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This work is related to Contract No. AID/csd-834 with The International Rice Research Institute.

Copies of this report have been filed with:

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JAN 28 1969

Paddy Wheel Study

Introduction:

In Substantive Report No. 1 four objectives were listed for the study of paddy wheels:

1. Develop a method for determining the performance of small wheels. (Performance factors to include drawbar force, power efficiency, and sinkage - each through a range of slip values.).

2. Determine relative performance of small wheels selected by IRRI and sent to us.

3. Analyze test data and develop wheels to extend information.

4. Analyze causes of power losses and forces acting on the wheel system.

In Substantive Report No. 3 data collection was planned for the summer and fall of 1968. The progress to date and when objectives will be realized are as follows.

The equipment necessary for making basic measurements from which performance can be evaluated has been built (Report No. 3). The tests were carried out on schedule in the fall of 1968. Some of the data reduction has been done but not a sufficient amount to determine the relative performance of the selected wheels. This will be included in the next report. Some indications on effect of diameter, width, number of lugs, etc., may be forthcoming, but the purpose of this study was to determine relative performance. It is hoped that one or two wheels may show superiority in several performance factors, but even if they do it may not be possible at this time to correlate performance with wheel geometry. Plans for extending the information by developing new wheels are being made. Dr. Kahn of IRRI has suggested a study on a special wheel where certain geometrical dimensions can be varied. Other special research wheels may have to be built to isolate the effects of specific design factors.

Power losses were to be analyzed. This should be in the next report. Sinkage was measured in all tests and by using a modified mechanics such as proposed by Chang and Cooper in Report No. 3, losses and forces may be determined.

The next report should bring realization of all objectives with the exception of extending information to other wheels. The analysis of the data should help in planning for extension of the information.

This report contains detailed information on the tests conducted during this reporting period with examples of the type data reduction being done.

Test Wheels and Soil:

Six right-side and one left-side paddy wheels, as shown in Figs. 1 & 2 and described in Table 1, were studied in the outdoor soil bin of NTML. Two soils were used for the tests, the Decatur silty loam and the Vaiden silty clay. A hard layer with a cone index of 500 psi was induced in each soil about 6" below the soil surface. The soils were flooded and tests conducted with about 1" of water above the soil surface. The soil conditions were characterized by moisture content and flat plate sinkage measurements.

Defining Slip:

In tractor tire tests at NTML zero travel reduction has been used which is defined at zero pull. In soft soil conditions there is considerable slip at zero pull. After a series of special tests, it was found that zero slip is better defined at zero torque which was adopted by this study. Based on this new definition of slip the test data indicated that the applied negative (pushing) force above the zero torque is giving positive slip instead of conventional negative slip which is questionable. A theoretical study will be made and an explanation of the new slip definition will be given in the final report.

Test Specifications:

In order to pick up the zero torque and to meet the special requirement of complete power tiller performance (rotary operation and tractive operation), the wheel tests were operated from approximately -10% slip to +60% slip.

Four series of tests were conducted on each of the two soils:

1. Effect of wheel design - 6 wheels used

   V (Initial forward velocity) = 1.75 ft/sec (1.19 mph) for rolling radius (r_o) = 16.5" (for W-2, 4, 5) and 1.45 ft/sec for r_o = 13.5" (W-1, 3)

   ω (Angular velocity of paddy wheel) = 1.25 rad/sec

   $\overline{W}$ (Static weight) = 400 lbs

2. Effect of load (Wheel W-5 used)

   $\overline{W}$ = 290, 350, 400, and 450 lbs

   V = 1.75 ft/sec (1.19 mph)

   ω = 1.25 rad/sec

3. Effect of velocity (Wheel W-5 used)

V_o = 1.75 ft/sec (1.19 mph) ω_o = 1.25 rad/sec

V_1 = 2.45 ft/sec (1.68 mph) ω_1 = 1.75 rad/sec

V_2 = 3.15 ft/sec (2.15 mph) ω_2 = 2.25 rad/sec

V_3 = 3.50 ft/sec (2.40 mph) ω_3 = 2.50 rad/sec

$\overline{W}$ = 290 lbs

4. Directional effect of wheel (Wheel W-5L)

V = 2.45 ft/sec

ω = 1.75 rad/sec

W = 400 lbs

Left-hand wheel operated on right-hand side for determination of performance in backing up.

