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THE APPLICATION OF SPHEROIDAL GRAPHITE CAST IRON IN BOSNIA AND HERZEGOVINA

UPORABA NODULARNE GRAFITNE LITINE V BOSNI IN HERCEGOVINI

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Modern technology ensures the quality and the economy of machine parts manufactured from spheroidal graphite iron (SGI) castings. Although this technology has been in widespread use in the EU countries for half a century and the production volumes continue to increase, in Bosnia and Herzegovina (B&H) there is no interest in the production and use of SGI. From an analysis of industrial facilities we have concluded that the foundry industry in B&H could also be competitive in the market for SGI.

Key words: Spheroidal graphite iron castings, machine parts

Moderna tehnologija zagotavlja kakovost in ekonomičnost strojnih delov, izdelanih iz nodularne grafitne litine. Čeprav je ta že pol stoletja veliko uporabljena v državah EU in v ZDA, obseg proizvodnje pa stalno raste, v Bosni ni zanimanja za proizvodnjo in uporabo nodularnih odlitkov. Iz analize industrijskih kapacitet sklepamo, da bi lahko bila livarska industrija v BiH konkurenčna tudi na trgu nodularnih odlitkov.

Ključne besede: nodularna siva litina, strojni deli

1 INTRODUCTION

Spheroidal graphite iron (SGI) castings are not produced and used in the metallurgical industry in Bosnia and Herzegovina (B&H), which is the opposite situation to most industrial countries, where the use of SGI castings increases at rates of up to 10 % per year (**Figure 1**). It is reasonable to expect that such industrial branches as energy, transport, agriculture, etc. will be forced into an increasing use of SGI, especially for moving and rotating machine parts, for example:

- The increasing speeds used on railways requires the substitution of some steel cast parts, for example, gears, with gears made from SGI. These gears are used to advantage when operating railways at speeds from a hundred up to a few hundred kilometres per hour.
- The automotive industry needs high-quality machine cast parts. The B&H foundry industry needs to set up for casting machine blocks from SGI, as well as other cast parts.
- The use of wind energy is a solution that B&H will soon exploit. When generating energy from wind machines, a great number of the parts are made from SGI.

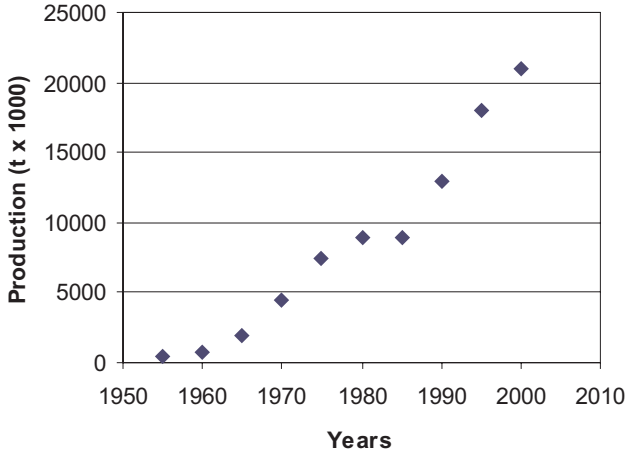

Figure 1: Growth in the world production of SGI from 1950 to 2000 [1]
Slika 1: Rast svetovne proizvodnje nodularnih odlitkov v obdobju 1950 do 2000 [1]

2 INVESTIGATIONS AND DEVELOPMENT OF SGI IN B&H

The development work for the production of parts from SGI castings began approximately 30 years ago at the "Kemal Kapetanovic" Metallurgical Institute in Zenica. The technology for the manufacture of specific SGI machine parts was developed at the institute, after which it was transferred to the former foundry of the Energoinvest company in Sarajevo, the foundry in Ilijaš, and other foundry companies.

The investigations were carried out to answer different questions, relating to:

- the economics of the production of SGI in B&H;
- the influence of properties due to the presence of residuals and impurities in the melting charge on the process of nodulation and the final degree of nodularity of the solidified SGI castings in relation to the extended and the conventional chemical analysis;

- the relation between the degree of nodularity and the microstructure homogeneity and the mechanical properties of SGI parts;
- the effect of the optimal addition of alloys and of the processing parameters on the nodulation;
- the kinetics of nodulation.

Many of the findings and the accumulated field experience could still be used for the renewal of the production of SGI and various castings [2,3], especially since customers may inquire about mutually exclusive properties for some specific castings.

3 CHARACTERISTICS OF SGI CASTINGS

It is clear that the production of castings from SGI of different quality levels could be revived in B&H in order to replace the supply or imports from abroad. In this way it is possible to produce castings from SGI for specific uses and for the substitution of steel castings. The melting temperature for SGI is about 300 °C lower than that for steel, and this in itself is a significant advantage in terms of saving energy and ecology. Apart from the better castability, the easier mechanical machining and the lower friction explain the continuous increase in the production of machine parts from SGI in the countries of the EU and the USA. It seems natural to expect that also in B&H SGI should again achieve the position it had in the foundry industry two decades ago, particularly since a large part of the production was delivered to customers abroad because of its high quality.

