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IMPLEMENTATION OF MODERN MATERIALS AND FOUNDRY TECHNIQUES IN WIND POWER ENERGETICS

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Summary. The article presents one of the most advantageous trends of the development in the world power industry: wind power stations. One third of the weight of the installations in the wind power stations consists of castings. Since the year 2006 an increase in the demand for such castings, and, consequently, an increase in the chances of the European and Polish foundries is foreseen. The Enterprise METALODLEW S.A. (Joint Stock Company) in Kraków as the main element of its development strategy assumed an increase in the production of large-sized, technologically advanced castings made in high quality foundry materials and designed chiefly for export. Among this group of castings are castings of parts for wind power stations. A challenge for METALODLEW and the scientific circles in Kraków, with whom this enterprise co-operates, was an order for a casting of a platform for the wind power station of the type N-60 according to the strictly determined acceptance requirements, quality inspection and anticorrosion protection. The authors of the article presented the characteristics of the above-mentioned casting of the platform and the preparatory work connected with the realisation of this order for the wind power station of the type N-60. Finally, the obtained mechanical properties of this casting which allow its application under extreme static and dynamic loads and low temperature were given.

Key words: wind power plants, ductile cast iron

INTRODUCTION

In experts' opinion, the use of recoverable energy is in many aspects the most desired trend in development of the world power engineering strategy [Kruse 2006]. This is quite true in the case of wind power plants. Using wind power plants, the EU member states intend to gain by 2010 about 12% of the overall produced energy. In its „Strategy for recoverable energy development in Poland", the Ministry of Environment expects that by this time the energy from recoverable sources will make 7.5% of the overall electric energy produced in Poland. The ten major producers of wind power plants – listed in Table 1 – covering 97% of the world market, supplied in 2001 installations estimated at a total power of 6627 MW. The chief users are Germany, USA and Spain – see: Table 2. The world consortia and industrial groups in Europe are planning to use on a wide-scale the potential hidden in wind power plants located in mainland and in the sea, estimating that in the sole German inshore sea areas there are conditions which enable generation of up to

4000 MW [Kruse 2006]. Poland also has favourable geographical conditions for development of wind power plants.

According to the statistical data, in terms of weight, 30% of the whole wind power plant are castings, and therefore in 2002 the demand for castings from the ten major producers was 235 th. tons. At the same time, by the year 2006, the total amount of castings operating in wind power plants is expected to grow further up to 425 th. tons. These are very optimistic forecasts for the foundry market in Europe, and also a good opportunity for the domestic foundries trying to fight the recession.

Table 1. Ten major producers of wind power plants

Supplier	Sales, MW	Market share, %
Vestas, DK	1648	24.1
Enercon,D	1036	15.2
NEG Micon, DK	874	12.8
Enron, USA	865	12.7
Gamesa, ES	648	9.5
Bonus, DK	593	8.7
Nordex, D	461	6.7
Made, ES	191	2.8
Mitsubishi, J	178	2.6
REpower, D	122	1.9
Total	6627	97.0

Table 2. Ten major users of wind power plants.

Country	New installations in 2001, MW	Total installed capacity, MW
Germany	2627	8734
USA	1635	4245
Spain	1050	3550
Italy	276	700
India	236	1456
Japan	217	357
Denmark	115	2456
England	107	525
Greece	84	358
China	75	406
All world	6824	24927

The leading producers offer always larger and larger installations. To give just an example, NORDEX produced the biggest in the world N-80 power plant of 2,5 MW capacity, and the next goal they have in mind is designing a sea wind power plant of total capacity going up to 5 MW, where a turbine with a propeller of 110 m diameter will be placed on the top of 86-metre tower [Kruse 2006]. The dynamically increasing size of the constructed wind power plants intensified the demand for large castings weighing up to 30 tons. These are mainly such elements as: platforms, frames, rings, casings, mountings for propellers, and blocks. Because of extra high-duty conditions to which parts of this type are exposed on running, specially preferred are ferritic grades of ductile iron assigned for operation at low temperature, like EN-GJS 400-18U-LT (-200C) and EN-GJS 350-20U-LT (-400C) [Vollrath 2004, Cabanne and Gagne 2004].

MANUFACTURE OF CASTINGS FOR POWER INDUSTRY THE CHIEF ELEMENT OF METALODLEW S.A. ENTERPRISE STRATEGY

All the past decade, METALODLEW SA has been persistent in its attempts at making the enterprise more modern, both as regards the technology and management system. A very important element in this part of activity was obtaining PCBC and IQ NET certificate in the scope of Integrated Quality, Environmental and Occupational Health Management System according to PN-EN ISO 9001:2001, PN-EN ISO 14001:1998, PN-N-18001:1999, and Certificate of Conformity for products made for power industry (SIMPTEST) [Von Tiroler 2005, Czekański 2006].