Type of Information Obtained:

A set of typical measured data and analysis are shown in Fig. 2 to Fig. 8. Figs 4-8 present sample performance data using wheel no. 2 in Vaiden soil with a static wheel weight of 400 lbs, 1.75 ft/sec initial forward velocity, and a constant wheel angular velocity of 1.25 rad/sec. The analysis of data was based on the modified Chang-Cooper mechanics by changing tan θ to sin θ and defining zero slip at zero torque (See Fig. 3).

Rotary Tillage Study

The project investigation leader, L. W. Larson, was transferred to Beltsville, Maryland, in June. J. G. Hendrick was assigned to conduct research in the area of powered tillage tools in November.

The analysis of data on the special blades constructed at NTML and described in Substantive Report No. 3 is still underway. F. P. Smits, who returned to Holland in July, has the data and is completing the analysis. The report of this work will complete the tentative blade evaluation study from the standpoint of power requirements.

Currently, it appears that there are four large areas in which research on rotary tillage is needed. Research must be conducted to provide:

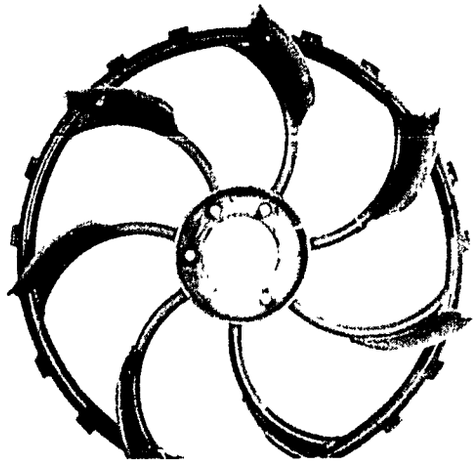
1. A method (or methods) to measure the performance of various powered tillage tools from a soil change standpoint. This will require an understanding of the cultural requirements of rice production and the intended function of the tillage tool.

2. An analysis of the comparative performance and energy requirements of selected existing rotary tools. Such research would provide information presently needed, and it should give insight into which phenomena need to be investigated in a more basic manner.

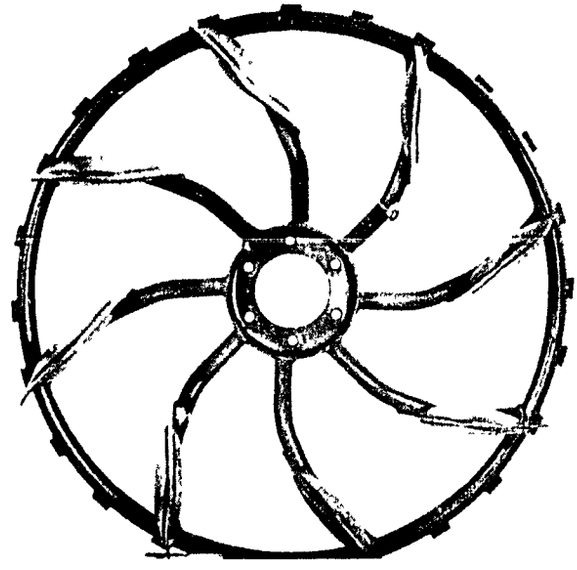
3. A better understanding of the soil-tool relationships in such relatively high speed tillage operations as rotary tillage in a wide range of soil conditions, to develop criteria for the design and production of efficient powered tillage tools.

4. The development of a tillage-mobility system for wet-and/or-dry-land culture, since it is apparent that tillage and mobility can't be isolated from one another in many instances.

