Air Methods A350B3e accident
Frisco, CO
July 3, 2015
CEN15MA290

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

ATTACHMENT 6

Test Plan and Results

10 Pages

TEST PLAN AND RESULTS FOR AIR METHODS AS350B3E ACCIDENT, FRISCO, CO, 7/3/2015

Devices:

AS350-B3e experimental aircraft (aircraft 1)
AS350-B3e training aircraft (aircraft 2)
AS350-2B1 simulator

Participants:

Aircraft 1

NTSB

Jennifer Rodi (Investigator in Charge)
Chihoon Shin (Aviation Engineering-Helicopters Specialist)

Air Methods

Dennis McCall (Director of Operations)

Airbus Helicopters

Tobin "Toby" Hart (Chief Test Pilot)
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Aircraft 2

NTSB

Katherine Wilson (Human Performance Specialist)
Marie Moler (Aircraft Performance Specialist)
Sathya Silva (Human Performance Specialist)

Airbus Helicopters

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Dave Burchill (Senior Test Pilot)

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Simulator

Airbus Helicopters

Steve Scroggs (Helicopter Pilot-Instructor)

FAA

Jon Jordan (Rotorcraft Flight Test Pilot)

Additional participants

Airbus Helicopters
Lindsey Cunningham (Director, Safety)

FAA
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Date: May 6, 2016

Objectives:

1. To allow the NTSB specialists to familiarize themselves with the AS350 cockpit, instrument displays, controls, systems, and normal takeoff/landing and emergency procedures.
2. To evaluate the AS350B3e yaw servo hydraulic check checklist/procedures.
3. To measure and assess pedal forces under different configurations of the hydraulic and accu test switches.

Overview:

Following an overview presentation and safety briefings, the NTSB investigative team, party members, and technical liaisons participated in an observational study at the Airbus Helicopters training center in Grand Prairie, TX. The test team divided into two groups to perform the work. Test team 1 performed the yaw servo hydraulic check in an AS350B3e (dual hydraulics) exemplar experimental helicopter (aircraft 1) using the Air Methods AS350B3e expanded checklist current at the time of the accident. In addition, the test team performed the yaw servo hydraulic check, but modified the order in which the steps were completed. Pedal forces were measured and assessed during this task. The steps to complete the yaw servo hydraulic check as indicated in the AS350B3e checklist are listed in Table 1.

Table 1. Yaw Servo Hydraulic Check steps

Step a.	Turn OFF collective mounted hydraulic switch (switch points aft)
Step b.	Press ACCU TEST button on center console (button is ON)
Step c.	Press ACCU TEST button on center console (button is OFF) (button reset)
Step d.	Turn ON collective mounted hydraulic switch (switch points fwd)

Test team 2 participated in an observation/familiarization task in a second AS350B3e exemplar training helicopter (aircraft 2) to better understand the yaw servo hydraulic check as performed at the time of the accident and the handling characteristics of the helicopter when lifting off to a hover.

Following aircraft testing, the test teams relocated to the simulator building and performed departures in an AS350B3 simulator, a similarly performing helicopter.

The team debriefed and completed the visit with a tour of the Airbus Helicopters facility.

Set Up:

The AS350B3e helicopter used for the testing was configured as closely as possible to the accident helicopter (weight: 4720 lbs). The helicopters were positioned relative to the wind direction that most closely represented the accident helicopter orientation at liftoff (left quartering headwind[1]). A Shimpo Instruments FGV-200XY hand-held, force gauge was used to measure pedal force data.

The AS350B3 simulator was configured with a weight of 4720 lbs, a left quartering headwind, and density altitude about 11,000 feet. The terrain surrounding the liftoff location closely replicated obstacles surrounding the helipad from which the accident helicopter departed in Frisco, Colorado.

Tasks and Conditions:

Task 1. Perform yaw servo hydraulic check in an AS350B3e exemplar aircraft.

