An Analysis of Factors Affecting Flight Performance

Respecting

DHC-6 Series 100 S/N 53, N203E

July 29, 2006

(NTSB Identification: CHI06FA210)

Prepared for

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Abstract

Despite the high outside air temperature prevailing at the time of the accident, the lightly loaded aircraft should have been able to maintain controlled flight and achieve a rate of climb of up to 300 feet per minute following the engine failure.

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Introduction

Brief Description of the Event

De Havilland DHC-6 Series 100, manufacturers serial number 53, registration N203E crashed shortly after takeoff from Sullivan Regional Airport (KUUV), Sullivan, Missouri, USA on Saturday, July 29, 2006, about 1345 Central Daylight Savings Time.

Meteorology

The photos taken by the witnesses to the accident show that good visual meteorological conditions with only scattered cumulus clouds and an easily discernable visual horizon prevailed. The wind favoured the runway that was used for takeoff. At 1253, the recorded weather at the Rolla National Airport, near Rolla, Missouri, was: Wind 290 degrees at 9 knots; visibility 10 statute miles; sky condition few clouds 5,000 feet; temperature 35 degrees C; dew point 20 degrees C; altimeter 30.04 inches of mercury. Rolla National Airport is located approximately 30 miles to the west of Sullivan Regional Airport; for the purpose of this analysis, the meteorological conditions from the 1253 Central Daylight Savings Time Rolla weather report will be used for all performance calculations.

Sullivan Regional Airport is approximately 933 feet above sea level, thus, for performance calculation purposes, an outside air temperature of 35°C corresponds to ISA +18°C.

Calculated Performance, AFM Procedures

Interpretation of the Flight Manual

The manufacturer approved Aircraft Flight Manual, de Havilland Product Support Manual (PSM) 1-61-1A at revision 39 (hereafter referred to as 'the AFM'), provides several different figures for V_{MC} and V_{YSE}. For the basic aircraft without modification 6/1278 embodied,[1] V_{MC} is 62 KIAS (flap position not stated), and V_{YSE} is 83 KIAS with flaps set at zero.[2] The subject aircraft was equipped with a 'long nose' rather than the short nose that was basic to the Series 100 DHC-6 aircraft. Amendment 6, Sheet 1 to the AFM states that if a Series 100 aircraft is equipped with a long nose, V_{MC} is 66 KIAS. However, amendment 6 also states that if modifications 6/1281 and 6/1278 have been incorporated, the V_{MC} speed published in amendment 6 is superseded by the V_{MC} speed provided in amendment 2, which speaks directly to these two modifications. Because the subject aircraft had modifications 6/1281 and 6/1278 embodied,[3] amendment 6 is not applicable to this aircraft.

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[1] Modification 6/1278 consists of installation of an autofeather system to meet legislative requirements that were promulgated after the aircraft was originally certified. De Havilland SB 6/214 at revision G refers.

[2] PSM 1-63-1A page 1-5-2 at revision 12.

[3] The author did not have access to the aircraft technical records to verify that these modifications had been embodied. However, NTSB scene photograph DSCN4173 clearly shows that the autofeather system (modification 6/1278) had been installed, as evidenced by the presence of a placard referencing the autofeather system, and NTSB scene photograph DSCN4161 clearly

Amendment 2 at issue 2 is applicable to aircraft that have modification 6/1281 and 6/1278 embodied. This amendment states that V_{MC} is 63 KIAS with flaps set to 10° and V_{YSE} is 78 KIAS with flaps set to 10°. These published speeds match the red and blue radial lines printed on the airspeed indicator of the subject aircraft.[4] The speeds published in amendment 2 at issue 2 thus supersede the speeds published on pages 1-5-1 and 1-5-2 of the basic AFM, and the introductory paragraph to amendment 2 at issue 2 makes this point quite clearly.

References

All references to 'Figures' in this analysis refer to figures contained in the AFM, using the figure identification numbers published in the AFM.

shows that modification 6/1281 had also been embodied, as evidenced by the blueline and redline on the airspeed indicator conforming to the specifications of modification 6/1281.

[4] NTSB scene photograph DSCN4161.

Two Engine Operations

Basic Aircraft Flight Manual Procedures (CAR 3 Compliance)

The takeoff procedures published in the basic AFM, page 2-4-1 at revision 25 and page 2-4-2 at revision 12 instruct the pilot to set propellers at the full increase (100% speed) position and to set flaps to 30° prior to takeoff. At the commencement of the takeoff run, power should be set to the value calculated from the Takeoff Power Setting Graph found in figure 4-3. The pilot then allows the aircraft to become airborne at the speed obtained from figure 4-8, and increases airspeed to attain the value in figure 4-8 by the time the aircraft has reached 50 feet AGL.

The takeoff power settings derived from figure 4-3 (AFM page 4-4-3 at revision 10) are dependent on pressure altitude, temperature, intake deflector setting and bleed air extraction. It is reasonable to assume from the 35°C prevailing outside air temperature that the pilot would have configured the aircraft such that the intake deflectors were up and no bleed air was being extracted from the engines for heating or de-ice purposes. Thus, for the pressure altitude and temperature prevailing at the time of takeoff, engine power should have been set to 35 pounds of torque with propellers at 100% speed. The torque pressure would then rise by approximately 2 PSI as the aircraft accelerated to takeoff speed, then target speed at 50 feet, and ultimately to enroute climb speed.

