

Wear resistance of cast iron

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Abstract

In this paper investigations of abrasive and adhesive wear resistance of different cast iron grades have been presented. Examinations showed, that the most advantageous pair of materials is the cast iron – the hardened steel with low-tempered martensite. It was found, that martensitic nodular cast iron with carbides is the most resistant material.

Keywords: Wear resistant alloys; Nodular cast iron with carbides; Abrasive and adhesive wear resistance

1. Introduction

In [1 ÷ 3] papers the possibility obtaining carbides in the nodular cast iron with different microstructure was presented. The aim of its obtaining was increasing wear resistance of cast iron. In connection with different grades of cast iron were examined.

2. Materials for research

Investigations were carried out on:

- EN-GJL-250 cast iron,
- EN-GJS-600-3 nodular cast iron,
- pearlitic, pearlitic-martensitic and martensitic nodular cast iron with carbides.

Dimensions of investigated cast iron samples and disk-samples are shown in figure 1.

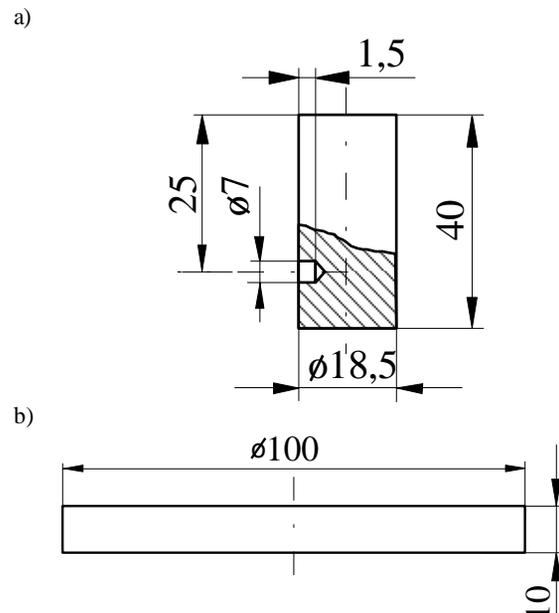


Fig. 1. Dimensions of investigated samples (a) and disk-samples (b)

To investigations of the abrasive resistance a P40A abrasive paper was used.

Disk-samples to adhesive resistance tests were made of C45 steel after following heat treatment:

- normalization (pearlitic-ferritic microstructure),
- hardening and low-temperature tempering (low-tempered martensite),
- hardening and sulfonitriding.

Hardness of testing materials was measured on HB scale on universal HPO-250 hardness tester for 2,5/187,5/30 conditions.

Hardness of disk-sample after normalization was measured on HB scale on universal HPO-250 hardness tester for 2,5/187,5/30 conditions.

Hardness of disk-sample after hardening was measured on HRC scale.

Microhardness of sulfonitriding layer was measured on HV scale with 100g weight.

Wear resistance examinations were carried out on the apparatus to model tribological tests, which is shown on figure 2.

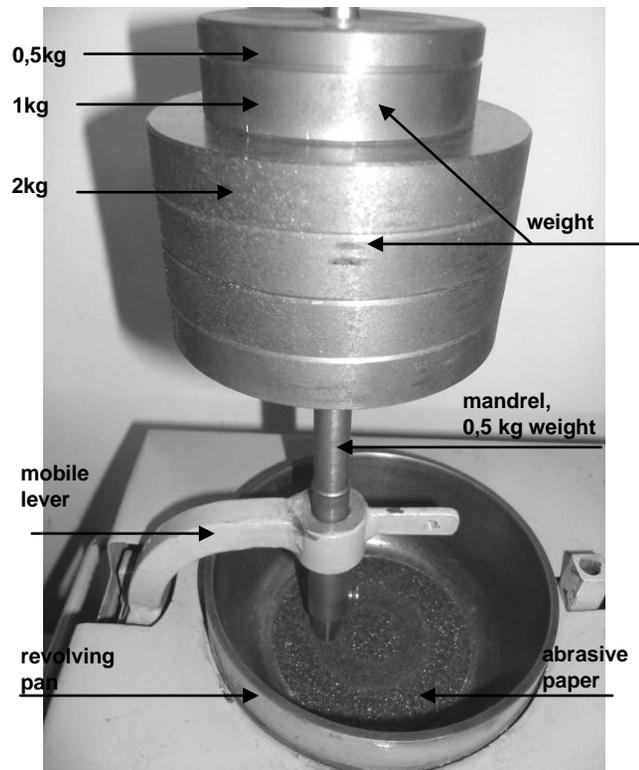


Fig. 2. Wear resistance test station

Experimental conditions were as following:

- sample load on abrasive paper and steel disk-sample: 98,0655N,
- sample abrasive face: 268,8mm²,

unite pressure:

$$\sigma = \frac{F}{S} = \frac{98,0665 \text{ N}}{268,8 \text{ mm}^2} = 0,36 \text{ MPa},$$

- rotational speed of disk: $\omega = 75$ circle/min.

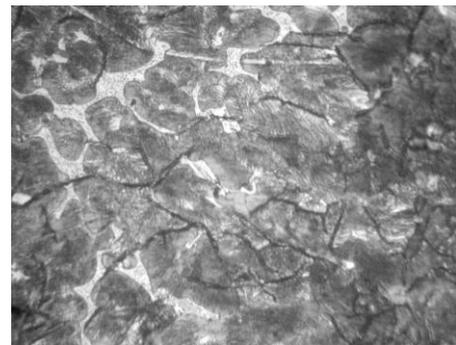
During the adhesive wear test, the mating materials was oiled ESSO Spartan EP 150 oil.

Abrasive and adhesive wear resistance was measured mass loss of sample on „Sartorius CP 224S-OCE” weigher accurate to 0,0001g (measuring error $\pm 0,0003$ g).

3. Results

In figure 3 (a ÷ e) the microstructure of testing cast iron was presented and in 4 (a ÷ c) figure the microstructure of steel disk-sample after different heat and thermochemical treatment was presented.

a)

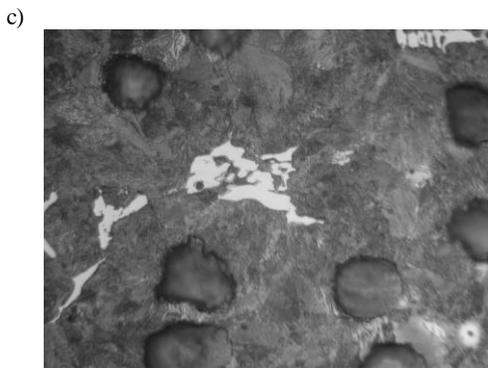


microstructure: flake graphite, pearlite, steadite, non-metallic inclusions

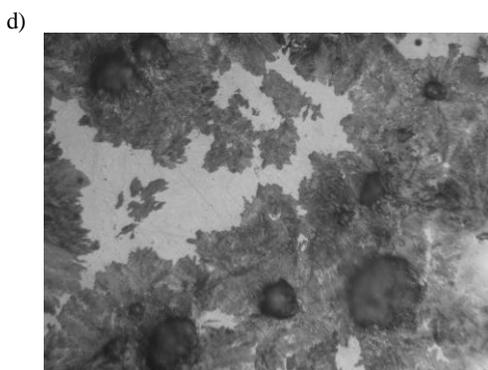
b)



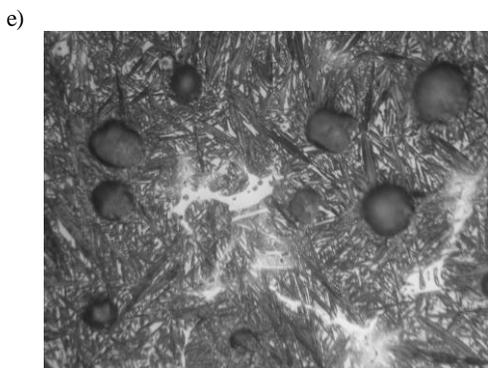
microstructure: nodular graphite, pearlite, non-metallic inclusions



microstructure: nodular graphite, pearlite, carbides, non-metallic inclusions

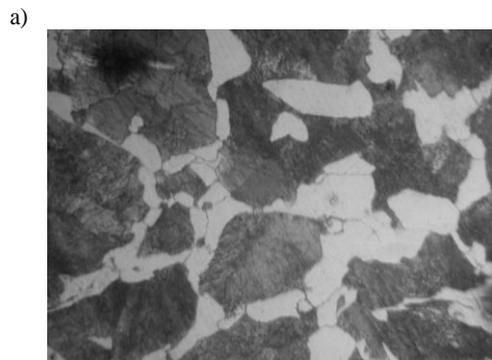


microstructure: nodular graphite, pearlite, martensite carbides, non-metallic inclusions

