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Safety Requirements and Test Methods for Electrical Self-balancing Vehicles

电动平衡车安全要求及测试方法

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Safety Requirements and Test Methods for Electrical Self-balancing Vehicles

1 Scope

This document defines the terms and definitions of electrical self-balancing vehicles, specifies the test conditions, general safety requirements, electrical safety, mechanical safety, environmental reliability, marking and description requirements, and describes the corresponding test methods.

This document is applicable to the design, production and sales of electrical self-balancing vehicles that use batteries as the power source.

2 Normative References

The contents of the following documents constitute indispensable clauses of this document through the normative references in the text. In terms of references with a specified date, only versions with a specified date are applicable to this document. In terms of references without a specified date, the latest version (including all the modifications) is applicable to this document.

GB 3565.2-2022 Safety Requirements for Bicycles - Part 2: Requirements for City and Trekking, Young Adult, Mountain and Racing Bicycles

GB/T 4208-2017 Degrees of Protection Provided by Enclosure (IP code)

GB 4706.18-2014 Household and Similar Electrical Appliances - Safety - Particular Requirements for Battery Chargers

GB 4943.1-2022 Audio / Video, Information and Communication Technology Equipment - Part 1: Safety Requirements

GB/T 5169.16-2017 Fire Hazard Testing for Electric and Electronic Products - Part 16: Test Flames - 50 W Horizontal and Vertical Flame Test Methods

GB/T 12350 Safety Requirements of Small-power Motors

GB/T 40559 Lithium Ion Cells and Batteries Used in Self-balancing Vehicle - Safety Requirements

3 Terms and Definitions

The following terms and definitions are applicable to this document.

3.1 electrical self-balancing vehicle

A wheeled manned mobile platform that is based on the inverted pendulum model and the principle of static instability, and is equipped with a rechargeable electric drive system, thus maintaining dynamic balance in an autonomous or manual mode of operation.

NOTE: the electrical self-balancing vehicle is referred to as the self-balancing vehicle for short.

3.2 safety alarm

An alarm (such as: sound, light and vibration, etc.) that may be clearly noticed by the user after being sent to the user, when an electrical self-balancing vehicle detects internal faults (such as: abnormal battery voltage and balance control unit failure) or dangerous driving actions or abnormal working conditions of the vehicle.

3.3 footrest tilting function

The function enabled for limiting the user to continue driving in case of overspeed, low-battery driving or overload driving detected in an electrical self-balancing vehicle, thus protecting the safety of the user, by automatically tilting up the front end of the footrest on the self-balancing vehicle.

3.4 enclosure

A shell that provides the type and degree of protection suitable for the intended use.

[source: GB 4943.1-2022, 3.3.2.2]

3.5 crash

A state where the electrical self-balancing vehicle’s posture or speed changes significantly so that it cannot continue to actively maintain the balance when the self-balancing vehicle is driven.

3.6 electrolyte leakage

Visible leakage of liquid electrolyte.

[source: GB/T 28164-2011, 1.3.9]

3.7 active protective device

An electrically propelled protective device.

NOTE: such as: battery management systems and control integrated circuits, etc.

4 Test Conditions

4.1 Test Roads

The test roads shall meet the following conditions:

a) The test shall be carried out on cement or asphalt pavement. Pavement shall be smooth, dry and clean, with a good adhesion coefficient;

b) The test area shall be set up on the test road. The test channel in the test area shall not be less than 1 m in width. There shall be an auxiliary driving zone long enough and a secondary zone that ensures safe parking on both ends of this test area, where it is able to drive in both directions.

4.2 Drivers

The drivers shall meet the following conditions:

a) If the maximum load of the product is greater than or equal to 75 kg, the total weight of the driver and its equipment shall be 75 kg; when the total weight is less than 75 kg, counterweight shall be applied. If the maximum load of the product is less than 75 kg, then, the total weight of the driver and its equipment shall be equal to the maximum load of the product;

b) Drivers shall master the driving skills and be familiar with the test methods;

c) Drivers shall be equipped with helmets, knee pads, elbow pads and other necessary protective equipment;

d) Drivers shall drive the test vehicles according to the operation methods specified by the manufacturer. Throughout the test, drivers shall try to keep the driving position without significant changes and avoid the operations which are not allowed by the manufacturer.

4.3 Test Environment

Unless otherwise required by the test items, the test environment shall meet the following conditions:

a) The temperature shall be within the range of nominal operating temperature of the electrical self-balancing vehicle. Unless otherwise specified, the room temperature specified in this document shall be (25 ± 5) °C;

b) Relative humidity shall not be greater than 75%;

c) Atmospheric pressure shall be within the range of 86 kPa to 106 kPa;

d) During the test, the average wind speed shall not be greater than 3 m/s; the instantaneous wind speed shall not be greater than 5 m/s;

e) If it is necessary to test outdoors, rain, snow and other weather shall be avoided.

