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Innovative construction of agricultural tools from modern casting materials

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Summary. The article discusses some results of work carried out in the framework of material and technological conversion, which aims to replace with cheaper and / or more durable castings, machine parts and agricultural equipment made so far in the forging and welding technology. The focus is on the agricultural tools working in the soil. The fallowing tools have been created and tested in extreme wear on the field: rotational plowshares, hoes subsoiler, cultivator tooth, cultivator spring, cultivator spring tooth point. Conducted field tests of prototype tools have confirmed the validity of the action taken.
Key words: castings, Austempered Ductile Iron – ADI, agricultural tools, performance tests.

INTRODUCTION

The aim of this study was to increase innovation, modernity and competitiveness of Polish industry in the manufacture of agricultural machinery and equipment.

Prior to the implementation of this work, a study focused on the conversion of agricultural machinery parts previously performed by conventional methods (forging machining, welding, etc.) on the elements made with casting technology, of course, where it seemed to be technically and economically viable.

Foundry is a very extensive industrial branch. It is estimated, according to data from the U.S., that castings are components of up to 90% of final industrial products. In the economies of developed countries there is observed a permanent increase in the production of castings. There are more new applications in the fields of industrial castings such as medicine, energy (including renewable energy), which require a sufficiently high standard, enhanced technical and operating parameters of cast components composing the final product.

It is the quality of the cast components that determines the quality of the final product and, consequently, its price.

Extensive use of castings as components of final products creates opportunities for conversion of various components of machinery and equipment originally performed by other machining technologies such as forging, welding, machining on the parts made with casting technology.

Business practice has shown possibility of replacing these items with casting elements, which often are lighter, more durable, resistant to abrasion, thermal fatigue, etc. [1, 2, 3, 4, 5, 6, 21, 22, 23, 24]. As a result of the conversion work on the material and technology, an experimental series of castings for agriculture have been done. These agricultural tools were made of high-quality ductile iron with alloy additives and heat treatment and they were working in the soil. The fallowing type of tools have been created: blades for rotational plows, subsoiler plough, cultivator points (duckfoot share), tooth for cultivator spring, cultivator spring tooth point [7, 7, 9, 10, 11, 12].

PLOUGH CASTINGS

On the Polish market there are available ploughs made by using two different technologies: bending with welding and stamping. Examples of blades made by using these technologies are shown in Figure 1

a.
b.

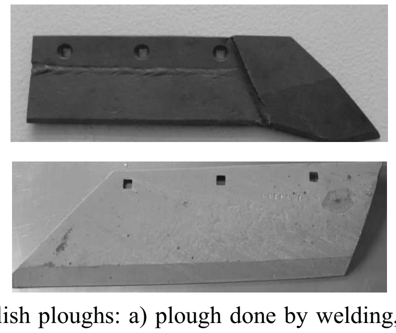


Fig. 1. Polish ploughs: a) plough done by welding, b) plough done by stamping

These ploughs were tested for mechanical and tribological properties. The obtained results were used to determine the material requirements that should be met after the change in the casting plough's material.

During working on the field ploughs of the plow are subjected to a very complex process of destruction. On the one hand there is a strong wear of the soil, on the other hand they are vulnerable to stress cracking due to the presence of high static and dynamic loads. Therefore, the material from which they are made must be very durable and resistant to erosive wear, but sufficiently plastic and able to transmit impact loads (frequently occurring) as a result of stone impact in the soil.

Among the casting materials, properties similar to steel that is plastically processed are possessed only by ductile iron after heat treatment (hardening of isothermal transformation ADI). That ductile iron is resistant to abrasion in different conditions. Its mechanical properties are dependent on the type and quantities of alloying additives, and especially on the parameters of the heat treatment. Such a ductile iron obtained after the isothermal tempering has the tensile strength in the range 800-1500 MPa and elongation up to 18%, depending on the process used. For obtaining the desired properties, the quality is significant of spheroidal graphite iron (particularly the form, size and number of graphite precipitates), and heat treatment parameters. Less significant is the chemical composition of the cast iron. Thus, it can be varied in a very wide range. However, it is necessary to add elements (corresponding to the wall thickness of the casting) to facilitate the hardenability of iron (for example, Ni, Cu).

In order to verify the suitability of the alloy elements of agricultural machinery operating under abrasive wear in direct contact with the cultivated soil, tests have been performed of casting prototype ploughs (shown in Fig. 2).

