GAS DYNAMICS

TYPES OF WIND TUNNELS AND MEASURING TOOLS

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Introduction

Wind tunnels are essential tools in the study of gas dynamics, providing a controlled environment to simulate and analyze airflow around objects. These facilities play a pivotal role in understanding aerodynamic properties, such as lift, friction, and pressure distribution, which are critical elements in the design and development of vehicles, .aircraft, and structures

The measurement tools used in wind tunnels enable engineers and researchers to collect accurate data on parameters such as speed, pressure, temperature, and forces acting on tested models. By using these tools in different types of wind tunnels, from subsonic to hypersonic, realistic conditions can be simulated and designs can be optimized for efficiency and .safety

This report discusses the different types of wind tunnels and their characteristics, as well as the measurement tools commonly used in experiments. It also highlights the importance of selecting the appropriate wind tunnel and tools for specific .applications in gas dynamics research

Types of wind tunnels

Subsonic Wind Tunnels

Subsonic wind tunnels are used to test objects moving at speeds below the speed of sound (less than 343 m/s at sea level). They provide a uniform and stable airflow to study aerodynamic forces such as lift and friction. They are ideal for testing designs of small aircraft, automobiles, and buildings to determine their stability and .performance in natural wind conditions

These tunnels are used to study objects moving at subsonic speeds, such as cars and small commercial aircraft.

Practical example: Subsonic wind tunnels are used to test the design of sports cars such as Formula 1 cars to improve aerodynamics and reduce air resistance. They are also used to analyze the effect of wind on tall buildings such as skyscrapers to ensure their stability against .storms

Hypersonic Wind Tunnels

Hypersonic wind tunnels are specially designed to study flows moving at supersonic speeds (between Mach 1.2 and Mach 5). Their design features high pressure chambers and special nozzles to accelerate the air flow. These tunnels are used to analyze the designs of aircraft and spacecraft that experience very high speeds, allowing us to understand the effects of heat generated by friction and to check the durability of .the materials used

They are ideal for testing objects moving at very high speeds, such as military aircraft and missiles.

Practical example: These tunnels are used to analyze the aerodynamic performance of the F-22 Raptor fighter jet while flying at speeds exceeding Mach 2. They are also used to design .spacecraft to ensure they can withstand the heat of re-entry

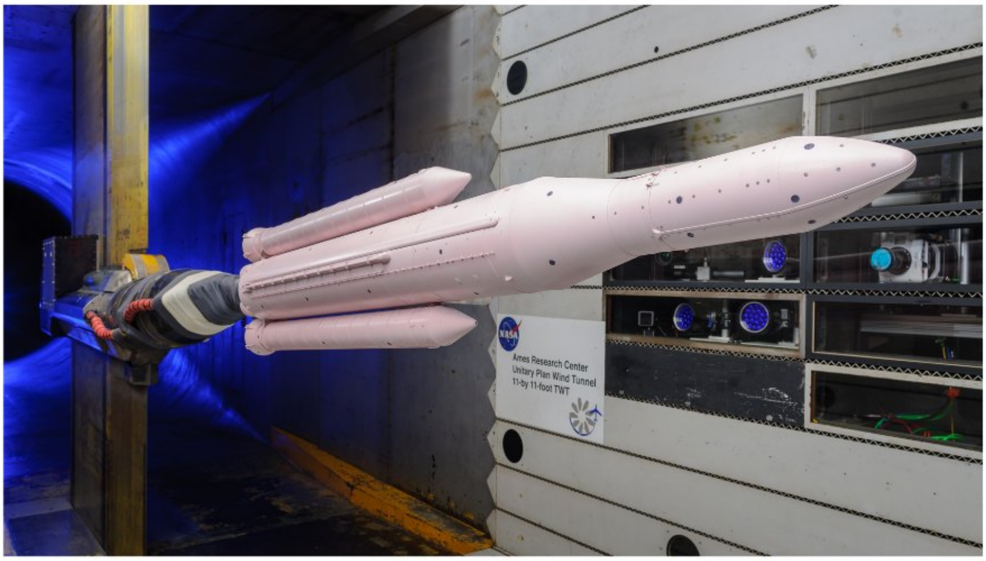
Transitional Wind Tunnels (Sub- and Supersonic)

These tunnels play an important role in studying the transition between subsonic and supersonic flows (between Mach 0.8 and 1.2). They are used to analyze the behavior of air during the transition phases, which is essential to improve the efficiency of aircraft and missiles when crossing these .ة.aerodynamic boundaries

Transitional Wind Tunnels (Subsonic and Supersonic)

Used to study the aerodynamic behavior of objects transitioning .between subsonic and supersonic flows

