UDC 669.18.046

THE INFLUENCE OF CARBON CONCENTRATION AT THE ISOTHERMAL PRECIPITATION OF CARBONITRIDE PHASES BASED ON Ti, Nb AND Al

A. I. Trotsan, Dr.Sci.Tech., professor; V. V. Kaverinsky, engineer, post graduate student; I. L. Brodetsky, Cand.Tech.Sci., senior researcher

Frantsevich Institute for Problems of Materials Science NAS Ukraine

The problem statement.

Carbonitride phase's formation takes a significant part in the processes of dispersive hardening of steels and in the deterring of the grain growth at heating [1, 2]. Microalloying by strong carbide and nitride formers (Ti, Nb, V) is one of the basic hardening factors for low-carbon steels [1 – 3] and the same way for ones with higher carbon content [4]. In the composition of many steels there is some admixture of aluminium that is also capable to formation of nitride [5, 6]. Hence, the estimation of the composition and amount of precipitated carbides and nitrides, and determination of remnant concentrations of the carbide and nitride forming elements (in the solid solution) at different contents of carbon are very important for the science and practice in order to work out and optimise technologies of a thermo-mechanical treatment.

The analysis of the last researches and publications.

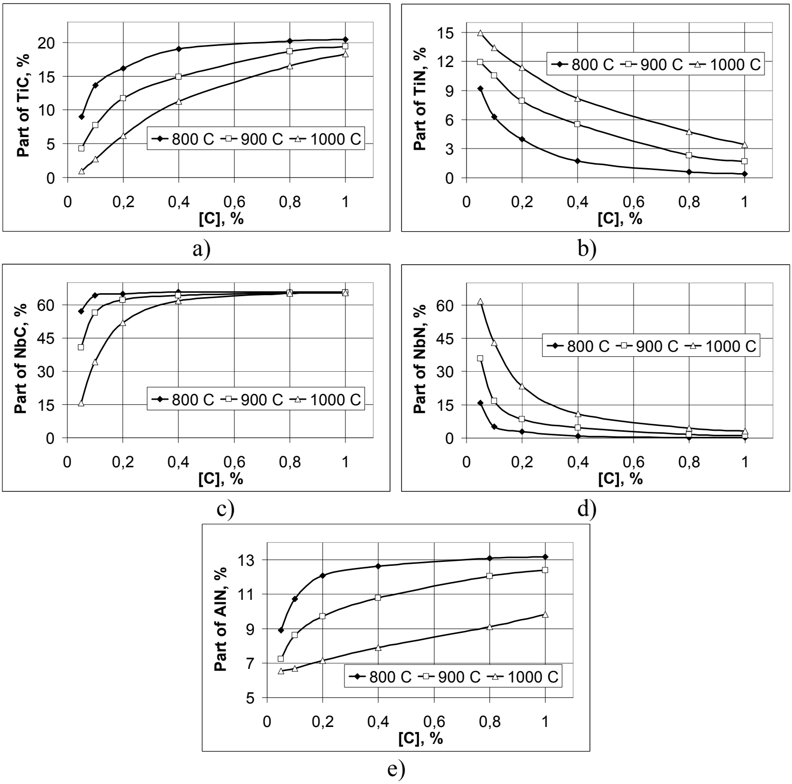
Processes of excess phase's precipitation from a solid solution have been investigated for many years mainly experimentally [1 – 5], nevertheless nowadays appeared some theoretical works [7, 8]. Before in our works [9 – 10] had been described formation of carbonitride phases in low-carbon complexly micro alloyed steels at a refrigeration process. In the work [11] the computer model for description of precipitation of carbides and nitrides from supersaturated solid solution at the isothermal conditions was developed, but the influence of carbon concentration on nitrides and carbides of Ti, Nb and Al formation depending on the temperature of isothermal aging was not considered. The application of mathematic modelling allows swiftly and with quite high precision realising thermodynamic calculations of the carbonitrides precipitation in the micro alloyed steels of complexly composition.

The purpose of the work – determination of compositions and masses of the precipitate carbonitride phases, and also of the remnant content of carbide and nitride formers in the solid solution in conditions of steel micro-alloying by Ti, Nb and Al for different concentrations of carbon and temperatures of isothermal aging.

The statement of the main information and discussion of the results

Let us consider the steels of the next composition (by mass %) Mn – 0.45; Si – 0.30; N – 0.006; Al – 0.02; Ti – 0.015; Nb – 0.03; content of carbon would varies from 0.05 to 1.00 %. Temperatures of isothermal aging: 1000 °C, 900 °C and 800 °C. It is assumed that at these temperatures from supersaturated solid solution carbides and nitrides of Ti and Nb, nitride of Al should precipitate, and in the initial moment all these elements are dissolved in the solid solution.