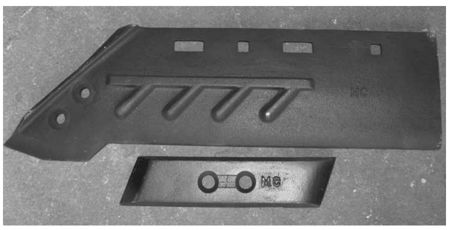


Fig. 2. Share casting and blade for standard and rotational ploughs [own construction]

Abrasion tests have been carried out both in the laboratory and during performance under field conditions. They revealed that the optimum type of ductile iron appears to be a cast (designated as W3) with the following characteristics:
R_m – about 1200 MPa,
A_5 – more than 1.5%,
KCU – over 7 J/cm²,
Hardness – approximately 40 HRC.

As it is shown in Figures 3 and 4, that type of ductile iron can be used successfully on the cast plough's blades in the place of expensive forged and welded blades.

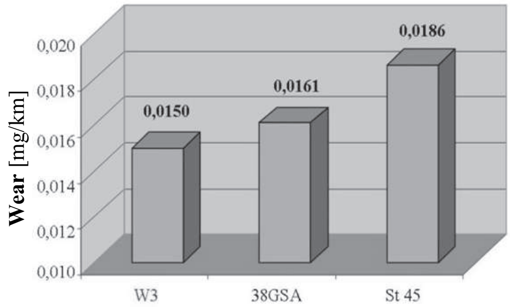


Fig. 3. Wear of alloys tested under dry friction [own research]

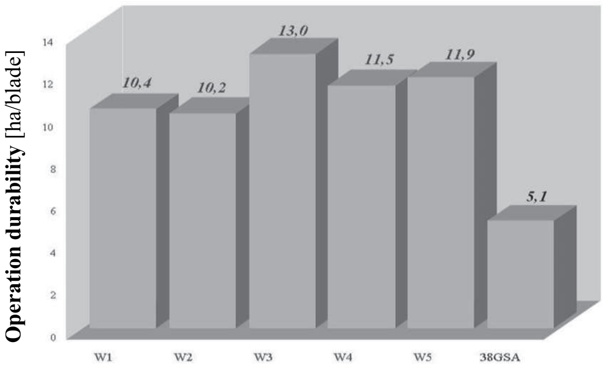


Fig. 4. Operation durability of the castings blades made of cast iron ADI (marked W1 - W5) and forged steel blades made of 38GSA steel [own research]

SUBSOILER PLOUGH CASTINGS

Currently used subsoiler ploughs are made as welded steel structures (Fig. 5). In this paper the conversion of material and technology of these tools have been presented. An innovative design and construction of subsoiler plough have been developed. Also, a short experimental series have been manufactured and tested (Fig. 6).

Manufactured experimental tools were tested in operational condition in the field. During preparation of field research, a study was made concerning the analysis of diversification of agricultural machines used by farmers, including subsoilers. As a result of such an analysis, a general conclusion can be stated that at present the majority of farmers (different acreage) uses a diverse construction machines including cultivation Subsoilers with welded subsoiler ploughs.

At the same time it should be noted that the assortment of soil machinery is constantly changing. Structural modifications of these machines also cause a new, individual for each manufacturer, way of attachment and shape of agricultural tools. Therefore, for the experimental tests were selected only those farms, whose machines can be fitted with the tested elements. The results of wear intensity of casting subsoiler made of ADI were compared with (in similar operating conditions) reference items purchased from a leading Polish manufacturer. Research has been carried out in accordance with the methodology developed in PIMR. Results showed that in the case of casting subsoiler a loss of weight on the 1 ha cultivated area was 58.75 g /ha

