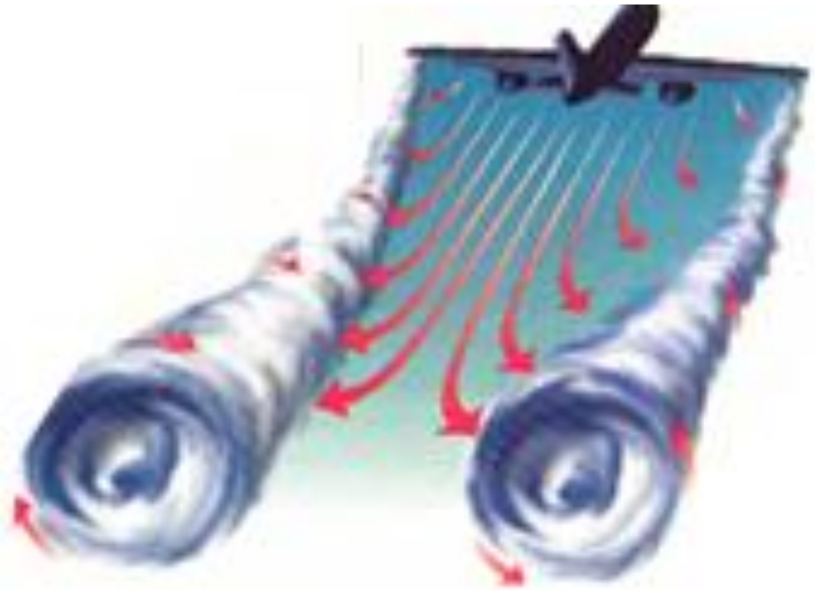
WAKE TURBULENCE

In today's aviation environment where flight operations has greatly increased at many airports it is possible to have infringement of the separation requirements between airplanes during the take-off & landing phases as prescribed in the ICAO DOC 4444.

WING–TIP VORTICES

The upper surface of the wing is subjected to a low air pressure in comparison to the lower section of the same wing this results the airflow to travel from the high pressure to the low pressure region thereby forming a vortex.



*The vortices are greater and more violent at higher angles of attack when formed by the aircraft **Wings** during Landing & Take-off phases. Vortices also form during all other phases of the flight i.e. as in cruise, climb, descent etc but are of more concerning during the landing & take-off as it could effect a following aircraft close to the ground to sudden loss of lift and other dangerous encounters. This is a real photograph of the trailing wing-tip vortices of a large transport aircraft taken by a special electron camera. Notice how the spiral waves formed by the two wings weave / intermingle together. The lower photo was taken of the same vortices after duration of about 10 secs. It can be observed how the intensity of the vortices increase as seen at the extreme left of the lower frame,*

The effect of ambient atmospheric conditions on the vortex generated is more concerning & effective when the winds are calm and the air density is higher. The vortices may get momentarily stagnant when there is a slight tail-wind making things even worse. Atmospheric stability will also add to the problem.

*The strength of the vortex generation and its associated vortices is determined by the **weight, speed and the shape of the wing** of the aircraft flying through a mass of air. The generation of vortices by an aircraft is greatest when the a/c is heavy, at lowest speeds and lesser flap extension. These conditions, along with the atmospheric conditions as mentioned above could subject the following aircraft to a very violent wake turbulence encounter.*

The effect of wing-tip vortices is <u>most vicious</u> when an a/c crosses the flight path of an aircraft at about 90 degrees

Vortices remains effective up to a distance of about 1000ft. below the flight path of the generating a/c and the sink rate of the vortices mass is about 450 fpm

*Hence it is very **important to adhere to the 2 / 3 mts. separation** minima as prescribed in the DOC 4444 of the ICAO document. There are often cases when the ATC prompts an aircraft asking " are you ready for an immediate take-off " ?*

It is poor airmanship to get tempted on such occasions, as it could be very hazardous.

EXPERIMENTAL DISPLAY of a VORTEX

An experiment was carried out to visually see the creation and characteristics of a vortex by spraying some coloured dust / smoke at the area just passed by a large aircraft wing.

