WIND TUNNEL TESTS ON A GENERIC EUROCOPTER 350Z HELICOPTER

Iskandar Shah Ishak, Tholudin Mat Lazim, Shuhaimi Mansor

Department of Aeronautical Engineering,
Faculty of Mechanical Engineering,
Universiti Teknologi Malaysia,
81310, UTM Skudai, Johor,
Malaysia.

Email Address:

shah@fkm.utm.my, tholudin@fkm.utm.my, shuhaimi@fkm.utm.my

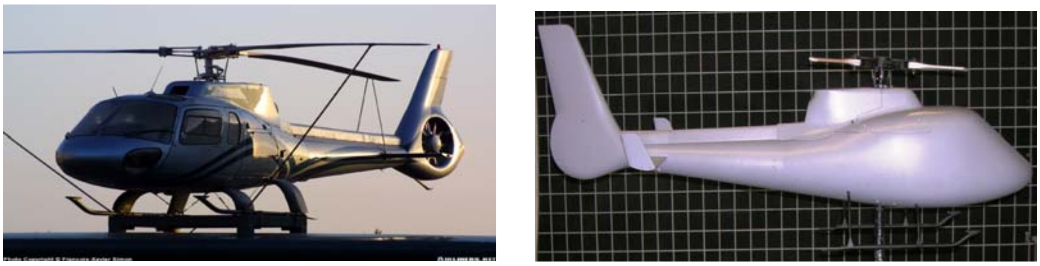
Abstract

This paper summarizes a wind tunnel investigation on the aerodynamics characteristic of a rigid 14% model of a hybrid Eurocopter helicopter. The test was conducted in the 2m x 1.5m Universiti Teknologi Malaysia – Low Speed Tunnel (**UTM-LST**). The model, supplied by Eurocopter France, is equipped with a high torque motor that can rotate the main rotor up to 900 rpm during wind-on condition. The aerodynamic loads measurements were made using a 6-components external balance, which is capable to determine 3 aerodynamics forces and 3 aerodynamics moments. As the aerodynamic loads vary with pitch and yaw angle, the wind tunnel test was performed in the range of -10^o to $+10^o$ of pitch and yaw angles, respectively. The selected test wind speed was 40 m/s, which corresponds to a Reynolds number of 3.7×10^6. To note the effects of main rotor rotation on the aerodynamic loads, the test was carried out 'with' and 'without' main rotor rotation. Given that the model had previously been tested, with participation of UTM Aerolab staffs, at Marignane Wind Tunnel, France in April 2006, results comparison could be made for this two different type tunnels since UTM-LST is a closed circuit-returned type tunnel, whereas Marignane Wind Tunnel is an open test section Eiffel type wind tunnel with semi guided air-returned with a free test section of 3m diameter and 2.7m length. In addition, test was also conducted without the tail part to investigate the lateral and longitudinal stability of this helicopter model.

Keywords: Aerodynamics characteristic; wind tunnel tests; lateral and longitudinal stability

1.0 Introduction

This paper aims to present experimental aerodynamic studies on a generic 14% scaled down model of Eurocopter helicopter. This model, supplied by Eurocopter France, is based on prototype of 350Z model. The model is equipped with a high torque main motor but with no tail motor. Figure 1 shows the actual 350Z prototype (a) and the generic scaled down model (b), respectively.



(a) (b)

Fig. 1. Eurocopter 350Z Helicopter

The model had been tested in two different kind of wind tunnels, earlier in Marignane Wind Tunnel, France in April 2006 and later, in Universiti Teknologi Malaysia – Low Speed Tunnel (UTM-LST) in March 2008. Marignane wind tunnel is an open test section Eiffel type wind tunnel with semi guided air-returned. It is a free test section of 3m diameter and 2.7m length with maximum wind speed of 45 m/s. Whereas 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 the maximum wind speed of 80 m/s.

However for this aerodynamic investigation, both tunnels used short blade configuration for the main rotor blade. The short blade is 0.25m in radius, which is only at one-third of original blade length.

