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Manufacturing and Evaluation of Low-Cost Power Tiller Blades

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ABSTRACT

This study was carried out under two different soil conditions (clay and sandy loam soils) to evaluate the performance of two different sources for manufacturing of power tiller blades from old steel leaf springs of Jeeps and Trucks compared with Japanese "Kobashi company" blades under Egyptian field conditions. The objectives of this investigation are to fabricate the power tiller blades under local condition to reduce the cost per effective operating hour, to find out a tendency of the shape variation of blade cutting edge by wearing during cultivation operation, and to discuss about why the farmers did not pay attention to the cutting edge shape.

The results of this investigation showed that, the life of blades fabricated from old leaf springs of Jeeps LJ and Trucks LT were 90 and 64 % respectively, compared with Japanese blades. However, the cost per effective hour has been reduced by 67.77 %. Also, there were no significant differences in decrease of blade width and weight among the three cutting edges due to wearing. The outside-edge resulted in less wore-off weight. The three edges were reshaped into a similar outside-cutting edge during cultivating operations. Therefore, the farmers did not pay attention to the cutting edge shape of the blade.

INTRODUCTION

Tools with positive drive such as rotary cultivator perform complex motions. Positive drive produces dynamic interaction between the tools and the soil and the plant roots therein. Therefor, the rotary cultivator can be used to break hard lumps of soils, to process severely weed infested soils, and to cut stalks and plant shoots ***(Klenin et. al., 1985).*** They added, the rotary tiller is a power intensive process, and the power consumed by rotary tiller is greater than that by plows. On the other hand, the rotary tillers are better for loosening and weed infested soils. So that power consumption during subsequent soil working is reduced. However, ***Kepner et. al. (1987)*** and *Bosoi et. al. (1987)* reported that the rotary cultivators are good for cutting up vegetative matter, mixing it throughout the cultivated layer and mixing chemical into the soil. Also they mentioned that the rotary cultivation has a positive effect on physical properties of the soil, on water and nutrient regimes of plants.

Sal'nikov (1980) indicated that, the maximum linear wear on the knives is observed on the bent section, which should be case-hardened by high frequency current. The complex structure of metal with different hardnesses and the different wear-resistance of different sections evidently creates conditions for wear of the metal with different intensities, which in turn will create conditions for self- sharpening of the blades. However, *Yatsuk et. al. (1981)* reported that the wear at the cutting edges of flat knives is up to 3-5 mm and the knives become incapable of further work when the working tools of rotary tillers operate under difficult conditions of abrasive wear and high cutting speeds in

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working 20-30 ha of land. They also indicated that, even for a cutting speed of 12 m/s minimum wear has been observed in the case of rotary cutting knives made of 55 S_2 spring steel, oil-hardened at 870°C; tempered to 460°C; hardness of HB 285. Therefore, they stated that, the use of high quality steels for the working blade rotary tillers does not prevent wear of the cutting edge of the blades. ***Khurmi and Gupta (1984)*** mentioned that, the steel C75 which contain 0.70-0.80% carbon(C) and 0.50-0.80% manganese (M_n) was mainly used in manufacturing leaf springs, shear blades and cultivator's shovels

Muro (1972) studied the shape variations of constriction machine tools by wearing with earth and sand. The variation of edge shape by wearing influenced cutting resistance and work performance. But his study did not mention about what shape of edge occurred with wearing when providing different original shapes of edge. ***Sakai (1975)*** mentioned that, the section shape of the blade is consider as the one of the important design factors relating to the performance of rotary blades, this is related to the value of the frictional resistance between the blade and the untilled soil. However, the pervious studies reported that an inside-edge reduced cutting or penetrating resistance by the decrease of pushing and/or pressing the untilled soil by the backside edge. (***Sakai and Shibata, 1977; Sakai and Hai, 1982; and Hai and Sakai, 1983***). Meanwhile, the combination-type sharpening of blade results in a reduction in soil cutting resistance. In this case the sharpening of the blade stem should be done from the inside and from the out side. Also, they reported that, the fine sharpening (20-25°) from the outer side (from the furrow bottom side) should be done for the blades . These blades were established that a decrease in the cutting angle to 28° and reduces the resistance of the cutting by 20-25% and the blades are more wear resistance, (***Yatsuk et. al. 1981***). Studies on wearing of tiller blades were tended to focus on decreases in weight and blade width (***Yamada, 1990***) but he did not pay attention to the shape variation of the edge. Power tiller is widely used in cultivation operation in Japanese farming and a lot of important data and information have been accumulated for designing and manufacturing power tiller blades. And how to shape an edge of the blade has been attractive and important issue for agricultural engineers, in order to reduce cultivation resistance, to keep them from wearing, and to save manufacturing costs (***Shibusawa, 1996***).

