Design of Stress-Strain Measuring System for Bulldozing Plate Based on Virtual Instrument Technology

S C Xu\textsuperscript{1}, J Q Li\textsuperscript{1} and R Zhang\textsuperscript{1,2}

\textsuperscript{1}Key Laboratory of Terrain-Machine Bionics Engineering (Jilin University), Ministry of Education, Changchun, China.
\textsuperscript{2}Department of Modern Mechanics, University of Science and Technology of China, Hefei, China

E-mail: xushc@126.com

Abstract. Soil is a kind of discrete, multiphase compound that is composed of soil particles, liquid and air. When soil is disturbed by bulldozing plate, the mechanical behavior of the soil will become very complex. Based on the law of action and reaction, the dynamic mechanical behavior of disturbed soil was indirectly analyzed by measuring and studying the forces on the bulldozing plate by soil currently, so a stress-strain virtual measuring system for bulldozing plate, which was designed by the graphical programming language DASYLab, was used to measure the horizontal force $F_z$ acting on the bulldozing plate. In addition, during the course of design, the experimental complexities and the interferential factors influencing on signal logging were analyzed when bulldozing plate worked, so the anti-jamming methods of hardware and software technology were adopted correspondingly. In the end, the horizontal force $F_z$ was analyzed with Error Theory, the result shown that the quantificational analysis of $F_z$ were identical to the qualitative results of soil well, and the error of the whole test system is under 5 percent, so the stress-strain virtual measuring system was stable and credible.

1. Introduction

The constituent of soil is very complex, and the mechanical behavior changing of the soil disturbed by other tool is unstable, so it is very difficult to quantificationally analyze the dynamic mechanical behavior of soil directly. How to use indirect measured magnitude to describe the dynamic mechanical behavior of disturbed soil is very necessary. Based on the law of action and reaction, the dynamic mechanical behavior of soil is often analyzed by measuring and studying the forces acting on the tool by soil currently. The forces subjected to the disturbed soil in the process of working are unstable and variational greatly, and the range of the forces was very large. Therefore, how to design a suitable measuring system is important [1,2]. Today, measure instruments and electronic technology developed quickly, however, as for traditional measure instruments, even if digital instruments and intelligent instruments which heighten the accuracy and function of the traditional measurement and analysis system, they still can not change their some shortcomings, such as single function, handle manipulating, large and ponderous volume, fixed channel number and high cost to develop functions etc. Aimed at the above demerits, a kind of virtual instrument that is developed with PC and correlative software emerged. Based on hardware, the core measure functions of virtual instrument depend on software, so the anti-jamming methods of hardware and software can be used to eliminate disturbance including static, magnetic filed and random error. Because of above merits, a stress-strain
virtual measuring system for bulldozing plate was designed by graphical programming language DASYLab [3-5].

2. Hardware and software design of the stress-strain virtual measuring system

According to the flow of signal, both the measuring theory of the stress-strain virtual measuring system for bulldozing plate and the different anti-jamming measures were shown in Figure 1. In order to improve the measuring accuracy, three demands were put forward as follows. Firstly, the anti-jamming technologies of hardware and software were used to reduce interferential factors correctly; Secondly, size of sample must be same in every experiment, in this way, the acquired data can be analyzed with statistic theory; Thirdly, the interference of random noise must be minimized.