Fig. 2. Short Blades

2. Test Description

The aerodynamic load test using external 6-component balance has a capability to determine the aerodynamic loads, namely 3 forces (lift, drag and side) and 3 moments (pitching, yawing and rolling). The Balance Moment Center (BMC) for this balance is at the centre of wind tunnel test section. Figure 3 depicts the model during testing in UTM-LST.

Fig. 3. Model with short blade during testing in UTM-LST

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

2.1 Reynolds Sweep

To select the appropriate test speed, Reynolds sweep needs to be conducted to determine at which velocity the aerodynamic coefficients i.e drag coefficient, become stable or independent of velocity. For this, Reynolds sweep was conducted at zero yaw and pitch angle with the wind speed varies from 10 m/s to 50 m/s, with 10 m/s interval. Results tell that at 30 m/s and above are the speeds where aerodynamic coefficient will become independent of velocity. Hence, wind speed of 40 m/s, which corresponds to a Reynolds number of 3.7×10^6, was selected to be a test speed throughout this testing.

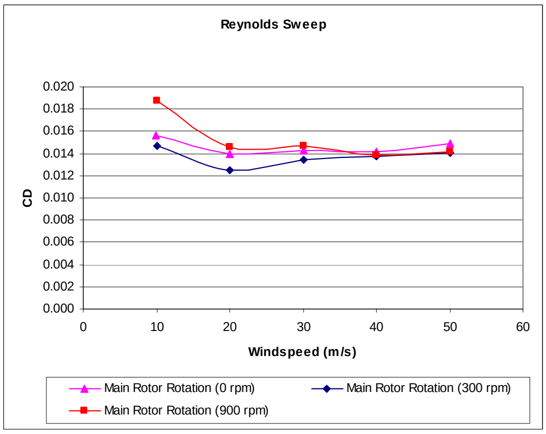


Fig. 4. Reynolds sweep for 3 different main rotor rpm

2.2 Test Configurations

For this aerodynamic load test, the main rotor blade angle is set to be -6.5^0 and rotate in counter-clockwise direction. Test configurations as follow:

i) Repeat Marignane test configurations.
ii) At zero wind speed, varying the rpm of main rotor.
iii) At wind speed of 40 m/s, varying the rpm of main rotor.
iv) Hysterisis Test.
v) At wind speed of 40 m/s, test without the tail part (horizontal and vertical tails).

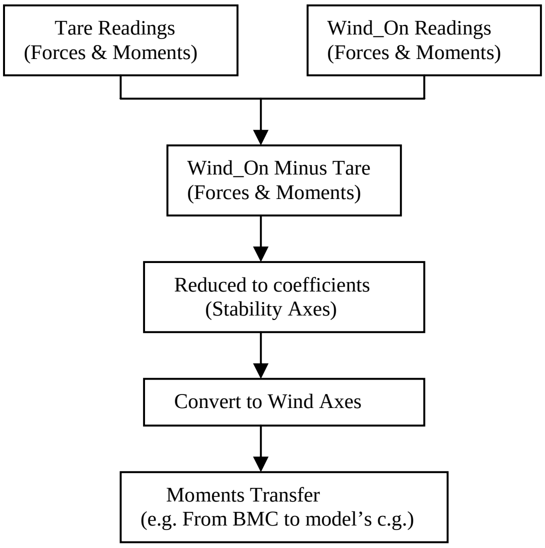


Fig. 5. Flow chart of data reduction

3. Results and discussion

Repeat Marignane test configurations

This test is to compare with Marignane's test results. Since the moment results for Marignane are referred to model's centre of gravity (c.g.), therefore the moment results for UTM-LST had also to be transferred from BMC to model's c.g. as well. With the same moment reference point, it allows comparison of moment results to be made for both tunnels.

Tests were done at similar configurations as tests in Marignane i.e. test wind speed was at 40 m/s and main rotor rotation was 300 rpm, except the yaw and pitch sweep range for UTM-LST was smaller (-10^0 to 10^0) compared to Marignane (-12^0 to 12^0). All results presented in this paper are in wind axes coordination.

