IOP Conference Series: Materials Science and Engineering

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To cite this article: Wei Zhou *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **768** 042032

Summary of research on road roughness

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Abstract. Road roughness is a key factor affecting vehicle ride comfort and occupant comfort. It is the basis for road grade evaluation and also determines the dynamic load of the vehicle. Measuring road unevenness is often used to evaluate the quality of road construction. However, with the development of smart cars, in order to adjust the speed and suspension parameters in real time according to the road roughness, to improve the ride comfort, the method for measuring the road unevenness in real time becomes New research hotspots. This paper firstly introduces the indicators and standards for evaluating road roughness, and then summarizes the research progress and direction of road roughness from both direct measurement and indirect identification. Among them, the methods of non-direct identification of road roughness are highlighted, which are classified into laser sensor based recognition, vibration model based recognition and neural network based recognition.

1. Introduction

Road roughness refers to the change of the road surface relative to the reference plane height along the road length. It is usually used to describe the undulation of the road surface. It is the main incentive during the driving process of the vehicle, affecting the ride comfort, ride comfort, steering stability, Parts fatigue life, transportation efficiency, fuel consumption and other aspects. Therefore, for automotive engineer, research and analysis of road roughness is of great significance[1].

The instruments and measurement methods used are generally suitable for situations where the road surface is not undulating and the frequency of use is low. However, with the development of smart cars, unmanned vehicles usually need to adjust the speed in real time by recognizing the road roughness, and even install smart suspensions that can mainly adjust the suspension parameters on high-class cars and off-highway vehicles, such as MBC(Magic Body Control) of Mercedes-Benz. control technology is to identify the road surface undulation in front of the vehicle by the camera placed in front of the vehicle to achieve the purpose of actively adjusting the suspension. This identification of road roughness places higher demands on real-time and reliability. First of all, in the process of driving the car, it is necessary to reduce the time to calculate the current road roughness as much as possible to achieve the purpose of real-time adjustment of the speed and suspension. Secondly, the roads for the vehicle are varied, and the road roughness identification algorithm must be more Strong robustness. This paper summarizes the research directions and progress in identifying road roughness in recent years, which can be used as reference for researchers in related fields.

2. Road surface roughness evaluation indicators and standards

2.1 International Roughness Index

In 1982, Sayers et al., under the auspices of the World Bank, used 11 different road surface roughness measuring instruments in countries such as Brazil to conduct the International Road Roughness Experiment (IRRE). The international standard IRI for road surface roughness measurement is used to promote the exchange of relevant international institutions. IRI can reflect real road elevation information and is usually used when it is necessary to describe the true contour of the road. IRRE is the ratio of the cumulative elevation of the road surface driven by a quarter-vehicle model traveling at 80km/h to the length of the test road. Index in m/km[2].

2.2 Power Spectral Density

The power spectral density indicates the finite mean square value of the signal in the unit frequency range. In the latest international standard ISO8608-2016, the displacement power spectral density and velocity power spectral density are mainly used to describe the vibration statistical characteristics caused by road roughness[3].

2.3 Standard Deviation

The standard deviation is usually used as an evaluation standard when using continuous measuring instruments. It is often used to evaluate the construction quality and quality of the road surface, but it is not suitable for measurement on roads with many pits and severe damage. In the actual measurement, the vertical displacement of the road surface is measured by the measuring instrument, that is, the road surface elevation change, and then the standard deviation of the elevation change is obtained. For example, the eight-round flatness meter is based on the plane touched by the eight wheels, and collects the vertical displacement values of the longitudinal fixed interval of the road surface, and then calculates the variance of the obtained data, the variance and the standard deviation. At this time, the smaller the variance, the higher the level of the road surface, and the lower the level of flatness.

2.4 Profile Index

The profile index is used to evaluate the road roughness of the tire track measured by the cross-section measuring instrument. In the actual measurement, the 7-meter crossbar is used as the reference displacement, and the vertical undulation of the surveying wheel is recorded with a tape recorder according to a certain ratio to form a longitudinal sectional view of the road surface. According to the different national regulations, blank strips with different widths are generally developed, generally 0 to 5 mm. When the blank strip width is 0, the resulting cumulative height is called cumulative unevenness. Place the blank strip at the center of the section, add the height above or below the blank strip, and divide by the horizontal distance. The resulting value is the profile index PI.

3. Road roughness measurement method

The evaluation method of the road roughness including direct measurement and indirect identification according to whether or not the computer is used for data processing, and the elevation of the road roughness is usually measured by using a wheel that is in contact with the ground; the method of indirect identification including the recognition based on the laser sensor, identification based on vibration model and recognition based on neural network.