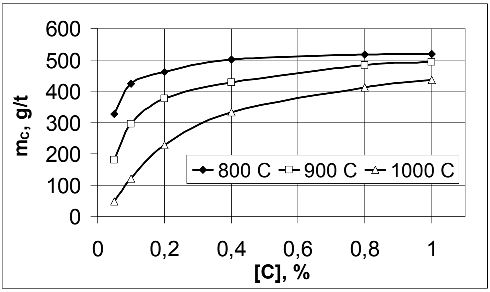
On picture 1 plots built with using of the computer model of precipitation of carbonitrides from supersaturated solid solution at the isothermal conditions are offered [11]. These plots describe the way of influence of carbon concentration on average composition of formed carbonitride phases at different temperatures of isothermal aging.



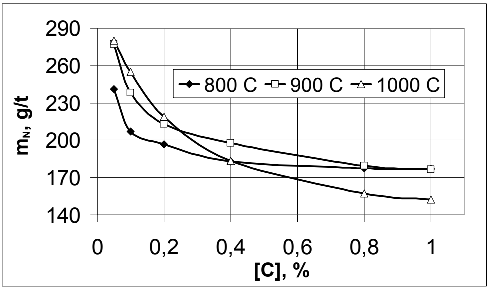
Pic. 1. The influence of carbon concentration on the composition of the carbonitride phase: a) part of TiC; b) part of TiN; c) part of NbC; d) part of NbN; d) part of AlN

Offered results shows that for Ti and Nb (forming carbides also as nitrides) the part of carbide component is increasing with magnification of carbon concentration. For Al, that does not form its carbide in the steels some increasing of the part of its nitride with increase of carbon concentration is observed. Presence of such dependence may be explained by change of activity of aluminium in solid solution at deviations of carbon concentration and decreasing of nitrogen consumption on forming of nitrides of Ti and Nb, which amount is lessening (picture 2). Temperature of isothermal aging has a significant influence on the form of offered dependences, specifically, by its decreasing the part of TiC is increasing, and its dependence from carbon concentration becomes more sloping. The similar situation is observed for NbC and NbN. Decreasing of expressiveness of the dependences of their parts from carbon content at temperature lessening is more considerable then for compounds of Ti. Significant influence on parts of NbC and NbN carbon makes in low-carbon and, a less degree, in middle-carbon steels. In high-carbon ones these dependences are insignificant, particularly at low temperatures.

On picture 2 calculated dependences of total masses of carbides and nitrides from carbon content, formed at different temperatures are shown. It is seen from these results that the mass of formed carbides significant increases by magnification of carbon concentration and decreasing of temperature of the isothermal aging.



a)

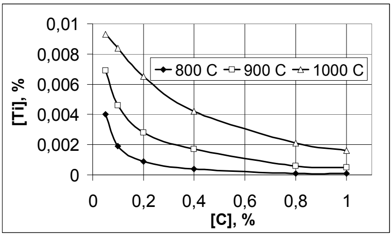


b)

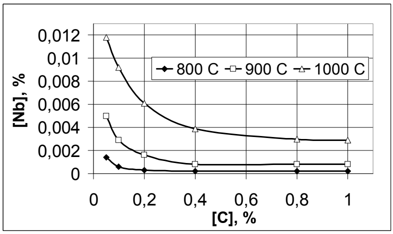
Pic. 2. The influence of carbon concentration on the total mass of carbides mC (a) and nitrides mN (b) at different temperatures of the isothermal aging

Thus the most expressive dependences are observed for low-carbon steels and at higher temperatures. For nitride phase changes of the form of this dependence at different temperatures are some more complex. The influence of temperature on the mass of these nitrides is contrary and less expressiveness in comparing with carbides. So at 1000 °C by increasing of carbon content the mass of the nitrides is quite decreasing. At lower temperatures this decreasing becomes less significative, especially for high-carbon steels. For low-carbon steels with temperature decreasing the mass of the precipitated nitrides somewhat reduced, conceding forming of the carbides. On the whole (except low-carbon steels at somewhat lower temperatures of isothermal aging) the mass of the forming carbides is significantly larger.