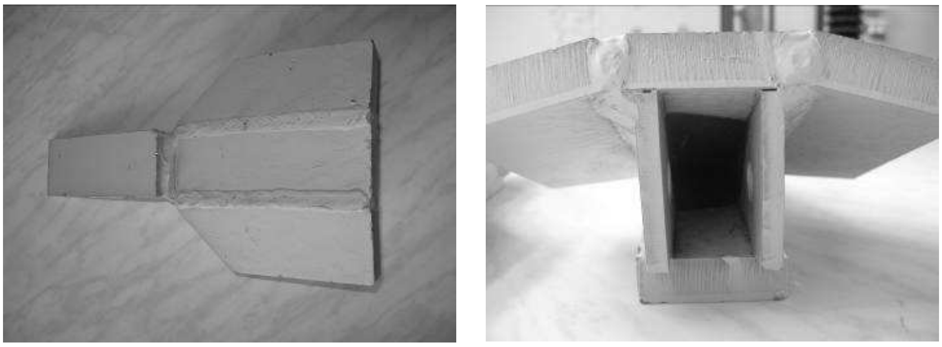


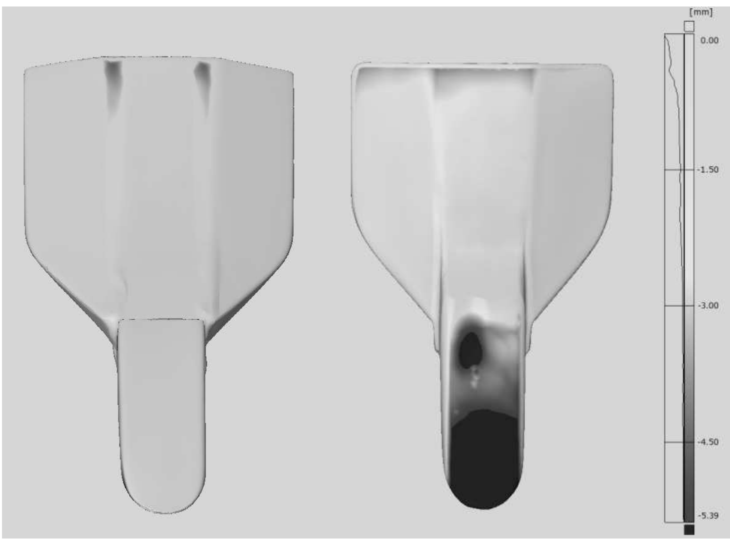
Fig. 5. Subsoiler plough welded from 7 elements

Fig. 6. Casting of subsoiler plough [own construction]

and welded coulter – 45.92 g/ha, and it was larger by the 27%. It should be noted that subsoiler plough has difficult working conditions, which are associated with significant thermal effects occurring in the soil at the depth of about 35-40 cm. These effects could be the cause of structural changes in particularly vulnerable to such changes ADI cast iron (decrease in the ausferrite hardness). Errors that occurred in the internal structure of the thick-walled castings could also contribute to the increased wear intensity of these components.

In the case of casting tools, a much bigger surface area had a contact with the cultivated soil compared to the traditional tools. That suggests a necessity of modification of the castings construction. Rockwell Hardness of reference subsoiler plough made of welded steel with boron is about 40 HRC. The hardness of ductile iron castings after isothermal hardening was also about 40 HRC (according to the technology assumption). Simultaneously, an area of reduced hardness lower than 30 HRC was observed under the gating system. That suggests a necessity of modification in that area: correction of the gate supply system.

Images of scanned subsoiler plough (Figure 7) show the distribution of surface wear intensity. Scanning image of these tools and investigations of surface (tribological aspect), showed no presence of anomalies in the nature of wear intensity and permanent deformation. Only small changes in surface on edges were highlighted.



Rys. 7. Comparison of subsoiler plough wear intensity, welded construction (left) and casting (right) [own research]

DUCKFOOT SHARE CASTINGS

As part of the material and technology conversion subject in the field of agricultural tools working in the soil, an innovative variant of casting duckfoot share for spring cultivator teeth has been developed. Currently produced duckfoot share is made from steel by forging and welding. Castings of Duckfoot shares are made of ductile iron tempered with isothermal transformation (ADI). Comparison of construction of an existing one and innovative design of duckfoot share is shown in Figure 8.

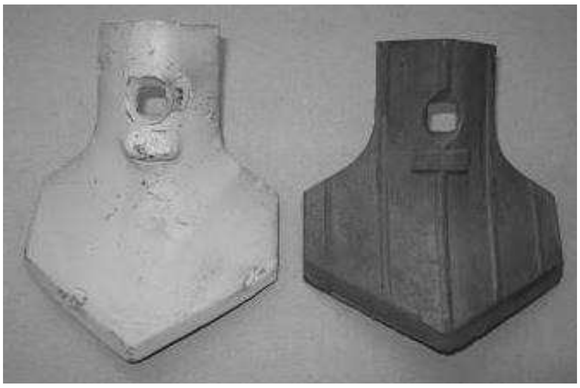


Fig. 8. Duckfoot share for spring cultivator teeth made by forging and welding (left) and as a casting (right (own construction)

