https://doi.org/10.26552/ pas.Z.2022.1.20

# TURBULENCE AS A DANGEROUS WEATHER PHENOMENON

**Alexandra Martincová**
Air Transport Department
University of Žilina
Univerzitná 8215/1
010 26 Žilina

**Miriam Jarošová**
Air Transport Department
University of Žilina
Univerzitná 8215/1
010 26 Žilina

**Abstract**

*The aim of the theme is to examine and clarify the turbulent flow on a larger scale, especially for better flight preparation in the field of turbulence. The work explains the air flow, the formation of turbulent flow and its division into important species. It is solved how the Förchtgott classification is divided according to the type of flow on the leeward side of the mountain obstacle. At the end, it contains information on the written topic. The information is found to be that turbulence is a dangerous weather phenomenon to be taken into account, especially by the pilot so as the turbulence information has been clarified.*

**Keywords**

*Air Transport, Turbulences, Wake Turbulence, Turbulence Measurement, Cumulonimbus, Clear Air Turbulence, Jet Stream*

## 1. INTRODUCTION

In a scientific article, I address the causes of turbulence in terms of aviation dangers. Turbulence in the aviation area is characterized by a forced change in aircraft altitude due to a given condition and situation in the atmosphere [1]. It falls into the category of dangerous weather events, which can have serious, possibly fatal consequences.

Turbulent flow is a well-known meteorological phenomenon, often a threat for some. At present, it is possible to accurately predict this phenomenon by measuring and determining its conditions of occurrence.

Meteorological information is very necessary for flight planning and precise study, because especially the weather can cause unpleasant situations. This topic inspired me in terms of a certain impact on aviation and interest in meteorology, specifically turbulence. The term impact on aviation means overall meteorology and its specifics and impact on flight. By developing this topic, it is possible to gain more new knowledge about what turbulence is, how it arises and other interesting properties.

## 2. PHYSICAL SUBSTANCE OF TURBULENCE

### *2.1. AIRFLOW*

The air flow is caused by differences in atmospheric pressure, which are offset by the flow from the higher air pressure area to the lower air pressure area.

It is a complex process made up of macroscopic gas molecules that flow in a certain direction and with each other.

they can change their position, direction. The main airflow distributions include laminar and turbulent flow.

The boundary layer, whether laminar or turbulent, can be identified by its velocity profile.

### *2.2. Laminar flow*

Laminar flow refers to a steady flow of gas at a lower velocity. It shows jets that are still, parallel to each other, and the gas layers are shifted one after the other. The laminar flow is smooth, and the velocity is constant at each flow point. Since a low velocity act at laminar flow, this means that vortices causing turbulent flow cannot be formed.

### *2.3. Turbulent flow*

Laminar flow can only take place at a certain speed. When the speed is exceeded, swirling or agitating air and unstable flow begin. We call such a flow turbulent. It is undergoing unpredictable changes. The velocity at irregular flow is not constant at every point of the flow.

### *2.4. Reynolds number*

The Reynolds number is a quantity used in hydromechanics and aerodynamics. It is called Re and is given as a dimensionless quantity by which the laminar and turbulent flow is determined. It is expressed by the value Re = 2320. The critical Reynolds number expresses the transition between laminar and turbulent flow, that is, if the value is less than 2320, laminar flow takes place and at a value greater than 2320, turbulent flow already occurs. It is one of the main control parameters in all viscous flows [4].

## 3. TURBULENCE AND ITS TYPES

The agitation of air as air particles move in the atmosphere is the movement of matter to which a flying aircraft responds depending on its speed and mass. Turbulence is caused by frequent changes in wind speed. It can be observed in the ground layer by means of wind gusts [5]. There are 3 types of turbulence.

### 3.1. Thermal turbulence

For the formation of thermal turbulence, a condition is given, which is an unstable stratification of the air. This means that the instability of the stratification, which occurs during sunny weather, is needed when the earth's surface heats up the fastest and has the highest temperature. It is usually the result of uneven heating of the earth's surface or a moving cold stream of air above the warm earth's surface.

In daytime, thermal turbulence reaches its maximum in the afternoon. The weaker intensity of this turbulence occurs before sunset, it is weak at night, but still during the night it is possible to observe a stronger occurrence of turbulence, especially in storm clouds.

In terms of seasons, thermal turbulence most often occurs in the spring and summer months [1].

