Paper No. 33

# A WING ON THE SA.341 "GAZELLE" HELICOPTER AND ITS EFFECTS

By M. TORRES
Aerodynamics Engineer

AEROSPATIALE - Helicopter division
Marignane - FRANCE

## 1. ABSTRACT

Flight testing of the "SA 349" research helicopter was carried-out in November and December 1973.

A prototype GAZELLE helicopter, equipped with a wing having an area of 54 square feet, airbrakes and an in flight trimmable stabilizer, was used for these tests.

The main purpose of these trials was the investigation into the "GAZELLE" flight enveloppe as affected by the fitting of a wing, particularly as regards the following points :

- maximum load factor
- maximum speed
- autorotation

These tests have shown a notable improvement in the basic aircraft controllability :

Increase in maximum load factor (0.8 g at 150 knots), which is no longer function of speed, very good stability in banked turns, high descent rate thanks to airbrakes, etc...

On the debit side, a wing is a negative factor in autoration, as it contributes greatly to the drop in rotor r.p.m.

Besides, the airbrakes induce an unsteady wake effect on the aircraft rear sections (stabilizer, fin, fan-in-fin), resulting in a buffeting of the whole aircraft.

The results obtained from these first tests being promising, it has been decided to run, early in 1976, a new series of trials using a production GAZELLE equipped with a wing of equivalent size, new airbrakes and ailerons. This aircraft will be overpowered so as to extend this assessment to higher speeds.

## 2. NOTATION

| | | |
|---|---|---|
| FzA | : | wing lift |
| FzT | : | total lift |
| Ix | : | roll inertia |
| $L_\alpha$ | : | roll control moment |
| Lp | : | roll damping moment |
| m | : | aircraft gross weight |
| Vp | : | true airspeed |
| $Z_\sigma$ | : | density altitude |
| $s_o$ | : | initial roll acceleration |
| $\tau_o$ | : | aircraft time constant in roll |
| $\delta$ | : | wing dihedral angle |
| n max | : | maximum load factor |
| $C_L$ max | | maximum lift coefficient |

## 3. INTRODUCTION

At the design stage, it has been determined already that the wing would have a detrimental effect on autorotation characteristics : in fact, in this flight configuration, wing lift is high, hence the rotor is unloaded and its r.p.m. decreases. Thus, we have been led to fit airbrakes, in this case acting rather as lift spoilers, both on the upper and lower wing surfaces.

Also, it has been foreseen that the wing, due to its deflection, would reduce the stabilizer efficiency, therefore the span of the latter has been increased from 77 to 94 inches.

Further, to be able to adjust the aircraft attitude, hence the wing angle of attack, the stabilizer setting could be changed in flight through a control push-button located on the cyclic stick.

At last, to enlarge the experimentation scope, possibility of ground adjustment has been provided for some parameters, such as wing area, dihedral and incidence angles, through the use of removable wing tips and adjustable struts.

BRIEF AIRCRAFT DESCRIPTION (fig. 1)

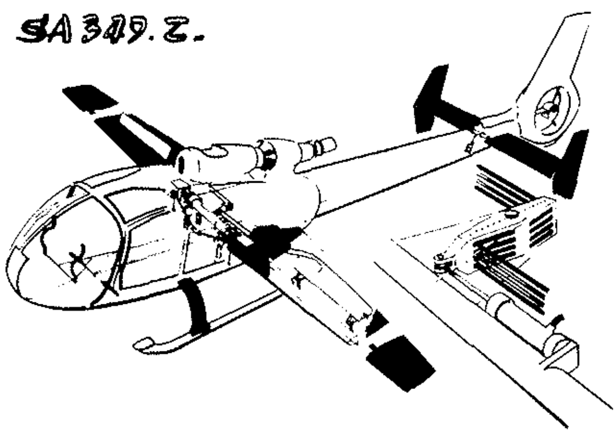


Figure 1

* Basic "SA 349" :

Prototype GAZELLE helicopter, fitted with landing gear fairings.

Some structural reinforcements had to be provided on the airframe to accommodate the wing loads.

