

Study of Frequency Characteristics of Vehicle Motions for the Derivation of Inherent Jerk

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ABSTRACT

Jerk in a vehicle is a feel of user which appears due to sudden acceleration changes. The amplitude and frequency components of the jerk defines quality of an engine or an AMT calibration tuning. Traditional jerk evaluation methods use amplitude (peak) of the jerk as a performance index and its frequencies are either used as weighing factor with amplitude or not taken into account. A method is proposed in this paper to quantify and differentiate the non-acceptable level of jerk which is perceivable to human body.

Jerk is obtained by differentiating the acceleration data which contains the frequencies in the lower to higher range. Differentiation of such signal causes an amplification of undesired noise in both analog and digital circuits. This results in significant loss or disturbances in the useful data. In the process of filtering out such unwanted noise or signals, frequency characteristics of test data collected on vehicle in different driving conditions are analyzed for the identification of predominant frequencies. A Butterworth low pass filter is implemented for the analyzed cutoff frequency to remove the undesired signals from acceleration data thus ensuring analysis on actual jerk. This filter has the advantages of low order and higher attenuation of frequencies in pass band, improving the stability and accuracy of its response. The results are verified by carrying out subjective and objective assessment on test vehicle for perceivable jerk.

The present work derives comprehensive method which can differentiate desired and perceivable frequencies from the test data and quantifies the actual jerk.

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INTRODUCTION

Jerk is defined as rate of change of acceleration with respect to time, that is,

$$\text{Jerk} = \frac{da}{dt}$$

where a denotes vehicle acceleration and t denotes the time. When we are in a moving vehicle and feel a jolt or a sudden shock, we are actually experiencing change in vehicle acceleration, or the jerk, of a vehicle. Prolonged exposure to such jerk of a vehicle will lead to ride discomfort and even weaken the health of driver and passengers. The human body responds very quickly to rates of change in acceleration rather than the actual velocity of the vehicle. With the rate of change of acceleration, the forces upon the body change and if severe enough, the vehicle passengers or driver will start to become uncomfortable. Thus it is needed to be controlled in acceptable manner.

Jerk is commonly considered as an objective performance index of shift quality or ride quality [1]. Nowadays Jerk has attracted more

attention in the area of vehicle design and control. The amplitude and frequency components of the jerk defines quality of an engine or an AMT calibration tuning. The acceleration data contains the frequencies in the lower to higher range. Differentiation of such data signal to obtain the jerk causes an amplification of undesired noise in both analog and digital circuits. This results in significant loss or disturbances in the useful data. To solve this problem, to measure the jerk without differentiation, different jerk sensors were proposed. But those sensors have their own drawbacks and restrictions of operations at lower frequencies and nonlinear phase distortions. This also leads to distortion in the output signal as input signal comprises of different frequency components.

Thus differentiating the acceleration signal remains the appropriate way to obtain the actual jerk. In the present work, we are analyzing the frequency characteristics of the different vehicle motions in all possible driving conditions. A method is proposed to quantify and differentiate perceivable frequencies from the test data and quantify the actual jerk.

FREQUENCY CHARACTERISTICS ANALYSIS OF VEHICLE MOTIONS

Jerk is the derivative of acceleration and acceleration is the derivative of velocity of vehicle. Therefore each of the three signals, velocity, acceleration and jerk comprises of same frequency components. Only the distribution of frequency components of those signals differs.

In order to study the frequency characteristics of the actual jerk, we can study the same for velocity and acceleration of the vehicle. We carried out the tests in different driving patterns to get the velocity and acceleration signals. Different test conditions are shown in [table 1](#).

Table 1. Test Conditions description

Parameters	Description	
Vehicle Models	Pickups	
Driving Patterns	Accelerator Throttle Position	0-100%, 20-80%, 25-100%, 50-100%
	Starting Engine Speed (RPM)	1000RPM, 1250RPM, 1500RPM, 1750 RPM, 2000RPM
	Gear No	1,2,3,4,5,6
Instruments	1) Data Acquisition System 2) MEMS Accelerometer 3) L350 Optical Sensor	
Location	Straight High Speed Track	

In different driving patterns, vehicle was driven considering different engine speed with different initial throttle conditions as mentioned in [table 1](#). In addition to the conventional driving, haste starting, repeated shifting, part throttle driving conditions were carried out to find and analyze the actual jerk.

