Design of and Research of Impact Absorber Based on Synthetic Material

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Abstract: This paper carries out the design and research work of related testing equipment, and successfully develop a vertical deformation measuring instrument based on the surface layer of synthetic material. The design principle is that simulates the human body by dropping a weight of a certain mass from a prescribed height according to the law of conservation of energy movement process. In the whole process, the potential energy of the object has converted into kinetic energy, and the test piece forms an impact. The energy data absorbed by the test sample is collected by the impact sensor, and the sensor is sampled at a high frequency using a high-speed data collector and divided into its transmission to the computer system. Then the computer system records, analyses, processes, and calculates the collected data in real time, and displays the pressure change curve of the entire impact process, and finally calculates the impact absorption value of the tested surface during the entire process.

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 gymnasium. The chemical properties of the synthetic materials, as well as the volatile gases produced, the degree of damage to the human body, as well as the mechanical properties, cushioning effect, and energy absorption characteristics of the materials must conform to ergonomics and protect the human body. Due to 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 monitoring of the synthetic materials used therein. The detection of the most important mechanical properties is related to the damage of human motion and the safety of the human body.

After the release of “Made in China 2025”[2], intelligent manufacturing and “Industry 4.0”[3] have become the common goal of China's manufacturing development, and the pursuit of green development has gradually become an inevitable road for the development of major industries. As a large manufacturing industry that seriously affects the environment, the development of green manufacturing is particularly valuable.

And in 2018, the newly established GB 36246-2018[4] standard has been promulgated, and in order to meet the IAAF and European standards EN14808-2003 “Measurement method for impact absorption of sports ground layer”[5].

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With the development of the industry, the progress of technology, the development of new products and other reasons, the raw materials, molecular structure, chemical components and forms of synthetic materials are various, so the requirements for detection equipment are relatively high. At present, in China’s product standards and method standards, some standards give more detailed equipment requirements for testing devices for testing, but most standards only give requirements for range and accuracy for test devices. This adds a lot of difficulty to the laboratory testing according to the standard. It is often the case that different laboratories or manufacturers perform testing according to the same standard, but the measured results have a small deviation, and the results of the comparison between the laboratories big different.

At present, there are many types of synthetic materials on the market, equipment for testing synthetic materials, test methods, technical experience of personnel, and standard implementation specifications. For the laboratory evaluation technical requirements, which is a very important item in the “man-machine material method environmental testing”, the compliance and accuracy of the testing equipment directly affect the laboratory’s testing data. Without reliable and standardized testing equipment, it is difficult for the laboratory to guarantee the experimental data.

In this context, the team developed and designed the equipment at the design and production office based on a large number of field visits through preliminary data surveys: a synthetic material surface impact absorption tester. Formed GB36246-2018 “Synthetic Material Surface Sports Fields in Primary and Middle Schools” and GB14833-2011 and other relevant standards of testing capabilities; Not less than 100 service-related enterprises and units.

2. The Design of System
The purpose of this equipment development is to fill the gap in the domestic test equipment for impact absorption of synthetic materials. This test device realizes systematic automatic control, simple operation, convenient disassembly, high accuracy of testing and small recording error, which is suitable for laboratory and field testing.

This equipment uses a certain weight to simulate the movement of the human body from a prescribed height. Throughout the process, according to the law of conservation of energy, the potential energy of the weight is converted into kinetic energy, which has an impact on the tested sample. Collect the energy data absorbed by the test sample through the impact pressure sensor, use a high-speed data collector to sample the sensor at high frequency, and transmit it to the computer system. The computer system records, analyses, processes, and calculates the collected data in real time, displays the pressure change curve of the entire impact process, and finally calculates the impact absorption value of the surface of the tested sample during the entire process.

The test equipment includes an electronic control system, a test weight, a buffer test bench, and a test frame; the electronic control system includes a pull pressure sensor, electromagnet pull-in control, power supply module, NI board, and human-machine interactive touch screen; test weight Including heavy hammer and impact head and sliding linear bearing; buffer test bench includes anvil, buffer spring, pressure sensor and lower test bench; test frame includes detachable legs, lower base, adjustable screw rod above, etc. . The power module has a power storage function and is connected to all electrical components. It is responsible for providing power supply for each sensor and test recorder on the entire test equipment; the precision control system includes high-precision pressure sensors, strong electromagnet pull-in control, 24V power module, Controller NI 6002 module, human-computer interactive host computer Labview operation interface; NI 6002 has a high-speed acquisition analog input terminal connected to the pressure sensor, the output terminal is connected to the electromagnet; human-computer interactive host computer Labview and controller NI 6002 module connection, as shown in the figure 1.
3. The Content of Design

