AIRCRAFT ACCIDENT REPORT 1/2010

ACCIDENT INVESTIGATION DIVISION

Civil Aviation Department
Hong Kong

Report on the accident to
Robinson R22 helicopter, B-LAT,
at a parking lot adjacent to the Hong Kong Aviation Club Limited,
Sung Wong Toi Road, Hong Kong
on 1 May 2009

Hong Kong

In accordance with Annex 13 to the ICAO Convention on International Civil Aviation and the Hong Kong Civil Aviation (Investigation of Accidents) Regulations, the sole object of this investigation is the prevention of aircraft accidents. It is not the purpose of this activity to apportion blame or liability.

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GLOSSARY OF ABBREVIATIONS USED IN THE REPORT

AN(HK)O	Air Navigation (Hong Kong) Order 1995
ATS	Air Traffic Service
CAD	Civil Aviation Department Hong Kong
º	Degree
ºC	Degree Celsius
FIS	Flight Information Service
IF	Induced Flow
HFOB	Helicopter Flying Orders Book
HKAC	Hong Kong Aviation Club Limited
HKO	Hong Kong Observatory
hrs	Hours
kg	Kilogram
km	Kilometre
kt	Knot (Nautical Miles Per Hour)
LTE	Loss of Tail Rotor Effectiveness
METAR	Aerodrome Routine Meteorological Report
MHz	Megahertz
m	Metre
POH	Pilot's Operating Handbook
PPL(H)	Private Pilot's Licence (Helicopters)
UTC	Coordinated Universal Time
VFR	Visual Flight Rules
VHF	Very High Frequency

ACCIDENT INVESTIGATION DIVISION

CIVIL AVIATION DEPARTMENT

Aircraft Accident Report 1/2010

Registered Owner:	Hong Kong Rotor Company Limited
Aircraft Type:	Robinson Helicopter Company R22 Helicopter
Nationality / Registration:	B-LAT
Place of Accident:	Parking lot adjacent to the Hong Kong Aviation Club Limited, Sung Wong Toi Road, Hong Kong. Latitude: 22° 19.6' N Longitude: 114° 11.2' E
Date and Time:	1 May 2009 at 0313 hrs (1113 hrs) All times in this Report are in Coordinated Universal Time (UTC) with Hong Kong Local Time in parenthesis

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SYNOPSIS

In the morning of 1 May 2009, a Robinson R22 helicopter of Hong Kong Rotor Company Limited operated by a pilot with one passenger on board took off at about 0230 hrs (1030 hrs) on a private flight conducted in accordance with Visual Flight Rules from the Hong Kong Aviation Club Limited (HKAC) at Kai Tak, Kowloon to the New Territories.

At approximately 0310 hrs (1110 hrs), the pilot carried out an approach to land at the HKAC at Kai Tak, he encountered difficulties in stabilising the helicopter and performed a go around. After an uneventful go around, the pilot made a second approach but eventually decided to perform another go around due to difficulties in stabilising the helicopter. As he was making a turn to the right, the helicopter started a spin in a clockwise direction. Whilst the helicopter was spinning, it began to lose altitude and drifted in a northerly direction until it impacted the windscreen of a coach parked in the parking lot adjacent to Sung Wong Toi Road. At the time of the accident, one person was working inside the coach. There was no post-impact fire but the aircraft was damaged. The pilot, the helicopter passenger and the person inside the coach sustained minor injuries.

Upon receipt of the notification from the duty Aerodrome Supervisor at the Hong Kong International Airport, a team of Civil Aviation Department (CAD) Inspectors of Accidents arrived at the scene to conduct a site appraisal and survey. The Chief Inspector of Accidents subsequently ordered an Inspector's Investigation into the accident in accordance with the Hong Kong Civil Aviation (Investigation of Accidents) Regulations. The sole objective of this investigation is the prevention of aircraft accidents. It is not the purpose of this activity to apportion blame or liability.

The investigation concluded the cause of the accident was that the helicopter during a downwind approach experienced a Loss of Tail Rotor Effectiveness (LTE) that resulted in the aircraft spinning to the right during a low airspeed tight turn to the right. This subsequently led to the total Loss of Tail Rotor Effectiveness due to a Vortex Ring State developing on the tail rotor disc. Six safety recommendations have been made.

1. FACTUAL INFORMATION

1.1 History of Flight

1.1.1 On 1 May 2009, a Robinson R22 helicopter, Registration B-LAT of Hong Kong Rotor Company Limited operated by a pilot, on the right hand seat in control at all times under Visual Flight Rules (VFR) with one passenger, aged eight, took off at about 0230 hrs (1030 hrs) from the HKAC at Kai Tak, Kowloon to the New Territories for a private flight in Hong Kong.

1.1.2 The flight was uneventful and at about 0310 hrs (1110 hrs), the pilot carried out an approach to land at the HKAC at Kai Tak. The approach path would require the pilot to fly towards the HKAC on a westerly track. The 1-minute mean wind speed was 16 knots from a direction of 102 degrees, and the visibility was more than 10 kilometres.

1.1.3 Under the effect of a prevailing wind of east-southeast at 16 knots and whilst the helicopter was flown towards the northwest in a downwind condition, the pilot encountered difficulties in stabilising the helicopter and performed a go around. After an uneventful go around, the pilot made a second approach at 0313 hrs (1113 hrs) towards the northwest still in an east-southeast downwind condition (121 degrees) of 1-minute mean wind speed at 17 knots, gusting up to 21 knots, and eventually decided to perform another go around at low airspeed due to difficulties in stabilising the helicopter. As he was making a turn to the right, the helicopter started a spin in a clockwise direction. Whilst the helicopter was spinning, it began to lose altitude and drifted in a northerly direction until it impacted the windscreen of a coach parked in the parking lot adjacent to Sung Wong Toi Road. At the time of the accident, one person was working inside the coach.

Photograph 1 Aerial View of the Accident Site

Photograph 2 Helicopter and the Damaged Coach – Front View

Photograph 3 Helicopter and the Damaged Coach – Side View

1.2 Injuries to Persons

Injuries	Pilot	Passenger	Total in helicopter	Other
Fatal	-	-	-	-
Serious	-	-	-	-
Minor	1	1	2	1
None	-	-	-	-
Total	1	1	2	1

Table 1 Injuries to Persons

1.3 Damage to Aircraft

The helicopter was damaged.

1.4 Other Damage

The front section of the parked coach was damaged.

1.5 Personnel Information

Pilot:	Male, aged 48 years
Licence:	Private Pilot's Licence (Helicopters)
Aircraft Rating:	Robinson R22
PPL (H) Flight Test on R22:	20 February 2005
Certificate of Experience:	25 April 2008

Medical Certificate:	Class 2, renewed on 25 August 2008, valid until 31 August 2010. Limitations: Corrective lens to be worn and additional spectacles to be available.
Flying Experience:	Total all types 318 hours (fixed wing and helicopter) Total on type 201 hours (Robinson R22) Last 28 days – 2.4 hours

1.5.1 The pilot's licence was reissued on 28 February 2008 due to changes to the pilot's particulars. The 'Signature of Holder' section of the licence had not been signed when inspected after the accident.

1.5.2 The pilot mentioned in his statement that he was wearing corrective lens and an additional pair of corrective lens was available on board.

