

# Experimental design for determining wear resistance of chisel plough blades

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## Keywords

wear  
chisel plough blades  
soil bin  
tillage tool

## History

Received: 21-08-2025

Revised: 10-10-2025

Accepted: 06-11-2025

## Abstract

Abrasive wear is one of the most critical problems encountered by tillage tools, as it significantly affects their efficiency and increases production costs. This study experimentally investigated the wear behaviour of three chisel plough blades made of steel with different chemical compositions, available in the local market of different origins. The experiment was conducted using a soil bin at 19 rpm speed, 100 mm depth and 30° penetration angle, in dry sliding conditions for 30 hours. Results showed that the highest cumulative wear reached 9.34 g and the highest wear rate reached 0.226 g/h for blade B3. In contrast, blade B1 experienced the lowest cumulative wear of 5.49 g and the lowest wear rate of 0.130 g/h over the same period. The wear rate initially was the highest, then gradually decreased and remained approximately constant towards the end of the test. The results also indicated that dimensional reduction had occurred. Blade B1 showed the lowest reduction (length and width), reaching 3.76 mm (3.6 %) and 0.85 mm (1.2 %), respectively, while blade B3 showed the greatest reduction, reaching 4.9 mm (4.7 %) and 1.75 mm (2.5 %), respectively. However, the thickness reduction for each blade varied with its location. The blade tip showed the most significant thickness reduction, followed by the outer and inner edges.

## 1. Introduction

The tillage operation improves many physical soil properties, and its quality is affected by the specifications of tillage tools. A chisel plough is the most common soil tillage tool, and due to its intense contact with the soil, its blades are subject to significant wear [1,2]. Tillage implement wear is a significant problem for farmers worldwide. Agricultural implements frequently experience significant wear, particularly in sandy soil, which is the primary cause of performance deterioration in machinery components [3-5]. This wear has considerable economic significance as it generally determines the operational lifespan of most agricultural implements and machinery, making it a substantial factor in predicting a tilling tool's longevity, particularly concerning the blades.

Breakdowns related to wear account for more than 50 % of equipment and machinery failures [6].

Tillage implements' durability is determined by their wear resistance and strength. Research on abrasion wear on tillage implements began in the 1920s [7]. Wear of tillage tools occurs due to contact and relative motion between the tool surface and abrasive soil components, including quartz, stones and sand [8]. Numerous studies indicate that the increase of friction and wear depends on factors such as surface load, surface geometry, relative motion, velocity, humidity, surface roughness, particle dimensions and morphology, material properties and other unforeseen environmental conditions [9,10]. The wear resistance of tillage implements is primarily linked to their surface hardness, since increased material hardness usually reduces wear rate [11]. Soil tillage implements are typically made of steel, a relatively soft material compared to the hard, sandy particles they work through. The blades on



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the market lack adequate heat treatment, resulting in a significantly higher wear rate than heat-treated blades. Therefore, the wear characteristics of tilling blades must be investigated [12,13]. Moreover, tillage machines' traction resistance increases, leading to increased fuel consumption and reduced tillage quality. This wear risks subsequent operations due to the possible tool loss [14].

Tillage tool materials require high toughness and wear resistance due to direct contact with hard abrasive particles in the soil. Therefore, steel is often employed for equipment operating in soil, depending on its characteristics such as hardness, chemical composition and microstructure. However, there are a limited number of studies on the material composition, hardness, and wear of blades, which are necessary for predicting the service life of blades in agricultural products [15,16]. Chisels' wear process and wear resistance primarily depend on the chemical composition of the materials employed, their hardenability and the heat treatment methods utilised. The material should ideally be economical, malleable, abrasion-resistant, heat-treatable and corrosion-resistant, exhibiting high tensile strength and elasticity [17].