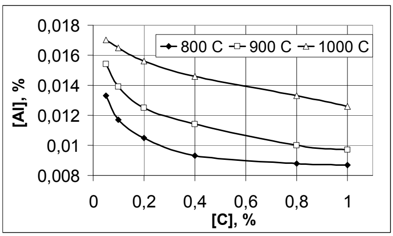
On picture 3 the values of the remnant concentrations (in solid solution) of Ti, Nb and Al at different contents of carbon and temperatures of the isothermal aging are shown. Offered dependences are in closely correlation with the quantity of formed carbide and nitride phases of these elements. So by decreasing of the temperature and increasing of carbon content the amount of the excess phases runs higher and the concentrations of carbide and nitride forming elements (Ti, Nb, Al) in the solid solution become lower. By increasing of carbon content the dependences become more acclivous, especially at lower temperatures. So, for instance, even at low concentrations of carbon at 800 °C niobium is almost entirely bonding in carbonitride phase, hence there is no any reserve for further increasing of its carbides quantity by running higher of carbon content (in the condition of the given initial concentration of niobium). Titanium in spite of the lower (in the given conditions) initial content, at lower temperatures of the isothermal aging remains in the solid solution in low-carbon steels in somewhat larger amounts then niobium. And just at higher temperatures and in high-carbon steels these concentrations are quite similar to each other.



a)



b)



c)

Pic. 3. The dependence of the remnant concentrations of Ti (a), Nb (b), Al (c) in the solid solution by carbon content and temperature of the isothermal aging

Given results of researches offers a theoretical basis for working out of technological recommendations of effective microalloying of steels (with different content of carbon) by carbide and nitride forming elements and for improvement of regimes of thermo-mechanical treatment.

Conclusions

The way of the influence of carbon concentration in steel on the precipitation of carbide and nitride phases of Ti, Nb and Al is shown. The average compositions and masses of formed carbides and nitrides and also the remnant concentrations of the carbide and nitride forming elements in the solid solution at differed contents of carbon and temperatures of the isothermal aging have been determined.

It was fixed that increasing of carbon content is able to make lower the remnant concentrations in the solid solution carbide and nitride formers, especially in low-carbon steels at the higher temperatures of the isothermal aging.

List of references

1. Матросов М. Ю. Исследование микроструктуры микролегированной ниобием трубной стали после различных режимов контролируемой прокатки с ускоренным охлаждением. / М. Ю. Матросов, Л. И. Эфрон, А. А. Кичкина, И. В. Лясоцкий // Металловедение и термическая обработка металлов. – 2008. – №3. – С. 44 – 49.
2. Гольдштейн М. И. Растворимость фаз внедрения при термической обработке стали. / М. И. Гольдштейн, В. В. Попов – М.: Металлургия, 1989.– 200 с.
3. Гольдштейн М. И. Специальные стали / М. И. Гольдштейн, С. В. Грачёв, Ю. Г. Векслер. – М.: Металлургия, 1985. – 408 с.
4. Рудюк А. С. Совершенствование технологии производства железнодорожных рельсов / А. С. Рудюк, А. А. Азаркевич, Р. С. Сидорчук, А. В. Акрмазин, И. М. Кошулэ // Металлург. – 2013. – № 9. – С. 85 – 88.
5. Бабаскин Ю. З. Конструкционные и специальные стали с нитридной фазой / Ю .З. Бабаскин, С. Я. Щипицин, И. Ф. Кирчу. – К.: Наукова думка, 2005. – 258 с.
6. Григорян В. А. Физико-химические расчёты электросталеплавильных процессов. / В. А. Григорян, А. Я. Стомахин, А. Г. Пономаренко и др. – М.: Металлургия, 1989. – 288 с.
7. Горбачев И. И. Термодинамическое моделирование карбонитридообразования в сталях с Ti и Nb / И. И. Горбачев, В. В. Попов, А. Ю. Пасынков // Физика металлов и металловедение. – 2012. – №7. – С. 727 – 735.
8. Венгренович Р. Д. Оствальдовское созревание в условиях смешанного типа диффузии / Р. Д. Венгренович, А. В. Москалюк, С. В. Ярема // Физика твёрдого тела. – 2007. – № 1. – С. 13 – 18.
9. Троцан А. И. Прогнозирование выделения карбонитридов и карбидов в микролегированной стали с применением термодинамических расчётов / А. И. Троцан, В. В. Каверинский, И. Л. Бродецкий // Металлофизика и новейшие технологии. – 2013. – № 7. – С. 919 – 931.
10. Троцан А. И. Влияние содержания циркония на карбонитридообразование в микролегированной низкоуглеродистой стали / А. И. Троцан, В. В. Каверинский, И. Л. Бродецкий // Строительство, материаловедение, машиностроение: Сб. научн. трудов. вып. 67 – Днепропетровск.– ПГАСА, 2013. – С.28 – 32.
11. Троцан А. И. Моделирование карбонитридообразования в микродегированных сталях. / А. И. Троцан, В. В. Каверинский, И. Л. Бродецкий // Металл и литьё Украины. 2014. – № 2. – С. 9 – 13.