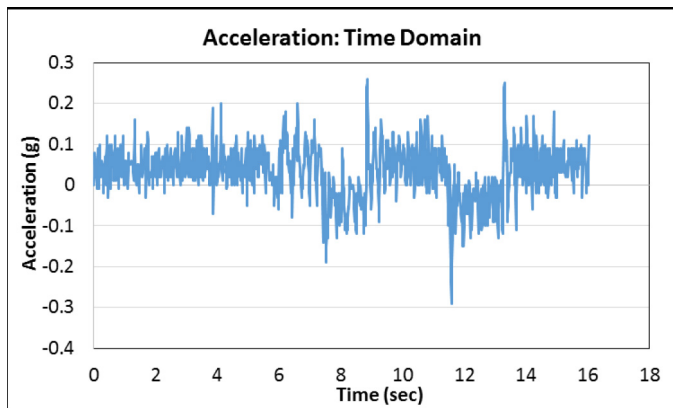


Figure 1. Vehicle Acceleration Data

Accelerometer used for the longitudinal acceleration of the vehicle was MEMS (Micro Electronic Mechanical System) type. In most of the MEMS accelerometer polysilicon string is used to build mechanical structure. This mechanical system is designed to realize a variable capacitor. But it is very sensitive to the vibration arisen from the uneven road surface. This is the primary source of the noise which gets induced in the acceleration output. Thus to identify

significant data, we found out the Fast Fourier Transform (FFT) of the acquired acceleration data. [Figure 1](#) shows the original acceleration signal and [figure 2](#) shows its Fast Fourier Transform.

From these figure we can see that low frequency signals are predominant in the acceleration data.

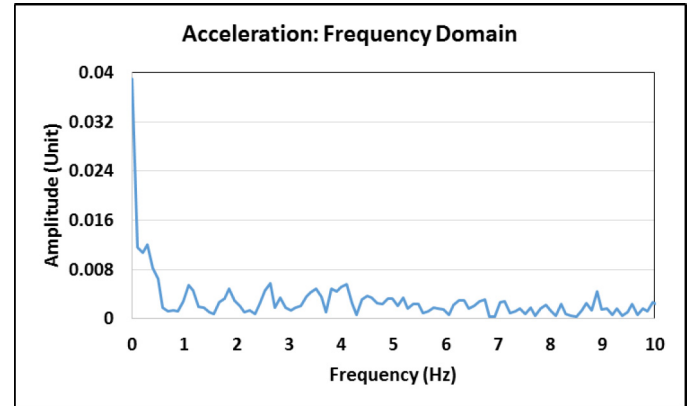


Figure 2. FFT of Vehicle Acceleration Data

Similarly the velocity data was analyzed as shown in [figure 3](#) and [figure 4](#). From the frequency analysis of vehicle motions we found that vehicle and acceleration signals mainly comprise of low frequency components. From [figure 2](#) and [figure 4](#) it can be seen that the power spectral density decreases as the frequency goes on increasing. So we can conclude that the vehicle motions contain the significant data between 0 to 3Hz.

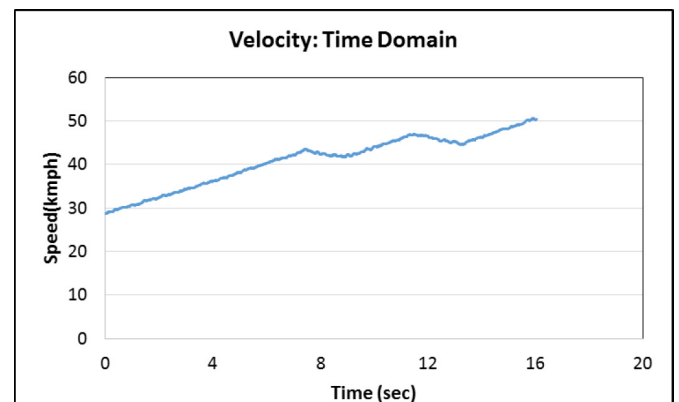


Figure 3. Vehicle Velocity Data

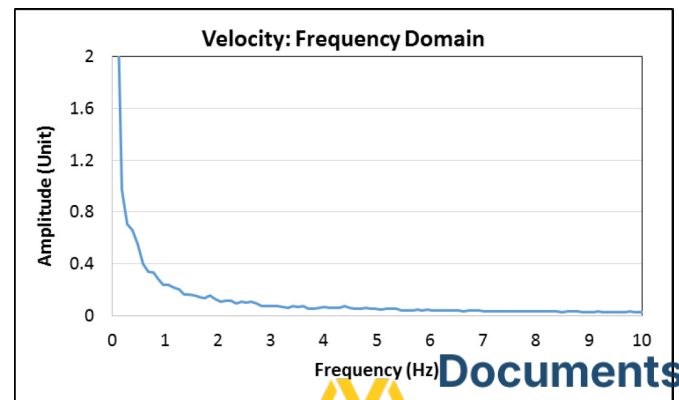


Figure 4. FFT of Vehicle Velocity Data