Wake turbulence from light rotorcraft and separation criteria

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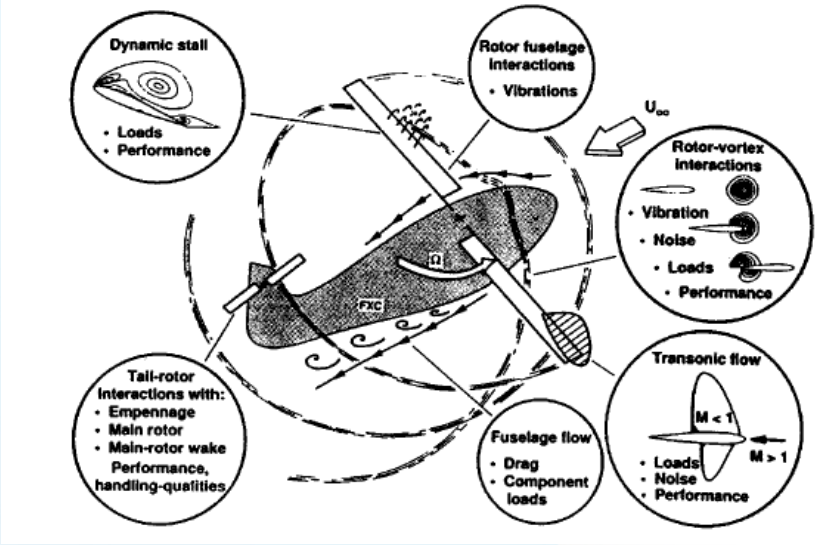
Separation criteria - Light helicopter leader

Aim: To investigate the need for separation criteria in the light weight category

An overview…



Source: Caradonna, 1992

Not straightforward…

Background information

- AAIB accident report

On approach to land a Piper PA-28 flew through the wake vortex generated by a Sikorsky S76 and the aircraft rolled uncontrollably to the right and struck the ground.

- Gasil articles

GASIL August 2010: Helicopter and wake turbulence
GASIL December 2002: Rotor downwash

Air Accidents Investigation Branch

AAIB Bulletin: 7/2010 G-BRWO EW/C2009/09/07

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-140 Cherokee, G-BRWO
No & Type of Engines:	1 Lycoming O-320-E3D piston engine
Year of Manufacture:	1973
Date & Time (UTC):	26 September 2009 at 1445 hrs
Location:	Humberside Airport, North Lincolnshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Serious) Passengers - N/A
Nature of Damage:	Right wing detached and forward fuselage severely damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	55 years
Commander's Flying Experience:	858 hours (of which 756 were on type) Last 90 days - 21 hours Last 28 days - 7 hours
Information Source:	AAIB Field Investigation

AAIB Bulletin: 7/2010 G-BRWO EW/C2009/09/07

Rotor downwash

The CAA receives reports fairly often from aeroplane operators complain taxying (or low flying) helicopters has affected them. These effects rang path (or their passengers), to damaging the flying controls by blowing controls may be expensive to repair, and if not noticed at the time may

The problems may be even more serious than that. Turbulence caused b of aeroplanes during take-off, landing, and in flight, with possible fatal con over just before touchdown by the wake turbulence from rotor downwash applies to the ever-increasing number of microlight aeroplanes, as reporte not exclusively. Hang gliders and para-gliders are also particularly a deflated. Damage on the ground may also affect flight, as demonstrate aeroplane whose stabilator (pitch) control jammed during take-off, whic being previously deflected harshly by downwash from a passing helicopte and become wedged against its guide washer.

As operators of aircraft which can cause genuine problems to humans and aeroplanes, it is up to us to ensure that we helicopter pilots keep our downwash well away from anything which might be adversely affected (or endangered!) by it. This is after all not only common courtesy, but common sense.

HELICOPTER GASIL
GENERAL AVIATION SAFETY INFORMATION LEAFLET

A CAA Accident Prevention Leaflet December 2002

Helicopter GASIL Special

Helicopters and wake turbulence

In its Bulletin 7 of 2010, the AAIB has published its report into the accident at Humberside in which the pilot of a Piper Cherokee lost control at a late stage of the final approach, and the aeroplane turned over on landing, seriously injuring him. The investigation concludes that the cause of the loss of control was most likely the wake turbulence of a helicopter which had recently made an approach and which was hover-taxiing close to the runway.

