

RESEARCH PAPER

EFFECT OF SALT BATH NITRIDING TIME ON THE PERFORMANCES OF 304 STAINLESS STEEL

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ABSTRACT

In this study, salt bath nitriding was carried out at 565°C for various times for 304 stainless steel (304SS). The effect of salt bath nitriding time on the microstructure, micro-hardness and wear resistance was investigated systematically. The results showed a nitriding layer was formed during salt bath nitriding, and the thickness of effective hardening layer is duration dependant. The maximum microhardness value of 1200HV_{0.01} was obtained at optimal duration of 150min, which was five times higher than that of the untreated sample. And the wear resistance could be significantly improved by salt bath nitriding, the lowest weight loss after wear resistance was obtained while nitriding for 150min, which was one tenth of that of untreated sample.

Keywords: 304 stainless steel; wear resistance; microhardness; salt bath nitriding

INTRODUCTION

Austenitic stainless steel has excellent corrosion resistance, but their surface hardness and wear resistance are poor [1-5]. In order to enlarge their real applications and meet the needs in various service environments, surface modification is essential to overcome these shortcomings.

Among the existed surface-modification techniques, nitriding treatment is one of the most widely used methods [6-10]. In real applications, there exist three kinds of normally used nitriding technologies, which are gas nitriding, plasma nitriding, and salt bath nitriding. And salt bath nitriding has highest efficiency and lowest production cost comparing the other two technologies [11-15].

Therefore, salt bath nitriding is conducted in this research, and the aim of the present study is to get rid of the empirical treating factors used by different users, and determine the optimum nitriding time of salt bath nitriding for 304 stainless steel by investigating the effect of nitriding time on the microstructure, microhardness and wear resistance, and thus the research will have important guiding significance to the industrial production in the salt bath nitriding for 304 stainless steel.

MATERIAL AND METHODS

The material used in this work is 304SS with the following chemical compositions (wt. %): C 0.06, Cr 18.64, Ni 9.31, Si 0.46, P 0.02, and Fe in balance. The substrate presented a microhardness of about 200HV_{0.01}.

Samples were cut in the size of 10×10×10 mm for microhardness test, and in the dimension of 32mm diameter and 5mm thickness disc for wear test. All of the flat surfaces of each sample were ground using various grades of SiC paper and polished to a mirror finish, and then ultrasonically cleaned in deionized water and alcohol for 5 minutes respectively before salt bath nitriding. The samples were pre-heated to 350°C for 30min in air and then processed in tailor-made nitride

salt bath with CNO⁻ concentration of 35% at 565°C for various time (60min, 90min, 120min, 150min and 180min).

The cross-sectional microstructure of the samples was observed by optical metallography (XUG-05). The cross-sectional hardness was measured by Vickers microhardness tester at a load of 10 gf and the holding duration of 15s. Each hardness value was determined by averaging at least 5 measurements. The wear tests were carried out on a Wear Test Machine Type MMW-1A under ambient condition (20±2°C and 50%RH). During the test, a 6 mm diameter GCr15 steel ball rotated at a speed of 200rpm on the surface of the samples for 60 min at a test load of 50N. The friction coefficient was continuously recorded during the test, and the weight of the samples before and after wear test was measured by a balance accurate to 0.1mg for calculating the weight loss.

RESULTS AND DISCUSSION

Metallographic observations

Fig. 1 shows the cross sectional microstructure of samples after salt bath nitriding for different nitriding time at 565°C. From the very surface to the core, a compound layer (bright layer) and diffusion layer are formed, and the compound layer thickness has no obvious difference with the duration increase from 60min to 180min. The diffusion layer is between bright-layer and matrix, which is hard to be clearly distinguished by optical microscopy, but can be determined by the effective hardening layer shown in the cross-sectional microhardness profile (Fig.2). Its main constitutions are solid solution or supersaturated solid solution of the N atoms (S-phase) in α-Fe, which could bring about an improvement of hardness comparing with the matrix [16-19].

