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Effects of Environmental Factors on Snow Simulation in Civil Aircraft Ground Testing

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Abstract. In this paper, the effects of environmental factors on snow simulation in civil aircraft ground testing are analyzed and technical support is provided for adaptive testing of civil aircraft in snowfall environments. Snowy weather has a significant impact on the propulsion system, flight control system, and flight performance of civil aircraft. Based on the analysis of natural and artificial snow formation mechanisms and the requirements for snowfall simulation testing, an outdoor simulation system for snowfall in civil aircraft ground testing was established. Tests were conducted to investigate the influence of environmental factors on snowfall simulation. Temperature and humidity ranges were established to achieve snowfall simulation, creating snowfall environments with specific snowfall intensity and density within these ranges. The results in this paper effectively support the adaptive testing of civil aircraft in snowfall environments.

Keywords. civil aircraft ground testing; snow simulation; environmental envelope; civil aircraft

1. Introduction

The operation of civil aircraft under snowfall meteorological conditions is inevitable, and the operation stages such as taxiing, takeoff, approaching, and landing of aircraft may all be affected by snowfall or blowing snow weather. Heavy snowfall weather can cause snow or ice accumulation on parts such as wings, control surfaces, engine intakes, and auxiliary power unit (APU) intakes, leading to problems such as jamming of movable components, reduced engine efficiency, and abnormal operation of APU, affecting aircraft performance and operational safety [1-3]. Therefore, civil aircraft must demonstrate their ability to operate under snowfall meteorological conditions during the airworthiness certification process.

It is difficult to find falling or blowing snow meteorological conditions that meet the requirements under natural conditions, so adaptive verification is needed in artificially simulated snowfall environments. Simulating a snowfall environment under laboratory conditions has good stability, but it has the disadvantages of high cost and longtime cycle. Simulating a snowfall environment under natural conditions has lower costs and shorter test cycles, but is easily affected by changes in temperature, humidity, and environmental airflow in the natural environment. Therefore, elucidating the influence of natural

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environmental factors on the simulation of snowfall environments is of great significance for supporting civil aircraft snowfall tests.

2. Snowfall Environment Definition

2.1. Snow formation mechanism

In natural environments, snow is solid precipitation in the atmosphere. After the cooling of the air, the vapor in the atmosphere forms supercooled water droplets and reaches a supersaturated state. Under the continued effect of low temperatures, supercooled water droplets can form small ice nuclei. Subsequently, the vapor and ice nuclei merge to form snow crystals, which continue to grow into snow crystal aggregates. When they reach a certain size, they will form natural snowfall. In nature, the process of snowfall requires three stages: the formation of ice nuclei, the growth and fusion of snow crystals, and the falling of snowflakes [4].

Artificial snowmaking simulates the natural snowfall process by spraying supercooled atomized water droplets into the environment under low-temperature conditions to produce ice nuclei, which promote the combination of water vapor in the atmosphere to form snow crystals, thus producing snowfall. The phase change process from atomized water droplets to snow crystals is the key to artificial snowmaking. Song's [5] study on the mechanism of snow crystal formation shows that environmental temperature and atmospheric humidity are the main factors affecting snow crystal formation. Liu Dao-ping [6] believes that necessary environmental temperature and supersaturation conditions of water vapor are essential for the continuous production of snowfall. Artificially simulating the snowfall environment uses suitable snow crystal formation conditions and snowmaking devices to create snowfall.

Environmental temperature and humidity are two important factors that affect the effectiveness of artificial snowmaking [7-9]. Environmental temperature affects the structure and strength of snowflakes, while environmental humidity affects the size and shape of snowflakes. Studies have shown that environmental temperature has a significant impact on the quality and quantity of snowflakes. When the environmental temperature is lower, the yield of snowflakes will increase, and the structure of snowflakes will be more robust. Humidity mainly affects the size and shape of snowflakes. When the humidity is lower, the moisture in the air is quickly absorbed, making the air drier and conducive to the formation of large and light snowflakes; when the humidity is higher, the moisture content in the air increases, which is conducive to the formation of small and dense snowflakes.

