Flight Testing the Royal Netherlands Air Force Apache Helicopter in Djibouti

Testing of 'Irathane' coated main and tail rotor blades to prevent sand erosion

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Abstract. In the year 2000 the United Nations decided to send a peacekeeping force to Eritrea and Ethiopia (Africa). The mission was called UNMEE (United Nations Mission for Ethiopia and Eritrea) and the assignment included boarder control, medevac and troop transportation. The Dutch supported together with the Canadian Forces this mission with four CH-47D Chinook helicopters and a battalion of marines. As an additional measurement, the Dutch parliament decided to deploy an Apache AH-64D detachment in Djibouti for the same period of time. In case of an emergency extraction in the UNMEE area, they would give the necessary support to the transport helicopters and ground troops. This was the first operational deployment of the new Apache AH-64D attack helicopter ever in the world. The detachment consisted of four helicopters with additional test and support equipment and some 130 personnel. The helicopters operated from Ambouli Air Base in Djibouti City, the capital of Djibouti State (Africa).
To prevent sand erosion in these desert conditions the Royal Netherlands Air Force decided to coat the main- and tail rotor blades with a compound called Irathane. This is an Israeli invention who are using these type of blades on the old Apache A-model for over seven years now. A Dutch flight test team, which comprised of an experimental test pilot and flight test engineer, was sent to Djibouti to evaluate this modification. Primary objective was to qualitatively and quantitatively evaluate the impact of the blade coating on the performance and controllability of the AH-64D Attack Helicopter. Secondary objective was to evaluate if the current Rotor Track&Balance procedures could be maintained. The contents of the evaluation and the results are presented in this paper.
The impact of the new blades was assessed during three sorties in Djibouti with a total duration of 5 hours. Prior to testing in Africa some performance validation flights were done in the Netherlands to verify flight manual accuracy. The modification of the main and tail rotor blades had no impact on the stability and control characteristics of the AH-64D attack helicopter nor introduced excessive performance penalties. However due to some data scatter in less relevant areas of the power curve, further data gathering was recommended.

C-5 transportation to Djibouti

1. Introduction. In the year 2000 the United Nations decided to send a peacekeeping force to Eritrea and Ethiopia (Africa). The mission was called UNMEE (United Nations

Mission for Ethiopia and Eritrea) and the assignment included boarder control, medevac and troop transportation. The Dutch supported together with the Canadian Forces this mission with four CH-47D Chinook helicopters and a battalion of marines. As an additional measurement, the Dutch parliament decided to deploy an Apache AH-64D detachment in Djibouti for the same period of time. In case of an emergency extraction in the UNMEE area, they would give the necessary support to the transporthelicopters and ground troops. This was the first international operational deployment of the new Apache AH-64D attack helicopter ever in the world.
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To prevent sand erosion in these desert conditions the Royal Netherlands Air Force decided to coat the main- and tail rotor blades with a compound called 'Irathane'. This is an Israeli invention who are using these type of blades on the old Apache A-model for over seven years now. A Dutch flight test team, which comprised of an experimental test pilot and flight test engineer, was sent to Djibouti to evaluate this modification.

2. Objectives. The objectives to be achieved during our test flights were defined as:

- Primary objective was to qualitatively and quantitatively evaluate the impact of the blade coating on the performance and controllability of the AH-64D Attack Helicopter.
- Secondary objective was to evaluate if the current Rotor Track&Balance procedures, by using the normal equipment, could be maintained.

The test aircraft was a normal, uninstrumented operational Apache D-model helicopter with 90 flight hours at the beginning of our tests. All the tests were flown at a representative all up mass and configuration. The contents of the evaluation and the results are presented in this paper.