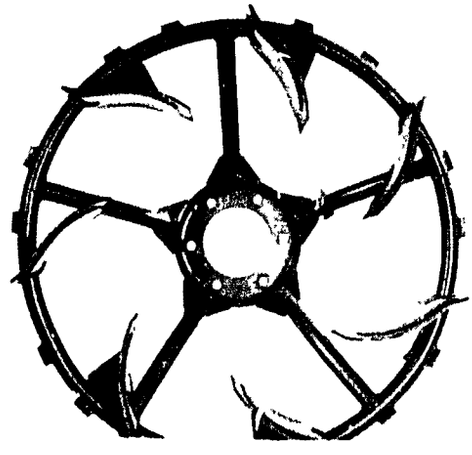
Research plans are being developed in these areas. Those projects which appear to have the most immediate need and those which appear to have the best potential for future benefit will be given priority.



W - 1

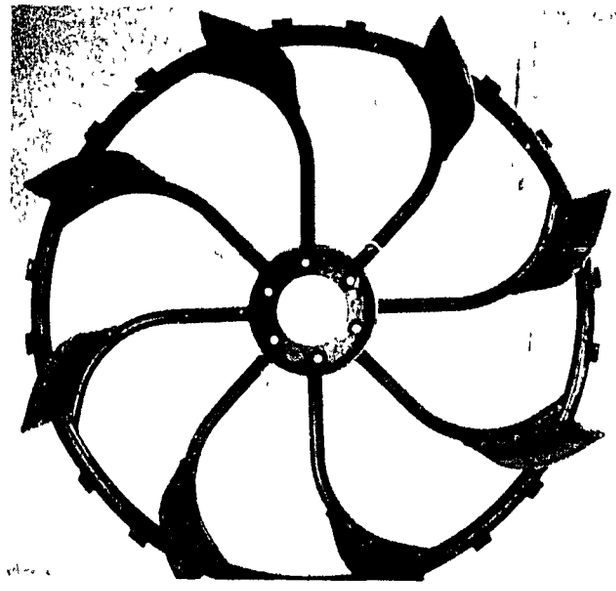


W - 2

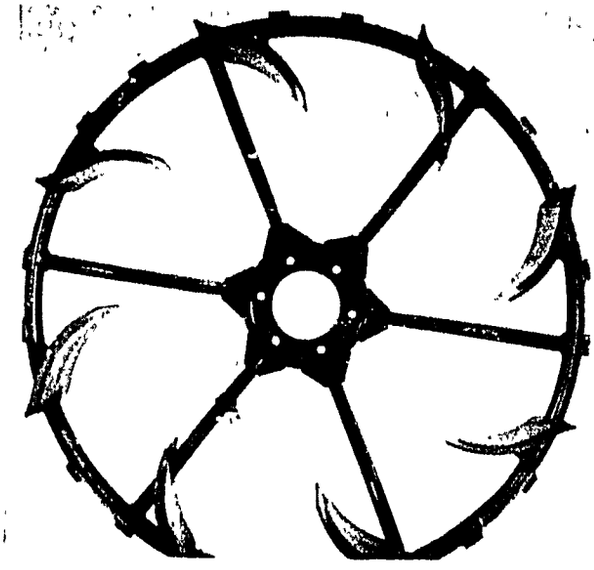


W - 3

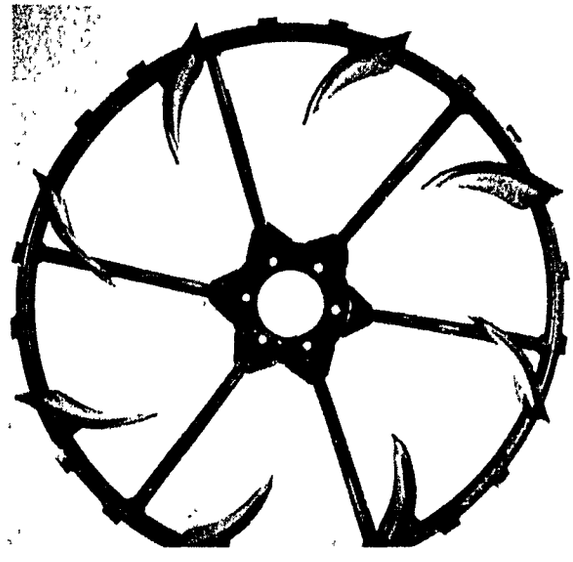
Fig. 1-1. Tested Wheels



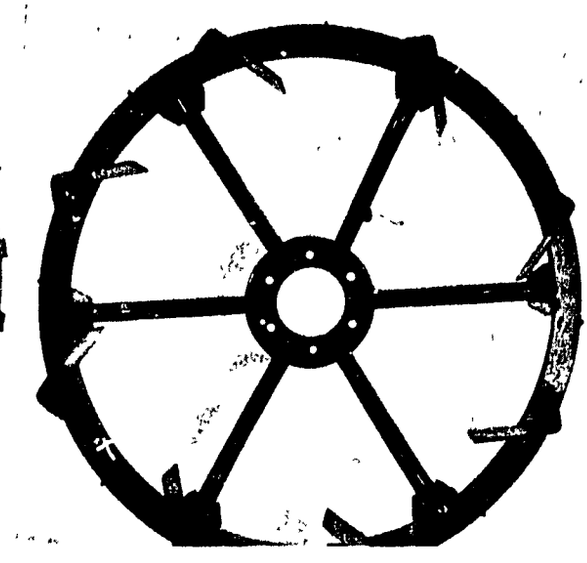
W - 4



W - 5



W - 5-L



W - 6

Fig. 1-2. Tested Wheels

Table 1. Dimension of the Tested Wheels (See Fig. 1, 2)

