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Letter to the Editor

Wear resistance of austempered pearlitic ductile iron

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Abstract

The influence of austempering temperature on tribological properties of austempered pearlitic ductile iron (ADI) was investigated. The as-cast ductile iron was subjected to heat treatments consisting of austenitization at 900 °C followed by austempering at temperatures of 250, 300 and 350 °C for 120 min. The austempered samples were subjected to abrasion and adhesion wear resistance tests using steel and ductile iron plates. The abrasive wear testing of the tribo-pair was undertaken with the sanding plate. The results of abrasion and adhesion wear resistance tests are presented, and the effect of austempering temperature is discussed.

Key words: austempered ductile iron, heat treatment, wear

1. Introduction

Austempered ductile iron (ADI) is a type of nodular iron. ADI is characterized by a unique microstructure composed of ausferrite, produced by the heat treatment (austempering) of ductile irons. The ausferrite is a mixture of ausferritic ferrite and carbon enriched retained austenite. Due to a combination of high strength, ductility, toughness together with good wear, fatigue resistance and machinability, these materials can be used for various applications, for example as a replacement for steel in expensive products made of rolled, forged and steel castings [1]. The main advantages of ADI are seen in its excellent machinability, increased processing speed, increased vibration damping, near net shape casting or product weight reduction.

Since the hardness of ADI increases during austempering, it is often preferable to machine components before heat treatments taking into account predictable dimensional expansion and assuming no significant distortion. In the case that the dimensional expansion is not suficiently consistent, the only option is to carry out most of the machining before heat treatments and to finish machining of critical dimensions after the austempering [1].

Mechanical properties of ADI depend strongly on the morphology of graphite particles [2, 3]. The strength of ADI material is up to two times that of the nodular iron of standard quality, with the same value of toughness and ductility [2]. Hardness and wear resistance can be increased by additions of titanium and boron in the hardfacings [4–6]. Previous studies have shown that alloying elements such as Cu and Ni influence temperature, initiation time and completion of the austempering reaction, which provides a larger processing window and easy control of the austempering heat treatments [7].

The present work aims to study the influence of austempering temperature on tribological properties of austempered pearlitic ductile iron EN-GJS-700-2.

2. Experimental materials and procedures

The chemical composition of the studied as-cast

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T a b l e 1. The chemical composition of as-cast ductile iron (wt.%)

C	Si	Mn	Cu	Mg	P	S
3.76	2.35	0.51	1.43	0.066	0.02	0.004

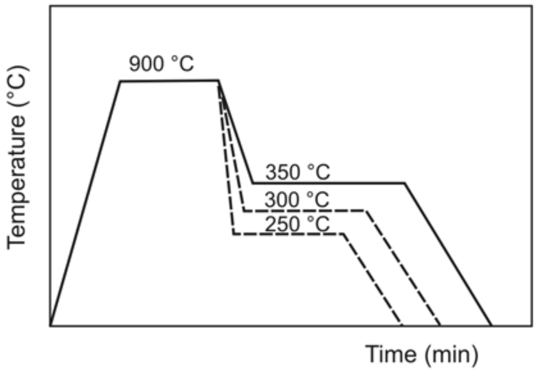

Fig. 1. Schematic presentation of temperature versus time of the austempering process on the upper bainite (full line) and lower bainite (dashed line) temperatures.

ductile iron EN-GJS-700-2 is given in Table 1. The specimens for mechanical testing were machined from the bottom parts of as-cast Y blocks with a thickness of 25.4 mm to exclude the effect of segregation or porosity on mechanical properties. The austempering of the specimens consisted of austenitization at 900 ℃ for 90 min in a protective argon atmosphere, quenching into a salt bath with an austempering temperature of 250, 300 or 350 ℃, holding at the austempering temperature for 120 min and cooling to room temperature, as shown in Fig. 1.

Adhesion wear testing of the austempered samples was carried out on two friction pairings such as an austempered ductile iron pin/nodular iron plate and austempered ductile iron pin/steel plate. The nodular iron plate material with dimensions of ø 120 × 3 mm^2 and hardness of 54 HRC was produced from EN-GJS-700-2 steel. The steel plate with dimensions ø 120 × 3 mm^2, guaranteed chemical composition and hardness of 56–58 HRC was produced from EN 10027-2 steel. Abrasive wear testing of the tribopair was undertaken with the sanding plate. The adhesion and abrasive wear tests were carried out according to ASTN-D 3389 using Taber Abrazer model 503 equipment. A pressing force of 10 N was applied on a pin with a diameter of 6 mm and length of 18 mm made of the austempered ductile iron samples. The rotation speed of the plate was changed from 1000 to 5000 rev min^{-1} at five steps during the tests. The measurement of the length of the pin test specimens

