Hovercraft

Final Report

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Rose-Hulman Institute of Technology

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by

Group 30

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Introduction:

At the dawn of the 20th century, the concept of the hovercraft was born when engineers came up with an experimental design to reduce drag on ships. The revolutionary idea was to use a cushion of air between boats and the water that they plowed through in order to reduce friction. This idea eventually led to what is known today as the hovercraft, basically, a vehicle that uses one or more fans to float on a cushion of air. These fans serve a dual purpose; to push air below the craft, filling up a flexible skirt around the craft and forcing it off the ground, and to create forward thrust by pushing air out the back of the craft. Steering is controlled by rudders located just behind the fan(s). The first technically and commercially viable model of a hovercraft was designed in 1955 by the English inventor Christopher Cockerell. Cockerell continued work on hovercrafts through the 1960's, was knighted for his services to engineering in 1969 and is credited with coining the word hovercraft to describe his invention. One of the greatest benefits of the hovercraft is its ability to travel over most types of terrain including land, water, and ice, making it very popular in the army and in many rescue situations. One example of a military hovercraft is the Zubr. This Russian vessel is the largest model of hovercraft in the world and is capable of carrying tanks, missiles, and personnel. It also features several turrets, cannons, and anti-aircraft guns. In fact, its weapons are so powerful that it is capable of tearing apart enemy ships of great size. This craft is clearly a great weapon because it is extremely powerful, but also very maneuverable. Though the concept of the hovercraft is fairly simple, we found it very difficult to design and build a successful one. Throughout the past two and a half weeks, we designed, built, and tested a remote controlled hovercraft. The hovercraft is capable of travelling over both land and water

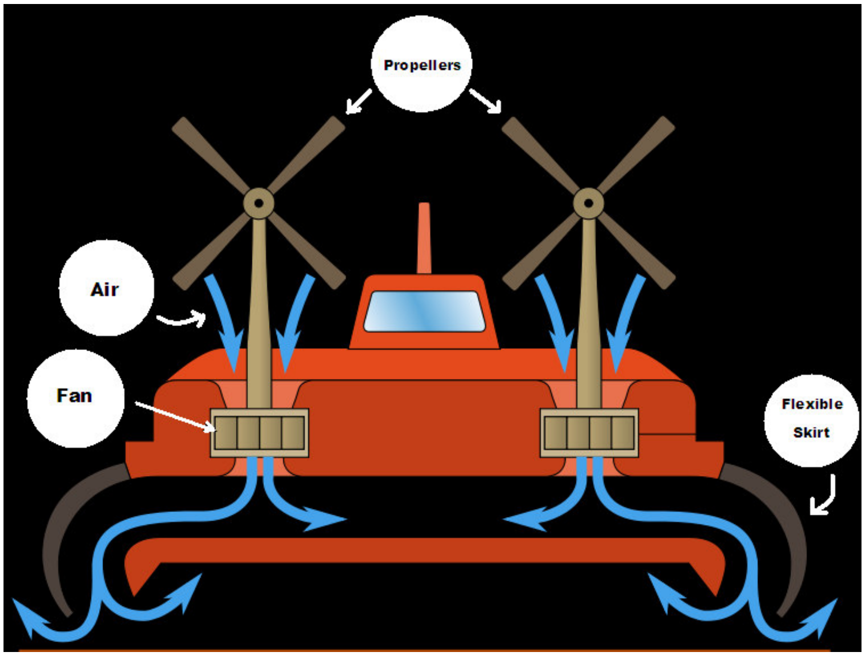

Figure 1: How a hovercraft works


Figure 2: The Russian hovercraft, Zubr, is the largest hovercraft in the world

and can be controlled remotely. It has undergone design changes, analysis, and testing which lead us into our design features.

