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Cast agricultural tools for operation in soil

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Summary. This paper describes new cast designs of agricultural tools operating in soil. Using previous experience with the implementation of new ADI cast shares for reversible ploughs and single-sided ploughs, the design and appropriate technology were developed to cast subsoiler coulters and cultivator duckfoot. These castings were heat treated (austempered) and used in performance tests. The development of these tools, innovative in terms of their shape geometry and selection of suitable cast material resistant to extra heavy operating conditions, improved the functionality and prolonged service life of the agricultural machinery.

Key words: iron alloys, ductile iron, ADI, computer simulation, agricultural tools.

INTRODUCTION

For many years the Foundry Research Institute in Cracow has been cooperating with the Industrial Institute of Agricultural Engineering in Poznan in the development of new designs and selection of materials for cast agricultural tools operating in soil to replace the components forged and welded [9, 10, 15-17]. As a result of this cooperation, a share was designed and cast to operate in the home-made reversible and single-sided ploughs. It won numerous medals and awards at home and abroad.

Currently, work is underway on new solutions. Among other things, castings of subsoiler coulter and cultivator duckfoot were designed, manufactured and submitted in a patent office.

CASTING OF CULTIVATOR DUCKFOOT

Cultivator duckfoot operates during field work in soil under the conditions of tribological wear. The technology applied so far to make this tool has been punching and forging of steel components, followed by drilling, welding, grinding, and applying a corrosion-resistant coating. A photograph of this tool working directly in the soil during pre-sowing land cultivation is shown in Figure 1.

Fig. 1. A photograph of forged duckfoot for the cultivator spring teeth

As a part of the ongoing work, a new innovative design of the cast duckfoot was developed. Documentation was elaborated, adapting the design of the tool to the operating conditions and casting manufacturing technology. Illustrative models were prepared next, using the design method based on CAD and Solid Works giving the possibility of any arbitrary shaping and modelling of elements, allowing for the type and intensity of loading applied to them. Figure 2 shows the developed models of a duckfoot for the cultivator spring teeth. A virtual model and a real model in the version selected for tests are shown in respective drawings.

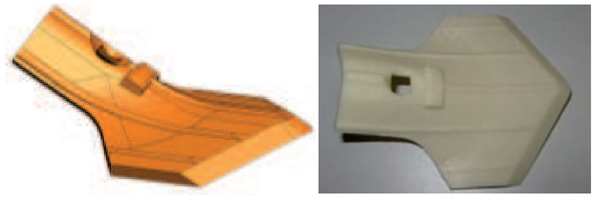
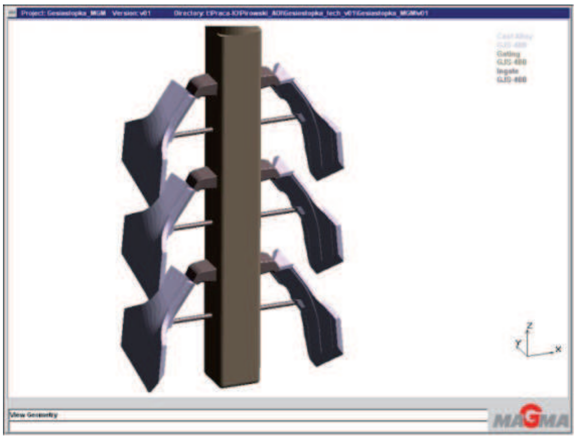


Fig. 2. Duckfoot for the cultivator spring tooth: virtual 3D model made in Solid Works (left) and pattern made by RP on a 3D DIMENSION 1200es printer (right)

The casting technology was developed by computer simulation. The simulation has shown that:
– reduced temperature of pouring and lower initial mould temperature reduce the casting porosity,
– the porosity is also reduced by proper treatment of liquid metal with a good degree of graphitisation,
– technology no. 2 where the technological mould component is shifted to the lower part of casting (Figure 3) reduces porosity in places of the hot spots during casting solidification.

1.



