Wind Tunnel Measurement Of Aerodynamic Characteristics Of A Generic Eurocopter Helicopter

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EXPERIMENTAL aerodynamic studies on a generic model of the helicopter by Eurocopter France, was based on a prototype of the 350Z model. Figure 1(a) shows the actual 350Z prototype and the generic scaled down model in Figure 1(b) respectively.

The model, was equipped with a high torque motor that can rotate

(a)

(b)

Figure 1(a) Eurocopter 350Z Helicopter Prototype (b) A generic 350Z model with 1:7.126 scaled-down

Figure 2: Model with short blade during testing at UTM-LST (looking downstream)

the main rotor up to 900rpm during wind-on conditions but with no tail rotor [1]. The model had been tested at the UTM-LST on March 2008.

UTM-LST is a closed circuit-returned type tunnel with a test section of 2m (width) x 1.5m (height) x 5.8m (length), and a maximum wind speed of 80m/s. In this aerodynamic investigation, both tunnels used short blade configuration for the main rotor blade. The short blade is 0.25m in radius, which is one-third the original blade length.

TEST DESCRIPTION

The aerodynamic load test using the external 6-component balance has a capability to determine the aerodynamic loads, namely, three forces (lift, drag and side) and three moments (pitching, yawing and rolling). The Balance Moment Centre (BMC) for this balance is at the centre of the wind tunnel test section. Figure 2 depicts the installed

model during testing at UTM-LST.

The aerodynamic loads obtained are then normalised to a non-dimensional with dynamic pressure and area. The reference area taken for this normalisation is πr^2 where r is the main rotor radius.

(i) Reynolds Sweep

To select the appropriate test speed, a Reynolds sweep needs to be conducted to determine at what velocity the aerodynamic coefficients, *i.e* drag coefficient, become stable or independent of velocity. For this, a Reynolds sweep was conducted at zero yaw and pitch angle, with wind speed varying from 10m/s to 50m/s, with 10m/s interval.

Results in Figure 3 shows that 30m/s and above are the speeds where the aerodynamic coefficient will become independent of velocity. Hence, wind speed of 40m/s, which corresponds to the Reynolds number
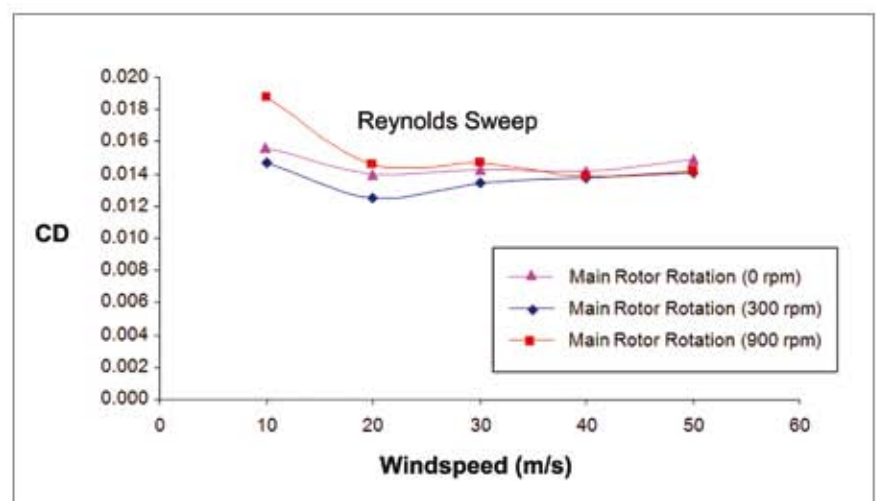

