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Studies on the Wear of Tines of Power Tillers

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I. Introduction

The wear of the tines of power tillers is a very important element that affects the machine performance and the economy of farmers. But we have had very few informations in this line. The following wear tests were performed in the laboratory with a special wear-test machine and also in the field with power tillers.

The laboratory tests were conducted occasionally from 1950 to 1952 and the field tests on September 1952.

II. Laboratory Test

In the laboratory test, we designed a special wear-test machine and measured the wear resistance of the tines with this machine.

(1) Wear-test machine

The wear-test machine is shown in Fig. 1 and 2. This machine consists of a soil tank made of iron plate, and a tine shaft driven by a 2-HP electric moter. The bearing of the tine shaft has a special construction so that soil in the tank may not get into it, when the tine is working in the soil. (see Fig. 3)

(2) Test tines

Three kinds of steel tines were selected on the market and we named these three No. 1, No. 2 and No. 3. The shape and the size of these tines are shown in Fig. 4. The original mean weight, the chemical components and the hardness of the tines are shown in Table 1, 2, and 3. The hardness of the tines was measured with Rockwell C scale at the mark points of both inner and outer surfaces as represented in Fig. 5.

In the test, two pieces of tines of the same kind, six pieces in all, were set on the tine shaft and the order of the tine setting was No. 1-No. 3-No. 2-No. 1-No. 3-No. 2 so that the tines may work uniformly on the soil in the tank.

(3) Soil

Dry sands were screened and only those grains of sands that passed through a 17-mesh screen were used. These grains are from approximately 0.25 to 1.2 mm. in diameter. The soil tank was filled with the sands in the manner that the working depth might be 12 cm. as uniformly as possible, and the sands were

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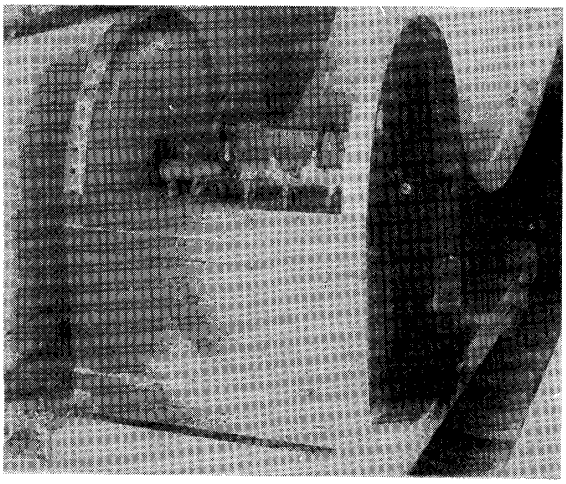


Fig. 1. Wear-test Machine

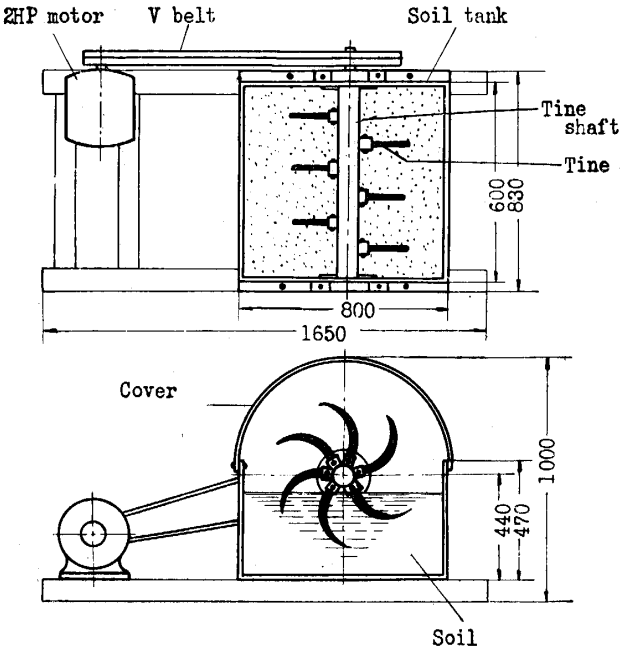


Fig. 2. Wear-test Machine in diagramatically (unit: mm)

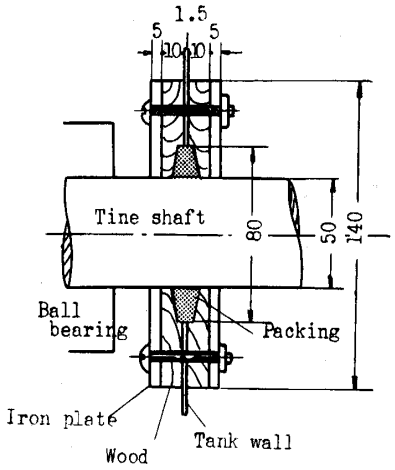
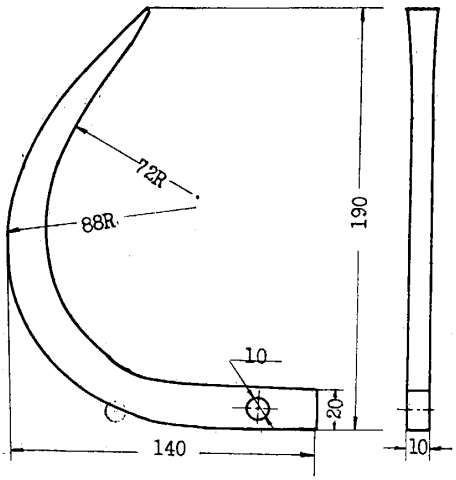
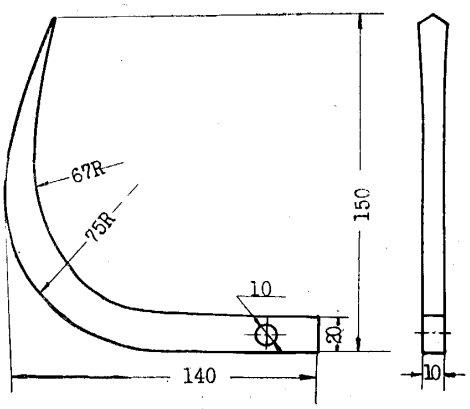


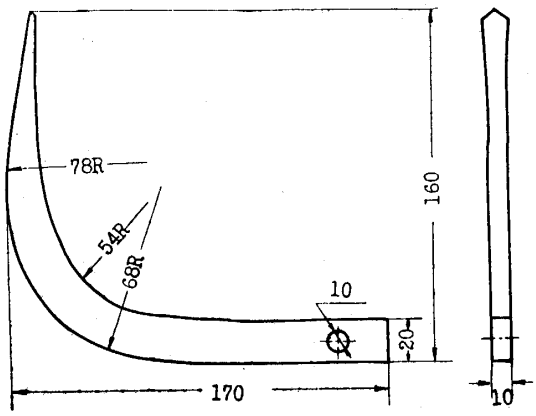
Fig. 3. Cross sectional view of special bearing is used on the wear-test machine. (unit: mm)



Tine No. 1



Tine No. 2



Tine No. 3

Fig. 4. Shape and Size of Three Tines on the Market (unit: mm)

