



Choice of material and development of technology to manufacture the working parts of a rotor operating in machine for turning of triangular heaps

W. Uhl^a, Z. Pirowski^a, E. Czekaj^b, J. Wodnicki^a

^a Department of Ferrous Alloys, Foundry Research Institute, ul. Zakopiańska 73, 30-418 Kraków, Poland

^b Department of Non-Ferrous Alloys, Foundry Research Institute, ul. Zakopiańska 73, 30-418 Kraków, Poland

Received 08.02.2008; accepted in revised form 17.03.2008

Abstract

The theoretical part of the study discloses the genesis of the research which originated from a possibility of replacing the so far used expensive machine parts with parts cheaper and yet offering similar quality and performance life. A short characteristic of the machine was given where the main operating parts made so far from steel were replaced with parts made from cast iron. The equipment and its main applications were described.

In the research part of the study several types of alloys were proposed. Their use is expected to ensure the required performance life of parts combined with price reduction. A short characteristic of the proposed material was given. A technology of making moulds for the said machine parts was developed. Using this technology, the respective moulds were made and poured next with three cast alloys.

One of the proposed materials was subjected to four types of the heat treatment, two alloys used as reference materials were left in as-cast state. The castings were fettled and weighed. The hardness of the cast materials was measured.

The working (turning) parts were delivered for operation to a sewage-treatment plant where, after assembly in a turning machine, the performance tests were conducted.

Keywords: Environmental protection; Innovative foundry materials and technologies; Wear-resistant alloys; Mechanical properties.

1. The aim and scope of the study

The present study was initiated by one of the sewage-treatment plants vividly interested in the possibility of replacing the so far used working parts of a turning machine with parts cheaper but of similar performance life.

Hence the main aim of the present work was making a trial lot of castings operating as parts of the machine for turning of triangle heaps (the turning paddles) using a material of the properties comparable with materials used so far but enabling a

reduced cost of the manufacture of these parts. In our activities carried out so far, quite often we faced the situations when a “weak” link in the operating equipment was the quality of some operating parts of machines and equipment and their high price. The example are ploughshares used by agricultural industry and bushings in mechanical coal miners. When these parts started to be made of proper materials, it has finally become possible to successfully match their long performance life with low cost of manufacture.

2. A short characteristic of the machine

The investigated machine (Fig.1) is used for turning of typical triangular heaps.



Fig. 1. The turning machine

When the machine is operating, two scrapers placed before the frame are pushing the turned stock from the wheel tracks to the inside where it is taken over by the revolving rotor and thrown backwards. This process also serves for the disintegration of large lumps. Since the processed material is in most cases thrown centrally, a new well-aerated heap is formed.

Optionally, the machine can be equipped with an installation for wetting of the heaps with water, ejected from ducts connected to a water feeding system or to a storage reservoir. Depending on the type of the turning machine, it is moving on wheels or caterpillars.



Fig. 2. Paddles on a rotor of the turning machine

As mentioned previously, the working elements of the turning machines are rotors with paddles fixed on the external surface - the, so called, turning paddles (Fig. 2).

The said machines are used in sewage-treatment plants and on municipal waste dump fields. One of the main tasks of the turning machine is mixing of organic matters, like straw, grass, hay, etc. with semi-liquid stock, obtained during the municipal waste treatment, and then with soil and refining additives to produce mineral fertilizers used in agricultural industry.

Below the example of overall dimensions and operating parameters of a turning machine is given:

overall dimensions of the machine:

- width – 5200 mm,
- length - 3200 mm,
- height - 3400 mm,

overall dimensions of the rotor:

- width – 4300 mm,
- diameter – 1000 mm,
- dimensions of a paddle – 148 x 120 x 10 mm

operating parameters of the machine:

- maximum rotational speed of the rotor – 240 1/min,
- accessories of the rotor – 8 combs – 44 tools (turning paddles),
- feed rate – up to 50 m/min,
- turning capacity - 300 – 3000 m³/h.

3. Discussion of results

3.1. General

To know the operating conditions of the machine for turning of triangular heaps, the main working parts of which are the paddles discussed in this article, a sewage-treatment plant where this machine is used has been visited.