As for hardware component, the stress-strain virtual measuring system was consisted of a piezoelectric three-axis force sensor of Type 9327A, a multichannel charge amplifier of Type 5019B, a signal acquiring and modulating modular of Type Wavebook/512, a high speed parallel conversion card of Type WBK20A, and a notebook PC. The connecting picture of devices is shown in Figure 2, where, a is the sensor of Type 9327A, b is the bulldozing plate, c is the soil bin test-bed, d is the amplifier of Type 5019B, e is the wavebook/512, battery, and WBK20A, and f is the Notebook PC. The sensor of type 9327A must be fixed and validated correctly before experiment. The validated result of $F_z$ was shown as Figure 3. The multichannel charge amplifier was used to convert the electrical charge signal of the sensor into voltage exactly proportional to the force $F_z$. Considered the complicity of soil experiment, the parameters of the charge amplifier, including TS (Transducer Sensitivity), SC (Scale) and LP (Low-Pass Filter), are set accurately. TS is given by the specification of the sensor, so TS can be set directly through the charge amplifier. LP is set 10Hz to eliminate the high-frequency noise in this experiment. The work conditions and the type of soil influence the dynamic mechanical behavior of soil greatly, which result in large range of forces acting on the bulldozing plate. Therefore, the choice of SC should make the displayed voltage approach to the maximum value of the output voltage, and the difference between these two values must be under fifteen percent. In addition, as for anti-jamming of hardware, the alternate magnetic field coursed by the different electrical installations was a main interference source, and changing in the internal electric network, the surge aroused by the operation of switches, starting/stoping of the bigger electrical installations and harmonics brought by AC/DC transmission system, all took bad effect on the measuring system. Therefore, aimed at the above interferences, the shielding technology of anti-jamming was selected to isolate them [6,7]. In the aspect of the data post processing, the virtual measuring system completely substituted for the traditional data processing instrument by fully using powerful functions of computer, including computation, analysis, process and storage, it completed
data real-time processing and analyzing successfully. From above all, compared with the traditional measuring system, about RMB 200 thousand Yuan could be decreased from the cost of hardware.

Figure 2. The connecting picture of hardware.

Figure 3. The validated graph of $F_z$.

Considered the signal features of soil experiment, the stress-strain virtual measuring system was designed by choosing function modules of DASYLab, such as A/D, FFT, Y/t, Switch, Action, Time Base, Bar Graph, Dig.meter, Stop, and Message modules etc, to realize the measure functions in Figure 4.

Figure 4. Software flow diagram of stress-strain virtual measuring system.

Figure 5. Operation panel of stress-strain virtual measuring system.

Additionally, during the course of software design, the experimental complexities and the interferential factors influencing on signal logging were analyzed when bulldozing plate worked, so the anti-jamming methods of software technology were adopted. For example, the best method that dispels the random noise was real-time fitting proposal, so the module, Regression, was set up for least square method. After the above modules were set correctly, the stress-strain virtual measuring system had the functions including data real-time acquisition, data real-time display and storage, and data real-time analysis and control. It can also realize the data replay after experiment [8,9]. Figure 5 shows its virtual operation panel.

3. Results of application and analyses

The stress-strain virtual measuring system for bulldozing plate was substituted for the traditional measuring system, data logging system, and data analysis system on the test of the horizontal dynamic forces acting on the bulldozing plate by disturbed soil. The dynamic mechanical behavior changing process of dry soil and cohesive soil were analyzed under the different driving angles of the bulldozing plate. However, the dynamic mechanical behavior of dry soil was analyzed only in this paper[2].

Figure 6 shows the dynamic changing process of dry soil under two kinds of driving angles (300 and 600). Seen from Figure 6, the upper layer of soils ahead of the bulldozing plate change more quickly than the under layer of the soils. The reason is that the functions of the bottom part of bulldozing plate are cutting soil and driving soil, and that the function of the part far from the bottom is only driving soil. When the driving angle is increased, the disturbance of the soils increase, and the
climbing height of soils along the surface of the bulldozing plate increase too. These phenomena are resulted from the reason that the driving function of the bulldozing plate increase and the cutting function of the plate decrease, and thus the whole disturbance of the soils increases with the driving angle being increased.