Aircraft gross weight : 1700 kg.

| | | |
|---|---|---|
| * Wing | : | - Span : 18 ft<br>- Aspect ratio : 6<br>- Airfoil : NACA 0015 to 0012<br>- Area : with wing tips : 54 sq.ft<br>without wing tips : 46 sq.ft<br>- Incidence angle, adjustable on the ground, from 5 to 12° (nose up)<br>- Dihedral angle, adjustable on the ground, from - 5 to + 5° |
| * Airbrakes | : | - On each wing panel, an upper and a lower airbrakes<br>- Total area (4 flaps) : 4.3 sq.ft<br>- Hinge position : 39 % chordwise<br>- Maximum extension angle : 90°<br>- Extension time : 2.7 seconds<br>- Extension or retraction may be stopped at any time<br>- Extension angle may be adjusted, on the ground, from 0 to 90°, and separately for upper and lower airbrakes |
| * Stabilizer | : | - Span : 94 inches<br>- Chord : 16 inches<br>- Incidence angle : from 4° nose up to 10° nose down, adjustable in flight by the pilot |
| * Test installation | : | - Multiplex magnetic recording of 72 parameters, 36 of which relative to stresses and accelerations. Manual or automatic processing. |

## 4. PRELIMINARY INVESTIGATIONS AND TESTS

### 4.1. Wind tunnel testing

A test period of 150 hours on a scaled down (1/7) unpowered model has been run to determine the airbrake shape and size together with the effect of parameters, such as :

- wing incidence and dihedral angles
- airbrake extension angle
- stabilizer incidence angle

The results of these tests have been used as the basis for simulation.

### 4.2. Fixed-base simulator testing

After having carried-out some checks on the unwinged aircraft, it has been possible, on the simulator, to determine the effect of the stabilizer and wing incidence angles on the longitudinal stability, both static and dynamic, foresee the wing/rotor lift distribution and study the effect of wing and airbrakes on "quick stop" manoeuvres.

Through the use of a simulator, many flight hours have been saved as part of the "trial and error" process could be eliminated and the flight trials with the winged helicopter efficiently planned.

4.3. Reference flight tests

The following flight characteristics of the basic SA 349 helicopter, wing not fitted, have been determined through exhaustive flight testing :

- Performance in hover, level flight and climb
- Autoration
- Maximum load factor versus speed
- Maximum speed ($V_{NE}$)
- Accelerations and "quick stops"
- Effect of stabilizer setting on static and dynamic stability
- Manoeuvrability
- Controllability
- Vibrations

# 5. FLIGHT TESTING OF WINGED HELICOPTER

## 5.1. First stage : determination of optimum settings

* Wing area :

As the wing, without tip, was giving a very low increase in load factor, the wing tips have been fitted definitively for the fourth flight.

* Wing incidence angle

It is a compromise between the maximum load factor (which increases as the angle of attack increases) and stability at low speed near wing stall A value of 10° has been selected.

* Wing dihedral angle

Angles of 0° and - 5° have been tested in flight.
The value of - 5° being detrimental to the spiral stability a value of 0° has been retained.

* Stabilizer setting

Pilots not being favourable to a permanent use in flight of this additional control (important work load, possibility of hardover due to erroneous action), a fixed setting of + 2° has been selected (against - 4° on the basic aircraft).

* Airbrakes

The simultaneous extension to 90° of upper and lower airbrakes represents the configuration resulting both in maximum drag and minimum lift at nose-up attitudes.

The extension to 90° of the upper airbrakes only results in a smaller drag but about the same lift decrease at nose-up attitudes.

In both cases, the induced pitching moment is small.

## 5.2. Results of in-flight assessment

### 5.2.1. Controllability

* Maximum load factor in turns (fig. 2)

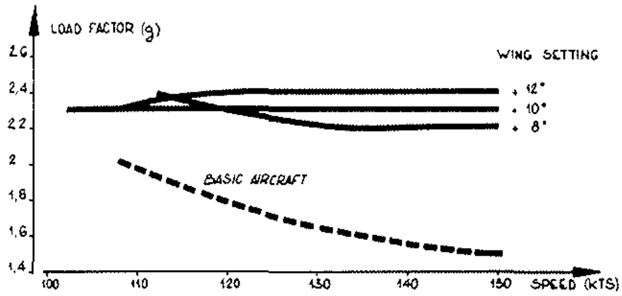


FIG 2: MAXIMUM LOAD FACTOR AT CONSTANT COLLECTIVE PITCH (13°)

The gain due to the wing is very important : at a collective pitch value of 13°, gain amounts to 0.8 g at 150 KTS and 0.3 g at 110 KTS. Thus, a "n max" value independent of speed is obtained. For the SA 349, it is 2,3 g at an all-up-weight of 1700 kg.

