Metalurgy

Influence of Hot Plastic Deformation on Austenization Process during Austempering of Ductile Iron

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In the presented paper the structure and properties of a new class of consrtuctional materials deformable high strength cast iron was investigated. The austenization parameters effect on the phase composition of ingot and hot plastic deformed ductile iron were studied. It was determined, that the combination of hot plastic deformation and heat treatment processes provide better multifactorial influence on the structures and exploitation properties of ductile iron. High strength cast iron with the following chemical composition 3.45% C, 2.30% Si, 0.25% Mn, 0.003% S, 0.05% P and 0.045% Mg was chosen as a research object. The experimental specimens were subjected to step by step 20% degree of primary hot plastic deformations. The deformed specimens were received without defect after rolling with total (60%) deformation. As a result of investigations it was determined, that hot plastic deformation of high strength cast irons increases the dispersity of metallic structure, contributes to the decomposition of primary austenite at intermediate temperature interval, increases carbon diffusion activity, speeds up homogenization of austenite and reduces austenization duration period. *© 2020 Bull. Georg. Natl. Acad. Sci.*

Austenization, plastic deformation, isothermal quenching, retained austenite, phase composition, structure formation

More and more attention is paid to the development of new class of structural materials, deformable high-strength cast irons. It is explained by the fact that the use of hot plastic deformation methods to manufacture cast-iron products make it possible to intensify technological processes, reduce metal losses and increase the level of its mechanical and exploitation characteristics. Besides, the combination of hot plastic deformation with austempering and isothermal quenching processes have multifactorial effect on the structure and properties of high strength cast iron. At the same time, the influence of the degree of preliminary hot plastic deformation on the homogenization and grain size of austenite, which significantly determines phase composition and morphology of isothermal quenching products in the intermediate temperature area, remain poorly studied for high strength cast iron [1, 2]. In the present paper the cast and deformed silicon cast irons were studied.

Experimental Procedures

The experimental melting of cast iron was carried out in a 50-kg-capacity crucible using an electric induction furnace of intermediate frequency. The furnace charge consisted of high-purity pig iron: 3.62% C, 2.00% Si, 0.35% Mn, 0.003% S, 0.06% P and up to 10% steel scrap. After melting at 1350°C the liquid metal was held for 5 min followed by spheroidization operation of graphite inclusions by treatment with metallic Mg. The cast iron was poured at 1430°C into Y block ingots (30 mm).

Table. Chemical composition of melted cast iron

Elements	C	Si	Mn	S	P	Mg
Weight %	3.45	2.30	0.25	0.003	0.05	0.045

The part of cast ingots were rolled in a laboratory mill at a speed of 0.8 m/sec, with various degrees of deformation (total Ɛ≈65%) at 950°C heating. Ingot and deformed specimens were isothermal by quenched at temperatures: 280°C and 400°C for 30 minutes in the melt Pb-Sb metallic alloy bath, after austenization at 900°C for 20, 40, 60 and 90 minutes. To study the relation of characteristics of structure components of high strength cast iron the metallographic and X-ray structural analyses were used.

According to the data obtained, the studied cast irons, depending on the degree of plastic deformation, differ in the form of graphite inclusions, in the amount of retained austenite and in the dispersity of metal matrix. In cast irons, whose degree of hot plastic deformation does not exceed 30%, graphite inclusions retain in their spherical shape and at higher degrees of deformations they are elongated to the direction of deformation. A metallographic analysis of the studied samples shows that with the increasing plastic deformation degree of ductile iron, the metallic matrix grain size decreases and the volume fraction of bainite increases. An irregular distribution of carbon is determined in the primary austenite at the beginning of austenitization. The isothermal decomposition of the primary austenite, inhomogeneous in composition in the intermediate temperature area is followed by the formation of bainitic metal matrix with an irregular distribution of the structural components. This is explained by higher stability of the areas of high-carbon austenite and requires optimization of continuing austenitization, ensuring the homogenization of the metal matrix without intensive growth of austenitic grain. The increase of the degree of deformation causes dimensional inhomogeneity of bainitic crystals, the finest of which are located near graphite inclusions. In the course of research it was determined that changing of the deformed state influences multivalued on the processes of formation of the final structure of the cast irons during their subsequent thermal treatment. According to the data of X-ray diffraction analysis, the increasing plastic deformation up to 30% causes increasing of the proportion of bainitic constituent in the structure of the metal matrix of studied specimens. Typical X-ray diffractogram of the studied austempered ductile irons is presented in Fig. 1. This dependency is evidently due to the grain size refinement of the primary austenite and the increase of nucleation centers number of bainitic crystals. More significant plastic deformation causes the decrease of the completeness of the γ—α transformation regardless of the temperature of isothermal quenching, which is the result of intensification of the carburization processes of the austenite due to the shape changing of graphite inclusions. As it seems from the data in Fig. 1, with an increase of austenitization time, the amount of the retained austenite continuously increases and stabilizes at final homogenization of primary austenite in all isothermally quenched cast irons (Fig. 2).

