UNIVERSITI PUTRA MALAYSIA

MOTION RESISTANCE ANALYSES OF TOWED NARROW WHEELS

FATAI BUKOLA AKANDE

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By

FATAI BUKOLA AKANDE

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

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DEDICATION

In the name of Allah SWT, the benevolent, the beneficent and the most merciful. I dedicate this thesis to my parents: Late Pa Sabitu Ajani Adesina-AKANDE who answered the call of Allah SWT four days into this programme and his widow, Mrs. Salemotu Yinyinola Amoke nee Muibi AKINYODE for her encouragement and steadfastness since the beginning of my educational career till this level. The thesis is also dedicated to my wife Mrs. Amina Dasola AKANDE for her understanding, sacrifice and endurance during the course of this study.

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

MOTION RESISTANCE ANALYSES OF TOWED NARROW WHEELS

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FATAI BUKOLA AKANDE

April, 2011.

Chairman: Professor Desa Bin Ahmad, PhD, Ir

Faculty: Engineering

The off and on-road performances of the narrow wheels with respect to the motion resistance and the motion resistance ratio were investigated to obtain design information for the development of simple and low cost agricultural machinery with narrow wheels as traction members.

A single wheel motion resistance test rig for towed narrow wheel was developed. The motion resistance was measured in real time by the use of Mecmesin Basic Force Gauge (BFG 2500) interfaced with the notebook with the Dataplot program installed for the display of the real time data acquisition from the BFG. Motion resistance data obtained through this method were called empirical data. While motion resistance ratios predicted from the analytical method using existing mobility and motion resistance ratio models were called analytical data. These analytical data were compared with those

obtained empirically under various test conditions on the tilled and wet surfaces. The motion resistance and motion resistance ratios of 660 mm, 610 mm, 510 mm and 405 mm pneumatic bicycle wheels were determined on paved surface, grass field, tilled and the wet surfaces. The other test variables were the dynamic loads at four levels 98.1 N, 196.2 N, 392.4 N and 588.6 N, and the tyre inflation pressures of 276 kPa, 345 kPa and 414 kPa, towing velocity; 4.44 km/h, 6.3 km/hr and 8.28km/h. The 660 mm wheel have the lowest occurring motion resistance, and a rigid wheel of the same rim diameter was constructed and its motion resistance was investigated on the four test surfaces with the same test variables (dynamic loads and towing velocity) as the 660mm pneumatic wheel. The effects of the overall wheel diameter, tyre inflation pressures, dynamic loads and towing velocity on the motion resistance ratio were investigated different test surfaces using regression analysis. The Analyses of variance was carried out at 95% confidence level on all the motion resistance measured on various test surfaces and test conditions. The results of the analyses of variance indicate that there were significant differences between the means of the motion resistance measured on the four test surfaces and between the means of motion resistance measured at all level of the independent variables.

Motion resistance recorded on the wet surface were greater than those obtained on the tilled surface and the least were obtained on the paved surface and the grass field although the motion resistances measured were close in values with those on paved surface leading. The motion resistance ratio is inversely proportional to the overall wheel diameter, similarly, the motion resistance ratio is inversely proportional to the

dynamic load but the motion resistance has a direct relationship with the dynamic load on all the test surfaces. However, the motion resistance ratio is directly proportional to the dynamic load on tilled surface. Some of the relationships between the motion resistance ratio and each of the test variables are test surface dependent as the relationship varied from surface to surface in some cases. Relationship between motion resistance ratios and the tyre pressure is inversely proportional as it also depends on the test surface and other variables.

The motion resistances of the rigid wheel were greater than the pneumatic wheel on all the test surfaces. The motion resistance ratio is inversely proportional to the towing velocity on paved and grass surfaces for pneumatic wheel and on paved and wet surfaces for the rigid wheel. The rigid wheel is a better traction member on wet surface at all levels of towing velocities.

A tyre inflation pressure of 414 kPa is recommended for all test surfaces at all levels of dynamic load. The motion resistance ratios obtained through the empirical method were higher than the analytical data on both the tilled and the wet surfaces. From the empirical data, mathematical models derived for predicting motion resistance ratio from the combination of the test variables show that different regression equations fit the different test surfaces; logarithmic relationship fits the tilled surface, while a full and pure quadratic relationship fits the paved surface and the grass field respectively. Some empirical models have been derived for the prediction of the motion resistance ratios of

pneumatic and rigid bicycle wheels from the comparison of data obtained by the two methods.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagi memenuhi kerperluan untuk ijazah Doktor Falsafah

ANALISIS RINTANGAN GERAKAN RODA KECIL TERTUNDA

Oleh

FATAI BUKOLA AKANDE

April, 2011.

Pengerusi: Professor Ir. Dr. Desa Bin Ahmad.

Fakulti: Kejuruteraan

Prestasi roda kecil pada permukaan jalan dan luar jalan mengenai rintangan gerakan dan nisbah rintangan gerakan telah dikaji untuk mendapatkan maklumat reka bentuk dalam usaha menghasilkan jentera pertanian murah dan mudah menerusi penggunaan roda kecil selaku komponen tukisan.