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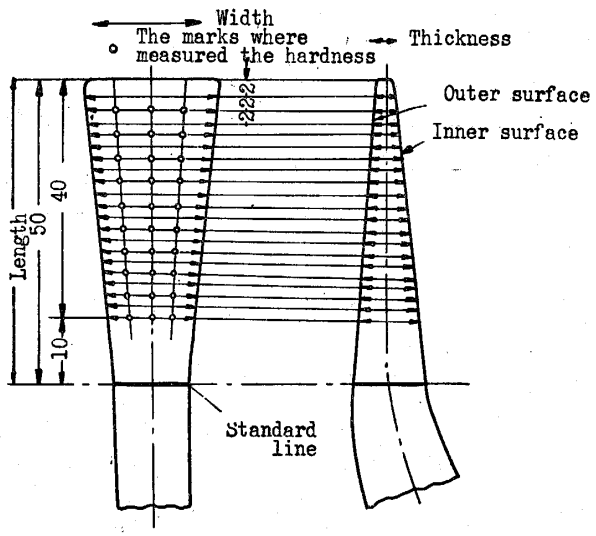

Fig. 5. The marks where measured the length, thickness, width and hardness (unit: mm)

Table 1.
Original weight of tines (mean)

Tines	Weight (gr.)
No. 1	318.72
No. 2	291.76
No. 3	269.38

Table 2. Chemical components of tines

Tines	C	Si	Mn	P	S
No. 1	1.20	0.21	0.48	0.051	0.010
No. 2	0.70	0.25	0.70	0.035	0.025
No. 3	0.30	0.15	0.50	0.081	0.045

Table 3. Hardness of tines

Tines	Hardness (Rockwell C scale)	
	Inner surface	Outer surface
No. 1	29.5	30.5
No. 2	52.7	33.8
No. 3	26.3	28.0

replaced with new ones every five hours, because the sands crushed to fine particles and changed in quality by the friction heat in the long running.

(4) Measurement of wear amount

The wear amounts were measured regarding the decrements of weight, lenght, width and thickness. To measure the decrement of length, the standard line was marked before testing at a distance of 50 mm. from the tine point, as shown in Fig. 5 and the decrement of length was determined by measuring a distance from the standard line to the tine point after the running.

The wear amounts of width and thickness were measured with a dial gauge on each mark line drawn at intervals of 2 mm. for 40 mm. from the tine point as shown in Fig. 5.

To find the relation between the wear and the running speed, the number of the revolution of the tine shaft was varied to 290, 400, 480, 570, 640 and 690 r. p. m. respectively.

The wear amounts were measured every five hours and the testing was finished after twenty hours' running, as the tines were worn away extremely.

(5) Result of the testing

(A) Decrement of weight. As the original weight of the tines differs more or less from each other, the decrement of weight is expressed by "wear rate" and if the original weight and the weight after wearing away are designated as W and W', the wear rate of weight is defined as follows:

$$\text{Wear rate of weight} = \frac{W-W'}{W} \times 100(\%)$$

The wear rates of weight of each tine at eace revolution are shown in Fig. 6.

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It is found that the wear rates of weight are increased as the revolution is higher, that is, the wear rates are about 2~3% at 290 r. p. m., 2~5% at 400 r. p. m., 6~7% at 480 r. p. m., 8~10% at 570 r. p. m., 8~12% at 640 r. p. m., 8~10% at 690 r. p. m. after twenty hours' running.

(B) Decrement of length. The decrements of length at each revolution are shown in Fig. 7. It shows that the decrements of length at high revolution after twenty hours' running, reached about 18~28 mm.; especially tine No. 3 wore away more than the others at the 640 r. p. m.

(C) Decrement of width. If the original width and the width after wearing away are designated as B and B', the wear rate of width is defined as follows:

$$\text{Wear rate of width} = \frac{B-B'}{B} \times 100\,(\%)$$

The wear rates of width of each tine at each revolution are shown in Fig. 8. At the higher revolution, the wear rate of width reached about 50~80%, especially that of tine No. 3 reached about 95%.

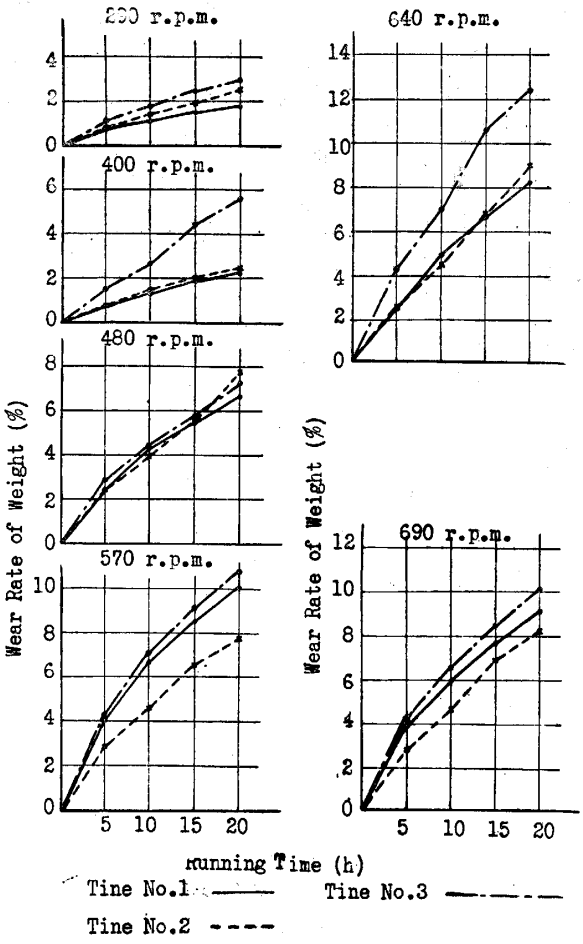

Fig. 6. Wear Rate of Weight

(D) Decrement of thickness. If the original thickness and the thickness after wearing away are designated as D and D', the wear rate of thickness is defined as follows:

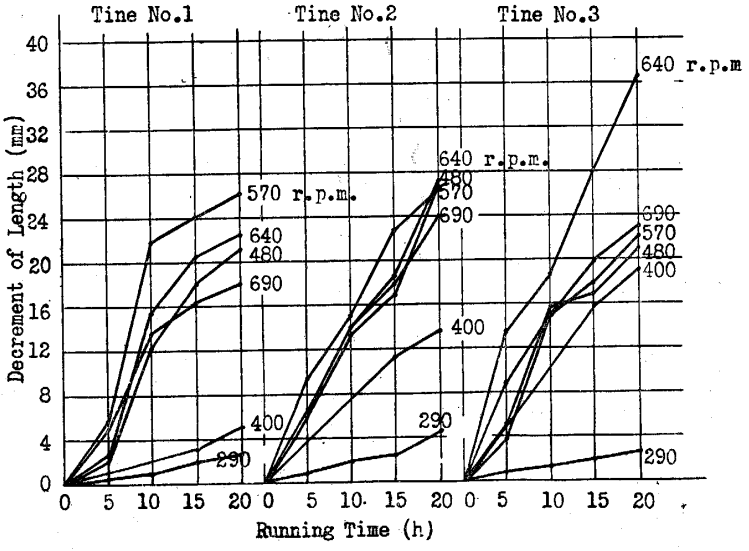

Fig. 7. Decrement of Length

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$$\text{Wear rate of thickness} = \frac{D - D'}{D} \times 100(\%)$$

The wear rates of thickness of each tine at each revolution are shown in Fig. 9. Generally as the revolution is higher, the rate is more increased.