Practical example: Used in the design of high-speed transport aircraft such as the new supersonic passenger aircraft (Boom Supersonic) to ensure a smooth transition between subsonic and supersonic speeds .during takeoff and landing



Specialized Wind Tunnels

.Specialized wind tunnels are designed to meet specific research needs

Environmental wind tunnels: Used to simulate real weather conditions to .test the effects of wind on structures such as bridges and towers

Vertical wind tunnels: Used to study vertical airflows and are applied in .vertical flight research and helicopter design

.Small wind tunnels: Used to test scale models, such as drone design

Specialized wind tunnels

.Used to meet specific needs and test unique scenarios

:Environmental wind tunnels

Practical example: Used to test bridge designs such as the Tacoma .Narrows Bridge to analyze their response to severe storms

:Vertical wind tunnels

Practical example: Used to develop helicopter and vertical takeoff aircraft .designs such as the V-22 Osprey

:Small wind tunnels

Practical example: Used to test small drones to determine their flight .efficiency, such as delivery drones used by companies such as Amazon

Wind tunnel measuring instruments

Pressure measurement

Pressure measurement is one of the most important tools in wind tunnel research to determine the pressure .distribution on models

:Pressure gauges

.They are used to measure static and dynamic pressure

Working example: Using a pitot tube to measure the difference between static and total pressure to determine .air velocity

:Pressure transducers

Convert pressure into electrical signals that can be analyzed .using computer systems

Working example: They are used to determine the pressure .distribution on an aircraft wing during experiments

The differential pressure transmitter is designed with dual remote sensors that enable it to accept high pressure in ranges up to 500 PSI

Pressure Measurement

:Pressure Measuring Instruments

Product: Pitot-Static Tube by TSI

Features: A robust and accurate instrument for measuring static and total .pressure, widely used in flight tests and subsonic wind tunnels

.Application: Analyzing the airflow around the aircraft body

Its price is about 3000 thousand riyals

Pressure Transducers:

Product: Kulite Semiconductor Pressure Transducers

Features: High-precision pressure transducers suitable for use in harsh .environments

Application: Measuring dynamic pressure on model surfaces in ultrasonic .tunnels

Its price is 400 riyals

Velocity measurement

Velocity measurement is an essential element in .understanding the airflow around models

:Hot Wire Anemometers

Used to measure changes in flow velocity with high .accuracy

How they work: They depend on cooling a hot wire due to the airflow, and the change in resistance is measured to .determine the velocity

Worked example: Studying boundary layers on wing .surfaces

:Laser Doppler Velocimetry (LDV)

Uses laser beams to determine the velocity of particles in .the flow based on the Doppler effect

Worked example: Analysis of airflows in high-speed .experiments

Speed Measurement

:Hot-Wire Anemometers

Product: Dantec Dynamics Hot-Wire Anemometer

.Features: High accuracy and excellent response speed

.Use: Study of boundary layers and turbulent flows around wings

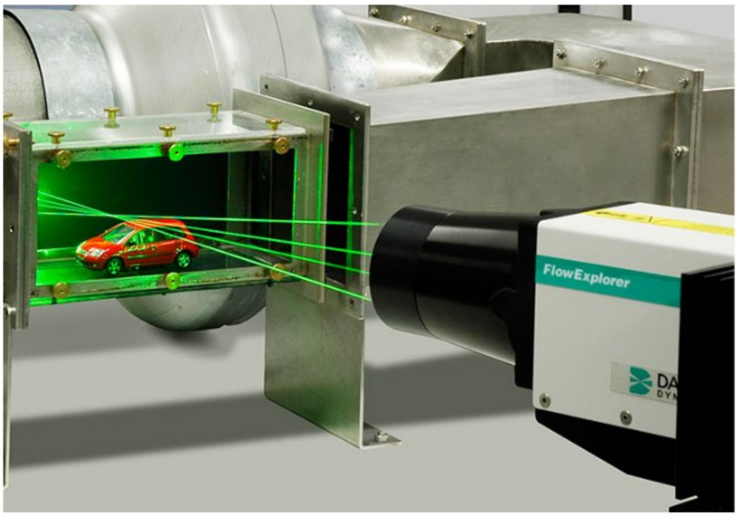
Its price is about 1500 riyals

Laser Doppler Velocity Measurement (LDV):

Product: TSI Laser Doppler Velocimeter

Features: Measures airflow velocities with an accuracy of up to .micrometers per second

.Use: Analyzes airflow around wind turbine blades or supersonic vehicles



Laser Doppler anemometer (LDA), also known as laser Doppler velocimetry (LDV), is an optical technique ideal for measuring the velocity and turbulence distribution in both free and internal flows at one-, two- and three-dimensional points.