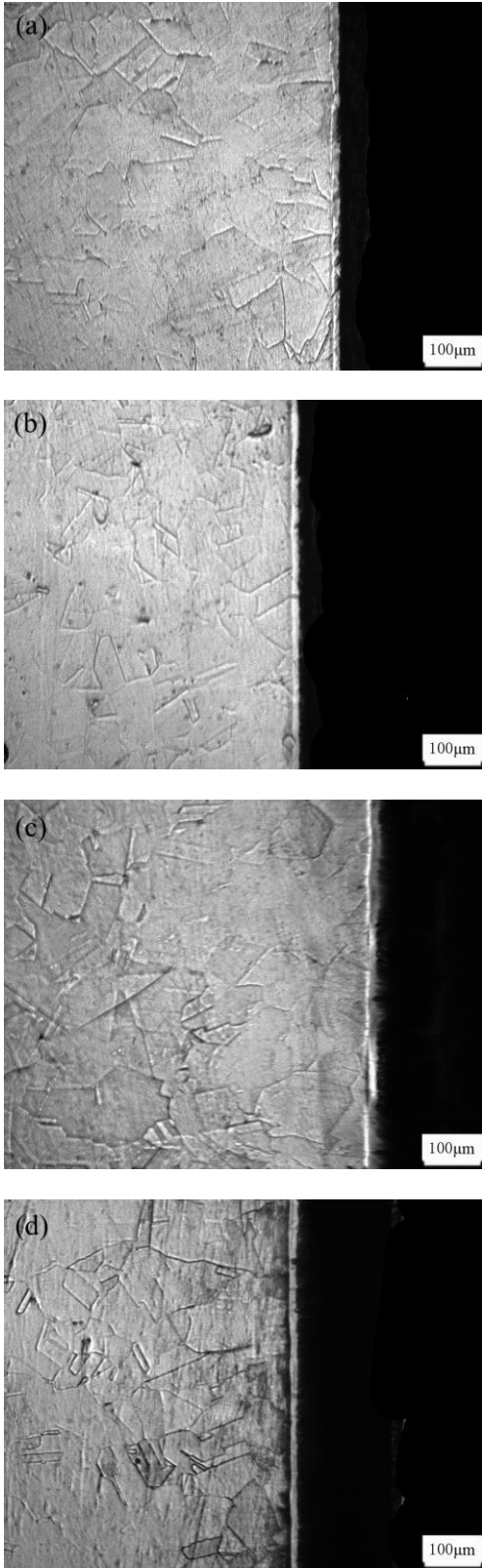


Fig. 1 The cross-sectional microstructures of specimens nitrided at 565°C for different time (a) 60min (b) 90min (c) 120min (d) 150min (e) 180min

Micro-hardness profile

Fig. 2 shows the microhardness profile for different nitriding time. The surface hardness reaches the maximum of 1200HV_{0.01} when nitrided for 150min, which is 5 times higher than that of untreated sample of 200HV_{0.01}. With the increase of nitriding duration, the surface hardness and the effectively hardening layer increase gradually at first, and then turn to decrease slightly when the nitrided time exceeds 150min. The possible reason of this phenomenon is due to a loose structure formed on the top of the compound layer, and meanwhile coarser grain size formed in the nitriding layer, resulting in the decrease of surface hardness once the nitrided time exceeding some duration [20-23].

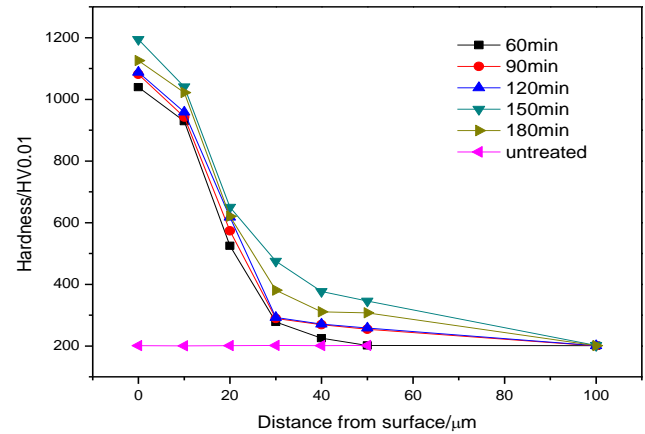


Fig. 2 The cross-sectional hardness profile of the specimens treated at 565°C for different nitriding time

Wear resistance analysis

The variation of weight loss for untreated and nitrided samples is shown in Fig. 3. It can be clearly seen that the weight loss of the untreated sample is much higher than those of nitrided samples, reaching around 0.09g. Whereas, the weight loss of samples after salt bath nitriding decreased dramatically, and a minimum of 0.0084g was obtained when nitrided for 150min, which is because a nitriding layer is formed on the surface after salt bath nitriding, resulting in excellent wear resistance. Meanwhile, it can be found that the weight loss has no obvious difference with the duration increase from 60min to 180min.

