

A Study of Parking Brake Cable Efficiency as Affected by Construction Type

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ABSTRACT

This paper studies the effects of various types of parking brake cable construction on parking brake system efficiency. Testing was conducted on a variety of common cable constructions from several industry sources. Cable construction variables include different types of conduit and wire strand. Input travel, input force, output travel, and output force were carefully measured under controlled conditions. Force, travel and hence work efficiencies were calculated and analyzed to identify any differences that might exist under the defined test conditions. Conclusions were drawn that might provide direction for improving parking brake system designs that have performance issues caused by poor cable efficiency.

INTRODUCTION

A conventional mechanical parking brake system in today's modern vehicle consists of numerous components, all of which introduce mechanical losses into the system. These components include the parking brake lever (hand or foot operated), the rear brake (drum brake, drum-in-hat, or integral park brake caliper) the connecting cables, and finally the various brackets and body panels. The sum of these losses can lead to difficulty in meeting the basic requirement of parking the vehicle to the legally mandated requirements, or in meeting customer requirements for feel and effectiveness. Although any one part can be insufficiently designed so that it results in unacceptably large force or travel losses, the parking brake cables may present a particularly interesting opportunity for improving parking brake system performance. For a typical system in which the components are well designed, the cables exhibit one of the highest mechanical losses, even in the best designs.

This paper explores the mechanical efficiency of a variety of cable constructions from several industry leading cable suppliers. It seeks to dispel or confirm the conception that various constructions are universally more efficient than others, or that suppliers produce a generic product for any fixed set of cable construction configurations.

In discussions of parking brake system design, it is common to refer simply to cable efficiency as if it were a single entity. But in order to get a more complete understanding for the purposes of a thorough analysis, and to achieve optimized results within the scope of a vehicle application, it is important to distinguish between force efficiency and travel efficiency. When combined properly, these two terms make up work efficiency; the efficiency of the cable to transfer work at the input end of the cable to the output end of the cable. Because the force developed in the parking brake system is not constant with increasing travel, work is not the simple product of force and travel, but rather the correct definition of mechanical work is given by one of the simplest of physics formulas:

$$W = \int_0^x F \cdot dx$$

Where;

W is mechanical work;

F is the cable force vector at any position x;

dx is the incremental position vector along the force travel curve;

x is the total travel of the cable.

We define force efficiency as:

$$\eta_F = (F_{out} / F_{in}) \times 100\%$$

where;

η_F is force efficiency

F_{out} is cable output force

F_{in} is cable input force

And we define travel efficiency as:

$$\eta_T = (T_{out} / T_{in}) \times 100\%$$

where;

η_T is travel efficiency

T_{out} is cable output travel from zero to x (lever at rest position to lever at any apply position)

T_{in} is cable input travel from zero to x (lever at rest position to same lever apply position)

And we define work efficiency as:

$$\eta_w = (W_{out} / W_{in}) \times 100\%$$

Since

$$W_{in} = \int_0^{x_{in}} F_{in} \cdot dx$$

And

$$W_{out} = \int_0^{x_{out}} F_{out} \cdot dx$$

where;

x_{in} is cable travel at the input end of the cable

x_{out} is cable travel at the output end of the cable.

Then it follows;

$$\eta_w = \frac{\int_0^{x_{out}} F_{out} \cdot dx}{\int_0^{x_{in}} F_{in} \cdot dx}$$

Embedded in this equation are both force and travel elements, hence both have direct and independent roles in determining the final work efficiency of the system. But in a cable system, the factors that influence force efficiency and travel efficiency are often different. As a starting point, cable construction would seem to be a good place to start to explore the overall efficiency of parking brake cables. Since similar constructions are available from several commercial sources, further exploration into variation from this factor can also be examined.

METHODOLOGY

TEST STAND DESIGN

The first step in conducting this test plan was to conceive, construct and validate a test stand that would provide accurate measurements of input force and travel, and output force and travel under realistic and repeatable conditions. Additionally, the test stand had to allow for efficient loading and unloading of test samples. After several development iterations, the test stand in [Figure 1](#) was validated.

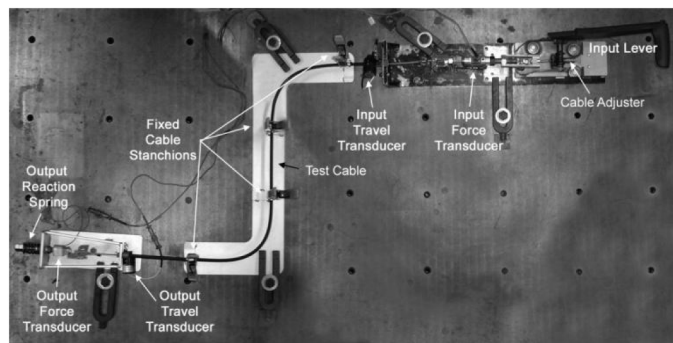


Figure 1. Cable Test Stand

Key elements of the test stand include analog force and travel transducers at both the input and output ends of the cable, and fixed stanchions for consistent positioning of the cable. The data acquisition specifications are presented in [Table 1](#). Input force and travel was obtained by use of a production hand lever with a total travel of 26 mm. A simulated output load was accomplished using a heavy spring resulting in a nominal value 1500N at full input travel. Cables were routed in a fixed position and were designed to be similar to a typical center mounted hand brake vehicle configuration. The two bends in the cable were designed to be a radius of 115 mm.