1.6 Aircraft Information

1.6.1 Airworthiness and Maintenance of Aircraft

Manufacturer:	Robinson Helicopter Company
Type:	R22 Beta II
Aircraft serial number:	4291
Year of manufacture:	2008

Certificate of Registration:	Issued on 21 May 2008 in the ownership of Hong Kong Rotor Company Limited
Certificate of Airworthiness:	Issued on 24 July 2008 in the Private Category and valid until 23 July 2009
Engine:	One Lycoming O-360-J2A piston engine
Maximum Approved Gross Weight:	622.7 kg
Total airframe hours:	162 hours

1.6.1.1 The helicopter was a new aircraft imported into Hong Kong in 2008 and had since been registered under Hong Kong Rotor Company Limited. Aircraft technical records indicated that the helicopter had been maintained in accordance with Maintenance Schedule CAD/MS/RHC/R22/LAT/01 Issue 1 and there had not been any significant airworthiness problems. The most recent scheduled maintenance check was a 50-hour Inspection carried out on 6 April 2009. At the time of that inspection, the airframe and engine had each accumulated 146.9 flight hours since new.

1.6.1.2 A review of the Aircraft Log Book indicated that the helicopter had no outstanding defects prior to the accident flight. The helicopter was fully serviceable in all respects.

1.6.2 Aircraft Description

1.6.2.1 General

R22 Beta II is a single-engined helicopter manufactured in the United States. It is developed, manufactured and marketed as an entry-level two-seater helicopter and is popular as a primary helicopter trainer.

The maximum gross weight for this helicopter is 622.7 kg. The primary structure of the fuselage is welded steel tubing and riveted aluminum. The tailcone is a monocoque structure in which the aluminum skins carry the primary loads. There are two seats in the cabin.

This helicopter is powered by a Lycoming O-380-J2A piston engine. Both the main and tail rotors have two all-metal blades and the main rotor turn in an anti-clockwise direction when viewed from the top. The helicopter is equipped with dual controls and certificated for single pilot operations on the right hand seat. The controls on the left hand seat were removed before the accident flight.

1.6.3 Performance and Centre of Gravity

The helicopter was within both longitudinal and lateral centre of gravity limits. The Maximum Approved Gross Weight of the helicopter is 622.7 kg; the take-off weight of the helicopter was calculated to be 553.6 kg and the weight of the helicopter at the time of impact was approximately 538.0 kg.

1.6.4 Fuel

The fuel on board was 15 U.S. Gallons at start up and was sufficient for a 110 minutes flight.

1.7 Meteorological Information

1.7.1 Weather Forecast and Observations

1.7.1.1 Weather Information issued by the Hong Kong Observatory (HKO).

1.7.1.1.1 The HKO issues Aerodrome Routine Meteorological Report (METAR) at half-hour intervals and Local Aviation Forecasts for 100-kilometre radius around Hong Kong three times a day. The METARs issued between 0200 hrs (1000 hrs) and 0630 hrs (1430 hrs), and the Local Aviation Forecast at 0130 hrs (0930 hrs) on the HKO website are as follows:

(i) METARs at the Hong Kong International Airport observed and issued between 0200 hrs (1000 hrs) and 0630 hrs (1430 hrs):

0200 hrs (1000 hrs):

"VHHH 010200Z 11014KT 070V130 CAVOK

26/14 Q1016 NOSIG="

0230 hrs (1030 hrs):

"VHHH 010230Z 11015KT CAVOK 27/14 Q1016 NOSIG="

0300 hrs (1100 hrs):

"VHHH 010300Z 12014KT CAVOK 27/14 Q1016 NOSIG="

0330 hrs (1130 hrs):

"VHHH 010330Z 11017KT 9999 FEW030 27/14 Q1016 NOSIG="

0400 hrs (1200 hrs):

"VHHH 010400Z 11017KT 090V150 9999 FEW030 27/14 Q1016 NOSIG="

0430 hrs (1230 hrs):

"VHHH 010430Z 11015KT 9999 FEW030 27/14 Q1015 NOSIG="

0500 hrs (1300 hrs):

"VHHH 010500Z 12016KT 9999 FEW030 28/14 Q1015 NOSIG="

0530 hrs (1330 hrs):

"VHHH 010530Z 12016KT CAVOK 27/15 Q1015 NOSIG="

0600 hrs (1400 hrs):

"VHHH 010600Z 12015KT 090V150 9999 FEW030 28/14 Q1014 NOSIG="

0630 hrs (1430 hrs):

"VHHH 010630Z 12017KT CAVOK 28/14 Q1014 NOSIG="

(ii) Extracts of the Local Aviation Forecast issued at 0130 hrs (0930 hrs) for the period from 0200 hrs (1000 hrs) to 1200 hrs (2000 hrs):

Surface wind:	090º 10-15 knots
Offshore wind:	090º 15-20 knots
Temperature:	23-28℃
Weather:	Mainly fine and dry
Cloud (AMSL):	FEW 4000 feet
Visibility:	10 km
Further Outlook:	Moderate easterly winds, occasionally fresh offshore and on high ground. Mainly fine.

1.7.1.2 After the accident, on the request from CAD, the HKO provided the following information on the wind conditions at Kai Tak:

Time (UTC)	10-min mean wind speed (knot)	10-min mean wind direction (degrees)	10-min gust (knot)	1-min mean wind speed (knot)	1-min mean wind direction (degrees)	1-min gust (knot)
0310	17	109	24	16	102	19
0311	17	110	24	17	112	20
0312	17	110	24	16	118	19
0313	16	111	24	17	121	21

Table 2 Wind conditions for Kai Tak as recorded by the anemometer at the southeast end of the ex-Kai Tak runway on 1 May 2009 (approximately three km southeast of the HKAC landing site at Kai Tak)

1.7.2 Meteorological Information Available at the HKAC

The HKAC is a subscriber of the Aviation Meteorological Information Dissemination System of the HKO. This system displays, inter alia, METAR, Local Routine Report, Local Aviation Forecast and Winds around Hong Kong to facilitate the provision, dissemination and display of meteorological information to users. In addition, the HKAC have access to the HKO internet website which provides information on aviation weather observation and forecast.

1.7.3 Meteorological Information Obtained by the Pilot

The pilot checked the weather reports before the flight. He gathered that the weather conditions in general were easterly wind between 10 and 15 knots with no significant weather.

1.7.4 Pilot's Assessment of Wind Conditions at Kai Tak

The pilot recollected that during his first approach to the HKAC towards the northwest, he felt quite strong tailwind. During the second approach in the same direction, the pilot checked the windsock located at the eastern corner of the HKAC's boundary fencing that indicated the helicopter was heading into wind. He noted that the windsock was quite straight and indicating a head wind at the ground level in relation to the helicopter.

1.8 Aids to Navigation

The flight was conducted in day light under VFR and the helicopter was appropriately equipped with navigation instrument for such a flight.

1.9 Communications

1.9.1 The accident location was in Island Zone, which is one of the seven Control Zones in Hong Kong. In Control Zones, 'Zone Control' is the Hong Kong Air Traffic Service (ATS) unit that provides flight information, air traffic control and alerting services to aircraft. In accordance with the provisions of the Hong Kong Aeronautical Information Publication issued by the Civil Aviation Department (CAD), local flights are permitted to take place under

VFR in Control Zones with two-way radio communication with 'Zone Control' on the designated VHF frequency 120.6 MHz.

1.9.2 The helicopter was fitted with a VHF radio communication equipment and the radio was serviceable on the day of the accident. The helicopter had maintained satisfactory communication with 'Zone Control' within Control Zones. The last communication with 'Zone Control' made by the helicopter was at 0310 hrs (1110 hrs) when the pilot acknowledged the flight plan was terminated.