Figure 7 shows the forces $F_z$ of the bulldozing plate with different driving angles ($30^\circ$ and $60^\circ$) subjected to dry soil with water content of 6 percent, which are measured by the virtual measuring system. Seen from Figure 7, the rightward horizontal forces $F_z$ increase gradually with time going, and these forces will reach steady values in a certain time. The reason is that soils ahead of the bulldozing plate accumulate gradually, and the magnitude of soil will approach to a constant value in a certain time. In addition, the forces $F_z$ increase with the driving angle being increased. This also indicates that the soils ahead of the bulldozing plate are disturbed to increase in the horizontal direction, and thus to make the whole disturbance of the soils ahead of the bulldozing plate increase with the driving angle being increased. From above all, the qualitative analysis is identical to the above quantificational results well. Therefore, the qualitative and the quantificational analyses of the interactions between a bulldozing plate and the dry soil under different conditions indicate that the virtual measuring system is reliable and accurate in analyzing the dynamic mechanical behavior of disturbed soil.

![Figure 6. The dynamic process of dry soil under two driving angles of the bulldozing plate.](image)

![Figure 7. The forces of the bulldozing plate with two driving angles subjected to dry soil.](image)

4. Conclusion

The qualitative and the quantificational analyses of the interactions between the bulldozing plate and the dry soil under different conditions indicate that the stress-strain measuring system for bulldozing plate based on the graphical programming language DASYLab was substituted for the traditional measuring system, data logging system, and data analysis system on the test of the horizontal dynamic forces acting on the surface of a bulldozing plate by disturbed soil successfully. And what’s more, the stress-strain measuring system also indicated more merits than the traditional system on many aspects. Firstly, its functions, including instrument self-checking, data real-time acquire, data real-time storage, data processing and replay etc, were all completed by the computer, so it had the very high automaticity. Secondly, the data of experiment was analyzed with error theory, the result shown that the stress-strain virtual measuring system had good dependability and high precision. The error of the whole measuring system is under 5 percent, which is satisfied with the soil experiment. Thirdly, it was one tenth of the traditional stress-strain measuring system in volume, and it need not network power supply, so it is very suitable for the field experiments. In the end, it has much higher ratio of performance to price.

Acknowledgments

The project was supported by National Natural Science Foundation of China (Grant No. 50175045), the Science and Technology Development Project of Jilin Province (Grant No. 20050539), the Doctor Subject Special Foundation of College (Grant No. 20050183015), and the 2004 Innovation Foundation of Jilin University.
References
[1] Zeng Dechao 1995 *Dynamics of mechanical soil* (Beijing Science and Technology Press)
[2] Zhang Rui, Li Jianqiao and Cui Zhanrong 2005 Application of piezoelectric three-axis force sensor on mechanical analysis of disturbed soil *Proceedings of the 6th international symposium on test and measurement (Dalian, China, June 2005)* 1-4
[3] Salvatore Nuccio and Ciro Spataro 2001 Assessment of virtual instruments measurement uncertainty [J] *Computer Standards & Interfaces.* 23 39-46
[4] Adrian Mihalciou, Lucian Dascalescu, Subhankar Das, Karim Medles and Radu Munteanu 2005 Virtual instrument for statistic control of powder tribo-charging processes [J] *Journal of Electrostatics* 63 565-570
[5] F.J. Jiménez and J. De Frutos. 2005 Virtual instrument for measurement, processing data, and visualization of vibration patterns of piezoelectric devices [J] *Computer Standards & Interfaces* 27 653-663
[6] Ge Wenfeng 2004 The Hardware of Anti-interference Measures of PLC Control System [J] *Coal Mine machinery* 11 57-59
[7] Quan Li, Chen Zhaozhang, Tang Ping, Cheng Li and Su Qingzu 2004 Design of hardware signal processing virtual instrument [J] *Chinese Journal of Scientific Instrument.* 25 413-417
[8] JinYan, Zheng Jianrong and Wu Qing 2003 Comparison of the realization of signal processing based on virtual instrument technology [J] *Machinery Electronics* 2 55-58
[9] Zhang Zhi-jie 2004 Research on error analysis in dynamic measurement [J] *Journal of test and measurement technology* 18 139-143