Sebuah kerangka ujian rintangan gerakan roda untuk kajian tukisan roda kecil yang ditunda telah dibina. Rintangan gerakan (Daya penarikan) telah diukur menggunakan Gauge Daya Asas Mecmesin (BFG 2500) yang disambung pada komputer riba lengkap dengan perisian program pemplotan data yang dapat mempamerkan data secara terus menerus dari BFG. Kaedah mendapatkan data cara ini disebut sebagai kaedah empirical manakala data rintangan gerakan disebut sebagai data empirical. Kaedah lain yang digunakan dalam kajian gerakan ini adalah kaedah analitikal atau kaedah semi empirical di mana model nombor gerakan dan model rintangan gerakan sediaada digunakan untuk meramal nisbah rintangan gerakan roda yang diuji pada permukaan berbeza termasuk

pada permukaan tanah bergembur dan pada permukaan tanah basah sahaja. Data yang dianalisis ini dibandingkan dengan data yang diperolehi secara empirikal. Rintangan gerakan dan nisbah rintangan gerakan bagi roda basikal pneumatic bergarispusat 660 mm, 610 mm, 510 mm dan 405 mm telah ditentukan pada permukaan berturap, permukaan berumput, permukaan tanah bergembur dan permukaan basah.. Pembolehubah lain adalah empat beban dinamik (98.1 N, 196.2 N, 392.4 N dan 588.6 N), dan tekanan udara tayar pada tekanan 276 kPa, 345 kPa dan 414 kPa, kelajuan tunda; 4.44km/j, 6.3 km/j dan 8.28 km/j. Roda bergarispusat 660 mm menunjukkan rintangan gerakan terendah, dan roda tegar bersaiz garispusat serupa telah dibina dan rintangan gerakannya dikaji pada empat permukaan ujian dengan parameter pembolehubah yang sama (beban dinamik dan kelajuan tunda) seperti roda pneumatik bergarispusat 660 mm. Kesan saiz roda, tekanan udara tayar, dan beban dinamik telah dikaji untuk mendapatkan hubungkait antara nisbah rintangan gerakan roda dengan garispusat roda keseluruhan, tekanan udara tayar dan beban dinamik pada pelbagai permukaan menggunakan analisis regresi. Analisis varian pada tahap 95% keyakinan telah dilaksanakan keatas nilai min rintangan gerakan pada semua jenis dan keadaan permukaan. Perbezaan bererti ditentukan antara nilai min rintangan gerakan dengan permukaan dan pembolehubah seperti saiz roda, tekanan udara tayar, beban dinamik dan kelajuan tunda. Keputusan analisis menunjukkan terdapat perbezaan bererti antara nilai min rintangan gerakan pada permukaan yang diuji. Analisi varian juga menunjukkan terdapat perbezaan bererti antara nilai min rintangan gerakan dengan beban dinamik pelbagai, tekanan udara tayar dan kelajuan tunda.

Rintangan gerakan roda berlainan saiz berbeza antara permukaan ujian dimana permukaan basah memberikan rintangan gerakan tertinggi diikuti oleh permukaan tanah yang digembur. Nilai rintangan gerakan pada permukaan yang diturap dan permukaan berumput tidak menunjukkan banyak perbezaan. Walau bagaimanapun permukaan berturap memberikan nilai rintangan gerakan lebih tinggi berbanding permukaan berumput. Hubungkait antara rintangan gerakan dan saiz roda adalah menyongsang. Nilai rintangan gerakan akan menurun apabila saiz roda meningkat. Nisbah rintangan gerakan menurun apabila beban dinamik meningkat manakala rintangan gerakan turut meningkat apabila beban dinamik meningkat pada semua permukaan. Walau bagaimanapun nisbah rintangan gerakan menunjukkan hubungan terus dengan permukaan tanah yang digembur. Beberapa hubungkait antara nisbah rintangan gerakan dengan setiap pembolehubah bergantung kepada permukaan ujian memandangkan hubungkait tersebut berbeza bagi permukaan berbeza dalam kes tertentu. Hubungkait antara nisbah rintangan gerakan dan tekanan udara tayar adalah menyongsang serta bergantung kepada permukaan ujian dan pembolehubah lain.

Rintangan gerakan roda tegar adalah lebih tinggi berbanding roda pneumatik pada semua permukaan.Hubungkait antara nisbah rintangan gerakan dan kelajuan tunda juga bergantung kepada jenis permukaan dan didapati mempunyai hubungan menyongsang pada permukaan yang diturap dan berumput bagi roda pneumatic dan permukaan bertar serta permukaan basah bagi roda tegar. Roda tegar memberikan tukisan terbaik pada permukaan basah pada semua kelajuan tunda

Tekanan udara 414 kPa adalah disyorkan untuk kesemua permukaan dan beban dinamik. Data empirical dan nisbah rintangan gerakan yang diperolehi dengan kaedah empirical adalah lebih tinggi dari data analitikal pada kedua-dua permukaan tanah bergembur dan permukaan basah. Dengan menggunakan data empirical, model matematik yang dihasilkan hasil gabungan pembolehubah kajian menunjukkan persamaan regresi yang dihasilkan adalah berlainan pada permukaan berbeza. Hubungkait logaritma sesuai untuk permukaan tanah bergembur manakala hubungkait kuadratik penuh dan gabungan kuadratik sesuai untuk permukaan berturap dan permukaan berumput. Beberapa model empirical turut diperolehi dalam penentuan ramalan nisbah rintangan gerakan roda pneumatik dan roda basikal tegar hasil perbandingan data yang diperolehi berdasarkan dua kaedah tersebut.

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I certify that a Thesis Examination Committee has met on the 26th April, 2011 to conduct the final examination of Fatai Bukola Akande on his thesis entitled "Motion Resistance Analyses of Towed Narrow Wheels" 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 Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows

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This thesis was submitted to the Senate of the 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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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.

FATAI BUKOLA AKANDE

Date: 26th April, 2011

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