The increase in the world production of SGI (**Figure 1**) asks the question, which casting iron will dominate the production of castings: spheroidal or lamellar graphite iron, malleable cast iron or cast steel? Malleable cast-iron production started to decrease in the early 1980s, while SGI production increases continuously, partly because of the substitution of other cast irons and partly because of new uses for the castings. The increase in the production of SGI becomes clear from a comparison of the casting technology and the cast's properties in **Figure 2 and 3** [4]. The comparison accounts for several factors, such as, the chemical analysis, the mechanical properties, the section and size of the cast parts, the processing time, the assortment, the energy consumption, the total costs, the sampling, the testing and the examination and control [2].

The effect of graphite nodules on the stress-strain relations can be calculated from the equation

$$R_m = (1 - e^{-\alpha E_o - \varepsilon_t})/\alpha$$

where E_o is the modulus elasticity, α is a factor of the dependence of E_o from the stress up to the value of $R_{p0.2}$ and can be expressed as $\alpha = 1/R_{p0.2}$, and ε_t is the elongation.

The as-cast microstructures of SGI castings depend on the chemistry and the cooling rate. The microstructure consists of ferrite, pearlite and free carbides,

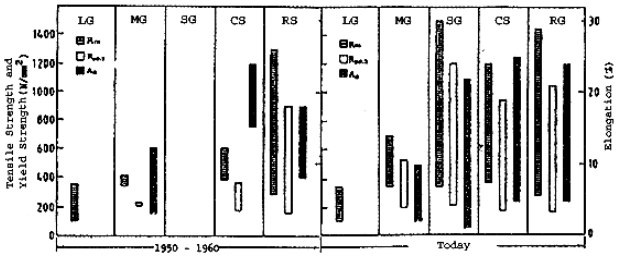

Figure 2: Mechanical properties of cast irons, cast steels and rolled steels for the period 1950–1960 (left-hand side) and 2000 (right-hand side) [2,5]; (LG – gray iron, MG – malleable iron, SG – spheroidal graphite iron, RS – rolled steel, CS – cast steel), (R_m – Tensile strength, $R_{p0.2}$ – Yield strength, A_5 – elongation)

Slika 2: Mehanske lastnosti železovih litin, litega železa in valjanega jekla za obdobje 1950–1960 (levo) in 2000 (desno) [2,5]; (LG – siva litina, MG – temprana litina, SG – nodularna litina, RS – valjano jeklo, CS – jeklena litina), (R_m – raztržna trdnost, $R_{p0.2}$ – meja plastičnosti, A_5 – raztezek)

and it can be modified by subsequent heat treatments. When compared to steel castings, SGI castings are less expensive, show a greater yield, and thus a greater weight of the final cast part versus the weight of the used melt. The consumption of energy for the production of SGI parts is one-third lower than that for cast steel parts. Also, the investment costs for the SG foundry are lower than those for a steel foundry [2,4].

The basic advantages of SGI are accurate dimensions, better uniformity of the strength properties, less hot and cold cracking, and an easy heat treatment. Additional advantages of the SGI castings are a lower coefficient of thermal expansion, less shrinkage and piping, better damping properties, better fluidity, better machinability and reduced surface scaling. Also, with SGI castings the effect of the wall thickness on the mechanical properties is smaller (2).

4 FURTHER DEVELOPMENT

The increasing market demand for a better and more uniform quality of castings and improved mechanical properties as well as the pressure to lower prices require that foundries develop and use improved technologies and new grades of castings. They have to do this even though the optimal combination of different properties can be obtained with SGI (**Figure 3**).

Accordingly, the world production of SGI is increasing rapidly; an increase of about 50 % was achieved in the past decade, a growth rate that is only rarely met with other major industrial products. However, methods for the production of parts competing for the same applications as SGI castings are also constantly improving and the SGI foundry industry is forced to compete, not only with other cast-iron alloys, but also other materials that are potential substitutes. In this competition SGI castings seem to be in better position than other iron castings because of the more

Properties	Cast Iron					
	Gray	Malleable	White	Steel	Nodular	
Fluidity						
Machining			NA			
Damping						
Surface hardening			NA			
Modulus off elasticity			NA			
Impact energy			NA			
Corrosion resistant						
Strength/Mass			NA			
Abrasion						
Costs						
The best						The worst

Figure 3: Properties of cast ferrous materials [5,6]
Slika 3: Lastnosti litih železnih materialov [5,6]

ecologically friendly production process and its lower costs.

With the introduction of new technological processes such as ADI and ESR better mechanical properties of SGI (**Figure 2 and 3**) are being achieved and the competitiveness of castings, especially for use in more severe conditions, is strengthened.

5 CONCLUSION

The overall competitiveness involving the economy of production and the properties make SGI castings very suited to a number of applications in machine parts. The increased production and use of SGI castings is justified if advanced technology and organisation are achieved in the production and delivery of castings with qualities that satisfy export-market requirements.

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