### 3.2. Mechanical turbulence

Obviously, the flow of air near the Earth's surface will flow through various obstacles, such as cliffs, mountains, buildings, structures. In this case, the arranged horizontal flow is interrupted and turns into an irregular complicated flow of currents.

The difference between thermal and mechanical turbulence is that mechanical turbulence needs a stable pruning to occur. In general, it arises as a result of the friction of the air on the earth's surface, therefore the obstacle, as well as the flow itself over the mountain obstacle [1].

#### 3.2.1. Turbulence due to friction on the earths's surface

This kind of turbulence occurs over the relatively flat surface of the Earth, due to the fact that individual vortices are created behind buildings, obstacles, or even forests. It is associated with thermal turbulence and occurs at a speed of 7 to 10 m / s.

#### 3.2.2. Turbulence due to flow over the mountains

- *Clouds*

The main role is represented by vertical air movements. The most well-known phenomena include Ac, rotor clouds and rib-shaped clouds. The orographic clouds also include the so-called pearl clouds. Pearlescent clouds are also referred to as stratospheric clouds, so they appear at higher altitudes. They have been observed, for example, in Norway, Scotland, Alaska and Greenland.

- Field research

The results obtained from observations from different mountain areas agree to some extent. The wave flow manifests itself as a vertical oscillation around a dynamically steady state, with the mountain obstacle being the source of the commotion and the gravitational force causing these oscillations. Gravitational waves occur in all mountains of the world [1].

#### 3.2.3. Förchtgott classification

The flow of air over mountain obstacles is divided into windward and leeward sides. On the windward side there are outgoing movements of the air and on the leeward side there are descending movements. According to Förchtgott, the leeward air flow is divided into four types: Laminar, Vortex, Wave, Rotor [1].

#### 3.2.4. Dynamic turbulence

Dynamic turbulence is divided into two categories from different perspectives and its manifestations. For turbulence in the lower layers and for turbulence in the upper layers of the atmosphere. It does not depend on obstacles, terrain, or storm clouds. It occurs in parts of the troposphere and stratosphere [1].

#### 3.2.5. Turbulence of the lower tropospheres

The dynamic turbulence of the lower layers of the troposphere is related to wind shear. Thus, significant changes in wind direction and speed in a short period of time prevail. The flow of layers on top of each other leads to turbulence because they cause changes in vertical movements. This type of dynamic turbulence takes place up to a height of 4 km. Temperature inversion is usually associated with wind shear or cloud change. These include stratus clouds, which turn into stratocumulus, and the species altostratus changes into altocumulus.

#### 3.2.6. Turbulence of the higher tropospheres

The dynamic turbulence of the upper layers is otherwise called CAT. It is the turbulence of the clear sky created in the upper troposphere or lower stratosphere that is connected or associated with the nozzle flow. This turbulence reaches a height of 5.5 km and occurs in a clear cloudless area of the air during strong wind gusts, as well as in clouds Ci, Cc, Cs. The waves that flow through a jet stream are called dynamically stable. Waves that act against the jet stream are called dynamically unstable.

### 3.3. Measurement and intensity of turbulence

Measurement of turbulence values is provided by an accelerometer. Accelerometers are special devices that work on the basis of inertia, therefore they use the principle of inertia of a fixed body. More precisely, the device records changes in the position of the body relative to the aircraft. It is indicated in "g" units. Aircraft overload means the ratio of lift in turbulent air impact to the aircraft to the ratio of lift in horizontal flight [1].

*Table 1: Manifestations of conditions from the intensity of turbulence. [1]*

| Intensity | Acceleration in g | Manifestations of conditions |
|---|---|---|
| Weak | do 0,20 | Smaller and light tilts of the aircraft |
| Moderate | 0,21 – 0,50 | Stronger impacts, to some people it causes nausea |
| Strong | 0,51 – 1,00 | Steep tilts, aircraft ambushes, flight mode disrupted, need to buckle up |
| Very strong | more than 1,00 | Major plane ambushes occur, plane damage risks |

## 4. EFFECT OF TURBULENCE ON FLIGHT

Turbulence acts on the aircraft by disrupting its aerodynamic properties. Disruption of aerodynamic properties causes poorer maneuverability of the aircraft, changes in height and tilt of the aircraft, or destruction and wear under increased stress. The tilt of the aircraft to one side is the reason why turbulent air movements pass through one side of the wing and an imbalance is created that tilts the aircraft to one side.

Aircraft overload is characterized by force and accidental acceleration, which is caused by turbulence on the aircraft structure.