The turning machine was installed in the sewage-treatment plant. A practical display of its operation under the standard operating conditions was arranged. The display demonstrated the conditions and the capabilities of the machine.

The practical display and the technical specification helped us understand the conditions that the material used for the directly operating parts of the machine, i.e. the turning paddles, should satisfy. The conditions are very demanding. First of all, the material should be characterised by high mechanical properties, like the tensile strength, ductility, hardness and abrasion wear resistance. It should, moreover, offer adequate corrosion resistance, taking into consideration the environmental conditions of its future operation.

Taking the above into consideration as well as the specification of the material used so far (manganese cast steel), the work on the choice of the best material and technology for casting of the turning paddles has started.

3.2. The scope of the research

- Choice of moulding technology and mould making process.

The sewage-treatment plant interested in the new cast material for the turning paddles provided us with a brand-new specimen of the paddle, which served us as a pattern for the die used in the proposed technology of mould-making (the technology of lost wax patterns). In the rubber die several wax patterns of the required configuration were made. After combining the patterns in clusters, the ceramic mould was fabricated by the successive application of six ceramic layers.

The ceramic slurry in which the pattern clusters were immersed was composed of Ekosil binder and silica flour in a ratio of 1 : 2. As a loose dry ceramic material for the successive layers we used silica sand - fine-grained, first, and coarse-grained, next. After drying of the last

ceramic coating, the wax patterns were melted out in a pressure autoclave in the atmosphere of steam overheated to a temperature of 120 °C.

One single cluster prepared for pouring was composed of four patterns of the paddles. Altogether 12 mould clusters were made.

The clusters were placed in metal boxes and supported with sand.

□ Selection of cast material, melting process and heat treatment

When selecting the cast material for the turning paddles, the high mechanical properties, i.e. hardness and tensile strength combined with relatively high ductility and abrasion wear resistance, have mainly been taken into consideration.

The following alloy types were considered:

- ADI after different types of heat treatment – the main material,
- high-alloyed cast steel – the reference material.

Melts were carried out in an induction furnace of 60 kg capacity made by Radyne. Two melts of spheroidal graphite cast iron were prepared. The chemical composition of the cast iron is given in Table 1.

Table 1.

S.g. iron melt	Chemical composition in %,					
	C	Si	Mn	Mg	Ni	Cu
	3,50-	2,50-	0,30-		1,10-	0,50-
	3,60	2,90	0,50	0,060	1,30	0,70

Two grades of cast steel were melted, one melt for each cast steel grade. The chemical composition of the cast steel is given in Table 2. From the cast iron melts, 32 castings of the chemical composition given in Table 3 were made.

Two cast steel melts were also conducted, making 4 cast pieces from each melt. The cast steel had the chemical composition as given in Table 4.

Table 2.

Melt No	Chemical composition in %,									
	C	Si	Mn	P	S	Ni	Cr	Mo	N	Al
No. 1	0,30	0,30	16,0	0,008	0,014	-	18,0	-	0,70	-
No. 2	0,10	1,00	0,60	0,008	0,015	4,80	25,0	2,20	0,70	0,15

Table 3.

Melt No.	Paddle No.	Chemical composition in %,							
		C	Si	Mn	P	S	Mg	Ni	Cu
1	1-16	3,60	2,75	0,35	0,06	0,01	0,070	1,15	0,57
2	17-32	3,70	2,90	0,27	0,055	0,005	0,09	1,35	0,43

Table 4.

Paddle No.	Chemical composition in %,									
	C	Si	Mn	P	S	Ni	Cr	Mo	N	Al
33-36	0,32	0,30	≅18,0	0,01	0,010	0,10	16,2	-	0,60	-
37-40	0,055	0,95	1,3	0,010	0,010	4,60	23,70	2,00	0,60	0,15

A set of cast paddles is shown in Fig. 3.



Fig. 3. A set of cast paddles

The paddles cast from s.g. iron were next subjected to a heat treatment to obtain the ADI structure. The heat treatment regime as given in Table 5 below has been adopted.