The main objective of this study is to fabricate power tiller blades under local manufacturing condition to reduce the cost per effective operating hour. While the specific objectives are to evaluate the locally fabricated blades for wearing pattern compared with imported blades, to find out a tendency of the shape variation of blade cutting edge by wearing during cultivation operation, and to discuss about why the farmers did not pay attention to the cutting edge shape.

MATERIALS AND METHODS

The field experiments were carried out in two different sites one of them was a sandy loam soil and the other was a clay soil, Gharbia Governorate, during 1999 and 2000 agricultural seasons. However the laboratory tests for measuring hardness and chemical compositions of the blade material were conducted in the laboratories of Kafr El-Sheikh Engineering Faculty, Tanta University. The soil mechanical analysis of the experimental fields was carried out in the soil research institute laboratory and the data is summarized in Table (1).

Table (1): The mechanical analysis of the experimental field soil.

Item		Site I	Site II
Practical size distribution	Clay, %	55.21	18.07
	Silt, %	26.16	20.61
	Sand, %	18.63	61.32
$CaCo_3$, %		1.37	1.49
Organic Matter, %		1.78	1.83
Soil Textural class		**Clay**	**Sandy loam**

The specification of the power tiller, which was used in this study and the conditions of the experimental field are listed in Table (2).

Table (2): Power tiller specification and experimental field conditions

Power tiller	Type	LAMBORDINI
	Rated power, kW	12.7
	Weight, kg	370
	Cultivation width, mm	700
Tested blades	Three groups of 8 blades with respective shape of cutting edge and source of blade were used.	
Cultivation conditions	Forward speed, km/h (m/s)	0.8 (0.22)
	Cultivation depth, mm	100
	Rotational speed, rpm	280
Soil moisture content	Ranged from 17 to 21% (d.b.)	

Scope of variables

1- Three different sources of manufacturing of power tillers blades, namely; fabricated blade from old leaf springs of Jeeps LJ, locally fabricated blades from old leaf springs of Trucks LT and Japanese blades supplied from Kobashi Company KC. (the original steel of three different sources was C75, ***Khurmi and Gupta ,1984***)
2- Three types of cutting edge shape (inside, out side and double side cutting edge)
3- Two different soil textural type (clay and sandy loam soils)

Methodology

An old leaf springs of Jeep or Truck with 20 mm width and 7mm thickness was used to fabricate the power tiller blades. Each piece of the leaf springs was kept 280 mm long. The pieces of leaf springs of Jeeps were heated and bent to the required shape of the blades under the hardening process. These blades were heated to 800°C followed by quenching with SAE-40 oil (according to ***Pradhan et. al., 1995***). Subsequently, the tempering process is carried out in two stages. First of all, the cutting tip portion of the blade was heated up to 300°C and cooled to room temperature. Thereafter, the holdon portion of the blade was heated up to 500°C followed by cooling to room temperature to obtain required hardness. However, the heat treatment process for old leaf springs was carried out without control in the heat temperature (locally fabrication). The fabricated blades were formed as the curved shape of Kobashi Company blades KC with same dimensions.

Three groups of 8 fabricated blades from old leaf springs of Jeeps with respective shape of cutting edge, namely; inside-edge, outside-edge and double side-edge were used to study the effect of cutting edge shape of the blade on wear patterns. An inside-edge is a single cutting edge sharpened on the one side (30° sharpen angle according to ***Shibusawa, 1996***) pushing and cutting into the uncultivated soil, and an outside-edge is also a single cutting edge but sharpened on the other side (30° sharpen angle) for the clearance. A double edge is a both-side sharpened edge (30° sharpen angle).

Measurements

1- Hardness and chemical compositions of the blade material.