5.4.1 Overspeed protection

The electrical self-balancing vehicle shall have such protection functions as continuous safety alarm beyond the speed limits and continuous tilting function or the like, so as to restrict the user from continued acceleration, thus protecting user safety.

5.4.2 Low-battery protection

The electrical self-balancing vehicle shall be capable of providing low-battery protection, that is, when the power of the electrical self-balancing vehicle's battery pack is lower than the minimum power required by the manufacturer for safe driving, the self-balancing vehicle shall have such protection functions as continuous safety alarm and continuous tilting function or the like, so as to restrict the user from continued driving.

5.4.3 Grade parking performance and protection

The electrical two-wheeled self-balancing vehicle shall have grade parking performance and protection function. After tested according to the method specified in 9.1.3, the electrical self-balancing vehicle shall meet either of the following two states:

a) The self-balancing vehicle gives no safety alarm and without any power failure; meanwhile, its motor has no loss of energy;

b) The self-balancing vehicle enables such protection functions as continuous safety alarm and continuous tilting function or the like, so as to restrict the user from continued driving.

5.4.4 Crash protection

The electrical self-balancing vehicle shall be capable of providing crash protection to prevent the self-balancing vehicle from hurting the user or the third party when its wheel(s) continue(s) to rotate after crash. After tested according to the method specified in 9.1.4, the wheel(s) of the electrical self-balancing vehicle shall be able to stop rotating within 5s (including 5s) after crash.

5.4.5 Overcharge protection with energy recovery function

For the electrical self-balancing vehicle with energy recovery function, certain protective measures shall be taken to prevent energy recovery from overcharging the battery or battery pack during downhill or deceleration. Safety alarms and tilting function or other similar protective measures shall be triggered before overvoltage of the battery or battery pack. In addition, the self-balancing vehicle shall not cut off the discharge circuit due to overvoltage protection of the battery or battery pack. When tested according to 9.1.5, the electrical self-balancing vehicle shall not catch fire or explode. Meanwhile, there shall be no rupture or electrolyte leakage on the enclosure.

5.4.6 Speed-limit alarm for battery pack in low battery

When tested according to 9.1.6, the electrical self-balancing vehicle shall trigger the safety

alarms and tilting function or other similar protective measures when the battery pack is in low battery. Before triggering the protection function, the self-balancing vehicle shall not cut off the discharge circuit due to low-battery protection of the battery pack. In addition, the self-balancing vehicle shall not catch fire or explode. Meanwhile, there shall be no rupture or electrolyte leakage on the enclosure.

5.4.7 Charge locking

When tested according to 9.1.7, the electrical self-balancing vehicle shall be unable to be turned on during charging. If it is able to be turned on, protective measures shall be taken to limit its normal driving, for example, non-powered wheel rotation.

5.4.8 Anti-spinning protection

The electrical self-balancing vehicle weighing less than 18 kg shall be tested according to 9.1.8. After startup, the self-balancing vehicle's wheel(s) shall not continue to spin or rotate for more than 5 s after lifted up using the designed handle assembly.

5.5 Devices

5.5.1 Battery and battery pack

The safety of batteries and battery packs for the electrical self-balancing vehicles using lithium-ion batteries and battery packs shall comply with the stipulations of GB/T 40559. Other types of batteries and battery packs shall comply with the stipulations of relevant national standards.

5.5.2 Charger

The safety requirements for the chargers or power supplies of the electrical self-balancing vehicles shall meet the requirements of GB 4943.1-2022 or GB 4706.18-2014 and be compatible with the battery systems of the electrical self-balancing vehicles. Compliance shall be checked by reviewing the battery system and charger specifications and the tests in this document.

The connectors, which are provided with the chargers and connected to the charging ports on the self-balancing vehicles for charging, shall be designed to prevent misalignment and reverse polarity.

5.5.3 Motor

The motors for the electrical self-balancing vehicles shall comply with the requirements of GB/T 12350 and the motor overload test specified in 9.2.1.

If the motors for the electrical self-balancing vehicles are beyond the scope of application in GB/T 12350, then, such motors shall comply with both the motor overload test specified in 9.2.1 and the motor locked-rotor test specified in 9.2.2.

5.5.4 Fuse

6.2 Wiring

Check the cables in the following order at room temperature, and the electrical self-balancing vehicle shall comply with the following requirements.

a) Cables shall be smooth and free of sharp edges with good insulation.

b) Cables shall be protected from contact with burrs, heat sinks or similar sharp edges that may affect insulation. The surfaces of the metal holes through which the cables pass shall be smooth enough, or cables shall be equipped with sleeves.

c) Cables shall be securely fastened to prevent contact between the cables and the moving parts. Where necessary, other mechanical fixings may be added.

