

Design and construction of an educational R.O.V.

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Abstract

R.O.V. stands for „Remotely operated underwater vehicle“. We have constructed a Mini R.O.V. whose maximum operating depth is 40m with safety factor 2. It has three motors, two for horizontal movement and one for vertical. It has a built in camera which is able to record video. We have also constructed a surface remote control station to operate the motor and camera.

Introduction

R.O.V. stands for Remotely Operated Underwater Vehicle. Remotely Operated means that you cannot directly see the device you are operating with. Instead, you are using mounted camera. Underwater Vehicle is used in industry, medicine, science, surveillance missions, underwater explorations and military purposes. If you want to make your R.O.V., you need to have some knowledge in the fields of electronics and mechanical engineering. There are several classes of R.O.V: Micro R.O.V.(max weight – 3kg), Mini R.O.V.(max weight – 15kg), Standard R.O.V.(max depth 1000m and max pressure 5hP), Light Work R.O.V.(max depth 2000m and max pressure 50hP), Heavy work R.O.V.(max depth 3500m and max pressure 220hP). Our R.O.V. belongs to the Mini R.O.V class. For that kind of R.O.V. you do not need very complicated parts, but you need a lot of patience and brain. Well, how does R.O.V. work you will have opportunity to see in the next chapter.



Calculations and modeling

For this project we needed to learn something about physical laws that govern our vehicle under the surface and how to make it float in the sea. This includes:

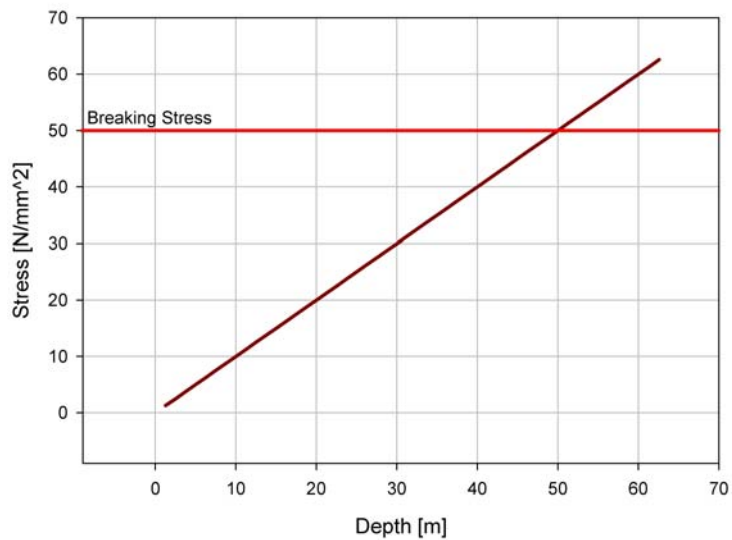
- Hooke's law $\sigma = E \cdot \varepsilon$
- Archimedes' law $F_b = \rho \cdot g \cdot V$
- Torque $\vec{M} = \vec{r} \times \vec{F}$, $M = |r| \cdot |F| \cdot \sin(\varphi)$
- Pressure $p = \rho \cdot g \cdot h$

We were interested in estimation of maximum operating depth, which is limited because of the stress produced by pressure of the water. To estimate that depth, calculations were performed, using information about maximum stress, pressure and pressure affected surface.