	Overall Dia. D (in)	Lug Width B (in)	Hub Length b (in)	Lug Length a (in)	Lug Radius R (in)	Lug Angle α (°)	No. of Lugs	Remarks
$\overline{W}$-1	27	8	0	6-1/2	6	45	7	Bent at end
$\overline{W}$-2	32-1/4	12	3	6(avg)	9	50	8	Hollow lug
$\overline{W}$-3	27	8	5-3/4	7-1/2	8	45	7	Bent at end
$\overline{W}$-4	33	9	4	7	6	45	8	Bent at end
$\overline{W}$-5	33	7-3/4	8	7-1/2	8	45	8	Bent at end
$\overline{W}$-5-I	33	7-3/4	8	7-1/2	8	45	8	Bent at end
		5	5	4-1/2, 2-1/2	∞	55	8	Bent 80°

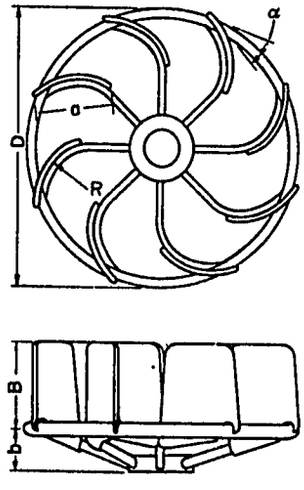
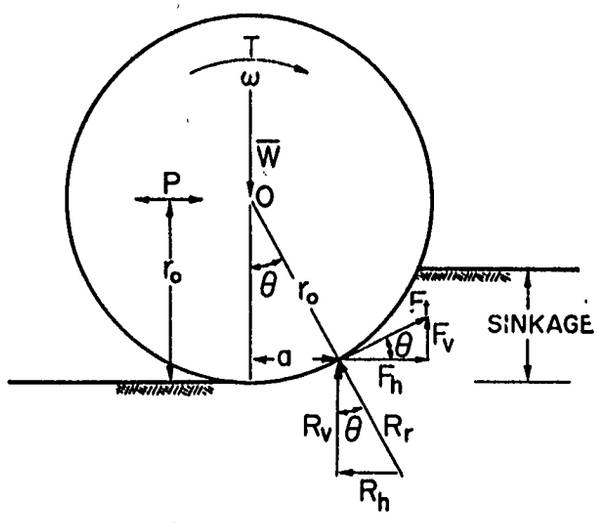