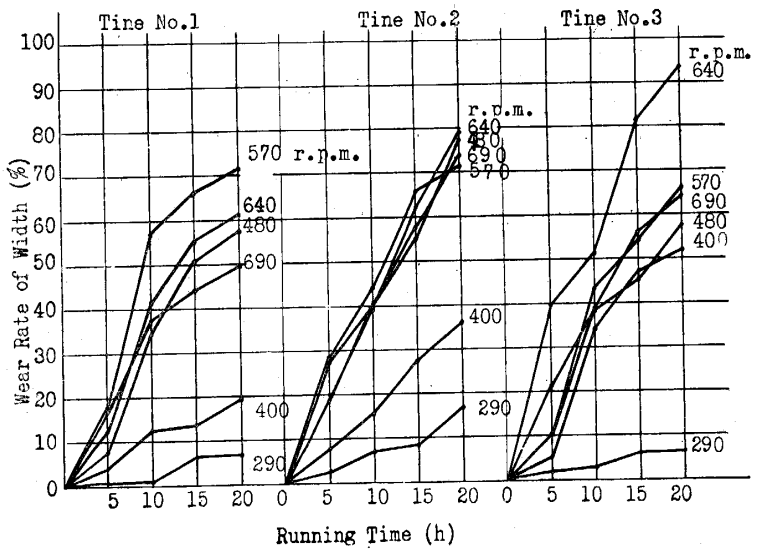

Fig. 8. Wear Rate of Width

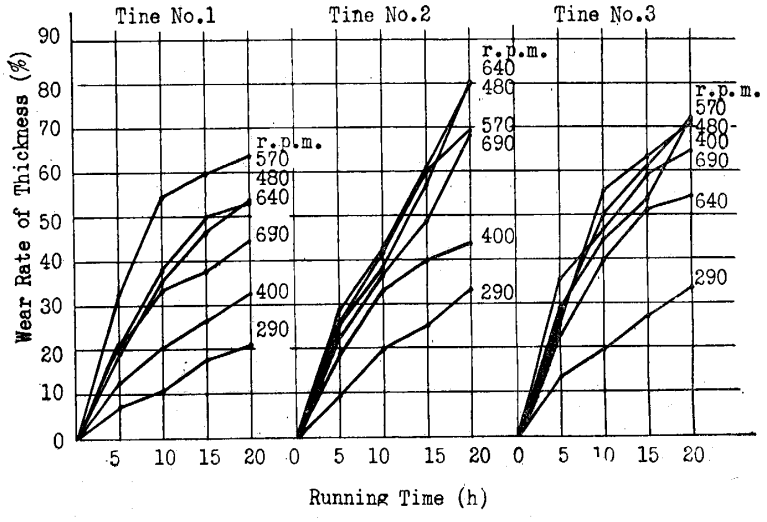

Fig. 9. Wear Rate of Thickness

(E) Appearance of worn tine. The appearance of worn tines after twenty hours' running is shown in Fig. 10~Fig. 15. It is found that the pitting breaks out on the surface and the irregular wear occurs at the point.

The appearance of worn tines observed every five hours is shown in Fig. 16~Fig. 21. It shows that the wear of tines is extreme in these tests.

(6) Discussion

The wear of the tines on the market is so severe, that they can hardly be used after twenty hours' running in the sandy soil.

The selection of material and the suitable heat treatment of tine are very important for prolonging the life of tine.

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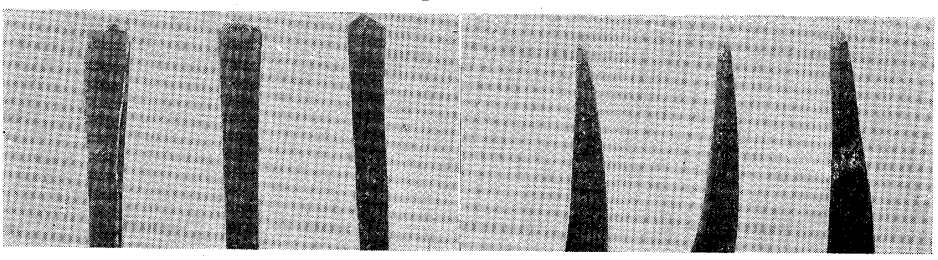
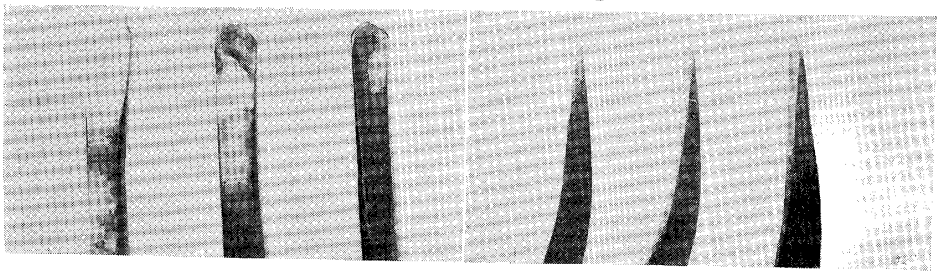
Fig. 10. Tines Revolution: 290 r. p. m.

No. 1 No. 2 No. 3 No. 1 No. 2 No. 3

Original Form



After 10 hours' running



After 20 hours' running

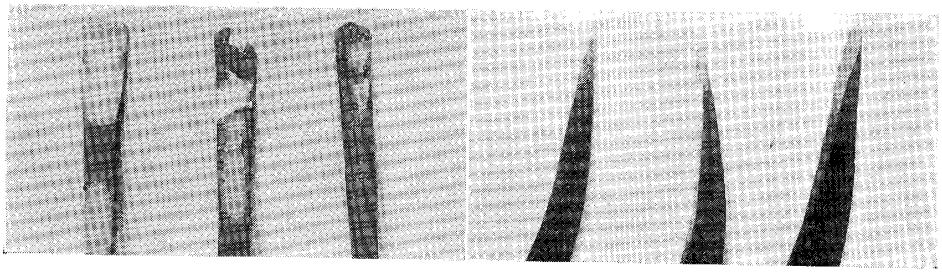
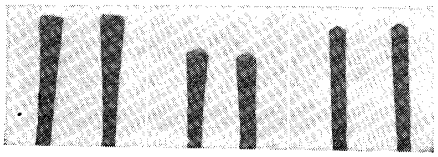


Fig. 11. Tines Revolution: 400 r. p. m.