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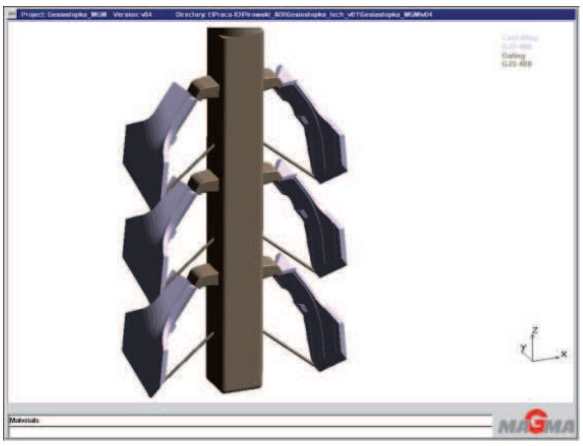

Fig. 3. Drawings of the two examined technologies

The cast iron of composition given in Table 1 was used for a pilot batch of duckfoot castings made according to technology no. 2. A photograph of these castings is shown in Figure 4.

Table 1. The results of chemical analysis of the melt

Ductile iron	Chemical composition; wt.%								
	C	Si	Mn	P	S	Mg	Ni	Mo	Cu
nickel-copper	3,60	2,45	0,32	0,035	0,020	0,065	1,90	-	0,93

Fig. 4. Duckfoot castings for the cultivator spring teeth (made by the developed technology)

The ready duckfoot castings were subjected to a heat treatment process (austempering). To reduce the oxidation process at high temperature, the austenitising treatment was carried out in a protective atmosphere of argon.

Hardness after heat treatment, measured on the three finished castings of duckfoot, ranged between 36 and 40 HRC which, according to PN-EN 1564, has qualified this material as EN GJS 1200-2 [1].

CASTING OF SUBSOILER COULTER

Subsoiler coulter operates in soil exposed to the conditions of tribological wear. The depth of soil cultivation reaches 80 cm. The technology used so far consists in punching and cutting of steel components, and then drilling, welding, grinding, and applying a protective anti-corrosion coating. A photograph of this tool operating directly in the soil during pre-sowing land cultivation is shown in Figure 5.

Fig. 5. A photograph of the welded subsoiler coulter

As a part of the ongoing work, a new innovative design of the cast subsoiler coulter was developed. A documentation was elaborated, adapting the design of the tool to the operating conditions and casting manufacturing technology. Illustrative models were prepared next, using the same design technique as for the design of the cultivator duckfoot castings. Figures 6 and 7 show models of the subsoiler coulter in version selected for trials.

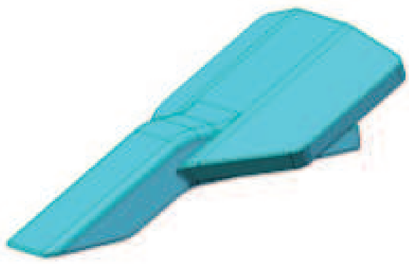

Fig. 6. Virtual 3D model of subsoiler coulter made in Solid Works

Fig. 7. Pattern of subsoiler coulter made by RP on a 3D DIMENSION 1200es printer

Based on the results of computer simulation, a technology for casting the subsoiler coulter was developed (Figure 8).

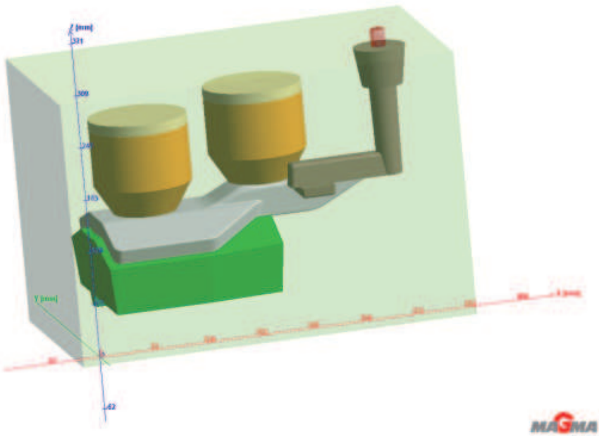

Fig. 8. Casting technology

The performed computer simulation of mould filling and metal solidification process according to the developed technology revealed that:
- the use of two risers in exothermic sleeves ensures full feeding of the casting,
- the obtained final properties indicate that the casting has a ferritic structure,
- the tensile strength R_m in the casting cross-section exceeds the value of 400 MPa, reaching in some areas 500 MPa and more,
- hardness ranges from 150 to 170 HB,
- elongation is from 16 to 19%,
- large variations of properties in the casting cross-section are due to variations in the wall thickness, and thus to a temperature gradient between the individual points of the casting [4-8],
- the applied heat treatment significantly changes the alloy properties, leading to their homogenisation in the casting cross-section [4-7].