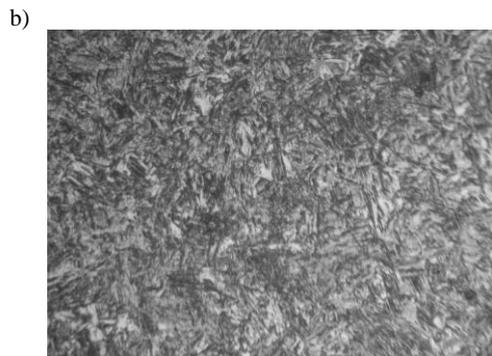


microstructure: nodular graphite, martensite, carbides, non-metallic inclusions

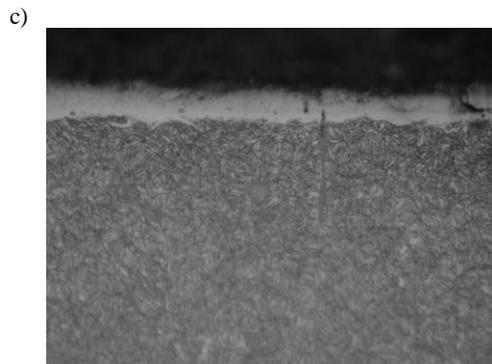
Fig. 3. (a ÷ e). Microstructure of: EN-GJL-250 grey cast iron (a), EN-GJS-600-3 nodular cast iron (b), pearlitic (c), pearlitic-martensitic (d), martensitic (e) nodular cast iron with carbides



microstructure: pearlite, ferrite, non-metallic inclusions



microstructure: low tempered martensite, retained austenite, non-metallic inclusions



microstructure: sulfonitrided case: sulfurized zone with FeS and Fe₂S; nitrogen compounds zone ϵ , $\epsilon + \gamma'$, γ' („white layer”) without FeS i Fe₂S, FeS fine compounds zone in ϵ phase, core: troostite, non-metallic inclusions

Fig. 4. (a ÷ c). The microstructure of disk-sample made of C45 steel after: normalizing (a), hardening and low-tempering (b), hardening and sulfonitriding (c)

In table 1 an average hardness of testing cast iron samples was shown. Results from it, that the least hardness has grey cast iron (215HB) and the greatest – pearlitic-martensitic (469HB) and martensitic (504HB) nodular cast iron.

Table 1.
Average HB hardness of testing cast iron

Grade of testing cast iron	Average HB hardness
EN-GJL-250 grey cast iron	215
EN-GJS-600-3 nodular cast iron	266
Pearlitic-martensitic nodular cast iron with carbides	469
Martensitic nodular cast iron with carbides	504

Average hardness of steel disk-samples is shown in table 2. Results from it, that the highest hardness has steel after hardening and low-tempering (49HRC) and hardening and sulfonitriding (517HV). Ferritic-pearlitic steel has the lowest hardness (225HB), comparable with grey cast iron hardness.

Table 2.
Average hardness of steel disk-samples

State of C45 steel:	Average hardness
Normalized	225HB
Hardened and low-tempered	49HRC
Hardened and sulfonitrided	517HV _{0,1}

In figure 5 the relationship of mass loss of testing cast iron grades mating with P40 abrasive paper in function of time is presented. Results from it, that among testing cast iron grades minimum abrasive wear resistance has grey cast iron. Mass loss of grey cast iron sample is very intensive to 6h and amounts to 26,58g. In 6 ÷ 10h period wear intensity decreases and at the end of the test amounts to 28,03g. For pearlitic nodular cast iron mass loss is relatively uniform and after 6h amounts to 3,70g and after

10h – 4,90g. Carbides presence in pearlitic matrix of nodular cast iron causes considerable decreasing of mass loss during the test and after 6h amounts to 2,46g, and after 10h – 2,67g. Pearlitic-martensitic and martensitic nodular cast iron with carbides demonstrated similar character of wear; its quantity amounts properly 1,59g and 1,48g and after 10h – 1,75g and 1,64g. Results from it, that differences between these cast irons are very small and constant during whole test.