2.2. Snowfall environment definition

In CS 25.1093(b)(1), falling and blowing snow are identified as weather conditions that need to be considered for the power plants and essential Auxiliary Power Units (APUs) of transport category aeroplanes [10]. Generally, falling snow refers to the natural snowfall process where snowflakes fall without being influenced by gusts, while blowing snow refers to the snowfall process where snowflakes are moved by wind gusts. Apart from wind effects, the liquid water content in the snow is also an important parameter for simulating snowfall environments. Snow can be classified as dry or wet snow depending on the amount of liquid water content present in the snow. Dry snow has a low liquid water content and can be easily blown by the wind, while wet snow has a high liquid water content and can easily adhere to the surfaces of objects.

EASA has provided detailed validation requirements for simulated snowfall environments in CS25 AMC25.1093, with indicators for snowfall intensity and temperature. The simulated snow intensity (visibility) for meteorological snowfall is required to be approximately close to 1 g/m^3, while the simulated snow intensity for blowing snow meteorology is required to be approximately close to 3 g/m^3, and the wind speed for blowing snow meteorology is required to be between 7.7 m/s and 12.9 m/s. The temperature for meteorological simulation of wet snow is between -3 ℃ and +2 ℃, and for dry snow, the temperature is between -9 ℃ and -2 ℃. ICAO has provided specific indicators for snowfall types, with a density of less than 0.35 g/cm^3 for dry snow and greater than 0.35 g/cm^3 but less than 0.5 g/cm^3 for wet snow. Based on the information above, the parameters for snow simulation are shown in Table 1 [11].

Table 1. Snow simulation conditions and parameters.

Condition	Intensity (g/m^3)	Specific gravity (g/cm^3)	Temperatures (℃)
Falling & Wet	1	$0.35 \leq \rho < 0.5$	$-3 \leq T \leq +2$
Falling & Dry	1	$\rho \leq 0.35$	$-9 \leq T \leq -2$
Blowing & Wet	3	$0.35 \leq \rho < 0.5$	$-3 \leq T \leq +2$
Blowing & Dry	3	$\rho \leq 0.35$	$-9 \leq T \leq -2$

3. Snow Environment Simulation System and Test Method

3.1. Snow environment simulation system

To research the impact of natural conditions on simulated snowfall environments, a set of simulated snowfall environment systems was constructed. The system consists of a windproof module, a water supply module, a power supply module, a snowmaking module, a blowing module, and testing equipment, as shown in Figure 1. The simulated snowfall environment system was built in an outdoor environment, and suitable meteorological windows and equipment parameters are adopted to simulate the required snowfall environment.

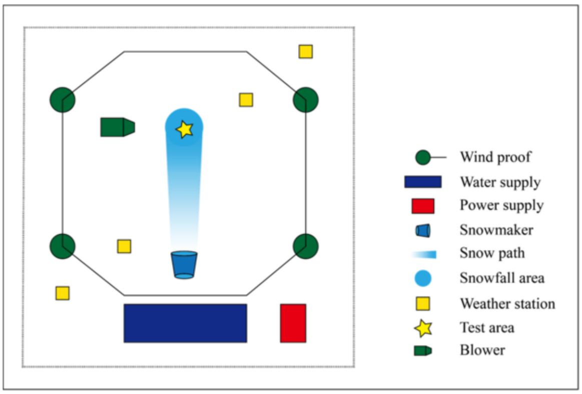

Figure 1. Snow environment simulation system.

The windproof module is used to reduce the impact of environmental wind on the snowmaking snow field. The windproof module consists of a load-bearing net, a windproof net, and a support structure. The windproof net and load-bearing net are arranged to be in close contact to block the entry of environmental wind into the simulated snowfall environment. The load-bearing net is connected to the support structure to withstand the load brought by the environmental wind. The windproof coefficient of the windproof device is 0.6, and a single windproof device can withstand a wind pressure of approximately 170 kg.

The water supply module is used to provide cold water with constant pressure and temperature for the snowmaking module. It consists of a pre-cooled water tank, a cold water unit, and a water supply main control system. The pre-cooled water tank and the water supply main control system are connected through a water inlet pipeline and a water pump to add water. The water is cooled using a cold water unit or natural cooling, with a minimum temperature of 0 °C. The water supply main control system can adjust the water supply pressure and flow rate, with a maximum water supply pressure of 5 MPa and a stable water supply flow rate of up to 40 m^3/h. The system has a water supply line and a return line, with electric regulating valves installed on both the supply and return pipelines. The maximum water pressure and flow rate of the water supply system can meet the water demand of the snowmaking module.