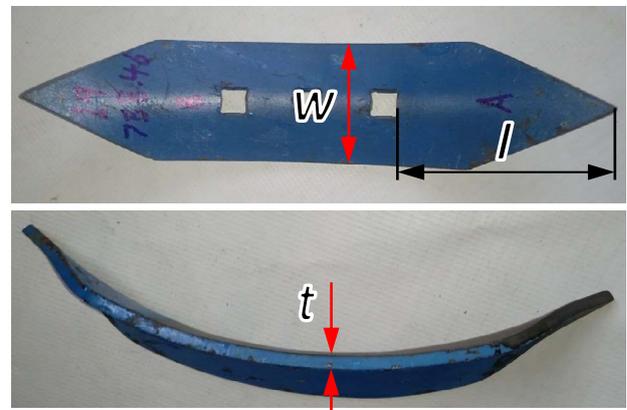
To minimise wear problems of tillage equipment and extend product life, researchers have employed various methods to modify or create new surfaces, including hardfacing and laser surface treatment, to enhance tools' wear resistance. Researchers have discovered that it is feasible to enhance the hardness and wear resistance of materials without compromising their substrate toughness or flexibility [18-20]. However, the efficacy of this approach depends on selecting appropriate procedures and materials tailored to the specific application of the modified components. Therefore, it is essential to investigate these factors meticulously, especially the wear characteristics of blades [14,21].

Many techniques have been developed for assessing wear caused by abrasion. The pin-on-disc tribometer (ASTM G99) and sand rubber wheel abrasion test (ASTM G65) are widely utilised methods for abrasive wear assessment, as well as field experiments. These methods, however, are not enough to simulate the wear properties of tillage tools under field conditions. In addition, field wear analysis is a time-consuming and expensive process. Consequently, a soil bin setup is an important tool for simulating actual field conditions to study the soil-tillage tool interaction [22,23]. This study aims to assess the wear of chisel plough blades, which are the most used by local farmers and available on the local market.

## 2. Materials and methods

### 2.1 Chisel plough blades

Three chisel plough blades (B1, B2 and B3), available in the local market from various commercial origins, were prepared for testing. Figure 1 illustrates the blade shape, while Tables 1 and 2 present its dimensions, hardness and chemical composition. The hardness and chemical composition were determined at the State Company for Inspection and Engineering Rehabilitation (SIER). For the wear test, gravel with irregular shapes and an average diameter of 5 – 10 mm was obtained from local markets as a dry test medium to accelerate the test. The gravel was washed and dried at room temperature before use.



**Figure 1.** Geometry of tested blades ( $w$  – width;  $l$  – length;  $t$  – thickness)

**Table 1.** Hardness and dimensions of blades

Blade	Hardness (HRBW)	Length, mm	Width, mm	Thickness, mm
B1	97	103.05	69.74	5.94
B2	92	103.12	69.42	6.01
B3	81	102.93	69.65	5.88

**Table 2.** Chemical composition of blades

Blade	Element, wt. %						
	C	Si	Mn	Cr	Ni	Cu	Fe
B1	0.47	1.81	0.69	0.06	0.05	0.10	balance
B2	0.35	1.64	0.63	0.18	0.07	0.20	balance
B3	0.22	0.25	0.52	0.08	0.08	0.18	balance

### 2.2 Soil bin

A review of tillage tool wear assessment methods revealed that most field wear tests are costly and time-consuming. An approach distinct from conventional field or laboratory procedures

was required to fix such problems and perform blade wear testing that simulates field conditions. Consequently, the soil bin method was selected, enabling testing in controlled laboratory environments that simulate field conditions. Since two types of soil bins exist: the longitudinal soil bin and the circular soil bin, the circular soil bin was selected due to its minimal space requirements, ease of transportation and ability to operate continuously in one direction, making it highly suitable for operational needs. The main components were designed and fabricated to help control the rotation speed and the blades' setting. Safety, ease of use, cost and efficiency were considered in the design of the soil bin. A soil bin was fabricated from carbon steel available on the local market. When manufacturing the soil bin, the applied load, stress, corrosion resistance and location requirements and conditions were considered.

A soil bin was constructed at the University of Baghdad. The soil bin consists of a cylindrical container with a diameter of 1000 mm, a depth of 65 mm and a wall thickness of 4 mm, including a hollow inner cylinder with a 60 mm outer diameter and a 25 mm inner diameter, through which the power transmission shaft passes. The shaft was fixed vertically at both ends with two bars to enable movement while maintaining its vertical position. A shaft was combined at the bottom with a pulley in the power transmission system via a belt. The shaft was combined with three horizontal arms (120° between every two arms) to enable the arms to rotate and vertically move in both directions by using a mechanical assembly designed for this purpose to control the ploughing depth. A vertical bar was fixed on each arm. It supports the shank that carries the blades, the levelling ruler and the compaction cylinder to level and compact the soil after ploughing. A 5 kW three-phase electric motor was used as a power source. It was connected to a control panel with a voltage and current control and measurement unit, and a counter to adjust and record the operating and cumulative working time. The motor was connected to a gearbox to control the rotation speed. The motion from the gearbox to the soil bin is transmitted via a pulley system. The soil bin was painted to protect it from corrosion. Figure 2 shows the soil bin and some of its components.

