Increasing Hydropower Flow Rate Using a Non-Linear Penstock

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The Brachistochrone Problem contemplates the shape of the path between two points, on the same vertical plane, such that a bead can slide down, with no friction and only affected by gravity, in the shortest amount of time. This problem has many applications in sports engineering, for example, in skiing and skateboarding. After exploring the solution of the Brachistochrone problem, a cycloid, I wanted to see how I could apply the Brachistochrone curve to something other than sports engineering. Since I am interested in energy studies, I tried to determine how these differently shaped curves could be applied to something in renewable energy, namely hydropower. After finding out that most hydropower penstocks were either straight lines or L-shaped curves, I wondered why cycloids weren't being used. The Brachistochrone Problem deals with a single point mass rolling down a curve from one point to another, not fluids like water. For this reason, I conducted this experiment to see if water flowing through a cycloid-shaped pipe would flow faster than it would through straight line or L-shaped pipe. If the water could flow faster through these cycloid-shaped pipes, then the power generated by the turbines would increase. I found out that using a part-cycloid, part-straight-line shaped curve is the fastest pipe shape. It produces the fastest flow rate and therefore gives a power generation increase of 36% when compared to a straight-line pipe and a 30% increase when compared to an L-shaped pipe. The optimal configuration for this pipe had a long height and small length. I also used the Dean Number, Reynolds Number, and Radius of Curvature of a Cycloid to show how turbulence is lessened in a part-cycloid, part-straight line curve as opposed to an L-shaped curve.

Awards Won:

Third Award of $1,000