### *4.1. Air accidents due to turbulence*

From the pilot's point of view, a flight in the area of turbulence is usually considered to be a disturbance to the comfort of the crew and passengers, not entirely a problem or a disturbance to the safety of the aircraft. The aircraft itself is designed to withstand a large amount of load, strain, and positive and negative overload. In the event of strong turbulence, we can observe a more frequent oscillation of the wings, because the wings are structurally flexible. The wings can bend up to 10 degrees, so it is not possible to "break" them under natural conditions. From the point of view of the design of the transport aircraft, turbulence is not dangerous. Where the danger of turbulence can be demonstrated, it is the crew or passengers.

From the technical side of the aircraft, such as the fuselage, structural nodes of the fuselage, wings, pins are several times more stressed on tension, pressure, torsion, bending. For smaller sport aircraft, the cover may twist on certain parts of the aircraft. In the case of incorrect technical capability, for example, a pin mounted in a wing suspension can manifest itself after loose turbulence by loosening and weakening of the pin wall. This leads to consequences such as shear damage and consequently to complete destruction of the wing support part.

### *4.2. Turbulence areas*

The occurrence of turbulence in the atmosphere is its natural characteristic. Areas with a stronger manifestation of turbulence fill a larger area evenly, therefore uniformly. Other times, under other conditions, the given turbulence manifestation occupies the zones separately. The occurrence of turbulence most often manifests itself from the ground level to a height of 3 kilometers. As we proceed above, between the 3rd and 6th kilometer, the turbulence of the atmosphere decreases. However, the 8th and 10th kilometer represent levels that are relatively more turbulent than those in the lower troposphere [1].

#### *4.2.1. Turbulence in the clouds*

The change in the height of the aircraft due to the turbulent phenomenon most often occurs in the clouds. The development of clouds is related to the outgoing movements of the air and thus the formation of condensation is connected. This means that if the output vertical movements meet together with the descending movements of the air, they represent the basic condition for the formation of turbulence.

Cb type clouds have the greatest credit for the development of turbulence in the cloud area, in which the maximum impacts of turbulence are manifested in the middle part of the cloud. Forced changes in aircraft altitude tend to be strong, reaching a drop or increase in altitude that exceeds hundreds of meters from the aircraft's original altitude. This is because their vertical currents reach speeds of around 40 m / s [1].

#### *4.2.2. Turbulence in the area of fronts*

The queues are divided into cold, warm, and occlusive queues. They are different in that behind the cold front, the air mass flows faster and with a higher air density, so it behaves differently than a warm front.

The rise of warm air along the sloping frontal interface and the subsequent friction between two different air masses creates turbulence in the frontal zone. Hot airflow properties such as humidity and instability are the result of significant turbulence and can be extremely strong if storms occur. Turbulences are mostly associated with cold fronts, but sometimes they can be present in the warm front [14] [5].

#### *4.2.3. Turbulence in jet stream*

The jet stream areas are connected in particular to the cyclonal side of the frontal zone. Occurrence of turbulence on the anticyclonic side tends to be very small.

In the upper layers of the troposphere, turbulence development is indicated by wind speed. The higher the wind speed, the more likely it is to occur. Jet stream is caused by changes in wind speed and horizontal changes in wind direction. It is also related to wind shear, as turbulence in the jet stream area is especially created at the edge of the flow zone.

Jet stream can also be observed by the clouds that specify it. They have different shapes, often parallel prominent bands according to the passing jet stream. The intensity of the turbulence can be determined from the appearance of the cloud. If the shapes of the clouds suddenly change, it is a strong turbulence. If the shape is mostly stable, it is sufficient to expect only weaker turbulence [1].

#### *4.2.4. Turbulence in a storm*

Storm activity is a meteorological phenomenon in which more intense turbulence is manifested. Strong turbulence from the storm area causes sharp tilts, aircraft overloads and significant changes in altitude. The basic condition in the area of the storm is to avoid the storm cloud during takeoff and landing. It is not possible to fly against a Cb cloud, where dangerous turbulence occurs with strong vertical impacts [16].

#### *4.2.5. Wake turbulence*

The wake turbulence means the turbulence that is caused by the flying aircraft when passing through the air. Airplanes are formed on the wings of the wings and so-called jetwash, which indicates fast-moving gases coming out of the engine. As a result, the areas behind the plane become too turbulent, but their duration is short. For vortices, the duration of turbulence is a little longer, it can be about three minutes, because the vortices at the ends of the wings are more stable. The wake turbulence creates a disturbed area of air [18].