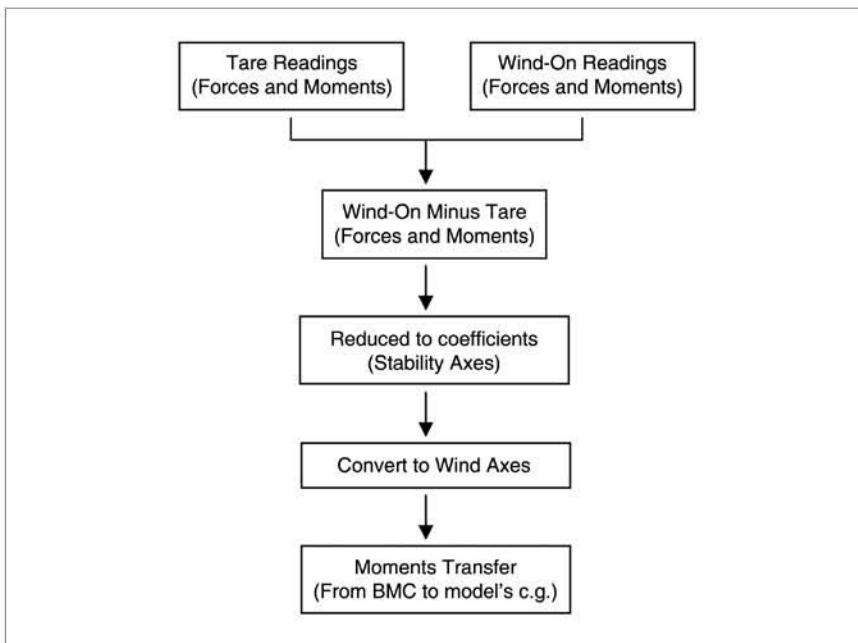Figure 3: Drag coefficient Reynolds sweep for three different main rotor rpm

Figure 4: Flow chart of data reduction [3-4].

of 3.7 x 10⁶, was selected to be the test speed throughout this testing.

(ii) Test Configurations

The test configurations conducted at UTM-LST, with the blade angle set at -6.5⁰ and rotates counter clockwise from plane view, is as follows:

i)   Comparison with Marignane France test results

ii) At zero wind speed, varying the rpm of main rotor

iii) At wind speed of 40m/s, varying the rpm of main rotor

The moments were then transferred from BMC to the model's centre of gravity. All results presented in this paper are in wind axes coordination. Figure 4 shows the flowchart of data reduction.

RESULTS AND DISCUSSION
(i) Comparison with Marignane Test Results [1]

For this, tests were done at similar configurations as tests in Marignane, *i.e.* test wind speed was at 40m/s and main rotor rotation was 300rpm, except that the yaw and pitch sweep range for UTM-LST was smaller (-10⁰ to 10⁰) compared to Marignane (-12⁰ to 12⁰).

Figures 5 to 8 shows that both tunnel results are in a good trend and agreeable with each other. The other aerodynamic coefficients are also in good agreement for both tunnels. Nevertheless, it is noted that the graphs do not exactly coincide. This discrepancy is due to the fact that the results shown here have not yet been corrected due to the blockage and interference of the model support systems.

The Marignane wind tunnel is an open test section of the Eiffel type tunnel with semi guided air-returned. It is a free test section measuring 3m in diameter and 2.7m in length with a maximum wind speed of 45m/s. Hence, the correction factor for each tunnel is different. It seems plausible that after correction, both results would be almost similar.

(ii) At zero wind speed (hovering), varying the rpm of the main rotor

This test was conducted to determine if the short blade is contributing to aerodynamic lift or not. For that, the test was conducted at zero wind speed with variations of the main rotor rpm. Surprisingly, the blade rotation has no effect on the aerodynamic lift. It may be due to the shortness of the blade
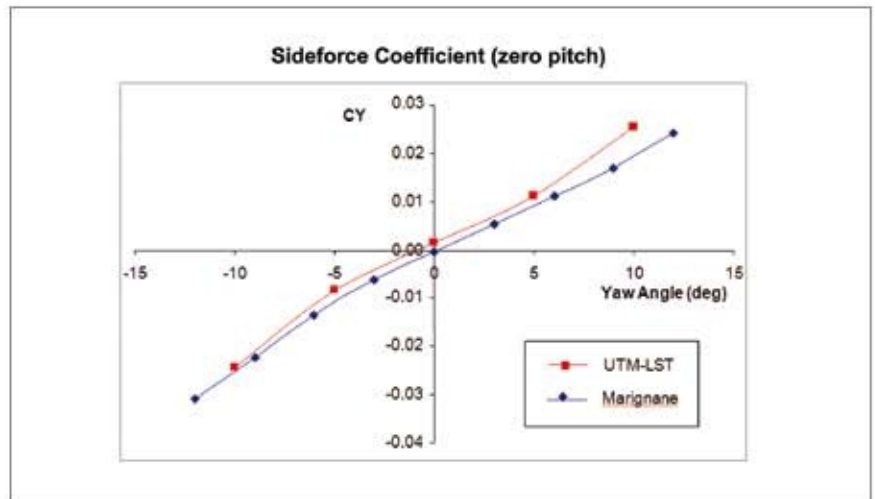
Sideforce Coefficient (zero pitch)

Figure 5: Sideforce coefficient at zero pitch

Pitching Moment Coefficient (zero yaw)
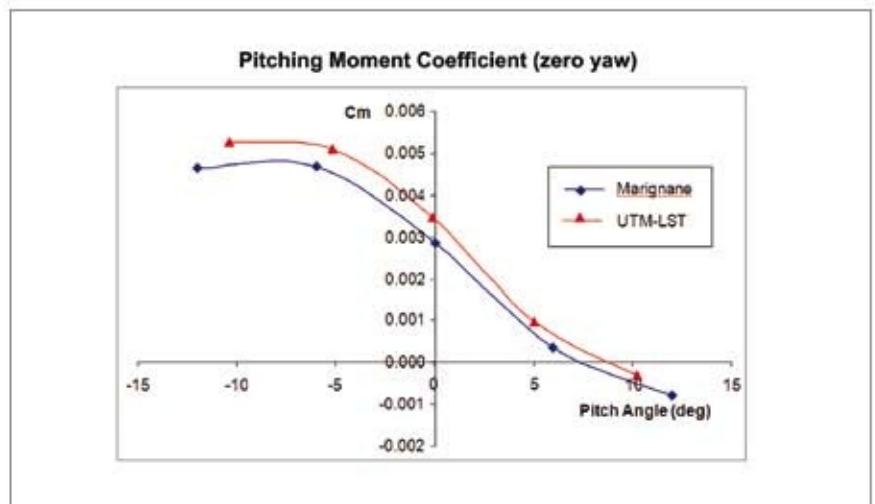

Figure 6: Pitching moment coefficient at zero yaw

and the blade's setting angle of -6.5°. The lift force was recorded at 0.60N and 0.02N at 300rpm and 900rpm respectively. Further investigation is required to confirm these results.

(iii) At 40m/s wind speed, varying the rpm of the main rotor

Figure 9 indicates, as predicted, that the drag increases with yaw angle. However, it seems that the main rotor rotation has almost no effect on the aerodynamic drag at zero yaw and pitch angles.

Figure 10 shows that the rpm of the main rotor with short blade, at zero pitch and yaw angle, clearly has no effect on the CD values. However, this may be true only for this specific case, i.e the main rotor blade is at one-third of the actual length.

Results also depict that the assembly of the main rotor hub, including the short blades, contributes about 35% of the overall CD of this helicopter model. Therefore, it can be concluded that the aerodynamic design of the assembly of the main rotor hub is very crucial as it significantly affected overall drag.

Interestingly, the graphs also show that there is no clear relation between the main rotor rpm with the aerodynamic loads. Further investigation is required to confirm these results.