Detachable parts of an electrical self-balancing vehicle, which will be removed during normal use or maintenance of the equipment, shall not cause undue pressure on the electrical connections and internal conductors, including the conductors that maintain earthing continuity.

6.3 Short-circuit Safety

After tested according to the method specified in 9.2.3, the self-balancing vehicle shall not catch fire or explode. Meanwhile, there shall be no rupture or electrolyte leakage on the enclosure.

NOTE: if the self-balancing vehicle's battery pack has passed the short circuit test, and in the case that according to the characteristics of the tested self-balancing vehicle, it has been evaluated that there is no difference between the short circuit test of the entire self-balancing vehicle and that of the battery pack, it may be unnecessary to carry out the short circuit test specified in this document.

6.4 Heating

The materials that are suitable for the structures of the components and the electrical self-balancing vehicle shall be selected, so that the temperature of the self-balancing vehicle will not exceed its temperature limit when operating under normal load. After performing the test according to the method specified in 9.2.4, the measured temperature limits of the materials for the self-balancing vehicle and the components shall meet the requirements of 5.4.1.4.3 in GB 4943.1-2022; the measured temperature limits of the accessible parts in the accessible area of the user shall meet the requirements of 9.3 in GB 4943.1-2022. In addition, during the test, the electrical self-balancing vehicle shall not catch fire or explode. Meanwhile, there shall be no rupture or electrolyte leakage on the enclosure.

6.5 Dielectric Strength

The electrical self-balancing vehicles or their components, which are directly connected to the AC grid, shall have adequate dielectric strength and be tested according to the method specified in 9.2.5.

7 Mechanical Safety

7.1 Degrees of Protection Provided by Enclosure (IP code)

The degree of protection provided by enclosure of the electrical self-balancing vehicle shall not be lower than IP34 or the degree of protection claimed by the manufacturer, whichever is more rigorous.

7.2 Static Strength

After the static strength test according to the method specified in 9.3.2, there shall be no visible crack or rupture in any part of the electrical self-balancing vehicle. Moreover, the self-balancing vehicle shall be able to function properly.

7.3 Dynamic Strength

After the dynamic strength test according to the method specified in 9.3.3, there shall be no visible crack or rupture in any part of the electrical self-balancing vehicle. Moreover, the self-balancing vehicle shall be able to function properly.

7.4 Handrail Strength

This requirement applies only to the electrical self-balancing vehicles with handrails.

Handrails of the electrical self-balancing vehicles shall have sufficient strength to ensure the safety under the actual conditions of use.

After the handrail strength test according to 9.3.4, there shall be no crack or rupture on the handrails of the electrical self-balancing vehicles; the fixed parts between the handrails and the self-balancing vehicles, as well as the components of the self-balancing vehicles shall not have cracks or ruptures.

7.5 Saddle Strength

This requirement applies only to the electrical self-balancing vehicles with saddles.

Saddles of the electrical self-balancing vehicles shall meet the requirements of 4.16.3 in GB 3565.2-2022.

The saddle strength of the electrical self-balancing vehicles shall meet the requirements of 4.16.4 in GB 3565.2-2022.

8 Environmental Reliability

8.1 Vibration

Perform the vibration test according to 9.4.1. After the test, there shall be no visible crack,

The overcharge protection with energy recovery function for the electrical self-balancing vehicle shall be tested according to the following method:

Turn on a fully charged electrical self-balancing vehicle and trigger it to enter the normal running state. Apply a constant charging current of 0.2 C (such charging current shall be the value that is needed to counteract the output current required by the self-balancing vehicle to maintain the running state) to the output end of the battery pack in the self-balancing vehicle, so as to continuously charge the battery pack, thus simulating the energy recovery of the self-balancing vehicle during downhill or braking. Monitor whether the self-balancing vehicle takes protective measures, such as: safety alarm, tilting or the like or turns off the power to stop running, before the voltage of the battery pack in the self-balancing vehicle reaches 1.03 times its specified upper limited charging voltage. During the test, the temperature of the battery pack shall also be monitored as a reference.

During the test, it shall be observed whether the self-balancing vehicle has a fire, explosion, enclosure rupture or electrolyte leakage.

9.1.6 Speed-limit alarm for battery pack in low battery

Discharge the battery pack in a fully charged electrical self-balancing vehicle to approximately 30% of the specified state of charge (SOC).

Trigger the electrical self-balancing vehicle to enter the normal running state, for achieving normal running of the self-balancing vehicle or simulating its normal running according to the parameters specified by the manufacturer. Meanwhile, monitor the battery voltage and battery temperature.

Perform the test until the self-balancing vehicle takes protective measures, such as: safety alarm, tilting or the like or turns off the power to stop running.