#### *4.2.6. Areas of turbulence in Slovakia*

From our own experience in areas in Slovakia, it is the most common occurrence with orographic turbulence over mountains such as Pohronský Inovec or Zobor. Above these hills, turbulence of stronger intensity was captured, either on either side of the hill, depending on the wind. Similarly, with thermal turbulence, there is experience over cities and fields, but always to a lesser extent.

The information obtained from other pilots is similar because they had the most common experience with turbulence over the mountains, hills and during the summer months with thermal turbulence over various areas. It contains an unpleasant experience of entering the rotor behind the Veľká Javorina mountains towards the Czech Republic. Another strong turbulent flow in the Lietava, Rajec and areas of Tatras.

The most common occurrence is in the High Tatras, more precisely from the Poprad-Tatry Airport, information is obtained where the southwest wind prevails. In this case, you can see how the air flow slowly moves towards the mountains, and then the turbulence is only very mild. The purely southern wind causes an air flow at Poprad-Tatry Airport, which goes with the terrain, therefore on the windward side, and creates good conditions for a flight similar to zero turbulence. This situation would change on the leeward side. When the north wind blows, the Poprad-Tatry Airport is located on the leeward side, where the turbulence is very strong.

Experience has shown that the best turbulence generation is close to the mountains, ideally on the leeward side. It does not have to be just the High and Low Tatras, but also other smaller mountains. For example, when the wind blows from the south side and the plane is located on the north side of the hill, therefore behind it, it is obvious that strong turbulence will cause. If it is located at the height of the top of the hill, slightly above it or below the level of the mountain range, but on the leeward side, then the turbulence is considerable.

## 5. DISCUSSION

If severe turbulence is observed or predicted, the Aeronautical Meteorological Service issues a SIGMET alert. The turbulence forecast and its criteria vary by type. Thermal turbulence and its prediction are related to the development and prediction of convective clouds. The developmental stage of the Cu cloud is characterized by weakness, while Cu and Cb clouds are characterized by mild to strong turbulence.

The prediction of mechanical turbulence is given in the presence of stably layered air layers at a wind speed of at least 10 m / s. The turbulence that causes the wave flow is expected especially when the direction of flow is perpendicular to the ridge of the mountain barrier [5] [1].

Wind shear is related to dynamic turbulence, so wind shear maps are mainly used to predict it. The basic tool is the use of on-board detectors, which are based on the horizontal change in air temperature, which is essentially related to the area of nozzle flow. However, horizontal changes tend to be small, as their usual on-board indicators do not show, and therefore more precise apparatus has been devised. With these more precise instruments, the indication is usually already when the temperature changes by tenths of a degree [1].

## 6. CONCLUSION

Turbulence is characterized in aviation as a weather phenomenon that can dangerously affect the track, passenger comfort and, last but not least, flight safety, without the intervention and influence of the pilot. Based on the mentioned air accidents and experience, turbulence really manifests itself as a problem that can endanger the flight. This is a dangerous weather phenomenon occurring over different areas and with which every pilot has some experience.

The aim of the bachelor's thesis, from which the scientific article follows, is to describe and find out more detailed information about the turbulence and its dangerous impact on air transport, and at the same time to understand its meaning in practice. It is important to know the substance of turbulence, because when planning a flight, it is necessary to deal with various meteorological phenomena, including turbulence.

The work provides important information on how and on what basis turbulence is determined, where it can occur and the adverse and dangerous effects of turbulence have been identified. Turbulence is a dangerous weather phenomenon that can cause some uncertainty for the pilot himself. It is especially dangerous in terms of flight near a mountain obstacle. If the pilot is very close to the mountain range and flies into a strong turbulent zone, this can cause a sudden drop in flight altitude to very close to the surface of the mountain obstacle, at worst directly into it, which would result in an accident. The aforementioned air incidents or experiences show that the turbulence itself needs to be taken care of, but there is no need to show signs of fear from the passengers' point of view.

If the flight is performed by a transport aircraft or a sport aircraft, this difference is determined only by how the passenger's turbulence is felt during the flight. There is a small probability of an accident causing turbulence, but this risk is never ruled out. Other factors have an impact. Therefore, it is necessary to properly respond to external influences and keep the aircraft under control when flying through a turbulent area. Pilots on longer routes at higher flight levels are able to prepare for flight using aeronautical meteorological maps, making the flight safer. I also documented the correct presentation of the issue on the examples, which I discussed in more detail in the discussion.

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