COROSION RESISTANT HIGH SILICON CAST IRONS

Veselinka Đorđević, Zvonko Gulišija, Marija Mihailović*, Zagorka Aćimović-Pavlović***, Milica Antić**

*ITNMS – Beograd, Franše d’Eperea 86
** Zavod za zavarivanje – Beograd, Grčića Milenka 67
***TMF – Beograd, Karnegijeva 4

Abstract: In domestic foundries production of acid resistance high silicon cast iron quite defined and because of that is with small productivity and many defect products. Process monitoring is with problems, because of that material is hard and brittle so sampling for characterisation is difficult, except of chemical analysis. That is reason for non destructive testing application, mainly ultrasonic.

Key words: FeSi alloys; casting, ultrasonic testing, structure: grain size, attenuation.

INTRODUCTION

Serious problem at many areas of metal materials application and main factor of production costs is corrosion, a.g. metal damage caused by chemical action of environment. Corrosion is caused by chemical reaction and because of that corrosion rate is in relation with temperature and reactants concentration and reaction products. Also, mechanical stresses and erosion are factors contributing to corrosion rate.

When choosing material for technical construction with corrosion resistance requirement, it’s useful to take account all conditions and rules, find appropriate correlation behind material properties - all corrosion aspects - economical and ecological aspects.

Special problem is research in whole production process, manufacturing technologies and production of parts with appropriate structural, structural, chemical and mechanical properties, e.g. production of parts with required quality under the best economical conditions. On this base, it was planned to research castings production with special properties like resistance to acids and with better resistance to abrasion.

High silicon iron in cast form with resistance to acid is modern way of production. This type of corrosion resistance iron contains more than 14.5% Si. It is hard and brittle, so casting with grinding the best process for manufacturing of different parts.

High hardness values of high silicon cast iron is reason for good abrasion resistance, but at the same time, low strength and high brittleness are reasons for mechanical impact and thermal shocks sensitivity.

It’s important to note that construction of this type castings is very different, that there are not domestic standards and that production of these parts depends of manufacturers of equipment for chemical industry in first order. Many chemical industry factories, for different acids production, many needs for high silicon cast iron satisfied by importing. Taking account high price of these castings to their mass unit, it’s possible to conclude cost level.

With aim to check casting quality, it’s possible to applicator appropriate NDT methods for surface defects presence and homogeneity testing.

In this case, ultrasonic testing is applied on test piece, special step sample containing 7 steps with different thickness about 10 to 70 mm.

Material structure control is based on sound attenuation and wave velocity throw testing object.
CHARACTERISTICS OF CORROSION RESISTANT HIGH SILICON CAST IRON

High silicon cast iron or acid resistance iron contains up 14% to 18% silicon. This type iron is aimed for acid environment exploitation, mainly for centrifugal pumps, equipment for sulphuric acids (blades, mixer and other), reaction apparatus, compressors etc. This material production is with number of difficulties: internal stresses, cracks, porosity and on the end many defective products. Also, it’s impossible to make better some characteristics by thermal treatment. Because of specifically process and material, it’s necessary to take care at high silicon cast production, on choose of raw material, meting process, manufacturing of moulds and cares and casting process.

CHARACTERISTICS AND APPLICATION

Corrosion resistant high silicon cast iron is standardized to BS 1591; 1949 which contains data about chemical analysis and heat treatment.

Table 1: Chemical analysis of corrosion resistant high silicon cast iron

<table>
<thead>
<tr>
<th></th>
<th>C %</th>
<th>Si %</th>
<th>Mn %</th>
<th>S %</th>
<th>P %</th>
</tr>
</thead>
<tbody>
<tr>
<td>standardized</td>
<td>0,35-1%</td>
<td>14,25-15,25%</td>
<td>max 1,0%</td>
<td>max 0,1%</td>
<td>max 1,0%</td>
</tr>
<tr>
<td>the most used</td>
<td>0,5-0,8</td>
<td>14-16</td>
<td>0,03-0,8</td>
<td>0,007</td>
<td>0,1</td>
</tr>
</tbody>
</table>

With higher content from Si, corrosion resistance is bigger with simultaneously loosening of relatively good mechanical properties and mach inability. Because of that, for an application it’s necessary to specially decide on chemical analysis of this material.

The Si Content has to be between 14 and 16%, reason for it is presence of continual protection film of SiO₂.

This film is easy formed on casting surface because of great affinity Si to oxygen.

STRUCTURE

Ferrum with strong energy with Si makes solid solution, lowering meting point of Fe. Temperature interval between liquidus and solidus is so small, so it’s difficult to form Si segregation. Silicon is an element which makes smaller γ area of ferrum. Because of that, modification points are on higher temperatures, so 17% Si moves these for 50°C. It’s reason for forming of rough gain during annealing, recristallisation and quenching.

