WIND SPEED AND DIRECTION MEASUREMENT IN AERONAUTICAL METEOROLOGY

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The article presents the description of wind direction and speed measurement at ground meteorological stations. The work contains a detailed description of the methods for wind direction and speed measurement and also a description of the equipment used for measurement of wind direction and speed. The work focuses attention on how the wind affects the air transportation. Attention is devoted to the characterization of the processing of the measurement results and the description of aeronautical meteorological reports, through which information about the wind direction and speed is further presented. The last part deals with chosen instruments that measure wind direction and speed, the description of the technical specifications and financial analysis of acquisition costs.

K e y w o r d s: anemometer, wind direction, wind speed, aeronautical meteorology

1 INTRODUCTION

The aim of the article is to describe the measurement of wind direction wind speed at ground meteorological stations. Measurement of wind speed and direction and the subsequent reporting of the measured values of wind are very important for the safe flights performance.

Of all the meteorological elements wind is one of the most important for aviation and aviation safety is very dependent on it.

The aim of this work is to demonstrate that the wind affects mainly the aircrafts during the take-off and landing and that wind was often the cause of the tragic accidents. Therefore it is very important to measure the wind that pilots and air traffic controllers always have current information about wind speed and direction, and to be able to prevent from such accidents.

2 CHARACTERISTIC OF WIND

Wind is one of the basic meteorological elements. Wind we can define as a predominantly horizontal movement of the air flow. This airflow causes horizontal equalization of pressure differences. Wind is an essential means of transferring energy, water, pollutants and other physico-chemical properties of the air masses.

Wind is the movement of air, which arises due to the existence of pressure gradients. Basically it is similar to the mechanism that sets in motion the water. The water flows through the influence of a gravitational force component which is parallel to the inclined plane from top to bottom. The pressure gradient is a vector whose vertical component will be considered as equilibrium with the gravitational acceleration and the horizontal component point in the direction from high pressure to low pressure.

For causing air flow, therefore wind, the horizontal force is responsible. Due to the existence of a pressure gradient the air pressure difference between locations on Earth occurs and the formation of wind is essential [1].

Wind direction is determined according to the world sides from which the air flows. In meteorology, the world sides usually indicate the English name (N - North - North, S - South - South E - East - East, W - West - West), and in the aviation meteorology it is usually given by the angle from 0 ° to 360 °. Wind direction is reported in the right degrees, which are rounded to the nearest whole degree.

Wind speed is a path that air particle overcome for some time. Wind speed is reported in kilometres per hour or knots. The value is rounded to the nearest 1 kt.

Gustiness wind is most often determined by the difference between the maximum and minimum wind speed at a certain time, for example in 10 or 15 minutes [2][3].

3 MEASUREMENT OF WIND SPEED AND DIRECTION

The wind is continuously measured at each weather station. There are also a large number of automatic weather stations that measure wind and obtained data dispatched to meteorological centres. This makes that the measuring sensors are also located in maritime buoys, on mountain tops and in other remote locations, information about wind speed and direction are easily accessible for meteorologists.

Ground level wind measured by the anemometer, which is located on the mast, which is 10 m high, therefore the wind is measured at 10 m above the ground. For this reason, we also usually talk about the wind at ground level [4].

3.1 Basic principles of air flow measurement

Wind vane

Wind direction indicator represents a sensitive and balanced system, which is located on the pivot pin. The base part of wind vane, wing direction, under wind pressure gives in a position that it acted least resistance. On the opposite side is a counterweight which the influence of wind, focuses his shoulder against the direction of air flow.

Robinson cross

Robinson cross with three hemispherical cups is based on the principle that the convex side, has a much lower resistance to air flow than concave side cup.

Paddle-wheel

Paddle wheel has a rotary part rotating about a horizontal axis. Pressure of air flow acts on the inclined blades and causes blade rotation.

Cooling effects

Surface which is heated is cooled. Cooling surface effects are expressed by changing the temperature or energy. These effects correspond to a certain velocity of wind.

Pitot tube

Pitot tube is used to instantaneous monitoring of air velocity speed. It consists of a tube pointing directly into the fluid flow. As this tube contains fluid, a pressure can be measured; the moving fluid stagnates as there is no outlet to allow flow to continue. This pressure is the stagnation pressure of the fluid, also known as the total pressure or (particularly in aviation) the pitot pressure [3].

