

# A Computational Method for Efficient Hub Offset Comparisons with Deflected-Disc Dampers

W. Bradley Cwycyshyn and Joseph Fedullo  
General Motors Company

## ABSTRACT

With deflected-disc dampers, digressive force-velocity shapes are achieved via the combined effects of disc stack stiffness and hub-offset. The degree of digressiveness can be adjusted to alter vehicle performance by changing the proportion of these parameters. Optimizing this relationship can yield substantial vehicle performance improvements, but the time consuming iterative process of developing a new disc stack for each hub-offset discourages experimentation.

To enable more efficient digressiveness comparisons, a regression-based computational method has been developed which converts disc stack stiffness from one hub-offset to other offsets directly, without iteration. Once an initial disc stack for one offset has been tuned by traditional methods, stacks for other offsets can be calculated that maintain overall damper control. This paper will present background information on deflected disc valving and curve shaping, describe development of the computational method, and show an example of a typical comparison, graphically.

**CITATION:** Cwycyshyn, W. and Fedullo, J., "A Computational Method for Efficient Hub Offset Comparisons with Deflected-Disc Dampers," *SAE Int. J. Passeng. Cars - Mech. Syst.* 6(3):2013, doi:10.4271/2013-01-1357.

## INTRODUCTION

In the automotive industry, customer clinics and owner surveys continually emphasize ride and handling performance as an important driver of purchase decisions and ownership satisfaction. Of the elements defining this performance, damper tuning is among the most important. Dampers having digressive force-velocity relationships have distinct vehicle performance advantages over linear and progressive dampers, emphasizing roll damping and low- to mid-speed motion control at reduced bump force levels.

The velocity range of automotive suspension dampers is generally divided into three regions: low-, mid-, and high-speed, with a different hydraulic valve controlling each range in rebound and compression. With digressive deflected disc dampers, mid-speed control force around the "blow-off" transition point is determined by the pre-load which arises from the product of hub off-set and disc stack stiffness.

To maintain mid-range control level, digressiveness is adjusted by simultaneously changing hub off-set and disc stack stiffness in opposite directions. Because this involves the development of a new complimentary disc stack, evaluation requires a laborious trial and error process. Shortened product development cycles preclude full

exploration of force digression if traditional methods are utilized.

To address this need, a regression-based method has been developed that directly calculates new disc stack stiffness to compliment changes in hub offset, enabling efficient optimization of damper digressiveness.

## BACKGROUND

### Digressiveness Defined

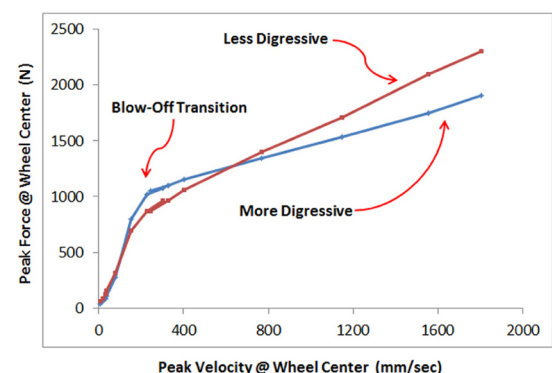


Figure 1. Digressive Force-Velocity Curves

For the purposes of this paper, a digressive damper is defined as one with a marked reduction in slope of the force vs. velocity curve above the “blow-off” force. Examples of two levels of digressiveness are depicted in [Figure 1](#).

## The Need for Digressiveness

Digressiveness is driven by vehicle-level requirements; the forces required for optimum hydraulic control in the low-mid velocity range (roll damping, primary motion control), and the forces required for optimum control at higher velocities (bump force, wheel control, etc.) cannot be achieved simultaneously without a force modulating device. Without this device, forces build either progressively or linearly with velocity resulting in excessive forces at higher velocities. Vehicles consistently acclaimed for dynamic behavior use various levels of digressive damping to their advantage. Determining the optimal level is an arduous task, and a more efficient method than stack iteration is needed.