1.9.3 There is no means of communication between the helicopter pilot and the HKAC at Kai Tak during normal flight operations.

1.10 Aerodrome Information

The helicopter departed from and intended to land at the landing site of the HKAC at Kai Tak. The landing site is part of the HKAC bounded by Sung Wong Toi Road to the south and southwest. Tall residential buildings are located immediately opposite to the HKAC at south of Sung Wong Toi Road. To the west and far north, the site is surrounded by roads and residential developments. Immediate north and east of the site are long term parking lots. (See Photograph 1)

A windsock is located at the boundary fence in northeastern end of the HKAC.

1.11 Flight Recorders

The helicopter was not fitted with any flight recorder and there is no requirement for this class of helicopter to be so fitted.

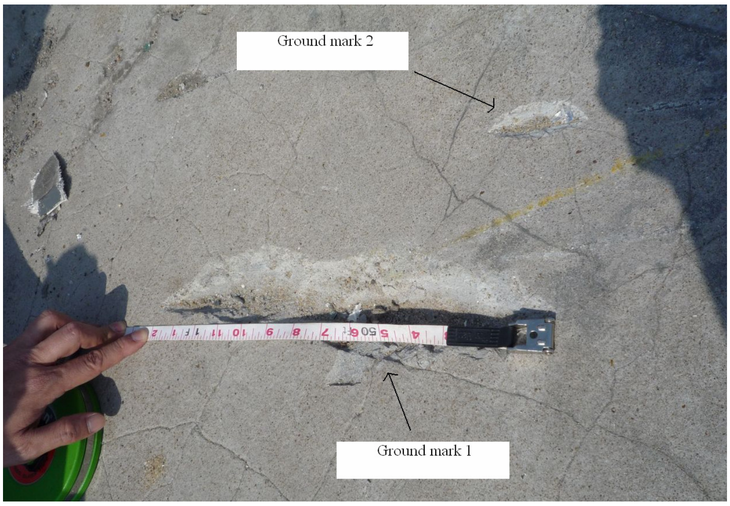
1.12 Wreckage and Impact Information

1.12.1 The helicopter crashed into a coach at approximately level attitude. The left-hand side skid struck through the windscreen of the parked coach. The helicopter came to rest on the left-hand side top corner of the coach with the right-hand side skid struck through the entry door. (Photograph 4)

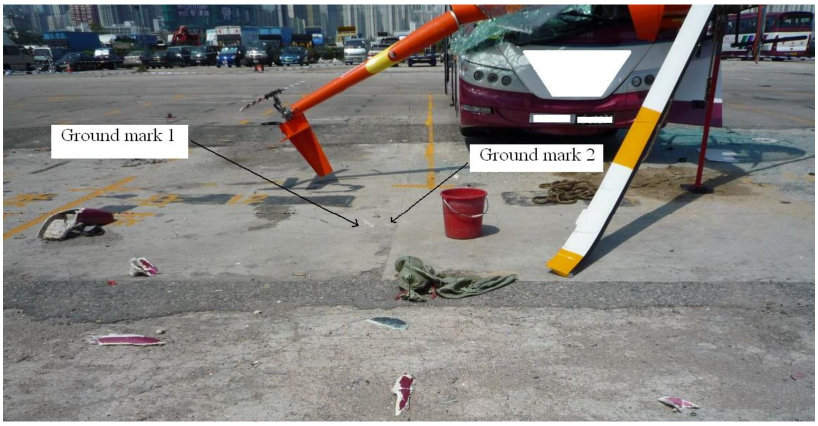
Photograph 4 The Wreckage

1.12.2 The main rotor blades were distorted with signs of impact at the tips. The blades had signs of rupture at the mid span areas. The tail rotor and the blades were intact with no sign of impact damage. The tail cone was broken at the mid section.

1.12.3 There were two ground marks made by the main rotor blades when they struck the ground. The bigger ground mark was measured 35.6cm x 6.4cm x 1.9cm and the smaller one was measured 6.4cm x 2.5cm x 0.6cm. (Photographs 5 and 6).



Photograph 5 Ground Marks – Close View



Photograph 6 Ground Marks – Relative to the Wreckage

1.12.4 Damages to the helicopter were as follows:

1.12.4.1 The right hand side skid was substantially damaged.

1.12.4.2 The main rotor blades remained attached to the helicopter but were significantly bent and twisted.

1.12.4.3 The tailcone was twisted and bent to the starboard (Photograph 7). The rivets attaching Bay 3 and Bay 4 of the tailcone were all sheared.

1.12.4.4 The centrifugal cooling scroll and fanwheel were severely damaged. (Photograph 8)

1.12.4.5 The magnetic compass was detached from the helicopter. (Photograph 9)

Photograph 7 The Tailcone

Photograph 8 The Centrifugal Cooling Scroll and Fanwheel

Photograph 9 The Magnetic Compass

1.13 Medical and Pathological Information

1.13.1 The Pilot

1.13.1.1 The pilot indicated that he operated the helicopter from the right hand seat and was wearing corrective lens.

1.13.1.2 The pilot received medical attention on-scene and at hospital. His general condition was good. He was diagnosed with soft tissue injury of bilateral lower limbs and left upper limb. There were no head and neck injuries.

1.13.1.3 An alcohol content test of the pilot was requested by the Accident Investigation Division of CAD. With the consent of the pilot, blood sample was taken and the alcohol level was reported as insignificant.

1.13.1.4 The pilot was treated and discharged from the hospital on the same day.

1.13.2 The Helicopter Passenger

The helicopter passenger received medical attention on-scene and at hospital. He sustained minor injuries and was treated and discharged from the hospital on the same day.

1.13.3 The person inside the coach

The person received medical attention on-scene and at hospital. He sustained minor injuries and was treated and discharged from the hospital on the same day.

1.14 Fire

No fire occurred in the accident. Minor fuel spillage was found on the accident site.

1.15 Survival Aspects

At 0314 hrs (1114 hrs), a '999' caller alerted emergency services to the location of the accident. At 0317 hrs (1117 hrs), the first fire engine arrived at the scene. The fire engines were dispatched from various fire stations, i.e. mainly from Ma Tau Chung, Wong Tai Sin, Kowloon Bay and Hung Hom Fire Stations. None of them is an aerodrome fire station. The nearest one at Ma Tau Chung is approximately 400m away from the scene. The pilot, the passenger and the person inside the coach were assisted to vacate the wreckage and were sent to hospital by ambulance at 0338 hrs (1138 hrs).

1.16 Test and Research

1.16.1 Rotation test on the main and tail rotors was carried out after the accident.

The main rotor was free to rotate by hand without binding; the tail rotor also rotated simultaneously with the main rotor.

1.16.2 Fuel sample was taken for analysis.

1.17 Organization and Management Information

The primary role of the HKAC is to promote light aircraft flying and provide flying training courses up to Private Pilot's Licence (PPL) level. Aircraft operated by members from the HKAC are to operate under the provisions of the HKAC, including the Helicopter Flying Orders Book (HFOB). If any members refuse or neglect to comply with any of the provisions, the HKAC General Committee may suspend the person's flying privileges for such period as the HKAC may determine or expel the person from membership of the HKAC.

The HFOB is written and published by the HKAC. It consisted of General Flying Orders and Flying Orders for specific helicopter types. These Flying Orders govern the operation of all helicopters by pilots out of the HKAC's premises. The limitations and procedures of the operation at Kai Tak were also stated in the HFOB.

