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Research Article

Investigation of Material Hardness Values of Active Elements of Some Domestic Production Tillage Equipment and Agricultural Machinery

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Abstract

It is estimated that the world population will be ten billion in 2050, and Türkiye's population will be 105 million. In order to supply the nutritional needs of the increasing population, new techniques, machine usage/mechanization and technologies are needed in agricultural production. In order for plant production to be conducted at the desired efficiency, the usage of machinery is one of top priority, and the first and most intensive stage is tillage. As a result of the contact and interaction with the soil of the machines used in tillage, some negative situations such as abrasion occur. In order to reduce wear as much as possible, value-added processes are applied to the tillage active elements. The most basic process is to provide the hardness values at the technically desired level by applying regional or general heat treatment to the active elements. The hardness limits of the machines are specified in the Agricultural Machinery and Tractors Test Principles. In this study, the hardness values obtained as a result of the static hardness test conducted in accordance with the standards on 469 active elements belonging to different types of tillage machines were evaluated. The hardness values of the tillage elements of these machines, such as shares, discs, teeth and blades, were examined and the average hardness and standard deviation values were calculated. According to the results, shares of the mouldboard plows (50.7±3.2 HR-C), discs of disc plows (48.5±2.1 HR-C), discs of disc harrows (47.8±2.4 HR-C) and teeth of toothed harrows (47.78±2.4 HR-C) are within the limits specified in the principles. The cultivator shares (41.2±6.0 HR-C), subsoiler shares (42.3±3.8 HR-C) and rotary tiller blades (43.8±2.8 HR-C) values are below the limits specified in the principles.
Keywords: Wear, Heat treatment, Cultivator, Plow, Share.

Yerli Üretim Bazı Toprak İşleme Alet ve Makinalarının Aktif Elemanlarından Malzeme Sertlik Değerlerini İncelenmesi

Öz

Dünya nüfusunun 2050 yılında 10 milyar, Türkiye'nin nüfusu ise 105 milyon olacağı tahmin edilmektedir. Artan nüfusun besin ihtiyacını karşılamak için tarımsal üretimde yeni teknikler, makina kullanımı/makinalaşma ve gelişmiş teknolojilere ihtiyaç duyulmaktadır. Bitkisel üretimin istenen etkinlikte yapılabilmesi için makine kullanımı en öncelikli konulardan biri olup birinci ve en yoğun aşaması toprak işlemedir. Toprak işlemede kullanılan makinaların toprakla teması ve etkileşimi sonucunda aşınma gibi bazı olumsuz durumlar oluşmaktadır. Aşınmanın olabildiğince azaltılması için toprak işleyici aktif elemanlara katma değer oluşturan işlemler uygulanmaktadır. En temel işlem ise aktif elemanlara bölgesel veya genel ısıl işlem uygulanarak sertlik değerlerinin teknik olarak istenen düzeyde sağlanmasıdır. Tarım Makinaları ve Traktörler Deney İlkelerinde tarım makinalarının aktif elemanlarına ait sertlik değer ve sınırları belirtilmiştir. Bu çalışmada farklı tipteki toprak işleme makinasına ait 469 adet aktif eleman üzerinde standartlara uygun olarak yapılan statik sertlik deneyi sonunda elde edilen sertlik değerleri değerlendirmiştir. Tarım makinalarına ait uç demiri, disk, diş ve bıçak vb. aktif elemanlarından elde edilen ortalama sertlik değerleri ile standart sapma değerleri hesaplanmıştır. Bulgulara göre, kulaklı pulluk uç demiri (50.7±3.2 RSD-C), diskli pulluk diskleri (48.5±2.1 RSD-C) ve diskli tırmık diskleri (47.8±2.4 RSD-C) ile dişli tırmık dişleri (47.8±2.4 RSD-C) ilkelerde belirtilen sınırlar içerisindedir. Kültivatör uç demiri (41.2±6.0 RSD-C), dipkazan uç demiri (42.3±3.8 RSD-C) ve toprak freze bıçağı (43.8±2.8 RSD-C) değerleri ile belirtilen sınırların altında kalmaktadır.
Anahtar Kelimeler: Aşınma, Isıl işlem, Kültivatör, Pulluk, Uç demiri.

