

University of Wales Trinity Saint David
School of Engineering

Integrating project

Richard Castle soapbox

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1. Introduction

For the second half of the project, the basic principles and designs decided on in the first half were used to create a basic CAD model and run simple dynamics calculations to estimate how the design might handle in the real world. First a model of the space frame was made, to which were added additional parts such as wheels, seating, and steering. Once the model was complete, Solidworks materials properties were used to estimate the weight of the design at about 225kg, which was then used as a base figure for the dynamics calculations.

2. Regulations

Our design follows the 2018 regulations for the Richard Castle Soapbox derby.

2.1 General conditions

We fulfil the general conditions:

- We have more than two members.
- We will paint our soapbox bright colours, when it comes to the production stage.
- Our logo will be proudly displayed in a visible area.
- We have disc brakes.

2.2 Technical, design and structural regulations

We also fulfil the technical, design and structural regulations.

- Our soapbox is 2458.06mm by 1475mm which complies with the max. dimensions of 2500mm by 1500mm.
- We have 4 wheels clad in pneumatic tyres on each corner of our design, which all will be in contact with the track.
- No more than two wheels are in line in our design.
- We have more than 50mm ground clearance.-Our seat is securely fastened in a feet forward manner.
- We will add a seatbelt in production.
- Brad (our driver) will be able to get in and out of the soapbox unaided.
- The roll bars are up to standard, over 35mm over Brad's helmet and over 25mm away from the steering wheel.
- All sharp corners are going to be ground smooth.
- There are no materials used that can cause injuries during a crash.

2.3 Safety regulations

Safety regulations are also adhered to:

- Brad owns a motorcycle helmet and gloves that he will use during the race.
- The team will buy an overall Brad can race in, no skin will be exposed.

3. Design

3.1 Frame

The CAD frame model was made using the final design sketch from the initial report. To begin, the design was split into three major sections: the main frame, the front sub-frame, and the rear swingarm. Each of these was modelled separately and assembled within Solidworks to make the entire frame.

As much as possible, the weldments feature was used to simplify the material requirements. Furthermore, only two weldment profiles were used: square 50x50x3 tubes, and 26.9x3.2 pipes. The larger square tubes were used in major corners and edges for their superior resistance to bending torque, and the smaller pipes were used as crosspieces to take advantage of their resistance to compression.

The decision to use a bulkhead to connect the front sub-frame to the main frame had two primary motivations, the first being design flexibility. With the front sub-frame isolated, it becomes easier to replace in the event of a damaging frontward collision or to accommodate redesigns of the frontal region to meet changes in suspension, steering, and aerodynamics demands. The second reason for the bulkhead is safety: though space constraints place the operator's legs forward of the bulkhead, it can still protect the user's body in the event of a crash or from any road debris thrown up from the wheels.

3.2 Handling

The main motivation for the use of a rear swingarm is cornering. While the competition's regulations forbid a true trike design, they do not specify a minimum axle length or wheel separation. Thus the two wheels placed close together approximate a trike design while meeting regulations. This means there are less protrusions from the rear of the frame, allowing the operator to cut closer corners around obstacles in the race without fear of catching any part of the vehicle that they cannot see.

3.3 Stability and Suspension

The wide front stance retains some cornering stability and resistance to torque caused from shifting loads, though the design does not have as much stability as a more traditional wheelbase would. As an added bonus, the rear swingarm design allows flexibility for rear suspension options for operator comfort. Alternately, it can be fixed rigidly to the frame via a solid bar where the suspension spring would be for simplicity.

4. Calculations

All the calculations are based on the assumption of our top speed being 55 km/h, which is 15.28m/s.

4.1 Acceleration

Our acceleration is calculated using equation 1: $a = \frac{v-u}{t}$. Our t value was taken from an on-board video on YouTube of a soapbox going down the Richard Castle track, with t being 50 seconds. With our values introduced it equates to $\frac{15.28}{50} = 0.31 \frac{m}{s^2}$.

4.2 Total time

We have calculated our total time it should take us to complete one run-through of the track with equation 2: $550 = 0t + \frac{1}{2} * 2t^2$ which we then transposed into $t = \sqrt{\frac{1100}{0.31}}$ resulting in t=59.57 seconds

4.3 Kinetic Energy

The Kinetic energy of our soapbox results in equation 3: $0.5 * 295 * 15.28^2 = 34.44 * 10^3 J$, which was calculated with the equation $K.E. = \frac{1}{2}mv^2$

4.4 Air Resistance at full velocity

Our air resistance totals 28.34N, resulting from equation 4: $A.R. = \frac{1}{2}pA_fC_d$. P being the Air density, A_f being the frontal area of our soapbox and C_d being the coefficient of drag. Inputting our data leading to $0.5 * 1.202 * 1.01 * 0.2 * 15.28^2 = 28.43N$.

4.5 Total Force acting down the starting ramp

Knowing that the starting ramp is $\sim \frac{1}{8}$, we can calculate the total force acting down the starting ramp. Equation 5: $295 * 9.81 * \frac{1}{8} = 361.74N$ is made up out of $mgsin\theta$ results in 361.74N.

4.5.1 Total force acting down the track

Using equation 5 again and changing the gradient to 1/11 we can calculate the total force acting down the track which equates to $295 * 9.81 * \frac{1}{11} - 28.43N = 234.66N$. The gradient of 1/11 has been calculated from the descent of 50m over the full track length of 550m, this info has been provided by the competition.

5. Evaluation

The project was moderately successful in that it resulted in a design with accompanying basic dynamic analysis. However, both design and analysis suffered from lack of detail and depth, due in no small part to major loss of manpower in the team. While the project started out with seven members, it ended with only 4, meaning around 40% of available manpower was lost from project inception to completion. With more time, greater detail and depth would have been possible, but under existing deadline constraints it was decided to simplify the latter elements of the project in order to keep workload under control. In further iterations of the project, greater care should be taken in early stages to manage the scope of the project as a whole in order to stymie workload creep in the event of unforeseen circumstances such as loss of team members. In hindsight, the main reason for the loss of quality in latter stages was insufficient planning in initial stages and loss of motivation and morale.