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FAIZAL AMRI AMRAN

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By

FAIZAL AMRI AMRAN

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β	tilt angle
ϕ	disk angle
θ	angle between soil surface and horizontal
ρ	soil density
σ	soil shear
A_d	area of disk furrow slice
A_r	area of rotary blade
c	vertical distance of soil surface upon center of diameter disk edge
d	diameter of disk
d_{or}	apparent height of soil slice to center point
Fx, Fz	force
Gy, Gz	center of gravity
H	tilling depth
Hc	apparent height of cut
Ix, Iy, Iz	area moment of inertia
Ixx, Iyy, Izz	mass moment inertia
My	moment on y axis.
m	mass of furrow slice
n	rotation of disk
R	radius of blade
r	radius of the disk edge circle
S	horizontal distance between soil surface and horizontal
Se	soil exposure
Tr	tilling pitch
t	width of blade
V, Vd, v	forward speed
Vr	rotary speed
W, Wt, Wd	cutting width
z	number of blade

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FAIZAL AMRI AMRAN

December 1997

Chairman: **Associate Professor Dr. Desa Ahmad, P. Eng**

Faculty: **Engineering**

An investigation was initiated to obtain some understanding on the behavior of wet clay soil and to explore the potential of combined operation of disk plow and rotary blade to reduce travelling of machine in paddy field.

Tests were conducted in a soil tank 20 m long, 3 wide, and .75 m deep, the Munchong soil was used and soil condition was controlled. A 25 HP tractor was modified as the prime mover. Frame to put disk plow and rotary blade was designed. An extended octagonal ring dynamometer was used to draft measuring and torque transducer to torque measuring.

Based on the existing information about disk plow-soil parameters, the effects of forward speed, disk angle, tilt angle and width of cutting were explored. Results between soil-disk parameter design were compared and the flow of soil slice on disk surface was determined. This would give some indication of the effect of soil-disk parameter and its initial wet soil flow on disk surface. The result of

plowing wet soil shows that tilt angle had no statistically significant effect on draft. The forward speed has main effect of design parameter on force requirement. Studies on soil flow on disk surface had shown that upward soil flow was more prominent causing soil clogging as the forward speed increased. Increasing of disk angle and tilt angle increased soil clogging on disk surface.

Based on the experiments flow on wet soil furrow slice on disk surface, the location of rotary blade was determined. The effects of forward speed, rotary speed, disk angle, tilt angle and width of cutting were explored. Results between soil-combined disk plow and rotary blade parameter design were compared and the flow of soil slice on disk surface determined. The forward speed and rotary speed have the main effect of design parameter on torque requirement. Increasing of rotary speed will decrease force requirement of disk plow. The use of a rotary blade with reversed rotation is an effective method to reduce force requirement. Distance of soil furrow slice on disk surface increases when the rotary speed increases. The combination of forward speed and rotary speed determined the length of soil slice.

Predictive models based upon mathematical formula of wet soil furrow slice were developed to predict the energy requirement of combined disk plow and rotary blade using all design parameters. Mass moment of inertia approach was used to develop the energy prediction model. An increase in forward speed increases draft due to soil inertia on disk surface and the soil disturbed exhibit compressive failure. Results of studies showed that the models could be used to predict energy requirement on combined disk plow and rotary blade.

In an effort to find the optimum condition for wet soil plowing, the results obtained showed that the best performance of disk plow is at a tilt angle of 0^0, disk angle of 40^0 and rotary speed of 400 rpm or above. Soil puddling is better achieved by combining the appropriate forward speed with a set of rotary speeds.

Abstrak yang dikemukakan kepada Senat Universiti Putra Malaysia
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PENCAPAIAN KERJA BAJAK PIRING YANG DIGABUNGKAN DENGAN PISAU BERPUTAR PADA TANAH LIAT BASAH

Oleh

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Fakulti: **Kejuruteraan**

Satu penyelidikan telah dijalankan untuk mendapatkan beberapa pemahaman tentang sifat tanah liat basah serta mengkaji potensi kombinasi bajak piring dan pisau bajak putar untuk mengurangi perlintasan mesin di sawah padi.

Penyelidikan dilakukan pada tangki tanah berukuran 20 m panjang, 3 m lebar dan .75 m dalam, tanah jenis Munchong digunakan dengan kondisi disesuaikan. Sebuah traktor 25 HP diubah suai untuk digunakan sebagai sumber tenaga. Kerangka untuk meletakkan bajak piring dan pisau bajak putar serta alat pengukur direka bentuk. Dynamometer segi enam dipanjangkan digunakan untuk mengukur gaya mendatar dan transduser torsi untuk mengukur torsi.

