Design and testing of a steam powered racing boat

Science

Abstract

This report is about a steam-powered racing boat designed. The boat designed achieves a sail time of 38. 6 seconds over 4m. The boat is made of aluminium from a can. It has a volume of 288^3, with a mass of 0. 209 kg. It travels at a velocity ranging from 0. 05 to 0. 15 m/s. It has a flat hull design [1] and an aluminium boiler.

Introduction

The objective of this project is to design a boat that will travel four meters in the shortest possible time while meeting the requirements of the constraints. The remaining report focuses on design and methodology, testing and results, recommendations and the conclusion.

Background

Specifications and constrains

The boat can only be made of recyclable materials. The use of specialty materials such as fibre-glass is prohibited. The power source must be a tealight candle. Longest dimension should not exceed 60 cm.

Success Criteria

The boat’s success is dependent on how long it will take to travel four meters, with a time under 30 seconds being regarded as a complete success.

Existing Solutions

There are at present several steam-powered boats. The hull design used by the designers already exists. Dr Guus Flogel says “ A copper coil with three turns performs better than a coil with two turns and another coil with four turns”. “ An advantage of using a copper coil engine is that it is very heat resistant [6]”. Copper tubing is generally slower.

Design And Methodology

Hull design

Hull Material

The designers used aluminium from a can to make the hull. Aluminium is soft and easily dented during building. The designers used pliers and a ball peen hammer [9] to flatten out the dents that formed. Working with aluminium poses a safety hazard because of the sharp edges that form when cutting it, to fix this the designers lined the edges of the hull with sellotape to prevent injuries when handling the boat.

Hull Shape

The hull designed used comes from an existing solution. This is a flat hull design, with a ‘ V’ shaped front. This design was chosen because of the stability the boat gains from the larger surface area (that is associated with this design) being in contact with water. The hull’s length, width and height are 0. 16 m, 0. 06 m and 0. 03 m respectively.

Boiler

Material

Initially the boiler used was a copper coil boiler. The designers changed this to a diaphragm boiler [6] which is made of aluminium. Aluminium proved to be a better heat conductor with a lower melting point (660 than that of copper (1084)[10]. This means that aluminium heats up faster than copper when they are both exposed to the same amount of heat (a tealight candle in this instance). The boiler was sealed using Prestik [6], because it is easy to work with and is a good adhesive. Two straws were used instead of copper tubing because no steam is lost to condensation along the walls of the straw like it is in copper tubing, once it gets to a cooler part of the tube. 3. 2. 2 Movement mechanism When the boiler is heated by the tealight candle, the water inside the boiler (approximately 40ml) heats up and begins to evaporate (this takes approximately 5-11 seconds).

Once the water has evaporated the pressure inside the boiler forces the steam out through the pipes. When the steam exits the pipes, it exerts a force on the water and the water exerts a force of equal magnitude but in the opposite direction on the boat. This is the force that causes the boat to move forward. This is according to Newton’s Third Law of Motion which states that for every action, there is an equal and opposite reaction. Given by the equation: (12)Fab= Force (in Newtons) of a applied on bFba= Force (in Newtons) of b applied on a.

Boiler design

The boiler design used is a diaphragm boiler [5]. In this design two straws are used as tubing. The boiler is made of aluminium, with a volume of 0. 31 m^3. The diameter of the straws is 6 x10^-3 m, with a length of 0. 15 m. The diameter of the straws was reduced by rolling each straw onto itself and held in that position until the straw would no longer return to its original circular shape. The size of the opening has now been reduced to 4 x10^-3 m. Decreasing the opening reduction was done to increase the pressure and ultimately the force with which steam exits the pipes.

Trade-offs

Aluminium's malleable and relatively small thickness (approximately 1mm) makes it easy to work with but also fragile, and hence needs to be handled with care because it can become deformed very easily. Once the aluminium is cut, due to its small thickness, sharp edges form and this poses a safety hazard. Straws do not handle heat well and melt when exposed to it.

Testing And Results

Testing was conducted outdoors in water-troughs. The boat was tested five times. The tealight candle was lit by a match and the time for the boat to travel 4 m was only measured once the boat started moving (5-15 seconds after tealight was lit).

Results critical analysis and discussion

The quickest time of 38. 6 seconds is attributed to the boat travelling in a straight line without bumping against the sides of the trough. From the results, there is a general trend that the boat performs better after each time it is tested, this due to the entire boiler being heated already from the previous testing, and an equal volume of water can now be boiled quicker as a result. The highest time of 45. 2 seconds was due to the boiler stalling temporarily while it was heating the cool water that had just entered it.

Engine Efficiency

Efficiency is the ratio of the output energy to the input energy. (Assuming water is at room temperature, 25, initially)(Assuming all heat is transferred to the boiler) Q= mc, Q= Heat energy (in Joules)m= mass of water (in kilograms)c= specific heat capacity (in J/kgK)T= Temperature change (in)Q=

mc=(0. 310)(4186)(100-25) = 97 324. 5 JThis is less than 1% efficient. Most of the output energy is lost to sound (in the form of the popping sound the boiler makes), light (some heat energy is given off as light) and the heating of the boiler-the boiler material may contain other metals that are affecting its conductivity. This efficiency is compatible with the 45. 2 second sail-time recorded.

Future Recommendations

To make the boat travel faster the pipes' diameter should be made smaller at the opening [6]. Make the boiler without the use of glue, and only use glue as a sealant if there is a leak in the boiler. This is to simplify the building process. Use a boiler shape that can contain the largest volume of water while having the greatest surface area being exposed to the flame.