UNIVERSITI PUTRA MALAYSIA

GEOMETRICAL CHARACTERISTICS OF FIXED MIRROR DISTRIBUTED FOCUS SOLAR CONCENTRATOR, SERDANG, MALAYSIA

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By

NG KHAI MUN

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

GEOMETRICAL CHARACTERISTICS OF FIXED MIRROR DISTRIBUTED FOCUS SOLAR CONCENTRATOR, SERDANG, MALAYSIA

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Chairman: Associate Professor Nor Mariah Adam, PhD, P Eng

Faculty: Institute of Advanced Technology

Fixed mirror distributed focus (FMDF) solar concentrator is a solar thermal concentrating system means to collect solar energy for sustainable power generation. The FMDF collector consists of a stationary spherical reflector and a moveable solar receiver with tracking mechanism. There is limited investigation on collector performance on a specific local point of solar receiver in daytime basis under tropics skies. In the present work, a detailed numerical modelling was developed to assess the collector as the first objective. The dimension reference of the simulation model was formulated based on the Universiti Putra Malaysia Solar Bowl. Mathematical models of reflection characterisation of the reflector, radiation interception, collector concentration ratio profile, solar flux density and radiation contour mapping were resolved in a segregated manner using MATLAB programming environment. A proposed model was introduced to investigate the collector performance numerically in daytime basis; to predict the overall solar flux concentration along the receiver in time domain. The model has been enhanced by adopting the actual measurement of

solar radiation data to predict the collector performance. As the second objective, a model FMDF collector was fabricated according to the geometry modelling executed in simulations. An outdoor experimental study was conducted in daytime operation located at Serdang area under hot tropical climate. Numerical results showed that single reflection was the major element in thermal concentration. The concentration ratio was the highest at the upper part of the receiver and decreased towards its lowest region. The results indicated that the concentration ratio and solar flux density of collector deteriorated substantially during the off solar noon hour. According to the simulation finding, during 08:00 and 16:00 solar time under clear sky of tropics, the percentage reduction of solar flux density was over 82% at all points of the receiver. This undesirable performance of collector was due to atmospheric attenuation and cosine effect of the stationary collector. The simulated radiation contour mapping of the receiver supported the result. The performance of the collector was impaired by the cloudy tropical climate that reduced the availability of solar radiation. It was discovered that the expected highest performance of collector at solar noontime might not be fully valid in the real tropics sky. Results showed that global radiation with less than 400 W/m^2 had no significant contribution on the thermal concentration at receiver. Besides, it was observed that the elevation of solar angular deviation promoted a very poor collector performance, which agreed to the predicted results. The numerical model was compared with the experimental data; and were in agreement. In general, the temperature profiles from the experiment had the similar trend patterns to the predicted solar flux density from the simulation model. The additional experiments confirmed the simulation results.

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

SIFAT GEOMETRI UNTUK PENGUMPUL SURIA CERMIN TETAP FOKUS TERAGIH, SERDANG, MALAYSIA

Oleh

NG KHAI MUN

November 2011

Pengerusi: **Profesor Madya Nor Mariah Adam, PhD, P Eng**

Faculti: **Institut Teknologi Maju**

Pengumpul suria cermin tetap fokus teragih (FMDF) adalah suatu sistem penumpuan haba suria untuk mengumpul tenaga matahari dalam penjanaan tenaga elektrik lestari. Sistem pengumpul suria FMDF terdiri daripada reflektor berbentuk sfera yang pegun dan penerima suria yang bergerak dengan mekanisme penjejakan. Penyelidikan untuk menganalisis prestasi pengumpul suria di titik tempatan tertentu penerima suria selama siang hari di bawah iklim tropika adalah terhad. Dalam kajian ini, pemodelan berangka yang terperinci dibangunkan untuk menaksir prestasi pengumpul suria sebagai objektif pertama. Rujukan dimensi dalam model simulasi adalah berdasarkan Kawah Suria Universiti Putra Malaysia. Model matematik untuk ciri-ciri refleksi pada reflektor, penangkapan sinaran, profil nisbah penumpuan, ketumpatan fluks suria dan pemetaan kontur sinaran diselesaikan dengan cara berasingan menggunakan sekitaran pengaturcaraan MATLAB. Sebuah model dibangunkan untuk menyiasat prestasi pengumpul suria secara kaedah berangka pada dasar waktu siang dengan meramal seluruh penumpuan fluks suria di sepanjang tempoh penerima