The target speed for lift-off and the target speed at 50 feet AGL provided in figure 4-8 of the AFM indicate that at a takeoff weight of 9,450 pounds, the lift-off speed should be 57 KIAS, and the speed at 50 feet should be 70 KIAS, giving a total takeoff distance to 50 feet above ground of 1,500 feet.

AFM Supplement 10 – SFAR 23 Compliance

Subsequent to the original certification of the DHC-6 Series 100 aircraft in accordance with the certification criteria contained in CAR Part 3, dated May 15 1956, including amendments 3-1 through 3-8 plus Special Conditions for multi-engine turbine-powered aircraft dated November 6, 1964, de Havilland published supplement 10 to the DHC-6 Series 100 AFM. This supplement provides operators of Series 100 aircraft with a method of complying with SFAR 23 dated January 7, 1969, and amendment SFAR 23-1 dated December 24, 1969.

The takeoff procedures published in supplement 10 to the AFM, SFAR 23 Compliance, page 5-10-2-2 at original issue instruct the pilot to set propellers at the full increase (100% speed) position and to set flaps to 10° prior to takeoff. At the commencement of the takeoff run, power should be set to the value calculated from the Takeoff Power Setting Graph figure 5-10-8. The calculated takeoff power for the subject flight using the takeoff performance graph in supplement 10 is exactly the same as the figure previously determined for CAR 3 compliance, 35 pounds of torque.

Supplement 10 also provides additional performance graphs that are not present in the basic AFM. These include a graph allowing the pilot to calculate maximum permissible takeoff weight based on one engine inoperative *takeoff* climb performance (figure 5-10-12), maximum permissible takeoff weight at or below 5,000 feet based on one engine inoperative *enroute* climb performance (figure 5-10-13), and an accelerate-stop total distance chart (figure 5-10-15). Based on prevailing meteorological conditions, the aircraft was not WAT limited by either of the two climb performance graphs, and for all practical purposes, sufficient runway and stopway was available from the intersection takeoff point to meet the ASD requirement.

Had the pilot elected to use the full length of the runway, rather than making an intersection takeoff, it is probable that the aircraft could have landed and come to a stop within the confines of the airport property if the pilot had elected to land straight ahead immediately after recognizing the engine failure.

AFM Supplement 12 – CAR 3 Operations Using 10° Flap

Supplement 12 presents procedures to be followed if the pilot wishes to take off with 10° of flap whilst operating under the certification criteria applicable to CAR 3, rather than the certification criteria applicable to SFAR 23. There are no procedural differences of any kind between supplement 10 and supplement 12 for the phases of flight (takeoff, initial climb, and single engine climb) examined in this paper, therefore, it is not necessary to discuss supplement 12 further – all of the results are identical to the procedures and calculations found in supplement 10, which have been discussed earlier.

AFM Supplement 14 – Operation with Inoperative Autofeather System When Long Nose Is Embodied

Supplement 14 at issue 2 provides guidance to the pilot concerning operations under both CAR 3 and SFAR 23 certification criteria when the autofeather system is inoperative and a long nose has been fitted to the aircraft.

For CAR 3 operations, the pilot is advised by the text of supplement 14 that the operational limitations in section 1 of the AFM, as amended by amendment 2 continue to apply. In this context, this means that none of the critical speeds such as V_{MC}, V_Y, or V_{YSE} change due to the inoperative status of the autofeather system. Normal procedures in section 2 of the AFM also remain unchanged, except that the pilot is advised to 'remove' amendment 3, which explains how to test and use the autofeather system. In practice, the pilot would simply disregard the instructions for testing, turning on, and turning off the autofeather system which are outlined in the five pages of amendment 3.

For SFAR 23 operations, there are only three procedural differences (i.e. differences from supplement 10), and all are straightforward. The pilot is not required to turn the autofeather system on prior to takeoff or off after takeoff, and if an engine fails, the pilot is required to manually feather the propeller.

Single Engine (Emergency and Abnormal) Operations

Basic Aircraft Flight Manual Procedures (CAR 3 Compliance)

The instructions given on page 3-1-1 at revision 39 of the AFM, item 3.1.1.c state: "If engine failure occurs above V_{MC} and a decision is made to continue the take-off proceed as follows:

1. Maintain heading by applying rudder and lowering wing against the live engine as necessary and lower nose to hold desired airspeed.
2. Advance power levers up to T5, torque or Ng limit, whichever is reached first.
3. Power lever of failed engine --- IDLE.
4. Propeller lever of failed engine --- FEATHER.

5. Hold 71 knots IAS if flaps at 30°; 73 knots IAS if flaps at 15°; 83 knots IAS if flaps at 0°.
6. When clear of obstacles, the flaps should be retracted in increments and the airspeed increased appropriately per the above schedule in order not to lose altitude during retraction. Best single engine rate of climb is achieved with flaps 0° at 83 knots IAS.
7. Trim aircraft as desired."