3.2 Devices used for wind direction and speed measurement

Wind sleeve

Wind sleeve is a device by which we can determine the direction and partly power of the wind. Wind sleeve is made of substance that is sewn into the shape of a truncated cone shell without base. Substance on the sleeve has a contrasting coloring. They are mostly used red and white stripes. Side wind sleeve with a larger diameter is mounted on a circular holder, which is usually metallic. The holder is mounted either in the vertical plane, so that it can freely rotate about a vertical axis, or on a pole is suspended by ropes. Sleeve length depends on the purpose for which the wind sleeve will be used. It ranges from less than one meter up to 3.6 meters.

Wind sleeves are mainly used in airports, on which are placed along the runways. The sleeves are also often placed on heliports. On the airports tend sleeves are lit for the case when used at night [6].

Figure 1 Wind sleeve

Wind vane

Wind vane is a device used for accurate measurement of wind direction. One of the parts of a wind direction is an indicator – it is a rotatable part that sets the action of wind in the direction of air flow. Wind vane position shall be determined in two ways, the first of which is a visual way, using a fixed wind rosette, a second way of determining the position of the wind vane for the remote transmission of position angle, which is read from the indicator, or registration of the device. Measuring characteristics of wind vane are dependent mainly on a rotational moment and the shape of the rotating parts. Wind vane is placed at the meteorological stations as anemometer, at the location where air flow is not deformed local impacts. So it is a distance that is greater than ten times the elevation of obstacles in the area.

Figure 2 Wind vane

Anemometer

Accurate meteorological wind speed and direction measurement is performed using instruments called anemometers. It is installed on hinged steel poles, to reach the lightning rod. Speed device is a small three cup cross, which use the effect of wind to rotate them. Of the shell-shaped cross shaft a magnet is mounted, which, when rotating, the solid stator winding indicates in the device electric current. Voltage that arises after the guidelines butt measured rectifier device called a voltmeter. The scale of voltmeter is numbered directly in meters per second. Measurement of wind direction allows that the wind vane, which is connected to the current induced cup cross, to rotate the movable contact. After the switch is turned to the wind direction measurement, which at this moment shows the wind vane, the indicator needle is deflected, allowing reading the wind speed. Voltmeter and switch are placed in the box indicating device that is installed in a room which is located at a distance of 50 m from the head.

Figure 3 Anemometer

Anemograph

Universal anemograph is a device used to measure wind direction, wind path and the instantaneous speed of the wind – wind gusts. And at the same time the information about the wind are registered in a twenty-four hours record. Basic parts of the anemograph are measuring head, registration and the indication part and the installation and operating accessories. The measuring head consists of sampling tubes measuring total and static pressure. The measuring head is called a speed tube, too and is used to measure the instantaneous wind speed using differential manometer method. Other part of the measuring head is a wind vane. The third part of the measuring head is the Robinson cup cross, which is used for measurement of the wind path and is composed of three cups made of light metal. Individual cups in the Robinson cross are oriented in one direction of rotation. So the wind, which acts on the hollow side cups are affected by greater pressure than the rounded side cups, causing spin cross. Very sensitive wind vane is also made of light metal. Wind vane movements are transmitted to the registration section, which indicates wind direction. Measuring head is mounted on the mounting pipe. This assembly pipe passes through the recording apparatus necessary pressure pipe and extension rod. The entire measuring portion is protected from the elements using a box in which it is stored.

The registration part of anemograph uses a pair of pens placed in the upper part to write the wind direction, the pen in the middle section record path of wind and pen, located at the lower section inscribed instantaneous speed of wind, therefore wind gusts.

Ultrasonic anemometer

Ultrasonic anemometer determines the instantaneous wind speed and direction. Ultrasonic anemometer records the phase shift of the reflected sound from the air molecules. Measurement of wind direction and speed is based on ultrasonic pulse slowing. It provides a very accurate measurement of air velocity independently from the direction of air flow. Ultrasonic device type 2D measures horizontal components of air flow. Ultrasonic devices 3D monitor the flow vectors in addition to the horizontal and downward flow.

