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A Technical Study on Snowboard Suits Equipped with Intelligent Airbag Buffering Devices

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Abstract: The giant success of the Beijing Winter Olympics 2022 has ignited a wave of interest in ice and snow sports. The rise of skiing has brought a great opportunity for the development of Chinese sports apparel. However, skiing, as a sport with high professional barriers and significant risks, has also exposed many potential drawback issues. This paper focuses on the technical research of intelligent airbag buffering snowboard suits, elaborating on the integration of inflatable airbags with ski suits and the intelligent fall detection system. It provides a new direction and solution for the current design challenges faced by snowboard suits.

Keywords: Intelligent Airbag Buffering Devices; Snowboard Suits Design; Design Innovation.

1. Research Status

Foreign ski brands have a long history of developing ski equipment, and the ski industry in the United States and Europe has reached its maturity. The audience for many high-tech products has expanded beyond professional athletes to the broader market. The integration of smart wearable devices with ski equipment is becoming increasingly popular, such as battery-heated ski suit liners, chips that record skiing data, and electronically tinted ski goggles.

In contrast, the development of skiing and ski equipment in China is still in its infancy, with relatively few brands, and it mainly focuses on e-commerce platforms, offering limited styles, poor quality assurance, and a noticeable tendency to copy foreign ski sportswear brands.

2. Snowboarding Injury Analysis

2.1. Classification of Snowboarding Participants

A questionnaire survey of the major ski resorts reveals that the primary group involved in snowboarding is young individuals with higher income and consumption levels, and this demographic generally has a higher demand for snowboarding gear. According to the study "Winter Sports Accidents, Injuries, and Safety Precautions Research" published in 2021, among snowboarders with less than five years of experience, 84% classified themselves as beginners, and the injury rate among beginner snowboarders is significantly higher than that of intermediate and advanced snowboarders.

2.2. Statistical Analysis of Injury Locations and Types in Skiing

The data from "Skiing injuries in Palandoken ski center: 156 cases-2007" indicates that in the 2007 analysis of 156 skiing injuries, sports injuries caused by skiing were primarily concentrated in the limbs (109 cases), followed by head and neck injuries (15 cases), chest (8 cases), abdomen (6 cases), and urinary system (2 cases).

The "Snowboarding Injuries" report of 2012 points out that in snowboarding, wrist injuries are the most common, followed by soft tissue injuries of the shoulder, ankle joint injuries, concussions, and clavicle fractures as shown in figures 2-3. The report also summarizes that the probability of injury in snowboarding is greater than in skiing, with the injured parties mainly comprising young beginners with no prior skiing experience and female snowboarders.

2.3. Factors Leading to Snowboarding Injuries

Since snowboarding has a relatively high learning difficulty, beginners, due to their short exposure to snowboarding, poor balance, and lack of experience, are highly prone to falls that can cause various degrees of injury. Relevant data indicate that about 80% of injuries among novice snowboarders are due to falls. Moreover, ski resorts generally categorize slopes into beginner, intermediate, and advanced levels, and the excessive flow of people on beginner slopes can lead to collisions. Since snowboarding involves both feet being fixed to the board, theoretically, the tendency to fall is divided into two main types: falling forwards or sitting down backwards.

2.4. Current Research on Protection

Professional ski wear products are divided into two parts: ski clothing and ski protectors, which generally can be worn independently or combined. Currently, ski protectors are categorized into two types: internal and external protectors, with protection areas including the buttocks, knees, armors, and elbows. Internal protectors are mainly made of soft composite materials with low density and high buffering, which are expensive. External protectors are mostly made of ABS hard plastic shells with EVA foam inner layers. They provide protection by increasing the overall volume and thickness of the material, which makes them less expensive but lacking in flexibility and aesthetics.

3. Technical Study on Intelligent Airbag Cushioned Ski Suits

3.1. Method of Manufacturing Inflatable Airbags

The most common solution for ensuring the air-tightness of inflatable products on the market relies on coatings and lamination. Lamination is an effective method to ensure the high air tightness of inflatable composite structures,

combining non-woven films that are inherently air and water-impermeable with textile fabrics, which significantly alters the fabric's mechanical properties, sealing capabilities, and appearance.

1) Choice of Base Fabric for Inflatable Materials When it comes to the field of inflation, the choice of materials and processes is often the most critical aspect. To achieve an airtight effect, fabrics with high density and high tear resistance are chosen for the base material. After analyzing and studying the fabrics available on the market, it has been determined that polyester fabric fits well with the concept and design.

2) Fabric Lamination with TPU Process To ensure the fabric is completely airtight, it is also necessary to laminate a layer of TPU film onto the base fabric. Laminated fabric is a new type of material formed by bonding one or more layers of textile or nonwoven material and other functional materials.