The helicopter was registered in Hong Kong under the ownership of Hong Kong Rotor Company Limited with a Certificate of Airworthiness in the Private Category. Aircraft maintenance services and hangarage of the helicopter were provided by the HKAC. On the accident flight, the helicopter was operated from the HKAC by a member.

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2. ANALYSIS

2.1 Flight Operations and Aircraft Airworthiness

2.1.1 Helicopter Flying Orders Book

2.1.1.1 According to the HKAC, it is mandatory for all helicopter pilots to read, sign and comply with the HFOB when operating out of the HKAC premises. Also, the HFOB is supposed to be reviewed by pilots periodically and when amendments have been made. Records showed that the HFOB was last signed on by the pilot on 7 July 2007. Pilots were to review the HFOB as of 18 April 2008 and 15 February 2009 as initiated by the HKAC. The pilot had not signed the respective entries before the flight. During the interview conducted on the same day of the accident, the pilot stated that he had read the HFOB and he would study it periodically and for the Annual Flight Review.

2.1.1.2 A downwind approach limitation was not specified in the HFOB on single-engined helicopter operating at Kai Tak.

2.1.2 Alternate Landing Sites

There was no provision for alternate landing sites as detailed in the HFOB. It was likely that the pilot would not have considered landing at an alternate landing site even when the downwind conditions were excessive to both the helicopter and the pilot for a safe landing to the HKAC at Kai Tak.

2.1.3 Cockpit Switches

All cockpit switches were found in their normal positions for flying except the master battery switch that had been put in the 'OFF' position by a rescue party to prevent ignition of the fuel dripping from the helicopter.

2.1.4 Aircraft Airworthiness

The pilot did not report any aircraft mechanical malfunctions, no warning light was found illuminated and no abnormal sound was heard. The damages to the helicopter and the ground marks observed were consistent with the consequential effects of the impact onto the coach. The post-accident test confirmed that the drive train between the main and tail rotor was normal. The fuel sample test report confirmed that the fuel quality conformed to AVGAS 100LL specification.

2.1.5 Downwind Approach

2.1.5.1 Over the years the surrounding development has been creating limitations to helicopter operation in/out of the landing site at the HKAC. The departure and arrival flight path for single-engined helicopters is generally at an east/west unidirection but no flight path has been defined as helicopters are operated under VFR. However, given the surrounding condition of the site, landing and take-off are normally made within an airspace sector to the east in order to avoid over-flying areas that would endanger persons and properties on the ground in the event of an engine failure. Without ample room for adjusting the flight path, pilots may face with situations of approaching the HKAC in a downwind condition which is not desirable in the context of flight operation.

2.1.5.2 A downwind approach is a more demanding manoeuvre for the pilot. Additional measures like training and landing limitations are to be considered in order to mitigate the risks associated with a downwind approach.

2.1.6 Aerodynamic Effects on Tail Rotor

2.1.6.1 The following is a discussion of the basic helicopter aerodynamic principles, Loss of Tail Rotor Effectiveness, and an analysis of the aerodynamic effects on the tail rotor of the accident flight from the low airspeed downwind turn to the loss of directional control of the helicopter in the yawing plane based on the following findings:

2.1.6.1.1 The description of the flight by the pilot and eye witnesses on the ground;

2.1.6.1.2 The wind direction according to the weather reports (Paragraph 1.7) and observation of the general wind in the area immediately after the accident for a period of three hours;

2.1.6.1.3 The tail rotor drive shaft and the tail rotor were fully functional before the impact;

2.1.6.1.4 The tail rotor control linkages were fully functional before the impact; and

2.1.6.1.5 The engine was providing sufficient power to the main rotor for the flight.

2.1.6.2 Loss of Tail Rotor Effectiveness (LTE) [Note 1]

LTE can be described as a critical low airspeed aerodynamic flight condition that can result in the loss of control of the helicopter if it is unchecked. It is a result of a control margin deficiency and is not a maintenance malfunction. Tail Rotor capability is a factor in a helicopter type that is prone to reaching full pedal. This type of helicopter when hovering out of wind, in Outside Ground Effect and High All Up Weight conditions, is more likely to suffer LTE due to the high power required to hover resulting in the requirement of a high anti-torque pedal application. To

Note 1: The figures within this analysis are for illustration purpose and may be out of scale. For simplicity and clarity, some of the forces acting on the aerofoil of a rotor disc are omitted in all the diagrams and the forces shown do not act from the centre of pressure.

understand LTE an understanding of the anti-torque system and some understanding of the Principles of Flight are required.

2.1.6.2.1 Anti-Torque System

Figure 1 is an illustration of the Anti-Torque Effect of the helicopter in the hover. With the main rotor blades rotating anti-clockwise, the helicopter would have a tendency to turn clockwise. This phenomenon is known as the Anti-Torque Effect, which can be seen in Figure 1 as Force Z1 and Z2 (of equal magnitude) acting on the fuselage and forcing the helicopter to yaw to the right. To prevent the helicopter from yawing to the right, the tail rotor of the helicopter must produce a Tail Rotor Thrust (i.e. Forces X1 and X2) to counteract the effect of Z1 and Z2. The tail rotor thrust is the result of the application of the anti-torque pedal by the pilot. If the tail rotor generates more thrust (left pedal) than that is required to counteract the main rotor torque, the helicopter will yaw or turn to the left about the vertical axis. If less tail rotor thrust (right pedal) is generated the helicopter will yaw to the right. By varying the thrust generated by the tail rotor, the pilot controls the heading when hovering and at low forward airspeed.

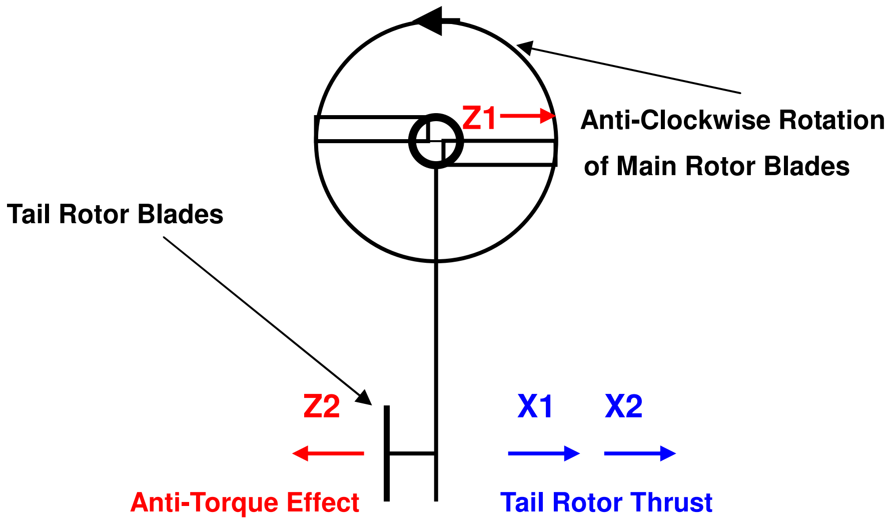

Figure 1 Anti-Torque Effect and Tail Rotor Thrust

2.1.6.2.2 Induced Flow

Newton's Third Law of action and reaction supports the principle that during helicopter flight the rotor must force down a volume of air. This volume of air is known as the Induced Flow. As a helicopter blade rotates along the Plane of Rotation it creates an airflow on its leading edge. The resultant of the Induced Flow and the Plane of Rotation will be the Relative Air Flow as shown in Figure 2.