### 2.3 Preparing the soil bin

The experiment was carried out at the Department of Agricultural Machines and

Equipment, College of Agricultural Engineering Sciences, University of Baghdad. An initial run of the soil bin was conducted to verify the working mechanism, the safety of the connection and assembly and the operation and speed control. The soil bin was filled with gravel, as shown in Figure 3, prepared in advance, to a height of 350 mm. Then, the shanks holding the blades with a 30° penetration angle were installed, along with the levelling ruler and compaction cylinder. The bin's operation was organised under controlled operating conditions. Before being used, the blades were thoroughly cleaned with water and alcohol to remove dust. Then, the blades were weighed using a digital electronic balance with an accuracy of 0.01 g, and their length, width and thickness were measured using an electronic vernier calliper with 0.01 mm accuracy.

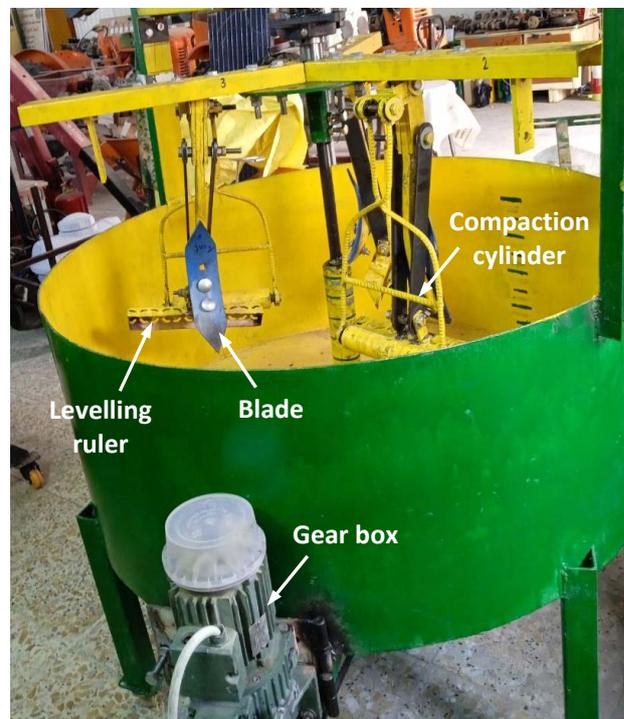


Figure 2. Soil bin

After recording the initial values, the blades were detachably mounted on the shank. The assembly was adjusted to operate at a depth of 100 mm and a rotation speed of 19 rpm, at a 250 mm radius to achieve a linear velocity of 0.5 m/s. The total operating time was set at 30 hours, divided into six periods of 5 hours each. After each period, the blades (samples) are removed from the wear test unit, cleaned, thoroughly washed with water, immersed in a dilute acetone solution and dried. The weight and dimensions were then measured, and the values were documented. The blades' mass loss was determined by calculating the difference

in mass before and after testing. The dimensional reductions in length, width and thickness were also measured. Each blade was tested only once.



Figure 3. Soil bin filled with gravel

### 3. Results and discussion

Initially, the blades were visually inspected. Wear was noticed on the edges and the blade tip, which had changed from sharp edges to approximately curved ones. Figure 4 shows the change in shape of the blade tip before and after wear. This result agrees with the findings of Tulaganova et al. [24]. The most common method for evaluating the wear of different materials is to measure mass loss and dimensional changes after a predefined sliding distance [25].



Figure 4. Blade tip before (left) and after wear (right)

#### 3.1 Wear

Figure 5 displays the cumulative wear of blades for each testing period. All blades show similar wear patterns. Furthermore, it was found that wear increased as the test progressed. However, the first testing period (5 hours) showed the highest wear rate for all blades. After that, the wear rate significantly decreased in the second period.

Nevertheless, in subsequent periods, the mass loss was not constant, but rather increased and decreased until the end of the test. This behaviour may be explained by gravel sliding on the blade, which can cause pressure on the surface. Hence, this process causes surface residual stress, somewhat increasing the hardness. This increase, although small, can lead to an improvement in wear resistance. Subsequently, the wear rate continues to fluctuate throughout the testing. In the first period, blade B3 exhibited the highest mass loss, reaching 3.70 g. At the same time, blade B1 showed the lowest value of 2.25 g during the same period. At the end of the test, blade B3 exhibited the maximum cumulative mass loss after 30 hours (total time), reaching 9.34 g, whereas B1 had the lowest cumulative wear of 5.49 g during the same period.

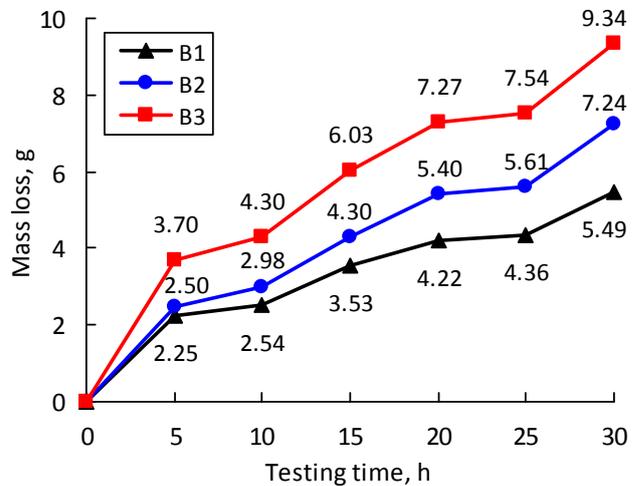


Figure 5. Wear curves for tested blades

Figure 6 shows the wear rate of each blade in g/h for the steady-state period (last 25 hours). Blade B1 had the lowest wear rate of 0.130 g/h, approximately 57 % of the wear rate of blade B3, which had the highest wear rate of 0.226 g/h.

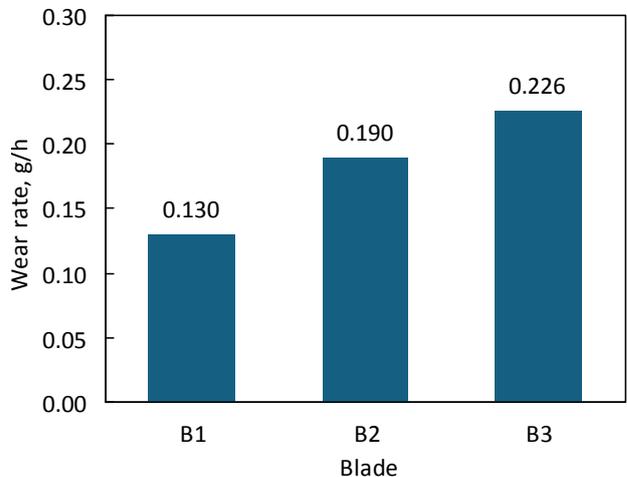


Figure 6. Wear rate of the tested blades for the steady-state period

### 3.2 Dimensional reduction

According to the results, the decrease in dimensions (length and width) followed a similar pattern to the mass loss of each blade. Figures 7 and 8 show that the length and width of the tested blades have decreased. Furthermore, it was noticed that the dimensions decreased as the test continued. This result agrees with the findings of More et al. [22]. Also, it was noted that the lowest cumulative reduction in dimensions (length and width) was in blade B1, as it reached 3.76 mm (3.6 %) and 0.85 mm (1.2 %), respectively, while the greatest reduction in dimensions was in blade B3, as it reached 4.9 mm (4.7 %) and 1.75 mm (2.5 %), respectively. Thus, the reduction of blade B1 in length and width is 76 % and 48 %, respectively, compared to blade B3. This result agrees with the findings of Chotěborský et al. [26].