Table 1. Data Acquisition System Specifications

Input Force Transducer	GSE Model 1154-2k Load cell (2000lbs load cell)
Output Force Transducer	Sensor Development Model 10192-052 (500lbs Load cell)
Input and Output Travel Transducers	Patriot Model MP-15A String Pot Transducer
Data Acquisition	National Instruments PCI-MIO-16XE-10 Data acquisition card

A jig was used to mark each cable sample with four fixed locations along its length. The cable was then clamped into the fixture at these common locations using simple spring clamps.

It is important to note that this configuration results in a fixed input travel, with output travel, output load, and hence input load, all dependent ultimately on the travel and force efficiency of the test sample. It also is important to understand that the data acquired from this fixture were unique to this specific cable routing. They were not intended, nor do they represent identical results to an actual vehicle configuration. But the results were expected to be similar when comparing one cable to another.

TEST PROCEDURE

Considerable effort was made to develop a test procedure that would result in efficient generation of data with a minimum of test to test variation. Ultimately, the following procedure was developed.

- Install cable in test stand.
- Tighten cable adjuster until moderate tension is achieved.
- Fully stroke input lever three times.
- Back off adjuster until full cable slack is achieved.
- Zero force transducers.
- Tighten cable adjuster until 10 N force is measured at cable output.
- Zero travel transducers.
- Set software to acquire data
- Stroke input lever to full travel and pause momentarily.
- Return lever home position.
- Stop data acquisition.
- Verify appropriate acquisition of data.

CABLE SAMPLES

Since the purpose of this test was to compare the performance of various cable designs, samples needed to be acquired. Four leading industry cable suppliers were solicited to provide samples of their various cable constructions. Standard test dimensions were provided to the suppliers along with a request for particular cable constructions. The samples were catalogued for future use. The samples covered a wide range of both strand and conduit constructions. In order to get an objective comparison and a valid statistical analysis, the experiment was narrowed to a $2 \times 2 \times 3 \times 4$ matrix; two different strand constructions, two different conduit constructions (four combinations total), three samples of each, and four suppliers for a total of 48 samples. These combinations were chosen due to their representation on a wide range of vehicles designed in North America, Western Europe and Asia. The test sample array is shown in [Table 2](#) for a single supplier, and is shown graphically in [Figure 2](#).

Table 2. Test Sample Array

	Flat Wire Conduit	Twin Wire Conduit
1 x 19 Strand	3 Samples	3 Samples
7 x 7 Strand	3 Samples	3 Samples

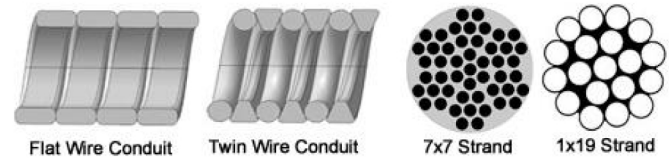


Figure 2. Typical Conduit and Strand Constructions

TEST STAND VALIDATION

Before testing of the complete array could begin, the test stand was validated by choosing a single sample of three different cable constructions that were expected to have a significant difference in performance. Each cable was tested three times for a total of nine tests. A test number was assigned to each and the test numbers were then randomized. Samples were tested in random number sequence.

The data was plotted and is presented in [Figure 3](#). The output travel versus input travel curves show that for a common input travel, the samples had somewhat different output travel. This can be seen clearer when looking at the efficiency curves. Here we saw a clear distinction in the travel efficiencies in the three samples. Additionally, we saw good repeatability within each sample.

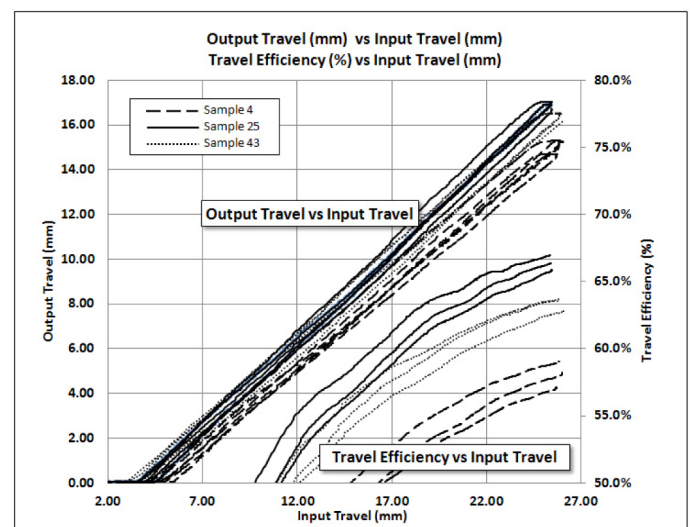


Figure 3. Test Stand Validation - Output Travel and Travel Efficiency vs Input Travel