The turmoil, shape and formation of the vortex can be seen and well imagined.

Combating WAKE - TURBULENCE

In Dec 2001 in USA, flight AA- 587 resulted in a tragic accident that perhaps encountered very identical Wake-Turbulence phenomenon as occurred with an Indian Airlines flight about 2 years back, as descried in page 2. Moreover there have been past incidents where aircraft have undergone experience of wake- turbulence caused by the preceding aircraft thereby subjecting the following aircraft to minor & vicious / violent effects.

Based on available information and experience, an attempt is made to establish a ***corrective escape maneuver*** *to combat this hazard, the frequency of such encounters could increase with the growing / increased air traffic in future aviation.*

ESCAPE - MANUEVER FROM WAKE-TUBULENCE

1. ***DURING CLIMB*** *:* ***Immediately disconnect A/Pilot & increase climb rate*** *as much as possible with intention to vacate the wake corridor ASAP. If the affected a/c can not accomplish a high rate of climb then initiate an immediate descent but this would cause a/c to respond slowly due inertia thereby subjecting the a/c to remain for a longer period comparatively within the turbulent zone. If there is an awareness that the preceding a/c is also climbing, then immediately descend.*

2. ***DURING DESCEND : Immediately disconnect A/Pilot & increase descent rate*** *as much as possible. If there is an awareness that the preceding a/c is also descending, then immediately level-off.*

3. ***DURING LEVEL FLIGHT : Immediately disconnect A/Pilot & climb or descend,*** *as suitable / appropriate.*

[ROC or ROD of about 4000 fpm will able to vacate the danger corridor in about 3 secs.]

(i) In all the above cases, ***DO NOT ATTEMPT*** *to use rudder to correct an upset or a loss of direction whereas the ailerons could be used which although may not have much effect to counter the invincible disruptive force.*

*(ii) The purpose to select A/P off is to prevent A/P inputs to the control surfaces, especially the rudder as the A/P if engaged, would try to maintain the current flight attitude thus inducing **added** stress on the a/c's structure thereby further aggravating the situation.*

The purpose to <u>increase climb or descent rate</u> is to immediately vacate the vortex premises which could have a diameter of about 200 - 300 ft. If possible, a change in direction towards the upwind side could be useful.

(iii) Aircraft structure such as the landing gear, engine pods and the tail-fin (vertical stabilizer) are not designed to cater for <u>higher lateral loads.</u> Hence any effort to counter an upset by use of rudder could further induce excessive loads upon the structure.

CHARACTERISTICS OF A VORTEX :

1. The magnitude of the vortices generated by the wings of an a/c depends on the speed, weight and flap configuration. When the a/c is heavy, slow and clean it will be generating the most severe amount of vortex, resulting highest intensity of wake turbulence.

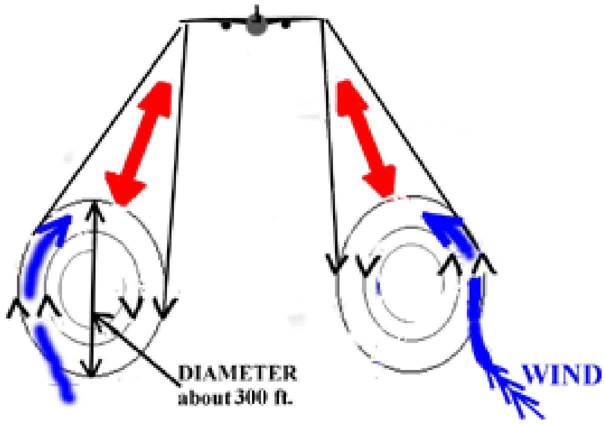
2. The right wing produces anticlockwise wake vortices whereas the left wing produces the same in a clockwise rotation. (As shown in wisdom 9)

3. The diameter of the vortex is about 200 - 300 ft.. which possesses a circular or an elliptical cross-section depending upon ambient conditions.