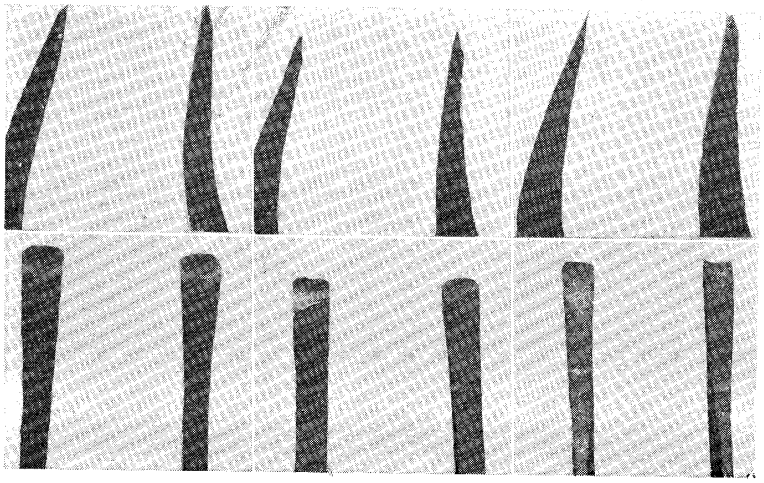
No. 1 No. 2 No. 3

Originlal Form



No. 1 No. 2 No. 3

After 10 hours' running



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After 20 hours' running

No. 1 No. 2 No. 3

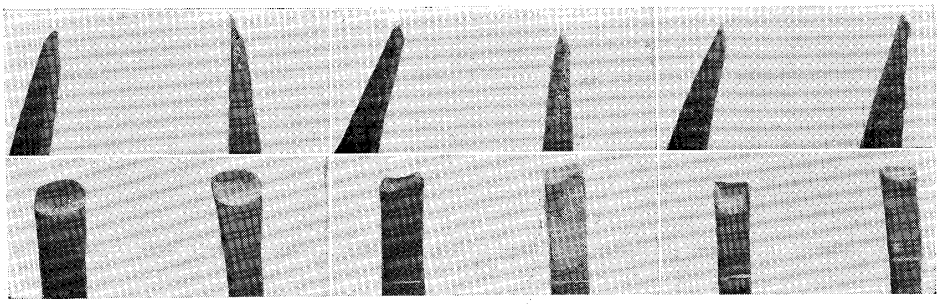
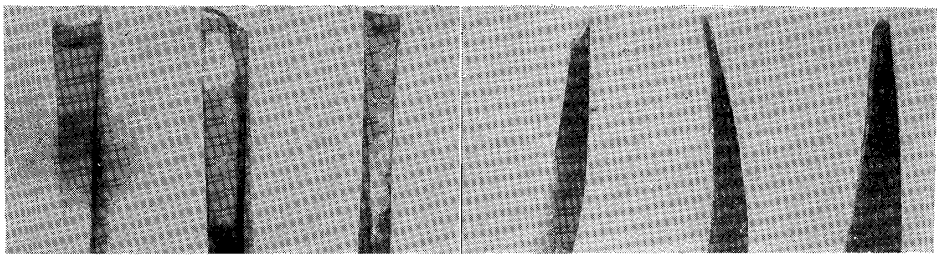


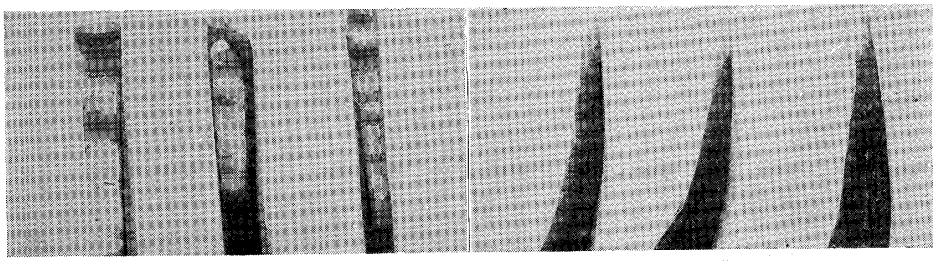
Fig. 12. Tines Revolution: 480 r. p. m.

No. 1 No. 2 No. 3 No. 1 No. 2 No. 3

Original Form



After 10 hours' running



After 20 hours' running

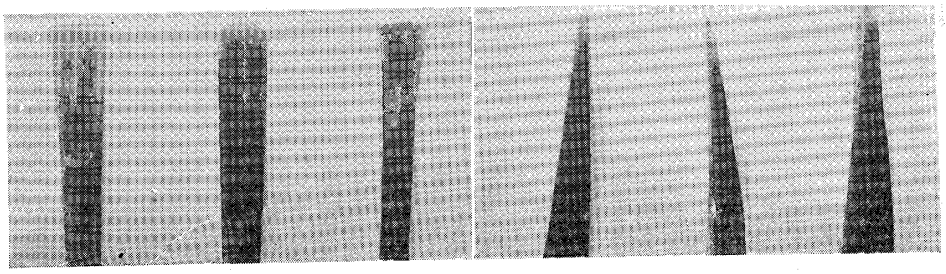
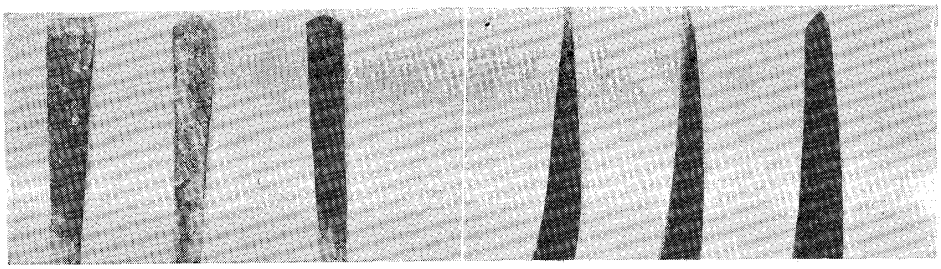


Fig. 13. Tines Revolution: 570 r. p. m.

Original Form

No. 1 No. 2 No. 3 No. 1 No. 2 No. 3



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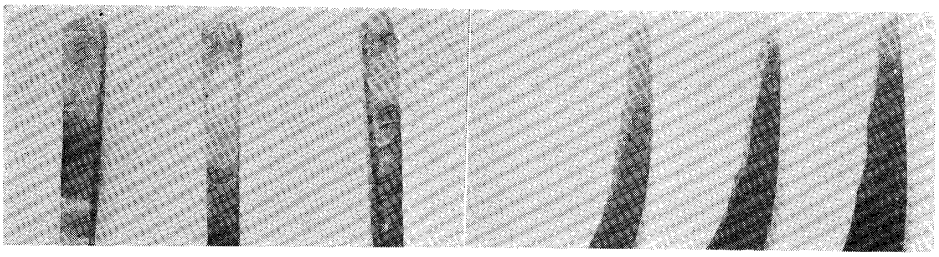
After 10 hours' running