Temperature Measurement

Temperature measurement is essential to understanding the thermal .effects on models during experiments

:Thermocouples

Measure temperature through an electric current generated by the .difference in metallic materials

Working example: Studying the effect of friction on the surface .temperature of spacecraft

:Infrared Sensors

Measure temperature remotely by analyzing the thermal radiation emitted .by objects

Working example: Measuring temperature on an aircraft structure during .supersonic speed simulation

Temperature measurement

:Thermocouples

Product: Omega K-Type Thermocouple

.Features: Withstands high temperatures up to 1000°C

.Use: Measures the heat generated by air friction on aircraft surfaces

Its price is about 500 riyals.

Infrared Sensors:

Product: FLIR Infrared Thermal Camera

Features: Highly accurate remote temperature measurement and thermal .imaging

.Use: Analysis of thermal changes on surfaces during high-speed tests

Its price is about 5300 riyals

Force and torque measurement

These tools are used to directly understand the effect of flow on .models

:Balance Systems

Measure the three main forces (lift, drag, and thrust) and the torques .about the three axes

.Working example: Testing the forces acting on an aircraft design

Balance Systems:

Product: MTS Multi-Axis Force Balance

Features: Measure forces and moments about three axes with extreme .accuracy

.Use: Evaluate the effect of airflow on aircraft models

Strain Gauges:

Used to measure the deformation caused by forces acting on .models

.Working example: Stress analysis on wind turbine blades

:Strain Gauges

Product: Vishay Precision Strain Gauges

.Features: High sensitivity for measuring precise strains

.Use: Testing the stress caused by air flows on fan blades or wings

Comparison of wind tunnel types

Type of Wind Tunnel	Speed Range	Applications
Subsonic Wind Tunnels	Less than 0.8 Mach	Aircraft, cars, buildings testing
Supersonic Wind Tunnels	1.2 - 5 Mach	Studying supersonic aircraft and rockets
Transonic Wind Tunnels	0.8 - 1.2 Mach	Transition studies between subsonic and supersonic flows
Specialized Wind Tunnels	Varies with purpose	Environmental, vertical, or scaled model testing

Advantages	Disadvantages
Low cost, easy to operate and maintain	Not suitable for high-speed testing
High precision for fast flows	Expensive to operate, generates high heat
Ideal for studying transitional flow	Limited speed range
Meets specific research needs	Not suitable for general tests

Comparison of Types of Wind Tunnels

Subsonic Wind Tunnels

Practical Examples: Designing racing cars such as Formula .1, testing the stability of skyscrapers

Advantages: Efficient in analyzing airflow at everyday .speeds (normal winds)

.Disadvantages: Cannot simulate supersonic flows

Supersonic Wind Tunnels

Practical Examples: Developing military aircraft such as .fighters or spacecraft

Advantages: Provides accurate simulation of thermal and .dynamic conditions at high speeds

Disadvantages: Requires advanced technologies such as .cooling systems and large power supplies

Transitional Wind Tunnels

Practical Examples: Studying the transition of aircraft .between different speeds during takeoff or landing

Advantages: Provides a comprehensive understanding of .the change in airflows over the model body

Disadvantages: Only used in specific cases due to their .narrow speed range

Specialized Wind Tunnels

:Practical examples

Environmental wind tunnels: Analysis of the effect of wind on structures such as bridges or simulation of environmental .pollution

.Vertical wind tunnels: Design of helicopters or wind turbines

.Advantages: Provides accurate results for unique applications

.Disadvantages: Not suitable for conventional tests

The most appropriate choice

.The choice of tunnel type depends on the required application

.For conventional or everyday tests: Subsonic tunnel

.To study high-speed flows: Ultrasonic tunnel

.To understand dynamic transitions: Transition tunnel

.For specialized applications: Specialized tunnel

Applications

Wind Tunnel Applications

:Aircraft Design

.Improving the performance of commercial and military aircraft

.Studying the distribution of pressure and lift on wings

:Automotive Development

.Reducing air resistance to improve fuel efficiency

.Improving the stability of cars at high speeds

:Civil Engineering

.Testing the resistance of buildings and bridges to wind

.Analysis of aerodynamic effects on skyscrapers

:Space Research

Studying the effect of high speeds on spacecraft when entering the .atmosphere

.Developing the design of heat shields

:Renewable Energy

.Improving the efficiency and design of wind turbines

.Studying the airflow around large fans

Conclusion

Wind tunnels are essential tools in aerospace engineering, civil engineering, and other industries. They provide a safe and accurate environment to study the effects of airflow on various models, helping to improve performance and design while reducing risk. As technology advances, wind tunnels have become more specialized, enhancing their ability to meet the demands of modern research.

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