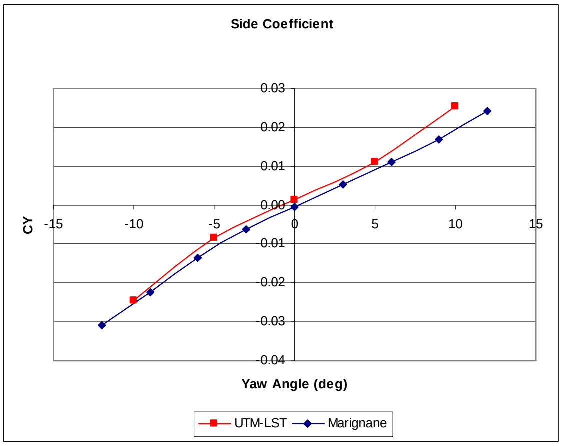


Fig. 6. Side force coefficient at alpha 0 deg

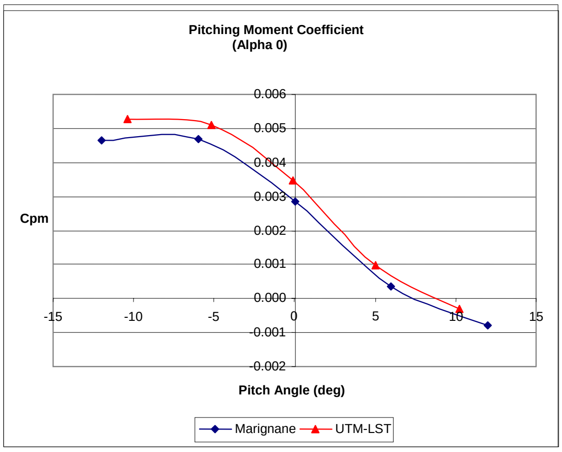


Fig. 7. Pitching moment coefficient at yaw 0 deg

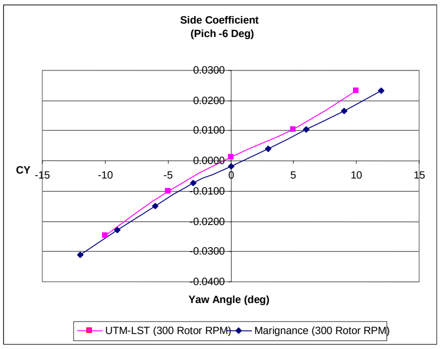


Fig. 8. Side Force Coefficient at pitch -6 deg

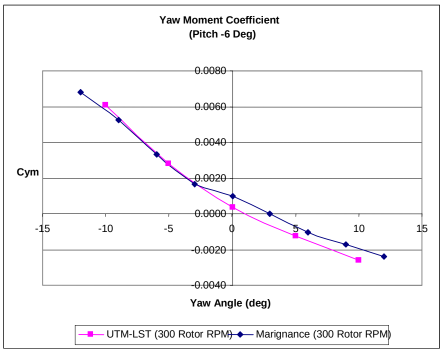


Fig. 9. Yaw Moment Coefficient at pitch -6 deg

Figure 6, 7, 8 and 9 show that both tunnel results are in a good trend and agreeable with each other (*Note: The other aerodynamic coefficients are also in good agreement for both tunnels*). Nevertheless, it is noticed that the graphs are not really coincide as one line. This discrepancy is due to the fact that results shown here are *uncorrected* results. As the two tunnels are in different types, hence the correction factor for each tunnel is going to be different. It seems plausible that after correction, both results would be even closer. Furthermore, some part of the model had been *shrinking* since its arrival due to Malaysian climate. Even though this shrinkage problem has been rectified, the model would not be as exact as the original shape that be tested in Marignane. This obviously will affect the aerodynamic results obtained.

At zero wind speed, varying the rpm of main rotor

This test is to determine either the short blade is contributing to aerodynamic lift or not. For this, test was conducted at zero wind speed with variation of main rotor rpm. Surprisingly, the blade rotation has no effect on aerodynamic lift. It may due to the blade setting angle of -6.5^0.