After 20 hours' running

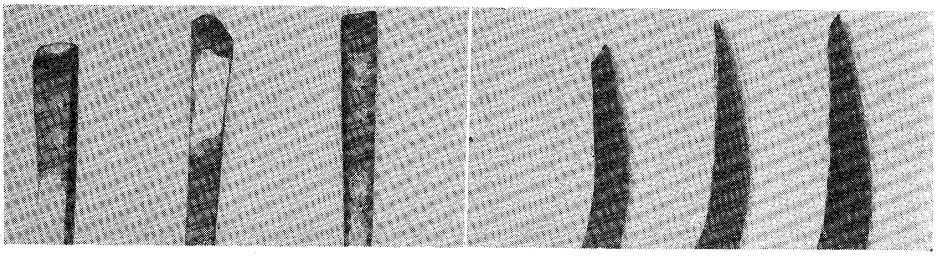
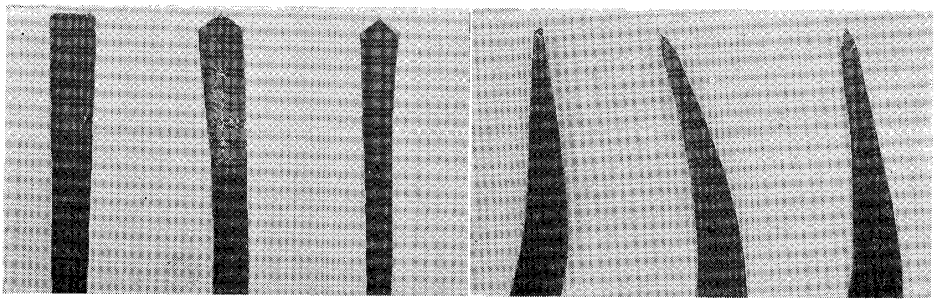


Fig. 14. Tines Revolution: 640 r. p. m.

No. 1 No. 2 No. 3 No. 1 No. 2 No. 3

Original Form



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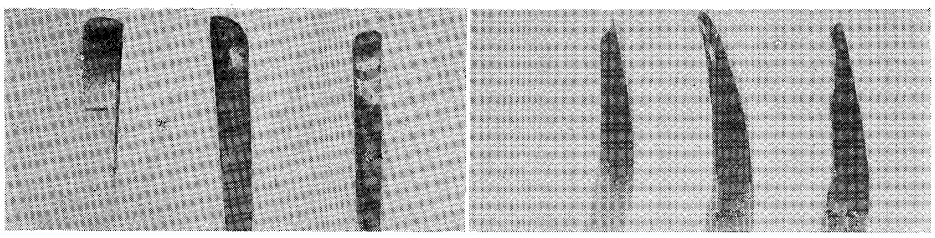

After 20 hours' running

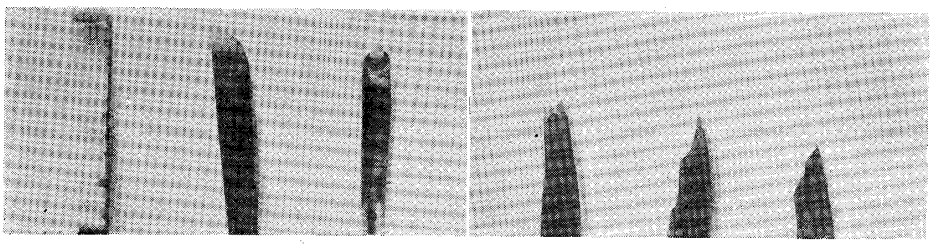

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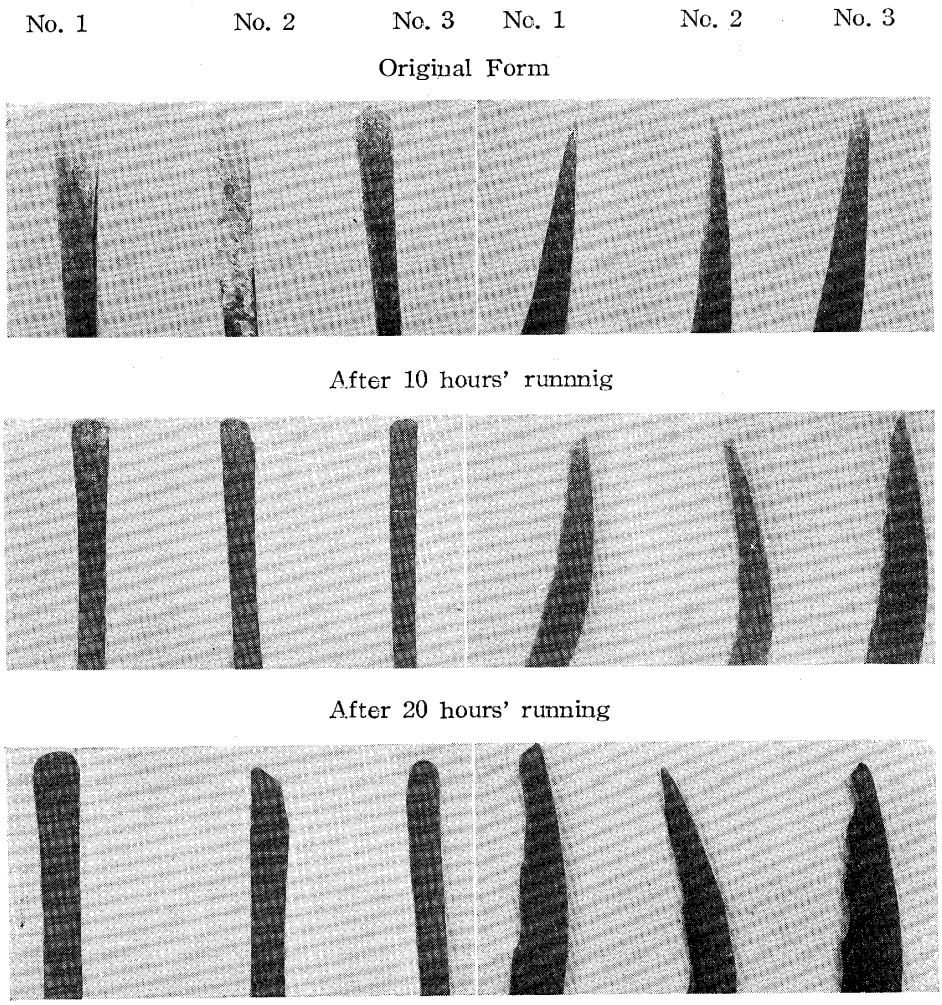
Fig. 15. Tines Revolution: 690 r. p. m.



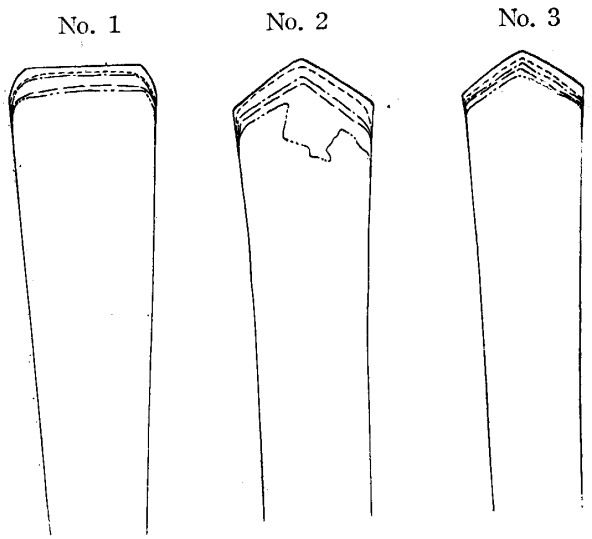


Fig. 16. Appearance of worn tine at 290 r.p.m.