The purpose of this task was to perform the yaw servo hydraulic check in an AS350B3e (dual hydraulics) exemplar experimental helicopter (aircraft 1) using the Air Methods AS350B3e expanded checklist current at the time of the accident (see Table 2). The order in which the checklist steps were performed were modified. Pedal forces were measured and assessed during each of the variations.

Table 2. Task 1 tests to perform

Test #	Checklist	Modification
1.1	AM AS350B3e dated 8/2014	NA
1.2	AM AS350B3e dated 8/2014	See Table 3 (aircraft 1 only)

Observe: all pretakeoff checks, pedal forces, visual, aural and/or tactile feedback.

[1] About midway through Task 1, winds were updated to 5 knots from the 11 o'clock position off the nose of the aircraft.

Table 3. Task 1.2 modifications to order of checklist items

Order to perform steps	[HYD] Switch End State	[ACCU TST] End State	Expected Pedal Forces
A, B, C	Switch is OFF TR Circuit Not Pressurized	Button is OFF (reset) YLC Not Boosted	High
A, B	Switch is OFF TR Circuit Not Pressurized	Button is ON YLC Not Boosted	High
A	Switch is OFF TR Circuit Not Pressurized	Button is OFF YLC Boosted	Moderate
A, D	Switch is ON TR Circuit Pressurized	Button is OFF YLC Boosted	Normal
A, B, D (same as A, C, D)	Switch is ON TR Circuit Pressurized	Button is ON YLC Not Boosted	Normal
B, C	Switch is ON TR Circuit Pressurized	Button is OFF (reset) YLC Boosted	Normal
A, B, D, C	Switch is ON TR Circuit Pressurized	Button is OFF (reset) YLC Boosted	Normal
B, C, A, D	Switch is ON TR Circuit Pressurized	Button is OFF (reset) YLC Boosted	Normal
A, D, B, C	Switch is ON TR Circuit Pressurized	Button is OFF (reset) YLC Boosted	Normal
A, D, B	Switch is ON TR Circuit Pressurized	Button is ON YLC Not Boosted	Normal

Task 2. Lift to hover evaluation.

The purpose of this task is to familiarize the test team with the yaw servo hydraulic check as performed at the time of the accident and the handling characteristics of the helicopter when lifting to a hover (aircraft 2). A test pilot was seated in the right seat and an observer was seated in the left seat. After performing preflight checks and lift to a hover, the aircraft was shut down and a second observer sat in the left seat and the same steps were performed again. Four observers were located in the second row/passenger seats of the helicopter.

Task 3. Perform takeoffs in a simulator.

The purpose of this task is to become familiar with how a normal takeoff should look/feel, including any associated yaw at liftoff with and without pedal input (see Table 4). An instructor pilot was seated in the left seat and an observer was seated in the right seat. Three additional observers were located in another row.

Table 4. Task 2 tests to perform

Test #	Pedal input	Takeoff
3.1	Yes	To hover
3.2	No	To hover
3.3	Yes	Max performance takeoff
3.4	No	Max performance takeoff

Observe: helicopter response during lift to hover and performing a maximum performance takeoff, development of left spin without pedal input

