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Behavior of Stacked Ortho-Planar Springs in CVT's

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Introduction

Compliant mechanisms are mechanical devices that achieve their motion from the deflection of flexible members rather than rigid links and moveable joints. One such mechanism using compliant design is an ortho-planar spring.

Ortho-Planar Springs

Ortho-planar springs, or OP-springs, are thin circular or polygon shaped flat springs that have a small central platform that moves up or down perpendicular or orthogonal to the plane of the spring. Flexible members in the design create the spring force. A pseudo-rigid body model equation for ortho-planar springs was derived from formulas available in *Compliant Mechanisms* (Howell 413).

Knowing that OP-springs are very compact and easily manufactured (Parise 1282) and the possibilities that they might be more economical than current spring designs (Herring 12) led to the development of a replacement spring for a continuously variable transmission (CVT).

CVT's

CVT's provide a simple solution for automatic transmissions. They continuously vary output speed using springs and centrifugal weights. CVT's are most commonly used in snowmobiles and ATV's but are gaining acceptance in the automobile industry and elsewhere.

Research Results

Building upon the significant work that has been done at BYU in compliant mechanism design of OP-springs, a prototype of an OP-spring was built for a Polaris® CVT (figure 1). The prototype was a design by Mark Anderson, Nathan Rasmussen, and Mike Whiting. Testing was then done on the design that confirmed many expected results.

Linear actuators with force transducers were used to accurately measure spring constants. A three-factor factorial test was run to check the statistical significance of lubrication, hysteresis, and the number of stacked OP-springs. The results concluded that on a 0.03125" thick spring of the Polaris® clutch OP-spring design, lubrication and hysteresis are statistically insignificant when determining the k-value of a stack of OP-springs. Also, the overall k-value of a stacked set of OP-springs can be closely predicted by simply multiplying the k-value of a single OP-



Figure 1. Picture of prototype ortho-planar springs mounted on a CVT.

spring by the number of OP-springs in the stack (figure 2). This testing verified the linear relationship that was hypothesized in the beginning.

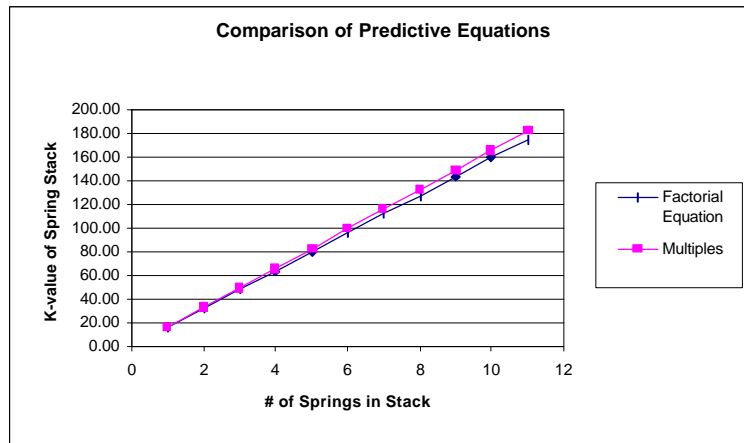


Figure 2. Graph showing that simply multiplying the k-value of a single OP-spring by the number of OP-springs in the stack will closely predict the true overall k-value.

Additional test setups allowed testing of the dynamics of the OP-spring in a CVT. Due to the linearity of stacking OP-springs, the testing showed that predictable adjustments are easily made to the CVT by the simple addition or subtraction of a spring layer. Other advantages that the OP-spring added to the CVT design were: simplified and accurate CVT tuning, reduced part count, decreased clutch size, and reduced rotating mass.

Presentations accentuating the advantages and the possibilities of this design were given to an industry giant in the field of snowmobiles and ATV's: Polaris Industries. Also, a disclosure statement was written in anticipation of working out an application patent.

Conclusion

Adequate testing was performed to verify the linearity of stacked OP-springs. This information along with initial testing of the dynamics of a stacked system of OP-springs in a CVT was shown to industry professionals to bring researched and proven theory into competitive consumer products. OP-springs provide many advantages over traditional spring technology and thus have a large marketability through implementation in other products/designs.

References

Herring A., Magleby S., Howell L., Todd R., "High Production Manufacturing Considerations for Metallic Compliant Mechanisms with Long Thin Beams," ASME 2001 Design Engineering Technical Conferences and computers and Information in Engineering Conference. Pittsburgh, Pennsylvania, Sep. 9-12, 2001.

Howell, Larry L. *Compliant Mechanisms*. New York: John Wiley & Sons, Inc. © 2001

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