However, it is to be pointed-out that the "n max" value for the basic SA 349 is smaller than for the production "GAZELLE", as its main servo-controls are less powerful and the control linkage is slightly different.

The stabilizer setting has no great effect on the "n max" value.

* Dive rate in banked turns (fig. 3)

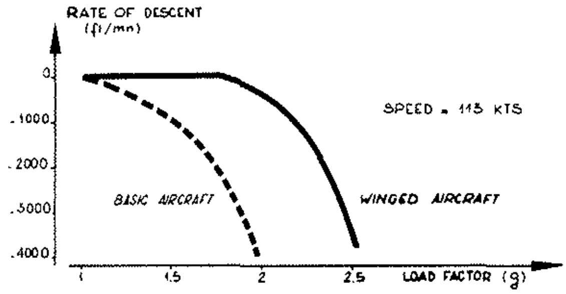


FIG 3: RATE OF DESCENT IN BANKED TURNS

It is appreciably less with the wing fitted than without, and is such than turns may be carried out up to 1,8 g at 113 KTS without loss of altitude (interesting characteristic for nap-of-the-earth flight).

* Quick-stop : Effect of airbrakes

At the beginning of a "quick stop" manoeuvre, the aircraft pitches up. If a wing is fitted, its lift increases, thus unloading the rotor which then cannot ensure properly its braking role. Due to the wing, the deceleration is 0.2 g instead of 0.28 g.

The use of airbrakes, having mainly in this case the role of spoiling wing lift, has allowed a deceleration value of 0.24 g.

* Rate of descent in autorotation : effet of airbrakes (fig. 4)

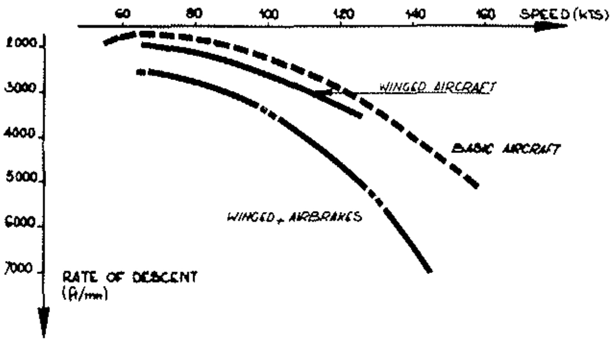


FIG 4 : RATE OF DESCENT IN AUTOROTATION

At 130 KTS, the extension of airbrakes increases the descent rate by 1800 ft/mn. This is an important factor in the controllability of a firing platform.

5.2.2. Safety

* Rotor r.p.m. in autorotation (fig. 5)

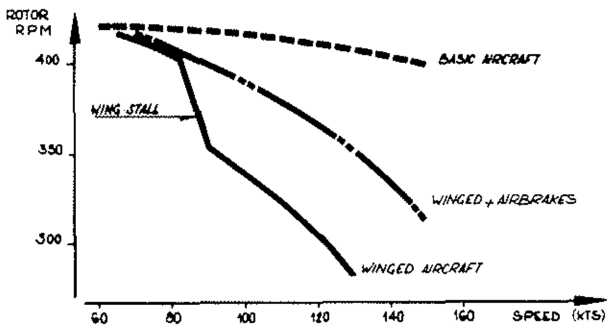


FIG 5 : EFFECT OF WING AND AIRBRAKES ON ROTOR RPM IN AUTOROTATION

As foreseen (paragraph 3 refers), the wing causes a large drop in r.p.m. and, more so as the speed increases.

At 120 KTS, the drop due to the wing amounts to 107 r.p.m. ; when airbrakes are extended, 65 rpm are re-gained.

Two criticisms have been formulated relative to the use of airbrakes in autorotation.

- Their efficiency would be insufficient above 160 KTS.
- Their extension time is too long (1 second desired)

* Wing stall

It has never occurred at high speed, even with load factor applied.