SafetySense leaflet 15 "Wake Vortex", available like all such leaflets from the CAA's website www.caa.co.uk/safetysense, describes the hazard and should be read by all pilots. It includes the advice that, when following a helicopter, pilots of light aircraft should consider allowing a greater spacing than would normally be used behind a fixed-wing aircraft of similar size. This is particularly applicable if the helicopter has been hovering, as it would when landing or taking off. The leaflet points out that AIC P064/2009 'Wake Turbulence', which is in the process of replacement, requires Air Traffic Controllers to provide specific separation distances and/or times between aircraft following each other on take-off or landing, but that VFR pilots are responsible for their own separation. A lack of warning doesn't mean a lack of hazard!

The AAIB report notes that the turbulence from a hovering helicopter can cover an area out to a distance of 3 times the rotor diameter. As the photograph kindly provided by a reader shows, the turbulence can affect even parked aeroplanes if they are not tied down. Helicopter pilots can reduce the effect of turbulence produced from their own wake by minimizing time spent in the hover close to the paths of other aircraft. For example, they should quickly move well clear of the runway to which they have approached, especially when on the upwind side of it. Where that is not possible, and certainly if still within 3 rotor diameters of the following aircraft's likely flight path, they should place their helicopter on the ground as soon as possible.

Although ideally helicopter operations should be separated completely from aeroplane operations, that is not always possible. Where the two must operate together, wheeled helicopters should ground taxi rather than hover taxi, and to keep the hazard to obvious areas any hover-taxiing should follow the standard taxiways if possible and safe.

6

Guidance on wake turbulence ICAO/UK

1. Weight groups

Category	ICAO and Flight Plan (kg)	UK Departures (kg)	UK Arrivals (kg)
Heavy (H)	≥ 136000	≥ 162000	≥ 162000
Medium (M)	> 7000 & > 136000	> 40000 & < 162000	N/A
Upper Medium (UM)	N/A	N/A	>104000 & < 162000
Lower Medium (LM)	N/A	N/A	>40000 & ≤ 104000
Small (S) (UK only)	N/A	> 17000 & ≤ 40000	>17000 & ≤ 40000
Light (L)	≤ 7000	≤ 17000	≤ 17000

2. AIC on helicopter wake turbulence

5 Helicopters

5.1 In forward flight the downwash from the main rotor(s) of a helicopter is transformed into a pair of trailing vortices similar to the wing-tip vortices of a fixed-wing aircraft (Fig 2). There is some evidence that per kilogram of gross weight, these vortices are more intense than those of fixed-wing aircraft. The initial acceleration manoeuvre into forward flight, the landing 'flare' and air taxiing may generate higher rotor wash velocities than those produced in a stabilised hover.

5.2 When hovering, or whilst air taxiing, a helicopter directs a forceful blast of air downwards that then rolls outwards in all directions. This can create problems on the apron, in parking areas and to light aircraft movement on taxiways and runways. In particular there is a risk of damage to fixed-wing control runs and surfaces caused by helicopter downwash driving unlocked control surfaces forcibly against their stops. The risk of damage from this form of turbulence may be reduced if the guidelines below are followed:

(a) whenever possible, ground taxi in a congested parking area rather than air taxi;

(b) if it is necessary to air taxi, ensure that as wide a clearance as possible is maintained from other aircraft or loose ground equipment;

(c) when air taxiing, avoid flying over parked aircraft or vehicles.

5.3 At events where a large number of helicopters of varying sizes are hovering in close proximity to one another care must be taken to ensure that power and control limits are not exceeded due to the downwash produced by adjacent aircraft.

5.4 Controllers and pilots should consider wake vortices generated when helicopters hover taxi across active runways and apply the appropriate wake turbulence separation minima. Caution should be exercised when a helicopter or fixed-wing aircraft of lower weight category is cleared to land on a runway immediately after a helicopter of higher weight category has taken off from that runway's threshold. Additionally it should be borne in mind that the downwash and associated turbulence generated by a hovering helicopter can drift a substantial distance downwind and may therefore affect an adjacent runway.

5.5 In cruise flight light fixed-wing aircraft should allow a substantial horizontal distance when passing behind and below large helicopters, which may produce greater than expected wake turbulence.

