INFLUENCE OF THE QUANTITY OF CARBIDE PHASE AND THE TYPE OF HEAT TREATMENT ON THE MECHANICAL PROPERTIES OF CARBIDE-BAINITE DUCTILE IRONS

Vladimir Todorov, PhD[1], Milen Svilenov[2], Assoc. Prof. Georgi Rashev ,
Department of Mechanical Engineering Equipment and Technologies, TU-Gabrovo [1,3], Bulgaria
Osum - Lovech[2], Bulgaria

Abstract: *The purpose of this research work is to determine the influence of the carbide phase and the austempering temperature on the mechanical properties of carbide-bainite ductile irons. Two groups of irons have been investigated: austempered at 300°, with a lower bainite structure, and at 400°, with an upper bainite structure. Tensile strength, yield strength, elongation, impact strength and hardness have been tested tested.*

Keywords:Carbidic Austempered Ductile Iron, Mechanical Properties, Heat Treatment.

1. Introduction

The combination of excellent casting properties and a set of high mechanical characteristics maintains increasing interest in spheroidal graphite irons [SGI] [1].

With the introduction of austempered ductile irons (ADI) in practice values for the strength complex, that successfully compete with greater part of forged- carbon and low-alloyed steels, have been obtained [2]. The optimum combination of high-carbon austenite and bainite ferrite ensures excellent mechanical properties of this kind of irons.

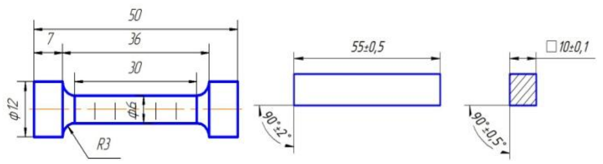
Another variant of bainite ductile irons is the so called “Carbide Austempered Ductile Iron –CADI. The final structure of CADI is formed as a result of austempering in the bainite area of SGI containing a cast carbide phase. A bainite-austenitic metal matrix containing a certain quantity of carbide phase and spheroidal graphite inclusions is fixed. Unlike ADI those irons have high wear resistance at the expense of their lower elongation and toughness [2, 3, 4].

Research in CADI field shows that the final set of properties is strongly influenced by the structure changing factors: austempering temperature, holding time at that temperature and carbide phase quantity [5, 6].

The purpose of the present study is to investigate the influence of carbide phase quantity and austempering temperature on the set of CADI mechanical properties.

2. Presentation

In order to investigate the influence of the quantity of carbide phase and the austempering conditions on the mechanical properties of carbide- bainite ductile irons four compositions of irons were cast. The content of carbide phase varied from 0 to 27 %. Tests on standard test samples were carried out (Fig.1). The following strength characteristics were tested: tensile strength – Rm, yield strength -$Rp_{0.2}$, hardness – HV, elongation –A_5 and impact strength–KC.



a) b)

Figure1.*Dimensions of test samples for tensile test – a) and impact test – b)*

The investigation was carried out for both isotherms of austempering - at 300°C with holding time of 90 min and at 400°C with holding time of 60 min thus providing two groups of bainite ductile irons - irons with upper bainite and lower bainite structure of the metal matrix.

The structure obtained after austempering of SGI at 300°C is lower bainite. Within this temperature range irons have high strength indices at the expense of lower ductile ones. This isotherm is characterized with the fact that the bainite ferrite is considerably more carbon-saturated than the balance content that provides the spheroidal graphite iron with high strength and hardness and relatively low elongation and toughness. Elongation reaches up to 5 % for the carbide-free structure. The presence of a carbide phase in the structure of the bainite spheroidal graphite iron leads to a significant change in the strength complex.

The investigation shows that strength decreases approximately two times as the quantity of carbide phase increases at the expense of an increase in hardness. The latter increases from 433 HV to 574 HV for structures with 27 % carbide phase – Table 5. The reduction of elongation is more sensitive: from 4,5 % for carbide-free structures to 0,8 % for structures with 27 % carbides. The change of impact strength for both structures is from 100J/cm^2 to 5 J/cm^2- Table 4.

The investigation results are shown in Tables 1-5 and in Figures 2-6.