Stall has been noted in the following flight cases only :
- Banked turn in autorotation, up to 100 KTS
- Descent at low speed (80 KTS)
- "Quick-stop" manoeuvres, at about 70 KTS

It is evidenced by a jerk in roll as the starboard wing is always stalled before the port wing.

This jerk is as more rough that the wing incidence is greater.

5.2.3. Performance

* Hover

Out of ground effect, aerodynamic lift decrease due to the wing is equivalent to 220 lbs ; in ground effect, the equivalent value is 88 lbs

* Level flight (fig. 6)

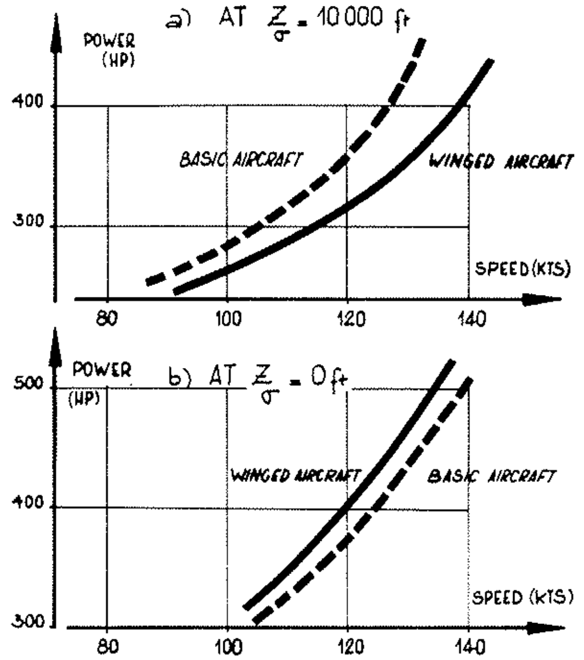


**FIG 6 : NECESSARY POWER VS TRUE AIRSPEED IN LEVEL FLIGHT AT DIFFERENT ALTITUDES**

- At ground level, a loss of 4 KTS is due to the wing.
- In altitude, on the contrary, the wing results in an appreciable gain : at 10000 ft and a power of 400 HP it amounts to 11 KTS.

This may be explained as follow : on the ground, rotor is far away from stall region and the rotor lift/drag ratio is better than that of the wing ; by unloading the rotor, a negative result is obtained.

On the contrary, in altitude, rotor is near the stall region and results are reversed.

5.2.4. Roll response to a step input (fig. 7)

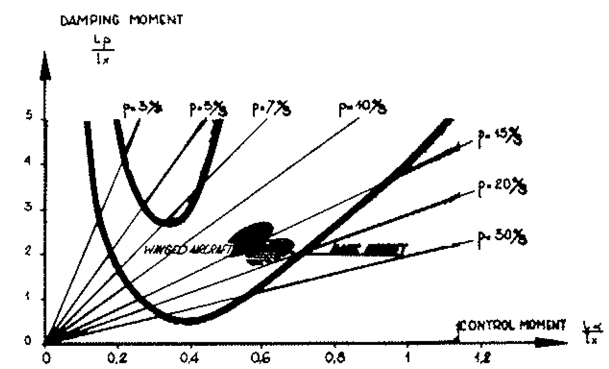


**FIG 7: ROLL RESPONSE TO A STEP INPUT OF 1 INCH AT 120 KTS**

The following effects are induced by the wing :

- the rotor being unloaded, its damping (Lp) and control moment ($L_\alpha$) decrease.
- roll inertia (Ix) increases.
- an additional damping (Lp), due to the wing, appears.

Hence : $s_o = \frac{L_\alpha}{I_x}$ decrease and

$\frac{1}{\tau_o} = \frac{L_p}{I_x}$ remains about constant

The angular roll rate, for a control stick displacement of 1 inch, becomes 14°/sec. instead of 17°/sec.

5.2.5. Static stability

* Lateral

- Unchanged, with the wing dihedral angle at zero.
- Poor spiral stability with a dihedral angle of - 5°.