3. Small and light aircraft types

LIGHT aeroplanes MTOM ≤ 17,000 kg	
Aero Commander	Dassault DA20 Falcon
ATR 42-300	Dornier 328
BA125	Embraer 110 Bandeirante
BAe Jetstream J31, J32 & J41	Learjet 25 / 55
Beechcraft 200 / 300	Piper Navajo / Seneca
BN Islander / Trislander	Rockwell Sabreliner
Bombardire Learjet 45, 55, 60	SAAB 340
CASA CN-235	Shorts 330 / 360
Cessna 31 / Citation	YAK40
SMALL helicopters	**LIGHT helicopters**
Aerospatial Puma	Augusta 109
Boeing Vertol Chinook	Bell 212
EH 101	Gazelle
Sikorsky S61N	Lynx
Sikorsky CH53 E	MBB BO 105
Westland WAH 64	Sikorsky S76

4. Separation criteria

Wake Turbulence Separation Minima - Final Approach

Leading Aircraft	Following Aircraft	Wake Turbulence Separation Minima Distance (NM)	
		ICAO	UK
Light	A380-800	#	#
Light	Heavy	#	#
Light	Upper Medium	#	#
Light	Lower Medium	#	#
Light	Small	#	#
Light	Light	#	#

No separation minima for light category!

Current procedures and immediate actions

Immediate actions:

➢ The AIC was updated to include additional guidance on helicopter wake in hover and in forward flight close to the ground. Introduced the 3-rotor diameter avoidance area from the FAA.

NATS

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UNITED KINGDOM

AERONAUTICAL INFORMATION CIRCULAR

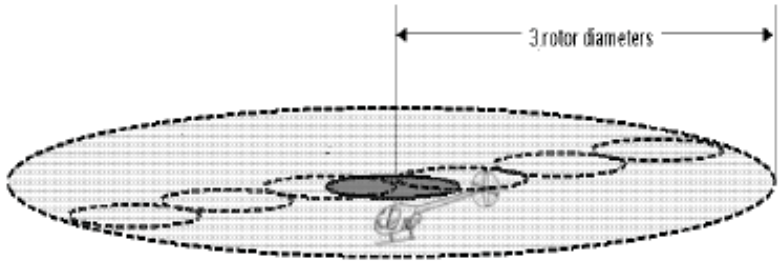
AIC: P 064/2009
13-AUG-2009
Safety

Civil Aviation Authority

Cancels AIC
P 018/2009

WAKE TURBULENCE

5.3 Pilots of light aircraft should avoid operating within three rotor diameters of any helicopter in a slow hover taxi or stationary hover (Fig 17). As a visual indicator: if the skids / wheels of the helicopter are resting on the surface then the helicopter will be producing a much reduced downwash. Caution should be exercised however since the helicopter may lift into the hover with little or no notice, thus increasing downwash significantly.



Currently:

There are no separation criteria for light aircraft following the same weight group helicopters (weight < 7,000 kg) **in hover or forward flight, in or out of ground effect.**

Need to address and further investigate this procedure!

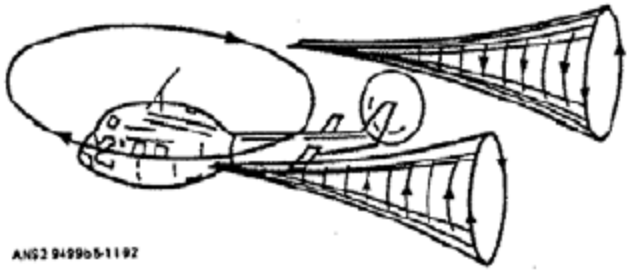
Helicopter wake vortex

➢ Helicopter rotor wake is three-dimensional and it is dominated by strong vortices that are trailed back from the tips of each blade.

➢The geometry and the strength depends on the operating state and the flight conditions (flight phase, rotor thrust, advance ratio, angle of attack, presence of other rotors).

➢In hover the tip vortices follow helical trajectories below the rotor.

➢In forward flight the rotor wake is skewed back behind the rotor by the free stream velocity and a series of nonaxisymmetric vortex trajectories are produced. (Vortex – vortex filaments interaction, roll up).