3.1. Hardware design

3.1.1. Framework
Use the 304 stainless steel square tube with the wall thickness as the outrigger, and build the overall frame of the production equipment with the 304 processed parts. This structure is suitable for the combination of frames with greater stress and strength. Its appearance adopts round corner transition, which is elegant and beautiful and resistant to corrosion. The whole structure is firm and reliable, simple disassembly and convenient transportation. 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
The transmission part of the equipment uses the 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 ensuring the safety of the operator during a sudden power failure, filling by a power-loss type electromagnet containing a permanent magnet. Before the measurement, because the electromagnet with permanent magnet is not charged and has suction power, the weight is fixed after the weight is held. After the electromagnet is activated on the operation interface, the electromagnet will lose its suction power when charged, and the permanent magnet will fail. The heavy hammer fell. Because the weight uses linear bearings to slide down on the guide rod without resistance, the full energy conversion of the weight is achieved. 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 buffer spring at the lower impact part is spirally wound with a three-section rectangular section, as shown in the figure 2.
In this way, the rigidity of the single-head winding during the processing of the spring can be reduced, and only one third of the rigidity of the whole spring is required, which is convenient for production and processing. After the single head is processed, the three single head springs are evenly distributed around the circumference with the glands at both ends. Finally, the integral compression spring as shown in the figure is completed, and it will not fail under a long-term large impact load, which can better ensure the test result. And the second heat treatment of the spring, the heat treatment process greatly improves the toughness and plasticity of the spring and the ability to resist fatigue.

3.1.3. Configuration and data of important components

Important components as shown in the figure 3.

3.1.4. Test technical parameters

1. Heavy hammer: quality 20 Kg±0.1Kg, with impact head with hardness HRC60 ~ 65, the diameter of the impact head is generally not less than 20mm
2. Anvil: surface hardness HRC 60 ~ 65
3. Buffer spring: rigidity range 2000±60N / mm, outer diameter 69mm
4. Guide sleeve: inner diameter 71±0.1mm, the frictional resistance between the buffer spring and the guide column when the weight falls is less than the weight of the weight, and can meet the requirements of guidance
5. Test bench: diameter 70±0.1 mm, the bottom of the chassis is arc-shaped, the radius of the arc is 500mm, and the thickness is not less than 10mm
6. Input power: 220V±10%, 50Hz
7. Power module output: DC24V
8. Data processing speed: maximum 20 kHertz
9. Maximum impact force value: 1T
10. Fine adjustment range: 40 mm
11. Rigidity of buffer spring: 2000±60N / mm
12. Weight: 20±0.1kg
13. The distance between the bottom of the impact head and the anvil (weight drop height): 55mm±0.25mm
14. Force sensor: 0 ~ 10000N, accuracy 0.5%, conversion speed 0.3 ms

3.2. Software design
The Labview software[6] is used as the human-computer interactive operation interface. At the same time, the USB 6002 high-speed acquisition board of NI is used. This board has the advantages of high acquisition frequency and high acquisition accuracy. At the same time, it has a digital output terminal. In the analog acquisition part, the high-precision analog-to-digital conversion programming method records and stores the collected signals in real time, and generates real-time curves.

Use continuous data collection, try to record data and other breakthrough data stream forms to achieve the processing of large amounts of real-time data, break through the limitation of data stream, greatly improve the accuracy and reliability of data, and collect and package the collected data 3. Optimization processing, finally curve fitting of the data and high-speed calculation of the data, and finally recording the measurement data. The system of schematic diagram has been shown in the figure 4.

![Figure 4 The system of schematic diagram](image)

The load sensor adopts double-layer shielded wire, which has a high-filtering, high-precision, and high-sensitivity pressure sensor. Its output sensitivity is 2.0648mV/V/zero balance 2.0% FS, comprehensive error ≤0.1% FS, and dynamic step response speed 0.1ms. The sensor is connected to the NI USB 6002 high-speed acquisition board with a collection speed of 200KHz to form a control signal collection system, which is used with the Labview software. This data collection method effectively avoids the impact of low-frequency Gaussian noise. At the same time, it can ensure that all data in the test process can be accurately recorded, which is convenient for data analysis.

Design a visual man-machine interface, set parameters on a tablet, view data and curves, and operate and manage in an intuitive way. The human-machine interface as shown in the figure 5.
4. Instrument determination method

Lift the weight of the simulated human body with a weight of 20 kg and pull it on the electromagnet. Adjust the distance from the impact head under the weight to the anvil by the hand wheel above the screw (55 ± 0.25) mm. The equipment signal caused the heavy hammer to fall. The falling weight falls on the anvil above the buffer spring, and the mass of the weight is transferred from the spring by the anvil to an arc-shaped base test stand placed on the synthetic material surface test sample. A pressure sensor is also installed between the test bench and the buffer spring, which can record the maximum pressure of the heavy hammer drop during impact.