In order to assess the operation durability of forged and cast iron duckfoot share, comparative tribological tests were conducted of these tools. They helped to assess their wear intensity in the stochastically varying conditions of operation in the soil. Studies were carried out in accordance with the developed methodology in PIMR and showed that in the case of cast duckfoot share, the average loss of weight per 1 ha of cultivated area was 1.11 g / ha (average from three farms) and was about 31% lower compared to the forged duckfoot share from steel with boron. It should be noted that the Rockwell hardness of cast duckfoot share from ductile iron tempered isothermally (according to the technology assumption) was about 40 HRC, while the hardness of forged steel duckfoot share was higher; approximately 45 HRC. Increased hardness of steel duckfoot share did not translate, therefore, in this case, on direct increase of operational durability of the tool.

Scanning images of duckfoot share after the wear intensity research in the field (Figure 9) showed the distribution of surface defects with a scale of values. Scannig image of these tools and investigations of surface (tribological aspect), showed no presence of anomalies in the nature of wear intensity and permanent deformation. Only small changes in surface on edges were highlighted, dispersion of deviations (losses) in the surface was 2.50 mm for the forged duckfoot share and 3.21 mm for duckfoot share casting.

CULTIVATOR POINT CASTINGS

Cultivator points for spring teeth are interchangeable tool designated for agragates for pre-sowing tillage, working directly in the soil. Current technology of manufacturing cultivator points uses fallowing methods; cutting, hammering, drilling, grinding (Fig. 10). High level of wear intensity of a large scale is one of the most significant premises for an attempt to try to replace steel cultivator points with castings. Therefore, a new design and construction were developed and experimental series of innovative cultivator points were manufactured from ADI ductile iron (Fig. 11).

Operational durability tests of cultivator points confirmed the validity of their implementation in casting variants ver. II and ver. V. Average wear intensity measurements

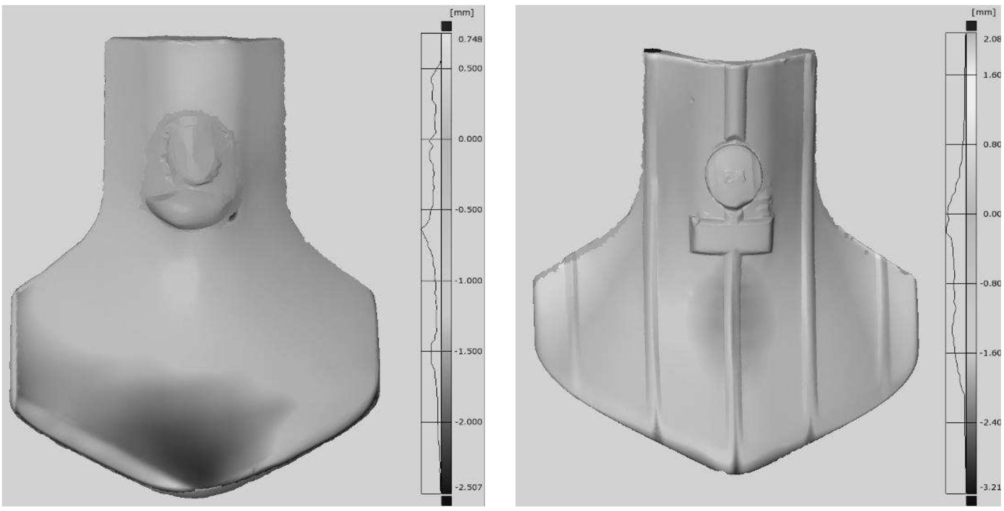


Fig. 9. Comparison of duckfoot share wear intensity, forged construction (left) and casting (right)

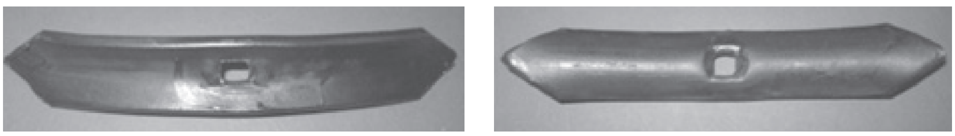


Fig. 10. Cultivator point for spring teeth made from steel

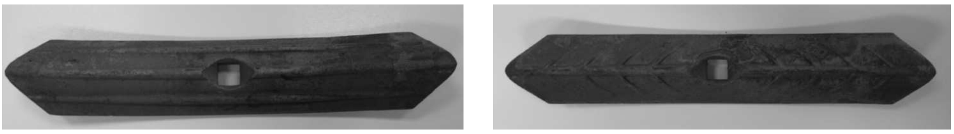


Fig. 11. Cultivator point for spring teeth made from ADI ductile iron (two variants: ver. II on the left, ver. V on the right)