In figure 6 the relationship of mass loss of testing cast iron grades mating with ferritic-pearlitic disk-sample in function of time is presented. Results from it, that grey cast iron has minimum adhesive wear resistance. After 1h mass loss of this sample was very intensive – 17,1g. In 1 ÷ 10h period wear intensity decreases and after 10h amounts to 20,8g. For pearlitic nodular cast iron wear character is similar. After 1h mass loss amounts to 14,7mg, and after 10h – 16,2mg. For two grades of nodular cast iron with carbides mass loss amounts to 0,3 ÷ 0,4mg, and after 10h – 0,8 ÷ 0,4mg. Results from it, that among testing cast iron grades, the least adhesive wear resistance have EN-GJL-250 grey cast iron and EN-GJS-600-3 nodular cast iron. Maximum adhesive wear resistance have pearlitic-martensitic and martensitic nodular cast iron with carbides. These grades of cast iron are 24 times more resistant than grey cast iron and 19 times than nodular cast iron.

In figure 7 the relationship of mass loss of testing cast iron grades mating with hardening and low-tempering disk-sample in function of time is presented. Results from it, that among testing cast iron grades the lowest adhesive wear resistance has EN-GJL-250 grey cast iron. Mass loss is considerable during whole test and the most intensive during 0 ÷ 1h – 1,2mg. After next 5h mass loss increases of 1,7mg and amounts to 2,9mg and after next 4h total mass loss amounts to 3,5mg. Pearlitic nodular cast iron has a similar wear character – it is about twice less and amounts to after 1h 0,6mg, and after 10h – 1,7mg. Different wear character has the pearlitic-martensitic nodular cast iron with carbides. The most intensive wear was during 0 ÷ 3h and amounts to 1mg. During 3 ÷ 10h mass loss was insignificant and amounts to 0,2mg; so during the whole test mass loss amounts to 1,3mg. The highest adhesive wear resistance has martensitic nodular cast iron with carbides. Mass loss after 1h amounts to 0,1mg and after 10h – 0,5mg.

