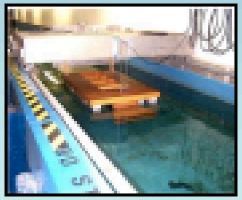
Tow Tank: Belt Drive Design

Background

The tow tank is a 120ft long 8ft wide and 4ft deep tank that is used to test the drag of various objects and shapes as they are towed in water. The tank holds 25,000 gallons of fresh water and is filtered to prevent any biological growth. An aluminum carriage runs on tracks across the length of the tank and achieves a maximum speed of about 1.5m/sec. The carriage is driven by a 3.4kW three phase motor that is digitally controlled by a programmable inverter with a stainless steel rope. The maximum drag force induced on the carriage is 540N (121lbf) and is measured by a strain gauge load cell mounted on the carriage. The system also has the ability to simulate waves.



Problem

The major issue with the tow tank which needed improvement was the stainless steel rope belt. The weight of the belt itself created a large amount of sag throughout the length of the belt. This sag, in combination with the wet environment of the tow tank created a very problematic and unsafe situation. The belt would actually jump off itself and would continuously need to be pried apart while the tank was in motion. The stainless steel rope belt would also slip on the pulley and cause the carriage to become stuck in place, rendering it useless for data acquisition.

Objective

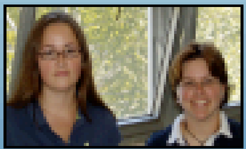
The focus of our project is to design and implement a new and improved belt drive system for the tow tank. The new belt drive system satisfies the following criteria:

- Eliminates belt contact issue
- Cost effective with little maintenance required
- Incorporates a positive drive system to prevent belt slippage

The specific results of this project are:

- Belt type selection
- Installation of new belt
- Pulley design
- Fabrication and installation of pulley
- Design of modified supports/guards
- Fabrication and installation of supports/guards

The Tow Tank team:



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Acknowledgements

We would like to thank Professor Michael Peterson, Art Pete, Neil Greenburg, John Riley, Thomas Lavoragne and the rest of the crew at the AMC for their assistance in this project.

Design

The design of our project was broken down into three major components, the belt design and selection, the pulley, and the guards/supports.

Belt Design:

Several design considerations were taken into account when choosing the belt type and material:

Corrosion Resistance: Because of the damp environment, corrosion was a significant design parameter. Corrosion resistance is usually determined by the material selection, however, due to formation processes some belt types are more prone to corrosion than others.

Cost: Cost needed to be kept at a minimum and was a significant design parameter.

Strength: The load involved in this project is relatively low (121 lbf), and therefore strength was not a critical design parameter.

Speed: The speed at which the carriage travels is relatively low (1.5 m/s), therefore it was necessary to select a belt which would perform well at low speeds.

Elongation/alignment: Due to the abnormally long length of the belt needed, elongation was a concern and should be kept at a minimum. Misalignment was also a concern and we therefore wanted to select a belt which did not require precise alignment.

Durability: The belt needed to be durable, wear resistant, and require minimal maintenance.

Efficiency: The tow tank is used infrequently and therefore efficiency is not a critical design parameter.

Belt Selection: Wire Rope

Our working load is 121 lbs and we chose a factor of safety of 8 so that the minimum breaking strength should be 8 times the working load. Our calculated minimal breaking strength is 968 lbs.

For our belt we chose a Stainless Steel Full Compliance Rope 7x19 class strand core (preformed), manufactured by McMASTER-CARR. This type of wire rope is ideal for applications that involve a rope being cycled back and forth over pulleys and sheaves and is pre-lubricated.

Diameter: 1/8"

Breaking Strength: 1,700 lbs

Cost Per Foot (100-199): $1.09

Pulley Design:

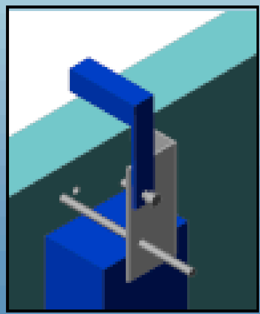
For maximum rope life, we chose a pulley that has a diameter of 40x the rope diameter. Because the carriage system is over a fixed length, not a continuous loop we needed to design the pulley accordingly.

Since the wire rope diameter is 1/8" we determined a minimum pulley diameter of 5". Our final selection for the pulley and idler diameter was 6".

Based on a 6" diameter for the pulley, we needed to determine the length of the pulley such that wire rope would not overlap and stall the motor. Taking into account the amount of pre-coiling of the wire rope needed to induce a positive drive, we determined an overall pulley length of 11". A 7.5" diameter stainless steel plate was attached to each end of the pulley to prevent the wire rope from slipping off. The material chosen for the pulley was HDPE (High-Density Polyethylene) because of its light weight and resistance to corrosion.

Guard Design:

Because the new pulley is longer than the previous one it was necessary to extend the guards that run the length of the tank to accommodate this extension in length. This was accomplished by designing guard extensions from aluminum angle stock and attaching them to the tank using stainless steel threaded rod. It was also necessary to ensure that the guards did not obstruct the path of the wire rope.

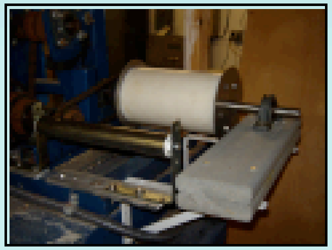


Fabrication

The first piece fabricated in this project was the entire pulley unit. The pulley was made from an 11" long piece of HDPE with two stainless steel 7.5" diameter plates mounted on each end. The plates were constructed from 10 gauge stainless steel sheet metal and were cut using a CNC plasma cutter. The plates were then welded to a stainless steel keyed shaft which runs through the center of the pulley. The plates were also bolted to the pulley to ensure that the shaft would induce a drive.

Once the pulley was assembled it needed to be mounted and attached to the motor. As the new pulley is longer than the previous one it was necessary to fabricate a shelving support for the pulley. As in all other aspects of this project it was important to mount the pulley using products which would not corrode or rot when exposed to water. With this factor in consideration the pulley was mounted by using plastic covered metal shelf brackets and a wood-plastic product.

Because the new pulley sits up higher than the previous one it became necessary to come up with a solution which would lower the height of the lateral movement of the wire rope without compromising the integrity of the rope. This was accomplished by installing a rotating stainless steel conveyor roller which the wire rope would travel under. This conveyor roller was installed in front of the pulley at a lower height.



There were several steps involved in the construction of these guard extensions and because it was necessary to fabricate and install 10 of these pieces, this section of the project proved to be the lengthiest of all.

Finally the wire rope was installed. To induce positive drive the wire rope was wrapped several times around the pulley then run down the length of the tank and looped around the idler. The wire rope was attached to the carriage by clamping it between steel plates which are connected to the carriage. The wire rope ends were then connected using oval sleeves.

Testing

Once the new belt drive was installed and testing was performed to ensure that the tow tank runs smoothly and efficiently. A drag test was conducted on a spherical object and data was obtained from this test.

Future Work

Future work for the tow tank may involve some modification of the guards to make them more safe. The current dynamometer should also be reconfigured to incorporate more degrees of freedom so that other measurements besides drag can be taken, such as pitch, etc.