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Original Research Article

Wear resistance of selected cultivator coulters reinforced with sintered-carbide plates

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ABSTRACT

Within the research, wear resistance of coulters used in cultivators was evaluated. Three constructional solutions of the parts were examined: (A) coulters reinforced in the blade area with brazed-on sintered-carbide plates; (B) coulters reinforced in the blade area with sintered-carbide plates and in their further part by pad-welding; (C) coulters with no reinforcement (made of homogeneous material). The examined parts were installed on a four-beam cultivator that was next used for cultivation of loamy-sand soils with significant humidity.

In comparison to the non-reinforced coulters, those reinforced with sintered-carbide plates only and with additional pad-welding were characterised by decidedly high resistance to abrasive wear. Reinforcement of coulters resulted in a change of their limit-state condition. Plates made of sintered carbides decreased rate of length reduction of the parts, which led to big loss of their thickness in the base material area. The limit wear condition of the coulters was related to rubbing-through or reduction of bending strength modulus of the coulters that broke when hitting at stones. For the non-reinforced coulters, the limit wear condition resulted from excessive reduction of their length.

1. Introduction

In the present-day agriculture, going away from the traditional ploughing system towards minimisation of cultivating operations is observed. These changes are in accordance with the idea of conservation agriculture (CA) promoted, among others, by the Food and Agriculture Organization (FAO) and European Conservation Agriculture Federation (ECAF). According to the FAO data, in 2015, 157 Mha of fields were utilised in the CA system (11% of total field area) [1]. Propagation of the CA system is characterised by high dynamics. At the beginning of 20th century, acreage of CA cultivation increased at 7 Mha per year [2–4] and after the season 2008/09 – even at 10 Mha/yr [5].

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Conservation agriculture is widely used in South-American (66 Mha) and North-American (54 Mha) countries, with a significant part of Australia (17 Mha), but with a small part of Asian and African countries [1]. According to data of European Statistical Office, in 2010 the CA system was used in UE countries on the area of ca. 23 Mha (nearly 25% of arable grounds) [6]. In the countries endangered by droughts (e.g. Australia, USA, Brazil, Argentina), apart from reduction of CO_2 emission and contamination of waters with deposits, sequestration of carbon in soil, protection of landscape, an important argument for utilisation of CA is a possibility to reduce wind erosion of soils that is conducted by plough tillage [3,7–9]. In European countries, the reason for using CA, more important than protection of soils, was so-far the economic factor [4,7] related to reduction of costs of soil cultivation [10–12].

The changes occurring in agriculture indicate that, in the future, development of the CA system is expected, with concurrent restriction of plough tillage. However, simplified cultivation systems with use of cultivation aggregates, cultivators or disk harrows, can gain importance. Thus, it is important to improve working parts of these machines by increasing their wear resistance, which results also in shorter times of operational stoppages of cultivating machines and reduction of costs related to replacement of worn parts [13].

Working components operating in soil are subjected mostly to wear as a result of action of particles (e.g. quartz or corundum) harder than material of the cultivating parts [14]. Therefore, one of the ways to increase abrasive wear of working components of tillage machines is increasing their hardness. This way, penetration of abrasive grains into material is minimised, thanks to that abrasive wear occurs with lower intensity [15]. However, such a procedure has some restrictions. The subject literature indicates a possibility that a non-linear relationship occurs between hardness and abrasive-wear resistance [16], linking abrasion resistance with material microstructure [17,18]. In addition, increase of hardness can be accompanied by decrease of impact resistance of the material.

With regard to the still unsolved problem of high intensity of wear of the parts working in soil, new material and constructional solutions are searched for. In the research works carried-out so far, usability of steels containing microaddition of boron [19] and boroned steel [20] were verified. In laboratory and field tests, the higher abrasive-wear resistance of ploughshares with coated single phase of Fe_2B in comparison to conventional ploughshares was demonstrated [20]. In these studies, it was also found that there is no proportional increase in abrasive-wear resistance along with the increase in the surface hardness of the ploughshares caused by boronizing. The well-known solutions, many times experimentally evaluated, include pad-welding of working parts. This applies, for example, ploughshares, for which the effectiveness of this solution was confirmed by Horvat et al. [21], by comparing weight losses and changes in the linear dimensions of such reinforced and not reinforced ploughshares during cultivation of sandy clay soil. The usefulness of pad-welding was also evaluated in case of cultivator coulters, confirming its beneficial effects depending on the method of applying the padding-weld to the blade [22]. The presently developed methods of increasing durability of components also include using of oxide ceramics and plates made of sintered carbides as the parts with high abrasive-wear resistance, installed in the areas most exposed to destructive action of soil. Foley et al. [23], as well Müller et al. [24] demonstrated the usefulness of ceramic plates made on the basis of Al_2O_3, confirming their high abrasive-wear in the soil. In addition, they pointed to the possibility of limiting of the brittleness of this material by using the appropriate technology for assembling the plates. Also Napiórkowski and Ligier in laboratory tests showed that specimens made of aluminium oxide are characterized by many times lower wear, depending on the abrasive medium grain size, than martensitic steel 38GSA [25]. In similar tests conditions, the tribological properties of plates made of sintered carbides B26 and G10 were also evaluated, showing a many times lower wear in relation to Hardox 500 steel [26]. On the other hand, in field conditions, the durability and geometry changes of subsoiler shanks furnished with sintered carbide plates, with respect to an evaluation of the usefulness of this constructional solution was verified. For one constructional solution of the shanks, the usefulness of sintered carbides plates was confirmed, while in other constructional solution of the shanks, intensive grinding of the plates was found, resulting from a large stoning of cultivated soil and too low stiffness of the base part on which the plates were assembled [27]. The influence of the geometry of the working elements with respect to their abrasive wear was also considered. In this area Fielke [28] demonstrated that the blunt cutting edge of the working parts working in soil can increase pulling force by up to about 80%, with a comparable increase in the force acting on the parts vertically upwards. Natsis came to similar conclusions, further proving that in case of ploughshares, blunting of their blades affects to the deterioration of quality of tillage [29]. Thus, the wear of the described working parts is multifaceted, directly related to the durability of the elements, the quality of the tillage and resistances accompanying tillage.

The present-day research works and commercial offer concerning working parts of tillage tools indicate that plates made of sintered carbides belong to perspective materials, more and more often used in practice. At the changes currently occurring in soil cultivation technology (CA), a conclusion can be drawn about a well-grounded need to carry out research works related to durability and wear mechanisms of working components of tillage tools equipped with plates made of sintered carbides. It should be emphasised that usability of these components is a resultant of properties of the applied materials and correctness of the constructional solution itself, resulting from selection of dimensions, location and thickness of pad-welded layers, location of sintered-carbide plates and durability of their coupling with base material of the parts. In this connection, tribological research works executed in service conditions should be considered especially well-grounded as the works objectively verifying usability of new structures of working parts operating in soil.

The presented research was aimed at evaluating wear resistance of cultivator coulters with various constructional solutions during their operation in service conditions.

2. Materials and methods

Fig. 1 shows cultivator coulters used in the tests. More detailed information on structures of the parts is given in Figs. 2–4.