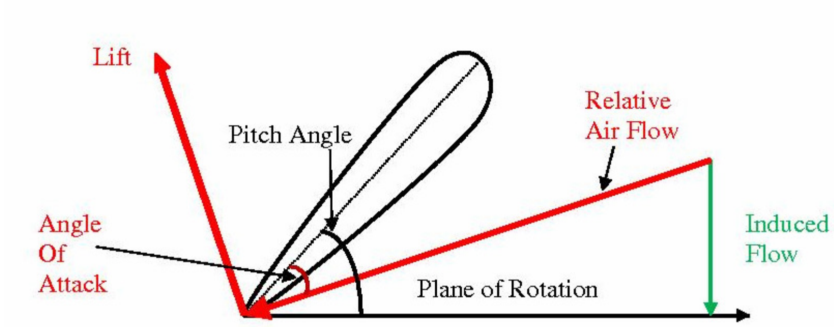

Figure 2 Induced Flow

It can be seen from Figure 3 that without moving the collective to alter the pitch angle and the power used, a reduction of Induced Flow, will rotate the Relative Air Flow clockwise resulting in a larger angle of attack and an increase in lift, and vice versa, an increase of Induced Flow will rotate the Relative Air Flow anti-clockwise resulting in a smaller angle of attack and a reduction in lift.

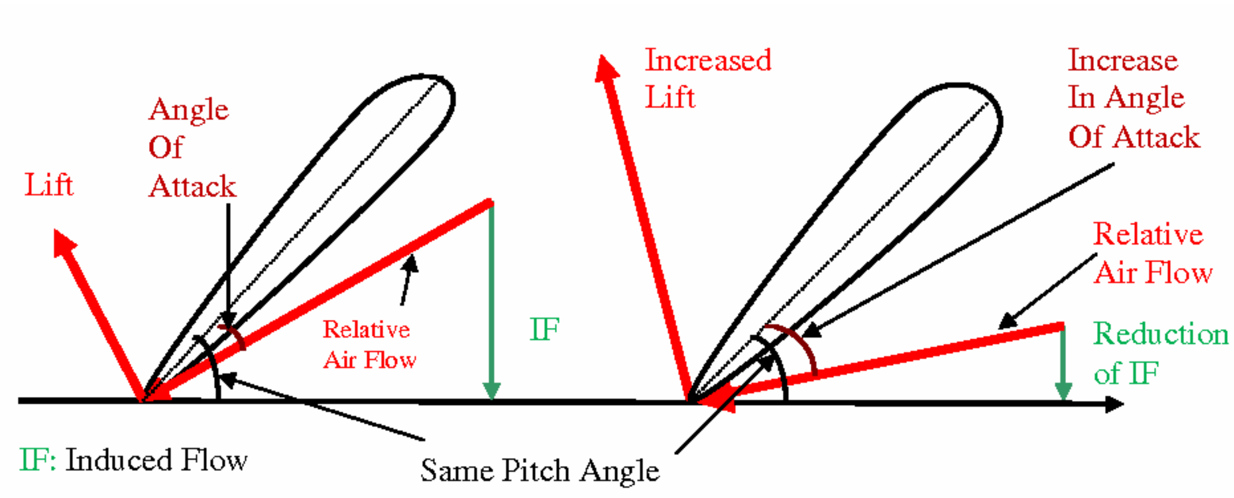

Figure 3 Reduction of Induced Flow

As with the main rotors, there will be Induced Flow produced by the tail rotors in the opposite direction of the Tail Rotor Thrust to counter the anti-torque effect as shown in Figure 4.

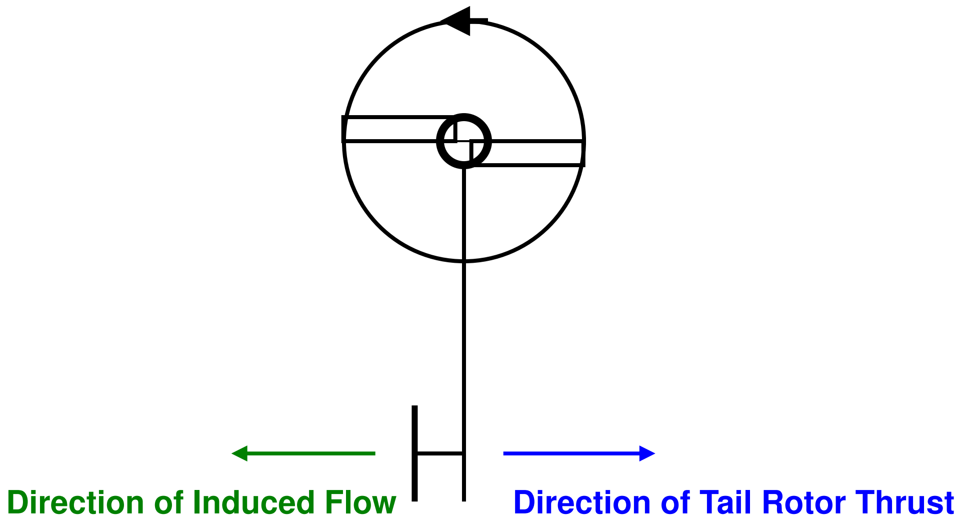

Figure 4 Induced Flow and Tail Rotor Thrust

2.1.6.2.3 Translational Lift

A helicopter moving forward from a hover to forward flight will cause an airflow moving horizontally across the rotor disc, this will reduce the Induced Flow thus increasing the angle of attack and lift. This increase of lift without moving the collective to increase the pitch angle is known as Translational Lift. Translational Lift normally occurs at about 15 knots and in the case of the Robinson R22 will increase with airspeed until 55 knots, at the best rate of climb airspeed, and after that will start decreasing again. The tail rotor will also experience Translation Lift as the aircraft moves forward from a hover.

2.1.6.2.4 Weathercock Effect

With a wind blowing, the helicopter at low airspeed tends to behave like a weathervane and will turn the aircraft to face into wind. The weathercock effect will be most prominent when the tailwind is at 120 degrees to 240 degrees from the helicopter heading.

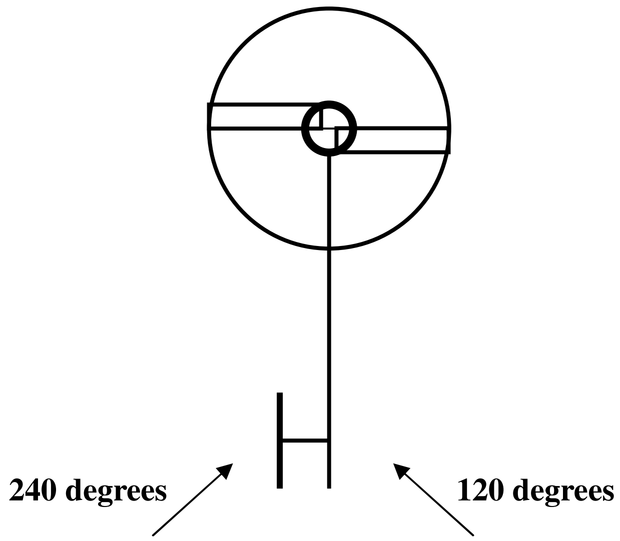

Figure 5 Weathercock Effect

2.2 Analysis of the Accident Flight and Loss of Tail Rotor Effectiveness

2.2.1 The pilot in his report by email dated 4 May 2009 reported that "---I took the normal landing approach aiming at the open space of HKAC. However I found that the crosswind from my right side was strong ---I found that I could not turn the aircraft straight by left pedal because of the strong wind---I decided to go around right to re-establish the approach ---I notice that the windsock at the edge of HKAC's fencing was flying towards my direction, i.e.

indicating a headwind". In his signed statement dated 25 May 2009, the pilot stated that, "During the approach I felt quite strong tailwind. The helicopter was crabbing in during the approach. - - - I looked at the windsock located at the eastern corner of the HKAC's boundary fencing that indicated the helicopter was heading into wind." This report made by the pilot indicated that the crosswind from the right was strong and that the windsock was flying in his direction (westerly wind) and the statement that he felt quite strong tailwind was contradictory. It is reasonable to suggest that sometimes at a distance a windsock downwind indication can be mis-interpreted as an into wind indication or vice versa as the profile of the windsock that is viewed directly into wind or downwind may look the same at a distance.