4. The vortex mass gradually sinks at a rate of about 500 fpm.and then its path levels off at about 1000 ft. below the flight path of the generating a/c for periods up to 3 minutes. or even more before its effect diminishes / dies away.

5. The wake vortex turmoil could be effective upto about 15 nm behind the generating a/c depending upon ambient atmospheric stability, air density etc.

6. The intensity and duration of the wake turbulence within a Vortex further gets increased when it is subjected to a slight tailwind component at angle as shown in the diagram.



The left & right wake vortices are shown trailing behind an a/c. The right vortex has an anticlockwise rotation. If these vortices are subjected to a gentle tail-wind component at a particular angle, the wind-flo can act as a catalyst to **:**

(i) compress the wake as shown by the red arrow, thereby causes intensification and delayed dissipation of the vortices.

(ii) the wind –flo at an angle as shown by the blue arrows could further augment the circular / spiral movement of the left & right vortices thereby increasing the intensity & also induce a buffet-effect in the existing rotors hence generating the ***most vicious effects*** *due to its irregular and inconstant rate.*

***AN EXPERIENCE WITH WAKE – TURBULENCE ENCOUNTER** :*

An Indian Airlines Airbus A-320 on flight during a step- climb behind a Boeing 747 by about 15 nm. encountered severe wake turbulence at about 20,000 ft.

The A-320 aircraft first got subjected to very violent wake- turbulence and was violently tossed about as it continued to fly within the wake section, subsequently its one wing dropped in to a bank of about ***70^o*** *and the a/c nose-downed. The Autopilot tripped and the aircraft lost about 1000 ft. of altitude. Several passengers were hurt due to the sudden unexpected violent jolting & tossing about of the a/c as long as the a/c remained flying within the wake's turbulent zone. Fortunately, it was only when the a/c 's one wing dropped / banked by itself due to the very vicious twist force of the vortex, as shown, and the fact that simultaneously the aircraft nose-dived it was able to descend & clear-off the wake-section region and then regain normal flight.*

SHEAR -EFFECT BY THE WAKE-VORTICES UPON AIRPLANE FIN

A prolonged flight in such a vicious wake effect could easily cause to shear-off the Fin / vertical stabilizer of an a/c

A sketch of the fin of an effected a/c within WAKE VORTICES is shown to *explain the reason as to why this vicious invisible force could uproot the fin of any aircraft* ***:***

(i) Normally the vertical stabilizer is subjected to some vertical and mostly longitudinal air loads as shown in the sketch by blue arrows, whilst in flight. Vertical loads are caused due gusts or normal turbulence associated with CAT & CB / clouds etc. which the aircraft's fin can easily withstand.

(ii) During a violent Wake encounter, the vertical stabilizer is ***also*** *subjected to vicious lateral G-loads, as shown by the red rotors. These rotors strike the fin at about right angles imposing additional side loads on the surface of the fin causing very abrupt torque / twist & vibrations at the base of the structure of the fin because the rotors strike with an unsteady & un-uniform force.*

[sometimes *a* strong CB cell could also subject an a/c to similar effects of a wake-turbulence due to presence of rotors within and around a CB so to cause the fin to shear-off. *]*

(iii) If the affected a/c is on a slightly cross-path of the vortices, i.e. the most critical situation, the a/c will be subjected ***also*** *to the second stream of vortices which would now act in the opposite direction tending to now hammer & bend the fin in the other direction. Such violent hammering of forces left & right, all subjected to within a short period of time results in metal fatigue causing the surface to shear away.* ***Any rudder inputs at this juncture would hasten the process of structure failure****. Larger the size of the fin i.e. greater the keel surface of the fin, more is the chance of being effected due to such high and violent side-loads.*

(iv) Once the fin is sheared-off the a/c will lose its directional stability, instead of a normal turn at 3^o/sec, the rate could increase much beyond 10^o/sec thereby suddenly jerking and swinging the a/c abruptly which would consequently result in separation of the engine/s due to excessive centrifugal / lateral forces and subsequent uncontrollability.