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THE WORKING TEMPERATURE INFLUENCE TO ISOTHERMAL TREATED DUCTILE IRON TENSILE AND IMPACT STRENGTH

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ABSTRACT
Isothermal treated ductile iron is the class of ductile iron that comes as the result of the characteristic thermal treatment procedure (austenization and isothermal improvement). The result of this treatment are high values of mechanical characteristics with emphasization to very positive tensile strength to weight ratio. High values of mechanical charasteristics (tensile and impact strength) of isothermal treated ductile iron are the result of specific ausferrite microstructure. The example of ductile iron samples production made by isothermal treatment and the mechanical characteristics (tensile and impact strength) values are presented in this labour. The values come on the austempering temperature of 870 °C in time interval of 90 minutes, and isothermal treatment made on temperature of 250 °C in time interval of 90 minutes, with further treatment made on temperatures of 150 °C, 200 °C i 250 °C in time interval of 10 hours.
Keywords: cast iron, tensile strength, impact strength, austempering, isothermal treatment

1. INTRODUCTION
During heating ductile iron castings onto austenization temperature and fast cooling in salt bath heated to isothermal improvement temperature (250-400 °C) with long enough holding on this temperature-the ausferrite microstructure will appear. Ductile iron treated like this is isothermally improved ductile iron. Cooling to isothermal improvement temperature must be fast enough to avoid ferrite or perlite forming, ie. to get ausferrite microstructure. The isothermal improvement process can result with diferrent microstructure constituents depending on isothermal improvement temperature (the salt bath temperature) and also depending on holding time on this temperature. The common characteristics of final microstructure are tensile strength high values while keeping material impact strength and its possibility of increasing hardness during working what gives much better resistance to trousing comparing to starting microstructure. This good combination of mechanical characteristics is actually the result of ausferrite (ferrite plus austenite) microstructure. The resulting ferrite phase and the amount of ferrite and austenite can be controled by thermal treatment parameters (temperature and time), what determines the treated material final characteristics. Ferrite phase in ausferrite microstructure is often called acicular (needle-shaped) ferrite because of its shape in which is most commonly found.

2. PARAMETERS WHICH INFLUENCE TO MATERIAL MECHANICAL PROPERTIES

2.1. The starting material

Ductile iron is used as a starting material for production of isothermal treated ductile iron.Ductile iron belongs to cast iron family in which graphite phase is in the form of nodules (spheres).This is kind of casting which is ideally placed between cast iron and steel cast iron properties, which joins strength and ductility, and in addition, in a very short time has found its application. Ductile iron is pseudo-binary alloy of iron and carbon, with predetermined share of carbon in shape of sphered graphite (nodules). Nodularity and the number of nodules has a significant influence to material properties. It is assumed that low nodularity and low number of nodules influence negatively to isothermal treated ductile iron properties. Considerably larger negative influence to isothermal treated ductile iron have carbides and porosity appereance. The lower nodularity values of starting material influence negatively to nodularity, segregation and carbides appereance on border areas of grain.

The increased wall thickness requires proximity material improvement, which demands increased alloying with elements like Cu, Ni and Mo.

2.2. Isothermal improvement

Unlike ordinary (classical) improvement, in the case of isothermal improvement, austenized ductile iron had been suddenly cooled to isothermal reaction temperature, then holded long enough on it, and then cooled to room temperature, fig 1.

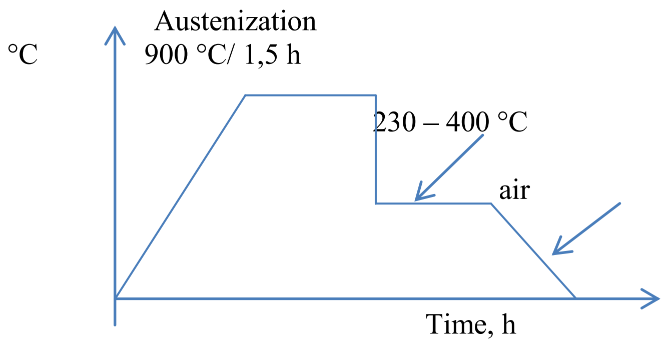

Figure 1. Schematic view of ductile iron isothermal improvement

Depending on desired values of mechanical and ductile properties, the isothermal improvement temperature is in 260 - 420 °C range. This way treated ductile iron is called isothermaly improved ductile iron. Cooling to isothermal improvement temperature must be fast enough to avoid perlite of ferrite forming, respectively, to get desired ausferrite microstructure (maximum mechanical and ductile properties values). The common charasteristic of formed microstructure are high value tensile strength with keeping material toughness and possibility of hardening while working, which gives much better wear resistance in regard to starting microstructure. This good combination of properties is actually the result of new formed microstructure (ausferrite microstructure).

