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DESIGN, FABRICATION AND EXPERIMENTAL  
EVALUATION OF PARABOLIC TROUGH SOLAR  
CONCENTRATOR AT BANGI, MALAYSIA

Ibrahim Magaji Kotorkoshi

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ISLAMIC SCIENCE UNIVERSITY OF MALAYSIA

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MALAYSIA

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## AUTHOR DECLARATION

I hereby declare that the work in this thesis is my own except for the quotations and summaries which have been duly acknowledged.

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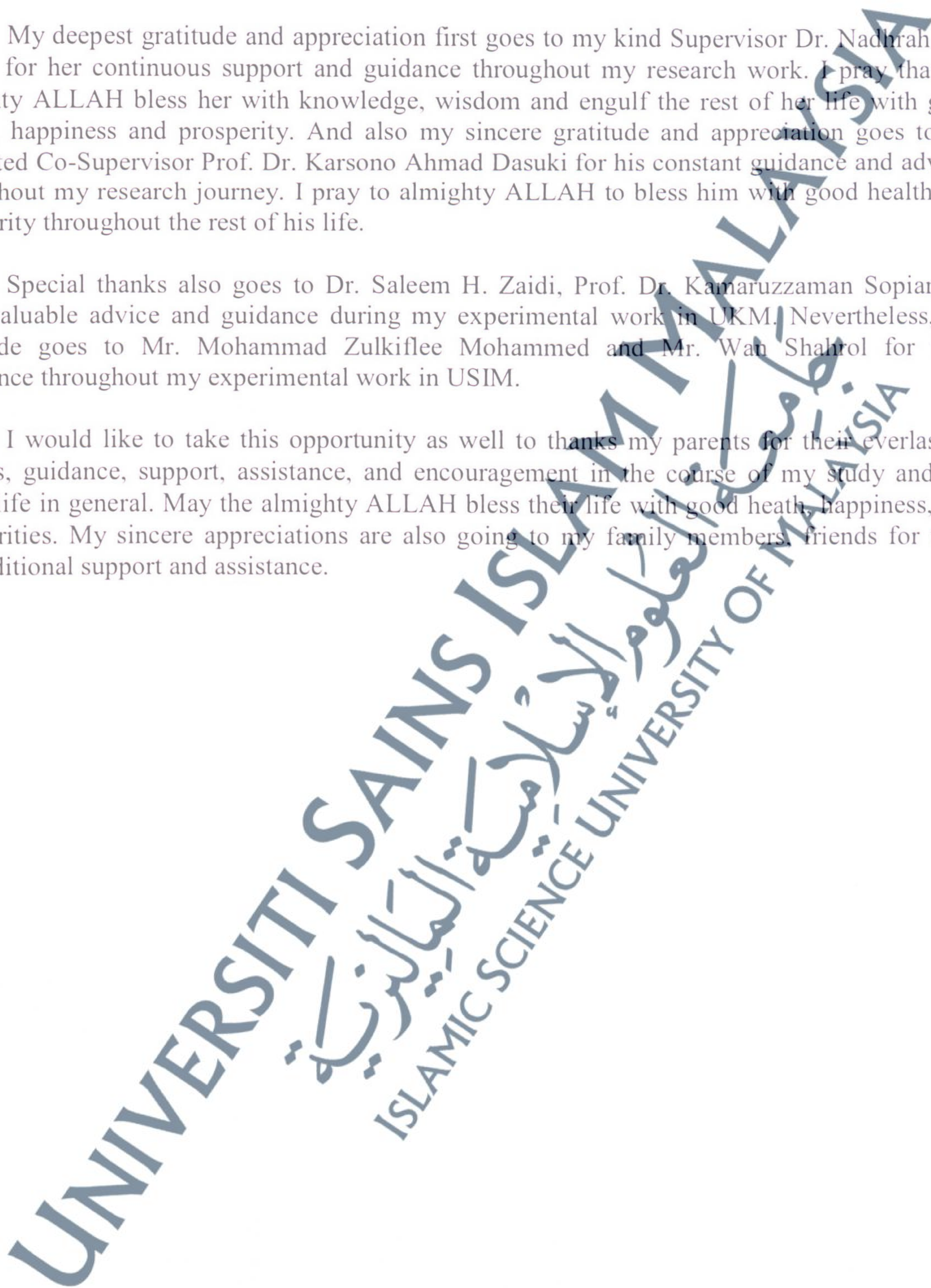
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## ABSTRAK