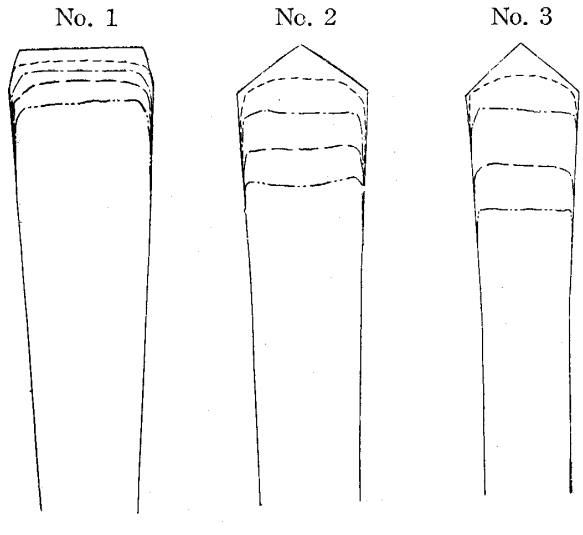


Fig. 17. Appearance of worn tine at 400 r.p.m.

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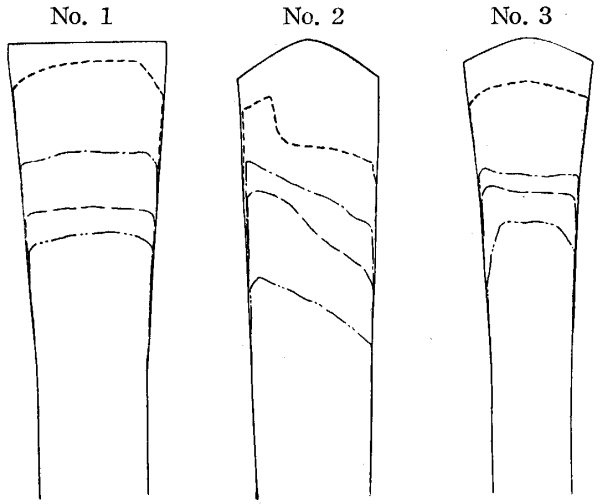
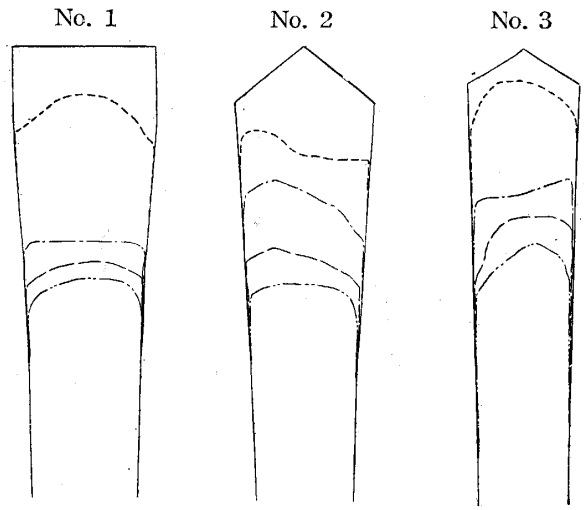


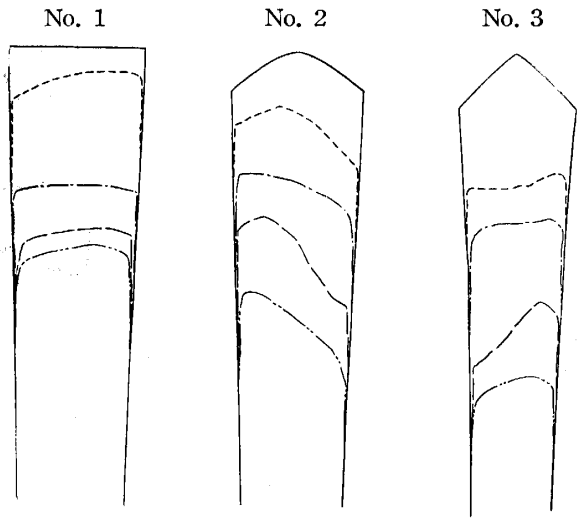
------ after 5 hours' running
—·—·— after 10 hours' running
— — — after 15 hours' running
—··—··— after 20 hours' running

Flg. 18. Appearance of worn tine at 480 r.p.m.



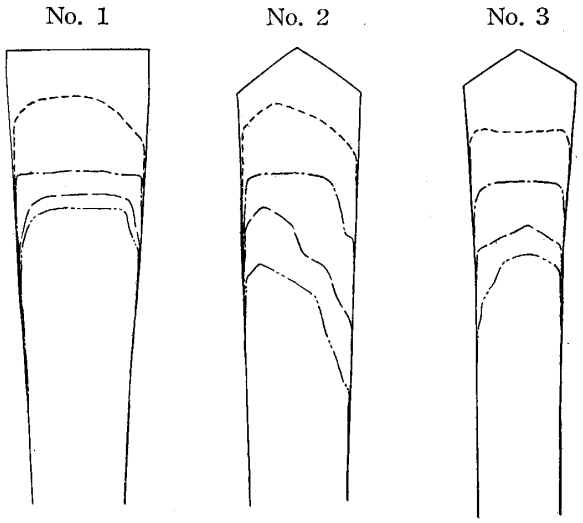
------ after 5 hours' running
—·—·— after 10 hours' running
— — — aftar 15 hours' running
—··—··— after 20 hours' running

Fig. 19. Appearance of worn tine at 570 r.p.m.



------ after 5 hours' running
—·—·— after 10 hours' running
— — — after 15 hours' running
—··—··— after 20 hours' running

Fig. 20. Appearance of worn tine at 640 r.p.m.



------ after 5 hours' running
—·—·— after 10 hours' running
— — — after 15 hours' running
—··—··— after 20 hours' running

Fig. 21. Appearance of worn tine at 690 r.p.m.

III. Field Test

In the field test, we used two power tillers and two kinds of tine; "Ordinary" type and "Flat knife" type. The former is the same kind as used in the laboratory test, the latter is called "Nata Tsume" in Japanese, which means "hatchet" tine and has an advantage that the weed does not twine round on it, but it seems to wear away rapidly.

In this investigation, we attempted to compare the wear resistance of both tines.

(1) Test tines. The tines that were tested in the field are shown in Fig. 22. The flat knife tine has a flat surface and it is curved near the point like the moldboard of the plow.