As the model demonstrates characteristics of $Cm_\alpha = -ve$ and $Cy_\beta = +ve$, hence it be concluded that it is statically stable in the longitudinal and lateral mode [2-5].
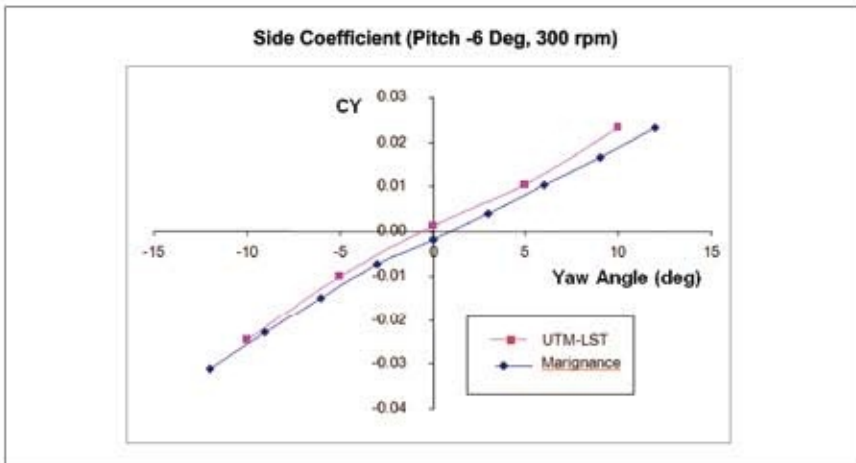
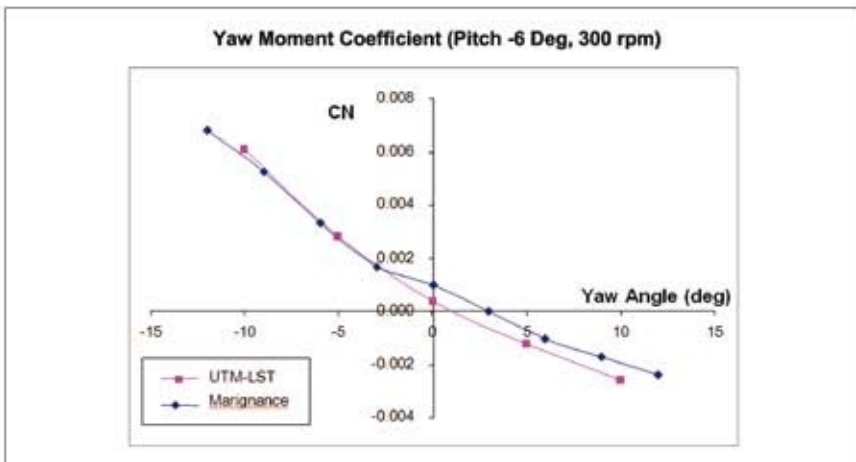Figure 7: Sideforce coefficient for -6 deg pitch at 300rpm

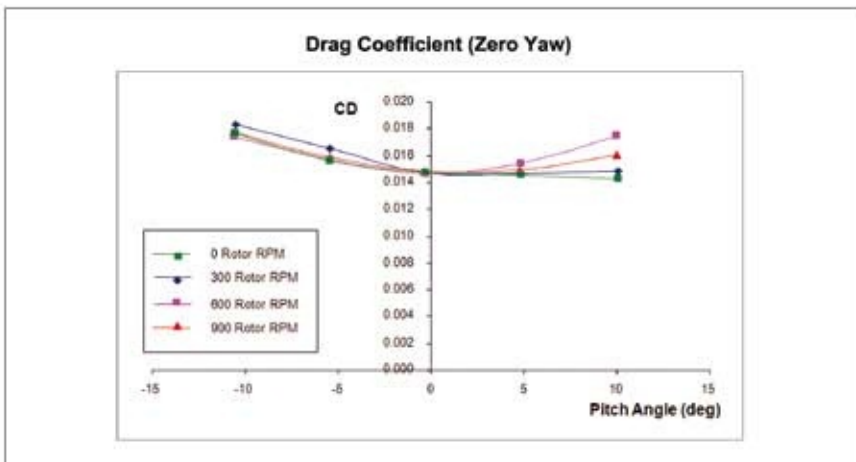Figure 8: Yaw moment coefficient for -6 deg pitch at 300rpm