The power supply module is responsible for providing a stable power supply for the water supply module, the snowmaking module, the blowing module, and the testing system. The power supply module consists of a diesel generator and its supporting components.

The snowmaking module is used to create an artificial snow field that meets the requirements of simulating a snowfall environment. The snowmaking module consists of custom-made snowmaking machines and supporting pipelines. The custom-made snowmaking machine consists of main components such as atomizing nozzles, nucleators, compressors, and fans. High-pressure cold water from the water supply module is atomized into mist at 0 ~ 2 °C through the atomizing nozzle. Compressed air (below 0 °C, 0.65 ~ 0.75 MPa) from the compressor and high-pressure cold water from the water supply module is mixed in the nucleator chamber. The mixture expands and cools locally after leaving the nucleator, and the atomized water droplets condense into crystal nuclei, and the aggregated mist forms snowflakes. The snow is formed by being jetted by the fan.

The blowing module is used to provide the required lateral wind for simulating a snowdrift environment. The blowing module consists of a wind tunnel and an axial flow fan. After the wind tunnel is installed, its centerline elevation is the same as the test position (such as the APU air intake). The wind tunnel includes a settling section, a contraction section, and a test section. The contraction ratio of the wind tunnel is 1.44, and the maximum wind speed at the outlet can reach 15 m/s, meeting the snowdrift wind speed requirements of 7.7 m/s to 12.9 m/s.

In order to measure the various parameters of the snowfall environment simulation system, this study used test equipment such as Weather station. The test equipment and its detailed parameters are shown in Table 2.

Table 2. Test Equipment Description.

Equipment	Parameters	Range	Accuracy
Weather station	Air temperature	-10 °C ~ 5 °C	±0.5 °C

	Relative humidity	20 % ~ 90 %	±3%
	Air pressure	90 kPa ~ 110 kPa	±0.5 kPa
	Wind speed	0 ~ 10 m/s	±0.7 m/s
Temperature sensor	Water temperature	-10 ℃ ~ 10 ℃	±1.0 ℃
Pressure sensor	Water pressure	0 ~ 50 bar	±0.5 bar
WCM2000	Total water content	0 ~ 10 g/m^3	±0.05 g/m^3
Angle ruler	Snowmaker angle	0 ~ 50 °	±1.0 °
Electronic balance	Snow weight	0 ~ 600 g	±1.0 g
Electronic stopwatch	Snowfall time	0 ~ 3600 s	±1 s
Measuring dish	Snow volume	0 ~ 7515 cm^3	±7 cm^3

3.2. Test method

The artificial simulation of snowfall is subject to the influence of both equipment parameters and environmental variables. To effectively study the effects of environmental variables on simulated snowfall, it is necessary to maintain stable equipment parameters within a certain range during artificial snowfall simulations.

Based on the components of the snowfall simulation system, the simulation of snowfall is affected by the water temperature and water pressure of the water supply, as well as the inclination angle and distance between the snow-making equipment and the target testing location. The equipment parameters for simulating snowfall are shown in Table 3.

Table 3. Parameter settings for snow simulation.

Conditions	Water Temperature (°C)	Water Pressure (bar)	Snowmaker Angle (°)
Falling & Dry	3 ± 1	10 ± 2	18.5 ± 1
Falling & Wet	4 ± 2	10 ± 2	18.5 ± 1
Blowing & Dry	3 ± 1	30 ± 2	27.5 ± 1
Blowing & Wet	4 ± 2	30 ± 2	27.5 ± 1

From the perspective of the snow-making mechanism in artificial snow production, environmental parameters include temperature, humidity, and wind speed. During testing, the atmospheric environment of the snowfall simulation area is monitored through a weather station.