Carbon influence on Fe/Si system diagram so that doesn’t change present phases configuration, but makes smaller solidification interval of system and also Si content at the eutecticum. Carbon present in high silicon cast microstructure exists like lamellar granul in form fine lamellas, rough lamellas and in form of small bars. Sometimes in microstructure carbide is present, specially in case rapid cooling, imidiatelly after solidification.
CORROSION RESISTANT HIGH SILICON CAST IRONS

Mechanical properties and corrosion resistance are lower with growing of grain size, specially intercrystalline corrosion resistance lowering.

TEHNOLOGICAL CHARACTERISTICS

High silicon cast iron has good castability. This characteristic is connected with higher Si content. Pry the rule, for casting, the most usable alloy is with eutectic content which is the best because of low melting point and small solidification temperature interval.

CORROSION RESISTANCE CHARACTERISTICS

Corrosion resistance characteristics of high silicon cast depends on formed film silicon dioxide (SiO₂). Ferrum atoms excretes from silicon-ferritic lattice and residual Si atoms are oxidized so the form protection film of silicon oxide which stops further corrosion.

High silicon cast iron is resistance on sulphuric and nitrogen acids action by very large range of concentrations and temperatures, and also on mixes of sulphuric and nitrogen acids.

High silicon cast iron is resistance on phosphoric acid action at room temperature, organic acids at all temperatures and concentrations nitrogen oxides at higher temperatures, carbon disulfide, solution of higher temperatures, solution of aluminium chloride, aldehyde and other arressive mediums.

SAMPLE TESTING

Chemical analysis of sample is: C-0,5%; S-0,014%; Si-15,32%;

TEST RESULT AND ANALYSIS

Longitudinal ultrasonic waves relacity is measured on known way with probe MB2F on thickness 24mm (2 sample step). Average value of these ways velocity is 2.478m/s.

It’s known that material structure (grain size, form and grain orientation) effects on ultrasonic penetration. If the grain size in similar to flowing wave length, than this effect is greater. Ultrasonic waves attenuation is great and is greater with transversal than longitudinal waves because of their nature.

Wave diffraction is with dominant effect on attenuation. On grain boundaries refraction and transformation wave is presented so that relation usefull signal / noise is smaller in this type of material and it's possible to divergence wave from the main beam.

Beside of that, if the material in transverse cross is anisotropical, than problem of the wave propagation is greater, e.g. testing / measurement is more difficult because of new unknown data.
But, by the other side, and for these materials it's possible with ultrasonic method (it's known that this method is comparative method of testing), by ultrasonic propagation, give some important material data.

In this sample testing, the aim is to determine conditional / comparative grain size on different thickness of sample. For conclusion it's necessary to use measurement results and metallurgical / metallographic knowledge.

Fig. 2. Test results

Table 2: Test results

<table>
<thead>
<tr>
<th>Step</th>
<th>First echo with amplification db</th>
<th>Second echo db</th>
<th>Attenuation 2 db/mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14</td>
<td>32</td>
<td>0,66</td>
</tr>
<tr>
<td>2</td>
<td>26</td>
<td>42</td>
<td>0,333</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>46</td>
<td>0,228</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>56</td>
<td>0,181</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>66</td>
<td>0,149</td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>74</td>
<td>0,133</td>
</tr>
<tr>
<td>7</td>
<td>There are many defects – it's not possible to determine attenuation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Attenuation on step "1"-(the smallest thickness) is not valid for analysis. Reason for it is presence of inclusions which checks "3" and "4" bottom echo.

According to measurement values of attenuation it's seen that attenuation, is the smallest on the cross with the biggest thickness, where was able to measure highness of second echo.

According to metallographic analysis samples which were with thickness range up 12 to 50 mm, it was seen following:

- structure of all tested thickness samples, consists of graphite form I (JUS C.A3.020);
- graphite orientation changes depending on thickness; on the part with the smallest thickness is A and D, sometimes E, but on the part with the biggest thickness, only A (JUS C. A3.020);
- graphite size is different depending on thickness 5/7 in sample with the smallest thickness and 3/6 on sample with the biggest thickness.

On samples with relatively small thickness (about 10 and 20 mm) it's seen dendrite porosity.

CONCLUSION

It's known fact that correlation between structural characteristics of metallic materials like grain size, microconstituent type, graphite size and form, intercrystalline corrosion etc by one side and some subcharacteristics of ultrasonic wave in material (attenuation, diffraction, reflection etc), by other side.

Comparing results of ultrasonic and etalographic testing, it's able to say that present relation between attenuation value and "fine" structure. Cooling rate which is the smallest on sample with the biggest thickness (compared thickness is 50 mm) declare assumption that structure is finer by slower cooling.
These preliminary testing could be substrate for further research with aim to establish rules of correlation between attenuation and grain size, which would be very useful for production testing of castings in foundry.

Literature