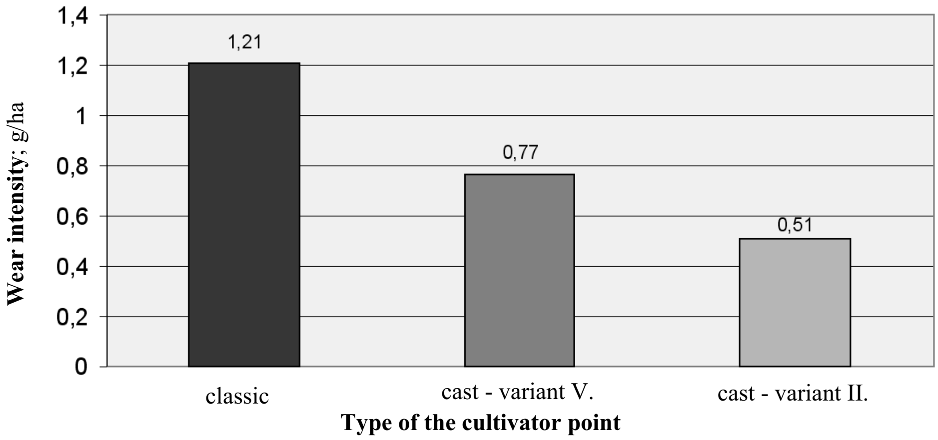


Fig. 12. Graph showing the average wear intensity of cultivator points in different construction variants (operational speed of 6-8 km/h area of 100 ha)

were made of newly developed cultivator points (at the "classical" speed of 6-8 km) in the variant II and V compared with classic cultivator points made from steel. The obtained results showed that there are significant differences in wear intensity (Fig. 12).

The average wear intensity of casting cultivator poins in variant II was 0.51 g/ha, and in variant V 0.77 g/ha, compared to the 1,21 g/ha in the case of classic cultivator point (made by forging). It can be easily calculated that castings are 2-3 times better than the classic equivalent.

CONCLUSIONS

Attempts of material and technological conversion of selected agricultural tools, in most cases provided promising results. Modern materials such as ductile cast iron tempered with isothermal transformation (ADI) can often compete with steel (constructional and tool type) [13, 14, 15].

Scanning images of surface defects on different tools working in the soil showed the most vulnerable places of wear. This will help in the future to improve the technology to increase the operational durability of these tools in key areas (e.g. possible application of laser welding with powder metal alloys – LMD).

The first attempts to use this technology in this field were carried out in the Department of Agricultural Machines Materials Testing and Development in PIMR in Poznan. Research on the effectiveness of laser technology application and laser cladding of metal alloy powders are ongoing, and their results will be subsequently published in scientific journals.

In parallel in the Foundry Research Institute in Cracow work is done on the development of new types of ductile cast iron tempered in isothermal transformation (CADI) [16, 17, 18, 19, 20]. Described in this paper agricultural tools castings working in the soil constructional solutions have been patented or patent pending by cooperating in this area research institutions: PIMR in Poznan and IO in Krakow.

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- research and development project No. N R03 0009 06: "Developing technologies and construction design of elastic elements to a new generation of soil preparation pre-sowing aggregates working with increased operating speeds", financed by the NCBiR in Poland, No. of agrement N R03 0009 06/2009.

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Streszczenie. W artykule omówiono wybrane efekty prac prowadzonych w ramach szeroko rozumianej konwersji materiałowo-technologicznej, której celem jest zastąpienie tańszymi i/lub trwalszymi odlewami, elementów maszyn i urządzeń wykonywanych dotychczas w technologii kucia i spawania. Skoncentrowano się na narzędziach rolniczych pracujących w glebie. Wykonano i przebadano narzędzia pracujące w ekstremalnych warunkach zużycia ściernego jak: lemiesze pługów obracalnych, redlice głębosza, gęsiostopki zębów sprężystych kultywatora, redliczki zębów sprężystych kultywatora. Przeprowadzone badania eksploatacyjne wykonanych narzędzi prototypowych potwierdziły słuszność podjętych działań.
Słowa kluczowe: odlewy, żeliwo ADI, narzędzia rolnicze, badania eksploatacyjne.