Introduction

Nutrition is the most basic need for moving creatures. Since their existence, humans have supplied their nutritional needs through hunter-gatherer and sedentary lifestyles. Agricultural activities accelerated the transition to settled life and allowed the storage of surplus products. The stored surplus food allowed people to engage in jobs other than food production and paved the way for the development of technology. Various methods have been developed and applied in order to obtain more efficient and quality products than in the current situation (Akın and Esgici, 2015; Ünal et al., 2007). One of the techniques applied since the beginning of agriculture is soil cultivation (Derpsch et al., 2024). With tillage, it is carried out to obtain the soil structure and a good seed bed preparation needed for the development of the seed, to ensure weed and pest control, to regulate the infiltration rate of the soil and to improve the water retention capacity, and to mix nutrients such as fertilizers with the soil (Keçecioğlu and Gülsoylu, 2002).

Tillage dates back to the beginning of agricultural activities. In the "Fertile Crescent" region, which is one of the first areas where agriculture emerged, animal bones, various stones and sticks were used as soil cultivation tools. The use of metal as a soil tillage tool is seen in the first half of the 19th century (Yazıcı, 2021). As a result of the Industrial Revolution, the change in production methods and the increase in the number of products have led to an increase in the use of metal in agricultural activities as well as in other sectors (Khan et al., 2024). The fact that the soil tillers are made of metal has extended the service life of the machine (Lüle and Koç, 2022).

The interaction with the corrosive substances in the soil has caused material loss in the metals. Material loss as a result of tillage has been reported as 150 g/ha annually (Bayhan, 2006; Önal et al., 1994). Various methods have been applied to reduce the wear (Cengiz and Arın, 2005; Çakmak, 1999; Güleç and Altuntaş, 2013; Lüle and Koç, 2022). It has been reported that the main method applied is to increase the wear resistance of the metal (Malvajerdi, 2023). Wear resistance improvement methods seen in the existing literature; alloying with wear-resistant metals, hardening by heat treatment and coating on the metal surface (Güleç and Altuntaş, 2013; Kvon et al., 2021; Bayhan, 2006; Natsis et al., 2008; Bedolla et al., 2018; Hayat and Uzun, 2011; Er and Par, 2006; Bobobee et al., 2007; Rani et al., 2022; Padhiar and Vincent, 2020; Wang et al., 2023; Yazıcı, 2024).

In the classification of tillage machines, the depth of cultivation, the method of cultivation and the movement of the soil during tillage are considered (Ertekin and Akman, 2019; Rani et al., 2022; Yazıcı, 2024). Tillage machines are classified under six main headings: plow, cultivator, rotary tiller, harrow, roller, and packer (Akar and Çelik, 2017; Altuntaş, 2020; Çakmak, 1999; Ertekin and Akman, 2019; Korkmaz and Hacıseferoğulları, 2014). Plows are divided into two groups: Mouldboard plows and disc plows. Cultivators are divided into four groups: Subsoiler, chisel, general-purpose cultivator, and field cultivator (Figure 1). Rotary tillers are divided into four types: Field rotary tiller, rototiller, vertical rotor mill and oscillating tiller. The harrows are divided into four types: Toothed, spring-loaded, disc and rotary. The rollers are divided into two as flat and shaped on the upper surface (Akar and Çelik, 2017; Ertekin and Akman, 2019). Apart from these machines, net harrows, throat filling plows, milled intermediate hoe, rigid leg cultivator and mechanical and laser levelling shovels used in soil cultivation and levelling are also listed (Keçecioğlu and Gülsoylu, 2002).

Figure 1. Various Examples of Tillage Machines.

In this study, the average and standard deviation values of the hardness values of the active working elements in tillage machines were determined and compared with the values specified in the current Agricultural Machinery and Tractor Test Principles and Methods.

Material and Method

Within the scope of the study, 469 tillage machines whose hardness values were measured were examined. The samples for hardness measurements were obtained from soil tillage machines dispatched to the Department of Agricultural Machinery and Technologies Engineering at Ege University via the General Directorate of Agricultural Reform of the Ministry of Agriculture and Forestry, provided by agricultural machinery manufacturers for testing purposes. The samples measured were previously unused, and soil tillage occurred subsequent to the hardness measurement. Hardness values were statistically evaluated according to the machine group. The hardness test of the active elements of these machines was conducted with a Karl Frank brand device in the Laboratory of the Faculty of Agriculture, Ege University, Department of Agricultural Machinery and Technologies (Figure 2).

Figure 2. Karl Frank Universal Hardness Tester.