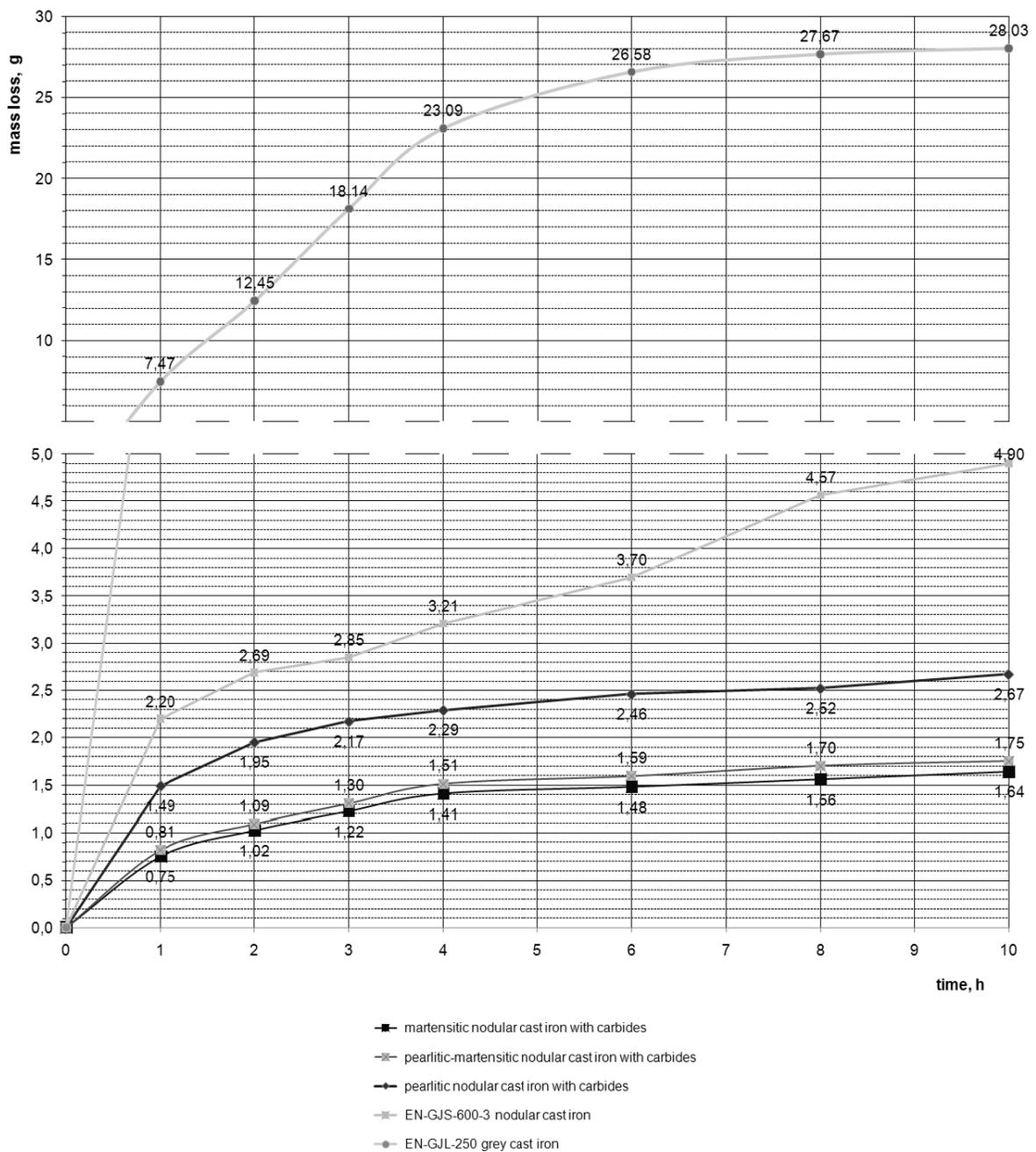


Fig. 5. Abrasive resistance of different grades of cast iron mating with P40 abrasive paper

