

Transmission Torque Converter Arc Spring Damper Dynamic Characteristics for Driveline Torsional Vibration Evaluation

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ABSTRACT

Torsional vibration dampers are used in automatic and manual transmissions to provide passenger comfort and reduce damage to transmission & driveline components from engine torsionals. This paper will introduce a systematic method to model a torque converter (TC) arc spring damper system using Simdrive software. Arc spring design parameters, dynamometer (dyno) setup, and complete powertrain/driveline system modeling and simulation are presented. Through arc spring dynamometer setup subsystem modeling, the static and dynamic stiffness and hysteresis under different engine loads and engine speeds can be obtained. The arc spring subsystem model can be embedded into a complete powertrain/driveline model from engine to wheels. Such a model can be used to perform the torsional analysis and get the torsional response at any location within the powertrain/driveline system. The new methodology enables evaluation of the TC damper design changes to meet the requirements. Simulation results reported provide examples of the presented virtual analysis method's capability.

CITATION: Li, Z. and Sandhu, J., "Transmission Torque Converter Arc Spring Damper Dynamic Characteristics for Driveline Torsional Vibration Evaluation," *SAE Int. J. Passeng. Cars - Mech. Syst.* 6(1):2013, doi:10.4271/2013-01-1483.

INTRODUCTION

In an automatic transmission, a torsional damper is generally made of a set of linear or arc springs that connects a primary side impeller to a secondary side turbine inertia. For better torsional vibration isolation, a low rate (long travel) damper is desired. Such an architecture usually uses arc spring systems. Isolation studies typically use a fixed spring rate and hysteresis derived from a static test. During higher engine speeds and torques, the arc spring tends to be pushed against the retainer wall, increasing the friction force during spring movement. This paper describes how to build a dynamic arc spring damper system model for calculating the dynamic stiffness and hysteresis of the damper under different engine loads and speeds that includes the effect of this friction. Such a model can be used not only to perform the torsional vibration analysis in the driveline system more accurately, but it can also be used to investigate detailed design of the damper parameters. Adjusting design variables (such as arc spring geometry, number of coils, mass, etc.) within the allowable ranges enables optimization of a design which produces the maximum torsional vibration isolation effect between primary and secondary inertia. An optimized damper design can be incorporated into a driveline torsional model to determine if vibration levels meet requirements.

The torque converter itself serves as a torsional vibration damper when the clutch is open [1]. The fluid coupling in the torque converter will greatly reduce the torsional vibration from engine to transmission. Unfortunately, while a viscous coupling of engine to driveline reduces torsional vibration, it is much less fuel efficient than a closed clutch connection. Fuel efficiency is significantly improved if the torque converter is locked up at low engine speeds. The potential risk at low speed clutch lock up engagement is the possible high torsional vibration. This paper presents a method for assessing the converter damper's effectiveness at controlling torsional vibration during locked-up converter operation.

There are two types of torque converter dampers, conventional dampers and turbine dampers [2]. The scope of this paper is limited to considering conventional dampers; i.e., those dampers where the damper spring is located between impeller and turbine. Turbine dampers in which damper springs are located between the turbine and transmission input shaft are not considered here. But the modeling method can be extended to turbine damper systems. The arc spring system in conventional dampers can be discretized into lumped masses and massless springs. A simplified method which utilizes only the static spring rate and constant hysteresis can be used to build torque converter damper model [3]. Unfortunately, if the torque converter

damper is made of arc springs then the simplified method fails to adequately capture system dynamics. This paper presents a systematic arc spring modeling method that more realistically predicts driveline responses. The simulation results obtained using the arc spring modeling and those that rely on the simplified method [3] will be compared. The results from the arc spring model are more accurate because the dynamic effects such as dynamic stiffness and hysteresis are captured in the modeling.

METHODOLOGY OF TC ARC SPRING DAMPER MODELING AND SIMULATION

The torque converter arc spring damper to be studied is shown in [Figure 1](#) schematically. There are four arc springs which are parallel between TC primary inertia and intermediate retainer. The arc springs are sliding against the holding plate outer wall. There is another set of linear springs between intermediate retainer and turbine flange. The arc spring set and linear spring set are in series. Instead of using the static stiffness and hysteresis, the arc spring geometry and mass properties will be used in the modeling. The dynamic stiffness and hysteresis of the arc spring system will be dependent on engine speed and torque due to friction changes between the spring and the contact wall. Accounting for this friction produces a more accurate simulation. For linear springs, the static rate and hysteresis are used because they are less sensitive to engine speed and engine torque.

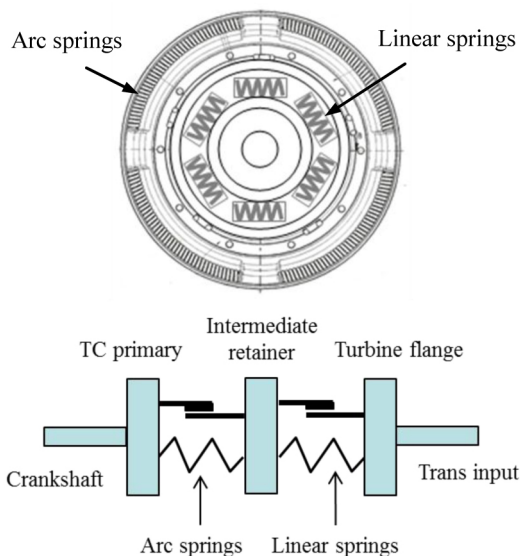


Figure 1. The schematic diagram of the torque converter damper to be studied

Arc Spring Design Parameters

Basic arc spring modeling parameters will be presented below. Some parameters need to be calculated based on given design parameters. When all information is available, Simdrive software can be utilized to build the model and perform the virtual analysis.

Arc spring geometrical parameters

Following geometry parameters are used in calculation to define the layout, initial position, and the limit of motion of the arc spring system.

Arc spring friction radius and effective radius

The spring outer radius contacts with the retainer wall. It is defined as the friction radius, which will be used in friction force (hysteresis) calculation. The spring center radius is defined as the effective radius, which will be used for spring generated torque calculation. [Figure 2](#) is an illustration of friction and effective spring radius.

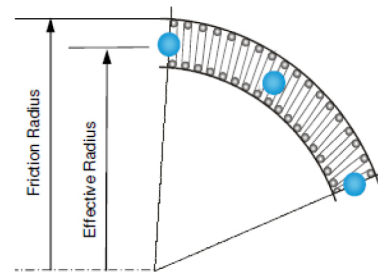


Figure 2. Arc spring friction and effective radius

Number of arc spring segment and number of coils in each arc spring

The number of arc spring segments will determine the damper structure and damper maximum travel limit. Because arc springs are arranged in parallel, more segments will usually produce bigger damper torque capacity but less damper travel. There are four arc spring segments in the system to be studied referring to [Figure 1](#). The number of coils in each arc spring is related with mass distribution and also spring travel.

Starting angle and angle of arc spring

The starting angle defines the arc spring end position and is being measured from the horizontal axis in counterclockwise direction. The angle of arc spring defines the length of the whole arc spring between two spring ends in built-in condition (assembled condition). [Figure 3](#) illustrates these two angles. These angles are necessary information for developing the equations of motion of the arc spring system.