Samples of fabricated blade from old leaf springs of Jeeps (LJ) and locally fabricated blades from old leaf springs of Trucks (LT) and Japanese Kobashi blade (KC) were sent to the laboratories of Kafr El-Sheikh Engineering Faculty, Tanta University to determine the hardness and chemical composition of the blade materials. The hardness at the tip, middle and holdon portion of the blade was measured as shown in Fig. (1) and the average hardness was calculated.

2- Wearing pattern in the blade

The width and weight of each blade was measured before and after the cultivation operation period to determine wearing pattern in the power tiller blades. The decrease in width due to wearing was measured at two sections A-A and B-B as shown in Fig. (1). B-B section, which might induce the maximal wearing off, was located at the intersection between vertical and horizontal portions of the blade. A-A section laid on the middle of the horizontal portion and its end was equal to the tip of the blade which cut the soil with the maximal speed of a rotating blade.

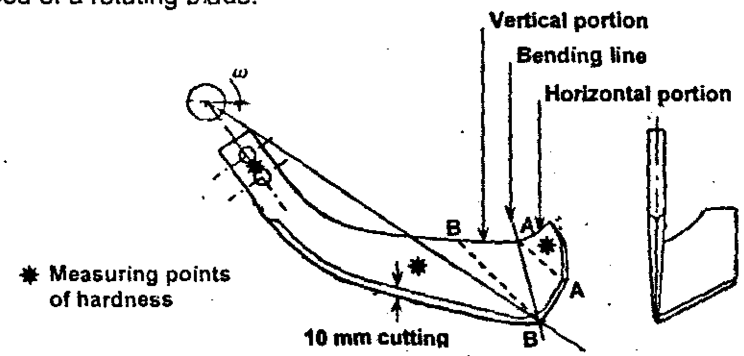

Fig. (1): Shape of test blades and measuring sections of blade width.

3- Effective operation hours

The effective operating hours (life of blade) was measured under the field conditions until of the blades' tip was completely worn out to determine the blade life, consequently, estimate the cost per operating hour for each manufacturing blade source.

RESULTS AND DISCUSSION

1- Hardness and chemical composition

The average hardness and chemical composition of fabricated leaf spring blades and Japanese (Kobashi Company) blades obtained from the laboratory

Engineering Faculty, Kafr El-Sheikh, Tanta University are presented in Table (3).

Table (3). average hardness and chemical composition of power tiller blades.

Source of blade	Hardness, HRC				Chemical composition, %			Original steel type
	At holdon portion	At middle portion	At tip portion	average	Carbon "C"	Manganese "Mn"	Silicon "Si"	
Kobashi Company, KC	43.4	45.2	44.9	44.9	0.63	0.72	1.58	Steel C75
Leaf springs of Jeeps	38.3	41.1	42.8	40.7	0.67	0.75	1.61	
Leaf springs of Trucks LT	33.9	34.8	34.4	34.3	0.69	[illegible]	1.67	

It was observed that Carbon, Manganese and Silicon content of old leaf spring blades were lightly more than that of Kobashi blades KC. The composition of blades fabricated from old leaf springs of Jeeps LJ and Trucks LT were nearly identical.

Considering the hardness at different portions on the blade, the minimum hardness was found to be at holdon portion for any given blade. The average hardness of LJ blades after heat treatment process was HRC 40.7, which is less than the KC blades (HRC 44.9). In case of the LJ blades the maximum hardness was found at the tip portion and the hardness was gradually decreased towards the holdon portion. But in the case of LT blades, the maximum hardness was found at the middle portion of the blade and the average hardness was only HRC 34.3. These results may be due to improper heat treatment process adapted.

Wearing pattern

.1 Effect of manufacturing blade source

The wearing pattern occurred in the Kobashi blades KC and in the fabricated blade from old leaf springs of Jeeps LJ and Trucks LT are presented in the Table (4). The data reveal that after 50 and 90 operating hours, the mean wear rate was 0.56 g/h and 0.48 g/h for KC blades, respectively. While. It was 0.61 g/h and 0.53 g/h for LJ blades after 50 and 81 operating hours, respectively. However, the corresponding values for the LT blades were 0.64 g/h and 0.56 g/h after 50 and 76 operating hours, respectively when operated blades in clay soil. It can be also observed that the wear rate for all blades under study was higher in case of sandy loam soil condition than that observed in case of clay soil condition. It may be due to increasing sand percentage, which results in more friction and more wear rate in the power tiller blades.