Method:

Our hovercraft has several interesting design features including an inner-tube skirt, a downward facing fan, and an intricate duct and rudder system. Designed on top of a cardboard sheet, the craft is approximately 6.5 inches tall, 2 feet long and 10 inches wide. On top of this sits a Styrofoam structure that houses the motor and fan. This is capped off by a Frisbee with the middle cut out of it. A chicken wire guard stretches across the large hole in the Frisbee to keep stray items from interfering with the fan. The Styrofoam is also sanded down as much as possible in order to keep the craft as streamlined as possible.

One of the key features of our hovercraft is the skirt which is fashioned from a bike inner-tube. This tube was pumped full of air, then hot glued around the edge of the cardboard base. This creates a pocket that traps the air, which, in turn, pushes the hovercraft up off the ground. Though we are not aware of any commercial hovercrafts that use this design, it has the same effect as a loose skirt; both designs create lift by means of trapping the air directed downward by the fan. Of course, for this to work, we also needed a foolproof fan design that would push enough air downward to fill the pocket and push the hovercraft up off of the ground. Therefore, we kept the downward thrust of the fan as our top priority in the early stages of the project as is apparent in our design.

The downward facing fan was designed in order to ensure that our hovercraft would have enough lift to get off the ground. The design shows that we were primarily interested in downward thrust. Especially at the beginning, but throughout the rest of the project as well, this remained our first priority. The fan is positioned toward the front of the craft, and sits, along with the motor, inside a Styrofoam structure. This structure directs the air downward and causes the air to accelerate downward into the air pocket and duct system. The positioning of the fan and motor is essential as it tips the craft slightly forward, helping move it forward. As you can see, a lot of planning went into the key component of the craft.

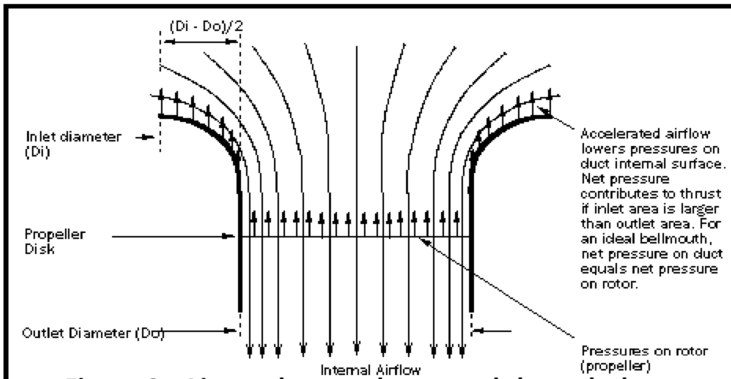

Figure 3: Air accelerates downward through the central duct system

The elaborate duct and rudder system on our hovercraft consists of two ducts which direct air from the fan chamber out the back end of the hovercraft. These are cut through the Styrofoam that encases the fan and motor and, when air is pushed through these channels, the hovercraft moves forward. The rudders, made of long cardboard pieces, sit behind these ducts and are glued directly to the servos. The servos sit in two metal "arms" constructed from small pieces of sheet metal. Turning the rudders causes the air leaving the ducts to be redirected. This results in the hovercraft turning left or right. We also included a method of slowing the hovercraft. This is achieved through the use of the two rudders, which make it possible to stop the majority of airflow out of the ducts. This duct and rudder system was very important because it was the only control we had over our craft after we turned it on.

Once we had everything planned out, we began building the hovercraft. We first started by cutting out the cardboard base so that the skirt could fit around it. Once this was done, we inflated the inner-tube and hot glued it around the outside of the cardboard. Since the craft would be operating over the water, we also caulked the joint on the underside of the craft only. Waiting for the caulk to dry, we began to build the Styrofoam housing for the fan and motor. Using a hot wire, we cut out two pieces of Styrofoam to the proper dimensions, hot glued them together, and then attached the fan to the structure using hot glue. We then glued the Styrofoam housing to the base and wired the fan to the on/off switch and battery. At this point, we began to cut the ducts out off the Styrofoam. Because only one person could work on this at a time, the other group members began to assemble the rudder system. The strips of cardboard that served as rudders were hot glued directly to the servos and then stuck on the craft using metal housings. After the building was completed we began testing the crafts capabilities.

