UNIVERSITI PUTRA MALAYSIA

DESIGN AND DEVELOPMENT OF A SEGMENTED RUBBER-TRACKED VEHICLE FOR SEPANG PEAT TERRAIN IN MALAYSIA

MD. ATAUR RAHMAN.

DESIGN AND DEVELOPMENT OF A SEGMENTED RUBBER-TRACKED VEHICLE FOR SEPANG PEAT TERRAIN IN MALAYSIA

MD. ATAUR RAHMAN

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

October 2005

Dedicated to the Eternal Souls of

Parents : Allahuarham Taher Uddin and Allahyarhamah Khodaja Begum
Brother: Allahyarham Rohul Islam

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

DESIGN AND DEVELOPMENT OF A SEGMENTED RUBBER-TRACKED VEHICLE FOR SEPANG PEAT TERRAIN IN MALAYSIA

By

MD.ATAUR RAHMAN

October 2005

Chairman: Associate Professor Azmi Yahya, PhD

Faculty : Engineering

The study describes the design and development of a segmented rubber tracked vehicle for operating on unprepared peat terrain. The vehicle was to traverse accurately and reliably on the 18.79kN/m^2 low bearing capacity peat terrain. The study observed four main contributions towards determining the mechanical properties of peat terrain, developing simulation models for optimizing the design parameters of the vehicle, designing and developing the vehicle to be able to traverse accurately on low bearing capacity peat terrain, and designing an innovative instrumentation system on the vehicle for collecting relevant data to measure vehicle tractive performance.

An analytical framework for determining the mechanical properties of peat soil in view of predicting the tractive performance of tracked vehicle was presented. It took into account the load-sinkage and shearing characteristics of peat. An experimental study on the mechanical properties of peat was conducted in Sepang, Selangor, Malaysia. The

stiffness values of surface mat and underlying weak peat deposit from load-sinkage test were determined by specially made bearing capacity apparatus. The mean values of surface mat stiffness before and after drainage were found to be 31kN/m^3 and 46kN/m^3, respectively. The mean value of underlying peat stiffness before and after drainage were found to be 252kN/m^3 and 380kN/m^3, respectively. The mean value of internal frictional angle, cohesiveness and shear deformation modulus of the peat soil sample were determined using a direct shear box apparatus in the laboratory. The mean value of internal frictional angle, cohesiveness and shear deformation modulus of the peat soil before and after drainage were found to be 22.80° and 24.31°, 2.63kN/m^2 and 2.89kN/m^2, and 1.21cm and 1.37cm, respectively.

A new simulation technique for studying the basic design parameters of the vehicle with rigid link tracks system on Sepang peat terrain in Malaysia was also presented. The proper track width, ground contact length, pitch and grouser height, idler diameter and location, sprocket diameter and location, road-wheel diameter and geometrical arrangement, the ratio of the road-wheel spacing to track pitch, location of the center of gravity (CG) of the vehicle are important to select to ensure good tractive performance of the vehicle on unprepared peat terrain. Simulation technique was then used to optimize the design parameters of the vehicle by establishing mathematical models for the track-terrain interaction mechanism. In the simulation study, the 25.5kN vehicle including payloads of 5.89kN was considered to traverse on the peat terrain at 10km/h.

The simulation study for the vehicle of straight running motion showed that the nominal ground pressure of the vehicle was 23.3% lower than the bearing capacity of the peat

terrain. From simulated tractive performance results, vehicle average motion resistance coefficient of 6.8 to 7.9%, drawbar pull coefficient of 25.22 to 47%, and tractive efficiency of 74 to 77%, were found for the slippage of 5 to 20%. For the simulation study on the vehicle of turning motion, the result showed that the vehicle ground contact pressure exit from outer track was 14.61% and from the inner track was 6.67% lower than the bearing capacity of the Sepang peat terrain, the sinkage of the vehicle outer track 10.5% lower and inner track 22.5% lower, torque of the outer track sprocket 7.85% higher than the turning moment resistance of the vehicle, and lateral resistance 7.4% higher than the centrifugal force of the vehicle which was ensured the vehicle to maintain the steady state turn on the Sepang peat terrain at a turning speed of 10km/h.

The vehicle field tests were conducted on three different types of peat terrains: *Terrain Type* I, *Terrain Type* II, and *Terrain Type* III with two loading conditions at travel speeds of 6km/h and 10km/h. The results showed that the tractive effort of the vehicle was increased 13.71% for *Terrain Type* I, 11.09% for *Terrain Type* II, and 13.53% for *Terrain Type* III when the traveling speed was increased from 6km/h to 10km/h. From the variation of the vehicle tractive operating environment, it was found that the tractive effort of the vehicle at traveling speed of 6km/h increased 8.08%, 5.12%, and 14.14% for changing the vehicle operating environment from *Terrain Type* I to *Terrain Type* II, *Terrain Type* II to *Terrain Type* III, and *Terrain Type* I to *Terrain Type* III, respectively. Similarly, the tractive effort for the vehicle at a traveling speed of 10km/h increased 6.32%, 7.42%, and 14.22% for changing the vehicle operating environment from *Terrain Type* I to *Terrain Type* II, *Terrain Type* II to *Terrain Type* III, and *Terrain Type* I to *Terrain Type* III, respectively. Furthermore, the tractive effort of the vehicle at a traveling