According to the requirements of AMC25.1093 for simulated snowfall environments, measurements of snowfall intensity and snow density are necessary. The snowfall intensity is characterized by the total water content (TWC), which is measured by the WCM2000 device. The WCM2000 is commonly used in aircraft and wind tunnel tests, and is capable of measuring both liquid water content (LWC) and total water content (TWC) simultaneously. This device has been used in FAA icing certification and ice wind tunnel calibration tests, and can accurately and in real-time measure the total water content in simulated snowfall environments. The snow density is calculated using the weight-volume method, in which snow is collected in a snow collector placed in the simulated snowfall environment, and weighed, and the snow density is calculated as the ratio of the weight of the collected snow to the volume of the snow collector, minus the weight of the snow collector. The snow quality is determined based on the snow density. The parameters that need to be measured are shown in Table 4.

Table 4. Measurement Parameters.

Parameters	Measurement value	Unit
Wind speed	-	m/s
Air temperature	-	℃
Relative humidity	-	%
TWC	-	g/m³

4. Results and Analysis

4.1. Effects of environmental wind on snowfall simulation

The environmental wind was tested using a weather station. As shown in Figure 1, the wind speed inside and outside of the snowfall simulation system was tested. The test results are shown in Figure 2.

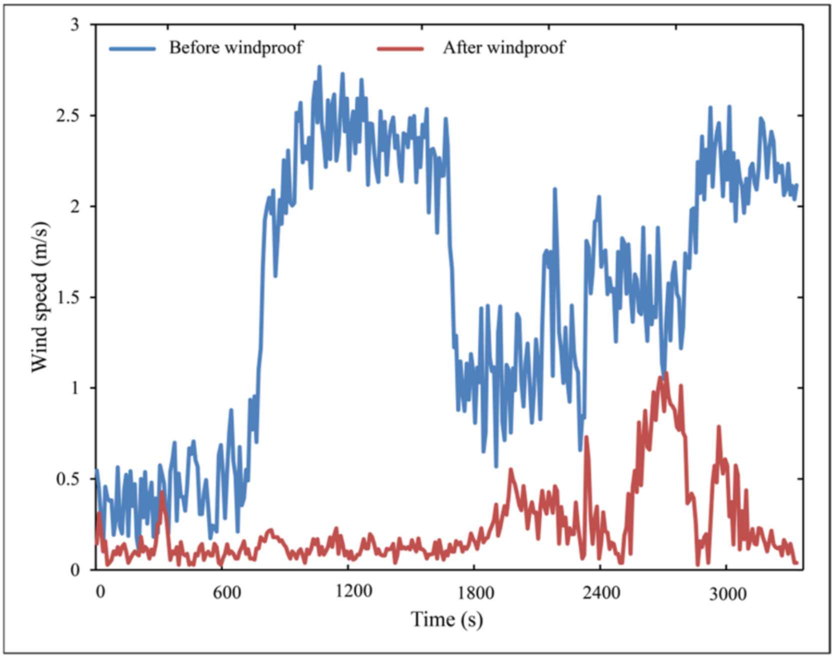

Figure 2. Windproof effect.

It can be seen from the test results that during the one-hour continuous test, when the environmental wind speed was below 3 m/s, the windproof module was able to reduce the environmental wind speed to below 1 m/s. When the environmental wind speed was less than 1 m/s, the impact of environmental wind on artificial snow production can be ignored. Therefore, the effect of environmental wind on snowfall simulation can be ignored in this snowfall simulation system.

4.2. Effects of environmental temperature and humidity on snow simulation

In the field of meteorology, wet bulb temperature is commonly used to indicate the influence of environmental temperature and humidity on natural snowfall. Therefore, the effect of environmental temperature and humidity on simulated snowfall environments can be converted into studying the effect of wet bulb temperature on artificial snowfall simulations. This chapter aims to find suitable temperature and humidity ranges for simulated snowfall environments by measuring the effect of wet bulb temperature on artificial snowfall under different temperature and humidity conditions. According to the simulated snowfall environment parameters shown in Table 3, the relevant equipment was set up to test the temperature and humidity ranges for simulating dry snowfall, wet snowfall, blowing dry snowfall, and blowing wet snowfall.

For the measurement of the dry snow temperature and humidity envelope in the simulated environment, the equipment parameters were set as follows: the water supply temperature was (3 ± 1) °C, the water supply pressure was (10 ± 2) bar, the snow-making equipment inclination angle was (18.5 ± 1)°, and the distance from the snow-making equipment to the test area was (31.5 ± 0.5) m. As shown in Figure 3, the green box indicates the measured wet-bulb temperature range, which was (-12.0 ~ -5.6) °C. Therefore, the temperature and humidity envelope for the dry snow in the simulated environment can be determined as the range within the blue and green areas in Figure 3.