2.2.2 The weather reports for the day from 0200 hrs (1000 hrs) to 0400 hrs (1200 hrs) indicated a wind from east-northeast to east-southeast at 6 to 22 knots gusting up to 29 knots based on 1-minute mean wind data. Observation of the wind on site shortly after the accident and for a substantial period after showed a constant wind from the east. At no time was the wind observed to be from a westerly direction. It would be implausible that at the moment that the pilot elected to make the approach, that the wind would be from the west. It can be deduced here that the pilot mis-interpreted his perception of the windsock indication to be into wind. He was in a downwind approach.

2.2.3 A downwind approach of a 1-minute mean wind speed of 17 knots gusting up to 21 knots is significant. The benefits of translational lift for a helicopter normally comes in at about 15 knots and will increase, in the case of the R22 up to 55 knots which is the helicopter's maximum rate of climb airspeed. At the time of the second approach, the 1-minute mean wind recorded at Kai Tak was from 121 degrees at 17 knots gusting to 21 knots.

2.2.4 The R22 while carrying out the approach to the HKAC open area would be decelerating. The pilot in his report dated 4 May 2009 reported "I took the normal landing approach ---I found that the crosswind from my right side was strong and I had to crab the aircraft for the approach. Around 200m out, I found that I still could not turn the aircraft straight by left pedal because of the strong wind, and that the aircraft was high. I decided to go around---". In his signed statement dated 25 May 2009 the pilot stated that "During the approach I felt quite strong tailwind. The helicopter was crabbing in during the approach. I tried to straighten the heading but the wind was so strong that I could not. As I was slowing down at about 100 feet, I felt so uncomfortable that I decided to go around." Although there are differences between the pilot's report and the pilot's signed statement, the decision taken by the pilot to go around was correct. The helicopter ended up high although the pilot stated that he took the normal landing approach because he was downwind, and the helicopter drifted forward as in a normal downwind approach, the approach angle would be much shallower because of the drift. The analysis that the helicopter is downwind and this is supported by the witness statement that he saw the helicopter approaching the HKAC at about the normal altitude but seem to be in an unsteady (not stable) state of flight, yawing and rolling about in an abnormal way. Normally in a downwind approach the helicopter is unstable as the aircraft is designed to fly forward and into wind.

2.2.5 The pilot decided to make another approach, but as stated by him "I made a 360 degree orbit but found the same problem. I noticed that the windsock at the edge of HKAC's fencing was flying towards my direction, i.e. indicating a headwind condition at the surface." As explained earlier sometimes at a distance a windsock downwind indication can be mis-interpreted as an into wind indication, which is not unusual even for an experienced pilot. It can therefore be deduced here that the helicopter was approximately, directly downwind and that the strong right crosswind mentioned by the pilot previously is incorrect. The tendency of the helicopter to yaw right was not the result of the strong right crosswind as deduced by the pilot.

2.2.6 The tendency for the aircraft to yaw right was because the helicopter was in a strong downwind approach. At the same normal ground speed in a calm wind situation, the airspeed would be 17 to 21 knots lower because of the downwind factor. At 200 metres out the helicopter would be below 20 to 30 knots ground speed, which meant that his forward airspeed would be below 15 knots or even less because of the gust and the pilot's perception that he was moving very fast over the ground. The helicopter would lose the benefit of translational lift, which meant that he had to apply substantial collective (power) to maintain a controlled rate of descend. In this case with the application of power the pilot would have to use a lot of left pedal to keep the helicopter straight.

2.2.7 The tail rotor would also be losing translational lift, therefore the induced flow acting on the tail rotor would be of a higher value resulting in a smaller angle of attack, lift and tail rotor thrust, even if the pitch angle remained the same. In other words, if the yaw pedals remained in the same position, the helicopter would yaw to the right due to insufficient tail rotor thrust to counter the anti-torque effect of the main rotor, this is sometimes known as an un-commanded yaw to the right. This is also known as Loss of Tail Rotor Effectiveness as the tail rotor is less effective at the same pitch angle. At the same time the downwash generated by the main rotor would start affecting the tail rotor much earlier in the approach because of the low relative airspeed. Vortices generated by the downwash would start disturbing the air around the tail rotor, resulting in a further decrease of tail rotor thrust contributing to the un-commanded yaw to the right, and a further loss of Loss of Tail Rotor Effectiveness.

2.2.8 With a forward airspeed the airflow around the helicopter would keep the helicopter flying straight. With the loss of airspeed the helicopter would be affected by the phenomena known as weathercock effect. With an un-commanded yaw to the right as explained above, and with additional left yaw pedals required to counter the increased in collective and power used, the helicopter would yaw right if insufficient left pedal is applied. The pilot stated, "I found that the crosswind from my right side was strong and I had to crab the aircraft for the approach." This indicated that the pilot did not use enough left pedal (more than normally required for an into wind approach) to counteract the anti-torque effect yawing the aircraft to the right. The aircraft was then subjected to weathercock effect. The relative wind on the tail rotor would be from the right. The effect is most prominent when the tail wind is at 120 degrees from the helicopter heading and will accelerate the yaw turn to the right. This was the reason the pilot stated in his first approach that "---I found that I could not turn the aircraft straight by left pedal---".

2.2.9 The pilot decided to go around turning right as he did so, to make use of the open space to the right, this was the correct action to take in the case of the onset of LTE. However although the pilot took the correct action, he did not realize that he was experiencing LTE. He made a second approach and experienced the same condition. He went around again, in the interview with the pilot he stated that in the second go around he made a tighter orbit to the right, and when questioned about the airspeed, he said that he was at a low airspeed.

2.2.10 In a low airspeed downwind turn, the pilot would have used his pedal in a partial pedal turn to the right, the pilot stated "As I was turning right heading to the north, the helicopter started yawing to the right. I felt something was going wrong. ---and stepped on the left pedal. Meanwhile, the helicopter started spinning to the right. ---By instinct, I headed toward a more open area. The helicopter then hit the coach".

2.2.11 In a go around the pilot should have increased his airspeed before making a turn to the right. By increasing the airspeed, the aircraft would have re-gained translational lift on the main and tail rotors, the downwash from the main rotors would no longer affect the tail rotors, and with the increase in airspeed the helicopter would no longer be subjected to the weathercock effect. Instead the pilot made a tight turn at low airspeed, this had all the conditions for the maximum Loss of Tail Rotor Effectiveness. In the low airspeed turn downwind the Total Thrust produced by the tail rotors, even with the application of full left pedal, could no longer balance the anti-torque effect and the result of the aircraft tendency to turn to the right due to LTE (as explained above), resulting in the acceleration of the turn and the helicopter spinning to the right.

