XL CILAMCE
IBERO-LATIN AMERICAN CONGRESS ON COMPUTATIONAL METHODS IN ENGINEERING
NOVEMBER 11-14, 2019
Praiamar Natal Hotel & Convention
Natal, RN-BRAZIL

MODELING FOR SIMULATION AND NUMERIC ANALYSIS OF CREEP GROAN IN DISC BRAKES

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Abstract. According to Brecht, Hoffrichter & Dohle [1], Creep Groan is a low frequency noise, from 20 to 200 Hz, that appearing in automotive brakes, mainly in automatic transmission cars, occurring in disc brake systems at low pressure and velocity conditions, i. e., in the beginning of movement and instants previous a complete stop. The Creep Groan noise may be easily identified by drivers and passengers which impacts directly the impression about the vehicle quality and reliability. Thus a better understanding of the parameters that cause the phenomenon is necessary to mitigate it and provide greater comfort to the passengers. Considering the existing means to study the phenomenon, a computational model was developed to numerical analysis focusing in the friction coefficient variation, so it may be compared to experimental test results. The model was developed aided by the MATLAB software. The model consists in a disc brake system simplification, a spring-mass model with one degree of freedom, so the movement and forces patterns may be easily described and understood.

Keywords: Creep groan, Model, Simulation, Numeric Analysis, Vibration

1 Introduction

The disc brake is composed by several elements, its operation goes by a hydraulic pressure that is transformed into a mechanical force which induces the contact of the brake pad against the disc brake, generating friction. Due to this operation the system produces an unwanted noise and of low frequency, called Creep Groan. In order to mitigate the Creep Groan phenomenon it is necessary to comprehend the parameters of its cause, therefore it is necessary to do experimental tests to categorize it, althoulg, those processes are costly considering time and cost. According to Fuadi, Adachi, Ikeda, Naito & Kato [2] the industry spends almost US$100 million a year in warranty claims alone.

In the last years the technological advance on computational technology allowed that numerous methods were incorporated on the research of those phenomena. The present study use a disc brake system simplification, with the intent of describing and comprehending the pattern of the movement and forces by a computational model on MATLAB, developed to numerical analysis focusing on the friction coefficient variation.

2 Scope

In this research were sought to test and compare mathematical models of the stick slip phenomenon to add on practical future experiments, yet to assist academic studies and works on the area.

3 Modeling

There are several models already proposed in the literature, as showed, e.g., by Bengisu [3], Oehlmeyer [4] and Fransson [5], and, for simplicity sake, the one degree of freedom model was chosen to be studied in the present work. It consists in a system with three elements: a mass, a spring and a belt conveyor. The brake pad is represented by the mass, the belt conveyor represents the disc brake and the spring is related to the system's rigidity, as showed in Fig. 1. In addition, Fig. 2 presents the free body diagram of the mass.

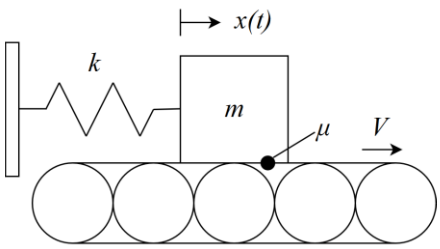

Figure 1. One degree of freedom model.

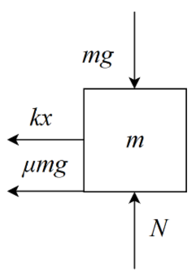

Figure 2. Free body diagram of the mass.

Where m is the mass, k is the spring stiffness, g is the gravity, N is the normal force, x is the displacement of the mass, $\dot{x}$ is the absolute velocity of the mass, $\ddot{x}$ is the absolute acceleration of the mass and μ is the friction coefficient. Kang [6] proposes a second degree differential equation to describe this model, adapted to the Eq. (1).

$$m\ddot{x} + \mu \cdot N + kx = 0 \qquad (1)$$

In addition, Suetti [7] proposes different friction coefficient behaviors, some of which depend on the relative velocity, v_{rel}, between the mass and the belt: constant kinetic friction coefficient, linear and exponential transitions between friction coefficients, presented respectively in Eq. (2) to (4).

$$\mu = \begin{cases} \mu_s\,, & when\ v_{rel} = 0 \\ \mu_k\,, & when\ v_{rel} > 0 \end{cases} \qquad (2)$$

$$\mu(v_{rel}) = \mu_k + \frac{(\mu_s - \mu_k) - (h - v_{rel})}{h} \qquad (3)$$

$$\mu(v_{rel}) = (\mu_k - \mu_k)e^{-h \cdot v_{rel}} + \mu_k \qquad (4)$$

To the linear and exponential transitions between friction coefficients models the additional dimensionless constant h is employed, which represents the transition's subtleness. Moreover, the subscriptions s and k to the variable μ are related to the static and kinetic nature of the friction, respectively.

4 Numerical simulation

To solve the listed equations and characterize the system's behavior, an algorithm was coded on the software MATLAB, collecting the values of the variables within an interval of 4 seconds and plotting the graphs of the Fig. (3) to (5). Values for the initial conditions were set based on Suetti [7], as follows: μ_s = 0.6, μ_k = 0.3, k = 50 N/m, m = 1 kg, g = 9.81 m/s² and V = 1 m/s.

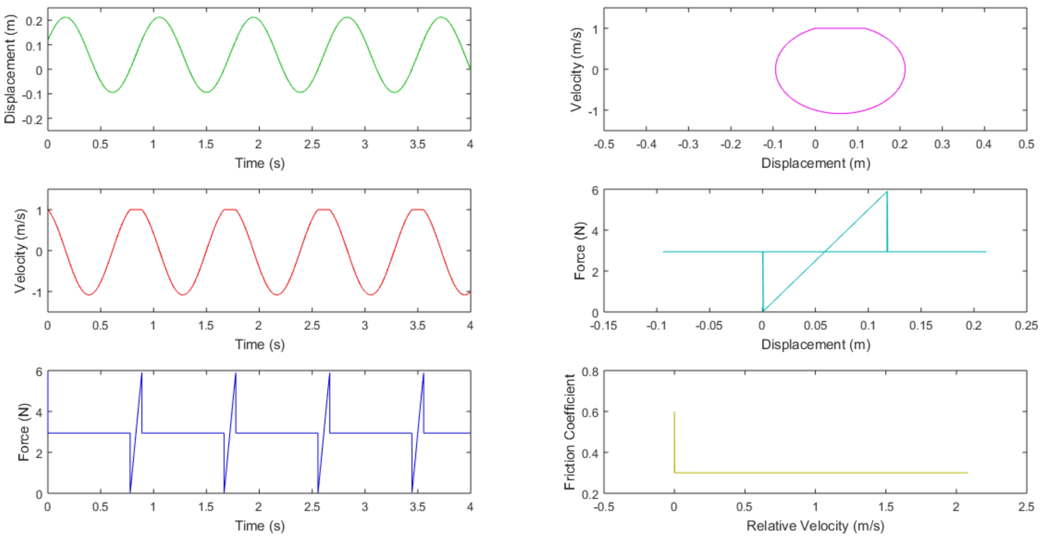

Figure 3. Constant kinetic friction coefficient.

