

Wood Canoe Paddle

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PURPOSE OF THE PADDLE - FUNCTION

The idea of a paddle is a fairly simple one. It is a rigid beam used to help propel a boat across the water. The paddle can be broken down into three basic sections that under go different types of loading, and as such, shall be analyzed separately.

HANDLE

The handle is mostly a pivot point. It remains relatively stationary, and help give the person paddling some control over the oar.

SHAFT

The shaft, as stated earlier, is simply a stiff column. This is where the person rowing will apply most of his force in order to achieve a powerful stroke.

BLADE

The blade will behave more like a thin sheet, and will be subjected to different types of loads than the shaft. This web-like part of the paddle is what interacts with the water in order to give the boat its forward motion.

OBJECTIVES AND CONSTRAINTS

The main objective when designing a paddle and choosing a material, is to keep it as light as possible, while at the same time, keeping it stiff and strong. Cost can also be an issue for consideration, but I will not be dealing with it in my discussion.

There are some details that are pre-defined and have to be taken into account when choosing materials to work with. First off, stiffness is going to be prescribed by the user in accordance to his/her personal preferences. Length is another property that is basically fixed. It must follow the convention of common paddle design. Another thing that must be considered is that the paddle must not break under normal use, including, but restricted to things such as bumping against rocks and being dropped, or even thrown.

OBJECTIVE FUNCTION

The main objective for a paddle, collectively the handle, shaft and blade, is to minimize the mass. To achieve this goal, we must maximize the material index for each section of the paddle.

First we start with the equations for mass, stiffness and failure load respectively:

$$m = AL\rho \quad S = CEI/L^3 \quad F_f = Cl\sigma_f/y_mL$$

Which will be the same for each section of the paddle. The properties that will vary between sections are the equations for area, A, and second moment of area, I.

Shaft

For the shaft, which is modeled as a simple beam,

$$A = \pi r^2 \quad I = \pi r^4/12.$$

Combining these equations, using radius, r, as the free variable, we arrive as the material indices of

$$M_1 = E^{1/2}/\rho \quad M_2 = \sigma^{2/3}/\rho [1].$$

Handle

The handle can be modeled similarly to the shaft. It undergoes the same types of load as the shaft, only on a smaller scale. This being the case, we will use the same indices when choosing materials.

Blade

Next we consider that blade of the paddle. This shall be modeled as a strong flat plate. For this model, the area and second moment of area will be

$$A = bh \quad I = bh^3/12$$

respectively.

Starting with the same equations for mass, stiffness and failure load, considering h as our free variable, and combining them with the new equations for area and moment, we arrive at

$$M_3 = E^{1/3}/\rho \quad M_4 = \sigma^{1/2}/\rho [1]$$

as our material indices.

Using the indices along with the charts in fig.1 and fig.2, we are able to decide on as material that suits our needs.

NON-NEGOTIABLE CONSTRAINTS

- Stiffness
- Strength
- Length

NEGOTIABLE CONSTRAINTS

- Cost
- Cross-sectional area

COMPARISON TO EXISTING PADDLES

ALUMINUM SHAFT – PLASTIC BLADE

From looking at the chart in figure 1, it is shown that an aluminum shaft would have greater stiffness than wood, but along with that, it also has a higher density, increasing making it heavier than both the wood and CFRP. Though, this increase in weight may be able to be offset by making a hollow shaft. The design using an aluminum shaft would also be fairly inexpensive to manufacture.

WOOD

The wood shaft is the best of the three for reducing weight. It has a very low density, while stiff having a high value for Young's modulus. One major drawback of wood is that they are costly to manufacture.

COMPOSITE SHAFT

A composite shaft, such as CFRP offers about the same stiffness as the aluminum shaft, but has less density, making it a little lighter. And, as with the aluminum shaft, there is the ability to make a hollow shaft, further reducing the mass. On the down side, the cost to manufacture CFRP paddles is greater than that of the aluminum.

CONCLUSION

Having weighed the options, it is apparent that the tried and true material remains the best choice for a paddle. Wood, while offering slightly less stiffness, it is the lightest alternative. Though CFRP will probably be slightly lighter when considering their hollow shaft design, the cost associated with it makes it less desirable. When deciding on a material, achieving reduced mass should carry more weight than stiffness. A little bend in a paddle is a desired characteristic, allowing it to have the right "feel" for the paddler. This being the case, the slight trade off of mass for stiffness would be acceptable, making wood the best choice.

REFERENCES

1. Ashby, Michael F. Material Selection in Mechanical Design, Second Edition.
Oxford, England: Butterworth-Heinemann, 1999

APPENDIX

Figure 1: Young's modulus plotted against density
Figure 2: Strength plotted against density