Berdasarkan kepada parameter bajak piring dan parameter tanah, pengaruh kelajuan, sudut piring, sudut condong, dan lebar potongan telah diselidiki. Hasil perlakuan parameter tanah dan bajak piring telah dibandingkan, aliran tanah pada permukaan piring diperhatikan. Ini memberikan beberapa petunjuk pengaruh

tanah-parameter bajak piring dan bentuk sebenar aliran tanah pada permukaan piring. Hasil pembajakan tanah lembab menunjukkan bahawa sudut condong mempunyai pengaruh yang kecil terhadap daya mendatar. Kelajuan mempunyai kesan utama terhadap parameter rekabentuk pada keperluan daya. Pemerhatian pada aliran tanah pada permukaan piring telah menunjukkan aliran tanah ke atas yang menyebabkan pengumpulan tanah terjadi dengan meningkatnya kelajuan. Begitu juga dengan peningkatan sudut piring dan sudut condong.

Berdasarkan kajian aliran potongan tanah basah pada permukaan piring, lokasi pisau bajak putar di permukaan piring dapat ditetapkan. Pengaruh kelajuan maju, kelajuan putar pisau, sudut piring, sudut condong, dan lebar potongan telah diselidiki. Hasil perlakuan parameter tanah dan kombinasi bajak piring dan pisau bajak putar tanah telah dibandingkan, aliran tanah pada permukaan piring diperhatikan. Kelajuan maju dan kelajuan putar pisau merupakan pengaruh utama parameter reka bentuk terhadap keperluan kilasan dan tenaga. Peningkatan kelajuan putar pisau akan menurunkan daya yang diperlukan pada bajak putar. Jarak potongan aliran tanah pada permukaan piring akan meningkat dengan meningkatnya kelajuan putar pisau. Penggunaan pisau berputar ke belakang adalah kaedah yang berkesan untuk menurunkan keperluan daya. Kombinasi kelajuan maju dan kelajuan putar pisau akan menentukan panjang ukuran irisan tanah yang terbentuk.

Model pendugaan didasarkan pada model matematik potongan tanah basah yang terjadi telah dikembangkan untuk memperkirakan keperluan tenaga interaksi antara tanah dan kombinasi bajak piring dan pisau bajak putar dengan menggunakan parameter yang ada. Pendekatan momen inersia dari massa telah digunakan untuk membina pendugaan model tenaga. Peningkatan dalam kelajuan meningkatkan daya mendatar yang diakibatkan inertia tanah pada permukaan piring dan perubahan bentuk tanah menunjukkan kegagalan akibat tekanan. Hasil kajian menunjukkan bahawa model yang dikembangkan dapat digunakan untuk menduga tenaga yang diperlukan pada kombinasi bajak piring dan pisau berputar.

Hasil yang diperolehi menunjukkan bahawa kedudukan bajak piring terbaik adalah pada sudut condong 0^0, sudut piring 40^0 dan kelajuan putar pisau pada 400 rpm atau lebih. Penggelodakan tanah yang baik dicapai dengan menggabungkan kelajuan maju dan kelajuan putar pisau yang sesuai.

CHAPTER I

INTRODUCTION

General

The ultimate aim of tillage is to manipulate soil to a desired condition and final soil condition is a measure of soil manipulation. The term soil condition includes all physical characteristics of soil that are pertinent to its use. Manipulation of wet soil is a serious problem both in tropical and temperate agriculture. Under tropical conditions, the greatest problem is the manipulation of soil for wetland rice production (Awadhal and Singh, 1985). For wetland paddy cultivation, several basic cultivation operations can be identified, namely loosening, mixing, inversion, compacting, and levelling. After harvest and at the beginning of the rice phase, the soil is often compacted and covered with weeds or trash. Tillage must loosen the soil and control weeds through incorporation by mixing or inversion.

Puddling is a common practice in land preparation in lowland rice growing areas. Puddling is considered essential for successful rice cultivation. Where there is enough water and power, puddling is always practiced in near impermeable soils with high expanding clay content, and also in plastic sandy soils. On paddy soil, puddling decreased the mechanical impedance and water intake rate of the soil (De Datta, 1981; De Datta *et al.*, 1978). Puddling can be defined as the mechanical reduction of the apparent specific volume of soil (Yamazaki, 1988). It also generally refers to breaking down soil aggregate at near saturation into ultimate soil particle (Tranggono and Willat, 1989).

The depth of tillage varies from 10 - 20 cm. This provides sufficient loose soil for the later formation of a satisfactory puddle. The first stage in the tillage operation is frequently the plastering of the inner surface of the clod either by hand or by turning a single furrow just inside the field with a plow. The topsoil is made finer, stirred and moved. A cutaway disk or turning plow that breaks large furrows and incorporates organic matter accomplishes this.

In the secondary tillage of plowed land, the harrow and rotary plow are two main implements. The rotary plow is the most favoured as it can produce a greater degree of soil puddling. The rotary plow is usually used for this task. Both first and second tillage can be combined together in one pass. The energy and time requirements are less than in separate operations to take puddling condition.