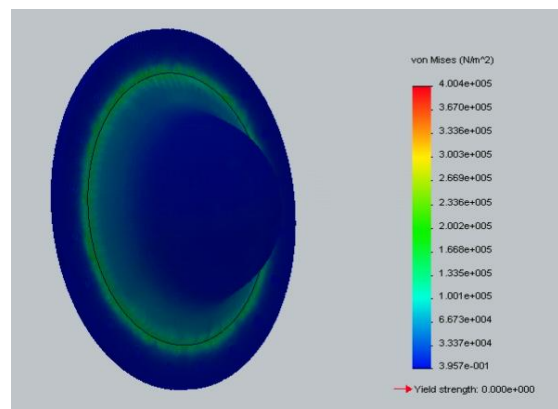
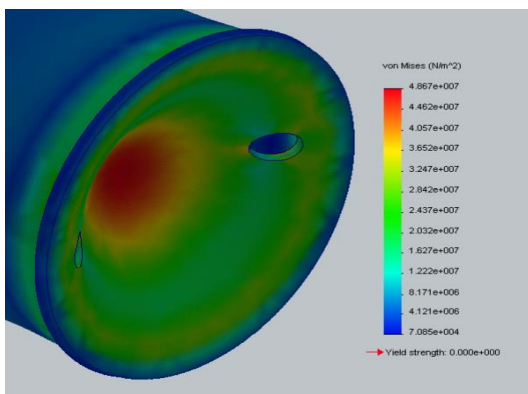
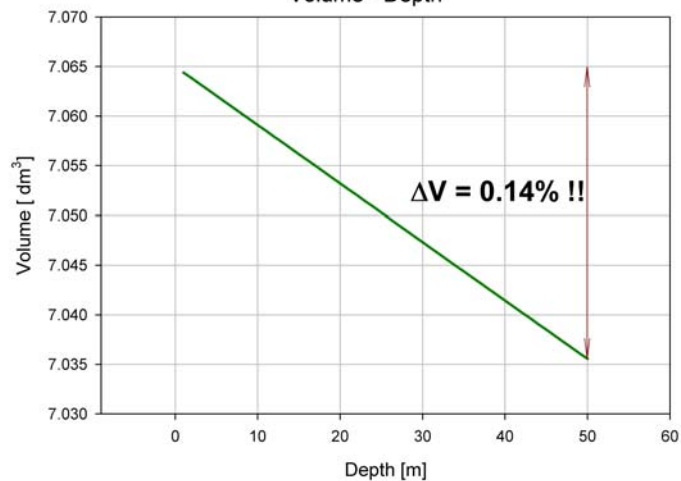
In calculations was as also used a safety factor, which acts as a kind of a warranty for engineers. If safety factor of 1 is used in calculations, then the resulting depth is the breaking point of R.O.V. and diving deeper than that point will be the end of your trip. In our case, a safety factor of two was used and the resulting depth was 53m, meaning it might actually go deeper than 100 m. ROV consists out of several parts – housing, electronics, motors and lights. Housing is body of R.O.V. made of PMMA (Polymethyl methacrylate). For construction of our housing we have used DS SolidWorks, 3D modeling software. It is used to construct different types of mechanical parts and also to make useful animations. First we had constructed our cylinder and the dome, later to be assembled into one part. To construct the cylinder, we were required to set the parameters. We also drilled holes on the back side of cylinder, one for power supply and communication with surface unit and one for motor connections.

Further more, holes were made on the dome because it had to be assembled with the cylinder somehow. We also used our calculations to determine the weakest part of our R.O.V.. Based on our calculations and modeling, the weakest part is the back plate of cylinder, and the safest part is the dome. Our calculations were tested in SolidWorks. In this case the result was 40m. It gave us the different results, because we previously neglected bending stress in rear plate of the housing for making calculations easier. To make diving possible, we needed to have neutral buoyancy. We ignored the change of the buoyancy with increasing depth, since it is only 0.14% at 30 m depth according to our simulations.