Falling Dry Snow Simulation Envelope																
Relative humidity (%)	Environmental temperature (°C)															
	3	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12
90%	2.4	1.5	0.5	-0.6	-1.5	-2.5	-3.6	-4.5	-5.4	-6.3	-7.3	-8.4	-9.4	-10.3	-11.3	-12.3
80%	1.8	0.9	-0.1	-1.1	-2.1	-3.1	-4.0	-4.9	-5.8	-6.8	-7.7	-8.6	-9.6	-10.6	-11.6	-12.6
70%	1.1	0.1	-0.7	-1.7	-2.6	-3.7	-4.6	-5.5	-6.3	-7.2	-8.1	-9.1	-10.0	-11.0	-11.9	-12.9
60%	0.3	-0.7	-1.5	-2.3	-3.2	-4.1	-5.0	-5.9	-6.7	-7.6	-8.5	-9.3	-10.4	-11.2	-12.2	-13.1
50%	-0.5	-1.3	-2.2	-3.0	-3.8	-4.7	-5.6	-6.4	-7.2	-8.1	-9.0	-9.9	-10.7	-11.7	-12.6	-13.4
40%	-1.3	-2.1	-2.9	-3.7	-4.4	-5.2	-6.1	-6.9	-7.7	-8.5	-9.4	-10.3	-11.1	-12.0	-12.8	-13.7
30%	-2.0	-2.8	-3.5	-4.3	-5.0	-5.8	-6.7	-7.4	-8.1	-9.0	-9.8	-10.6	-11.4	-12.3	-13.1	-14.0
20%	-2.9	-3.5	-4.3	-5.0	-5.7	-6.5	-7.2	-7.9	-8.7	-9.4	-10.2	-11.0	-11.8	-12.7	-13.5	-14.3
10%	-3.5	-4.3	-5.0	-5.6	-6.3	-7.1	-7.8	-8.5	-9.2	-9.9	-10.6	-11.4	-12.3	-13.1	-13.8	-14.6

Figure 3. Falling dry snow simulation envelope.

For the measurement of the temperature and humidity envelope for simulating wet snowfall, the equipment parameters were set to a water supply temperature of (4 ± 2) °C, a water supply pressure of (10 ± 2) bar, and a snowmaking equipment inclination angle of (18.5 ± 1) °, and the distance from the snowmaking equipment to the test area was (28.5 ± 0.5) m. As shown in Figure 4, the green box indicates the tested wet bulb temperature range, which was (-6.7 ~ -2.3) °C. Therefore, the temperature and humidity envelope for simulating wet snowfall can be determined as the blue and green areas in Figure 4.

Falling Wet Snow Simulation Envelope																
Relative humidity (%)	Environmental temperature (°C)															
	3	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12
90%	2.4	1.5	0.5	-0.6	-1.5	-2.5	-3.6	-4.5	-5.4	-6.3	-7.3	-8.4	-9.4	-10.3	-11.3	-12.3
80%	1.8	0.9	-0.1	-1.1	-2.1	-3.1	-4.0	-4.9	-5.8	-6.8	-7.7	-8.6	-9.6	-10.6	-11.6	-12.6
70%	1.1	0.1	-0.7	-1.7	-2.6	-3.7	-4.6	-5.5	-6.3	-7.2	-8.1	-9.1	-10.0	-11.0	-11.9	-12.9
60%	0.3	-0.7	-1.5	-2.3	-3.2	-4.1	-5.0	-5.9	-6.7	-7.6	-8.5	-9.3	-10.4	-11.2	-12.2	-13.1
50%	-0.5	-1.3	-2.2	-3.0	-3.8	-4.7	-5.6	-6.4	-7.2	-8.1	-9.0	-9.9	-10.7	-11.7	-12.6	-13.4
40%	-1.3	-2.1	-2.9	-3.7	-4.4	-5.2	-6.1	-6.9	-7.7	-8.5	-9.4	-10.3	-11.1	-12.0	-12.8	-13.7
30%	-2.0	-2.8	-3.5	-4.3	-5.0	-5.8	-6.7	-7.4	-8.1	-9.0	-9.8	-10.6	-11.4	-12.3	-13.1	-14.0
20%	-2.9	-3.5	-4.3	-5.0	-5.7	-6.5	-7.2	-7.9	-8.7	-9.4	-10.2	-11.0	-11.8	-12.7	-13.5	-14.3
10%	-3.5	-4.3	-5.0	-5.6	-6.3	-7.1	-7.8	-8.5	-9.2	-9.9	-10.6	-11.4	-12.3	-13.1	-13.8	-14.6