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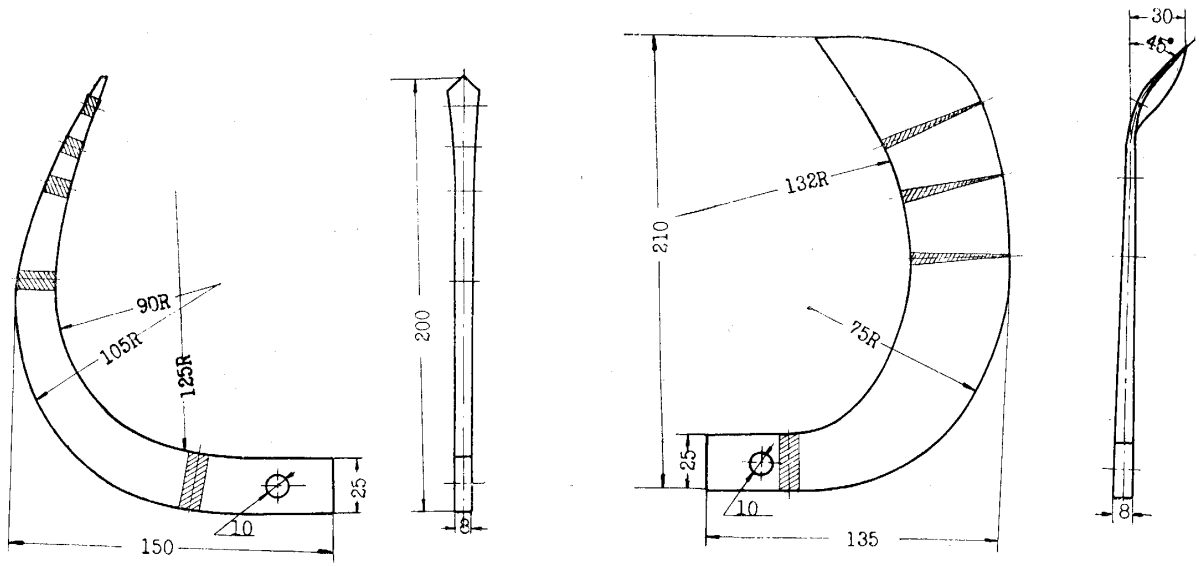

Fig. 22. Shape and size of the tines tested in the field. Left is the ordinary type. Right is the flat knife type (unit: mm)

Sixteen pieces of these tines were set on each power tiller.

The mean weight of the ordinary tine is 357.2 gr. and the flat knife tine is 351.5 gr. The hardness and the chemical components of both tines are shown in Table 4 and 5.

Table 4. Chemical components of tines

Tines	C	Si	Mn	P	S
Ordinary tine	0.32	0.36	0.60	0.032	0.014
Flat knife tine	0.41	0.15	0.72	0.031	0.017

Table 5. Hardness of tines

Tines	Hardness (Rockwell *C* scale)
Ordinary tine	Mean 29.0 Max. 51.8
Flat knife tine	Mean 38.8 Max. 57.0

(2) Power tillers. The power tillers used in this investigation were equipped with $4\frac{1}{2}$HP water cooled petrolem engine as shown in Fig. 23.

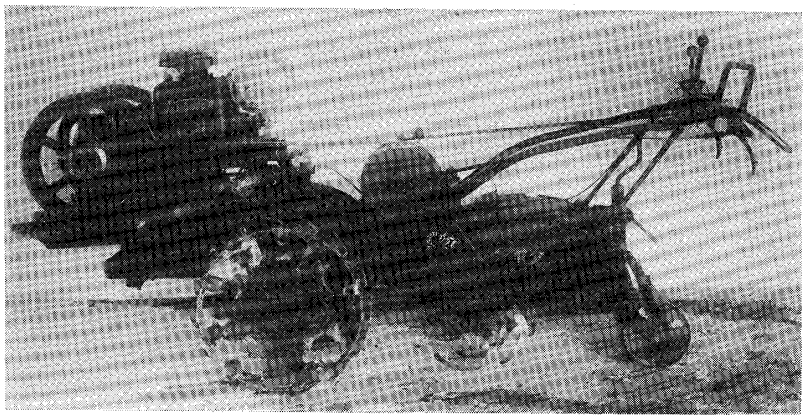

Fig. 23. The power tiller used in the field test

(3) Field. The field that was offered to the test is the farm of our university, the soil is sandy or clay loam. When the test was being performed, the land was furrowed and weeds covered it considerably.

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Table 6 shows the tilling operation area and the water content of the soil. Table 7 shows the conditions of the testing operation.

(4) Measurement of wear. The measuring methods of wear

Table 6. Soil conditon

	Field, tilled with Ordinary tine	Field, tilled with Flat knife tine
Area (Tan)	5.76	7.02
Water content of soil(%)	18.2	17.5

"Tan" is the Japanese unit of area, it is equal to 991.7m².

Table 7. Conditions of testing operation

	Power tiller equipped with Ordinary tine	Power tiller equipped with Flat knife tine
Speed (m/s)	0.35	0.37
Revolution of tine shaft (r. p. m.)	262	265
Mean tilling depth (cm)	7.4	5.5
Mean tilling width (cm)	60.0	60.0
Capacity of tillage (Tan/h)	0.36	0.45
Fuel comsumption (l/Tan)	7.75	2.80

are the same as in the laboratory test. The wear amounts of the tines were measured on the marks indicated in Fig. 24.

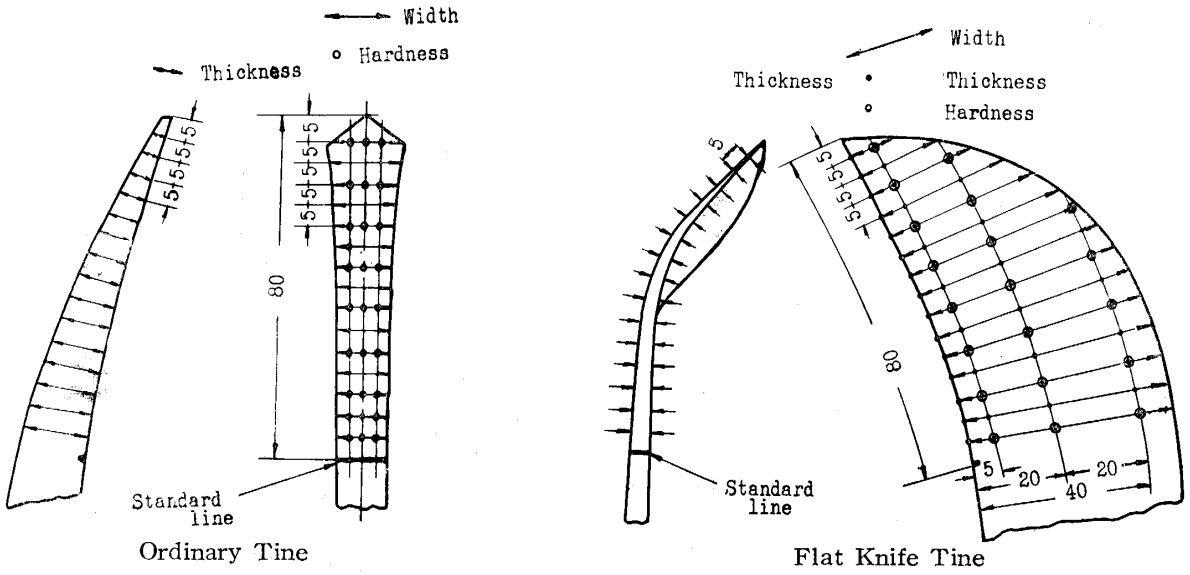

Fig. 24. The marks where measured the length, thickness, width and hardness (unit: mm)

The power tillers were operated for fifteen hours and the wear amounts were measured every five hours.

(5) Results of test

(A) Wear rate of weight. The wear rates of weight are shown in Fig. 25. As figure shows, the wear rate of weight of the ordinary tine is about 3.5%, and the flat knife tine is about 12%; the wear rate of the latter is about 3.4 times as great as the former.