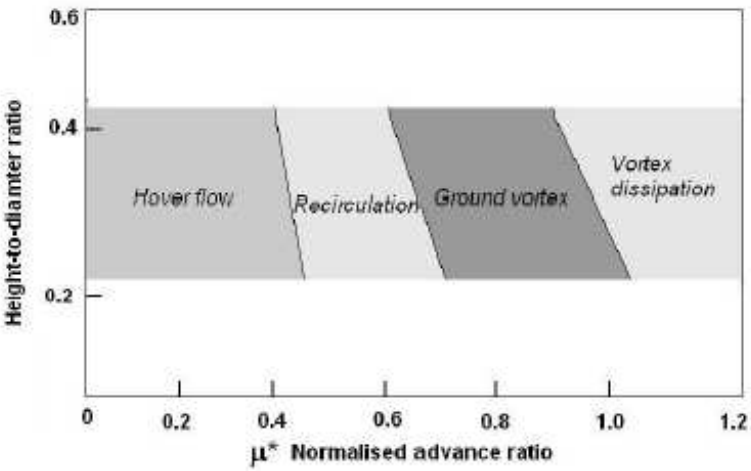


Hover and forward flight close to the ground

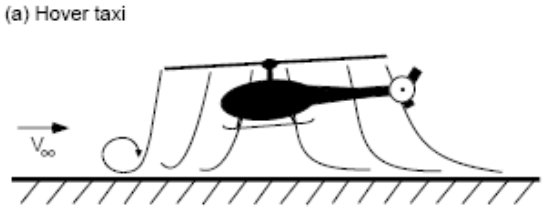
- Hover flow – downwash vortices
- Ground vortex forms at very low forward speeds
- As forward speed further increases the ground vortex is eventually swept downstream away from the rotor

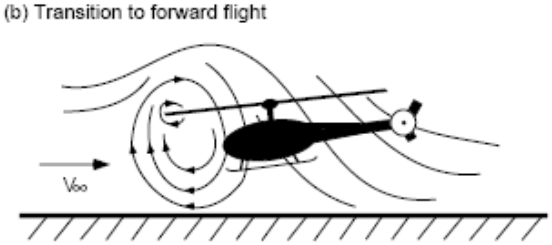
Flow regimes with advance ratio

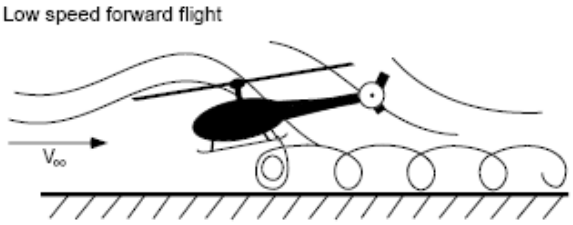
$$\mu^* = \frac{\mu}{\sqrt{0.5 C_T}}, \mu = \frac{V_0}{V_{tip}}$$

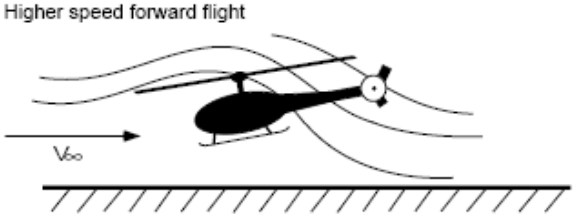


Source: Curtiss









A brief literature search - 1

➢ FAA report addresses the separation distances for light aircraft following helicopters.

The study concluded the following:

Leader: Helicopter(s)
Follower: T-34C

Helicopter	MTOW (kg)	Separation (nm)
CH-53E	31,638	3.1
CH-47D	22,679	2.7
UH-60A	7,375	2.4
S-76A	4,672	1.0
UH-1H	3,469	1.0

➢ Light helicopters such as S-76A and UH-1H can leave active hazardous vortices for up to 90 secs

➢ The study however did not address the following which needs to be done to determine operational implementation:

Separation distance in hover in ground effect
Separation distance in forward flight in ground effect

➢ The study concluded:

Hazards associated with rotor wash generated by helicopters in hover or in air taxi operations should be investigated. In the absence of encounter measurements for the case of hover flight, it is recommended that small airplanes, at the same altitude and downwind of a hovering helicopter, maintain at least 500 feet of separation.

A brief literature search - 2

Flight Safety Digest March - April 2002 guidance for helicopter wake vortex includes:

- Hover or slow hover: High velocity outwash vortices that extend to a distance about three times the diameter of the rotor
- Forward flight: A helicopter generates a pair of spiralling wake vortices from the rotor blades that are similar to those of larger fixed wing aircraft.