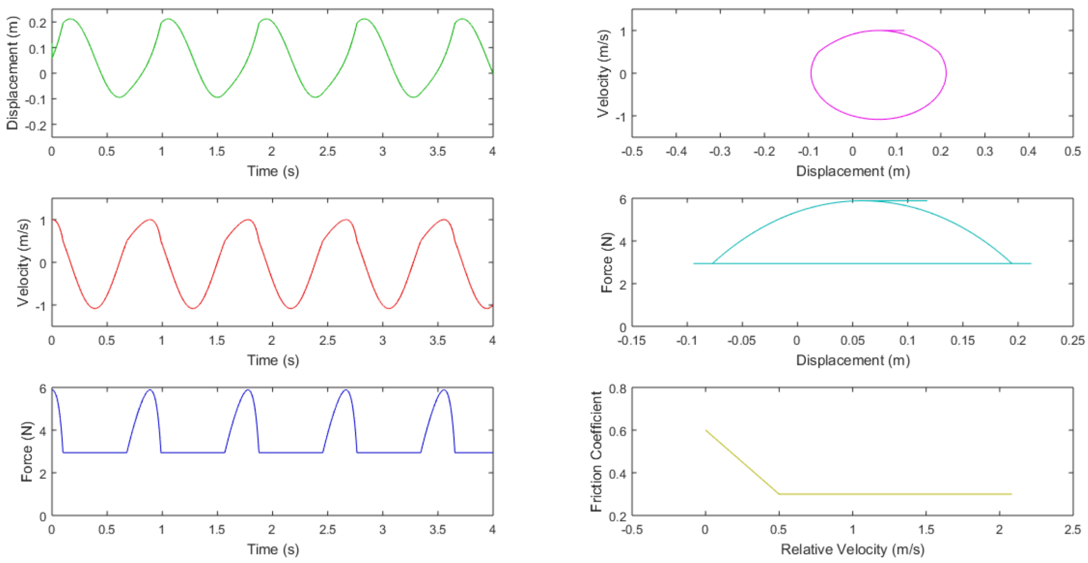

Figure 4. Linear transition between friction coefficients.

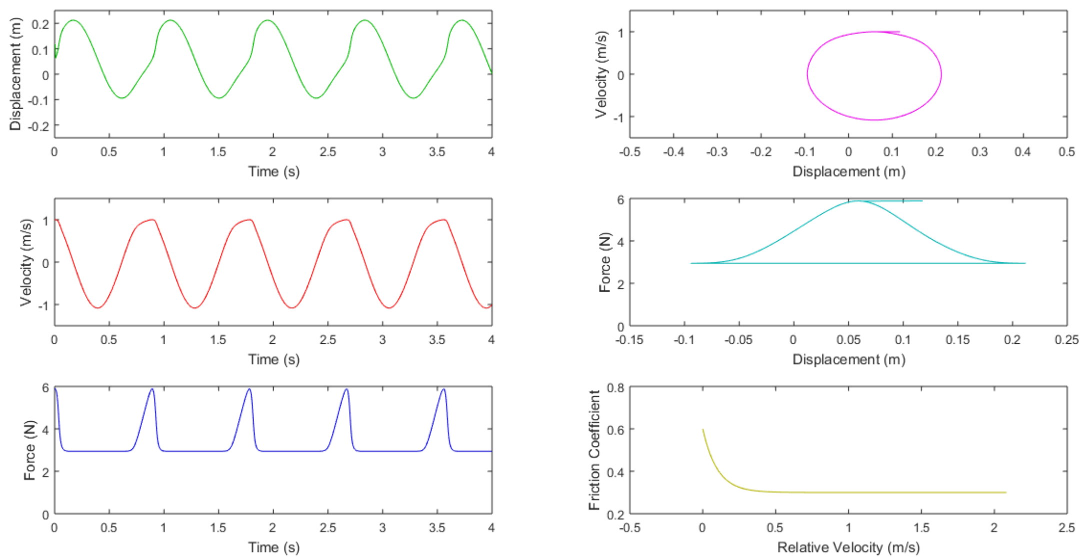

Figure 5. Exponential transition between friction coefficients.

The values applied were h = 0.5 and h = 10 to the linear and exponential transitions models, respectively.

The stick phase is easily identified on the graphs containing the velocity, once it changes the sine pattern as it gets closer to its peak that is also the belt's speed. Furthermore, the plots displaying the force explicit the shift it suffers during the transition from and to stick phase.

5 Conclusion

The models behave similarly for most of the slip phase, differing mainly during the transition of phases. In fact, the linear and exponential transition models indicate that the stick phase is a limit rather than well-defined phase, meanwhile the constant kinetic friction coefficient model points a period that stick occurs.

Because of their differences, the models may be satisfactory depending on the physical system or the necessary accuracy and the constants' values may be optimized to match experimental results. Although, the algorithm coded to this work is only usable for the non-constant transition models in a limited range of constants' values, for example, as the friction coefficients get closer to each other the simulations present instabilities and the stick slip behavior gets compromised. So it is necessary to improve the algorithm to become more robust and describe the phenomenon to any input values.

Acknowledgements

We thank to Universidade Federal do Ceará and to all the employees of the educational institution for all the support and to proportionate a propitious environment to develop our research, especially to our teacher and advisor Rômulo do Nascimento Rodrigues, for his commitment to the project. We thank too to ours parents, friends, work and research partners, for all the help and support during this important phase.

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