Fig. 2. Dimensions of the Tested Wheels



$\overline{W}$ - Dynamic weight

T - Torque

ω - Angular velocity

F_t- Resultant Tangential force

F_h- Thrust force

F_v- Vertical frictional force

R_r- Resultant radial force

R_h- Rolling resistance

R_v- Vertical component of R_r

θ - Rolling angle

P - Push & pulling force

r_o- Rolling radius

Fig. 3. Proposed force diagram for the tested paddy wheels

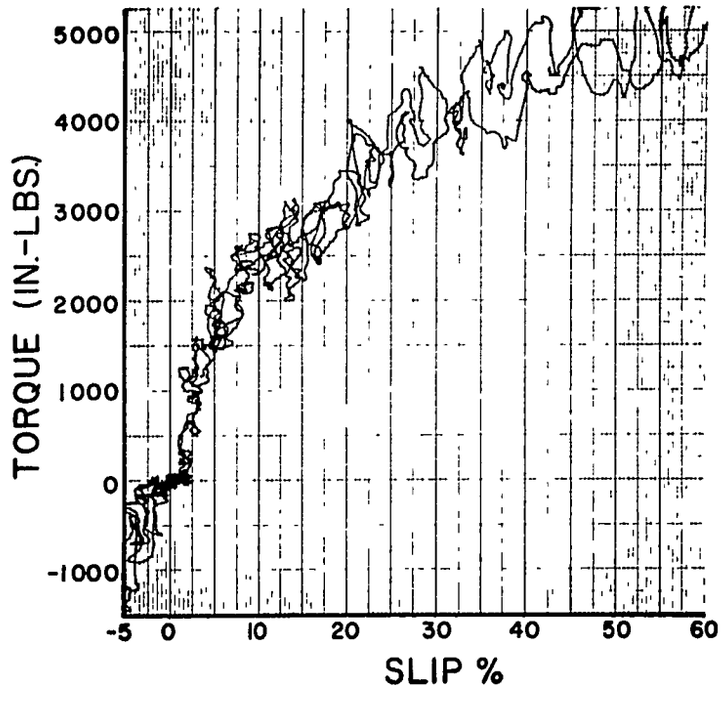


Fig. 4. Original torque-slip curve plotted by X-Y plotter for W-2, 2 replications PW-8 and PW-9

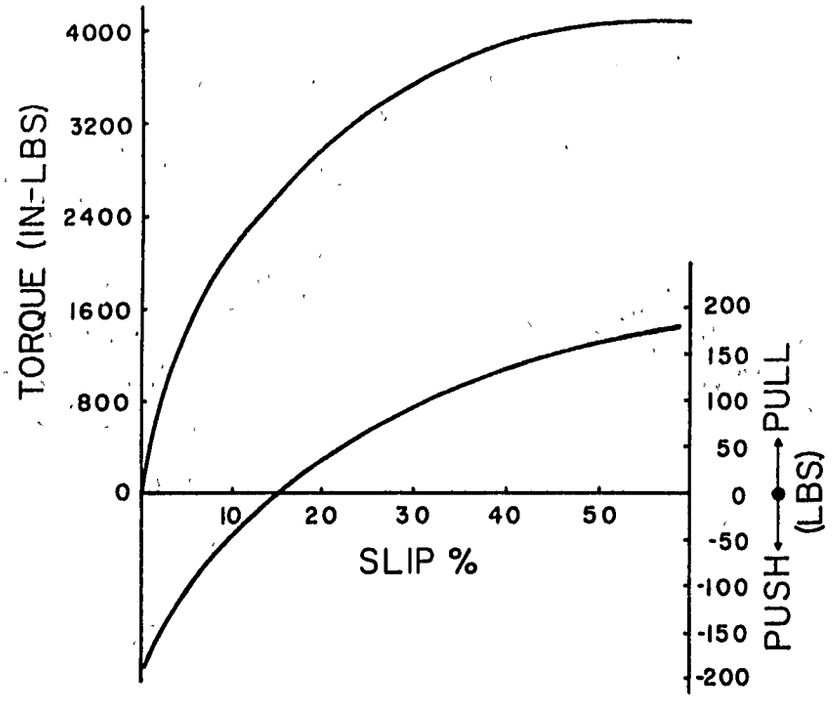


Fig. 5. Torque push and pull versus slip for W-2 (Test PW-9 - W-2)