## Digressiveness Implications for Vehicle Dynamics

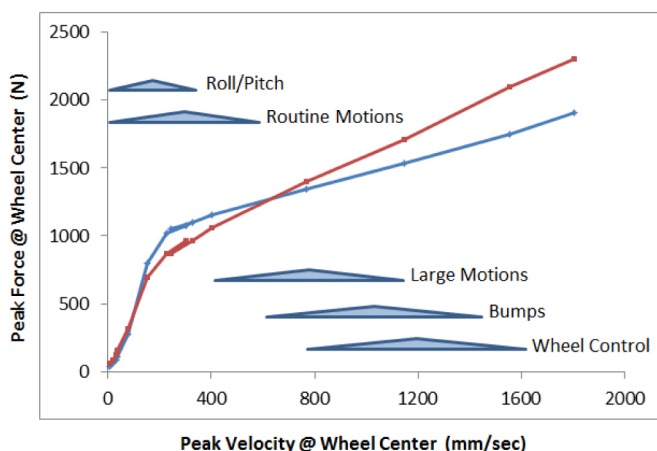


**Figure 2. Velocity Ranges for Vehicle Dynamics Events**

The degree of digressiveness affects vehicle performance by altering the trade-offs made between several performance attributes. Higher levels, in which the peak-force peak velocity (F-V) curve “blows off” flatter but has higher force at the transition, favor roll and pitch damping, low-mid speed body motion control, and reduced bump forces. These advantages are obtained somewhat at the expense of large motion control and wheel control. Lower levels of digressiveness favor motion progressiveness and smoothness, and wheel control. See [Figure 2](#). Either extreme or solutions in between can provide adequate damping; however the best overall vehicle performance is achieved when digressiveness is optimized to the requirements of the application.

## How Digressive Shape is Created in Dampers

Digressive F-V properties can be created by two types of force blow-off devices: coil spring blow-off and pre-loaded deflected disc valving. When used separately or in combination, hydraulic flow ports in the damper piston or base-valve casting are blocked off by a cover disc held closed by a pre-loaded spring element. As the damper is displaced by road inputs, hydraulic pressure builds against the cover disc until the resulting force exceeds the pre-load force. At this point, the valve opens creating the “blow-off” transition, or “knee in the curve”. As stroking velocity increases further, force buildup is modulated by the expanding curtain area caused by additional spring deflection.

## Deflected Disc Function

Until the early 1980's the primary pre-load device was a tunable coil spring pre-loaded against a floating non-clamped cover disc. With this system, selection of the spring for mid-speed control is relatively straightforward; there are a limited number of spring pre-loads arranged in discrete steps. With deflected disc valving, the function of both spring element and cover disc is served by a tunable stack of clamped deflectable discs. Pre-load force holding the stack in the closed position is produced by hub offset on the clamping surface of the casting (the outer ring, or annulus, is at a higher elevation than the hub surface). See [Figure 3](#). This offset pre-bends or displaces the disc stack when it is clamped into place. See [Figure 4](#).

Prior to the blow-off point (in the low-speed bleed range), oil flows through a fixed orifice, and the force increases quadratically with velocity. Above blow-off, the greatly reduced slope of the F-V curve is controlled by disc stack stiffness. During tuning, when the stack is adjusted to alter mid-speed force, the slope also changes, affecting shake, bump force, wheel control, and large body motion damping in the vehicle. To change the blow-off point or slope independently, adjustments must be made to both the stack and hub offset.

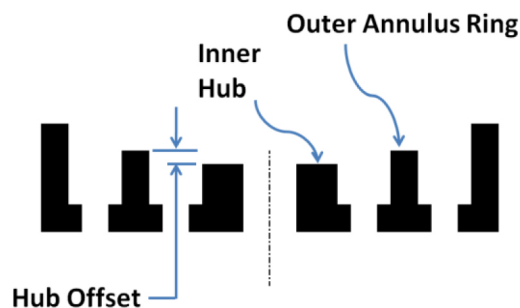


**Figure 3. Damper Piston Cross-Section**