3. Coating. The erosion protective coating used on the rotor blades was called 'Irathane 155' and consisted of a grey coloured layer of elastomeric compound (polyurethane) which was sprayed on the leading edge of each individual blade. It was designed to provide excellent resistance to both corrosion and abrasion in a large number of different environments. The whole layer was about 2mm thick and was about 10cm in length at the bottom and top of the blade. By adding the coating to the main rotor blades they weighed approximately 1.5lbs heavier. The tail rotor blades came out only a fraction heavier than without the coating. Although the higher gross weight of the blades, this did not impose any additional limitations for the current Track&Balance procedures.

PICTURE OF COATING

4. Preparation. Prior to commencing the actual flight tests in Djibouti, some validation flights were done in the Netherlands with the normal blades, to verify flight manual performance accuracy. It was decided to assess the accuracy for the In- and Out of Ground

Effect (IGE / OGE) hovers and the performance of the helicopter at 2,000ft and 8,000ft pressure altitude (Hp) with varying temperatures. These were the primary areas of interest due to operational requirements in the Djibouti and Eritrea theatre. The test team performed several spot checks of which the results are found in the following paragraphs and figures.

4.1 Hover performance. To validate the AH-64D Operator's Manual four hover points were flown at a representative all up mass of 15,000lbs. The results are presented in Table 4-1 below. Table 4-1 shows also the difference between the flown data and the hover data extracted from the manual.

Hp (ft)	OAT (°C)	Ht (ft AGL)	Tq used (%)	Tq FM (%)
-240	+3	5	60	59
-165	+3	80	69	73
2,000	+2	--	71	73
8,000	-1	--	76	76

Table 4-1; AH64D hover data

The hover performance data, which are important for an attack helicopter, were almost on top of the flight manual predictions. One hover was 4% of, which was still regarded as **satisfactory**.

4.2 Level flight performance. In addition to the hover performance, two sets of stabilised level flight performance points ('power curve') were flown using the Mean All Up Mass (MAUM) method. Both sets of results are presented in Figures 4-1 and 4-2 below. Figure 4-1 and 4-2 show the difference between the flown data (blue curve) and the data extracted from the manual (pink curve).

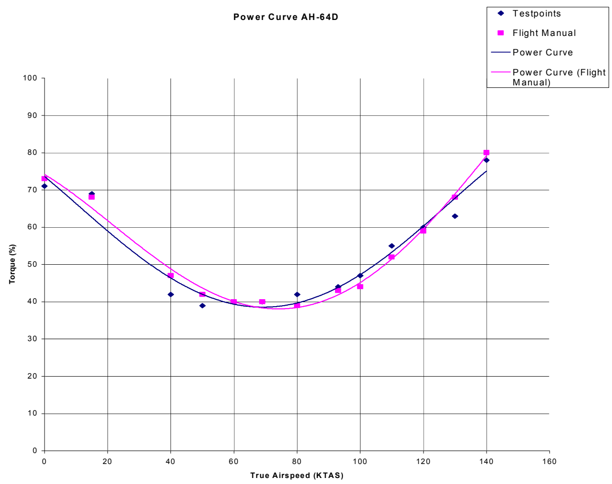

Figure 4-1; 2,000ft Hp

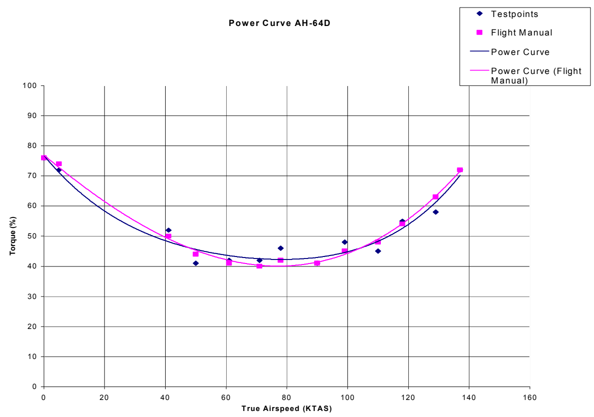

Figure 4-2; 8,000ft Hp

The first figure represents a power curve at 2,000ft Hp. All the flight data were within 5% of the flight manual predicted torque values, which was considered accurate enough for our testing purposes. The minimum power required speed ('bucket speed') is a little bit displaced (68 versus 78KTAS) but this was possibly due to data scatter and classified as non-essential. To verify this assumption, the climb performance was checked at 80KTAS and no further anomalies were found.