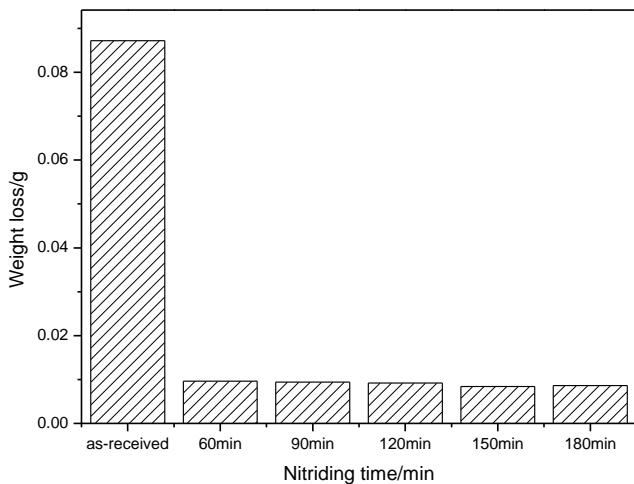


Fig.3 Weight loss of samples untreated and nitrided at 565 °C for different nitriding time

Fig.4 is the friction coefficient curve of the samples untreated and nitrided for different duration. It could be seen that the friction coefficient of nitrided 304SS was lower than that of the untreated samples. The average friction coefficient was 0.51 for the untreated sample, while decreased to some extent after nitriding, and the average friction coefficient is nitriding duration dependant, corresponding to 0.49, 0.46 and 0.42 for nitriding time of 60min, 90min and 150min, respectively. While it turned to be much rough for samples nitriding for 180min, possibly due to the looser surface formed at this long nitriding time.

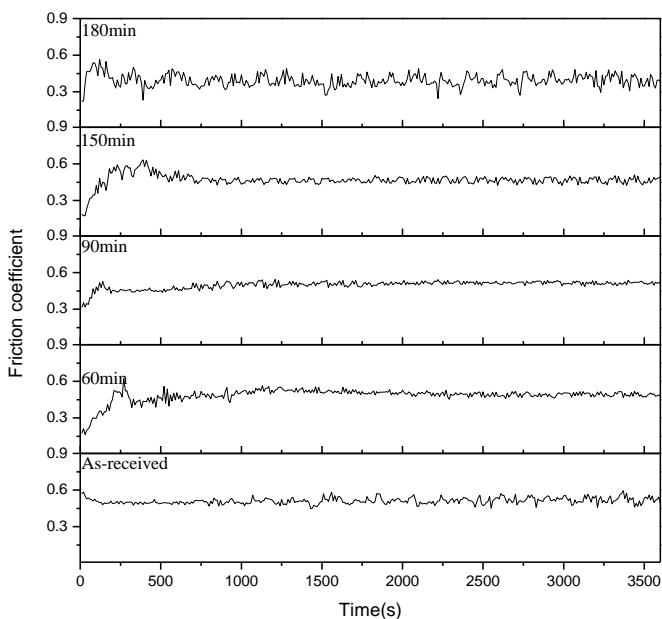


Fig.4 Friction coefficient of the samples samples untreated and nitrided for different time

CONCLUSION

- (1) A nitriding layer was formed on the surface of 304SS after salt bath nitriding, and the thickness of the compound layer had no obvious difference with the duration increase from 60min to 180min.
- (2) The optimal nitriding time was 150min for 304SS, with maximum surface hardness and best wear resistance.

(3) The surface hardness of 304SS was increased significantly after salt bath nitriding, reaching the maximum of 1200HV_{0.01}, 6 times as high as 200HV_{0.01} of the untreated sample.

(4) The wear resistance of 304SS was improved dramatically after salt bath nitriding, the weight loss after wear test decreased to only 1/10 comparing with that of untreated sample.

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