3. PERFORMING THE EXPERIMENT

3.1. The charging material

For experimental part of this labour, ductile iron with conventional chemical composition were used. The chemical composition of this charging material is presented in table 1. The material used were ferrite-pearlite casting with about 65-70 % of ferrite.

Table 1. The chemical composition of charged material

Elements	C	Si	Mn	S	P	Mg	Cu	Mo	Ni
%	3,56	2,69	0,309	0,007	0,033	0,0316	0,464	0,287	0,495

Material was casted to U tests, which then were used for trimming of tensile strength test tubes by standard BAS EN 10054-1/98. The tensile strength test tube appereance is given on figure 2.

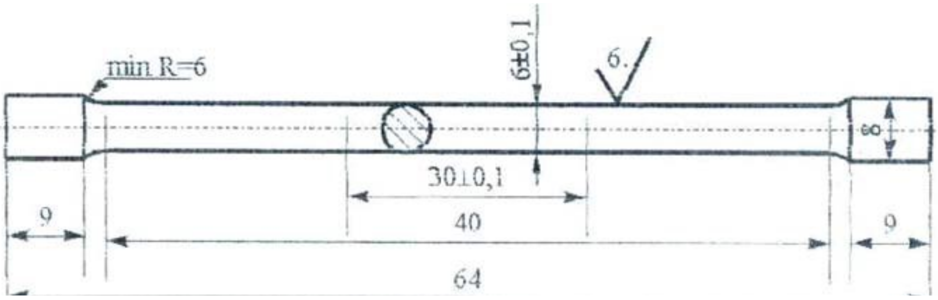

Figure 2. The tensile strength test tube

3.2. Thermal treatment

The tensile strength test tubes had been heated to austenization temperature of 870 °C in time interval of 90 minutes, after which they were tempered in KNO_3 bath on 250 °C and time interval of 90 minutes.After this procedure, test tubes were air cooled. This made test tubes then were additionaly treated on temperatures of 150 °C, 200 °C i 250 °C in time interval of 10 hours.

3.3. Tensile strength measurment

After tensile strength test tubes had been prepared, tensile strength measurment were done by standard BAS EN ISO 6892-1 B:2011. After tensile strength testing, test tubes were used for hardness measurment. Three measurments were made on each test tube. The tensile strength results are given in table 2:

Table 2: The tensile strength results for additional treatment- 150/10; 200/10; 250/10

Treated material [°C]		Additionaly treated		Test tube informations		Max force [kN]	Tensile strength [N/mm²]
		T [°C]	t [h]	Diameter [mm]	Square area [mm²]		
870/90	250/90	150	10	5,98	28,07	38,4	1368
870/90	250/90	150	10	6,13	29,5	32	1085
870/90	250/90	200	10	6,22	30,37	42,9	1413
870/90	250/90	200	10	6,1	29,21	37,2	1274
870/90	250/90	250	10	6,05	28,73	39,4	1371
870/90	250/90	250	10	6,1	29,21	44,4	1520

3.4. Impact strength testing

For impact strength testing, test tubes 10x10x55 mm were used. The measurment was performed with machine for measuring the amount of energy absorbed by material during fracture-Charpy test machine. Test tubes without 'V' notch were used.

Table 3: The results of impact strength for additional treatment °C/h – 150/10; 200/10; 250/10

Treated material [°C]		Additionaly treated		Test tubes informations (mm)			Nominal impact energy [J]	HRC		
		T [°C]	t [h]	Length	Width	Heigth				
870/90	250/90	150	10	55,4	10,02	10	150	46	46	47
870/90	250/90	200	10	55,3	9,9	9,94	150	44	42	43
870/90	250/90	200	10	55,5	10,02	10,02	150	43	42	42
870/90	250/90	250	10	55,6	10,11	10,1	150	41	38	40

4. CONCLUSION

The essential parameters related to this labour are changes of tensile strength and hardness in regard to initial material values. After experimental result analysis, the following conclusions can be made:

- The tensile strength values of basic material move from 716 to 760 N/mm^2

- The tensile strength values after additional heat treatment move up to 1500 N/mm^2, what show that this procedure is very desirable in case of materials with high tensile strength needed, eg. railway parts, mine parts, agricultural machines etc.

- The impact toughness values of basic material move from 14 to 17 HRC, and the impact toughness of additionaly treated material move up to 47 HRC, what is, regarding to basic material, increased approx 2,5 times.

- Due to values showed above, it can be concluded that additional treatment influence to mechanical strength and impact strength, what manifests as its values increase.

5. REFERENCES

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