The three different speeds given for the three different flap settings make sense when considered in the context of the normal procedures contained in section 2 of the basic AFM, whereby the pilot is instructed to conduct the takeoff with flaps set to 30°. When a flap 30° takeoff is made, normal practice is to first retract the flaps to 15°, trim the aircraft as needed, and then retract the flaps to 0° in preparation for the transition to the climb phase of flight. A flap 30° takeoff gives the advantage of a considerably shorter ground roll, although the total takeoff distance to a 50 foot height is greater than it would be if the takeoff was conducted with flaps set at 10°.

For the conditions prevailing at the time of the subject flight, the single engine rate of climb with flaps set to zero, airspeed 76 KIAS, one engine feathered and the other operating at maximum continuous power would be approximately 300 feet per minute, this figure derived from interpolation of the data presented in the AFM figure 4-11 (CAR 3.85b Enroute Single Engine Rate of Climb). The rate of climb would likely be slightly higher if the pilot set power on the remaining engine to the first redline, as instructed to do so by the AFM, rather than to maximum *calculated* continuous power, the basis of the data in AFM figure 4-11.

AFM Supplement 10 – SFAR 23 Compliance

Supplement 10 mandates the use of 10° flap for all takeoffs. The instructions given in supplement 10, page 5-10-3-1 at issue 9 item 5.10.3.2.1.b."if engine failure occurs at or above the speed V_1" follow a slightly different sequence than the instructions given in the basic AFM because it is assumed that the autofeather system is in use. The most significant difference in operational procedure is item 5.10.3.2.1.b.3, which states "Hold the aircraft on or near the ground until the speed V_2 (figure 5-10-14) is attained. Climb out at V_2." This is significantly different than step 5 of the engine failure procedure set out in the basic AFM, but the reason for the difference is clear – the flaps will always be at 10° when a takeoff is made in accordance with the instructions given in supplement 10.

Supplement 10 provides a more precise way of determining single engine climb performance if the engine failure occurs during the takeoff phase of flight when the aircraft is configured with 10° of flap extension. Figure 5-10-18 shows that for the conditions prevailing at the time of the subject flight, single engine rate of climb should have been 220 feet per minute if the aircraft was flown at 70 KIAS, and would have been no less than 80 feet per minute if the aircraft was flown at the blueline speed of 78 KCAS.

AFM Supplement 12 – CAR 3 Operations Using 10° Flap

The instructions given for an engine failure during takeoff in supplement 12 are a combination of CAR 3 procedures that assume no autofeather system is present, and SFAR procedures that assume use of flaps 10° for takeoff and the higher V_1 and V_2 speeds published in figure 5-12-2. The V_1 and V_2 speeds published in figure 5-12-2 at original issue in supplement 12 are exactly the same as the SFAR 23 V_1 and V_2 speeds

– in fact, the graph is exactly the same as the graph used in the SFAR 23 supplement figure 5-10-14.

Supplement 12 provides single engine climb data in a graph entitled "Enroute Rate of Climb – One Engine Inoperative." Although the flap configuration is the same as in the graph provided for supplement 10 (SFAR) single engine climb, the phase of flight is different – enroute, rather than takeoff. The results derived from using the supplement 12 graph (Figure 5-12-5) yield a rate of climb of 260 feet per minute, slightly better than the rate shown in the supplement 10 graph, perhaps because it is assumed that the enroute climb configuration, the pilot has set the propeller of the functioning engine to 96% Np, the point at which it achieves maximum aerodynamic efficiency.

AFM Supplement 14 – Operation with Inoperative Autofeather System When Long Nose Is Embodied

Two possible circumstances are addressed in the supplement 14 instructions for an engine failure during takeoff when the autofeather system is known to be inoperative – operation in accordance with CAR 3 procedures and operation in accordance with SFAR 23 procedures.

In the case of operations in accordance with CAR 3 procedures, the pilot is referred back to the basic AFM procedures that would apply to an aircraft that does not have an autofeather system installed. The pilot is told to 'remove' (in practice, disregard) the procedures published in amendment 3, sheets 6 and 7. Another way of expressing this would be to say that the pilot should simply follow the original instructions published in the emergency section of the basic AFM. These have already been discussed.

In the case of operations in accordance with SFAR 23 procedures (i.e. supplement 10) that are conducted with an inoperative autofeather system, the pilot is advised to feather the propeller of the failed engine manually, then proceed in accordance with the emergency instructions that are published in supplement 10.

Although the text on page 5-14-1-2 of supplement 14 at item 5.14.3.2 indicates that V_{MC} during a go-around with an inoperative engine is 66 KIAS – three knots higher than the V_{MC} under similar circumstances for an aircraft equipped with a short nose – it must be remembered that this V_{MC} assumes the aircraft is configured with flaps 30° for landing. Furthermore, amendment 6 (previously discussed) which addresses fitment of a long nose clearly states that the 63 KIAS V_{MC} in the flap 10° takeoff configuration published in amendment 2 supersedes the V_{MC} of 66 KIAS (unspecified flap setting) that is published in amendment 6.