Table 3. Task 1 pedal force data

Task/ Test	Order steps performed	[HYD] Switch End State	[ACCU TST] Switch End State	Expected Pedal Force	Zero Force Pedal (mm)[2]		Average Pedal Force (lbs)[3]		Anecdotal Observations
					Left	Right	Left	Right	
1.1	A, B, C, D	Switch is ON TR Circuit Pressurized	Button is OFF YLC Boosted	Normal			3.1	2.2	Normal aircraft at idle
1.2a	A, B, C	Switch is OFF TR Circuit Not Pressurized	Button is OFF (reset) YLC Not Boosted	High	25	27	27.1	38.1	Right pedal forward then back, hyd 2 (flash every 4 sec)
1.2b	A, B	Switch is OFF TR Circuit Not Pressurized	Button is ON YLC Not Boosted	High	25	27	29.7	40.6	
1.2c	A	Switch is OFF TR Circuit Not Pressurized	Button is OFF YLC Boosted	Moderate	23	28	60.0	34.4	Right pedal forward, left pedal opposite accumulator
1.2d	A, D	Switch is ON TR Circuit Pressurized	Button is OFF YLC Boosted	Normal			2.9	2.2	
1.2e	A, B, D	Switch is ON TR Circuit Pressurized	Button is ON YLC Not Boosted	Normal			3.1	2.3	Pedals move
1.2f	B, C	Switch is ON TR Circuit Pressurized	Button is OFF (reset) YLC Boosted	Normal			2.9	2.2	No change in pedals
1.2g	A, B, D, C	Switch is ON TR Circuit Pressurized	Button is OFF (reset) YLC Boosted	Normal			3.0	2.2	No change in pedals
1.2h	B, C, A, D	Switch is ON TR Circuit Pressurized	Button is OFF (reset) YLC Boosted	Normal			2.9	2.2	No change in pedals
1.2i	A, D, B, C	Switch is ON TR Circuit Pressurized	Button is OFF (reset) YLC Boosted	Normal			2.9	2.2	No change in pedals
1.2j	A, D, B	Switch is ON TR Circuit Pressurized	Button is ON YLC Not Boosted	Normal			2.8	2.3	Very light pedals

[2] Pedal displacement was measured from a screw, located at the aft end of the respective pedal's track, to the respective pedal post. The difference in millimeters between the two numbers was the pedal displacement relative to each other.

[3] Three measurements were taken for each condition to ensure consistency and were averaged to determine the average pedal force. See Appendix 1 for raw data.

Task 2 – Aircraft 2 Observations:

A. Test pilot performed engine startup
   - Observer pilot felt rotor pedals with boost.
     - Observer 1: Normal/easy pedal forces, equal force required between R/L pedals
     - Observer 2: Normal/easy pedal forces, equal force required between R/L pedals

B. Test pilot performed Yaw Servo Hydraulic Check procedure at ground IDLE.
   - [HYD] switch OFF, observer felt rotor pedal with hydraulics off and load compensator boosted.
     - Observer 1: Moderate pedal forces, R pedal easier to depress than L; HYD2 light illuminated
     - Observer 2: Moderate pedal forces, R pedal easier to depress than L; HYD2 light illuminated
   - [ACCU TST] switch ON, observer pilot felt rotor pedal with hydraulics off and load compensator not boosted.
     - Observer 1: High pedal forces, L pedal slightly easier to depress than R
     - Observer 2: High pedal forces, L pedal slightly easier to depress than R
   - [ACCU TST] switch RESET, observer felt rotor pedal without hydraulics and load compensator not boosted.
     - Observer 1: High pedal forces, L pedal slightly easier to depress than R
     - Observer 2: High pedal forces, L pedal slightly easier to depress than R
   - [HYD] switch ON, observer felt rotor pedal with hydraulics ON and load compensator boosted.
     - Observer 1: Normal/easy pedal forces, equal force required between R/L; HYD2 light extinguished
     - Observer 2: Normal/easy pedal forces, equal force required between R/L; HYD2 light extinguished

C. Test pilot performed lift to hover, observer controlled rotor pedals and cyclic while in hover.
     - Observer 1: Normal/easy pedal forces, equal forces required between R/L
     - Observer 2: Normal/easy pedal forces, equal forces required between R/L

D. Test pilot performed Yaw Servo Hydraulic Check procedure at Flight IDLE.
   - [HYD] switch OFF, observer felt rotor pedal with hydraulics off and load compensator boosted.
     - Observer 1: Moderate pedal forces, R pedal easier to depress than L but not as pronounced as ground IDLE; HYD2 light illuminated
     - Observer 2: Moderate pedal forces, R pedal easier to depress than L but not as pronounced as ground IDLE; HYD2 light illuminated

- [ACCU TST] switch ON, observer felt rotor pedal with hydraulics off and load compensator not boosted.
    - Observer 1: High pedal forces, equal forces required between R/L
    - Observer 2: High pedal forces, equal forces required between R/L