The wake turbulence takes different forms, depending on how a helicopter is being flown:

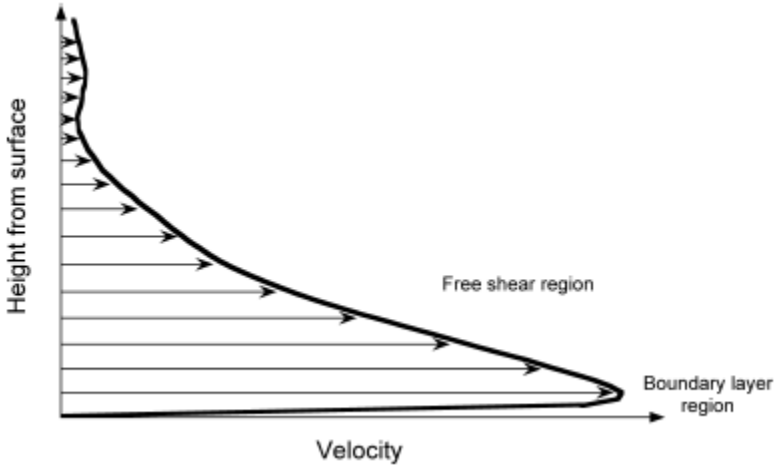
- During stationary hovering or a slow hover taxi, a helicopter generates downwash — high-velocity outwash vortices that extend to a distance about three times the diameter of the rotor (Figure 1). The outwash vortices resemble airplane vortices, although the helicopter outwash vortices circulate outward, upward, around and away from the main rotor (or main rotors) in all directions.[2] FAA says that pilots should not operate small aircraft within three rotor diameters of a helicopter in a stationary hover or a slow-hover taxi;[3] and,

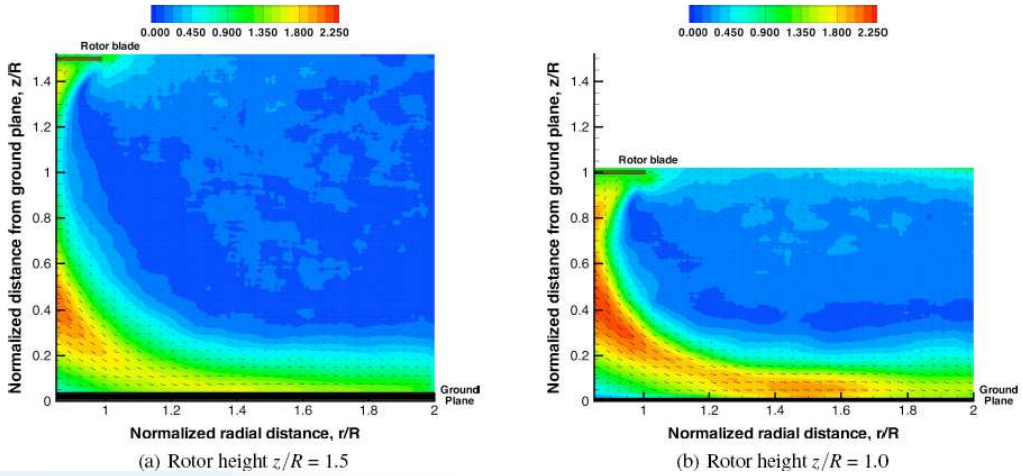
- During forward flight, a helicopter generates a pair of spiraling wake vortices from the rotor blades (Figure 2). Wake turbulence also occurs in the rotating air beneath the helicopter.[4,5] The FAA *Aeronautical Information Manual (AIM)* says that the wake vortices are similar to those of larger fixed-wing aircraft. FAA says that pilots of small aircraft should use caution when trailing helicopters in forward flight.[6]

A brief literature search - 3

Simulation of hover in ground effect

- Outwash velocity profile forced to expand radially outward as a wall jet.
- For the z/R = 1.0 rotor height case, as shown in the overall flow was found to be similar to the z/R = 1.5 case, but now much higher localized flow velocities were produced at the wall for radial stations between r/R = 1.2 to 1.8.
- At the higher rotor heights the vortex filaments spin down and diffuse under the action of viscosity and turbulence before they can ever reach the ground; at the lower rotor heights the turbulence in the developing wall jet quickly shears the vortices, which causes them to lose their coherent flow structures within only two rotor revolutions of wake age.