Along with raising technical level, the structure of sales has also changed. In 1993, 97% of castings were made for the in-plant needs of T. Sendzimir Steelworks (HTS), power industry using only 3% of production. In 2002, HTS SA was consuming 8% of production, while 16% was for power industry [Von Tiroler 2005, Czekański 2006]. In the development strategy adopted by Chief Executive Officers (CEOs) of Metalodlew SA Enterprise, special emphasis was put on increasing the share of production of large and advanced castings poured from high-quality cast materials, assigned mainly for export. The sector of castings for power engineering industry - especially as regards wind power plants – fits in an excellent way the adopted strategy of development. The already possessed certificates of Det Norske Veritas, Germanischer Lloyd, Lloyd's Register and Bureau Veritas has enabled active search for customers abroad and being effectively competitive in international market of castings [Von Tiroler 2005, Czekański 2006]. The CEOs activity regarding modernisation of the technical and technological conditions of the Enterprise as well as active cooperation with research and development centres have enabled undertaking even more ambitious tasks. As an example may serve implementation to production of cast base frames (grundrahmen) for N-60 type wind power plant made by NORDEX. So far, only few foundries in Europe have been able to produce castings of this type.

CHARACTERISTIC OF CAST BASE FRAME FOR N-60 TYPE WIND POWER PLANT MADE BY NORDEX

The cast base frame has a complex design with numerous ribs and great variations in wall cross-section; it has well developed flat surfaces. The overall dimensions are 4.139 × 2.710 × 1.370 mm. The weight of a raw casting is 12 700 kg; average wall thickness– about 100 mm, with minimum of 60 mm and maximum of 160 mm. So, in terms of the art of founding, this is a highly intricate shaped casting with high requirements as regards surface quality, cast material homogeneity and mechanical properties. The cast material was in this case ductile iron, grade EN-GJS 400-18U-LT according to PN-EN 1563.

Table 3. Material characteristics

Parameter	Designation according to PN-EN 1563	
	EN-GJS 400-18U-LT	EN-GJS 350-20U-LT
Tensile strength Rm, N/mm^2	370	320
Proof stress 0,2%, Rp 0.2 N/mm^2	220	200
Elongation A5, %	12	15
Impact resistance KCV, J	10 (-20^0C)	10 (-40^0C)

The table gives the, required for the above mentioned ductile iron grades, minimum mechanical properties, measured on cast-on test pieces for castings of the wall thickness comprised in a range of $60<t<200$ mm.

TECHNICAL ACCEPTANCE REQUIREMENTS (TAR)

The Customer specified all details concerning the required test methods, quality control, properties, and anti-corrosive protection. The following conformity certificates and reports were needed:

– testing of mechanical properties according to PN-EN 1563, measured on cast-on test pieces for castings of the wall thickness comprised in a range of $60<t<200$ mm,
– non-destructive magnetic powder and ultrasonic inspection in class S3V3 according to DIN 1690 Part II for selected zones of casting,
– casting measurements,
– anti-corrosive coating.

DEVELOPMENT OF TECHNOLOGICAL PROCESS

The technological process of making cast base frame was developed by a team of process engineers from METALODLEW SA and experts from R&D centres in Kraków – Foundry Research Institute and the University of Mining & Metallurgy. The personal constitution of the team was established by CEOs of the Enterprise. The Chief Coordinating Officer was Dr Eng. J. Turzyński. The short (one-month only) period available for project execution required maximum concentration of means and efforts, and reducing the technological tests to minimum. The reduction of the number of tests to the most indispensable minimum was also dictated by the very high unit cost of making one single casting. Therefore the team adopted as a starting point the rule of „zero defects". The emphasis was put on a careful analysis of problems that might be encountered in a technological process, application of modern methods in foundry technology designing and computer-aided simulation of pouring, solidification and feeding. Additional drawback was the fact that the melting and moulding shops were located in separate bays, distant from each other by over 200 m. Thus, besides strict observance of the work safety conditions during the 20 minutes when 15.000 kgs of metal were transported by car, it was also necessary to counteract the possible drop of metal temperature. The short period available for contract execution also required ready-at-hand solution to a number of problems regarding logistics, i.e. supply of special tooling (boxes, ladles, pattern, core boxes), as well as high-quality moulding and charge materials, which needed active involvement from almost all the departments and services operating at METALODLEW SA, supported by the cooperating units.