E. Test pilot got aircraft light on skids with hydraulics off, load compensator not boosted.
- [ACCU TST] switch ON - observer felt rotor pedal with hydraulics off and load compensator not boosted.
    - Observer 1: High pedal forces, very little movement of pedals; aircraft began to turn left without pedal input

F. Test pilot performed engine shutdown
- Once rotor stopped moving, observer observed/felt rotor pedal natural movement, then returned pedals to neutral/center position
    - Observer 1: Right pedal moved slightly forward
    - Observer 2: Right pedal moved forward

Task 3 – Simulator Observations:

Observed out of the window view, flight controls, and flight instruments during the following test cases:

- Test 3.1: Normal takeoff with pedal input
    - Established hover, tested controls, established max performance and climb
    - Stabilized yaw
- Test 3.2: Normal Takeoff without pedal input, climb above obstacles
    - Left rotation began immediately after liftoff, developed quickly
    - Three 360 degree rotations performed
    - Helicopter deviated from initial lift point without cyclic input
    - Spin alleviated with full right pedal input and climb above obstacles
- Test 3.3: Max Performance takeoff with simultaneous departure to left with pedal input (Video 1)
    - If no pedal was used to facilitate left turn for departure, left rotation that developed was similar to a max performance takeoff without pedal input (test 3.4a/b). Pedal input alleviated left turn when on heading and stabilized climbout continued.
- Test 3.4a: Max performance takeoff without pedal input
    - Left rotation began immediately following takeoff, developed even more quickly than normal takeoff
- Test 3.4b: Max performance takeoff with simultaneous departure to left without pedal input (Video 2)
    - With no pedal input to facilitate left turn for departure, left rotation developed similarly to Test 3.4a.
    - Full pedal input required to alleviate spin.

- Test 3.4c: Max performance takeoff without pedal input, with hover, and recovery + demonstration of high/low collective on yaw rate (Video 3)
    - Liftoff felt similar to Test 3.4a, however spin continued when hover established. When collective was increased yaw rate increased substantially. When collective was decreased, yaw rate decreased noticeably.
    - Full right pedal input required for recovery.
    - Nose pitched down during recovery.

Table 1. Pedal force raw data

	Newtons (N)						Pedal (mm)		Pounds (lbs)						Lbs	Lbs
Task/ Test	Left 1	Left 2	Left 3	Right 1	Right 2	Right 3	Left	Right	Left 1	Left 2	Left 3	Right 1	Right 2	Right 3	Avg Left	Avg Right
1.1	14	13	15	10	10	10			3.1	2.9	3.4	2.2	2.2	2.2	3.1	2.2
1.2a	116	135	111	136	184	189	25	27	26.1	30.3	25.0	30.6	41.4	42.5	27.1	38.1
1.2b	130	132	134	166	188	188	25	27	29.2	29.7	30.1	37.3	42.3	42.3	29.7	40.6
1.2c	216	289	296	139	146	174	23	28	48.6	65.0	66.5	31.2	32.8	39.1	60.0	34.4
1.2d	13	13	13	10	10	10			2.9	2.9	2.9	2.2	2.2	2.2	2.9	2.2
1.2e	14	13	14	9	10	12			3.1	2.9	3.1	2.0	2.2	2.7	3.1	2.3
1.2f	13	13	13	9	11	10			2.9	2.9	2.9	2.0	2.5	2.2	2.9	2.2
1.2g	14	13	13	10	9	10			3.1	2.9	2.9	2.2	2.0	2.2	3.0	2.2
1.2h	13	13	13	9	10	10			2.9	2.9	2.9	2.0	2.2	2.2	2.9	2.2
1.2i	13	13	13	10	10	10			2.9	2.9	2.9	2.2	2.2	2.2	2.9	2.2
1.2j	13	12	13	10	11	10			2.9	2.7	2.9	2.2	2.5	2.2	2.8	2.3

	N	Lbs
Conversion	1	0.224809

Averages of left/right pedal forces per condition

	Left	Right	
Normal	3	2	Lbs
No boost	60	34	Lbs
YLC-only	28	39	Lbs