



UNIVERSITI PUTRA MALAYSIA

***LIFT AND DRAG IMPROVEMENTS OF AIRFOIL THROUGH
UTILIZATION OF ROUGH SURFACE AT TRAILING EDGE***

ABDULLAH SAAD MAHMUD

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**LIFT AND DRAG IMPROVEMENTS OF AIRFOIL THROUGH
UTILIZATION OF ROUGH SURFACE AT TRAILING EDGE**

By

ABDULLAH SAAD MAHMUD

**This Thesis Submitted to the School of Graduate Studies, Universiti Putra
Malaysia, in Fulfilment of the Requirements for the Degree of
Master of Science**

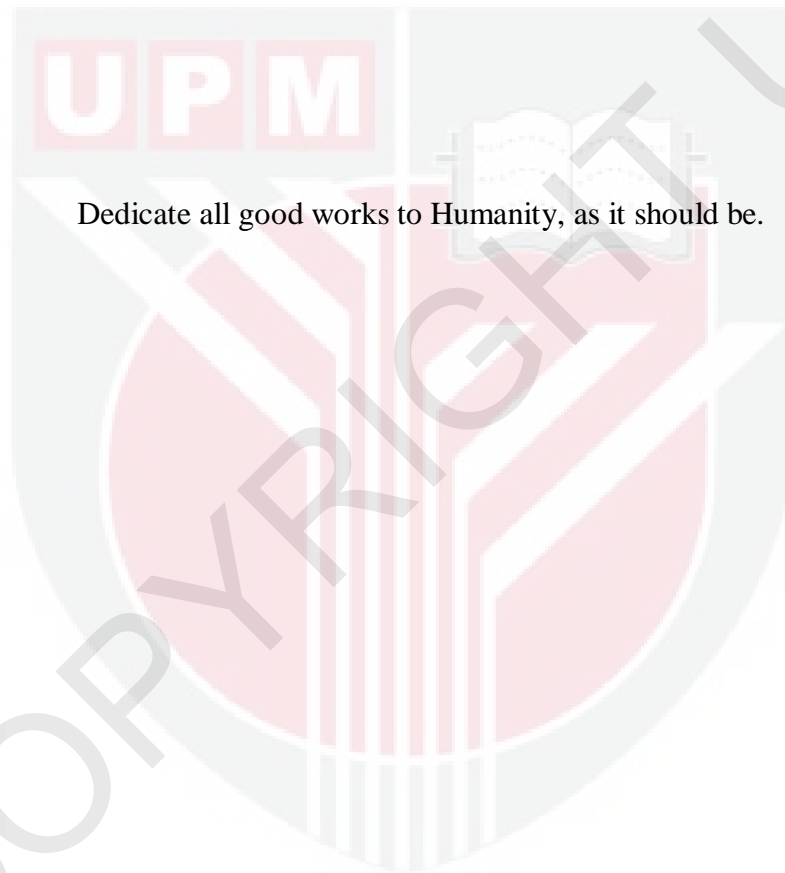
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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

LIFT AND DRAG IMPROVEMENTS OF AIRFOIL THROUGH UTILIZATION OF ROUGH SURFACE AT TRAILING EDGE

By

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June 2014

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It is well known that roughness effect is detrimental for the aerodynamics performance of a surface or airfoil in the sense that it produces higher drag and lower lift. However, literature study lead to the understanding (fact) that in low subsonic regime for free stream velocity Reynolds number between 10^4 to 10^6 , the lift to drag ratio of smooth and rough airfoil exhibit striking difference; L/D of smooth airfoil increases non-linearly with Reynolds number while for rough airfoil it increases only linearly. In addition between Reynolds number 10^4 to 10^5 , the rough airfoil has better L/D values. Some other researchers have also confirmed such behaviour, however, the details of the roughness characteristic is not well defined. It will be of interest how the distribution of surface roughness along the airfoil will influence such aerodynamics performance gain. It is with such motivation that in this research, a set of experiments are used to determine the effects of surface roughness at the trailing edge of an airfoil with low subsonic free stream velocity (Reynolds number, Re , less than 10^6) conditions. Some additional information may be useful in the present study; a numerical study is available in literature, which could be used for validation and comparison.