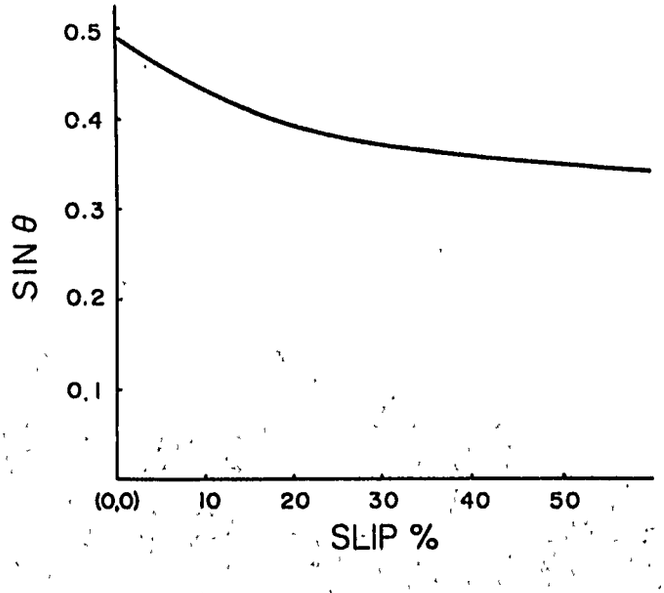


Fig. 6. Sin θ versus slip for W-2 (Test PW-9 - W-2)

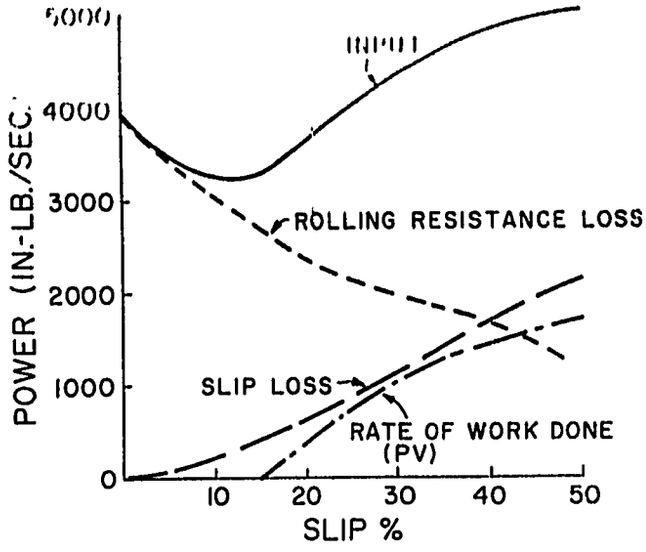


Fig. 7. Input and output versus slip for W-2 (Test PW-9 - W-2)

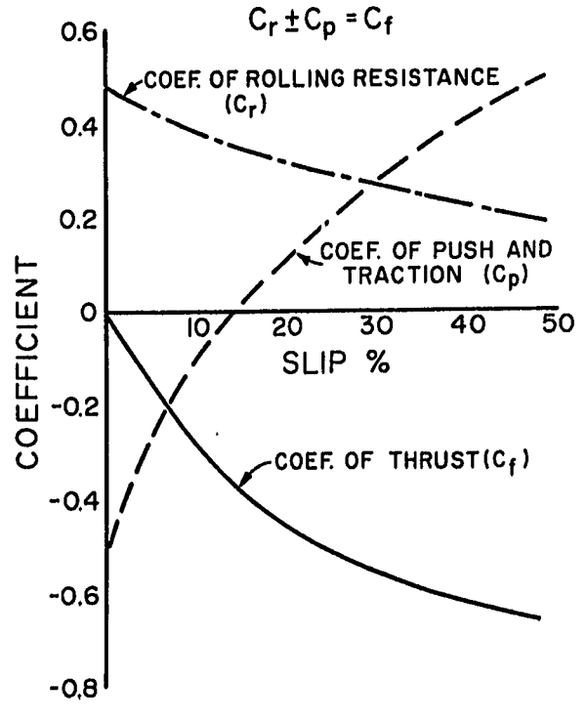


Fig. 8. Coefficient of horizontal forces versus slip for W-2 (Test PW-9 - W-2)