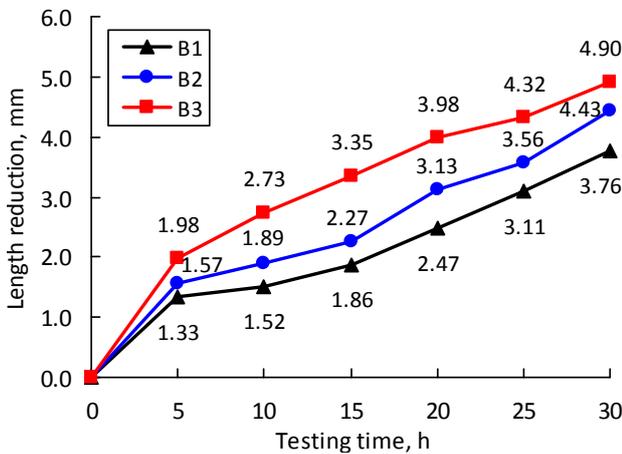


Figure 7. Length reduction of the tested blades

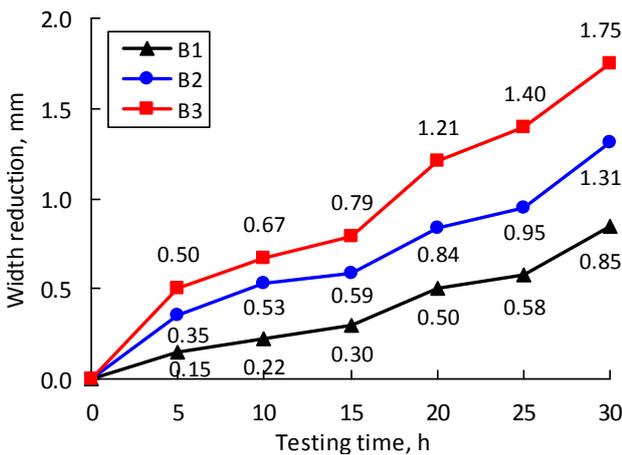


Figure 8. Width reduction of the tested blades

The thickness reduction of the blades was shown in Figures 9, 10 and 11. It was also noticed that the thickness reduction increases over time, as does the length and width. Furthermore, it was noticed that the thickness reduction of each blade differed by its location, with the blade tip (T) exhibiting the

maximum thickness reduction, followed by the outer edge (Eo), which was farthest from the centre of rotation and then the inner (closest) edge (Ei), which had the lowest thickness reduction. The reasons for these differences depend on the location. The blade tip shows the greatest thickness reduction because its small area allows pressure

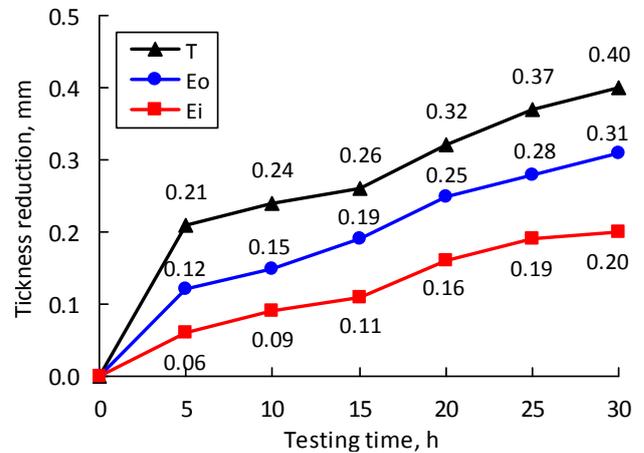


Figure 9. Thickness reduction of blade B1 (T – blade tip; Eo – outer edge; Ei – inner edge)

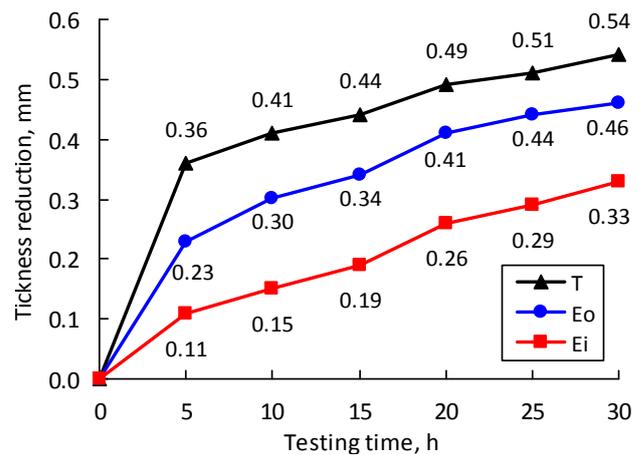


Figure 10. Thickness reduction of blade B2 (T – blade tip; Eo – outer edge; Ei – inner edge)