The main advantages of ultrasonic anemometers in comparison to conventional anemometers are that ultrasonic anemometers have no moving parts, therefore, are less difficult to maintain. One device measures the speed and direction of wind. A further advantage is that they have a heating and therefore they are not sensitive to icing and may also be used in areas with low air temperatures [6].

Figure 4 Ultrasonic anemometer

4 IMPACT OF WIND ON AIR TRANSPORTATION

Wind is characterized by direction, variability of direction, speed and spasmodic, but also a change of direction and speed along the vertical or horizontal. More rapidly wind changes are called wind shear. Wind direction is very important for take-off and landing aircrafts, because each aircraft has exact limits for side and tail-wind components during this phase of flight. For example, the glider can land on the wind with a speed of 5 m/s blowing from abeam. And airliner cannot land on the side or tailwind component at a speed of 20 m/s. The reason for specifying limits for every type of aircraft lies in the maintaining of the security of take-off and landing.

In addition, the wind affects the take-off and landing, also affects the travel performance of each aircraft. This is mainly because the fact that the wind affects the speed of the flight and thus changes the duration of the flight. For example, the wind glider has different slipperiness; motor aircraft has different fuel consumption per unit distance. Wind has to be taken into account during the flight planning, calculation of the necessary amount of fuel, gliding tactics, navigation (solutions drift) and also in many other situations. Variability of wind direction affects can be dangerous again during the take-off and landing. This is due to the fact that while a few minutes before landing can be on the runway headwind indicated, during landing it may change the direction to the tailwind and thus extends the length of the runway necessary for the landing. The lighter or slower the aircraft is, the more the aircraft is influenced by the wind. Variable winds, however, are usually associated with very small flow velocities, it is usually only up to 10 kt. Wind speed during take-off or landing or take-off affects the roll out of the aircraft. The front wind component increases the buoyancy of the aircraft relative to the IAS and heat shortens the range, the tailwind component contrary heat and extended range. Wind speed also has an impact on the eventual drift - lateral wind component, which causes some specifics in piloting, the greater, the speed is higher crosswind.

Surface wind gustiness is the risk that unexpected sudden changes in wind speed causes increased or decreased lift of the aircraft. Momentum of the aircraft shall apply with respect to a stationary Earth's gravitational field, while the aerodynamic forces resulting from wrapping bearing surfaces of the aircraft convection. Thus, the aircraft flies at a certain forward momentum while trying to maintain the speed while a sharp fall in the rate headwinds may lead to sudden aerodynamic lift and only can lead to a crash of the aircraft. The side gusts of wind have the effect of rapid changes in the tilt of the aircraft and may also result into the collision of the aircraft wing with the ground [4].

5 MEASUREMENT RESULTS PRESENTATION

Aviation weather services produce various types of messages, reports, forecasts and warnings that serve to the international exchange, and thus are effectively and immediately available everywhere. Air weather service in this direction becomes quite irreplaceable. Without the support of this service would not be possible to operate air transportation.

5.1 Aeronautical meteorological reports

Airports ensure continuous observation of the weather. The usual interval of issuance of periodic reports is 30 or 60 minutes. If the value of monitored meteorological elements exceeds a certain defined value, irregular reports are issued.

Of the regular meteorological observations METAR messages reporting the current weather are built [7].

In case if any of the certain elements for the weather, for example: visibility, cloud height and amount, or change direction or wind speed exceeds a set value in the intervals between regular term observation, meteorological observer issues a special report SPECI.

Landing forecast is called TREND.

TAF is forecast for airport produced by meteorological office and contains a brief description of the expected weather in the area of the airport.

GAMET forecast is defined as the general area forecast meteorological phenomena for flights at low altitudes.

AIRMET can be defined as information issued by a meteorological watch office concerning the occurrence or expected occurrence of certain weather phenomena on the track.

Warning issued for any meteorological phenomenon is a warning that has to anticipate possible complications or risks in aviation operations [8].

6 COMPARISON OF TECHNICAL SPECIFICATIONS AND PURCHASE COSTS OF SELECTED COMMERCIAL ANEMOMETERS

Devices manufactured by Gill company are suitable for larger airports and hence for example types WindObserver 65, Gill WindObserver 70 and Gill WindObserver 75 have de-icing systems, their operational temperature starts at –55 °C. According to the type they can measure wind speed up to the 65 – 75 m/s, which influences also the prices of these anemometers, which are higher.

Gill WindSonic and Gill WindSonic M devices can measure wind speed only up to the 60 m/s and although Gill WindSonic M is heated, can be operated only for temperature higher then –40 °C.

The selected devices work with the wind speed measurement precision of ±2 %, the wind direction measurement precision is ±3 % in case of the Gill WindSonic and Gill WindSonic M and ±2 % in case of Gill WindObserver 65, Gill WindObserver 70 a Gill WindObserver 75. The resolution of all devices is 0.01 m/s for the wind speed and 1° for the wind direction measurement.

VAIASALA company also offers many products. For example WAA 252 anemometer and WAV 252 are heated and their temperature operational range starts from –55 °C. Unheated versions WAA 151 and WAV 151 can be operated from –50 °C. But all of these devices contain moving parts and so they have higher demands on the maintenance and are inclinable to wear. For the wind speed and direction measurement two devices are necessary, which is a more expensive solution. This disadvantage solves WM 30. No moving parts and connected disadvantages have WMT 52 and WMT 700.

WM 30 and WMT 52 are capable to measure wind speed up to the 60 m/s, but WAA 151, WAA 252 and WMT 700 up to the 75 m/s. The wind direction can be measured with the precision of ±2 % in case of WMT 700 and with the precision of ±3 % using other mentioned VIASALA devices. The resolution is 0.01° and 0.01 m/s in case of WMT 700 and 1° and 0.1 m/s in case of WMT 52 device.

From the YOUNG company two devices were compared. The heated version YOUNG 85004 can operate from the temperature of –50 °C and is of course more expensive than the unheated version YOUNG 85000. Both devices are able to measure the wind speed up to the 70 m/s. Their precision is ±2 % for the wind direction and ±3 % for the wind speed measurement and their resolution is 1° in the wind direction and 0.1 m/s in case of wind speed measurement.

For the Slovakia the most convenient compromise would be the Gill WindObserver. The best technical characteristics has the VAISALA WMT 700 device and the cheapest from the chosen devices with technical specification satisfactory for our republic has the YOUNG 85000 device, which can be also used in our conditions, where no heating is necessary.

The comparison of purchase costs of compared devices is summarized in Tab. 1.

Tab. 1 Purchase costs of selected wind speed and direction measurement devices

Device	Purchase costs / €
Gill WindObserver 65	1 824
Gill WindObserver 70	2 225
Gill WindObserver 75	2 647
Gill WindSonic	1 452
Gill WindSonic M	1 728
VAISALA WAA 151	768
VAISALA WAV 151	830
VAISALA WAA 252	2 108
VAISALA WAV 252	2 222
VAISALA WM 30	1 092
VAISALA WMT 52	1 538
VAISALA WMT 700	2 783
YOUNG 85000	1 146
YOUMG 85004	1 606

CONCLUSION

One of the most important meteorological phenomena is the wind. Wind direction, wind speed and various manifestations of wind greatly affect the flight, but mainly affect take-offs and landings.

Despite the fact that the proposals for airport wind figures as one of the essential factors affecting the orientation of the runway, pilots have to deal with dangerous manifestations of the wind during landing, such as wind gusts, downburst, or wind shear.

Therefore, it is very important to observe and measure wind direction and speed, to ensure safe flights. Wind direction can be determined using a wind sleeve, or using a device called a wind vane. To measure wind speed anemometer, anemograph or ultrasonic anemometer are used.

The measured values of wind direction and wind speed are recorded and subsequently the air weather service issued periodic messages involving the encrypted measured values. These reports are METAR, therefore report on the current weather, emergency report SPECI, landing forecast TREND, weather forecast for airport TAF, forecast meteorological phenomena for flights at low altitudes GAMET, AIRMET report, which contains information regarding the expected occurrence of certain weather phenomena on the track.

The final part of the presented article compares technical specifications and the purchase costs of selected commercial wind speed and direction measurement devices.

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