After the blade's tip was completely worn out, the effective operation hours were found to be different for each blade source under study. The KC blade gave the highest effective operation hours of 90 and 82 h when operated in clay and sandy loam soils, respectively. While, the minimum effective operation hours of 76 and 68 h was obtained by using LT blade in clay and sandy loam soils, respectively.

It can be also noticed that the wear rate after blades' tip was completely worn out was lower than that after 50 hours of operation. The wear rate of 0.48, 0.52 and 0.57 g/h were obtained due to using KC, LJ and LT blades after 90, 81 and 76 operating hours, respectively in clay soil condition. However, the corresponding values of wear rate after 82, 71 and 68 operating hours in sandy loam soil condition were 0.55, 0.63 and 0.67 g/h using KC, LJ and LT blades respectively.

Table (4): wear pattern for different blades under field conditions

Soil type	Source of blade	After 50 hours of operation		After the blade s [illegible] was completely worn out		
		Weight loss, g	Wear rate, g/h	Effective operating hours	Weight loss, g	Wear rate g/h
Clay	Kobashi Company, KC	27.80	0.56	90	43.82	0.48
	Leaf springs of Jeeps, LJ	30.70	0.61	81	42.64	0.53
	Leaf springs of Trucks, LT	31.80	0.64	76	43.00	0.57
Sandy loam	Kobashi Company, KC	32.65	0.65	82	44.91	0.55
	Leaf springs of Jeeps, LJ	35.50	0.71	71	44.69	0.63
	Leaf springs of Trucks, LT	36.65	0.73	68	45.74	0.67

The wearing patterns of LJ and LT blades were observed to be similar to the KC blades. It is also observed that the maximum, typical and minimum wearing of a particular blade was irrespective of its position in the rotary drum. The maximum, typical and minimum wearing patterns of the KC blades are shown in Fig. (2-A,B,C).

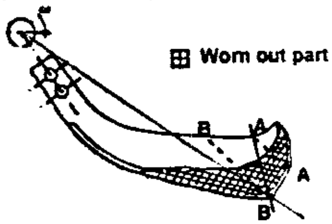

Fig. (2-A) : The maximum worn out of KC blade

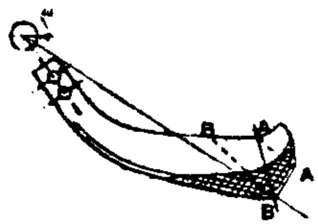

Fig. (2-B) : The typical wearing pattern of KC blade

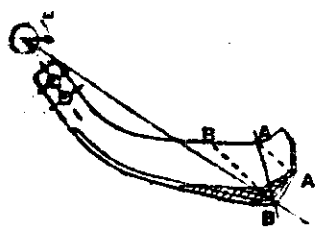

Fig. (2-C) : The minimum worn out of KC blade

Considering the wearing pattern of these three groups of blades under field conditions, it was observed that the mean wear rate has been reduced during the latter period and the blades could be successfully used for 90, 81 and 76 hours of operation for KC, LJ and LT blades, respectively. The maximum mean wear rate of 0.64 g/h after 50 hours of field operation was observed for LT blades. Whereas, the minimum rate for KC blades was 0.56 g/h in case of clay soil condition. In addition, brake and distortion of blades were also noticed for locally fabricated blades from old leaf springs of Trucks. The breakage and distortion of blades were due to low value of hardness (34.3 HRC), as proper heat treatment process was not adopted for them.

2-2 Effect of cutting edge shape of the blade

The fabricated blades from old leaf springs of Jeep which prepared to study the effect of the shape of cutting edge on the wearing pattern were operated under the clay and sandy loam field conditions up to the blade's tip was completely worn out. The average of reduction in width and weight due to wear are summarized in Table (5).

Table (5): average reduction in width and weight of the fabricated blades and standard divination after the blades' tip was completely worn out.