(B) Wear of length. The wear amounts of length are shown in Fig. 26. In the wear amount of length, the ordinary tine wore away more than the flat knife tine.

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(C) Wear rate of thickness. The wear rates of thickness are shown in Fig. 27. The flat knife tine wore away more than the ordinary tine, especially after ten hours' running, and after fifteen hours' running, it wore away about 58%, that is about 3.5 times as great as the latter.

(D) Wear rate of width. The wear rates of width are shown in Fig. 28. It shows that the flat knife tine wore away considerably and after fifteen hours' running it reached about 55%, that is about 3.5 times as great as the ordinary tine.

The appearance of worn tines observed every five hours is shown in Fig. 29.

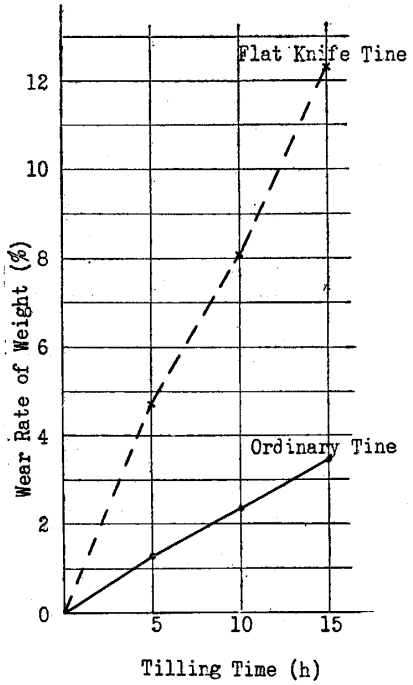

Fig. 25. Wear Rate of Weight

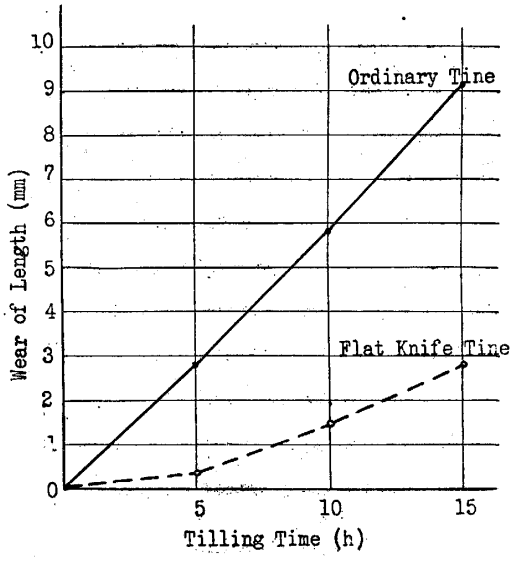

Fig. 26. Wear of Length

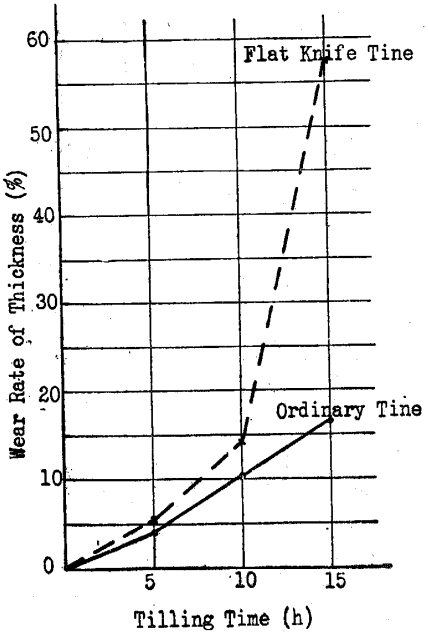

Fig. 27. Wear Rate of Thickness

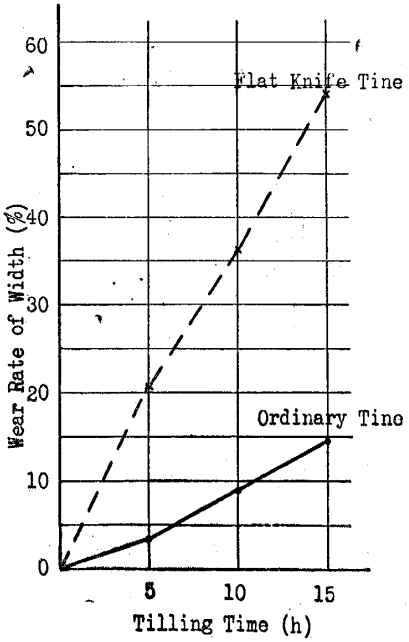

Fig. 28. Wear Rate of Width

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(6) Discussion

The wear amounts of the flat knife tine are generally much more than the ordinary tine, not withstanding that the flat knife tine is superior in hardness.

The flat knife tine has an advantage that the weed does not twine, but it wore away so rapidly that it can not be used after about fifteen hours' running in the field; therefore, it should be improved, especially as to the material and the heat treatment.

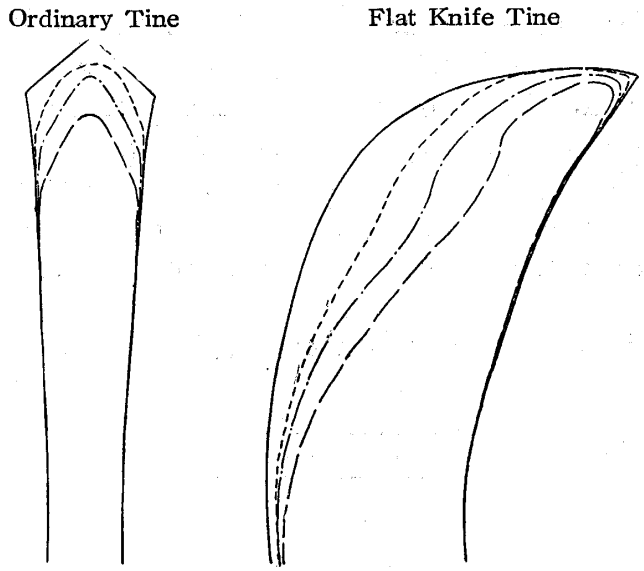

Fig. 29. Appearance of worn tine

IV. Summary

1. A special wear-test machine was designed and the wear tests were performed with it in the laboratory.

2. The tines used in the laboratory test were selected on the market and set on the tine shaft which revolved in the soil tank.

3. The number of revolution of tine shaft varied from 290 to 690 r.p.m. and the tines ran for twenty hours and the wear amounts were measured every five hours.

4. The higher is the revolution, the more increase the wear amount after about twenty hours' running; all the tines wore away so much that they can hardly be used.

5. In the field test, two tines were tested, the one is the ordinary tine and the other is the flat knife tine so-called " Nata Tsume ".

6. These two kinds of tines were set on two power tillers, which carried sixteen pieces of both tines and were operated in the field for fifteen hours.

7. In these investigations, the wear amounts were measured as to weight, length, width and thickness of the tines, and also the hardness and the chemical components of the tines were measured.

8. In the laboratory test, the tines on the market wore away so much that they can not be used after twenty hours' running.

9. In the field test, the flat knife tine wore away much more than the ordinary tine and both tines can not be used after fifteen hours' running.

(November 1953)

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