Design of and Research of Vertical Deformation Measuring Instrument based on Synthetic Material

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Abstract: With the publication and implementation of the national standard GB 36246 “Sports Ground for Synthetic Materials in Primary and Secondary Schools”, relevant testing activities have come in droves. However, the smooth development of testing requires not only standards, but also corresponding testing equipment. Therefore, in accordance with the requirements of the national standard GB 36246 for vertical deformation measurement indicators, this paper carried out the design and research work of related testing equipment, and successfully developed a synthetic material-based surface Layer vertical deformation measuring instrument, which connects the electromechanical control system composed of electromagnetic control system, main structure, etc. and the data storage and analysis system, realizes the systemization and automatic control of the synthetic material surface vertical deformation measuring device, and meets the national standard GB 36246 and European standard EN14809 “Measurement method of vertical deformation of ground layer of sports field”.

1. Introduction
The synthetic material [1] surface is commonly known as the plastic runway, which is an indispensable building material in the school gymnasium and gym. With the rapid development of national infrastructure construction and the large number of new construction of school sports venues, it is necessary to conduct comprehensive quality control of the synthetic materials used in it and introduce relevant standards. In 2018, the national standard GB 36246-2018[2] “Sports Fields of Synthetic Materials for Primary and Middle Schools” was issued and implemented. However, the testing equipment design and research work related to the national standard GB 36246 is relatively lagging. Under this background, the team launched the design and research work of the instrument for measuring the vertical deformation of the synthetic material surface layer. Based on the vertical deformation tester of synthetic material surface, it has formed the testing ability of more than 10 relevant standards such as GB36246-2018 “Synthetic Material Surface Sports Ground of Primary and Middle Schools”, serving more than 100 related enterprises and units. This article focuses on the design ideas and detailed design contents of the above measuring instruments.

The building materials industry is one of the important industries related to national economy and people's livelihood, and is of great significance for improving the living conditions, governing the improvement of the ecological environment and supporting the virtuous circle of economic development. As a typical manufacturing industry mainly based on kilns and mineral products
processing, the building materials industry has a high degree of dependence on water resources, energy and other resources. Because the building materials industry has always existed extensive production, and slow replacement of process technology equipment, such as water consumption and water pollution, should not be underestimated. As a typical building material product, ceramic tiles (boards) consume a lot of water resources and produce a large amount of sewage during the production process. Therefore, this paper analyses the current status of the water footprint of ceramic tiles (boards), mainly including ceramic tiles (boards) Status of water footprint standard and status of water footprint calculation method of ceramic tiles (boards).

2. Overall design

The design goal is to develop an instrument for measuring the vertical deformation of synthetic material surface. The instrument should have the characteristics of systematic and automatic measurement, easy operation, high test accuracy, small measurement error, high working efficiency, and wide application range.

The design idea is to simulate the movement process of the human body by dropping a certain weight from a prescribed height according to the law of conservation of energy\[3\]. In the whole process, the potential energy of the object is converted into kinetic energy, which has an impact on the test piece. Collect energy data absorbed by the test sample through the impact sensor and transmit it to the computer system. Then the computer system analyses, processes, and calculates the collected data, and finally shows the vertical deformation amount and deformation parameters of the test piece during the entire process.

![Figure 1 Design technical solutions](image)

The design scheme is that the measuring instrument should include an electronic control system, an electromagnet, a test bench, a force measuring device, and a signal amplifier; the electronic control system includes a tension pressure sensor, an electromagnet pull-in control, a power supply module, a controller PLC module, and an analog module. Digital module and human-machine interactive touch screen; the power module is connected to all electrical components and is responsible for providing power supply for the entire testing machine. The input of the analog module is connected to the tensile pressure sensor, and the output is connected to the controller PLC module; digital The input end of the module is connected to the PLC module of the controller, and the output end is connected to the electromagnet; the human-computer interactive touch screen is connected to the PLC module of the controller, as shown in the figure 1.

3. Detailed design content

3.1. Hardware design

3.1.1. Framework

Use 40 × 40mm wall thickness 4mm304 stainless steel square tube as the outrigger, and build the overall frame of the production equipment with 304 processed parts. This material is suitable for the combined structure of the frame with large stress and strength. Its appearance adopts round corner transition, which is elegant and beautiful and resistant to corrosion. Make the whole structure strong
and reliable. Even if there is a large impact load during the test, the device will not generate vibration and offset, thus ensuring the accuracy of the measurement results.

3.1.2. Transmission structure
The electromagnet and manual lifting screw are used to control the weight movement. This method is convenient, fast, and environmentally friendly. It does not cause secondary pressure on the test piece when lifting the weight, which greatly improves the service life of the impact sensor and extends the use time of the equipment. The entire transmission structure avoids hydraulic control, so that the metal components in the equipment will not be corroded due to excessive oxidation, nor will the equipment run smoothly due to oil pollution.

The buffer spring is made of spring steel wire, and the spring is subjected to secondary heat treatment. The heat treatment process greatly improves the toughness and plasticity of the spring and the ability to resist fatigue. Ensure that the buffer spring fully meets the requirements of the standard for deformation during the test of the device.

Displacement measurement components, using well-known brand displacement sensors, are rigidly connected to the equipment through aluminum alloy mounting plates, and the upper and lower positions can be adjusted in height according to the test site and the thickness of the test product. The accuracy can reach the level of 0.02 mm, which greatly improves the accuracy of the settlement measurement of the test article.