Testing with Results:

Our first design was created with the fan facing the wrong direction, thus the fan casing was designed and built around that idea. In testing this design, we were consistently getting about a quarter inch of daylight clearance. When we finally did find out about our design flaw, we were forced to change many elements of our hovercraft. We designed and built a new casing that held the fan in the correct position and we began testing our new design. Our first major hindrance was a large crack in the base of the fan. This caused it to vibrate and hit the casing. To fix this problem, a new, more secure base was built. Secondly, we had problems with the wiring because the two wires were reversed leading to the motor, which made the propeller spin the wrong way. Unfortunately for us, we didn't realize our wiring error until after two days of testing. As soon as we had the wiring fixed, the new design hovered without any major problems.

The next step in the process was to test the thrust system. We initially cut a hole in the back of the casing and tested to see if this would produce enough thrust to move the craft. We decided against this design because too much air escaped through the blade guard. Next, we designed a duct system that consisted of two shafts cut out of the Styrofoam casing. This design was tested and it was found that this system provided sufficient thrust to propel the hovercraft at an acceptable speed. Unfortunately, the hovercraft drifted to the right because of bad weight balance. We tried to counteract this by testing the hovercraft with the battery and other weight on the left side, and eventually we were able to get it to travel in a straight line. One major design flaw was that every time we tested the hovercraft, we would have to readjust the battery and all of the other weight until we had it balanced. Eventually, we taped the battery onto the hovercraft in a fixed spot to get rid of the problem.

The final step was to develop a rudder system to control the direction of the hovercraft by controlling the airflow from the shafts. The first design was using hard plastic rectangles, and connecting them to the servos so they would hang down in front of the air shafts. The rudder system worked the first time it was tested, and was capable of turning efficiently. The only downside was that they made the back end of the hovercraft very heavy which threw off the balance. We tried to cut the rudders, but they were too thick to cut. We then changed the design to cardboard because it was lighter and still as effective. Once the rudders were in place we began testing with the remote control. In the last couple of tests, we had to add more items to our hovercraft and we ended up losing some of our daylight clearance. Upon completion, the hovercraft was able to hover fine and propel itself slowly. In the end, we were also able to have nominal controlling capabilities.

Analysis:

From the time we began building our hovercraft up until the final race, several modifications in our design had been made and our hovercraft looked much different than we had originally planned. Taking after the first hovercraft ever built, the SN-R1, we chose to use a downward-facing propeller mounted in the middle of the craft and surrounded by a foam casing. This accelerated the air as it moved down towards the cushion. The first time we had lift, we had positioned the fan in the wrong direction so that it was running in reverse. After fixing that problem, the fan was too high for the foam casing. That led us to the first design change which consisted of a new casing for the fan. After that, the craft was too heavy to hover and we had to change the design again. We then decided that the best course of action would be to remove the new casing and make a new one out of one inch foam board. This was added to the already existing structure and ended up fitting perfectly. However, when we tested this new design, the hovercraft was still unable to hover. It was at this point that we discovered a major wiring issue. The wiring to the fan had been reversed, causing the fan to spin in the wrong direction. After this had been fixed, the craft hovered easily and was ready for the propulsion system.

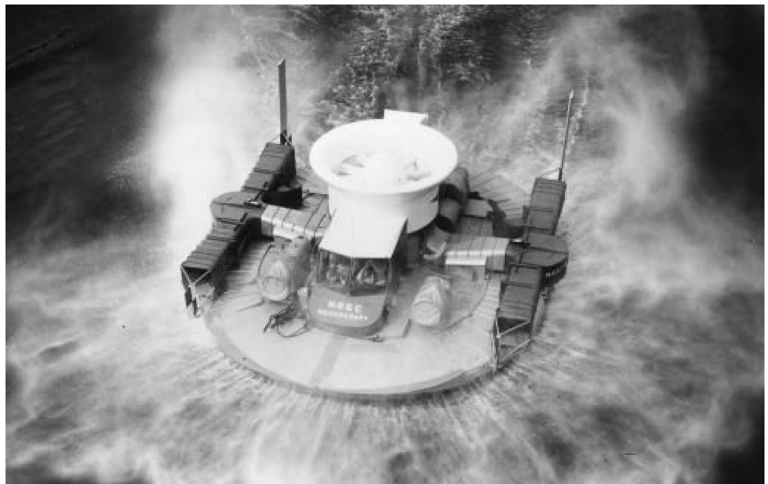

Figure 4 : SN-R1- The first hovercraft design. It was designed with a downward-facing propeller.