The problem statement above is further limited to laminar flow which is considered to prevail in flight vehicles flying in this Reynolds number range, particularly UAV, and for Wind-Turbine blades. Experimental work is carried out for this purpose using an airfoil which is specifically designed and built and using a wind tunnel with 1 by 1m cross-section and Reynolds number 4.29×10^5 and 5.65×10^5 , which is considered to be typical and appropriate for the study. In addition, measurements are carried out using PIV technique and flow visualisation. Results obtained confirms the behaviour identified here. In addition, several other interesting and beneficial aerodynamic characteristic are revealed and elaborated. Overall the result obtained is considered to meet the objectives of the research as well as novelty, such as through improved design configurations of the trailing edge roughened surface.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
Sebagai memenuhi keperluan untuk ijazah Master of Sains

**PEMBESARAN DAYA ANGKAT DAN SERET MELALUI PENGGUNAAN
PERMUKAAN KASAR PADA AEROFOIL**

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Memang diketahui bahawa kesan roughness adalah memudaratkan bagi prestasi aerodinamik permukaan atau airfoil dalam erti kata bahawa ia menghasilkan lebih tinggi seret dan lif yang lebih rendah. Walau bagaimanapun, literatur kajian membawa kepada pemahaman (fakta) bahawa rejim bebanan yang rendah secara percuma halaju aliran nombor Reynolds antara 104 hingga 145, Lif untuk mengheret nisbah airfoil halus dan kasar mempamerkan perbezaan yang ketara; L/D dalam airfoil lancar meningkatkan bebas linearly dengan nombor Reynolds manakala bagi airfoil kasar ia meningkatkan hanya linearly. Di samping itu antara nombor Reynolds 104-105, airfoil kasar mempunyai nilai-nilai L/D yang lebih baik. Sesetengah penyelidik yang lain juga telah mengesahkan tingkah laku itu, Walau bagaimanapun, butir-butir mengenai ciri-ciri roughness adalah tidak ditakrifkan dengan baik. Ia akan menjadi menarik bagaimana pengagihan roughness permukaan di sepanjang airfoil yang akan mempengaruhi keuntungan prestasi aerodinamik tersebut. Ia adalah dengan motivasi tersebut bahawa dalam kajian ini, satu set eksperimen digunakan untuk menentukan kesan-kesan permukaan roughness pada ridip airfoil untuk dengan halaju aliran percuma bebanan yang rendah (Reynolds nombor, u , kurang daripada 106) syarat-syarat. Sesetengah maklumat mungkin berguna dalam kajian masa kini; satu kajian berangka terdapat dalam kesusasteraan, yang boleh digunakan untuk pengesahan dan perbandingan.

Pernyataan masalah di atas adalah lagi terhad kepada laminar aliran yang dianggap di kenderaan penerbangan terbang dalam julat ini Reynolds nombor, terutamanya UAV, dan bilah turbin angin. Kerja-kerja eksperimen dijalankan bagi tujuan ini menggunakan airfoil yang khusus direka bentuk dan dibina dan menggunakan terowong angin dengan keratan rentas 1 dengan 1 m dan Reynolds nombor 4.29×10^5 dan 5.65×10^5 , yang dianggap sebagai tipikal dan sesuai untuk kajian ini. Di samping itu, pengukuran yang dijalankan menggunakan teknik PIV dan aliran visualisasi. Keputusan yang diperolehi mengesahkan tingkah-laku yang dikenal pasti di sini. Di samping itu, beberapa lain menarik dan bermanfaat aerodinamik ciri-ciri akan didedahkan dan dihuraikan. Secara keseluruhan hasil yang diperolehi dikira untuk memenuhi objektif-objektif kajian serta sesuatu yang baru, seperti melalui peningkatan rekabentuk konfigurasi permukaan roughened ridip.

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APPROVAL

I certify that a Thesis Examination Committee has met on 19 June 2014 to conduct the final examination of Abdullah Saad Mahmud on his thesis entitled "Lift and Drag Improvements of Airfoil Through Utilization of Rough Surface at Trailing Edge" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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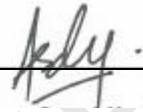
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