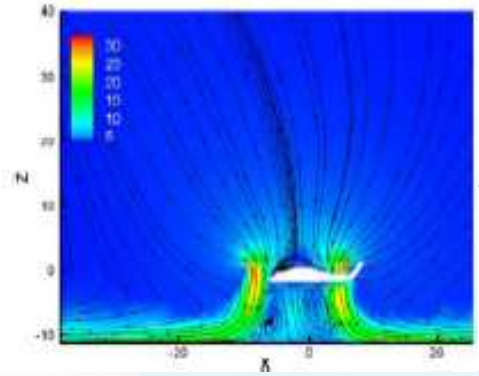


Source: Timothy E. Lee E. T., Leishman J. G., Ramasamy M., "Fluid Dynamics of Interacting Blade Tip Vortices With a Ground Plane" Department of Aerospace Engineering Glenn L. Martin Institute of Technology University of Maryland.

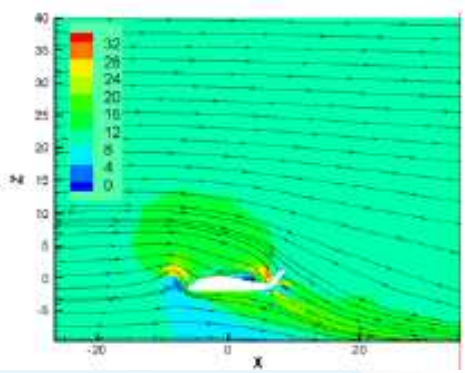
A brief literature search - 4

CFD simulations of a UH-60 (10,660 kg) helicopter in hover and in forward flight in ground effect

Hover, Height: 1.5R



V = 11m/s, Height: 1.5R



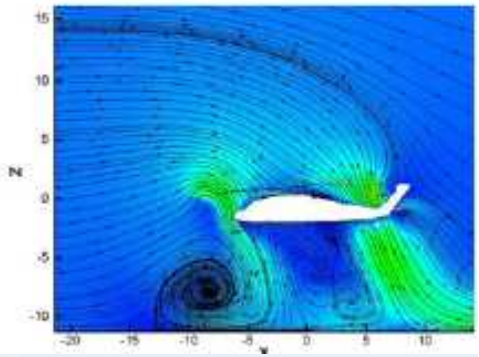
- **For V = 11m/s, Height: 1.5R**

The calculated flow does not contain any recirculation as the ground vortex that would exist at lower speeds or possibly lower heights has dissipated and passed beneath the helicopter.

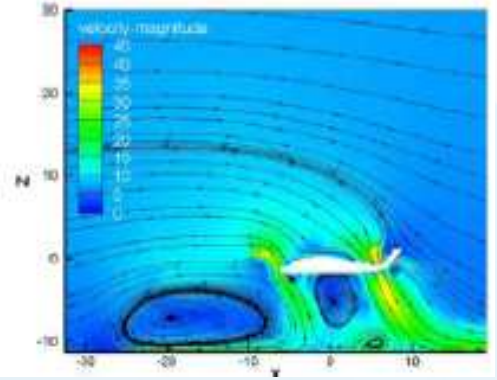
- **V = 6m/s, Height: 1.5R**

The constraining effect of the ground is obvious in that a large ground vortex exists in the flow in front of the helicopter, forward of the fuselage.

V = 6m/s, Height: 1.5R



V = 6m/s, Height: 1R



- **V = 6m/s, Height: 1R**

When the rotor height is reduced to 1R while being flown at the same lower speed of 6m/s, a considerably larger vortex appears

Source: Modha A. N., Blaylock T. A. and Chan W. Y. F. "Brown-out – Flow Visualisation using FLUENT® VBM". International Aerospace CFD Conference, Paris, June 18 – 19 2007.

Next steps

Review to date:

- Academic studies (scientific papers etc.)
- FAA flight tests
- Further tests and measurements are needed to acquire evidence
- These can be a combination of CFD simulations and experimental measurements

In progress:

- Vortex measurements using Lidar equipment – under discussion
- Liaise with FAA and other organisations to find out more about related research efforts
- Engage with DGAC and follow up FATO study – *Location of infrastructures for helicopters on an aerodrome*
- Liverpool university master research project simulations and thorough literature search
- Inform ICAO wake turbulence study group

Proposed methodology

To establish separation criteria in the light weight category