SIMULATION OF POURING, FEEDING AND SOLIDIFICATION

The simulation of pouring, feeding and solidification was performed on MAGMASOFT program, using its wide computation potential. Different designs of the gating and feeding system were examined, along with the directional solidification of casting forced by a system of chills. The parameters obtained in the simulation process, time of pouring, directional distribution of metal volume, solidification process, and the adopted porosity index shortened the time of implementation and, more important even, enabled the cost of tests to be reduced to the minimum (Fig. 1).

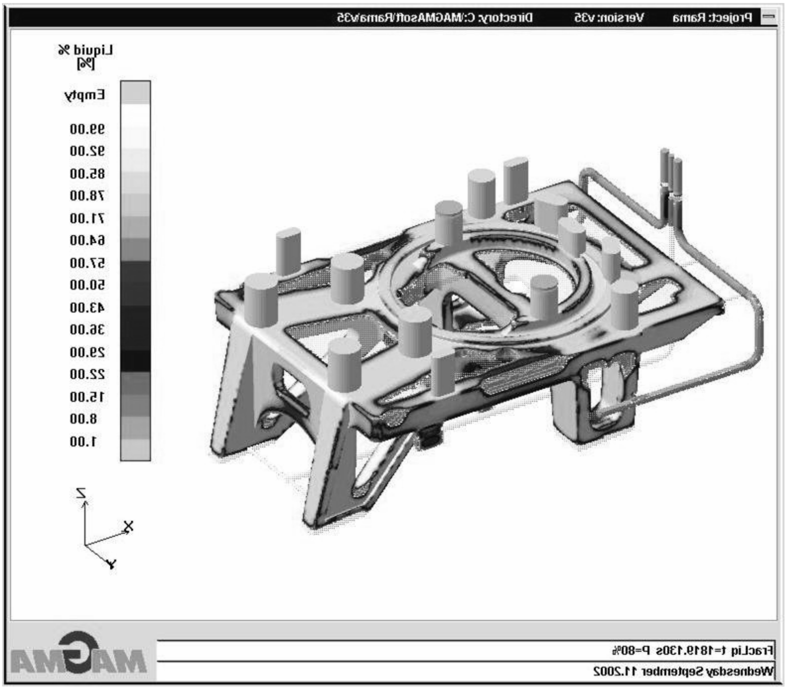

Fig. 1. Simulation of solidification

MECHANICAL PROPERTIES OBTAINED

Making the first casting of base frame in August 2002 crowned all the efforts taken by METALODLEW SA Work Team and marked the beginning of production of large shaped castings poured in iron of grade EN-GJS 400-18U-LT for wind power plants (Phot. 1).

Preparatory works have also been started on implementing in practice the production of even larger and heavier castings. The obtained mechanical properties were consistent with the requirements of PN-EN 1563 Standard (Tab. 3). The metallographic examinations, made on cast-on specimens, fully confirmed the presence of ferritic structure in as-cast condition (over 95%), with graphite of the type A6 PN-EN ISO 945.

The homogeneous and fine-grained structure was obtained applying a multi-step inoculation with complex inoculants. Due to the adopted technological regime, it was possible to obtain in as-cast condition the structure ensuring high toughness of cast iron, satisfying the requirements established for the grade EN-GJS 350-20U-LT. This, in turn, enabled safe application of castings under extra high-duty conditions of static-dynamic loads and low temperature (-400C). The obtained properties exceeded even the Customer's expectations put forward in TAR.

Phot. 1. Raw casting of platform

Table 4. Mechanical properties of ductile cast iron – N60 base frame

Base frame no.	Rm MPa	Rp0,2 MPa	A %	Z %	KV – 20şC J	KCV – 20şC J/cm^2
1	386	234	21,6	22,8	10,6	13,3
2	384	219	24,6	24,7	19,4	23,1
3	416	241	23,4	20,3	10,4	13,1
4	448	258	17,9	16,4	10,6	13,2
5	409	252	25,0	24,1	12,6	15,7
6	403	246	24,1	25,9	14,3	18,0
7	393	246	23,1	24,8	16,3	20,2

CONCLUSIONS

The statistical data indicate a dynamic growth of the wind-propelled power industry, with increasing rated power of turbines and growing size of power plants. Raising demand for castings made in high-quality ductile iron creates various opportunities also for Polish foundry industry. For the CEOs at METALODLEW S.A. the opportunity of starting up the production of large castings for wind power plants is a very important element in the adopted strategy of development. And more important even, manufacturing successfully the cast base frames for N-60 wind power plant made by NORDEX in a time so short has been :

– a confirmation that the basic guidelines adopted in the strategy of development are correct,

– an obvious success of the research and technical team,

– another step made by METALODLEW S.A. towards raising the quality of products and the technical and technological level of the Enterprise,

– a good example of cooperation between several research and development centres operating in Kraków.

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