Objective

Our goal is to implement a continuously variable transmission (CVT) on a bicycle.

What is a CVT?

A continuously variable transmission does exactly what the name says—it is a transmission that can vary its output to input speed ratio without discrete steps. A conventional transmission can only change its speed ratio in steps.

Why use a CVT?

While the use of CVTs in automobiles and utility vehicles is common, its use in bicycles is rare. Only one product, the NuVinci hub, is commercially available. A CVT can overcome many of the problems associated with traditional chain & derailleur bicycle drivetrains. These including shifting under load, stepped gear changes, and shift delay.

Design Concept

Our chosen implementation of a CVT is based on combining four 4-bar linkages (Figure 1) acting 90 degrees out of phase from each other on a common shaft. The motion of the linkages is ‘summed’ together using one-way clutch mechanisms. A simplified version representing the analytical model is shown in Figure 2 below. Speed ratio is adjusted by offsetting the input and output shafts.

Analytical model

An analytical model was developed to determine the output to input speed ratio as a function of shaft offset. The results for a theoretical design with an input speed of 10.47 rad/s, 0.5” offset, and 1.5” radius are shown in figures 3 and 4.

Prototype

Our prototype implements a one-way mechanism in the form of a ratchet fixed to the output shaft, and each 4-bar linkage drives the output through a pawl.

Results

The prototype was configured with an approx. 0.4375” shaft offset, with a 1.5” radius. 2048 CPR encoders were sampled every 10 ms to calculate speed. A drill was used as the input, and the output shaft was unloaded. The input/output data in figure 7 was smoothed using a 5 point loess filter to improve readability. The speed ratio data in figure 8 was filtered with a 15 point moving average. An input to output speed difference is evident at all input speeds (figure 7). The average output/input speed ratio over the entire range was calculated to be 1.1447.

Conclusions and Next Steps

Our prototype achieved an output speed increase of approx. 14.5% over our input, showing our proof of concept is a success. However the 3D-printed parts did not have the required tolerances, causing the linkage shafts to flex out of alignment and bind. Closer fitting and stronger components are needed to continue validating our design.

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