move an aluminum shaft with 1" diameter. An arrangement of the gears can be seen in Fig.13.

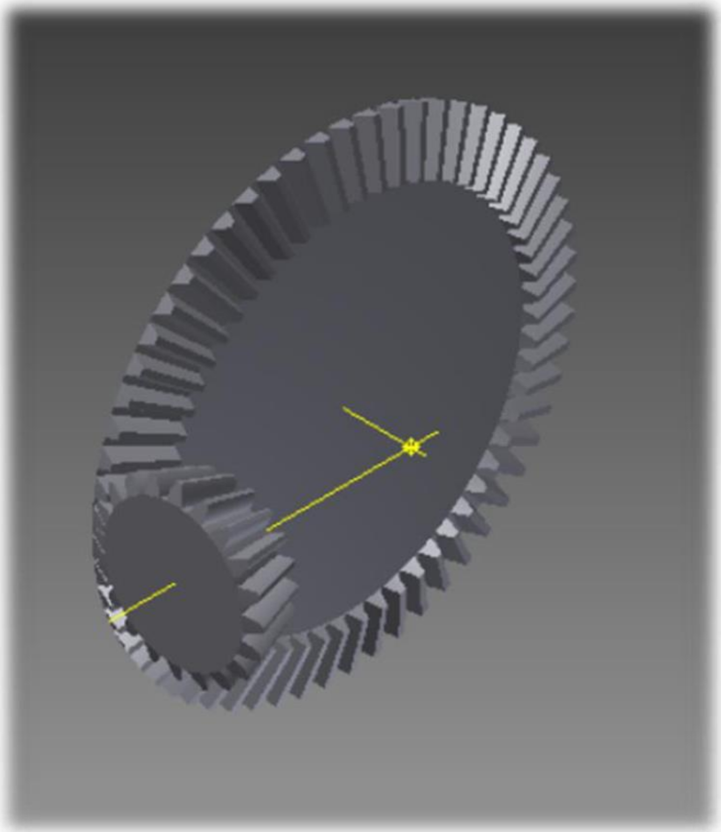

Fig.13 Gear arrangement.

4.HULL CONSTRUCTION

4.1 HULL MOLD CONSTRUCTION

We first built a mold for the hull, and to build it, we adopted the same way we built the scale models, just with some different things. We first draw the sections of our submarine over wood and then we cut them to then align every section along a wood beam of 3 m. long of rectangular section. All this over a rectangular section of 3.5 m. long and 1.5 m. width. Fig.1 thru 16.

Fig.14 Cutting the sections.

Fig.15 Detailing the sections.

After we had aligned our sections over the wood beam we were ready to put the polyurethane between the sections, but we noticed that we were going to use a lot of polyurethane so we decided to put some Styrofoam to reduce the quantity of polyurethane and then we started adding the polyurethane between the sections as shown in Fig.17 and 18.

Fig.17 Adding the polyurethane between the sections

Fig.18 Adding the polyurethane between the sections

After we had all the sections full with polyurethane we started detailing the shape, until we had a uniform and very fine line. Then we put paste to give it stiffness to our mold and to have no problems when we put the fiberglass, we sanded the entire surface to eliminate the excess and we obtained a very uniform shape ready to receive the fiberglass to build our mold. Fig.19 thru 24.

Fig.19 Putting paste over the polyurethane base.

Fig.20 Sanding the paste surface.

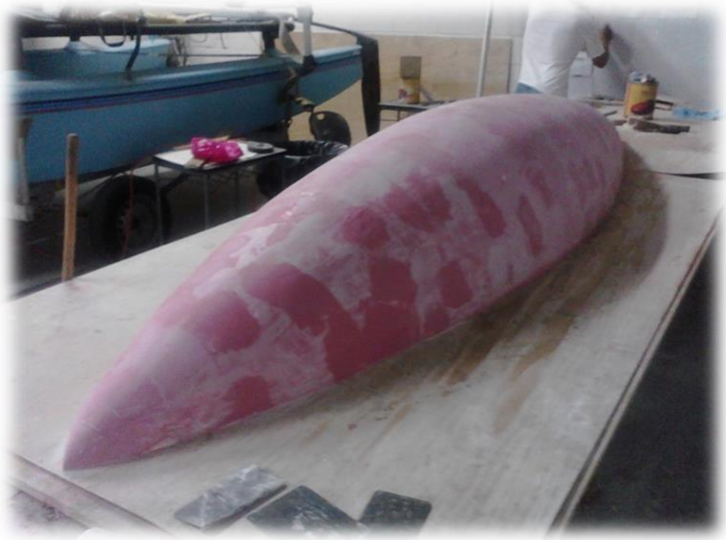

Fig.21 Surface finished and ready to receive the fiberglass.

After we finished sanding the surface we were ready to put on the fiberglass, this way we were going to build a negative mold, from which we built the final hull.

Fig. 22 Building the negative mold.

Once we had our negative mold, we built the 2 parts of the hull, and then we put them together with the aid of stiffeners and this way we ensure our hull will be stronger enough and won't have structural problems.

Fig.23 Taking off the negative mold.

Fig.24 Negative mold ready.

4.3 HULL CONSTRUCTION.

Fig.25 Putting fiberglass on the negative mold to obtain the first half of the hull.

Fig.26 Taking off the first half of the hull.

When we had the two halves, we joined them with fiberglass and resin paste and we started cutting the main access.

Fig.27 Cutting the main access.

We've place three windows at the bow of the submarine for the operator to see where he's heading.

The construction continues with the propellers and the transmission system.

For the propeller we decided to print shapes of the propeller and to cut wood with that shape and start placing them one on top of another.

The resuts were far better than expected.

As a contingency plan, we went with an experienced carpenter and asked him to do it for us. This plan was done with the idea to have an extra propeller in case of emergency.

The shaft and many other smaller components, along with the propeller core and the variable pitch control system were done at a numerical control lathe shop owned by a teacher from our faculty.

The idea is to simulate a bicycle system for the main propulsion and we've used and aluminum shaft with nylamid bearings.

This combination was with the intention of reducing friction and other undesired resistances in comparison with aluminum bearings.

Finally, the variable pitch control system was design by one of our Mechanical Engineering student and even though it's hard to explain with words how it functions it's a really simple solution to a big problem we've had months thinking how to solve it.

Basically, the system has two small shafts which move along to the main shaft with a static bearing. The small shafts make the propeller blades rotate when they move.

The submarine has been taken to test 2 times and has given much to move and things to change. We are currently working on them.

5.Conclusion.

As off this report the submarine is not complete. We've had problems in all the systems and we're making changes for the better. Tests are on their way.

It's easy to say we are a group of focused and encouraged-to-win students whose only goal is to take home the first place.

As before, we hope that the information and our experience in this project help future generations to improve designs and have better participations year after year.

Photos of the final stages of the construction will be added in the final draft of this report, when the submarine is complete and functional.

Team Arcangello

Universidad Veracruzana, Facultad de Ingeniería.