3.1 Direct Measurement

A test instrument designed for the soft road surface roughness designed by Jilin University of Technology in 1990. As shown in Figure 1, three accelerometers mounted on the test wheel axles of the tester are used to measure when the tester is towed. The acceleration signal on the axle is sent to the tape drive through the charge amplifier for recording or sent to the computer, and the original road surface roughness is obtained after analysis [4]. Other measuring equipment is similar to the above instrument.

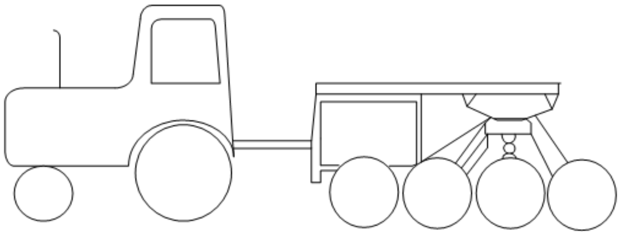

Figure.1 equipment of soft road roughness measuring

3.2 Indirect Measurement

Since the 1990s, the measurement method of road roughness has gradually evolved from direct measurement to recognition by a combination of laser sensors, acceleration sensors, displacement sensors, and computers.

3.2.1 Laser Based

The key to laser recognition of road surface roughness is how to eliminate the vibration of the vehicle body to ensure that the laser range sensor can obtain real road elevation information. The general solution is simply to measure the vertical acceleration of the car body by the accelerometer. The acceleration value is integrated twice to obtain the vibration displacement of the vehicle body, and then the laser measured distance is subtracted from the vibration displacement to obtain the true elevation information of the road surface. Feilong Liu designed a mobile off-highway topographic measurement system OUS-TSMS, as shown in Figure 2. The system uses five laser sensors to measure the terrain, and is equipped with an inertial measurement unit and GPS to achieve centimeter-level accuracy data [5].

Figure 2. OUS-TSMS[5]

3.2.2 vibration model

In addition to the method of reproducing the road surface with a laser, it is also possible to install a displacement or acceleration sensor on the wheel and the body to obtain the displacement or acceleration response of the vehicle, and calculate the road surface pair by establishing an accurate vehicle vibration model and a transfer function of the vehicle system. The vehicle's excitation, in turn, identifies road roughness. This method usually requires accurate vehicle models and vehicle vibration parameters, which are less accurate and less real-time than laser recognition methods. However, this method only requires a number of sensors on the vehicle, which is lower than the laser identification method. The basic principle is that the displacement signal or the acceleration signal is obtained through the vibration model to obtain the excitation signal of the road surface, and then the power spectral density of the excitation signal is obtained, and the corresponding road surface level is obtained. Cao Yue of Jilin University established C-class, D-class, and E-level road surface excitation models for Reloadyn/Colink for the classic loader, and analyzed the body acceleration response of the loader under different road excitations and different driving speeds. According to the response of the vehicle, the parameters of the oil and gas suspension are optimized, which reduces the vibration of the vehicle body and increases the driving comfort[6].

3.2.3 Neural Network Based

The neural network can directly train the road excitation and the vehicle response as input and output, and obtain the relationship between the two, without the complicated work of establishing the model and the transfer function. Firstly, the excitation signal of the known grade road surface and the corresponding vehicle response signal are collected and divided into training set, test set and verification set. Then the neural network is trained by training set and test set, and the verification set verifies the accuracy of the neural network. Finally, after inputting any vehicle response, the corresponding road grade can be obtained. Harry.M. Ngwangwa studied the road roughness of mine roads with the study of super-large mining trucks. It is difficult to establish a mathematical model for a super-large mining truck and to obtain an accurate road surface profile on a walking road surface, resulting in insufficient training data, and the conventional method is no longer applicable. In this situation, he proposed a neural network-based approach that identifies road surface defects and road grade ranges[7].

4. Summary and outlook

This paper introduces the common methods of measuring road surface roughness and the research progress and direction in recent years. After years of research, road surface roughness has gradually become a relatively mature technology. Its application is not only in road construction acceptance and road grade differentiation. In the field of vehicle intelligence, real-time adjustment of vehicle speed according to road conditions and intelligent suspension have gradually become luxury car brands. The standard, which requires real-time, reliable measurement equipment and measurement methods to identify road roughness.

At present, the laser profiler is mainly used to identify road roughness, but the laser profiler is expensive, and the laser is easily interfered by natural factors such as dust. Most of them are used in highway grade evaluation and other fields, and are not suitable for long-term use. The neural network-based method has lower cost and higher precision, and will become a research hotspot of road unevenness in the field of intelligent vehicle research. In the future, the recognition method based on deep learning and reinforcement learning will also become the research direction at home and abroad. Through deep learning and reinforcement learning, the neural network can be adjusted according to different working conditions, which can improve the recognition accuracy.

5. Acknowledgments

This work was financially supported by State Key Laboratory of Intelligent Manufacturing of Advanced Construction Machinery.

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