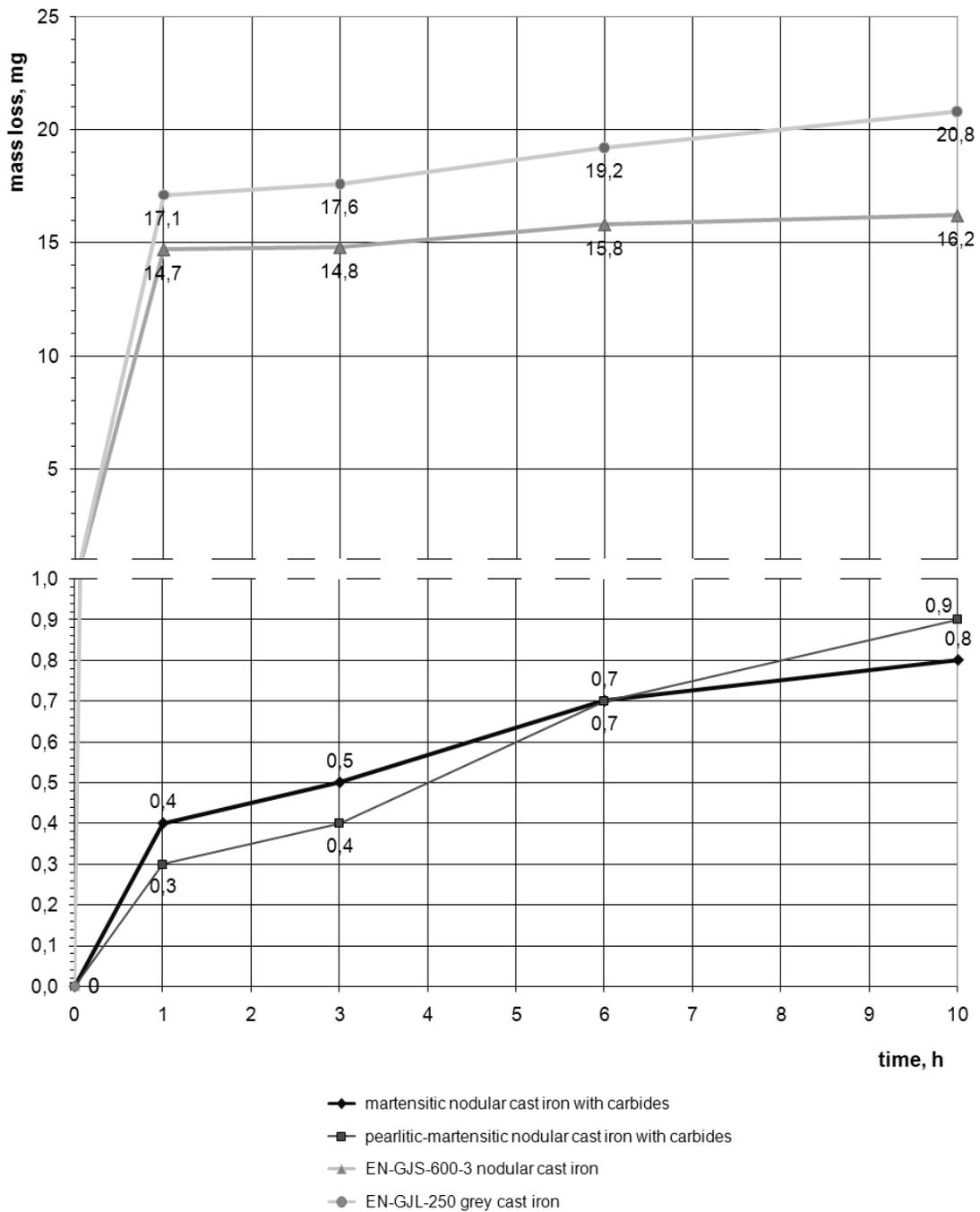


Fig. 6. Adhesive resistance of different grades of cast iron mating with pearlitic-ferritic steel disk

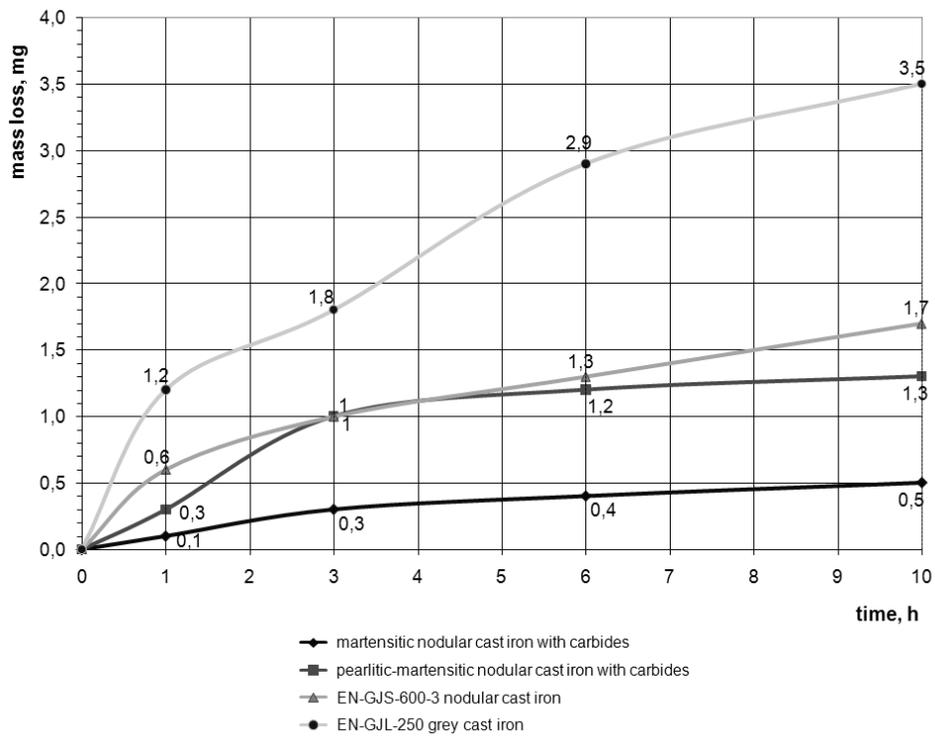


Fig. 7. Adhesive resistance of different grades of cast iron mating with martensitic steel disk