Table 5.

Casting No.	Temp austenitising [° C]	Time austenitising [hours]	Temp. salt bath [° C]	Holding time [hours]
1-8	930	3	280	4
9-16	930	2	340	2
17-24	930	2	300	2
25-32	930	2	320	2

The paddles cast from steel were not heat treated. A photo of a single paddle is shown in Figure 4.



Fig. 4. Photo of a single paddle

□ Mechanical tests of the castings and quality assessment

At this stage of the studies, testing of mechanical properties consisted in measurement of the casting hardness taken on the working surfaces of paddles cast from ADI. The measurements were taken with a stationary hardness tester.

The results of the hardness measurements taken on ADI castings are given in Table 6.

Table 6.

Casting No.	Temp. salt bath [° C]	Results of hardness measurements [HRC]	Mean hardness values [HRC]
1-8	280	35,33,33, 40,36,40	36
9-16	300	36,29,28,32,34,29,31	31
17-24	320	20,19,21,20,20,20	20
25-32	340	26,32,29,26,35,26	29

The results of the hardness measurements taken on steel castings are compiled in Table 7.

Table 7.

Casting No.	Results of hardness measurements [HRC]	Mean hardness values [HRC]
33-36	37,39,41,38,40	39
37-40	30,32,29,27,30	30

The quality assessment included visual inspection of the external surfaces of paddles (to check them for the presence of surface defects) and X-raying of castings.

The visual inspection of the casting surfaces did not reveal the presence of any defects which would disqualify the castings; only small pinholes and veins were noticed and were removed.

The X-ray inspection did not reveal any internal defects that would disqualify the castings.

□ Performance tests

The research program included making the following castings of the turning paddles:

- from ADI – 32 pieces,
- from alloyed steel – 8 pieces

Castings were handed over for performance tests carried out in a sewage-treatment plant where they were assembled in a machine for turning of triangle heaps, and where their positions on a rotor were periodically changed according to a standard schedule of operation. Before assembly the paddles were weighed to check them later for the loss of weight during performance tests.

During the initial period of operation (four months and about 400 motohours) one paddle made from the cast iron was totally damaged. The remaining castings revealed standard wear and tear and remained in operation. The Institute will be informed on the results of the performance tests made by the user upon completing of the tests. So far, a set of paddles has been reported to operate for a mean time of 800 motohours.

4. Conclusions

4.1. Tentative economic analysis

From the information supplied by the sewage-treatment plant where the performance tests have been carried out it follows that the price of 1 kg of the proprietary paddles operating in a heap-turning machine is 50 PLN. The estimated cost of making 1 kg of castings in small-lot production from the proposed cast material (ADI) and using the proposed moulding technology should amount to about 40 PLN/kg.

If the technology of moulding in e.g. sodium silicate sands is adopted, the cost per piece in small-lot production will be cut down to about 30 PLN/kg.

So, assuming a similar performance life of parts, it should be possible to reduce the cost of the paddle manufacture by approximately 20-40%.

4.2. Summary

The outcome of the research was manufacture of a pilot lot of cast turning paddles operating as a main element in the machine for turning of triangular heaps, used in both sewage-treatment plants and in the municipal waste dump fields.

The tests and examinations made so far have proved an extended life of the proposed new cast materials and advantages resulting from the proposed technology of manufacture.

Using this material in small-lot production it is possible to reduce the cost of the working parts by about 20-40%.

The next conclusions will be drawn upon completing of the performance tests and complex material examinations.

Acknowledgments

The studies were done under the Commissioned Research Project PBZ/KBN/114/T08/2004 financed by the Ministry of Science and Higher Education (Task I-1-Iron and nickel alloys, alloys endogenously hardened with nitrogen).

References

- [1] Principles of construction and operation of a turning machine made by Backhus,
- [2] W. Uhl, Choice of material and development of technology to make parts of pumps resistant to abrasion wear, operating in sewage-treatment plants. A statutory work of Foundry Research Institute, I.O., Kraków, 2006.
- [3] PN-EN 1564 Founding. Austempered ductile cast irons.