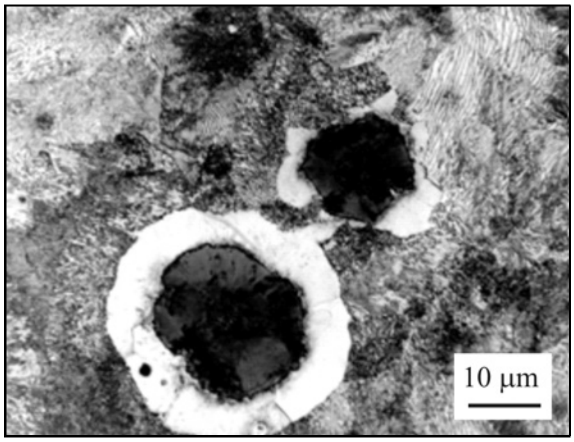

Fig. 2. The typical microstructure of nodular ductile iron before heat treatments [6].

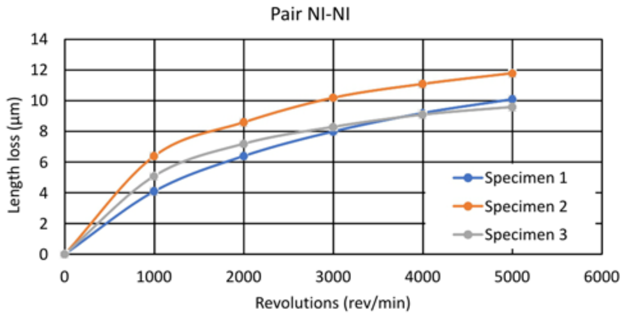

Fig. 3. Comparative adhesion wear diagram expressed as a dependence of length loss on the number of revolutions; pair NI-NI.

was performed by a micrometer. The measurements of the weight of the pin specimens were done using an analytical balance. The adhesion and abrasion tests were carried out at a temperature of 18 to 20 ℃ and relative humidity of 60 to 70 %.

3. Results and discussion

Figure 2 shows the typical microstructure of the studied ductile iron before the heat treatments. The microstructure consists mainly of pearlite (78 vol.%), ferrite (10 vol.%) and graphite particles (12 vol.%). The applied heat treatments of the ductile iron samples lead to the spheroidization of the majority of graphite particles (more than 85 %) with a nodule size ranging from 45 to 55 µm. Figures 3 and 4 show comparative diagrams of the adhesion wear of the contact pairs of the austempered ductile iron pin on the nodular iron plate (pair NI-NI). The adhesion wear resistance is presented in terms of the length loss (Fig. 3) and mass loss (Fig. 4) of the ductile iron pins austem-

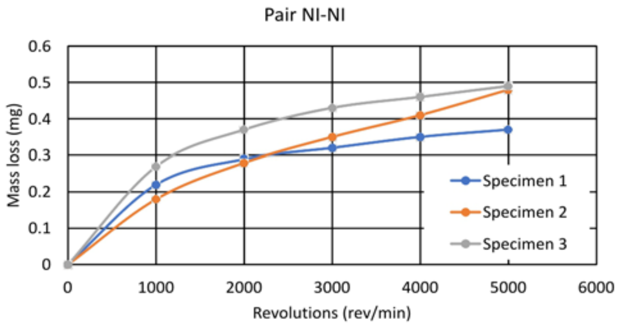

Fig. 4. Comparative adhesion wear diagram expressed as a dependence of mass loss on the number of revolutions; pair NI-NI.

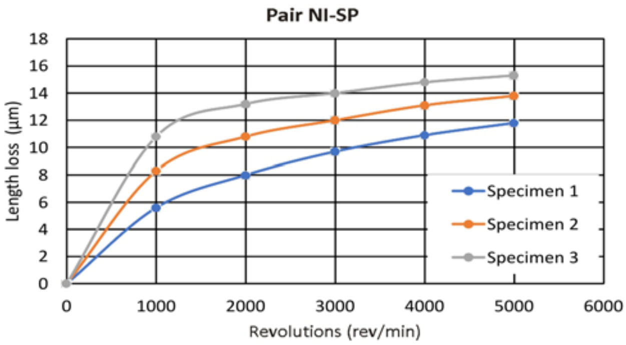

Fig. 5. Comparative adhesion wear diagram expressed as a dependence of length loss on the number of revolutions; pair NI-SP.