Tenaga solar terma adalah salah satu daripada sumber tenaga yang dapat melengkapkan bahan api fosil dalam sistem kuasa elektrik dan pemanasan air. Pengumpul solar terma (STC) antara sistem yang kos efektif dalam teknologi ini. Pengumpul parabola palung (PTC) ialah antara teknologi rekabentuk pengumpul solar terma yang paling baik. Walau bagaimanapun, pelaksanaan sistem solar terma di kawasan tropika seperti Malaysia menghadapi cabaran akibat keadaan cuaca yang dicirikan oleh hujan lebat, pembentukan awan, angin sekali-sekala, suhu yang berbeza-beza dan kelembapan yang tinggi. Oleh itu, kajian ini mengkaji kecekapan maksimum sistem pemanasan air terma yang dicapai dari rekabentuk mudah pengumpul solar terma di bawah iklim Bangi, Malaysia. Parabola palung yang di rekabentuk sebagai pengumpul terma mempunyai keluasan  $0.96 \text{ m}^2$  dengan sistem pergerakan automatik dan dilitupi aluminium. Sistem penerima telah diuji menggunakan tiub tembaga dan aluminium dengan diameter, saiz dan situasi (dilindungi dan tidak dilindungi) yang berbeza. Penilaian eksperimen sistem pemanasan air diperiksa dibawah keadaan sistem air statik dan mengalir. Keputusan eksperimen menunjukkan bahawa pengesanan PTC automatik dengan 2 cm tiub aluminium dan tembaga mempunyai prestasi yang baik dengan purata kecekapan haba masing-masing 36 % dan 30 %. Keputusan juga menunjukkan sistem solar terma dengan pergerakan automatik menggunakan tiub penerima yang lebih kecil dengan diameter 1 cm tetapi tertutup di dalam kotak berupaya mencapai kecekapan 27%. Yang paling penting, parabola palung rekabentuk murah berjaya digunakan sebagai sistem pemanas air sehingga suhu  $100^{\circ} \text{C}$  di bawah keadaan iklim tropika Bangi, Malaysia.

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## ABSTRACT

Solar thermal energy is one of the potential sources of energy that compliments the fossil fuels for electricity and water heating system. Solar thermal collectors (STC) are among the cost-effective systems of this technology. The parabolic trough solar collector (PTC) is among the most promising technology of solar thermal collector design. However, implementation of solar thermal system in tropical regions like Malaysia face challenges due to the characteristic nature of the country that characterized by heavy rainfall, formation of clouds, occasional winds, varying temperatures and high humidity. Therefore, this study investigates the maximum thermal efficiency of water heating system achieved from a simple solar thermal collector design under climatic conditions of Bangi, Malaysia. The design used is parabolic trough solar collector of aperture area of  $0.96 \text{ m}^2$  embedded with automatic tracking system with aluminum foil reflecting material. Receiver of the system was tested using copper and aluminum tube with different diameter, size and conditions (covered and uncovered). Experimental evaluation of water heating system was carried out under the static and flowing water conditions. Experimental results indicate that the automatic tracking PTC together with 2 cm aluminum and copper tube receivers performed adequately with an average thermal efficiencies of 36 % and 30 % respectively. Results also indicate that the solar thermal system with automatic tracking together with smaller 1 cm diameter tube receiver enclosed inside a cover box achieves efficiency of 27 %. Most importantly, inexpensive parabolic trough reflector with low-cost design successfully used as water heating system up to temperature  $100^{\circ} \text{ C}$  adequately under tropical climatic condition of Bangi, Malaysia.