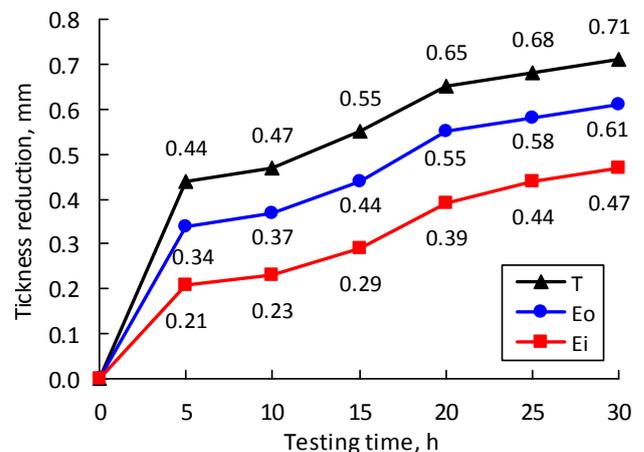
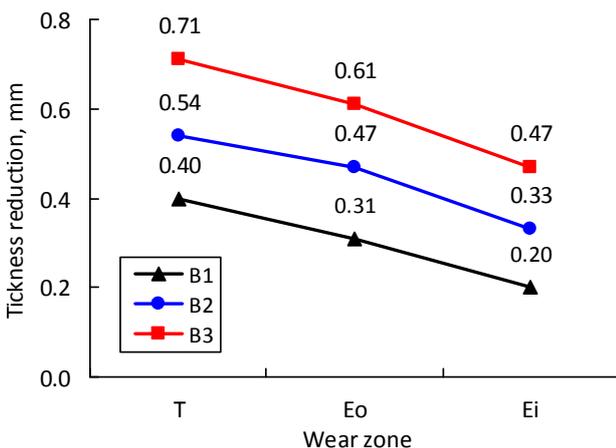


Figure 11. Thickness reduction of blade B3 (T – blade tip; Eo – outer edge; Ei – inner edge)

and friction to act on it from all sides, resulting in severe, intensive wear. At the same time, the difference in thickness reduction between the blade edges comes from the working mechanism of the circular soil bin. The plough blade's circular movement creates a variation in the radius of rotation between the two edges of the blade equal to its width. As the movement continues, this variation causes a slight increase in the sliding distance of the blade's outer edge. Continued work results in a noticeable increase in wear.

Figure 12 shows the total thickness reduction for all blades at the same zones. It differed from one blade to another. It also shows that blade B3 had the greatest thickness reduction across all zones, i.e. 0.71, 0.61 and 0.47 mm for zones T, Eo and Ei, respectively, while blade B1 had the lowest reduction, reaching 0.40, 0.31, and 0.20 mm for the same zones. In comparison, blade B2 exhibited wear values that were approximately average between those of blades B1 and B3 in all wear evaluations.



**Figure 12.** Thickness reduction at all zones of the tested blades

Finally, it has been verified that blade B1 has the highest wear resistance, while blade B3 has the lowest. To explain the wear behaviour of the blades, their hardness and chemical composition were reviewed in Tables 2 and 3. It was found that blade B3 had the lowest hardness and the lowest carbon, silicon and manganese content among the blades, while blade B1 had the highest, which led to improved wear resistance.

#### 4. Conclusions

The following conclusions can be drawn from this study.

The experiment has proven that the soil bin is an effective tool for simulating wear in the field

under controlled conditions, which contributed to reducing experiment time and lowering costs by using electricity instead of fuel.

The blades showed similar wear behaviour with varying values, with blade B1 showing the lowest wear rate of 0.130 g/h and the smallest length and width reductions of 3.76 and 0.85 mm, respectively.

The tip zone on each blade showed maximum wear, followed by the outer edges and then the inner edges.

The results indicate that the hardness and chemical composition of the material used in blade manufacture affect the wear resistance.

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