Soil type	Measuring section	Inside-edge		Double-edge		Outside-edge	
		Average	SD	Average	SD	Average	SD
Clay	Section A-A, mm	4.45	1.07	4.85	0.87	4.70	0.77
	Section B-B, mm	4.70	1.26	5.75	1.21	5.65	1.12
	Weight, g	42.31	6.92	42.64	2.78	36.66	2.31
Sandy loam	Section A-A, mm	4.75	1.23	5.20	0.94	5.05	0.91
	Section B-B, mm	5.90	1.41	6.35	1.29	6.20	1.26
	Weight, g	44.26	7.11	44.69	3.07	41.98	3.01

These results cleared that, the average value of the reduction in blade width and weight due to wear was greatly affected by the shape of cutting edge of the blade and soil conditions. The reduction in blade width was higher at the measuring section B-B than that A-A. Also, the values of blade width reduction were found to be higher under the sandy loam soil condition than that under clay soil condition as shown in Figs. (3 and 4). B-B section gave a relatively normalized distribution of the data for the three edges compared with the data of width reduction at A-A section.

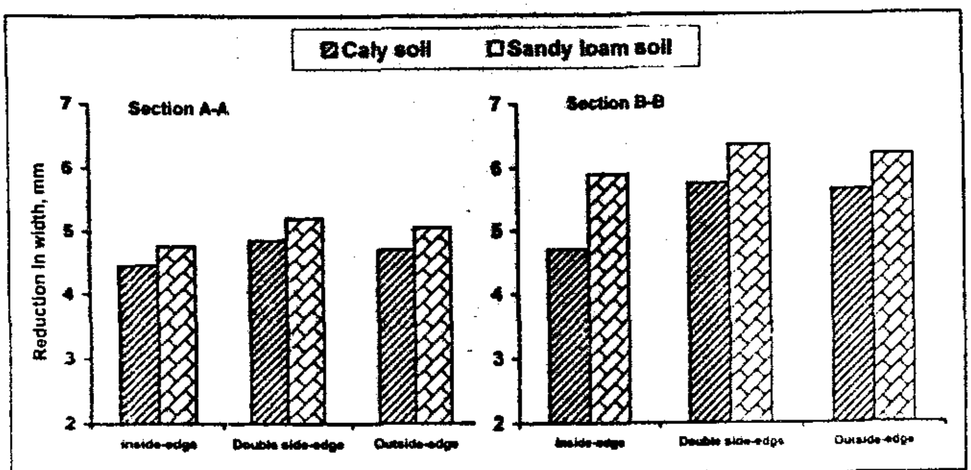

Fig (3): Effect of the shape of cutting edge on the reduction in width due to wear.

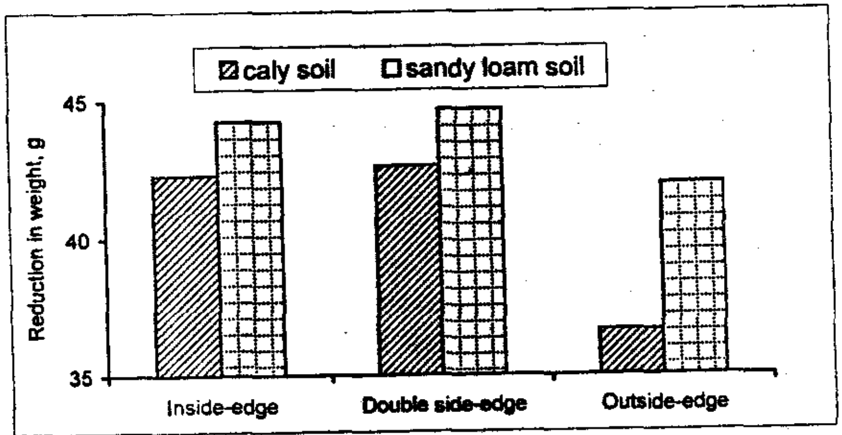

Fig.(4): Effect of the shape of cutting edge on the reduction in weight due to wear.

The maximum reduction in width and weight of the blade due to wear was obtain for double cutting edge shape at both measuring section A-A and B-B under any given soil conditions. However, the inside cutting edge provided the largest range (highest standard deviation) between the maximal and minimal values of reduction in width and weight of the blade due to wear. While, the outside cutting edge gave the lowest standard deviation. In addition, the value for average of weight reduction in the outside-edge was lower than other two shapes. Therefore, it could be cleared that, the outside cutting edge resulted in less wore off width and weight.

