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## RESEARCH ARTICLE

# EFFICIENT TORQUE SPIKE MITIGATION EMPLOYING A PLANETARY GEAR SPRING SYSTEM

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**ARTICLEINFO**

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**ABSTRACT**

Planetary gear systems are a useful and ubiquitous means for power transfer. Ap- plications range from agricultural equipment drive lines to wind power generator gear- trains. In many applications torque spikes or reversals are an issue that shorten bearing and component life. In many applications a clutch design is used to soak up torque spikes (Hogan, 1996) or de coupling the drive during the event (Packer, 2015). This work documents and tests a design that potentially reduces torque spikes that may occur during drive line operation. It was discovered that the springs reduce both the torque spikes and the vibration amplitudes. This reduction of amplitudes in torque reversals will increase the life of the mechanical drive train.

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## INTRODUCTION

Due to torque spikes, or reversals, being a leading cause for wear on drive systems it important to work toward mitigating these spike events. Wind generator gear trains, for example, have not performed to life expectancy standards (Musial *et al.,* 2007; Paul Dvorak, 2012). This is due to torque change events arising from wind conditions or power grid fluctuations. These events wreak havoc those systems. Power trains for vehicles or other systems with discontinuous loads. Conventional approaches employ dampening clutches to "soak up" the torque spikes but at a cost of turning that energy into heat. This research was conducted in order to see if implementing a spring coupled planetary system would reduce torsional spikes. Planetary systems are unique in that there are two mechanical control inputs that dictate the output power ratio. These inputs can be coupled together by a spring-damper link to create a ratio compensating system. This project is replicating a high deceleration event and using a spring link in the planetary hub to reduce the torque spikes on the system as well as change the ratio to overcome the obstacle. This design will soak up the torque spikes and store that energy until the event is over. This use of a spring as an energy accumulator will decrease the torque spikes and vibration frequencies.

**Experiment Setup:** The test setup is orchestrated to repeatably simulate torque spikes. Figure 1 shows the basic illustrated view of the planetary system with the carrier coupled to the annulus by springs.

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In the baseline tests these springs are replaced with solid links to treat the system as a locked coupling. In this experiment the sun gear has 12 teeth, the planetary gears 21 teeth, and the annulus 54 teeth. This gives a ratio of $\omega_{Sun}$ to $\omega_{Carrier}$ (when $\omega_{Annulus} = 0$ of 1:5.5. A DC drive motor powering the sun gear to simulate the drive train and a second DC motor connected to the ring gear is used to simulate the torque spike events. This entire system is illustrated in figure 1 and shown below in figure 2 with the sun motor being in the front. In the first test there is a solid link connecting the ring gear and the carrier to simulate normal operation. This setup is to create a baseline and is where the torque spikes are most apparent without planetary reduction. Once the torque spikes occur the solid link is replaced with 3 25.5 lbs/inch springs. To collect the data and control the system utilizes LabVIEW®. Speeds and torques for the two motors are recorded using encoders and force sensors on moment arms. The sun motor powers the system, and the dyno motor stops the system in order to simulate a high torque event. The dyno motor is connected to the ring gear which is considered to be the system output. All data was recorded and saved to excel.

### Tests

The experiment is simple in that a baseline measurement is taken by powering the sun gear at a constant velocity then producing a torque spike event on the annulus and recording the sun gear torque. After the baseline is established another test is done with springs linking the annulus ring to the carrier of the planetary system. The same test scheduled is performed and the sun gear torque and rpm are again recorded.

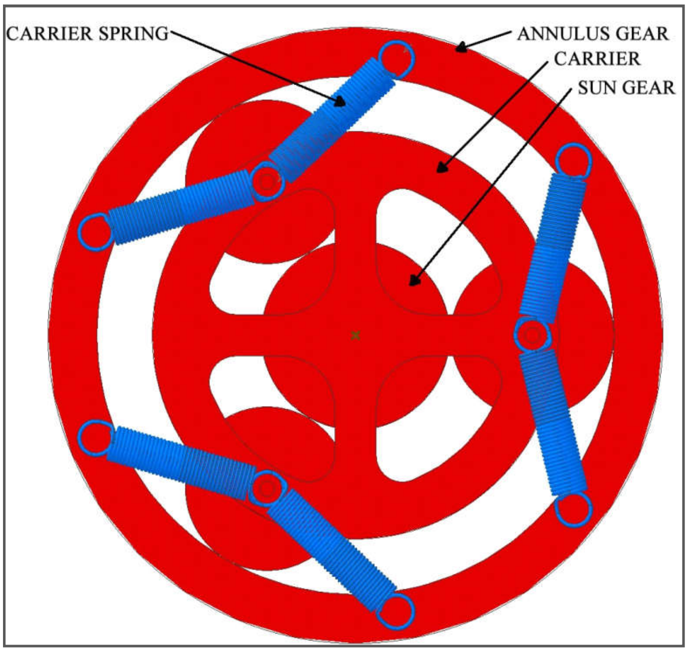


**Figure 1. Planetary system diagram illustrating carrier springs**

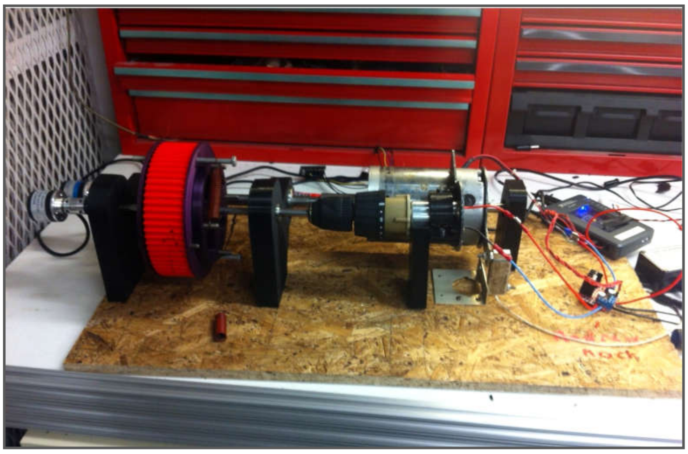

**Figure 2. Test Apparatus**

## RESULTS

The baseline test was performed to collect any torque spikes and operational vibrations that were experienced during a normal (solid) system. Resultant torque spike can be seen in Figure 3.

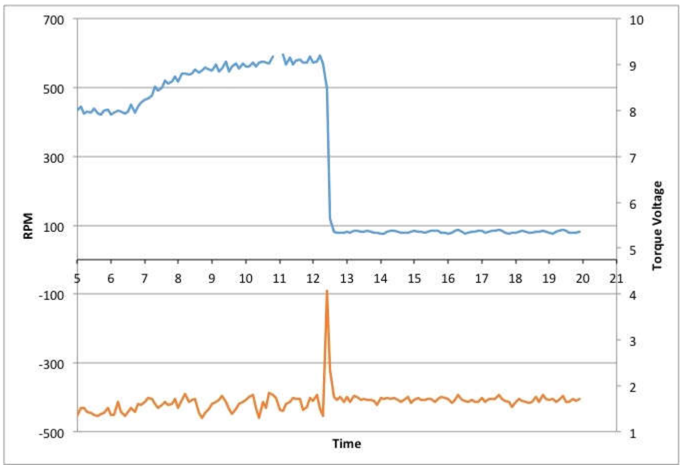


**Figure 3. Solid Link Torque Response**

Figure 3, shows the average spike when the system is stopped. In this test the torque spike reaches 4.06 in-lb, which is an increase of 2.37 in-lb over the average torque of 1.69 in-lb. It is also noticed that the torque stays relatively stable while running in normal operations. The standard deviation during steady state operation was calculated as .14 in-lbs which is 8% of steady state values.

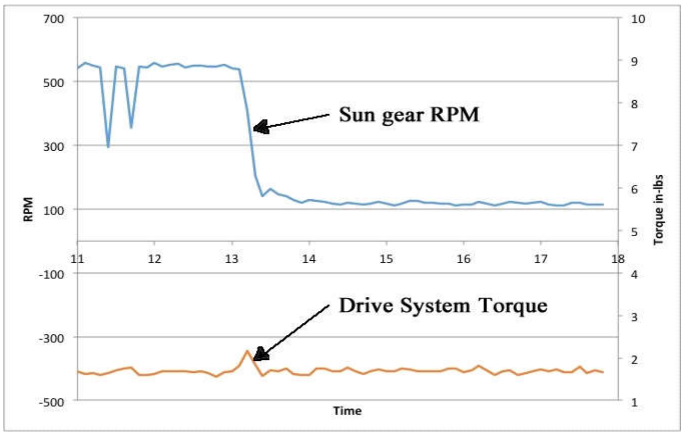


**Figure 4. Spring Link Torque Response**

**Spring system:** The second set of tests were conducted to see if a spring would reduce any torque spikes. Figure 4 shows that the torque spike was greatly reduced with an increase of only .46 in-lbs which is 80% less than the solid link system. The steady state behavior was also reduced to a standard deviation of .06 which is a 54% reduction of steady state vibration.

### Conclusion

This was a simple and easy experiment to illustrate that a planetary spring system could be used to reduce torque spike events. In this specific experiment the system reduced the torque spikes to a quarter and cuts the vibration to half of what the solid couple setup experienced. This shows that the spring mitigates torque spikes and helps in decreasing steady state vibrations which could have potential in reducing the stresses that occur during operations of drive systems. Further testing and development is needed in realizing what potential this concept has with applications such as wind generating power trains, agricultural equipment, and planetary exploration as a way to mitigate torque spike events.

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