Figure 4. Falling wet snow simulation envelope.

For the measurement of the temperature and humidity envelope in a snowdrift dry snow environment simulation, the equipment parameters were set to a supply water temperature of (3 ± 1) °C, a supply water pressure of (30 ± 2) bar, and a snow-making device inclination angle of (27.5 ± 1)°, and the distance from the snowmaking equipment to the test area was (31.5 ± 0.5) m. As shown in Figure 5, the green box indicates the tested wet bulb temperature, which was measured to be in the range of (-12.2 ~ -6.7) °C. Therefore, the temperature and humidity envelope for the snowdrift dry snow can be determined to be within the blue and green areas in Figure 5.

Blowing Dry Snow Simulation Envelope																
Relative humidity (%)	Environmental temperature (°C)															
	3	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12
90%	2.4	1.5	0.5	-0.6	-1.5	-2.5	-3.6	-4.5	-5.4	-6.3	-7.3	-8.4	-9.4	-10.3	-11.3	-12.3
80%	1.8	0.9	-0.1	-1.1	-2.1	-3.1	-4.0	-4.9	-5.8	-6.8	-7.7	-8.6	-9.6	-10.6	-11.6	-12.6
70%	1.1	0.1	-0.7	-1.7	-2.6	-3.7	-4.6	-5.5	-6.3	-7.2	-8.1	-9.1	-10.0	-11.0	-11.9	-12.9
60%	0.3	-0.7	-1.5	-2.3	-3.2	-4.1	-5.0	-5.9	-6.7	-7.6	-8.5	-9.3	-10.4	-11.2	-12.2	-13.1
50%	-0.5	-1.3	-2.2	-3.0	-3.8	-4.7	-5.6	-6.4	-7.2	-8.1	-9.0	-9.9	-10.7	-11.7	-12.6	-13.4
40%	-1.3	-2.1	-2.9	-3.7	-4.4	-5.2	-6.1	-6.9	-7.7	-8.5	-9.4	-10.3	-11.1	-12.0	-12.8	-13.7
30%	-2.0	-2.8	-3.5	-4.3	-5.0	-5.8	-6.7	-7.4	-8.1	-9.0	-9.8	-10.6	-11.4	-12.3	-13.1	-14.0
20%	-2.9	-3.5	-4.3	-5.0	-5.7	-6.5	-7.2	-7.9	-8.7	-9.4	-10.2	-11.0	-11.8	-12.7	-13.5	-14.3
10%	-3.5	-4.3	-5.0	-5.6	-6.3	-7.1	-7.8	-8.5	-9.2	-9.9	-10.6	-11.4	-12.3	-13.1	-13.8	-14.6

Figure 5. Blowing dry snow simulation envelope.

For the measurement of the simulated snowdrift wet snow environment, the equipment parameters were set as follows: the supply water temperature was (4 ± 2) °C, the supply water pressure was (30 ± 2) bar, the snowmaking equipment inclination angle was (27.5 ± 1)°, and the distance from the snowmaking equipment to the testing area was

(28.5 ± 0.5) m. As shown in Figure 6, the green box indicates the wet bulb temperature that has been tested, and the tested wet bulb temperature range is (-8.5 ~ -5.0) °C, so the temperature and humidity envelope of the snowdrift wet snow can be determined as the blue and green areas in Figure 6.