The second figure represents a power curve at 8,000ft Hp and essentially shows the same trend as the 2,000ft curve. All the flight data is even within 4% of the flight manual predicted data and there was no difference in the minimum power required speed.

Based on these results there was no reason to doubt the flight manual performance data. The test team had gained sufficient confidence in this part of the manual and went off to Djibouti.

5. Track&Balance.

After removal of the standard rotor blades, the modified coated blades were installed on the aircraft (tailnumber: Q-13) and track&balance for the tail rotor was started first. Both main and tail rotor blades were already statically balanced in Israel. We started out with the ground runs by using the normal equipment and standard procedures.

5.1 Tail rotor. Balancing of the tail rotor within the normal vibration limits was easily achieved without any problems.

5.2 Main rotor. Tracking and balancing of the main rotor within the normal limits was achieved without any problems and without the requirement of extra flights.

5.3 Autorotation. The autorotation rotor RPM was also checked to ensure rotor RPM could be maintained after a double engine failure. This is also a normal procedure after fine-tuning the track&balance of the blades. In this case we also looked for any adverse effects of the changed rotor blade airfoil (due to the coating) on the autorotation RPM. With both engines set to IDLE an autorotation was made at the recommended speed of 80KTAS. The outcome was a rotor RPM of 100%, which was in middle of the allowed range based on weight and density altitude.

6. Stability and Control.

The extraction and escort role of the Apache helicopter in this UN scenario required both high agility in the low airspeed regime and the capability to perform very accurate and stable hover manoeuvres. Furthermore the helicopter needed to display good stability and control characteristics in forward flight requiring low workload for speed, heading and altitude maintenance. To assess the impact of the blade modification on the stability and control characteristics of the helicopter, a brief qualitative evaluation of the manoeuvre stability and directional control was conducted.

6.1 Manoeuvre stability. The manoeuvre stability of the Apache helicopter was assessed by performing left and right turns with a maximum of 60° Angle Of Bank (i.e. 2.0g). During these manoeuvres, the tendency to pitch, airspeed control, predictability of 'g' response, pilot workload and unusual vibrations were noted. Control problems were not encountered nor control limits were reached. Pitch behaviour, 'g' response, airspeed control and workload were, respectively, predictable, easy and not different when compared to a non modified helicopter.

6.2 Directional control. Directional control was assessed by performing pedal turns In and Out of Ground Effect. During these manoeuvres, control problems were not encountered nor control limits were reached. Directional control during the manoeuvres was easy and not different when compared to a standard Apache helicopter.

It was therefore concluded that the stability and control characteristics of the modified AH-64D helicopter were **satisfactory**.

7. Performance.

To evaluate if there were any performance penalties due to the main and tail rotor blade modification, hover, level flight and climb performance was assessed and compared to the data depicted in the AH-64D Operator's Manual (TM 1-1520-251-10). The impact of the new blades was assessed during three sorties in Djibouti with a total duration of 5 flight hours. In general the weather was excellent during our test flights although there was some light turbulence present at lower altitudes. Temperature varied from 28°C early in the morning to almost 40°C in the afternoon. In this paragraph, the test results and test techniques used are presented.

7.1 Hover. Several hovers were made In- and Out of Ground Effect at masses between 15,000 and 16,000lbs. The results are shown in Table 7-1. The actual data were checked against the manual.

Hp (ft)	OAT (°C)	Ht (ft AGL)	Tq used (%)	Tq FM (%)
50	+28	5	65	65
125	+27	80	82	81
2,000	+24	--	77	75
8,000	+15	--	87	86

Table 7-1; AH64D hover data

Just like what we already saw during the test preparation in the Netherlands, the hover performance data, were almost on top of the flight manual predictions, which was regarded as **satisfactory** as no significant increase in hover torque was required due to the coating modification.

7.2 Level flight performance. As done in the Netherlands before to verify the flight manual accuracy, two sets of stabilised level flight performance points ('power curve') were flown using the MAUM method. Both sets of results are presented in Figures 7-1 and 7-2 below. Figure 7-1 and 7-2 show the difference between the flown data (blue curve) and the data extracted from the manual (pink curve).

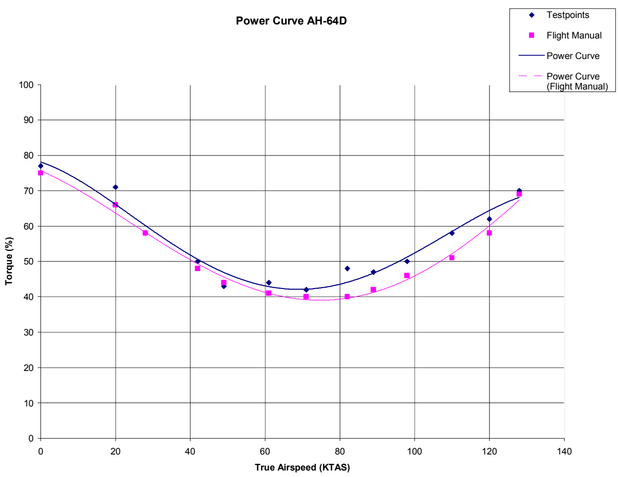

Figure 7-1; 2,000ft Hp

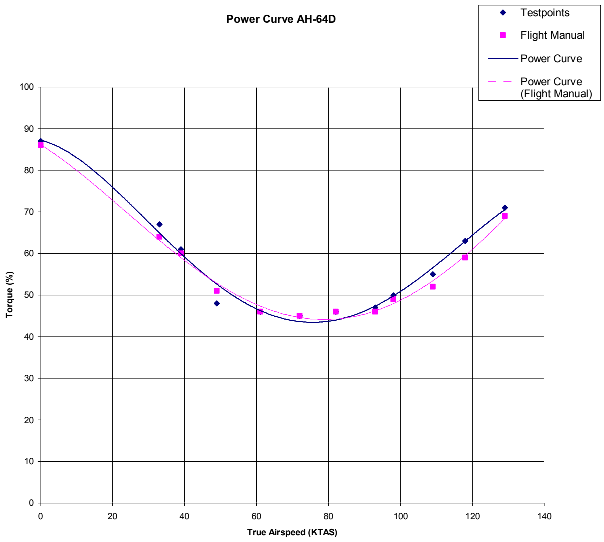

Figure 7-2; 8,000ft Hp

Figure 7-2, which represents the data of the test run flown at 8,000ft Hp, shows no significant difference between the predicted and actual required torque. All the flight data were within 5% of the flight manual predicted torque values. However, the test run flown at 2,000ft Hp (Figure 7-1) shows a consequent increase in required torque at speeds above 70 KTAS with a maximum difference of 8%. During this run a slight increase in turbulence was noted, which could have compromised the data. To fully evaluate the 'Irathane' blade coating and for confidence building, further data gathering at lower altitudes was recommended. The minimum power required speed is a little bit displaced but this was classified as non-essential. **Hence, there were no clear performance penalties and no reason to alter flight manual performance data.**

7.3 Climb performance. A partial climb was performed at 80 KTAS using a torque setting which was 20% above the normal level flight power setting at the same airspeed. The actual rate of climb obtained was slightly higher than the rate of climb predicted by the flight manual, respectively 1,000ft/min and 950ft/min. Hence there was no significant difference between the climb performance before and after the modification of the rotor blades. The climb performance was assessed as **satisfactory**.

8. Conclusions. After finishing the test flights and analysing the results the following conclusions were drawn:

- The modification of the main and tail rotor blades with the 'Irathane 155' coating had no impact on the stability and control characteristics of the AH-64D helicopter
- nor introduced excessive performance penalties.

The main and tail rotor blade modification did not require a change of the operator's manual and was assessed as **satisfactory**.

9. Recommendations. During the test period at Ambouli Air Base, Djibouti it was confirmed that flight operations, conducted by the Netherlands Apache Detachment, were carried out in a 'sandy' environment. To reduce the risks of sand erosion while operating in these conditions it was recommended to reconfigure all four helicopters with the modified blades. However due to some data scatter in less relevant areas of the power curve, further data gathering was recommended at lower altitudes (2,000ft Hp).

10. Remarks. During the last test run a main rotor blade strap pack was broken. An AH-64D strap pack consists of several V-shaped stainless steel straps, which provides the means for feathering, flapping and lead-lag movement of each blade. The cause was not immediately clear. This and some other cases are still under investigation. A first impression revealed an impending corrosion problem.

11. Lessons learned. As with every flight test program, how small it may be though, there are always some lessons learned. To get flight test hours during an operational deployment was not always easy. Technical personnel were scarce and there was a pretty tight training schedule for the operational pilots in Djibouti who also needed a serviceable helicopter. But we stuck to our original test plan and sortie requirements. Crew rest was paramount due to the very warm, humid and for Dutch unusual climate. On average we had to drink at least 6 litres of water every day. Testing in a foreign country, especially in Djibouti, was at least an astonishing experience. There was no special test area and we had to fly through civil airways the whole time. Together with somewhat different airway control rulers this made the test team extra alert during the flights. Although flying above camels, swimming turtles, dolphins, sharks and a sometimes-beautiful scenery had its' own charm.

12. References.

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3. RNLAF, Operational Research and Evaluation Branch (flight test). *Test report AH-64D Blade Coating (Air Force Commander Directive 01-16)*, 06 April 2001.
4. Empire Test Pilots' School. *Stability and Control Aide Memoire*, 1997.
5. Empire Test Pilots' School. *Rotary Wing Performance Aide Memoire*, 1997.

13. Biography.

Captain Wandert Brandsen currently works as an experimental test pilot within the Royal Netherlands Air Force Flight Test Office at AFB Gilze-Rijen. He is a graduate of the UK Empire Test Pilots' School Rotary Wing course (1998). Wandert was an operational and maintenance test pilot on the Alouette III, Bolkow-105, Apache AH-64A helicopters and still operational on the Apache D-model. He has logged over 2.500 flight hours.

Captain Antoine van Gent works as a flight test engineer also for the Royal Netherlands Air Force and is primarily engaged in flight testing of rotary wing aircraft. He is a graduate of the UK Empire Test Pilots' School No. 22 FTE course (1998). Antoine is also a graduate of the Dutch Royal Military Academy aerodynamics and structural design course (1988-1992). He worked in a number of technical assignments within the Air Force prior to the FTE course. Antoine is a member of the Society of Flight Test Engineers.

14. Background information.

The digitised AH-64D is flown by a crew of two, a CPG (Copilot/Gunner) seated in the front as pilot-in-command, and a pilot seated in the back. Two General Electric T-700-GE-701C engines, with 1962 shp each, power the Apache. The helicopter has a length of 15.47m and a gross weight of 23,000lbs. The maximum airspeed is 197 knots, endurance is 2.5hrs. The four pylons underneath the two wings can carry the following weapon load: 16 Hellfire (laser or radarguided) anti-tank missiles or 76 rockets (2.75inch) or a mixture of Hellfires and rockets. The 30mm chain gun carries a maximum of 1200 high explosive rounds.