Table 1. Aerodynamic lift on different main rotor rpm

Main Rotor Rotation	Lift (N)
300 rpm	0.60
900 rpm	0.02

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

Figure 10 indicates, as predicted, the drag increases with yaw angle. However, it seems that main rotor rotation has almost no effect on the aerodynamic drag at zero yaw and pitch angles.

Table 2. Drag coefficient on different main rotor rpm at zero pitch and yaw angles

Configurations	CD
No Main Rotor Assembly	0.0097
Main Rotor (0 rpm)	0.0148
Main Rotor (300 rpm)	0.0147
Main Rotor (600 rpm)	0.0146
Main Rotor (900 rpm)	0.0149

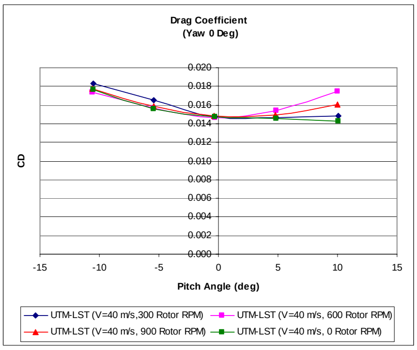


Fig. 10. Drag coefficient during pitch sweep

Table 2 shows that the rpm of main rotor with short blade, at zero pitch and yaw angle, clearly has no effect on the CD values. However this may true only for this specified case i.e the main rotor blade is at one-third of actual length. Results also depict that the assembly of main rotor hub, including the short blades, contributes about 35% overall CD of this helicopter model. Therefore it can be concluded that aerodynamic design of the assembly of main rotor hub is very crucial as it significantly affected overall drag.

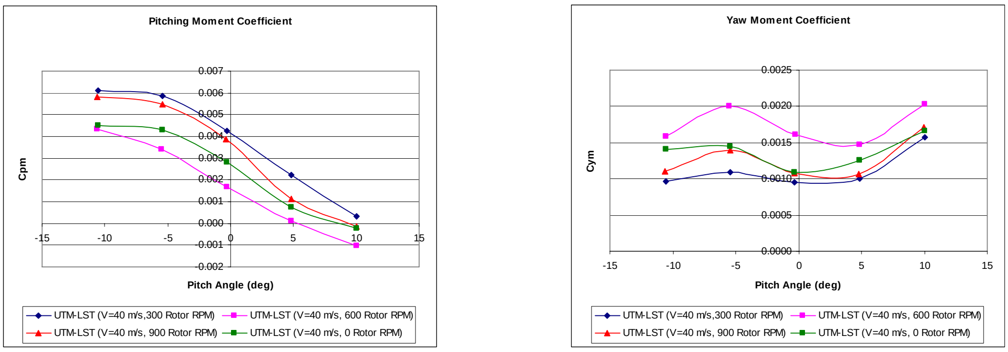


Fig. 11. Pitch and yaw moments characteristics for different main rotor rpm

Interestingly, the graphs also show that there is no clear relation between main rotor rpm with aerodynamic loads.

3.4 Hysterisis Test

This test is to inspect either the result will be the same if the test is started in reverse sweep angle direction. A test at 40 m/s wind speed without main rotor rotation was conducted from pitch angle of -10^0 to 10^0 and then repeated, with the same configuration, but now from pitch angle of 10^0 to -10^0. Figure 12 demonstrates that hysterisis is very good as both graphs coincide with each other.