* Longitudinal (fig. 8)

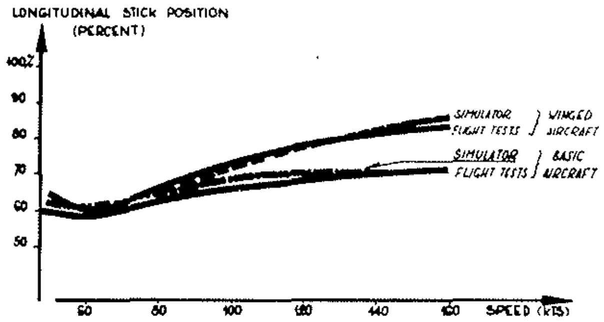


**FIG 8 : STATIC SPEED STABILITY AT CONSTANT COLLECTIVE PITCH (13°)**

The setting of stabilizer at + 2° has resulted in a satisfactory static stability, similar to that of the basic aircraft with the stabilizer set at - 4°.

It is to be noted that, as the wing unloads the rotor, the rotor disc tilt has to be greater to obtain the same thrust (or even slightly higher), hence the cyclic stick has to be pushed further.

5.2.6. Dynamic stability

It is :

- Satisfactory in most of conventional flight configurations.
- Excellent in banked turns.
- Very poor with airbrakes extended : wake effect on aircraft rear section (stabilizer, fin, fan-in-fin) induces vibrations and buffeting about the three axes.
  These phenomena have been reduced by extending the upper airbrakes only, but this has little effect on airbrake performance in autorotation and "quick stop" manoeuvres (the airbrakes acting as lift spoilers in both cases).

5.2.7. Determination of wing lift (fig. 9)

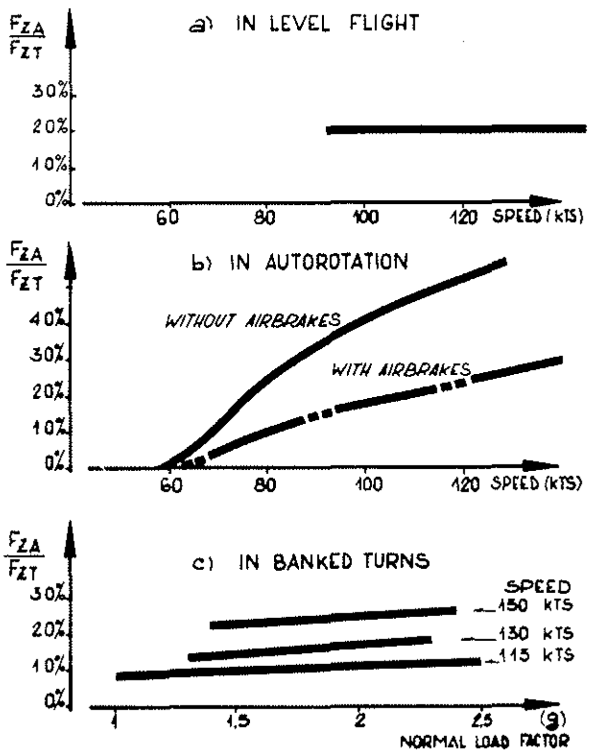


**FIG 9 : WING LIFT, IN PERCENT OF TOTAL LIFT**

It has been made in three different ways :

1) Measurement of bending moment distribution along the wing.
2) Measurement of rotor lift, with and without wing fitted, through strain gauges affixed on rotor mast.
3) Determination of rotor lift, with and without wing fitted, by measuring the loads acting on the main gear box mounting bars.

The first two methods did not yield satisfactory results due to problems with the gauge sensitivity.

The results obtained with the last method were better.

In all cases, before testing, a re-setting was carried out in a hover.

Results are shown on figure 9.

5.2.8. 3/rev. vibration level

When wing is fitted, the vibration level is reduced to half its value.

## 6. CONCLUSIONS

* Negative points

  - Speed reduced by 4 Knots at ground level
  - Lift loss in hover (220 lbs O.G.E and 88 lbs I.G.E)
  - Rotor r.p.m. drop in autorotation (107 r.p.m. at 120 Knots). Airbrakes compensate part of this drop (65 r.p.m.)
  - Important wake effect, when airbrakes are extended
  - Poor braking in "quick stops"

* Positive points

  - Increase in controllability
    - The maximum load factor in turns is no longer function of speed, the gain amounting to 0.8 g at 150 Knots.
    - Turns up to 1.8 g at 113 Knots may be made without loss of altitude.
    - Stability in banked turns is excellent.
    - High descent rates may be obtained when using the airbrakes.
    - Speed gain in altitude : 11 Knots at 10000 feet at a power 400 HP.