Considering the high-energy consumption of the rotary plow, the sizes of tractor available are frequently unable to achieve the required depth of work, hence a new generation of implement is needed.

Wetland Cultivation

Presently mechanical cultivation of wet paddy presents a difficult problem in developing countries where mechanization has not been successfully practiced. In countries where power resources are limited, cultivation may be done using a hand tool or in some cases by treading of animals. Animal drawn implements often consist of comb harrows or wooden or metal drums with lugs or blades. On the contrary, in countries where mechanical resources are in abundance, the land is usually cultivated dry and drilling in slightly moist soil, followed by irrigation or by broadcasting over already flooded areas. In these countries, a rubber tyre tractor may be used. Tractor drawn puddles may include a steel drum with blades, tine tillers, disc harrows or power rotary tillers aided by cagewheels. Cagewheel extensions have proved advantageous in assisting the puddling, improving traction and pressing down organic matter.

Despite the number and types of implement currently available in the market, no standard implement has so far been recommended for creating the desired puddled layer although the rotary cultivator, disc harrow, rotary puddler and tine tiller have been found popular. The capacity of this equipment is low and the draught of the conventional disc harrow is high (Dutt *et al*., 1986).

Tillage operations are especially consume a lot of energy. The consumption of energy as well as the wear and tear of tractors and implements increases sharply with working depth. The traditional and still widely practiced tillage is based on a series of primary cultivation, aimed at breaking the soil mass into a loose system of clods of mixed sizes, followed by secondary cultivation aimed at pulverization, repackaging and smoothing of the soil surface. These practices performed uniformly over the entire field often involve a whole series of successive operations each of which is necessary to correct or supplement all the previous operations at the cost of energy usage.

Sarker (1985) has compared pre-irrigation and post irrigation tillage techniques on a basis of water consumption, rice yields and cost of operations. Results obtained show that some farmers tilled their land as many as five times before final land preparation. Comparing figures on water use for land soaking and land preparation show that water saving associated with pre-irrigation tillage practices is highly significant. Pre-irrigation tillage reduces the number of tillage operations after land soaking to a minimum of one, and more tilling operations are not required. On the other hand, post irrigation tillage requires at least three tillings or plowing operations and the same number of puddling operations to prepare land for transplanting. It was found that the variations in crop yields for pre-irrigation tillage and post irrigation tillage practices were significantly different at the one-percent level with pre-irrigation tillage giving the higher yields. However, the difference in costs for tillage operations between these two practices was statistically insignificant. In the light of these findings, savings in water needed for land preparation are possible by practicing pre-irrigation tillage rather than post irrigation tillage.

Constraints to Improving Soil Cultivation

Presently considerable progress has been made in designing low energy implements for dryland cultivation. For wetland cultivation, however, the design of new implement is limited. The pressing need for design information to supplement the current qualitative procedures has demanded that methods for design be developed. Basic tools such as the traditional wooden plow date back to antiquity, yet, they are still found in their original form in many parts of the rice growing countries. Even in more advanced societies the moldboard plow is designed by empirical methods. The tool is varied in some manner and acceptable designs are identified when the resulting soil condition is adjudged to be satisfactory. Quantitative descriptions or representations of the final soil condition are seldom used and, in addition, the forces required to move the tool are frequently not quantitatively assessed.

The success of any tillage operation depends on creating the right disturbance and this is determined by implement shape that can be categorized into very narrow blade, narrow blade and wide blade. There are three more groups of implements that cover sideways angled blades, wheels or rolls and powered tines. The sideways angled blades include moldboard plows, disc plows and disc harrows, while the wheel category includes plain, peg tooth, grumbler rolls and presses. The powered tines include horizontal and vertical axis powered rotary cultivators.

Over the years, there has been little improvement in the implements used for rice cultivation. The introduction of tractor power has often not affected the type of implement used. Spoor *et al.* (1985) reported that for efficient equipment design and selection, it is vital to have knowledge of the necessary soil condition and of the transformation needed to achieve them. Implements selected or desired must produce the required results under prevailing soil and moisture conditions and utilize minimum power and draught. In the light of the difficulty in developing new implement for wetland cultivation, advances could be made by resorting to fundamental studies under the prevailing soil and moisture conditions.

According to Gill and Vanden Berg (1968), the key to the development of a scientific approach to tillage is the establishment of a soil-implement mechanic base capable of describing and predicting the action of a tillage tool on the soil. Once a realistic soil-implement mechanic base is developed, it can serve to predict soil behavior and help in the selection of appropriate tillage tools and in the improvement of tillage efficiency. Hence, for wetland tillage research, it is vital to conduct an investigation on the reaction of wet soil to external forces imposed by agricultural implements and the energy input required while working in the wetter range. This is important since choice of implement and the level of moisture content have significant effect on the power requirement and resultant mixture.

There are many obstacles to machine use: low soil-bearing capacity, deficiency of farm roads, high machinery prices, lack of mechanical knowledge,