2.2.12 The accelerated yaw turn to the right resulted in another airflow coming into play. This airflow is the Rate of Turn Airflow that will directly oppose the Induced Flow. With a high rate of turn the Rate of Turn Airflow would be strong. The meeting of these two opposing strong airflows at the tail will cause vortices to form at the periphery of the tail rotor disc spreading inwards contributing to the loss of tail rotor thrust. This may develop into a full Vortex Ring State on the tail rotors whereby there would be a total loss of tail rotor thrust.

2.2.13 The pilot would lose control of the aircraft in the yawing plane, which explains the pilot stated "I cannot recall how many times the helicopter had spun but the spin was getting faster and faster".

2.2.14 In the spin the pilot tried to control the aircraft as it drifted northwest until it impacted on to the coach.

2.2.15 Procedures for Loss of Tail Rotor Effectiveness (LTE)

The pilot experienced LTE during the first approach and went around, and in the second approach he again experienced LTE. In the onset of LTE the pilot should have increased his airspeed to get out of the conditions that caused LTE instead he made a tight turn to the right at low airspeed exacerbating the conditions for LTE resulting in the loss of control in the yawing plane until the aircraft impacted on to the coach.

2.3 Communications

2.3.1 The flight took place at Kai Tak within Island Zone with satisfactory two-way communication with ATS units.

2.3.2 Once a helicopter is airborne, there is no direct communication means between the helicopter and the HKAC for a weather information update. The only real time wind information that is available to the pilot is a windsock situated at the northeastern end of the HKAC Kai Tak compound. The direction of the wind can be mis-interpreted as the pilot of a single-engined helicopter cannot over-fly the windsock to confirm the direction due to the restricted forced landing areas available in Kai Tak. The windsock does not provide a definitive value of the wind speed. An anemometer is not available in the HKAC to provide this definitive and important wind information to the pilot. The latest wind information cannot be passed to the pilot before making an approach to the HKAC landing site to prevent the mis-interpretation of the wind direction and speed.

2.4 Environment

2.4.1 The HKAC is mainly surrounded by long term parking lots from the North and the East. There is a single flight path that has an east-west alignment, making it clear of the parking lots with more suitable areas for a forced landing for single-engined helicopters. However, the HKAC did not specify this flight path for single-engined helicopters operating from the

HKAC at Kai Tak.

2.4.2 A single flight path will invariably place the helicopter on an approach with a downwind component when the wind is in an easterly direction and vice versa a downwind take-off when the wind is from a westerly direction.

2.4.3 A downwind take-off or approach is a more demanding manoeuvre with all the conditions that give rise to LTE. Therefore considerations should be given to the followings:

2.4.3.1 That a downwind approach limitation be set when operating at Kai Tak.

2.4.3.2 That when this wind limitation is exceeded, an alternate site is available for the helicopter to make an into wind approach.

2.4.3.3 That only pilots who have the skills and experience to fly a helicopter in a downwind take-off or approach be allowed to operate from the HKAC. These pilots are to be given additional training in the recognition of LTE and the difficulties associated with a downwind take-off or approach.

2.5 Aircraft Type

Design of the tail rotor capability of certain types of single-engined helicopters is more susceptible to LTE. These types of helicopters when operating at low airspeed out of wind, in Outside Ground Effect and high All Up Weight conditions are more likely to suffer from LTE. As either the approach or take-off to and from the HKAC will invariably be downwind, consideration should be given to limit the Maximum All Up Weight of the helicopter, to a prescribed percentage of the Maximum Approved Gross Weight allowed by the respective flight manual / POH, when operating at Kai Tak for a better safety margin.

2.6 Survivability

2.6.1 Crashworthiness survivability analyses were conducted which included the following aspects:

(a) Container – structural airframe crash resistance, control cabin space integrity, resistance to incursion by external objects
(b) Restraints – occupant harnesses
(c) Energy Absorption Features – design of seats and aircraft structure
(d) Post-Crash Factors – exits, entrapment, escape, fire and smoke, search and rescue organization.

2.6.2 Container

The general shape and dimensions of the control cabin were preserved, no obvious damages were found on the perspex canopy following the impact. Impact damages were mainly on the skids and from the middle to rear portion of the helicopter. There was no evidence of any injury caused by protruding objects. (Photograph 10)

Photograph 10 Side-view on the damaged helicopter

2.6.3 Restraints

The three-point inertia-reel harnesses restrained the pilot and passenger. These harnesses were attached wholly to the helicopter cockpit frame structure and were fastened by standard flap release buckles mounted on short straps attached to the frame. The pilot and passenger seats were constructed integrally with the floor and comprised a pressed-sheet aluminium frame and seat cushion backed by aluminium plate. It was concluded that the three-point harnesses functioned normally and did not contribute to any injury or entrapment of the occupants. (Photograph 11)

Photograph 11 The Harnesses

2.6.4 Energy Absorption Features

Design Standards pertaining to this helicopter are based on the United States' Federal Aviation Regulations (FAR) Part 27 dated 1 February 1965, including Amendments 27-1 through 27-10. In particular to the energy absorption features, FAR 27.561 at Amendment 0 which remains effective on Amendments 27-1 through 27-10 requires that occupants have a reasonable chance of escaping when impact forces applied to them do not exceed those in the following table:

Requirements / Load Directions	FAR 27.561 dated 1 February 1965
Upward	1.5 g
Forward	4 g
Sideward	2 g
Downward	4 g

It was not possible to accurately determine the actual crash forces in this accident from the available evidence.

2.6.5 Post-Crash Factors

2.6.5.1 Escape / Exits

The accident occurred at 0313 hrs (1113 hrs). The pilot and the passenger exited the helicopter through the right hand side door.

2.6.5.2 Entrapment

There was no evidence of physical entrapment of the pilot or the passengers.

2.6.5.3 Fire and Smoke

There was no post-crash fire.

2.6.6 Based on the above analysis, it was concluded that the accident was survivable.

2.7 Air Traffic Service

2.7.1 The helicopter received air traffic control services from 'Zone Control' and the provision of such service was appropriate.

2.7.2 Fire Services Communication Centre and the pilot of another aircraft, B-HJN, alerted the duty Aerodrome Supervisor of the accident who then initiated alerting actions in accordance with CAD Air Traffic Management Division Emergency Procedures Manual. The provision of alerting service by ATS units was in order.

2.8 Emergency and Rescue Services

2.8.1 The accident site was easily accessed by road vehicles. The injured persons received preliminary on-scene medical attention and subsequently sent to hospital in a prompt manner.

2.8.2 The alerting action, emergency response and level of attendance of the emergency service personnel were efficient and effective.

2.9 Regulatory Review of General Aviation in Hong Kong

2.9.1 Grant, renewal and effect of Flight Crew Licences

Article 20(1)(c) of Cap. 448C – AN(HK)O states "A licence granted under this Article shall not be valid unless it bears thereon the ordinary signature of the holder in ink". It was noted that the pilot's PPL(H) licence had not been signed.

3. CONCLUSIONS

3.1 Findings

3.1.1 The pilot held a Private Pilot's Licence (Helicopters) with a Robinson R22 aircraft rating and a valid Class 2 Medical Certificate. However, the licence did not bear the signature of the pilot. (Paragraphs 1.5, 1.5.1 and 2.9.1)

3.1.2 The pilot had not signed the review column of the HKAC Helicopter Flying Orders Book before the flight. (Paragraph 2.1.1.1)

3.1.3 The pilot gathered the weather conditions of the Hong Kong area prior to the flight. (Paragraph 1.7.3)

3.1.4 The flight was conducted in day light under VFR and the helicopter was appropriately equipped with navigation instrument for such a flight. (Paragraph 1.8)

3.1.5 Communications between the pilot and the ATS units were satisfactory. (Paragraphs 1.9.1 and 1.9.2)

3.1.6 The pilot was on a strong downwind approach to the HKAC. (Paragraphs 2.2.2 and 2.2.3)

3.1.7 A downwind approach limitation was not specified in the HFOB on single-engined helicopter operating at Kai Tak. (Paragraphs 2.1.1.2 and 2.4.3.1)

3.1.8 The pilot on both approaches decided to go around because he could not turn the aircraft straight by the use of the left pedal. He did not realize that he was experiencing LTE even when he had used the full control of his left pedal. (Paragraphs 2.2.4, 2.2.6 and 2.2.9)

3.1.9 Based on the pilot's observation of the windsock, he thought the helicopter was heading into wind on the second approach. (Paragraphs 1.7.4 and 2.2.5)

3.1.10 Based on weather information and observation after the accident, it was concluded that the pilot had mis-interpreted the wind direction. (Paragraph 2.2.2)

3.1.11 The pilot thought that he had to use more than the normally required left pedal because of a strong wind from the right. (Paragraph 2.2.8)

3.1.12 In the second approach the pilot when experiencing LTE did not increase his airspeed before going around which is the required action for getting out of the effects of LTE. (Paragraph 2.2.11)

3.1.13 In the second approach the pilot reduced his airspeed in a tight turn causing the aircraft to go into a spin to the right and entering into a total state of LTE. (Paragraphs 2.2.9 to 2.2.11)

3.1.14 The pilot did not take the correct action when experiencing LTE. (Paragraphs 2.2.9 to 2.2.15)

3.1.15 During the conduct of flight operations at Kai Tak there was no procedure to establish a radio communication between the aircraft and the HKAC operations room to enable the pilot to access the latest meteorological conditions of the area. (Paragraph 2.3.1 and 2.3.2)

3.1.16 There is one flight path that can be made clear of the parking lots with more suitable areas for a forced landing for single-engined helicopters operating from the HKAC at Kai Tak. (Paragraph 2.4.1)

3.1.17 The HKAC did not specify this flight path in the HFOB. (Paragraphs 2.4.1 and 3.1.16)

3.1.18 With only one flight path, a single-engined helicopter would invariably take-off or approach in a downwind condition. (Paragraph 2.4.2)

3.1.19 A downwind take-off or approach is a more demanding manoeuvre that may be compensated by better pilot's skill and experience and an aircraft mass that is lower than the normal maximum aircraft mass allowed. (Paragraphs 2.4.3, 2.4.3.3 and 2.5)

3.1.20 There were no alternate landing sites in the planning of the flight in case an aircraft experiences difficulties in a strong downwind approach. (Paragraph 2.1.2)

3.1.21 Three persons (i.e. the pilot, the passenger and the person inside the coach) sustained minor injuries. (Paragraphs 1.13.1 to 1.13.3)

3.1.22 The accident was survivable. (Paragraphs 2.6.1 to 2.6.6)

3.1.23 Pilot's blood sample was taken and the level of alcohol was reported as insignificant. (Paragraph 1.13.1.3)

3.1.24 The helicopter had a valid Certificate of Airworthiness and was maintained in accordance with the approved maintenance schedule. (Paragraphs 1.6.1 and 1.6.1.1)

3.1.25 The helicopter had no outstanding defects prior to the accident flight and was fully serviceable in all respects. (Paragraph 1.6.1.2)

3.1.26 The main rotor blades remained attached to the helicopter but were significantly bent and twisted as a result of impact with the ground. (Paragraph 1.12.4.2)

3.1.27 The helicopter tailcone was twisted and bent to the starboard as a result of impacting the coach. (Paragraph 1.12.4.3)

3.2 Cause

The helicopter during a downwind approach experienced a Loss of Tail Rotor Effectiveness that resulted in the aircraft spinning to the right during a low airspeed tight turn to the right. This subsequently led to the total Loss of Tail Rotor Effectiveness due to a Vortex Ring State developing on the tail rotor disc. (Paragraph 2.2)

3.3 Contributing Factors

3.3.1 The pilot had mis-interpreted the direction and strength of the wind and carried out a downwind approach of a 1-minute mean wind speed of 17 knots gusting up to 21 knots. (Paragraphs 2.2.1 to 2.2.5)

3.3.2 The pilot did not realize that he was experiencing a Loss of Tail Rotor Effectiveness. (Paragraph 2.2.9)

3.3.3 The pilot made a tight turn to the right at low airspeed when he was experiencing a Loss of Tail Rotor Effectiveness (LTE) and failed to increase his airspeed first to get out of the conditions that caused LTE. (Paragraphs 2.2.11 to 2.2.15)

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4. SAFETY RECOMMENDATIONS

4.1 Recommendations

4.1.1 Recommendation 2010-3

It is recommended that the HKAC review the control procedures to ensure pilots are current with the Helicopter Flying Orders. (Paragraph 3.1.2)

4.1.2 Recommendation 2010-4

It is recommended that the HKAC review and establish conditions and limitations for single-engined helicopter operation at Kai Tak in the Helicopter Flying Orders. (Paragraphs 3.1.7 and 3.1.19)

4.1.3 Recommendation 2010-5

It is recommended that the HKAC establish a means of communication be available whenever flight operations are conducted in Kai Tak to provide pilot with the latest wind information of Kai Tak. (Paragraphs 3.1.15 and 3.3.1)

4.1.4 Recommendation 2010-6

It is recommended that the HKAC specify alternative landing sites whenever the conditions, procedures and limitations set out in the

Helicopter Flying Orders cannot be complied with by single-engined helicopters whilst conducting flight operations at Kai Tak. (Paragraph 3.1.20)

4.1.5 Recommendation 2010-7

It is recommended that the HKAC only allow pilots who have the skills, experience and additional training to fly a single-engined helicopter in a downwind take-off or approach and the recognition of the onset of LTE before they can operate at Kai Tak. (Paragraphs 2.4.3.3, 3.3.1 to 3.3.3)

4.1.6 Recommendation 2010-8

It is recommended that the HKAC define the flight path for single-engined helicopters when operating at Kai Tak. (Paragraphs 2.4.1, 3.1.16 and 3.1.17)

4.2 Safety Actions Already Implemented

4.2.1 The HKAC has established the control procedures that pilots are required to review and sign the Helicopter Flying Orders quarterly.

4.2.2 The HKAC has revised the Helicopter Flying Orders on Kai Tak Procedures to include a downwind approach limitation of 10 knots and a 10% margin between the helicopter gross weight and the maximum gross weight allowable in the Pilot's Operating Handbook.

4.2.3 An HKAC Duty Operations Officer provides the latest wind information by means of VHF radio communications to all helicopters before making an approach to Kai Tak.

4.2.4 The HKAC has revised the Helicopter Flying Orders to require all pilots operating from Kai Tak to select one of the alternate landing sites specified by the HKAC prior to takeoff.

4.2.5 A Kai Tak Authorised Pilot programme has been established by the HKAC. To be eligible as a Kai Tak authorised pilot, the candidate should have a total of 250 flying hours in a helicopter and should have completed a course of briefing on LTE and downwind approach and the appropriate flight training, and checked by an Authorised Examiner.

4.2.6 The HKAC has revised the Helicopter Flying Orders to define the flight path for single-engined helicopters when operating at Kai Tak.

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