From the cast iron of the composition given in Table 2, a pilot batch of subsoiler coulters was cast. A photograph of these castings is shown in Figure 9.

Table 2. The results of chemical analysis of the melt

Ductile iron	Chemical composition; wt.%								
	C	Si	Mn	P	S	Mg	Ni	Mo	Cu
nickel-molybdenum	3,85	2,90	0,61	0,050	0,010	0,080	1,50	0,47	-

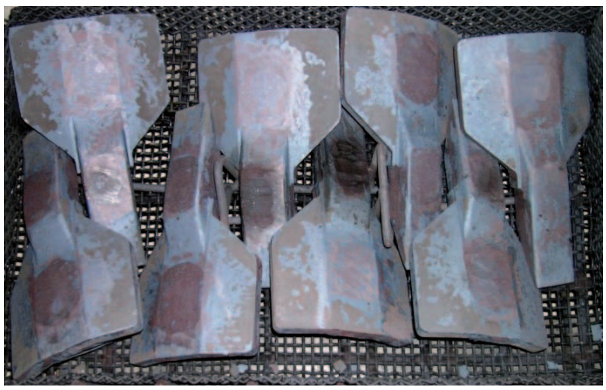

Fig. 9. Subsoiler coulters cast by the developed technology

The heat treatment process of the subsoiler coulters was performed in an LT ADI -350/1000 technological line using the following equipment:
- electric chamber furnace, type B4 - ENL,
- salt bath, type WS-4/450 EL,
- washing and drying device, type WPSD-4EL.

Hardness after heat treatment, measured on the six finished castings of subsoiler coulters ranged between 39 and 42 HRC which, according to PN-EN 1564, has qualified this material as EN GJS 1200-2 [1].

CONCLUSIONS

The investigation of the operating conditions and of the wear and tear behaviour of the cultivator duckfoot and subsoiler coulters allowed, using special computer programmes, for the design of these tools in a new geometry, better adjusted to the requirements of the casting technology.

The tests previously conducted on ADI enabled the selection of the best material for the designed new items, optimising at the same time the heat treatment parameters [2, 3, 11-14, 18-20].

The, developed through computer simulation, casting technologies for the manufacture of subsoiler coulter and cultivator duckfoot allowed making high-quality cast tools for the cultivation of agricultural land. Prototype castings of these tools were transferred to the operational testing and the results will be discussed in a publication to follow.

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ODLEWANE NARZĘDZIA ROLNICZE PRACUJĄCE W GLEBIE

S t r e s z c z e n i e. W pracy opisano nowe konstrukcje odlewanych narzędzi rolniczych pracujących w glebie. Wykorzystując dotychchczasowe doświadczenia związane z wdrażaniem nowych lemieszy do pługów obracalnych i zagonowych wykonanych z żeliwa ADI, przystąpiono do opracowania konstrukcji i odpowiedniej technologii odlewania redlicy głębosza oraz gęsiostópki kultywatora. Odlewy te obrobiono cieplnie (hartowanie z przemianą izotermiczną) i przekazano do badań eksploatacyjnych. Opracowanie tych innowacyjnych narzędzi pod względem geometrii kształtu i doboru odpowiedniego tworzywa odlewniczego odpornego na szczególnie trudne warunki pracy pozwoliło zwiększyć ich funkcjonalność i trwałość eksploatacyjną.

S ł o w a k l u c z o w e: stopy żelaza, żeliwo sferoidalne, ADI, symulacja komputerowa, narzędzia rolnicze.