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## ملخص البحث

إنّ الطاقة الحراريّة الشمسيّة تعدّ إحدى الموارد الكامنة التي تكون تتمّة للوقود الأحفوريّ للكهرباء ونظام تسخين الماء. كان المجمعون للطاقة الحراريّة الشمسية من بين أنظمة هذه التقنية المجزية. وإنّ مجمع القناة المكافئية الشمسية هو الآخر أحد تقنية تصميم مجمع الحرارة الشمسيّة الواعد. وعلى كلّ حال، إنّ تحقيق نظام الحرارة الشمسيّة في المناطق الاستوائية، مثل دولة ماليزيا، تواجه بعض التحدّيات بسبب الخصائص الطبيعيّة للقطر الخاضعة لنزول المطر الهائل، وتكوين السحب، والرياح العرضيّة، واختلاف الحرارة والرطوبة المرتفعة. لذا، تبحث الدراسة عن درجة الفاعلية الحراريّة القصوى لنظام تسخين الماء الذي تمّ إنجازه من خلال استخدام تصميم مجمع الحرارة الشمسية البسيط تحت الظروف المناخية لمنطقة بنغي في ماليزيا. فالتصميم الذي تمّ استخدامه هنا هو مجمع القناة المكافئية الشمسية الذي كانت نسبة مكان فتحته 0.96 مترين مربعين مكونا فيه نظام المسار التلقائي مع مادة رقيقة معدنية نحاسية عاكسة. تمّ اختبار مستقبل النظام من خلال استخدام أنبوب النحاس والألومنيوم بمختلف قطر الدائرة والحجم والظروف (مغطّى وغير مغطّى). وبعد ذلك، تمّ التقييم التجريبيّ لنظام تسخين الماء خاضعا لظروف الماء الراكد والجاري. وفي نهاية المطاف، أظهرت نتائج الإجراءات التجريبية أنّ المسار التلقائيّ مع حجم 2سم من مستقبل أنبوب النحاس، كان أحسن فاعلية بمعدّل فاعلية حرارية نسبتها 36% و 30% على التوالي. كما أفادت النتائج هي الأخرى بأنّ نظام الحرارة الشمسيّة مع المسار التلقائي باستخدام ظاهرة أصغر أي 1 سم من مستقبل أنبوب قطر دائرة المغلق في صندوق مغطّى، له فاعلية نسبتها 27%. ومن أهم شيء، لقد تمّ استخدام عاكس القناة المكافئية الرخيص بنجاح، مع التصميم الرخيص، كجهاز تسخين الماء إلى درجة الحرارة مقدارها  $100^{\circ}\text{C}$  درجة مئوية، تحت الظروف المناخية الاستوائية في حارة بنغي ماليزيا.

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## ABBREVIATIONS

$I_b$	Direct Solar Insolation
$R_b$	Tilt Angle
$T_i$	Inlet Temperature
$T_o$	Outlet Temperature
$A_a$	Aperture Area of the Collector
$A$	Aperture Weight
$C_p$	Specific Heat Capacity
$D_r$	Receivers Diameter
$f$	Focal Length
$F_R$	Heat Removal Factor
$L$	Length of the Collector
$L_r$	Length of the Receiver
$m$	Mass Flow Rate
$Q_u$	Useful Heat Energy Gained
$R$	Radius of the Parabola
$U_L$	Heat loss Coefficient ( $W/m^2$ )
$\alpha$	Collector Absoptance
$\beta$	Angle of Incidence
$\delta$	Declamation
$\eta_o$	Optical Efficiency
$\theta$	Angle between the Incident flux and normal to a Plane Surface
$\tau$	Transmittance
$\varphi$	Surface Azimuth Angle
$\theta$	Rim Angle
$\tilde{\omega}$	Hour Angle
$\Theta_z$	Zenith Angle
$\mu$	Collators Thermal Efficiency
$T$	Absolute Temperature
$CST$	Concentrated Solar Thermal
$CSP$	Concentrated Solar Power
$PTC$	Parabolic Trough Solar Collector
$HWS$	Hot Water System