3) Crafting of the Inflatable Airbag Creating an inflatable airbag requires the use of a needleless sewing process. Using traditional sewing methods would compromise the airtightness of the fabric by leaving needle holes. This technology was first used in outdoor sports clothing and related outdoor sports products in European and American countries.

3.2. Design of Airbag Protective Ski Suits

The design of ski suits requires functional design features as well as the structural design of the airbag fall protection system. Firstly, as a qualified ski suit, it should exhibit necessary functional designs such as being waterproof and windproof, and offer storage options. Secondly, the airbag should replace certain parts of the ski suit fabric to provide protection for specific body areas that are prone to injury, necessitating a deconstructed design of the ski suit.

3.3. Integration of Inflatable Airbags with Ski Suits

Integrating inflatable airbags with ski suits involves designing based on the four main body parts that are most susceptible to injury during a snowboard fall: the knees, elbows, back, and buttocks. The airbags' exterior form should be centered around these critical injury points in the design structure.

4. Intelligent Detection System

4.1. Selection of Acceleration Sensor

The MPU-6000 represents the world's first 6-axis motion processing component to be integrated into a single unit (as shown in Figure 3-16). Compared to multi-component solutions, it eliminates the issue of axis misalignment between gyroscope and accelerometer components, thereby significantly reducing packaging space. The MPU-6000 combines a 3-axis gyroscope and a 3-axis accelerometer and includes a Digital Motion Processor (DMP) hardware acceleration engine that can be connected to accelerometer, magnetometers, or other sensors from different manufacturers via a secondary I2C port.

It outputs complete 9-axis fusion computation data to the application end in a single data stream through the main I2C port, utilizing Inven Sense's motion processing database, which manages complex motion sensing data. This reduces the computational load on the operating system and provides a structured API for application development.

4.2. Selection of Control Module -Arduino UNO

Arduino is an open-source hardware platform based on micro-controllers, accompanied by a dedicated development environment. It can be used to develop interactive products, such as reading signals from various switches and sensors, and controlling a wide range of lights, motors, and other physical devices.

4.3. Selection of Inflation Pump

The inflation pump (as shown in Figure 3-19) chosen is developed by the domestic brand Kejinghui. It is an indispensable part of the protective module. The operating voltage of the pump is rated at 4.5-8.4V, with a no-load current greater than 600mA, a maximum vacuum of at least -58kpa, and an airflow rate of at least 3.0L/min. It is equipped with both an inlet and an outlet, which can be programmatically switched in function. The plug is xh2.53, compatible with sm2.54.

4.4. Code Writing and Overall Assembly

The Arduino IDE is the programming environment for Arduino products, with programming done in C language. The general logic is as follows: set a threshold for the acceleration sensor, and when the acceleration exceeds 10, it is determined as a fall, at which point the pump starts working. The inflation state is maintained for three seconds, after the person completes the entire fall motion, the pump starts to deflate.

After completing the program writing, connect the sensors, power supply, and pump to the Arduino UNO as required. After verification, it operates accurately according to the correct logic.

4.5. Airbag Ski Suit Design

The design of the airbag ski suit places airbags on the elbows, chest, and back. The elbow airbags employ a lateral multi-airway design, greatly enhancing the flexibility of the elbow joints and facilitating the skier's ability to spread their arms to maintain balance. A large airbag is placed on the chest to increase the contact area, which can absorb a significant amount of impact force in the event of a forward fall, effectively protecting the ribs, chest cavity, and abdomen. The airbag near the neck is designed to protect the sixth and seventh cervical vertebrae, which are prone to injury during backward falls due to their longer spinous processes. An inverted triangular airbag accommodates the movements involved in skiing while providing effective protection for the neck. Additionally, the design of the cuffs and collar effectively prevents wind and water penetration, ensuring that cold air or snow does not enter the inside of the garment during high-speed activities, thus reduce the skier's body temperature and make them uncomfortable.

The trousers are equipped with airbags at five locations to protect the thigh muscles, knees, calves, and buttocks. In the event of a forward fall or frontal collision, these airbags safeguard the thighs and knees. The lower part of the suit features airbags designed to protect the calves; frontal falls in snowboarding typically do not impact the front of the calves, with most injuries resulting from side impacts, such as lateral falls, rolls, or collisions with other skiers. Therefore, placing airbags on the sides offers more effective protection.

5. Research Conclusion

The airbags which are made from polyester fabrics and combined with TPU coating can achieve excellent air tightness when operated properly, and can be integrated with an intelligent detection system to complete the main research subject: an intelligent fall-detection system. Airbags designed according to specific human body structures can accurately cover areas of the body that are prone to injuries during snowboarding. Continuing to develop inflatable fabric technologies for thermal insulation and expanding their use into impact protection represents a breakthrough in a new field, offering a novel direction and solution to current issues faced by snowboarding apparel design, such as slow development, lack of variety, insufficient protection, and excessive bulkiness.

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