Table 1.*Influence of the quantity of carbide phase on the tensile strength of CADI austempered at 300°C*

T*aust.*, °C	Structure No	Carbide phase %	Tensile strength Rm, MPa
300	1	0	1430
	2	9	930
	3	18	750
	4	27	690

Table 2.*Influence of the quantity of carbide phase on the yield strength of CADI austempered at 300°C*

T*aust.* °C	Structure No	Carbide phase %	Yield strength Rp0.2, MPa
300	1	0	1265
	2	9	780
	3	18	726
	4	27	680

Table 3.*Influence of the quantity of carbide phase on the elongation of CADI austempered at 300°C*

T *aust.* °C	Structure No	Carbide phase %		Elongation A_5, %
300	1	0		4,5
	2	9		2
	3	18		1,3
	4	27		0,8

***Table 4**.Influence of the quantity of carbide phase on the impact strength of CADI austempered at 300°C*

T *aust.* °C	Structure No	Carbide phase %	Impact strength KC, J/cm^2
300	1	0	100,65
	2	9	19,57
	3	18	8,42
	4	27	5,25

***Table 5**.Influence of the quantity of carbide phase on hardness of CADI austempered at 300°C*

T *aust.* °C	Structure No	Carbide phase %	Hardness HV, kgf/mm^2
300	1	0	433
	2	9	481
	3	18	505
	4	27	574

Spheroidal graphite irons austempered in the upper bainite temperature range of 400°C are characterized with high toughness. The elongation of materials witnin this group reaches up to 10-15 %. This complex is obtained from a bainite-austenitic metal matrix free of carbides and brittle phases.

The presence of a carbi-de phase, which the carbide-bainite spheroidal graphite irons (CADI) possess, abruptly changes the strength complex. In this respect the ductile characteristics – elongation and hadrness - are especially sensitive.

The results of the influence of the carbide phase quantity on the mechanical characteristics of CADI austempered at 400°C are shown in Tables 6-10 and Figures 2–6.

***Table6**.Influence of the quantity of carbide phase on the tensile strength of CADI austempered at 400°C*

T *aust.* °C	Structure No	Carbide phase %	Tensile strength Rm, MPa
400	1	0	969
	2	9	810
	3	18	699
	4	27	590

***Table7**.Influence of the quantit yof carbide phase on the yield strength of CADI austempered at 400°C*

T *aust.* °C	Structure No	Carbide phase %	Yield strength Rp0.2, MPa
400	1	0	760
	2	9	650
	3	18	630
	4	27	495

***Table8**.Influence of the quantity of carbide phase on the elongation of CADI austempered at 400°C*

T aust. °C	Structure No	Carbide phase %	Elongation A_5, %
400	1	0	11,8
	2	9	7
	3	18	4,2
	4	27	2,6

***Table9**.Influence of the quantity of carbide phase on the impact strength of CADI austempered at 400°C*

T aust. °C	Structure No	Carbide phase %	Impact strength KC, J/cm^2
400	1	0	152
	2	9	25,4
	3	18	14,6
	4	27	9,6

***Table10**.Influence of the quantity of carbide phase on the hardness of CADI austempered at 400°C*

T *aust.* °C	Structure No	Carbide phase %	Hardness HV, kgf/mm^2
400	1	0	396
	2	9	442
	3	18	462
	4	27	496