9.1.7 Charge locking

Turn on a not fully charged self-balancing vehicle three times, in order to ensure that the self-balancing vehicle is able to run normally after startup.

USE a standard charger specified by the manufacturer to charge the self-balancing vehicle in off state. During charging, turn on the self-balancing vehicle three times. If it is unable to start up, the test is over. If it is able to start up normally, test whether the self-balancing vehicle is capable of running.

9.1.8 Anti-spinning protection

Turn on the electrical self-balancing vehicle to enter its normal running state. Rotate the wheel(s) through manual means or test equipment. When using the designed handle assembly to lift up the self-balancing vehicle, record the duration from the wheel spinning starting when the self-balancing vehicle is lifted up to the wheel stalling.

fault condition of any protective device in the relevant battery protective circuits (for single fault analysis and determination, see Appendix A). During the test, the temperature of the tested self-balancing vehicle shall be monitored in real time.

The self-balancing vehicle shall remain short-circuited until its temperature falls back to room temperature or it suffers from a fire or explosion.

After the test, turn on three times to check whether it is able to start up and run normally. If it is able to normally start up for running, the tested self-balancing vehicle shall be conducted with one charge-discharge cycle according to the parameters specified by the manufacturer. Let the self-balancing vehicle stand for one-hour observation.

9.2.4 Heating test

During the test, the temperatures of the battery, motor and other components of the self-balancing vehicle and the temperatures of the surfaces accessible to the users shall always be monitored. The test shall be carried out according to the following procedures:

a) At room temperature, use a standard charger specified by the manufacturer to charge a fully discharged electrical self-balancing vehicle with the maximum charging parameter, until the voltage and current detected on the battery reach the state of charge specified by the manufacturer;

b) Discharge the fully charged self-balancing vehicle at the maximum load specified by the manufacturer. Monitor the battery voltage and current until the self-balancing vehicle reaches the prescribed discharge cut-off voltage;

c) Repeat the steps a) and b), until two full charge-discharge cycles are completed.

During the charge-discharge cycle, it shall be ensured that the voltage, current and measured temperature of the electrical self-balancing vehicle shall not exceed the parameter limits specified by the manufacturer.

9.2.5 Dielectric strength test

9.2.5.1 Pretreatment

The moisture-proof treatment shall be carried out in a damp heat cabinet at a temperature of (40 ± 2) °C and with a relative humidity of (93 ± 3)% for 120 h. During damp heat test, the sample shall not be electrified or turned on.

Before damp heat treatment, the sample shall be placed in an environment at t °C to (t + 4) °C for at least 4 h, among which t represents any temperature value between 20 °C and 30 °C, where condensation will not be produced.

After moisture-proof treatment, perform the test in 9.2.5.2 immediately.

9.2.5.2 Test procedure

This test shall be carried out after pretreatment.

This test procedure shall meet the requirements of 5.4.9 in GB 4943.1-2022, among which, the peak working voltage is the maximum charging voltage of the electrical self-balancing vehicle.

9.3 Mechanical Safety Tests

9.3.1 IP code test

The method for testing the degree of protection provided by enclosure of the electrical self-balancing vehicle shall meet the requirements of GB/T 4208-2017.

9.3.2 Static strength test

At room temperature, for a seat-free electrical self-balancing vehicle, apply a static load, which is three times the manufacturer-specified upper weight limit, to the center point of the footrest through a support (for example, a wooden block, etc.) with a cross-section of 102 mm × 254 mm. Apply the load gradually over 5 s and maintain it for 30 s.

If the footrest has two or more pieces or consists of multiple parts, then, the load shall be evenly distributed in accordance with the method described above at the center of each piece or each part.

For an electrical self-balancing vehicle with a seat, a static load, which is three times the manufacturer-specified upper weight limit, shall be applied at the center of the seat surface in the same mode.

9.3.3 Dynamic strength test

9.3.3.1 Pretreatment

If the footrests or frames or other load-bearing structural members of the self-balancing vehicles are made of plastic materials (except for decorative parts), then, the sample shall be placed in an environment at a temperature of at least (–5 ± 1) °C or at the minimum operating temperature claimed by the manufacturer, whichever is lower, for 6 h.

9.3.3.2 Test procedure

This test shall be started within 1 min after the completion of sample pretreatment and shall be completed within 5 min.

At the center of the footrest of the electrical self-balancing vehicle in the power-on state, apply the maximum load specified by the manufacturer through a support (for example, a wooden block, etc.) with a cross-section of 102 mm × 254 mm. If there are multiple load-bearing footrests, each footrest shall equally distribute the maximum load. The self-balancing vehicle runs at a speed of 8 km/h ~ 10 km/h, and the drop height is 1/4 of the wheel diameter. If appropriate, tyre pressure shall be adjusted in accordance with the maximum value provided by the manufacturer. Repeat the test 2 times, then, check for damage.

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