suria. Model ini telah dipertingkatkan dengan mengambil kira pengukuran sebenar data sinaran suria untuk ramalan prestasi pengumpul suria. Sebagai objektif kedua, model pengumpul suria FMDF dibina mengikut model geometri yang dihasilkan dalam simulasi. Eksperimen luar dijalankan pada siang hari di kawasan Serdang di bawah iklim tropika yang panas. Keputusan berangka menunjukkan bahawa refleksi tunggal adalah unsur utama dalam penumpuan termal. Nisbah penumpuan suria adalah tertinggi di bahagian atas penerima suria dan semakin berkurang menuju bahagian yang paling bawah. Keputusan kajian menunjukkan bahawa nisbah penumpuan dan ketumpatan fluks suria merosot dengan kadar yang besar pada luar masa tengah hari. Menurut penemuan simulasi, antara jam suria 08:00 dan 16:00 untuk langit tropika yang cerah, peratusan penurunan ketumpatan fluks suria adalah melebihi 82% di semua titik tempatan penerima suria. Prestasi pengumpul suria yang tidak diingini ini adalah disebabkan oleh kemerosotan atmosfera dan kesan kosinus akibat reflektor yang pegun. Pemetaan kontur sinaran penerima suria yang telah disimulasi menyokong keputusan ini. Prestasi pengumpul suria terganggu oleh iklim sebenar tropika yang mendung yang telah mengurangkan kadar sinaran suria. Ini adalah ditemui bahawa prestasi pengumpul suria yang dijangka tertinggi pada masa tengah hari mungkin tidak sah sepenuhnya di bawah langit tropika yang sebenar. Keputusan kajian menunjukkan bahawa nilai sinaran suria global yang kurang daripada 400 W/m^2 didapati tidak menyumbang penumpuan haba yang ketara di penerima suria. Selain itu, ini adalah diamati bahawa peningkatan sudut sisihan matahari menghasilkan prestasi pengumpul suria yang sangat lemah, yang bersamaan dengan hasil ramalan. Model berangka telah dibandingkan dengan data uji kaji. Model simulasi pada dasarnya adalah bersamaan dengan eksperimen. Secara umum, profil suhu daripada hasil eksperimen mempunyai corak perkembangan yang serupa

dengan keputusan ketumpatan fluks suria yang dijangka oleh model simulasi. Eksperimen tambahan telah mengesahkan keputusan simulasi.

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I certify that a Thesis Examination Committee has met on 14th November 2011 to conduct the final examination of Ng Khai Mun on his thesis entitled "Geometrical Characteristics of Fixed Mirror Distributed Focus Solar Concentrator, Serdang, Malaysia" 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.

Members of the Thesis Examination Committee were as follows:

Napsiah Ismail, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Abdul Rahman Ramli, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Mohd Zainal Abidin Ab. Kadir, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Mohamad Yusof Sulaiman, PhD
Professor
Solar Energy Research Institute
Universiti Kebangsaan Malaysia
(External Examiner)

BUJANG BIN KIM HUAT, PHD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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

Nor Mariah Adam, PhD
Associate Professor Ir.
Institute of Advance Technology
Universiti Putra Malaysia
(Chairman)

Azmi Zakaria, PhD
Professor
Institute of Advance Technology
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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 at any other institution.

NG KHAI MUN

Date: 14 November 2011

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