3.1.3. Configuration and data of important components
Important components as shown in the figure 2.

![Figure 2 Important components](image)

1 — Heavy weight, quality 20 Kg ± 0.1Kg, with a hard impact needle, the diameter of the needle is generally not less than 20mm
2 — Anvil, the surface hardness is not less than HRC 60
3 — Spring, elastic range 40 ± 1.5N / mm
4 — Guide column, inner diameter 71 ± 0.1mm, the friction resistance generated between the heavy object and the guide column is smaller than the quality requirement of the heavy object, and can reach the guide requirement
5 — Force plate, diameter 70 ± 0.1 mm, the bottom layer of the chassis is arc-shaped, the radius of the arc is 500mm, and the thickness is at least 10mm
6 — Displacement sensor, effective range 12mm, accuracy 0.02mm

3.1.4. Test technical parameters
Power supply: 220V ± 10%, 50Hz
   Data processing capacity: Max 20 kHz
   Fine adjustment range: 40 mm
   Limit bearing impact force value: 0.5T
   Impact force resolution: 0.01N
The distance between the bottom of the impact needle and the anvil (weight drop height): 120mm ± 0.25mm
Force measuring mechanism: accuracy 0.5%, conversion speed 0.3 ms
Deformation measuring mechanism: precision 0.02mm, conversion speed 0.3ms

3.2. Software design
Using NI company Labview[4] genuine software as the working platform, using NI's high-speed acquisition board, using high-speed loop mode to collect sensor data, and using high-precision analog-to-digital conversion programming, the collected signals are recorded and stored in real time. And generate real-time curves.

Design a visual man-machine interface, set parameters on a tablet, view data and curves, and operate and manage in an intuitive way.

The breakthrough data stream is used to process a large amount of real-time data, breaking through the restrictions of the data stream, repackaging and reprocessing all data, and finally performing curve fitting and data calculation, and recording the measurement data. The system schematic diagram is shown as 3.

The load sensor is a double-shielded line pressure sensor with high filtering capability and high sensitivity. The resolution is 0.5% FS and the dynamic step response speed is 0.1ms. The sensor and the high-speed NI acquisition board with a collection speed of 200KHz Connected to form a control signal acquisition system, used with NI's genuine Labview, this data acquisition method completely avoids the influence of low-frequency Gaussian noise[5], and ensures that all data during the test can be accurately recorded for data analysis.

The displacement sensor adopts Keyence high-precision displacement sensor, with an accuracy of up to 1um, and amazing detection duration. The sampling period is 1ms. The displacement sensor is connected to a high-speed NI acquisition board and used with NI Company's genuine Labview to record the test in real time. All data in the process and generate curving. The human-machine interface as shown in the figure 4.

Figure 3 System schematic
Figure 4 The human-machine interface
The Visualized man-machine operation interface, parameters can be set on the tablet, and data and curves can be viewed.

The transmission part of the equipment uses electromagnet and manual lifting screw to control the movement of the weight. In order to prevent the weight from causing a second pressure on the test piece and ensure the safety of the operator during the sudden power failure, the permanent magnet is included in the way Realization: Before the measurement, due to the permanent magnet, the weight is fixed. After the electromagnet is activated on the operation interface, the electromagnet will cancel the magnetic field of the permanent magnet, the permanent magnet fails, and the weight falls.

4. Instrument determination method
According to national standard GB 36246-2018 and IAAF and European standard EN14809-2003[6]. When testing the vertical deformation value of the synthetic material sample, place the testing instrument vertically on the synthetic material sample, adjust the lower end of the falling weight to be directly above the anvil (120±0.25) mm, release the falling weight Free fall hit the anvil. Record the deformation value of the surface of the synthetic material during the impact. After one test, perform a second test at intervals of (60±10) s. After passing the impact surface, in order not to load the surface of the synthetic material for too long, the heavy object should be lifted from the anvil within a few seconds. Each point is tested 4 times, and the value of the last 3 times is used to calculate the vertical deformation value, and the result is taken as the arithmetic mean. The results indicate that the vertical deformation is calculated based on the reading of more than 400 N in the 1500 N dynamic shock test. The test result is the average of the last three impacts.

5. Conclusion
The vertical deformation tester of synthetic material surface described in this paper connects the electromechanical control system composed of electromagnetic control system, main structure, etc. and the data storage and analysis system, and realizes the systematic and automatic control of the test device. It is easy to operate and test. High precision, small measurement error, high working efficiency and wide application range.

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References
[1] JP Norris, DS Breslin, DR Staskin. (1996) Use of Synthetic Material in Sling Surgery: A Minimally Invasive Approach. Journal of Endourology. vol. 10, No.3.
[2] China Standardization administration. (2018) GB 36246:2018, Sports areas with synthetic surfaces for primary and middle schools. http://www.gb688.cn/bzgk/gb/newGbInfo?hcno=4582A6129CD00E3D737BE27C49328062
[3] G. Sarton, J. R. Mayer, J. P. Joule, and Sadi Carnot. (1929) The Discovery of the Law of Conservation of Energy. Isis. vol. 13, No.1.
[4] Bishop, Robert H. (2007) LabVIEW 8: student edition. Upper Saddle River, NJ: Pearson, New York.
[5] I Demker.(2009) Determination of mechanical comfort properties of floor coverings. Digitala Vetenskapliga Arkivet. SP Rapport, ISSN 0284-5172.
[6] D Slepian - Bell System Technical Journa. (1962) The one-sided barrier problem for Gaussian noise. Wiley Online Library, vol. 41, pp.463-501.