Outlooks of the worn edges are illustrated in Fig. (5). All new tested blades had 30° edge angle. After the 50 hours of operation, wearing deformed the original angled edges, followed by reshaping a new outside-edge with angles of about 70°.

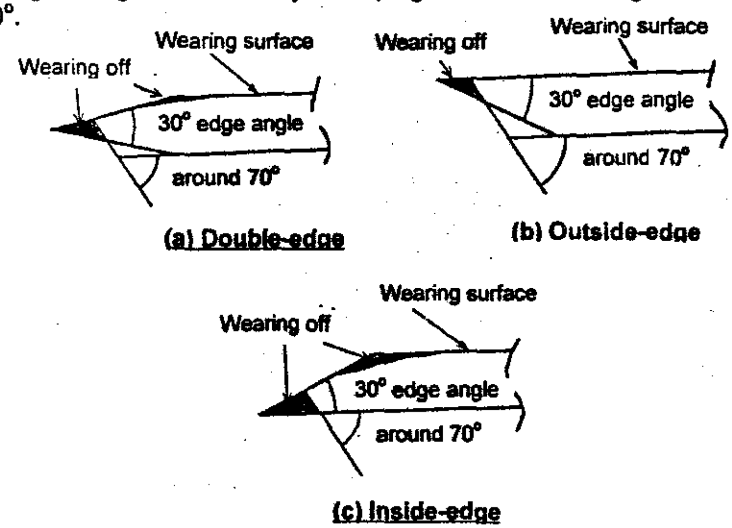

Fig. (5): Wearing off patterns around the blade edge.

In the cases of the inside and double side-edges, the angle on the intersection between the edge and the scoop surface was abraded off and flattened. Consequently, the different types of edge disappeared and changed into a similar shape of edge as an outside-edge of 70° in angle. This phenomenon induced more wearing of weight for the inside and double side-edges. This fact also led to another aspect: any shape of edge was often/usually re-shaped into a similar edge early in the using period, and then the farmers had used a similar type of blades in spite of getting new different blades. This may be the main reason cleared why the farmers did not pay attention to the cutting edge shape.

3- Operation cost

The data of life (effective operation hours) and cost per operation hour of the three different sources of power tiller blades under study are listed in Table (6). From these results it was observed that the Kobashi blade KC costing 38 LE per set * and it could be used for 90 operation hours costing 0.422 LE/h. Whereas, the fabricated blade from old leaf springs of Jeeps LJ cost only 11 LE/set and this could be used for 81 hours costing only 0.136 LE/h under clay soil condition. Thus the cost of operation could be reduced by about 67.77%, when using the fabricated blade from old leaf springs of Jeeps instead of Japanese "Kobashi" blades.

The effective operating time of LJ and LT blades were about 90 and 84%, respectively compared with Japanese blades under the clay soil condition. However, the corresponding values under the sandy loam soil condition were 87 and 83%, respectively. Therefore, it could be cleared that, the effective operating hours of the fabricated leaf spring blades is nearly par with the Japanese "Kobashi" blades whereas, the cost per set of these blades has been reduced by 27 LE. Even though the locally fabricated blades from old leaf springs of Trucks is gaining popularity among the power tiller owners because of their low cost (0.132 and 0.147LE/h under the clay and sandy loam conditions, respectively). These blades need proper heat treatment to prevent distortion and breakage.

Table (6): The life and cost per operation hour of the power tiller blades

Soil type	Blade source	Initial cost, LE/set	Life of blade, h	Cost, LE / operating hour	Reduction in cost, %
Clay	Kobashi Company, KC	38	90	0.422	00.00
	Leaf springs of Jeeps, LJ	11	81	0.136	67.77
	Leaf springs of Trucks, LT	10	76	0.132	68.70
Sandy loam	Kobashi Company, KC	38	82	0.436	00.00
	Leaf springs of Jeeps, LJ	11	71	0.155	66.52
	Leaf springs of Trucks, LT	10	68	0.147	68.25

* 1 U S A $ = 4.23 LE (Average price 2001)

Conclusion and Recommendations

The following conclusions can be derived from the above study:

1. The hardness and composition of old leaf springs of Jeeps LJ and Trucks LT are suitable for fabrication of low-cost proper tiller blades if proper heat treatment process is adopted, and it could be manufacturing it in Egypt.
2. The effective operating hours under clay soil condition are 90, 81 and 76 hours for Japanese "Kobashi" blades KC, fabricated blade from old leaf springs of Jeeps LJ and locally fabricated blades from old leaf springs of Trucks LT, respectively.
3. There is saving of 27 LE/set in the fabricated blade from old leaf springs of Jeeps in comparison to "Kobashi" blades.
4. Locally fabricated blades from old leaf springs of Trucks have gained popularity among the power tiller owners because of their low cost per effective operating hour. However, these blades need proper heat treatment for longer life to prevent distortion and breakage.
5. The outside-edge shape resulted in less wore-off weight. The shape variation by abrasion was clearly different among the three edges. The three edges were reshaped into a similar outside-edge during the cultivation operation.
6. Farmers had been using a similar reshaped edge on tiller blades during the most part of the using period, though they got new blades with different shapes of edge and did not pay attention to the cutting edge shape.

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الملخص العربى

تصنيع وتقييم أسلحة منخفضة التكاليف للعزاقة اليدوية

دكتور / محمود السيد العراقي*

أجريت هذه الدراسة بهدف تصنيع أسلحة عزيق محلية منخفضة التكاليف للعزاقات الدورانية لتخفيض تكاليف التشغيل / ساعة وتقييمها تحت ظروف التربة المصرية. كما استهدفت الدراسة إلقاء الضوء على مدى تأثر درجة تآكل الأسلحة بشكل الحافة القاطعة لها.

لتحقيق الأهداف عاليه من هذا البحث أجريت دراسة مقارنة بين نوعين من أسلحة العزيق المصنعة محليا من الصلب الزنبركي (C75) لورق سوست السيارات الجيب (LJ blade) وورق سوست المقطورات (LT blade) مقارنة بأسلحة عزيق مصنعة باليابان (KC blade) إنتاج "شركة كوباشي" اليابانية، في نوعين مختلفين من الأراضي إحداهما طينية والأخرى رملية طميية بموقعين مختلفين بمحافظة الغربية خلال عامي ١٩٩٩ ، ٢٠٠٠ . ولدراسة تأثير شكل الحافة القاطعة على معدل التآكل وشكل السلاح بعد التآكل اخذت ٣ مجموعات من الأسلحة المصنعة محليا من ورق سوست السيارات الجيب (LJ blade) وتم تشكيل المجموعة الأولى بحافة قطع داخلية والثانية بحافة قطع خارجية والثالثة بحافة قطع مزدوجة (من الجانبين) . وقد أوضحت النتائج المتحصل عليها من هذه الدراسة أن: -

- عمر السلاح (عدد ساعات التشغيل الفعلية) للأسلحة المصنعة محليا تحت ظروف التصنيع المصرية يناهز إلى حد قريب عمر السلاح المستورد والمصنع باليابان، حيث بلغ ٩٠ ، ٨٤% للسلاح المصنع من ورق سوست السيارات الجيب أو من المقطورات على الترتيب من عمر السلاح الياباني.
- أدى استخدام مثل هذه الأسلحة المصنعة محليا محل الأسلحة المستوردة إلى انخفاض تكاليف التشغيل بنسبة ٦٨,٢٤ % ، ٦٧,٣٩ % في المتوسط تحت ظروف التشغيل في الأراضي الطينية والأراضي الرملية الطميية على التوالي.
- أعطى السلاح ذات الحافة القاطعة الخارجية أقل معدل تآكل نتيجة التشغيل . وكل من أشكال الحافة القاطعة الثلاثة يعاد تشكيل حافتها القاطعة إلى شكل جديد مرة أخرى بعد فترة من التشغيل (حوالي ٥٠ ساعة) بشكل يشابه إلى حد بعيد شكل الحافة القاطعة الخارجية ، ولهذا لا يهتم المزارعون بشكل الحافة القاطعة للسلاح عند استخدامه.

ولهذا توصي الدراسة بتصنيع أسلحة العزاقات الدورانية (Power tiller) في مصر من ورق سوست العربيات الجيب أو المقطورات مع معاملتها المعاملة الحرارية المناسبة.

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