UNIVERSITI PUTRA MALAYSIA

MAGNETIC ATTITUDE CONTROL OPTIONS FOR EARTH POINTING SMALL SATELLITE

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MAGNETIC ATTITUDE CONTROL OPTIONS FOR EARTH POINTING SMALL SATELLITE

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

MAGNETIC ATTITUDE CONTROL OPTIONS FOR EARTH POINTING SMALL SATELLITE

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April 2011

Chairman: Associate Professor Ir. Renuganth Varatharajoo, PhD

Faculty: Engineering

The active magnetic attitude control technique is a promising attitude control option for small satellites operated in Low Earth Orbit (LEO). It is accomplished using sets of magnetic torquer that can generate a mechanical torque thus producing control actions when the torquers interact with the geomagnetic field. The magnetic attitude control structure can be developed based only on the magnetic torquers or in conjunction with other actuators. The purpose of this thesis is to develop and evaluate the options for the active magnetic attitude control system of low-cost small satellite missions. Three options of control algorithms have been developed for a gravity-gradient satellite and a momentum bias satellite. The first algorithm is structured for the gravity-gradient satellite employing three magnetic torquers onboard (Option A). The algorithm has been configured for controlling roll, pitch and yaw attitudes using a proportional-derivative (PD) controller. The second and the third algorithms are structured for the momentum bias satellite employing three (Option B) and two (Option C) magnetic torquers onboard, respectively. The structured algorithms are for controlling the attitude

and nutation of roll/yaw axes using a proportional controller (P) as well as unloading the excess angular momentum of the wheel using a proportional-integral (PI) controller. The developed control algorithms are modeled using the MATLAB® SIMULINK® codes. The developed control algorithms were tested using the complex and simplified geomagnetic models for a reference space mission. Their attitude performances were compared and it is found that the accuracies of all the three developed control algorithms are comparable and fulfill the mission requirements. However, the system in option B satellite gives a better attitude performance with a perfect pointing accuracy along the pitch axis, whereas between $-0.05°$ and $0.15°$ along the roll axis and between $-0.05°$ and $0.3°$ along the yaw axis. This research is dedicated for LEO small satellites in a nominal attitude control operation and it provides us the trade-offs when designing the magnetic attitude control subsystem for low-cost space missions.

Abstrak tesis dipersembahkan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PILIHAN KAWALAN ATITUD MAGNETIK UNTUK SATELIT KECIL MENGHALA KE BUMI

Oleh

NURULASIKIN BINTI MOHD SUHADIS

April 2011

Pengerusi: **Profesor Madya Ir. Renuganth Varatharajoo, PhD**

Fakulti: **Kejuruteraan**

Teknik aktif magnetik kawalan atitud merupakan salah satu teknik pilihan yang menjanjikan bagi satelit kecil yang beroperasi di orbit rendah bumi. Ia dilaksanakan dengan menggunakan beberapa rod pengilas magnetik yang boleh menjana kilasan seterusnya menghasilkan aksi kawalan bila ia berinteraksi dengan medan magnet bumi. Struktur kawalan magnetik atitud boleh dibangunkan hanya dengan berasaskan rod pengilas magnetik atau bersama dengan penggerak lain. Tujuan kajian ini dijalankan adalah untuk membangunkan dan menilai pilihan bagi sistem kawalan atitud magnetik aktif untuk misi satelit yang berkos rendah. Tiga pilihan algoritma telah dibangunkan untuk satelit kecerunan graviti dan juga satelit pengaruh momentum. Algoritma pertama dibangunkan untuk satelit kecerunan graviti yang menggunakan tiga rod pengilas magnetik (pilihan A). Algoritma tersebut distruktur untuk mengawal paksi oleng, anggul dan rewang dengan menggunakan pengawal terbitan berkadaran. Manakala algoritma yang kedua dan ketiga distruktur untuk satelit pengaruh momentum yang menggunakan tiga (pilihan B) dan dua (pilihan C) rod pengilas magnetik. Algoritma ini distruktur

untuk mengawal atitud dan egahan pada paksi oleng/rewang dengan menggunakan pengawal berkadaran juga untuk mengurangkan lebihan momentum roda dengan menggunakan pengawal kamiran berkadaran. Algoritma yang dibina ini dibentuk dengan menggunakan kod MATLAB® SIMULINK®. Algoritma ini diuji dengan menggunakan model kompleks dan mudah medan magnet bumi bagi misi angkasa. Prestasi atitud satelit bagi pilihan ini dibandingkan dan didapati ketepatan bagi kesemua algoritma boleh dibandingkan dan memenuhi kehendak misi. Walaubagaimanapun satelit sistem pilihan B memberikan prestasi atitud yang terbaik dengan ketepatan sempurna pada paksi anggul, antara $-0.05°$ dan $0.15°$ pada paksi oleng dan antara $-0.05°$ dan $0.3°$ pada paksi rewang. Kajian ini dijalankan untuk kawalan atitud satelit kecil pada normal operasi dan ia menyediakan kita dengan keseimbangan bila mereka bentuk subsistem kawalan atitud magnetik untuk misi berkos rendah.

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Finally, I would like to offer my regards and blessings to all of those who have helped me in any respect during the completion of this thesis.

I certify that a Thesis Examination Committee has met on **14th of April 2011** to conduct the final examination of **Nurulasikin binti Mohd Suhadis** on her degree thesis entitled "**MAGNETIC ATTITUDE CONTROL OPTIONS FOR EARTH POINTING SMALL SATELLITE**" in accordance with the Universities and 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 Doctor of Philosophy.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of **Doctor of Philosophy**. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or other institutions.

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NURULASIKIN MOHD SUHADIS

Date: 14 April 2011

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