We encountered many problems with the thrust system of our hovercraft, the main one being that the propeller powering our hovercraft was facing down instead of the more common design featuring a forward facing fan. We created this design in order to get more lift; however, we encountered a unique problem when trying to design a propulsion system. To solve this problem, we designed, built, and tested several different duct systems until we finally found one that worked. The first design we tested was a duct cut out of a Styrofoam ring above the fan. At the end of the duct, we created one rudder made of metal which would allow the hovercraft to turn. However, the thrust provided was nearly nonexistent and the hovercraft did not move forward or respond to changes in the rudder position. We then understood that the duct system would need to be lower so that more air from the fan would go through it. We came up with a final design consisting of two ducts running from the fan chamber, through the casing, and out the back end of the craft. We developed a new rudder design consisting of two rudders, made out of the same materials as before, that were hot glued directly to the servos. While the thrust was significantly better than the previous design, the speed was still significantly under our needs. We solved this problem by creating two scoops underneath the fan that would direct more air through the ducts.

The final problem we encountered was that the hovercraft was still too heavy for our purposes. We solved the weight problem by removing the rudders made of metal and replacing them with cardboard rudders. While the lightweight cardboard help lower the weight, it became soggy and useless in the water race and it became difficult to control when they became malleable.

The first hovercraft competition was held on land on a very uneven floor, in which we had to maneuver through a course with obstacles. The Hovertug did not perform as we had hoped. Our battery was not fully charged and our craft kept getting stuck in indentations in the floor. After the competition, we changed its appearance to make it look more stream-lined. We sanded it down to give it a smooth flowing finish. After the first trial run, we altered the place of the battery on top of the craft. Then, in the water race, our craft was just a bit too light and the power of the fan caused the craft to oscillate, making it nearly impossible to control. As you can see, several design changes were made to our craft as a result of the testing we did throughout the past two and a half weeks.

Discussion:

Throughout the course of the project, the group progressed a lot and learned many new things about both engineering and hovercrafts. The hovercraft we made worked better than expected, but if we did it over there would be many things we would do differently. Even though the downward facing fan worked fine, the torque created from the rotation of the fan caused the hovercraft to constantly spin. We tried a number of times to counteract this problem with balancing the weight of the electronics and equipment of the hovercraft, but never managed to completely balance the hovercraft and as a result, we could never control it in the competitions. Many times the craft did not finish. A second change we would make would be to be less creative but more efficient. In place of our design, we would use the standard design with the fan facing backwards directing air downward into the cushion instead of our design with the fan facing down. Other than the general design, we think that our decisions made for the down facing fan hovercraft were the best possible, and we would not change them. For the most part, when we encountered flaws in our design we fixed them immediately.

None of us began the project with any previous knowledge of how a hovercraft works or how one would be built. While this did benefit us by not constraining us to designs of what we previously had notions of how a hovercraft should be built, it possibly prevented us from creating the best design possible. This prevented us from creating a craft that could perform at an optimal level. Additionally, we learned a lot about mechanical engineering, and how many steps a prototype vehicle or product must go through before becoming usable. Our hovercraft, and the many incarnations of it, showed us how a mechanical engineer would go about designing and building a product, and how difficult it can be sometimes. Overall, despite the fact that our hovercraft was not the best designed, it was a very fun project for all of us. The experience of being both Rose-Hulman students, and mechanical engineers was very enlightening and we thoroughly enjoyed working with each other and Dr. Ferro.

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