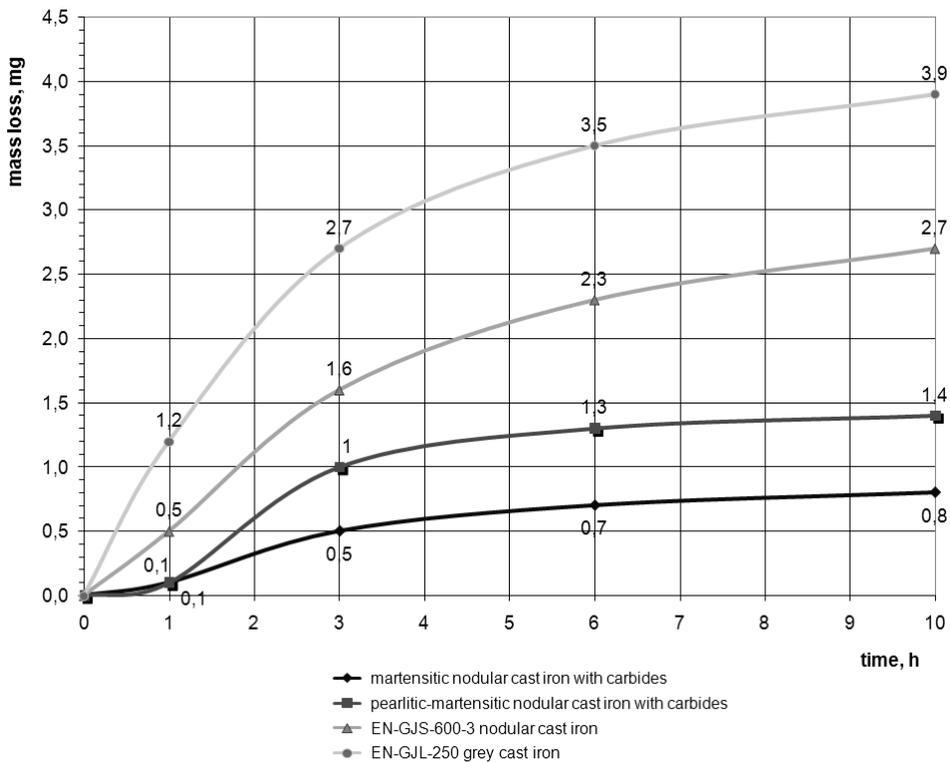


Fig. 8. Adhesive resistance of different grades of cast iron mating with steel disk after hardening and sulfonitriding

In figure 8 the relationship of mass loss of testing cast iron grades mating with hardening and sulfonitriding disk-sample in function of time is presented. Results from it, that among testing cast iron grades the least adhesive wear resistance has grey cast iron. During first period of the test the mass loss is maximum and amounts to 1,2mg after 1h. Afterwards the mass loss progressive decreases and amounts to 3,9mg after 10h. Pearlitic nodular cast iron has higher adhesive wear resistance than grey cast iron and after 1h amounts to 0,5mg and after 10h – 2,7mg. Pearlitic-martensitic nodular cast iron with carbides is more resistant and the mass loss after 1h amounts to 0,1mg and after 10h – 1,4mg. The mass loss was the most intensive during 1 ÷ 3h and amounts to 0,9mg. The most adhesive wear resistance has martensitic nodular cast iron with carbides. After 1h the mass loss was the same like pearlitic-martensitic nodular cast iron, i.e. 0,1mg, and after next 9h – 0,8mg.

From figure 7 and 8 results, that all grades of testing cast iron had higher adhesive wear resistance when they mated with hardened and sulfonitrided disk than with hardened and low-tempered disk.

4. Conclusions

The results have indicated the following:

- mass losses were diversified in function of test time during mating testing cast iron grades with abrasive paper and steel disk-samples,
- first test period to 1h was characterized by the most intensity of abrasive and adhesive wear resistance,

- 6 ÷ 10h mating time is the period of the lowest intensity of abrasive and adhesive wear,
- cast iron – C45 steel is the most advantageous mating materials. The mating of cast iron with this steel was characterized by the lowest mass loss of testing cast iron grades,
- C45 steel after sulfonitriding has the surface layer, decreasing the wear intensity in the first period of the test (lapping, 0 ÷ 1h),
- the most advantageous mating materials in respect of wear are hard materials,
- mating of relatively soft materials or soft material with hard is not advantageous,
- the highest adhesive and abrasive wear resistance has martensitic nodular cast iron with carbides.

References

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