speed of 6km/h increased 2.28% for *Terrain Type* I, 5.124% for *Terrain Type* II, and 6.46% for *Terrain Type* III when the vehicle changing operating loading condition from without payload to with full payload. Similarly, the tractive effort of the vehicle at a traveling speed of 10km/h increased 1.76% for *Terrain Type* I, 2.61% for *Terrain Type* II, and 6.69% for *Terrain Type* III when the vehicle changing operating loading condition from without payload to with full payload.

Abstrak tesis yang dikemukakan Kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluaan untuk ijazah Doktor Falsafah

MEREKA BENTUK DAN MEMBINA SEBUAH KENDERAAN TAPAK BERSEGMEN GETAH UNTUK PERMUKAAN TANAH GAMBUT SEPANG DI MALAYSIA

Oleh

MD. ATAUR RAHMAN

October 2005

Pengerusi : **Profesor Madya Azmi Yahya, PhD**

Fakulti : **Kejuruteraan**

Kajian ini menjelaskan pengujian dan mereka bentuk pembangunan bagi sebuah kenderaan tapak bersegmen getah untuk beroperasi di atas rupa bumi tanah gambut yang tak tersedia. Kenderaan ini seharusnya melakukan pejalanan secara mandatar secara tepat dan berupaya bengerak dengan 18.79 kN/m^2. Kapasiti galas rendah untuk rupa bumi tanah gambut iaitu 18.79 kN/m^2. Objektif tersebut adalah sukar dan memerlukan ketepatan sifat reka bentuk dan binaan pengeseran mantap untuk mengabut kenderaan ini di kedua dua pengerakan samada lurus atau membelok. Kajian ini melaksanakan empat sumbangan utama kearah pencapaian objektif tersebut dan menentukan sifat sifat mekanikal rupa bumi tanah gambut, membangunkan model simulasi untuk mengoptimalkan parameter reka bentuk kenderaan, mereka bentuk dan membangun kenderaan, mereka bentuk dan membangun kenderaan yang lebih tepat bagi mengawal kenderaan tersebut ketika melakukan perjalanan mendatar di rupa bumi tanah gambut

yang terselia dan mereka bentuk pembinaan data sistem instrumentasi kenderaan untuk mendapatkan data yang berkenaan bagi mengukur keupayaan bekas tapak kenderaan.

Analisis rangka kejuteraan dilaksanakan untuk menentukan sifat-sifat tanah gambut dan ciri tanah gambut mericih. Kajian penyelidikan terhadap sifat sifat mekanikal tanah gambut dilakukan di kawasan Sepang, Selangor, Malaysia. Nilai kekakuan untuk permukaan balas dan lapisan kemah tanah gambut diperolehi dari ujian beban-bebanan dari ianya ditentukan mengunakan alat kapasiti galas yang telah direka bentuk.

Nilai min untuk lapisan tanah gambut kaku sebelum dan selepas pengairan yang diperolehi adalah 252 kN/m^3 dan 380 kN/m^3. Nilai min untuk suatu rintangan dalaman kelekatan dan modulus kerosakan ricih bagi sampel tanah gambut telah ditentukan dengan menggunakan alat direct shear box. Nilai min untuk suatu rintangan dalaman kelekatan dan modulus kerosakan ricih untuk tanah gambut bagi sebelum dan selepas pengairan adalah 22.80^0 dan 24.31^0, 2.63 kN/m^2 dan 2.89 kN/m^2 , dan 1.21 cm dan 1.37 cm, masing-masing.

Sebuah teknik simulasi telah dihasilkan parameter reka bentuk asas bagi kenderaan tersebut melalui sistem rantaian keras bekas tapak di kawasan tanah gambut di Sepang. Lebar bekas tapak yang bersesuaian panjang, sukatan tanah pit dan tinggi gronser diameter idler dan posisinya diameter sprocket dan posisinya diameter roda-jalan dan penyasunan geometri. Teknik simulasi tersebut kemudiannya digunakan untuk mengoptimumkan reka bentuk parameter kenderaan dengan mungujudkan model

matematik untuk mekanisma interaksi bekas tapak-permukan bumi melalui simulasi ini. Kenderaaan dengan dengan berat 25.5 kN yang menanggung beban penuh sejumlah 5.89 kN adalah dipertimbangkan bergerak mendatar di atas rupa bumi pada 10 km/h.