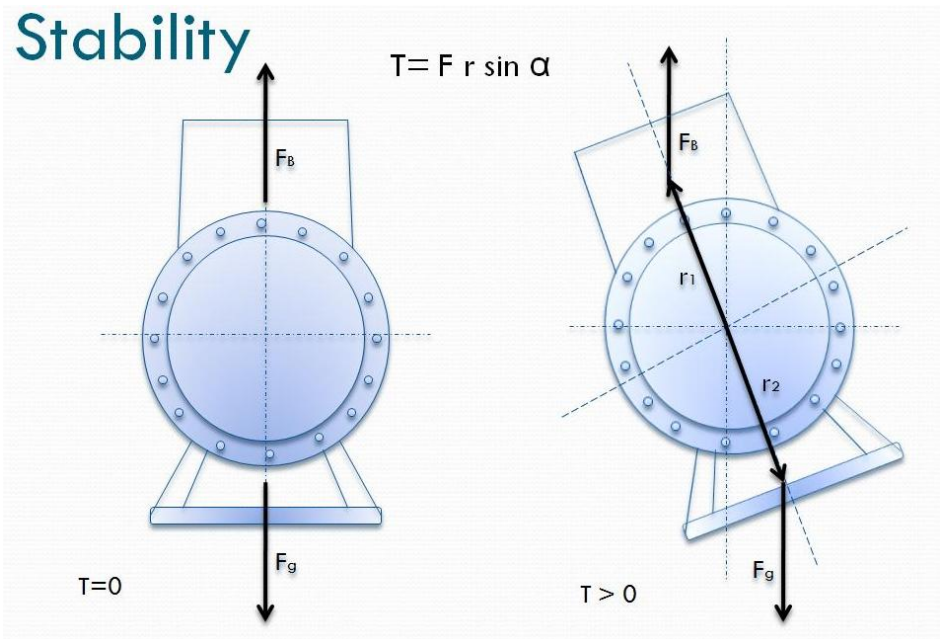
Stress - depth



Volume - Depth



R.O.V. needs to have centre of gravity as low as possible to reduce rocking. It works in the following way. On the first picture we can see the R.O.V. in neutral position with $M=0$ because force and radius are collinear. On the second picture it is inclined for an angle so torque is trying to rotate it back to the neutral position. Because of inertia it will pass beyond neutral position and repeat movement in damped oscillations similar to mathematical pendulum



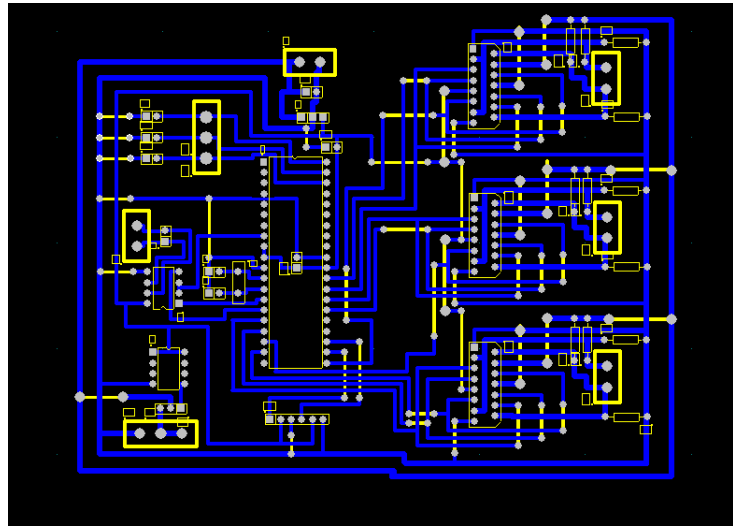
Materials and components

For our housing we used PMMA (Polymethyl methacrylate). Our vehicle has two main components: Cylinder shaped body with electronics inside and the dome that enables camera better viewing. We also have a hub on the top of our cylinder. It is made of styrofoam-fiberglass sandwich composite and we placed our vertical motor in it. We have three motors: one on the each side for horizontal movements and one on the top of the housing for the vertical movements. On the motor mounts we also have two LED lights to lighten our descent into the darkness. Our landing gear is made of copper tube, which allows us to increase the weight of the vehicle. Now, let's say a few words about electrical components. Microcontroller (MC) is the brain of our system. It is the component on which we load our programs, necessary for the later usage of a vehicle. H-bridge is a component which enables motors to rotate in both directions. Crystal is a precise clock for microcontroller (it's about frequency, most of you have microprocessors in home PC clocked around 3.0GHz or more, if you have dual or quad core processors). We also used voltage stabilizer to convert 24V to 5V, which is needed for logic components.

Electronics

Using raw electronic parts we had at our disposal, we were supposed to build two fully functional circuit boards, one for the R.O.V. itself and the other one for surface unit used to control our vehicle. First we had to design the boards in a computer program called Protel. It is the most important step in making a chip, because everything must be connected right and when you have hundreds of lines, it's not that simple. After choosing components layout we plan to use in the program, we made virtual board and connected pins with lines.

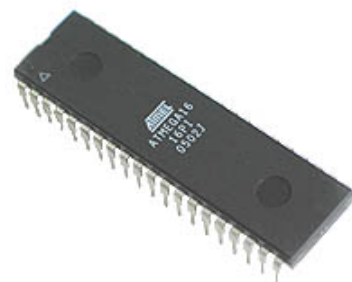
This layout was printed on a folium and layes on a special plate consisting of four layers: plastic surface, copper layer, foto-sensitive layer and its protective layer. Process begins with removing protective layer, followed immediately by putting printed layout and lighting it all with UV light for 8-10 minutes. Printed black lines on folium will protect foto-sensitive layer above copper we want to keep from light. Unprotected surface of foto-sensitive layer will change



chemically. Next step is placing the plate into NaOH which will remove chemically changed foto-sensitive layer and leave copper under it unprotected. What follows is etching the plate with a mixture of HCl and hydrogen peroxide, which finally washes off unnecessary copper. Final product was a plastic plate with full copper layout of our chip. Chip for R.O.V. is much more complex then surface one, beacuse it controls motors, lights and camera. For accelerating our motors, we used a method called PWM (Pulse width modulator). We decided to chose PWM,, which is a great solution for our type of electromotor, because it is a very efficient way of providing intermediate amounts of electrical power between being turned on and turned off. A simple power switch with a typical power souce provides full power only, when switched on. PWM is a comparatively-recent technique, made practical by modern electronic power switches. This board also contains smaller microcontroler for lights and lots of resistors and capacitors. Surface chip is much smaller because it is used only to turn on LED lights and convert analog to digital signal and other way around using analog to digital converters or ADCs. These components need to be soldered into the place we predicted for them in our layout design. For soldering, we need holes for sticking pins into and they were made by heavy drill. After we drilled necessary holes, our plate was ready for soldering components. It is not a simple procedure, as only one mistake can cost you a few hours of troubleshooting. End of soldering does not equals end of making chip, but beginning of the testing phase. This proved to be the longest phase of our electronic work, because it seems that these things simply never work from the first try. When we finished testing phase, we started with connecting two boards together in order to test if they communicate the way they were programed. Adjusting the program for 5 to 10 times is normal. If this part works smooth, then you have all the electronics needed to build yourself an R.O.V.

Programming

Our computers are not as smart as you may think (for now, anyway). They don't think, they follow array of commands which must be written by people. As you may presume, our R.O.V. isn't driven by A.I., so we were had to learn how to program and then use that freshly gained knowledge. Basically, what we needed to do is to tell the brains of our R.O.V. – the microcontrollers, what we expect them to do. We used the simple program BASICOM, similar to Qbasic. After we wrote a program that passed through a compiler



(this never works for the first time), we ‘uploaded’ our program onto microcontrollers using a developing board called EasyAVR4.. Microcontroller is plugged into corresponding connector and program is written on it using board software. All in all, we have written about 10 programs for testing components and the real thing.

Assembling

We came to probably the most difficult part of our task, assembling. When we had finished electronics and housing, we had to put them together and make them work. It is enough to solder something wrong and you will come to the end of your trip. At the first, our motors had not worked because one wire was connected in a wrong way. For detecting that problem, we spent around three hours because when you have that kind of problem, you need to check every part of a construction to detect the mistake. After a few unsuccessful attempts, we have succeeded to connect them to work fine. We were extremely happy not to see the end of the trip. The next step was establishing communication between microcontrollers.

Conclusion

Building an R.O.V. is not an easy task. It requires a lot of preparations, calculations and planning. And spare parts. During the process, many mistakes are likely to be made and solving of which will take a lot of time and nerves. Nevertheless, you should not underestimate yourself and your group and give up, even if it looks like the end of trip.