Blowing Wet Snow Simulation Envelope

Relative humidity (%)	Environmental temperature (°C)															
	3	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12
90%	2.4	1.5	0.5	-0.6	-1.5	-2.5	-3.6	-4.5	-5.4	-6.3	-7.3	-8.4	-9.4	-10.3	-11.3	-12.3
80%	1.8	0.9	-0.1	-1.1	-2.1	-3.1	-4.0	-4.9	-5.8	-6.8	-7.7	-8.6	-9.6	-10.6	-11.6	-12.6
70%	1.1	0.1	-0.7	-1.7	-2.6	-3.7	-4.6	-5.5	-6.3	-7.2	-8.1	-9.1	-10.0	-11.0	-11.9	-12.9
60%	0.3	-0.7	-1.5	-2.3	-3.2	-4.1	-5.0	-5.9	-6.7	-7.6	-8.5	-9.3	-10.4	-11.2	-12.2	-13.1
50%	-0.5	-1.3	-2.2	-3.0	-3.8	-4.7	-5.6	-6.4	-7.2	-8.1	-9.0	-9.9	-10.7	-11.7	-12.6	-13.4
40%	-1.3	-2.1	-2.9	-3.7	-4.4	-5.2	-6.1	-6.9	-7.7	-8.5	-9.4	-10.3	-11.1	-12.0	-12.8	-13.7
30%	-2.0	-2.8	-3.5	-4.3	-5.0	-5.8	-6.7	-7.4	-8.1	-9.0	-9.8	-10.6	-11.4	-12.3	-13.1	-14.0
20%	-2.9	-3.5	-4.3	-5.0	-5.7	-6.5	-7.2	-7.9	-8.7	-9.4	-10.2	-11.0	-11.8	-12.7	-13.5	-14.3
10%	-3.5	-4.3	-5.0	-5.6	-6.3	-7.1	-7.8	-8.5	-9.2	-9.9	-10.6	-11.4	-12.3	-13.1	-13.8	-14.6

Figure 6. Blowing wet snow simulation envelope.

The environmental temperature and relative humidity lines of simulated snowfall show that different snowfall intensities and different snow densities have different lines. Within the required range of the same snow density (such as wet snow), the lines of different snowfall intensities overlap, but due to the different total water content (TWC) of artificial snow-making fields, the wet bulb temperature required for the simulated wet snow environment is relatively high, while the wet bulb temperature required for the initial phase of simulated snowfall by snow blowing is relatively low. Similar situations exist in the simulated dry snow environment. Under the same snowfall intensity, there may be overlapping simulation boundaries for snowfall environments with different densities. This is because there are certain fluctuations in equipment control parameters such as water supply temperature, which result in instability in the density of artificially generated snowfall in the overlapping area. Therefore, it is recommended to avoid this area as much as possible when conducting artificial snowfall environment simulation.

5. Conclusion

Through the analysis of snow formation mechanisms in natural and artificial environments and the requirements for simulated snow conditions, an outdoor system for simulating snow environments has been established. Through experimental research on environmental factors affecting snow simulation, the following conclusions can be drawn:

(1) Under the condition of environmental wind speed not exceeding 3 m/s, a windproof device can reduce the environmental wind speed to below 1 m/s, and thus the effect of environmental wind on snow simulation can be neglected after establishing a suitable windproof device.

(2) Under the given equipment parameters, the main factors affecting outdoor snow simulation are environmental temperature and relative humidity, which can be characterized by wet bulb temperature.

(3) For falling snow (snow intensity of 1 g/m^3) environment simulation, the wet bulb temperature envelope of dry snow ($\rho \leq 0.35$ g/cm^3) is (-12.0 ~ -5.6) ℃, and the wet bulb temperature envelope of wet snow (0.35 g/cm^3 $\leq \rho <$ 0.5 g/cm^3) is (-6.7 ~ -2.3) ℃.

(4) For blowing snow (snow intensity of 3 g/m^3) environment simulation, the wet bulb temperature envelope of dry snow ($\rho \leq 0.35$ g/cm^3) is (-12.2 ~ -6.7) ℃, and the wet bulb temperature envelope of wet snow (0.35 g/cm^3 $\leq \rho <$ 0.5 g/cm^3) is (-8.5 ~ -5.0) ℃.

(5) Under the same snow intensity, the envelopes of simulated snow conditions with different snow densities overlap due to fluctuations in equipment parameters such as water temperature. Therefore, when conducting artificial snow simulation, this area should be avoided as much as possible.

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