Kajian simulasi untuk kendaraan yang bergerak lurus telah menunjukan bahawa tekanan kecil bumi adalah 23.3% lebih rendah dari keupayaan galas bumi tanah gambut daripada simulasi perlakuan bekas tapak. Dari simulasi rintangan pengerakan pada 6.8 hingga 7.9 % pekali tarikan heret pada 25.22% hingga 47% dan kekuatan tukisan pada 74 hingga 77% dan peratusan gelinciran pada 5 hingga 20%. Kajian simulasi untuk pengerakkan pusingan kenderaan menunjukkan bahawa tekanan sentuhan bumi kendaraaan keluar berlaku dari bekas tapak luaran 14.61% lebih rendah dari keupayaan galas permukaan tanah gambut Sepang. Kikisan bekas tapak luaran 10.5% lebih rendah dan bekas tapak dalaman 22.5% lebin rendah. Nilai kilasan gegancu bekas tapak luaran adalah 7.85% daripada momen pusingan rintangan kenderaan dan rintangan sisi adalah 7.4% lebih tinggi daripada gaya sentifugal yang mana menjamin kendraan tersebut untuk sentiasa dalam keadaan mantap ketika membuat pusingan itu permukaan tanah gambut pada kelajuan pusingan 10 km/h.

Ujiankenderaan di dalam ladang telah dilaksanakan pada tiga keadaan permukaan tanah gambut. Jenis permukaan I, jenis permukaan II dan jenis permukaan III. Dengan 2 keadaan bebanan dengan kelajuan perjalana 6 km/h dan 10 km/h. Keputusan menunjukkan bahawa daya tarikan telah meningkat 13.71% untuk jenis permukaan I, 11.04% untuk jenis permukan II dan 13.53% untuk jenis permukaan III dengan

peningkatan kelajuan pengerakan dari 6 km/h di pada 10km/h. Daripada perlbagai daya tarikan untuk permukaan berlainan didapati bahawa daya tukisan pada kelajuan pergerakan 6km/h meningkat sebanyak 8.05%, 5.12% dan 14.14% bagi pertukaran persekitaran operasi kenderaan dari jenis permukaan I ke jenis permukan II, jenis permukan II ke jenis permukan III dan dari jenis permukan I ke jenis permukan III, begitu juga, daya tukisan untuk kelajuan pergerakkan 10km/h telah meningkat 6.32%, 7.42% dan 14.21% . Perubahan persekitaran operasi kenderaan dari jenis permukaan I ke jenis permukan II, jenis permukan II ke jenis permukan III dan dari jenis permukan I ke jenis permukan III masing-masing. Tambahan lagi apabila operasi kenderaan bertukar dari tanpa bebanan ke beban penuh, daya tarikan untuk kelajuan kenderaan 6km/h telah meningkat 2.28% untuk jenis permukan I, 5.124% untuk jenis permukan II dan 6.46% untuk jenis permukan III. Begitu juga dengan daya tukisan untuk pergerakan pada kelajuan 10km/h telah meningkat 1.76% untuk jenis permukaan I, 2.6% untuk jenis permukaan II dan 6.69% untuk jenis permukaan II apabila beroperasi dari pada tiada beban ke bebanan penuh.

ACKNOWLEDGEMENT

At the outset, I bow to the grace and mercy of the Almighty Allah without whose desire I could not have materialized my dream to complete this thesis.

I would like to acknowledge my sincere gratitude to my respected supervisor Associate Prof. Dr. Ir. Azmi Yahya, Dean, Faculty of Engineering, Universiti Putra Malaysia, for his untiring inspiration, encouragement and invaluable guidance towards the write up of this thesis. Without his scholastic criticisms, whole-hearted assistance, unfailing interest, constructive criticism, continuous supervision and valuable suggestions throughout the period of this research, I could not conclude this thesis.

I would also like to express my deepest gratitude and indebtedness for the kind cooperation of my co-supervisors Prof. Dato' Dr. Ir. Mohd. Zohadie Bardaie, Vice Chancellor, Prof. Dr. Ir. Wan Ishak Wan Ismail, Director, Institute of Advanced Technology, and Prof. Dr. Ir. Desa Ahmad, Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia in the successful completion of this study. Their contribution and suggestions helped to overcome many errors and showed me the right path during the course of this work.

I would also like to express my gratitude to the School of Graduate Studies, Universiti Putra Malaysia for granting Graduate Research Assistantship through the RM7 IRPA

project, Ministry of Science Technology and Environment, Malaysia for the financial support during study in Universiti Putra Malaysia.

There are many other people whom I would like to thank for their help and support during study in Universiti Putra Malaysia especially Mr. Abdul Aziz, Mr. Rushdi, Mr P.C Tuang of MAC Engineering SDN. BHD. and Mr. William Wu of UEW SDN. BHD. for their assistance in the fabrication process of the machine.

Thanks also go to the other members of the research group namely Dr. Mutalib, Darius El Pebrian, Wee, Skgew, Boon, Hafiz, Rozlan and Yap with whom I shared idea for four years. They not only helped me to complete this study but also helped me to make my time in Malaysia more enjoyable.

I owe my greatest debt to my late mother and my father and my brother who taught me how to live and study. I would like to express my special thanks to my wife Dr. Rafia Afroz who has given me love and support throughout my time here in Malaysia.

Finally, I would like to show my confidence in the manner that the followers will drive maximum benefit from this study.

The Author

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES