A Study on Plowshares Wearing Behavior under Conditions of Sandy Loam Soil

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ABSTRACT

The wearing behavior of three different plowshares A, B and C with different HVN Vickers hardness number 417, 363 and 320 HVN was experimentally investigated. The experiment was conducted in sandy loam soil with 8 and 11% moisture contents. Wearing rate, wearing resistance, critical wearing value, specific wear and share expected life were determined as a function of change in share position (front and rear), soil moisture content and working time.

The obtained results have revealed the following:

- Share expected life increased while wearing rate decreased by increasing share surface hardness.
- Share expected life was higher while wearing rate was lower for rear share compared with the front share.
- Increasing soil moisture content from 8 to 11% decreased share expected life for the three experimental shares.

Keywords: Plowshares, Hardness, Wearing Rate, Wearing Resistance, Critical Wearing Value, Specific Wear Expected Life.

INTRODUCTION

Wear can be caused by hard particles sliding on a softer solid surface causing displaying or detaching material. The different types of interactions are distinguished between the sliding particles and the wearing surface of the solid. The wearing methods depended on the implements, the combinations of implements and the intensity of the wearing. The wear of tillage implement may be classified on the basis of the degree of soil disturbance.

Hendawy (1986) indicated that the wear in front share exceeded the last and the medium shares. The ratios of the wear were 1.3: 1 :1.2 for the front, the middle and rear shares, respectively. He added that the wear on the front shares was observed after 50 working hours.

Fielke (1993) showed that the wear rate (based on distance) to be independent of the speed of tillage but the soil type and condition had a large effect on the wear rates and tillage forces. The draft force, vertical up force and wear rate of 5-mm-thick pressed steel shares were compared with those of 10-mm-thick cast steel shares, the blunter cutting edge in moist soil conditions increased the draft and vertical up forces.

Zygmunt (1996) presented the results of wear on steel samples in the laboratory and on ridger shares under field conditions. Wear was determined by measuring the change in length and thickness of shares, and from the weight of samples. Relative resistance against abrasive wear was determined for four grades of steel, considering the type and condition of the soil. The effect of steel hardness and microstructure on wear was analyzed.

Ferguson (1997) stated that the wear reduces the efficiency of plow shares. The wear rates of commercial sweep shares increased at different sites in South Australia. The life of the shares at the different sites in terms of distance traveled, ranged from 9 to 168 km with wear rate being strongly dependent on the gravel content of the soil. At site (sandy clay–loam), the wear rate was found to increase as the soil moisture content decreased.

Natsis (1998) presented the results of field tests to investigate the influence of soil type and soil water content on the wear of soil tillage tools. The soil water had a positive effect for loam and clay soils because the wear decreased as the water content increased. For sandy soils however, wear increased with soil water. As the thickness of the cutting edge of the plow increased, draught force and fuel consumption increased considerably, while the rate of work and tillage depth decreased. The quality of the tillage was seriously reduced, that is, the size of the soil clods increased as the thickness of the cutting edge of the plow increased. Also, the percentage of surface residues was greater as the thickness of the cutting edge of the plow increased. The best overall performance of the plow was obtained from the sharpest share cutting edge with a thickness of 1 mm.

El- Deanasory (2000) showed that the wear rate of shares had 335 and 185 Brinell hardness numbers were 2.83 $g.h^{-1}$, and 5.08 $g.h^{-1}$, respectively at the same soil condition. The wear of wide share was higher than the wear of narrow share. Also, the expected life of share varied in a wide range according to the weight of new share, hardness of share and soil condition.

Emmanuel (2006) stated that the average wear rates of the imported and improved blacksmith shares when pulled by tractor in soils containing 50%, 64% and 74% sand were 297, 362 and 562 $g.ha^{-1}$, respectively. The average wear rates of the new share when pulled by animals in the major soil classifications were: Eutric Plinthosols, 146 $g.ha^{-1}$; Plinthic Lixisols, 164 $g.ha^{-1}$ and Haplic Lixisols, 176 $g.ha^{-1}$, respectively. This gave an average durability of 3– 8 ha/share before the farmer declares the new plowshare completely worn. This compares with 1–2 ha and 2–5 ha per share wear rates for the blacksmith-forged and the imported shares, respectively.

Lorella et al. (2006) found that the best behavior was observed for the more hardenable Fe–C–Mo steels with higher moisture content, sintered under conditions giving rise to bainitic microstructures. A determining role was also played by the porosity content and pore shape: reduction in porosity (obtained by increasing the sintering temperature and the compacting pressure), as well as an increase in pore roundness, which led to a significant improvement in the resistance to sliding wear.

Therefore, the objectives of this work are to:

1- Study the wearing behavior of the three different plowshares.

2- Determine the effect of share position, soil moisture content and working time on wearing rate and wearing resistance.

3-Estimate the expected life for the three shares under the experimental conditions.

MATERIALS AND METHODS

Field experiments were carried out in Jan 2006 at El-Gheran Institute Agricultural-Farm, Tripoli province at The Great Socialist Peoples Libyan Arab Gamahiriya. All experiments were conducted under constant tractor forward speed of 3.4km/h and constant tillage depth of about 12cm.

Soil Characteristics:

The mechanical analysis of the experimental soil was classified as a sandy loam soil having 7.70% clay, 13.40% silt, 78.90% sand. Soil parameters measured throughout the farm included the real density which was 2.63 $g.cm^{-3}$

The Specifications of the Equipment

The technical specifications of the experimental equipment are summarized as follows:

Tractor Elgedh 275- type made in El-Gamaheria four cylinders, four stroke, diesel engine (56 kW).

Mounted chisel plow: Universal, the plow dimensions (length x width x height) 165 x 200 x 105 cm, number of share 9, mass, 423 kg.

The share specification: Three types of plowshares were used and manufactured by A-Beuota Spanish-417 VHN, B-MayarTunisian-363 VHN, and C-Local ploughshares 320- Vickers hardness number (Fig. 1and 2).

Soil Measurements:

The physical properties of soil were calculated as follows:

Soil Moisture Content:

The soil moisture was calculated by using the following formula:

$Sm= W-W_1 / W *100 \%$

where: W: mass of soil sample before drying (g),

W_1: mass of soil sample after drying (g),

Beuota Spanish- A   **Mayar Tunisian- B**   **Local ploughshares- C**

Fig.(1): Share types

Soil Bulk Density:

The bulk density was determined with the help of a core sampler made of metal cylinders of known volume . Bulk density was calculated as follows:

Bulk density $Db = Ms/Vt$ g. cm^{-3}

where, Ms= mass of soil sample (g)

Vt =total volume of soil sample(cm^3).

The Plowshares Measurements:

The share specification tests were carried out in the center of Mechanical Engineering Research - Tripoli. Libya. The plowshares measurements as macro hardness using Vickers Hardness Test (VHN), micro hardness using Rockwell hardness test (HRC),dimensions measurement using (CMM) test, chemical analyses using J-Y 132-F spectrometer and roughness value (Taylor-Hobson) which were measured by the above mentioned devices were tabulated in Tables (1and 2).

Table 1: The mechanical specification of the three plowshare types.

Plow share types	Dimensions mm.		Hardness number		Roughness degree	Weight gram
	Length	thickness	VHN	HRC		
BeuotaSpanish- A	19.7	3.60	417	42	2.02	851
MayarTunisian- B	19.4	3.95	363	37	1.55	831
Local - C	19.2	3.98	320	32	1.50	810

Table 2: The chemical specification of the three plowshare types.

Plow share types	Fe	C	Mn	W	Si	Cr
Beuota Spanish- A	98.24	0.31	1.22	0.008	0.38	0.20
Mayar Tunisian- B	98.10	0.34	1.26	0.005	0.55	0.20
Local ploughshares- C	98.00	0.34	1.28	0.000	0.58	0.21

Beuota Spanish- A **Mayar Tunisian- B** **Local ploughshares- C**

Fig. (2) Share microstructure focusing 100X

Share Hardness

Share hardness is defined as the load divided by the surface area of the indentation. Vickers Hardness Number (VHN) is determined from the following equation (George, 1984):

$$VHN = \frac{2p \sin\left(\theta/2\right)}{L^2}$$

P= applied load, kg.

L= average length of diagonals, mm

θ = angle between opposite face of diamond

Share Mass Losses Percent

Share mass losses percent was calculated as follows**:**

$$\text{Share mass losses (percent)} = \frac{W_0 - W}{W_0} \times 100 \,(\%)$$

where: W_0 = mass of share before using and W = mass of share after using

Wearing Rate

Wearing rate was calculated as a removal weight g., or removal area from share surface divided by operating time h., or, area m^2, or tillage length km., as follows:

$$\text{Wearing rate } (g.h^{-1}) = \frac{\text{The removal of materials from share surfaces (g.)}}{\text{time(h.)}}$$

Wearing Resistance

Wearing resistance was calculated as inverted wearing rate (Kantarc, 1982)

$$\text{Wearing resistance, } (km.g^{-1}) = \frac{1}{\text{Wearing rate, } (g.km^{-1})}$$

Critical Wearing Value

Critical wearing value was calculated as hardness share surface, S_t divided by hardness of abrasion $A_t = 1060$ quartz hardness, (Eyre, 1976)

$$\text{Critical wearing value} = \frac{S_T}{A_T}$$

Specific Wear

Specific wear was calculated as follows**:**

$$\text{Specific wear} (g.m^{-3}) = \frac{\text{The removal of materials from share surfaces, } (g.)}{\text{volume of tillage soil} (m^3)}$$

Share Expected Life

Share expected life (EL) was calculated as follows**:**

$$EL, (h.) = \frac{\text{weight of new share, g - weight of worn share after the expected wear (g.)}}{\text{wearing rate, } (g.h^{-1}.)}$$

weight of worn share after the expected wear = $1/3$ *weight of new share (Ulusoy, 1977)

Experimental Design

The experiments were designed in a randomized complete block design with three replications using three share types.

Experiments were carried out under the following conditions:

1- Share position (front and rear).

2- Soil moisture content (8 and 11%).

3- Working time (10,20,30,40,50 and 60 hours).

4- Share hardness 320, 363 and 417 VHN.

RESULTS AND DISCUSSION

The obtained data will be discussed under the following items:

Effect of Share Position, Soil Moisture Content and Working Time On Share Mass Losses

Share position as well as soil moisture content and working time affect greatly share mass losses (Figs. 3 and 4).

Concerning the effect of working time on share mass losses, results show that increasing working time from 10 to 60 hours for the front share at soil moisture content of 8% increased share mass losses from 1.40% to 16.47%, from 2.66% to 21.63% and from 3.79% to 25.66 % under the three used shares A, B and C, respectively. Also, at soil moisture content of 11% under the same previous conditions results show that increasing working time from 10 to 60 hours increased share mass losses from 1.70% to 21.70%; from 2.80% to 23.67% and from 3.70% to 26.40 %, respectively. While at the rear share and soil moisture content of 8%, the results show that increasing working time from 10 to 60 hours increased share mass losses from 1.21% to 15.72%; from 1.90% to 20.47% and from 3.10% to 25.20 %. Also, at soil moisture content of 11% under the same previous conditions, results show that increasing working time from 10 to 60 hours increased share mass losses from 1.60% to 20.40%; from 2.58% to 25.00 % and from 3.30% to 26.00 %, respectively.

Relating to the effect of share position on share mass losses, data obtained show that share mass losses values were higher for the front shares compared with their values for the rear shares under all experimental conditions. This can be explained by the fact that the front share subjected to high soil resistance tends to increase wear comparing with the rear share.

As for the effect of soil moisture content on share mass losses, results show that increasing soil moisture content increased share mass losses for both front and

rear shares. This can be explained by the fact that a small percentage of acid and salts (common salt, calcium, magnesium chlorides, that increasing soil moisture content increased share mass losses for both front and rear shares. This can be explained by the fact that a small percentage of acid and salts (common salt, calcium, magnesium chlorides, phosphates and other salts) is always present in sandy and sandy loam soils at a moisture content of 11%-13%, which when dissolved in water considerably increases the activity of the adsorbent medium and facilitates the process of dispersion of the share material.

Effect of Share Position, Soil Moisture Content and Working Time on Wearing Resistance.

Share wearing resistance is greatly affected by share position, soil moisture content and working time (Figs 5 and 6).

Concerning the effect of working time on wearing resistance, results show that increasing working time from 10 to 60 hours for the front share at soil moisture content of 8% decreases wearing resistance from 3.19 to 1.62 g.km^{-1}; from 1.71 to 1.26 g.km^{-1} and from 1.22 to 1.08 g.km^{-1} under the three used shares A, B and C, respectively. Also, at soil moisture content of 11% under the same previous conditions results that increasing working time from 10 to 60 hours show a decrease of wearing resistance from 2.55 to 1.23 g.km^{-1}; from 1.57 to 1.13 g.km^{-1} and from 1.04 to 0.932 g.km^{-1}, respectively.

While the results show that increasing working time from 10 to 60 hours for the rear share at soil moisture content of 8% decreases wearing resistance from 3.48 to1.70 g.km^{-1}; from 2.34 to 1.34 g.km^{-1} and from 1.46 to 1.12 g.km^{-1}. Also, at soil moisture content of 11% under the same previous conditions results show that increasing working time from 10 to 60 hours decreases wearing resistance from 2.75 to 1.31 g.km^{-1}; from 1.74 to 1.32 g.km^{-1} and from 1.21 to 1.06 g.km^{-1},

respectively.

Regarding the effect of share position on wearing resistance, data show that wearing resistance values were lower for the front shares compared with the resistance values for the rear shares under all experimental conditions.

As for the effect of soil moisture content on wearing resistance, results show that increasing soil moisture content decreases wearing resistance for both front and rear shares due to the effect of dissolved salts, which are presented in sandy loam soils, which considerably decreases wearing resistance.

Effect of Share Hardness on Wearing Rate and Share Expected Life

The share expected life and wearing rate are considered important parameters for good management of plow shares. Figs.7 and 8 show the effect of Vickers hardness number, share position and soil moisture content on wearing rate and share expected life.

Concerning the effect of share Vickers hardness number on share expected life, results show that increasing Vickers hardness number, increases share expected life. The expected life reached up to 187.40 hours for share A (427 VHN) while decreased to114.07and 93.30 hours for shares B (363 VHN) and C (320 VHN) at a moisture content of 8% for the front shares. Also, the expected life reached up to 198.86 hours for share A (427 VHN) while decreased to125.16 and 101.76 hours for shares B (363 VHN) and C (320 Vickers hardness number) under the same conditions for rear shares.

As for the effect of soil moisture content on share expected life, it has been noticed that increasing soil moisture content from 8% to 11% increases the share wear and as a result expected life for front shares decreased from 187.40 to 141.10 hours, while decreases from 198.86 to 148.70 hours for rear shares.

Effect of Share Hardness on Critical Wearing Value and Specific Wear

Wearing behavior is influenced mainly by many factors such as the composition of share materials and its hardness, strength and toughness.

Figs 9 and 10 show the effect of share Vickers hardness number on both average wear and critical wear value. Data obtained show that increasing Vickers hardness number from 320 to 417 decreases specific wear from $1.12E^{-02}$ to $6.46E^{-03}$ $g.m^{-3}$ and vice versa was noticed with critical wear value which increases from 0.30 to 0.39 by increasing Vickers hardness number at a soil moisture content of 8%. Also, at soil moisture content of 11%

under the same previous conditions the results show that increasing Vickers hardness number decreases of specific wear from $1.23E^{-02}$ to $8.61E^{-03}$ $g.m^{-3}$ for the front shares.

Data also show that increasing Vickers hardness number from 320 to 417 decreases specific wear from $8.95E^{-03}$ to $6.15E^{-03}$ $g.m^{-3}$. at a soil moisture content of 8%. Also, at soil moisture content of 11% under the same previous conditions the results show that increasing Vickers hardness number from 320 to 417 decreases specific wear from $1.16E^{-02}$ to $8.17E^{-03}$ $g.m^{-3}$ for the rear shares. The obtained results prove that the share can resist the wear by increasing its Vickers hardness number.
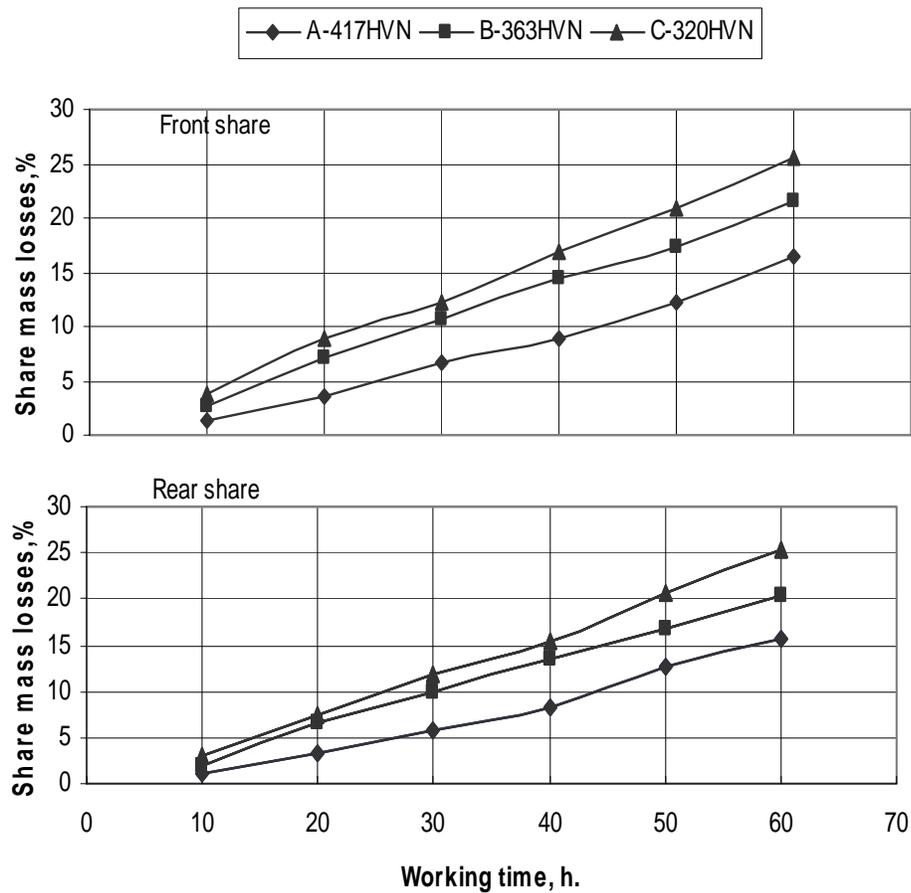

Fig. 3: Effect of working time and share position on share mass losses at soil moisture content of 8% for the three experimented shares.
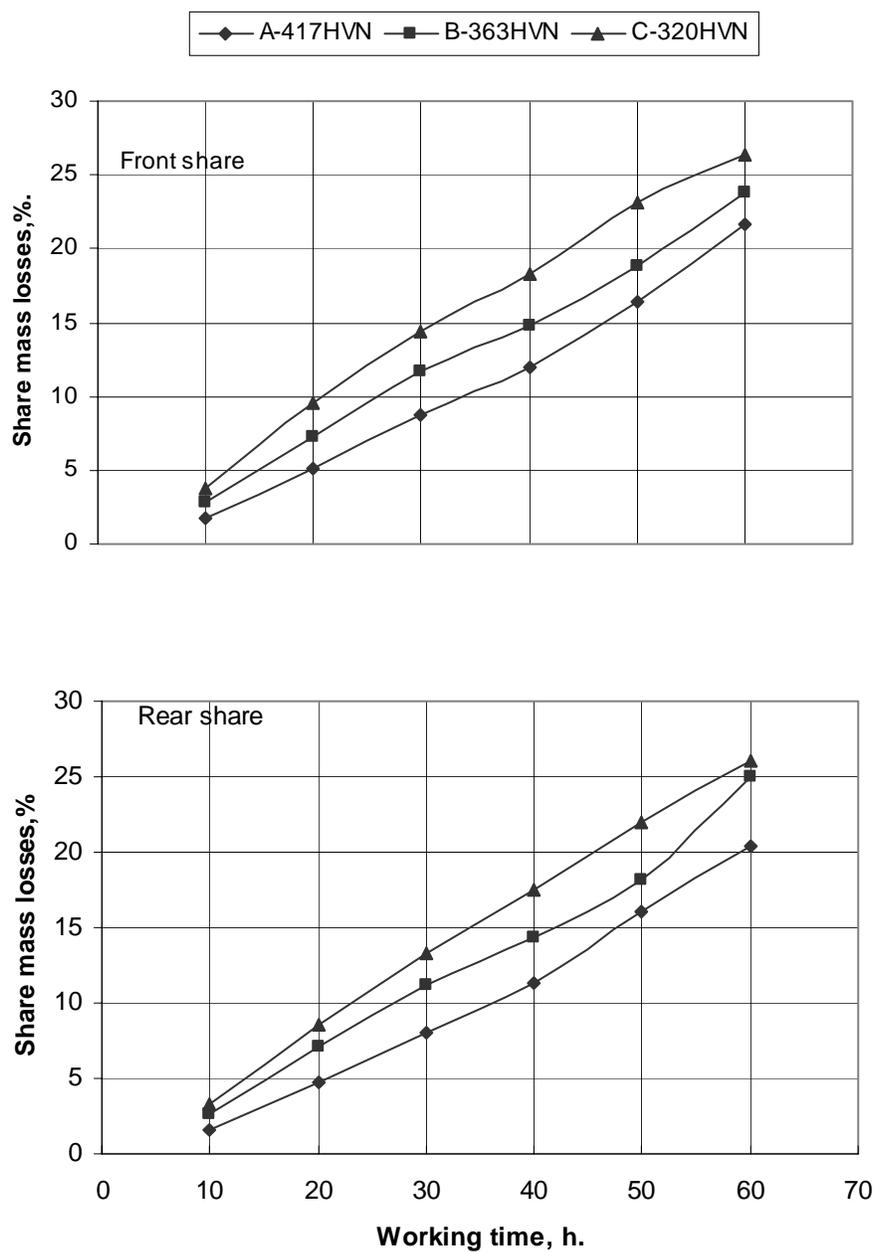
Fig. 4: Effect of working time and share position on share mass losses at soil moisture content of 11% for the three experimented shares.
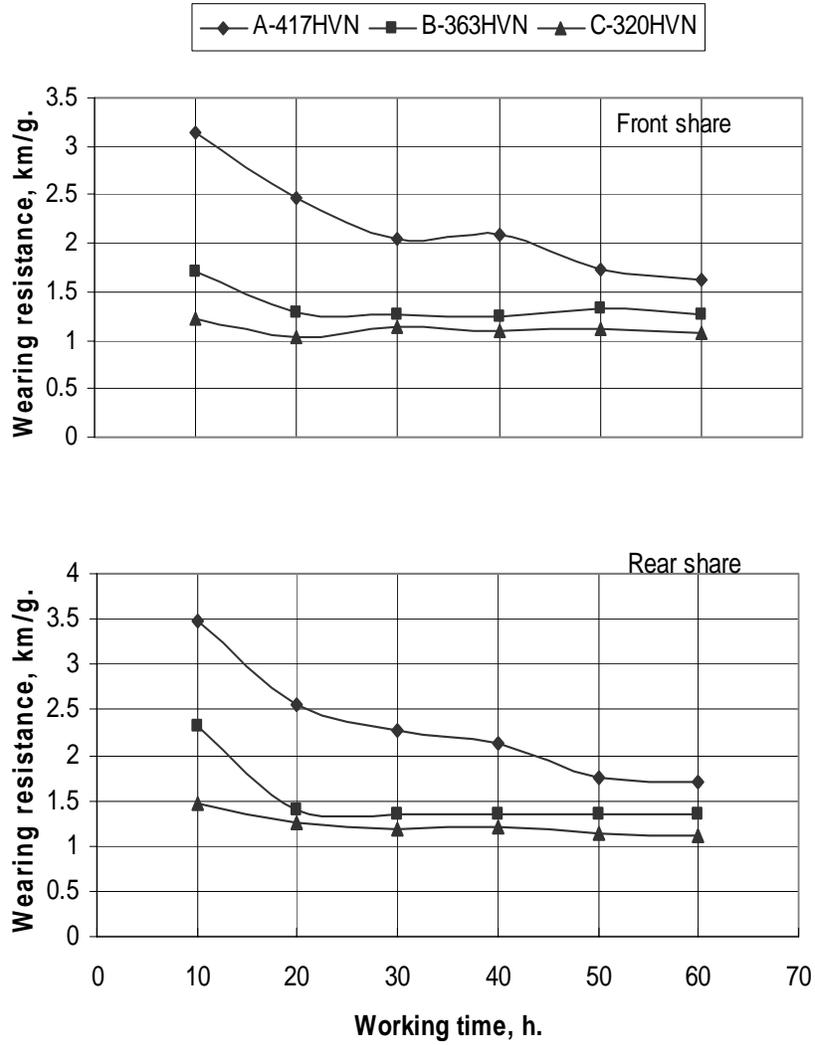
Fig. 5: Effect of working time and share position on wearing resistance at soil moisture content of 8% for the three experimented shares.
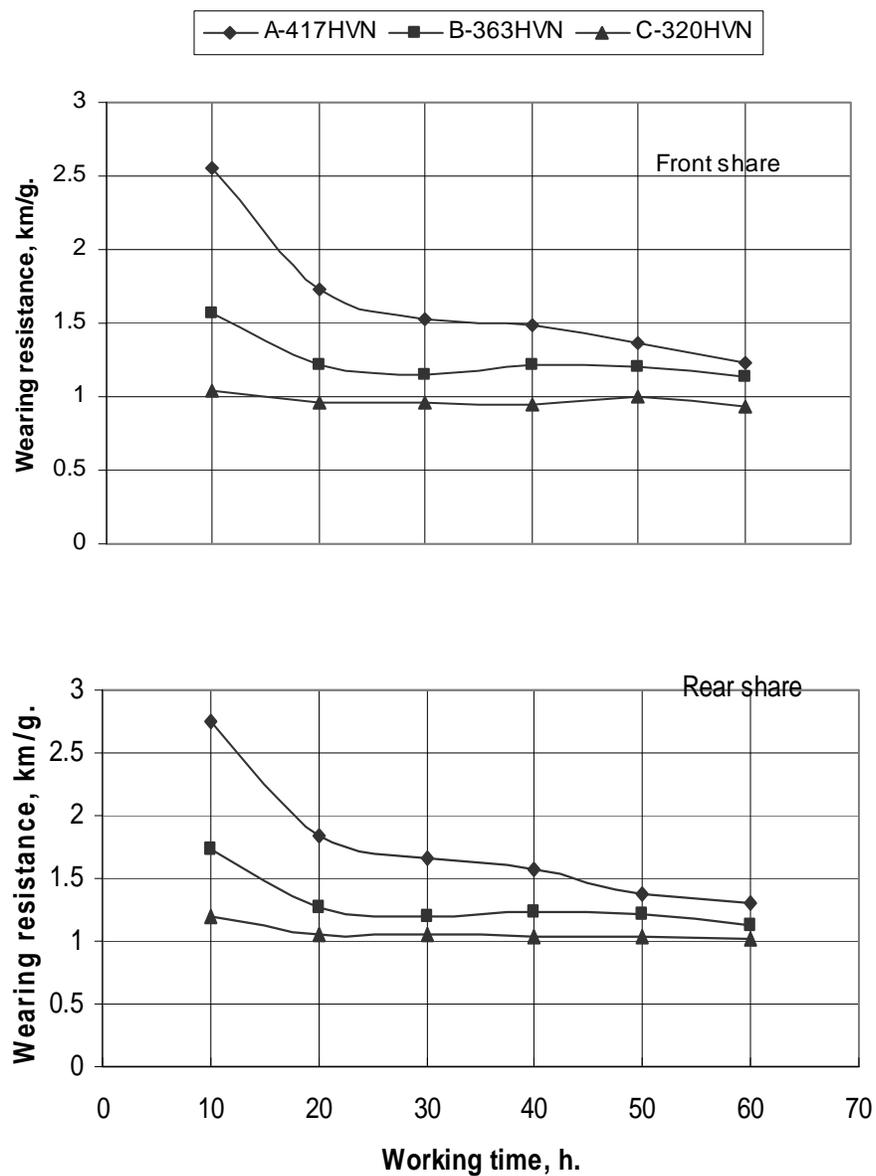
Fig. 6: Effect of working time and share position on wearing resistance at soil moisture content of 11% for the three experimented shares.
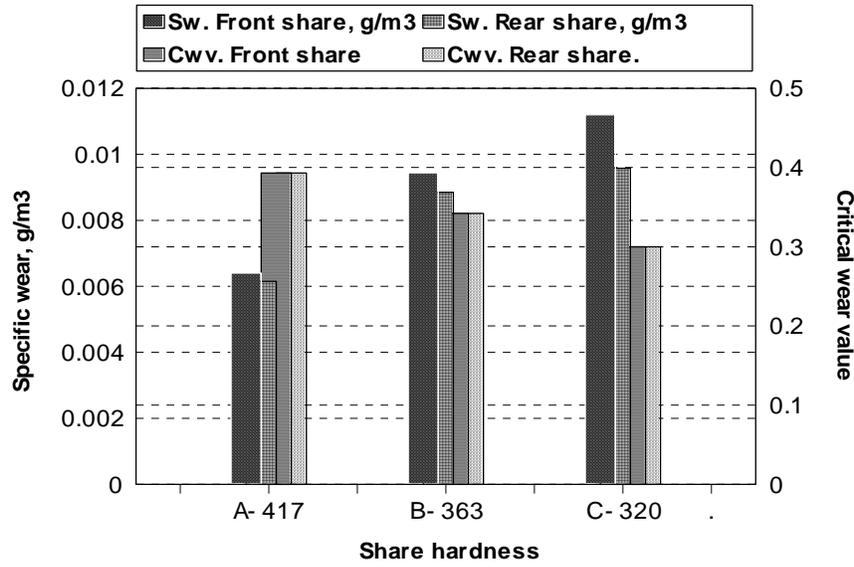
Fig. 9: Effect of share hardness and share position on the critical wear value and specific wear at soil moisture content of 8%
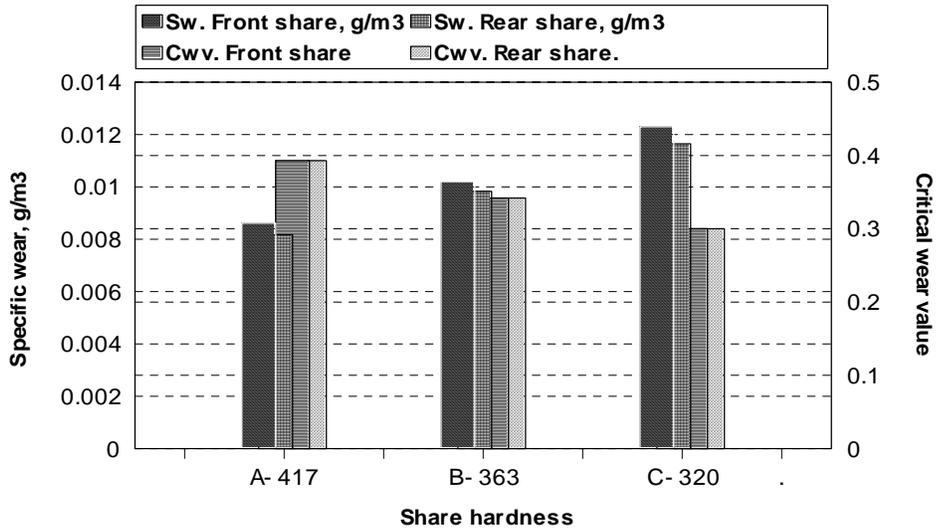

Fig. 10: Effect of share hardness and share position on the critical wear value and specific wear at soil moisture content of 11%

CONCLUSIONS

The obtained results reveal the following:

Average wearing rate, average wearing resistance, and share expected life values were 1.52, 2.43 and 2.93g.h^{-1}; 2.09, 1.16 and 0.954 km.g^{-1}. ;187.40,114.07 and 93.32 hours for the three experimented front shares A,B and C, respectively under soil moisture content of 8%.

Average wearing rate, average wearing resistance and share expected life values were 2.07, 2.63 and 3.32 g.h^{-1}; 1.41, 1.07 and 0.840 km.g^{-1}; 141.10, 106.60 and 83.03 hours for the three experimented front shares A,B and C, respectively under soil moisture content of 11%.

Average wearing rate, average wearing resistance, and share expected life values were 1.41, 2.21 and 2.66 g.h^{-1}; 2.65, 1.70 and 1.05 km.g^{-1}. ;198.86, 125.16 and 101.76 hours for the three experimented rear shares A,B and C, respectively under soil moisture content of 8%.

Average wearing rate, average wearing resistance and share expected life values were 1.96, 2.50 and 3.09 g.h^{-1}; 1.51, 1.13 and 0.90 km.g^{-1}; 148.71, 112.60 and 105.00 hours for the three experimented rear shares A,B and C, respectively under soil moisture content of 11%.

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417, 363, 320 HVN   A, B, C

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A, B,

%29.87   16.80   %36.50 21.60   A   B, C

%29.38 24.27   %36.78 21.67

% 5.23, 5.39, 14.46   %6.57, 8.64, 6.21   A, B, C

%5.66, 8.23, 9.85

A,B,C   %11   8

24.62, 7.89, %8.94   %26.57, 7.60, 11.40

%24.70, 6.54, 11.01   %10.93,7.69, 27.20,   A,B,C

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