After testing the surface layer of the synthetic material, remove the synthetic material sample and test it on the concrete surface. Place the device vertically on the concrete floor, adjust the end face of the impact head below the falling weight to be directly above the anvil (55 ± 0.25) mm, release the falling weight, and let it fall freely on the anvil. Record the peak value of the impact force on the concrete surface during the impact. Repeat the above test process 10 times to make the total test times 11 times. Record the average value of the second to eleventh peak impact force as a record and record in the software. The recorded value should be within the range of (6.60 ± 0.25) Kn. If the value exceeds this data, the test result will be considered invalid. The usual test should be done every three months as a calibration test for the instrument and test environment. Compare the highest value of the force measured on the surface layer of the synthetic material with the result measured on the concrete surface to calculate the percentage of impact absorption on the surface of the synthetic material.

When testing the impact absorption value of synthetic material samples in the laboratory, the samples should be tested at 3 temperature points 0 ℃±2 ℃, 23 ℃±2 ℃, 50℃±2 ℃. Record the peak value of the impact force on the surface of the synthetic material during the impact. After one test, the second test is performed at intervals of (60±10) s. After passing through the impact surface, in order not to load the surface of the synthetic material for too long, the weight should be lifted from the anvil within a few seconds.

When testing samples from the 0 ℃ temperature point to the high temperature point in sequence, first place the sample to be tested in a -5 ℃ refrigerator for 1 h, then remove the sample and place it on the test platform to be tested. When the surface temperature of the sample rises naturally to 0 ℃±2 ℃, 23 ℃±2 ℃, start the test separately. The test of each temperature point should be completed within 5 minutes. Each point is tested 4 times. The value of the last 3 times is used to calculate the impact absorption value. The arithmetic mean value is the measured value of this point at the corresponding temperature point.

When testing samples from the temperature point of 50 ℃ to the low temperature point in sequence, first place the sample to be tested in a 55 ℃ oven for 1 hour, and then take the sample to the test platform to be measured, when the surface temperature of the sample naturally drops to 50 ℃ When±2 ℃, start the test, each temperature point test should be completed within 5 min, each point test 4 times, take the value of the last 3 times to calculate the impact absorption value, the result is taken as the arithmetic mean of the point. The measured value of the corresponding temperature point.

The surface temperature of the sample is measured using a calibrated infrared thermometer.
Results calculation and calculation method:
The impact absorption is calculated according to formula (1):

\[
\text{Shock absorption } = (1 - \frac{F_s}{F_c}) \times 100% \quad (1)
\]

In the formula:
F_s—Test reading on the surface of synthetic material, the unit is Newton (N);
F_c—Test reading on the concrete surface, the unit is Newton (N).

5. Conclusion
The impact absorption test equipment for the synthetic material surface layer of the sports field described in this article combines the electromechanical control system composed of the electronic control system and the impact structure with the data storage and analysis system to realize the system automation of the test device. The equipment is easy to operate, has high test accuracy and small recording error, and can be used in laboratory and outdoor field tests at the same time. This equipment design technical specification is based on the relevant domestic technical standards, and refers to the domestic and foreign relevant standards in terms of equipment structure, fulcrum, component use, etc. At the same time, it has conducted unique research and design on the buffer spring. At present, there are no special devices and verification procedures for testing the impact absorption of synthetic surface layers of sports fields at home and abroad. We combine the years of research experience of the National Building Sanitary Ceramics Quality Supervision and Inspection Center in the field of construction materials, so that the sports venue synthetic material surface impact absorption test equipment has filled the domestic gap and has a certain leading level in China.

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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] LLi.(2018)China's manufacturing locus in 2025: With a comparison of “Made-in-China 2025” and “Industry 4.0”. Technological Forecasting and Social Change. vol. 135, pp. 66-74.
[3] H Lasi, P Fettke.(2014)Industry 4.0. Business & Information Systems Engineering. vol. 6, pp. 239-242.
[4] China Standardization administration (2018). GB 36246:2018, Sports areas with synthetic surfaces for primary and middle schools.
http://www.gb688.cn/bzgk/gb/newGbInfo?hcnno=4582A6129CD00E3D737BE27C49328062
[5] I Demker.(2009) Determination of mechanical comfort properties of floor coverings. Digitala Vetenskapliga Arkivet. SP Rapport, ISSN 0284-5172.
[6] Bishop, Robert H (2007) LabVIEW 8 : student edition. Upper Saddle River, NJ : Pearson, New York.