Figure 9: Drag coefficient during pitch sweep at different rpm

CONCLUSION

Results comparison made for UTM-LST and Marignane tunnels show a good agreement with each other. Throughout this paper, results of the aerodynamic loads in a variation of pitch and yaw angles, as well as the main rotor rpm sweep, on a generic 350Z model helicopter had been presented.

It is found that with short blades, for this specific blade length and blade
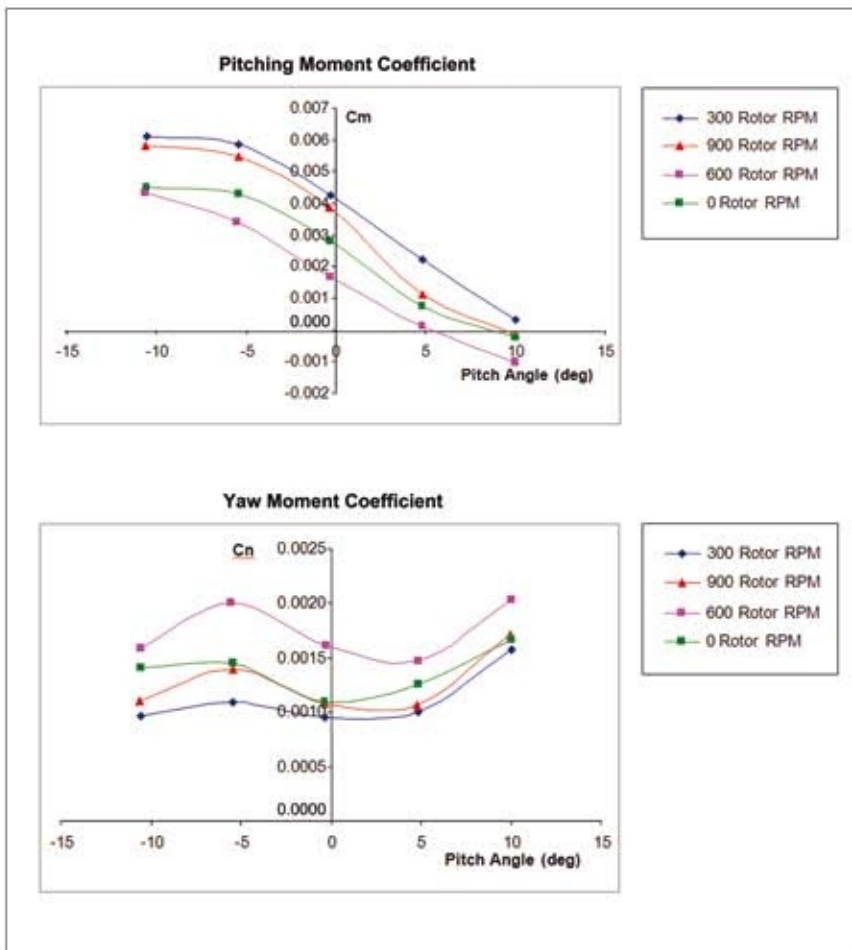
Figure 10: Pitch and yaw moment characteristics for different main rotor rpm

pitch angle, the main rotor rpm has a very small influence on the aerodynamic drag at zero yaw and pitch.

Results also indicate that at zero pitch and yaw, the main rotor hub assembly contributes about 30% of the model's total aerodynamic drag. In terms of stability analysis, results demonstrate that the model is statically stable.

ACKNOWLEDGMENT

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