Typical microstructures of the investigated ductile irons are presented in Fig. 3, 4.

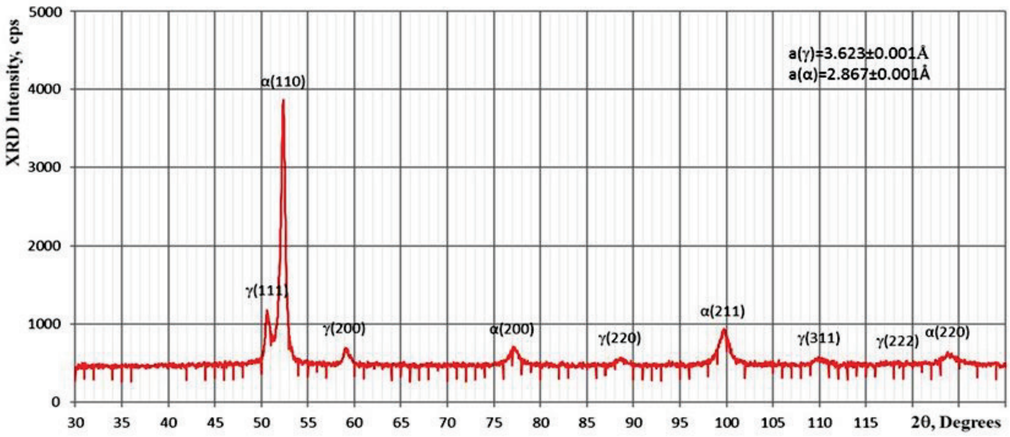

Fig. 1. XRD diffractogram of bainitic ductile iron.

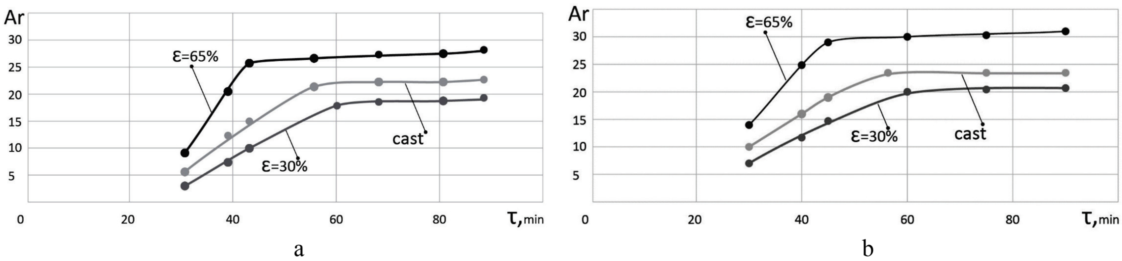

Fig. 2. Influence of austenization time on the amount of retained austenite after isothermal treatment during 30 minutes at the temperatures: a) 280°C and b) 400°C.

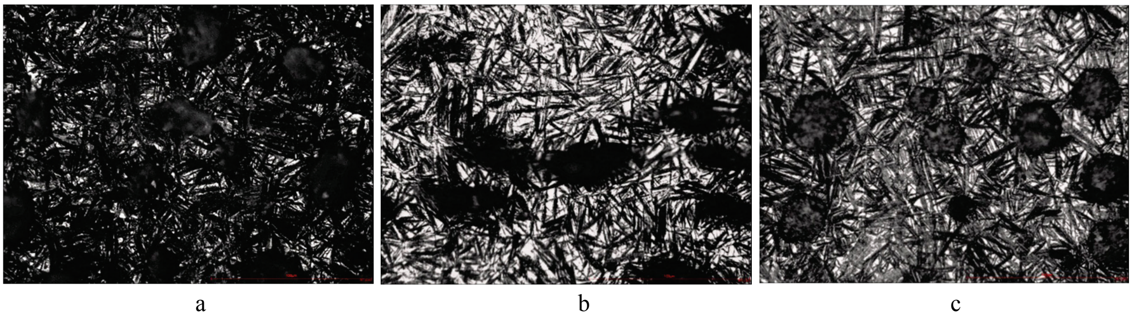

Fig. 3. Microstructures (X400) of isothermal quenched (at the 280°C) ductile iron, depending on the degree of plastic deformation: a) Ɛ≈30%, b) Ingot, c) Ɛ≈65%.

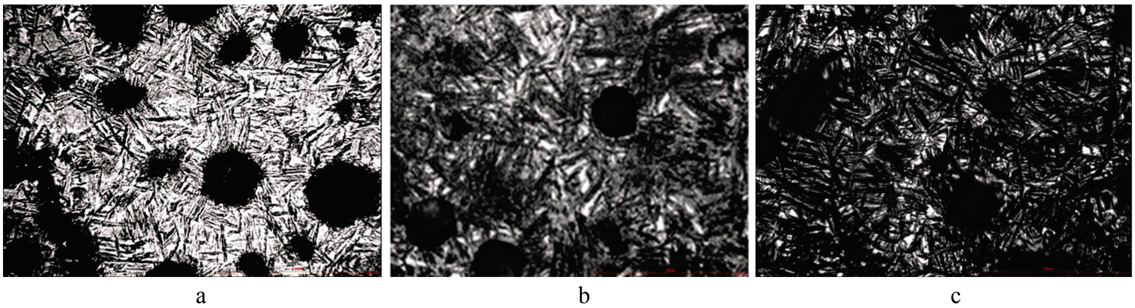

Fig. 4. Microstructures (X400) of isothermaly quenched (at the 400°C) ductile iron, depending on the austenitization time: a) 30 min, b) 45 min, c) 60 min.

Conclusions

Based on the data obtained, it can be concluded that combination of hot plastic deformation and isothermal quenching processes allows to have wider influence range on the process of structure formation of high-strength cast irons. During the experiments it was determined that hot plastic deformation:

1. Increases the dispersion of grains of the metal matrix and microhardness by 4-6 units of HRC accordingly.

2. Increases the degree of decomposition of the primary austenite during isothermal quenching, if the degree of plastic deformation does not exceed 30%.

3. Causes elongation of graphite inclusions and stabilizes primary austenite with increasing degree of deformation over 30%.

4. Increases the diffusion activity of carbon, accelerates the process of homogenization of the primary austenite and reduces duration of austenitization at compression degree over 30%.

მეტალურგია

ცხლად პლასტიკური დეფორმაციის გავლენა აუსტენიზაციის პროცესზე მაღალმტკიცე თუჯის იზოთერმული წრთობისას

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წარმოდგენილ ნაშრომში გამოკვლეულია საკონსტრუქციო მასალების ახალი კლასის – დეფორმირებადი მაღალმტკიცე თუჯების სტრუქტურა და თვისებები. შესწავლილია სხმული და დეფორმირებული მაღალმტკიცე თუჯების აუსტენიზაციის პარამეტრების გავლენა შენადნობების ფაზურ შედგენილობებზე. ნაჩვენებია, რომ პლასტიკური დეფორმაციის და თერმული დამუშავების პროცესების თანმიმდევრული შეთავსება უზრუნველყოფს გაცილებით მრავალფაქტორიან გავლენას მაღალმტკიცე თუჯის სტრუქტურასა და სამომხმარებლო თვისებებზე. კვლევის ობიექტად შერჩეულ იქნა მაღალი სიმტკიცის თუჯები 3,45% C, 2,30% Si, 0,25% Mn, 0,003% S, 0,05% P და 0,045% Mg-ით. საცდელი ნიმუშების გლინვა ხორციელდებოდა

საფეხურებად 20%-იანი პირველადი მოჭიმვებით. ჯამში, 60% მოჭიმვით მიღებულ იქნა უდეფექტო ფურცლოვანი ნამზადი. ჩატარებული ცდების შედეგად დადგენილია, რომ მაღალმტკიცე თუჯის ცხლად პლასტიკური დეფორმაცია აწვრილმარცლოვანებს ლითონური ფუძის სტრუქტურას, ხელს უწყობს პირველადი აუსტენიტის დაშლას ტემპერატურების შუალედურ ინტერვალში, ზრდის ნახშირბადის დიფუზურ აქტივობას, აჩქარებს აუსტენიტის ჰომოგენიზაციას და ამცირებს აუსტენიტიზაციის ხანგრძლივობას.

REFERENCES

1. Soliman M., Nofal A., Palkowski H. (2018) Effect of hot working parameters on microstructure evolution and mechanical properties of ausformed austempered ductile iron. *Materials Science Forum,* **925:** 218-223.
2. Soliman M., Ibrahim H., Nofal A., Palkowski H. (2014) Effect of intercritical annealing on phase transformation and mechanical properties of thermo-mechanically processed dual matrix ductile iron. TMS: 143rd Annual Meeting & Exhibition pp. 959-965.

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