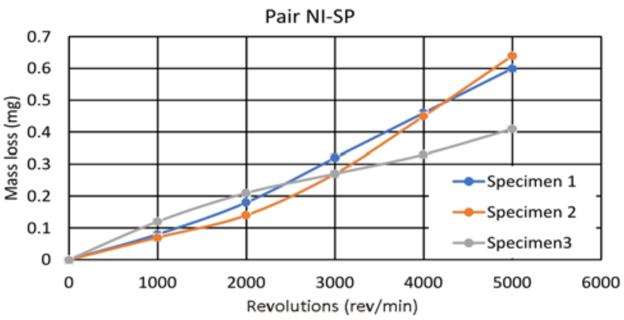

Fig. 6. Comparative adhesion wear diagram expressed as a dependence of mass loss on the number of revolutions; pair NI-SP.

pered at a temperature of 250 °C (specimen 1), 300 °C (specimen 2) and 350 °C (specimen 3). It is clear from these figures that the increase in the number of revolutions increases both the length and mass loss of the austempered specimens. The highest mass loss shows the specimen 3 and the lowest the specimen 1 for the tribo-pair NI-NI.

Figures 5 and 6 show the adhesion wear of the con-

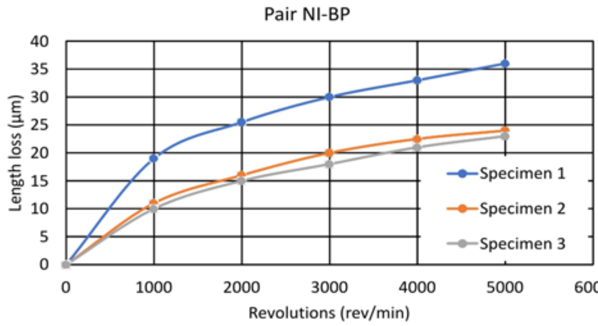

Fig. 7. Comparative diagram of abrasion wear expressed as a dependence of length loss on the number of revolutions; pair NI-PB.

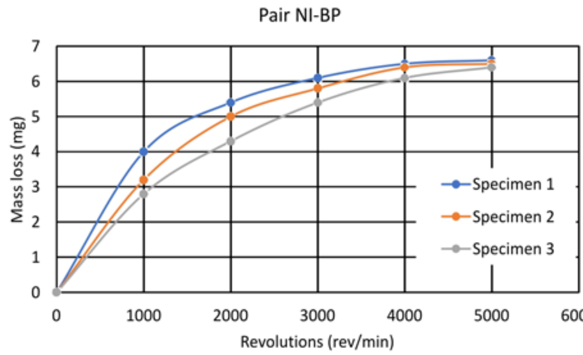

Fig. 8. Comparative diagram of the abrasion wear expressed as a dependence of mass loss on the number of revolutions; pair NI-PB.

tact pairs of austempered ductile iron pins on the steel plate (NI-SP). It is clear from these figures that the length loss (Fig. 5) and mass loss (Fig. 6) increase with the number of revolutions. While the length loss shows an increase with the increasing austempering temperature and is the lowest for the specimen 1 (250 °C), the evolution of the mass loss with the number of revolutions is not explicitly defined.

Figures 7 and 8 present comparative diagrams of the abrasion wear of the contact pairs of the austempered iron pins on sanding plate (NI-BP). It is clear from these figures that the increasing number of revolutions leads to an increase in length loss (Fig. 7) and mass loss (Fig. 8). The highest abrasion wear is measured for specimen 1 and the lowest for specimen 3. The mass loss is stabilized at 5000 rev min^{-1} at which the austempering temperature does not affect this abrasion wear parameter.

Comparison of length loss and mass loss wear tests indicates that the wear resistance is higher when the specimen made from the austempered ductile iron is in the tribo-pair with the steel plate. The improved lubrication due to the presence of nodular graphite particles decreases considerably the wear resistance of the austempered ductile iron specimens which are in the tribo-pair with the nodular iron plate. The results of tribology testing show that the resistance to abrasive wear of the tested pins is mostly a function of the austempered temperature. The highest resistance to abrasion shows the ductile iron specimen austempered at a temperature of 250 ℃. A somewhat lower resistance to the abrasive wear exhibit the specimens austempered at temperatures of 300 and 350 ℃.

4. Conclusions

The influence of austempering temperature on tribological properties of the austempered pearlitic ductile iron has been studied. The achieved results can be summarized as follows:

1. The austempering temperature does not substantially affect the adhesion wear resistance of the austempered ductile iron.

2. Formation of spheroidized graphite nodules during austempering treatments decreases the wear loss due to lubrication effect of graphite.

3. The lower the austempering temperature, the higher the wear resistance of the studied austempered ductile iron.

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