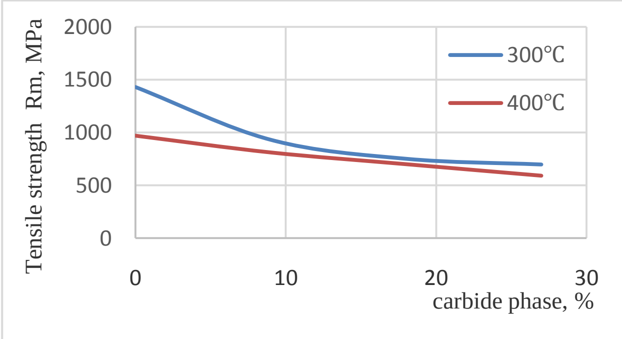


***Figure 2**.Influence of the quantity of carbide phase on tensile strength*

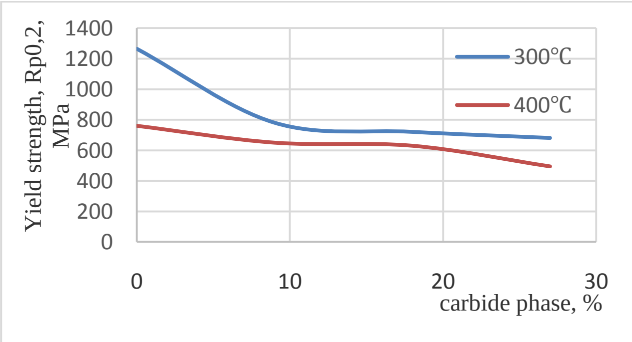


***Figure 3**.Influence of the quantity of carbide phase on yield strength*

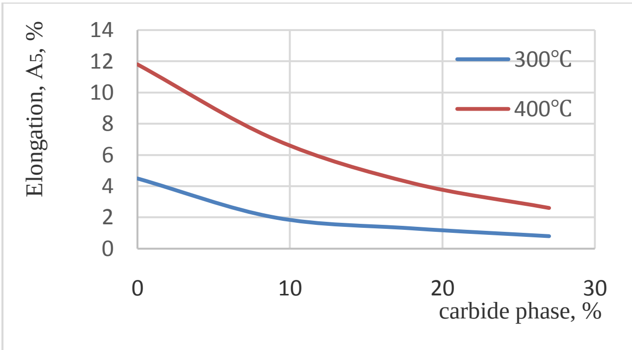


***Figure 4**.Influence of the quantity of carbide phase on elongation*

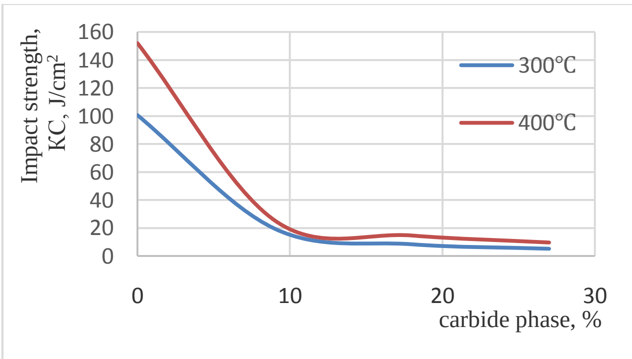


***Figure 5**.Influence of the quantity of carbide phase on impact strength*

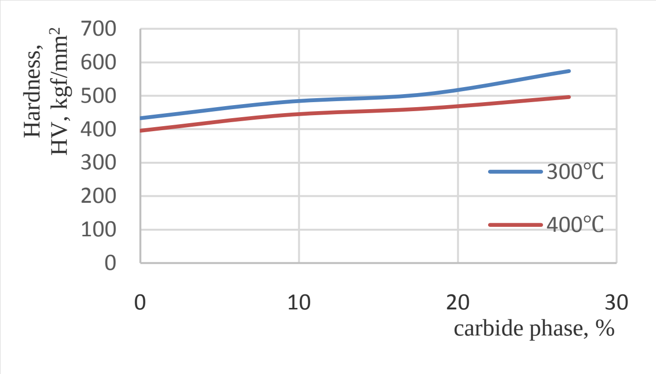


Figure 6*.Influence of the quantity o carbide phase on hardness*

3. Conclusions

The influence of the quantity of carbide phase up to 27 % on the strength complex of carbide-bainite spheroidal graphite irons at two austempering temperatures: 300°C and 400°C have been identified.

As carbide phase quantity changes, CADI strength properties considerably change as well. When its percentage content increases, the whole strength complex decreases. Tensile strength, yield strength, elongation and impact strength decrease whereas hardness increases. Elongation and toughness appear especially sensitive to the presence of a carbide phase.

The changes of both isotherms are as follows:

- At austempering temperature of 400^{o}C:

Strength decreases from 969MPa for the carbide phase-free structure to 590 Mpa for 27 % carbide phase. The change of ductile characteristics such as impact strength and elongation is more sensitive. Elongation decreases from about 12% to 2,6% for the initial structure while impact strength from 152 J/cm^{2}to 9,6 J/cm^2 for the structure with 27% carbides.

- At austempering temperature of 300^{o}C:

Strength decreases from 1430 MPa for the carbide phase-free structure to 696 Mpa for 27 % carbide phase. Elongation decreases from 4,5% to 0,8% and impact strength from about 100 J/cm^{2}to5,25 J/cm^2 .

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