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Electric Outboard Lower Unit Drive Design

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Abstract

Grand Canyon River Outfitters Association (GCROA) is a non-profit trade group of 16 professional river outfitters that guide whitewater rafting trips down the Colorado. Outboards currently use 30 hp 4-stroke gasoline-powered engines. GCROA wants to transition to an electric outboard motor which uses an environmentally-sensitive, non-fossil fuel-based propulsion system with low emissions and low noise. The NAU capstone team designed and manufactured a new lower unit using a pulley system to transmit power from the electric motor to the propeller. This project required collaboration with the University of Utah (UU) capstone team who developed the controls for the electrical system. The UU and NAU teams designed a universal mounting plate as a compatible interface between the two projects.

Project Objectives

Design and manufacture a proof-of-concept outboard lower unit powered by an electric motor supplied by UU that mounts to the existing Honda saddle.

Collaborate with UU on the design and manufacture of a universal mounting plate to interface between the lower unit and power head.

Design Specifications

Power Transmission Requirements:

The Honda propeller shaft has an output of 70 N-m at 2000 rpm. Given the supplied electric motor, which runs at 60 N-m at 3000 rpm, the designed system must have a propeller shaft output that matches the Honda outboard.

Ease of Operator Use:

GCROA required the team to design a quick-release motor mount to allow the electric motor to detach from the lower unit in case of damage to either component. This allows the guide to easily and quickly remove either part while on the river.

Design Selection

Three critical components were identified: drive system, quick-release motor mount and universal mount. Ideas considered for the drive system included: shafts, belt and chain drives. A belt drive system was chosen because it is just as efficient as shaft drives[2] and quieter than chain drives. Two options for a belt drive were considered: a direct system or an intermediate system to allow for the required torque output.

The direct system was chosen for this proof-of-concept prototype because it was a simpler design that met the requirements. The intermediate belt drive could serve as another iteration of the belt drive concept.

The quick-release motor mount design evolved from several concepts utilizing clamps, cam locks and bicycle skewers. The final design is an combination of these ideas.

The universal mounting plate was designed through collaboration with UU. The final design is a hybrid of UU and NAU's requirements. Figure 1 shows CAD renderings of the final design.

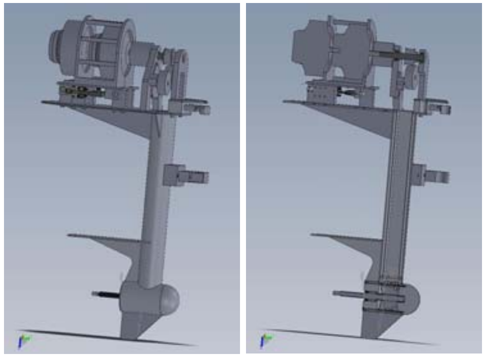

Figure 1. CAD renderings: final design (left); Cut-away of final design (right)

Theoretical Analysis

The power transmission specifications determined the required belt and pulley dimensions. With these dimensions, the input shaft was designed. The shaft was analyzed for failure using the Modified Goodman fatigue failure criteria.[1] There were three critical locations to check for failure: the shoulders at each of the two bearings and the shoulder at the pulley seat. Table 1 provides the safety factors for each of these locations. The shaft design was accepted because the safety factors were greater than 1.5. The team decided to use the Honda propeller output shaft for ease of manufacturing and because it is already designed to the power requirements.[3]

Table 1. Safety factors at critical locations on input shaft

Critical Location	Safety Factor
Input-side Bearing Shoulder	1.51
Bearing-side Bearing Shoulder	1.81
Pulley Seat Shoulder	2.22

The pulleys and the torque-limiting coupler are attached to the shafts via keys. These keys prevent the pulleys and coupler from spinning freely on the shafts. Safety factors for the keys, as seen in Table 2, were determined by performing shear failure analysis.

It is preferred that the torque-limiting coupler will disengage before components in the drive system break; however, the fail-safe is the belt will snap. The key safety factors ensure that they will not break before the belt.

Table 2. Key safety factors

Key Location	Safety Factor
Torque-Limiting Coupler	3.93
Top (Input) Pulley	2.29
Lower (Output) Pulley	6.32

Manufacturing

The majority of prototype manufacturing and assembly was done at the NAU machine shop by the team and the shop employees. Water-jet cutting by Stone Design, Inc allowed some parts to be cut to precise dimensions. The aluminum housing was welded by Mayorga's Welding to ensure a professional weld.

The biggest set-back was the warping of the propeller shaft housing during welding. To repair this, the housing was bored out using a variety of tools found in a basic automotive shop. Figure 2 shows several of the manufactured parts.

Figure 2: lower belt-guide journal (left); input shaft (top right); propeller shaft housing assembly (bottom right)

Testing

A timing belt was selected for the drive system because it is used in similar applications. The belt was tension tested and withstood 1300 lbf, twice the required load as determined through the analysis. Further testing of power efficiency and torque transmission will occur in mid-May when the UU and NAU teams test together.

Budget

The allowable project budget was $3,000. Labor costs of machining and welding done outside of NAU, as well as tools that the were not readily available at the NAU machine shop, were an additional cost to the materials of the prototype. The prototype was constructed under budget at $2,731.84. Table 3 shows a breakdown of costs for the project.

Table 3. Final project costs

Assembly	Cost
Mounts (Universal + Quick Release Motor)	293.03
Drive System	744.16
Housing	269.75
Manufacturing + Tooling	1,231.37
Administrative	84.04
Taxes + Shipping	109.49
Total	**$2,731.84**

Conclusions

This proof-of-concept outboard lower unit is powered by an electric motor and mates with the existing Honda saddle. The prototype matches the Honda power transmission requirements using a belt drive system. A quick-release mount design allows for the motor and lower unit to be removed separately while on the river. Through collaboration with UU, the universal mounting plate was designed to meet both school's needs. Future iterations of the belt drive outboard concept will further improve the design.

References

[1]Budynas, Richard G, and J.Keith Nisbett. Shigley's Mechanical Engineering Design. Ed 8. New York: McGraw-Hill, 2008.

[2]Erickson, Wallace D. Belt Selection and Application for Engineers. New York: Basel, 1987.

[3]Honda BF25A Motor Repair Manual. Honda Motor Co, LTD. March 1994.

[4]Marks' Standard Handbook for Mechanical Engineers, 11th Edition, Avallone, E., Baumeister, T. and Sadegh, A. Editors, McGraw-Hill Professional, 2006

Acknowledgements

The team wishes to thank our technical advisors, Dr. M.R. Mitchell and Dr. Brent Nelson for their support and suggestions. The team also wants to thank Mayorga's Welding, Dean Dunaway, Don Stone and Sam Heffelfinger for machining and welding.

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