Hardness is the resistance of the material against the force applied to the surface of the material with the help of a standard indenter. Depending on the hardness of the material and the hardness measurement method, ball, pyramid, or cone shaped indenters are used. As a result of the force applied according to the test method with these indenting tips, a mark is formed on the material surface according to the method or the net sinking depth is measured. The hardness value of the material is determined by calculations made using the average diameter of this trace or the sinking depth values.

Since the active elements used in tillage machines are required to have high wear resistance, the Rockwell Hardness Test is widely applied to measure the hardness of such materials. This test allows measurements to be made for different metallic materials according to different indenter tip and force values. A diamond conical tip with a 120° peak angle is used as an indenter tip to measure the hardness of tillage active elements (Figure 3). Symbols are used to indicate the applied force. In this study, Rockwell Hardness Test C Scale measurements were made. In this method, a pre-load of 150 kg was made with a diamond tapered tip with a peak angle of 120°, and then the hardness values were read from the device dial and recorded (BTU, 2024).

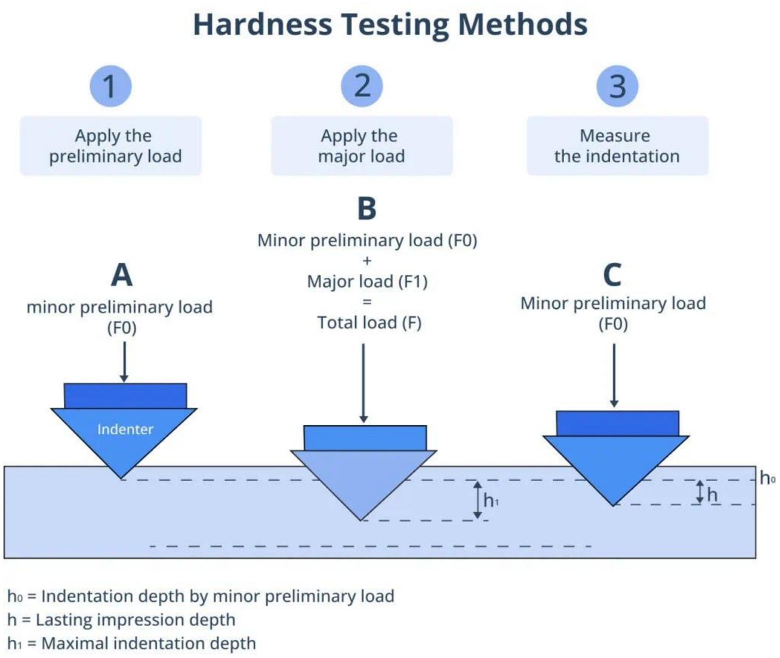

Figure 3. Indenter tip and measurement method used in Rockwell hardness testing experiments (Xometry, 2024)

For the mouldboard plows, the hardness values of the plow were measured 20 mm from the tip point. The arithmetic means of the obtained values were calculated as HR-C. For disk plows, the hardness values of the disks measured on a 50 mm wide strip around the disk circumference were taken. The arithmetic means of the obtained values were calculated as HR-C. The hardness values of the cultivator shares were measured from 10 mm to 20 mm inside the cutting edges and at least 4 points on each share in accordance with TS EN ISO 6508 - 1. The arithmetic means of the obtained values were calculated as HR-C. For toothed harrows, three teeth were randomly selected from each batch, and their hardness was measured at least 2/3 of the way from the tooth tip. The arithmetic means of the obtained values were calculated as HR-C.

In disk harrows, hardness values were measured 50 mm inside the circumference of the disks. The arithmetic means of the obtained values were calculated as HR-C. The hardness values of the subsoiler shares were measured 20 mm from the tip and at least three different locations. The arithmetic means of the obtained values were calculated as HR-C. The hardness values of the rotary tiller blades were measured at three different points: the middle and ends of the cutting edges, within an area 20 mm wide from the cutting edges. The arithmetic means of the obtained values have been calculated.

Results and Discussion

The data of the machines included in the tillage machines, mouldboard and disc plows, cultivator and its combinations, chisel and combinations, subsoiler, toothed/disc harrows, rotary tiller, mechanical and laser levelling shovels and soil auger were examined. The obtained data were evaluated by statistical analysis and the average hardness values of the active elements of these machines produced by different manufacturers and their standard deviation were calculated. These values of the tiller elements of tillage machines are given in Table 1.

According to the "Agricultural Machinery and Tractors Test Principles" published by the General Directorate of Agricultural Reform of the Ministry of Agriculture and Forestry of the Republic of Türkiye in November 2023, the test methods of tillage machines are specified. According to this regulation machine and active element match and hardness values have to be; mouldboard plow share 38-50 HR-C, disc plow discs 34-46 HR-C, subsoiler share 45-53 HR-C, harrow discs 45-50 HR-C, harrow teeth 45-50 HR-C, cultivator share 48-52 HR-C, rotary tiller blades 45-50 HR-C, earth auger cutter blades 42-48 HR-C (T.C.TOB, 2024) (Table 2).

Table 1. Tillage Machinery Processor Elements standard deviation values

Tillage Machines	n (number of active parts)	Active element whose hardness is measured	Average Hardness Value (HR-C)	Standard deviation (±, RSD-C)
Mouldboard Plow	160	Share	50.7	3.2
Disc Plow	4	Disc	48.5	2.1
Cultivator + Combinations	134	Share	41.2	6.0
Toothed / Disc Harrow	136	Tooth / disc	47.8	2.4
Subsoiler	4	Share	42.3	3.8
Rotary Tiller	31	Blade	43.8	2.8

Table 2. Average Hardness compared with values of Experimental Principles and Methods of Tillage Machines

Tillage Machine	Average Hardness Value (HR-C)	Values of Experimental Principles and Methods (±, HR-C)	Comparison
Mouldboard plow	50.7	38-50	↗
Disc plow	48.5	34-46	↗
Cultivator + Combinations	41.2	48-52	↓
Tooth / Disc harrow	47.8	45-50	✓
Subsoiler	42.3	45-53	↙
Rotary Tiller	43.8	45-50	↙

According to the results obtained from the experiments were compared with the values in the test principles, it has seen that the hardness values of the active elements of the mouldboard plow (50.7±3.2 HR-C), disc plow (48.5±2.1 HR-C), disc and toothed harrows (47.8±2.4 HR-C) were in the appropriate range. It was observed that the average hardness values of the active elements of the subsoiler (42.3±3.8 HR-C), cultivator (41.2±6.0 HR-C) and rotary tiller (43.8±2.8 HR-C) were close to the lower limit. Cengiz and Arın (2005) encountered different values in the hardness measurements they applied to the scratch end irons in their researches. As a result of these values, they reported that the end irons were insufficient to meet the desired technical specifications. Güleç and Altuntaş (2013) reported that cultivator shares could not fulfill the values specified by Turkish Standards. In their study in 2021, Kvon et al. examined the effect of heat treatment applications on corrosion resistance in steel with moderate carbon used in agricultural machinery. They reported that as a result of different heat treatment applications, the wear resistance could be improved by 15-18% and the hardness value could be increased in the range of 12-14%, but the hardness values could not be increased above 47 HR-C. The results obtained from the current studies support this situation.

Agriculture is a sector of increasing strategic importance day by day. Growing crops to supply the nutritional needs of living beings in the face of the increasing world population necessitates the use of new techniques and technologies. Soil tillage, which is the initial and energy-intensive stage of plant production, is the stage where new research and development is needed the most. Wear and tear during tillage is among the biggest causes of machine failure. Defects and/or shape changes caused by abrasion affect the quality of tillage. Therefore, it causes the agrotechnical demands of the cultivated plant to be met incompletely or inadequately. This situation causes product loss and low yield.

One of the methods applied to improve the wear resistance of tillage machines is to increase the hardness value by heat treatment. According to the data obtained from previous studies and the current study, this method is applied in soil tiller elements with different hardness values. In the present study, it has seen that production was conducted with machines with appropriate hardness values were mouldboard plow share, disc plow and toothed harrow discs and toothed harrow teeth. It is seen that the subsoiler shares, cultivator narrow, and duck sweep share and rotary tiller blades approach the appropriate hardness values at the lower limit. Soil tillage active elements produced in accordance with the "Agricultural Machinery and Tractors Test Principles" regulation determined by the Ministry of Agriculture and Forestry of the Republic of Türkiye will allow an increase in the service life of the machine and to meet the agrotechnical demands at an adequate level. It should be ensured that the awareness levels and knowledge levels of the manufacturers of these machines could be increased with various trainings. It is recommended to enrich the data provided to the existing literature with new studies to be conducted by comparing different coating methods and materials and materials produced from different alloys on different machines.

Contribution of the Authors as Summary

The authors declare that they have contributed equally to the article.

Conflict of Interest Statement

The authors of the article declare that there is no conflict of interest between them.

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