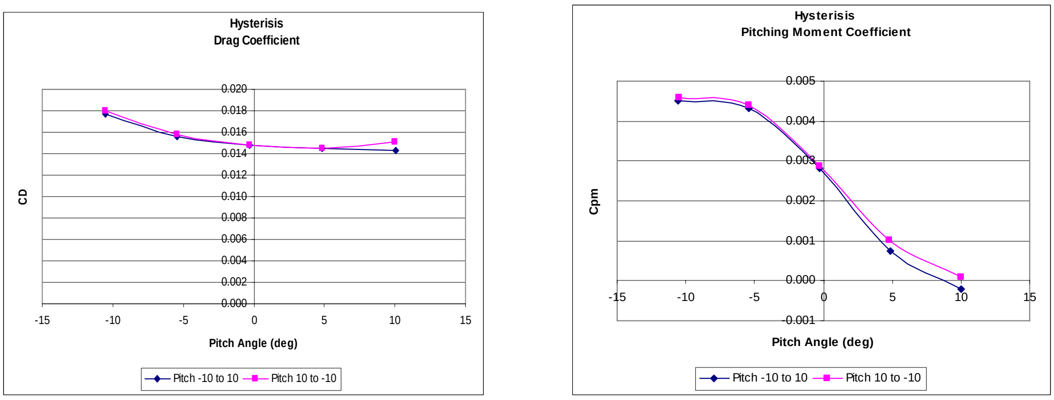


Fig. 12. Hysterisis Analysis

3.5 At wind speed of 40 m/s, test without the tail part (horizontal and vertical tails)

To investigate the static longitudinal and lateral stability of this model, test was done without both horizontal and vertical tails. Figure 13 shows the model without the tail part and the following Figure 14 and 15 depict the model static stability's characteristics in longitudinal and lateral mode, respectively.

Fig. 13. Model without horizontal and vertical tail

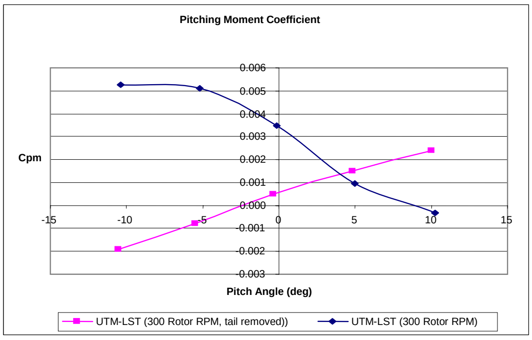


Fig. 14. Longitudinal static stability characteristics

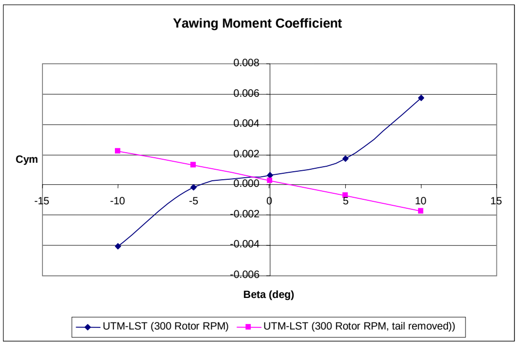


Fig. 15. Lateral static stability characteristics

As the model demonstrates characteristics of $Cm_{\alpha} = -ve$ and $Cy_{\beta} = +ve$ with the tail part on, hence it be concluded that it is statically stable in longitudinal and lateral mode.

4. Conclusion

Results comparison made for UTM-LST and Marignane tunnels show a good agreement with each other. Throughout this paper, results of aerodynamic loads in variation of pitch and yaw angle, as well as for main rotor rpm sweep, on a generic 350Z model helicopter had been well presented. It is found that with short blades, for this specific blade length and blade pitch angle, the main rotor rpm has no or very small influence to aerodynamic drag at zero yaw and pitch angle. Results also indicate that at zero angles for pitch and yaw, the main rotor hub assembly contributes about one-third of model total aerodynamic drag. In addition for stability analysis, results demonstrate that the model is statically stable.

Acknowlegment

1. Marignane Wind Tunnel, France.

References

[1]. Eurocopter Marignane, **Documentation Training on Helicopter Wind Tunnel Test**, EADS, France, April 2006.
[2]. Prouty, R.W., **Helicopter Performance, Stability, and Control**, Robert E. Krieger Publishing, 1986.
[3]. Barlow J.B. et al, **Low Speed Wind Tunnel Testing**, 3rd edition, New York: A Wiley – Interscience Publication, 1999.
[4]. S.J. Zan, **Overview of Data Reduction Procedures for 3-D Aircraft Model Testing in the Universiti Teknologi Malaysia Wind Tunnel**, National Research Council of Canada, 2002.
[5]. G.D. Padfield, **Helicopter Flight Dynamics,** Blackwell Science Ltd., 1996.