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WEAR OF WORKING ELEMENTS MADE OF HADFIELD CAST STEEL UNDER INDUSTRIAL CONDITIONS

Key words

Hadfield cast steel, crusher hammers, structure of cast steel, wear in service.

Summary

Crusher hammers are tools that operate under changeable service conditions and are susceptible to catastrophic failure. They demonstrate different behaviour, which depends on the delivery and the supplier. Generally, independently of the tool origin, the accelerated degradation of hammer material is observed to follow the wear of the external layer that is characterised by fine, compact structure. Particularly quick degradation of hammer material occurs if casts have internal defects.

Introduction

In technological crushing systems where quarried rock material is reduced to smaller size, the highest loads are applied to the hammers of crushers. Impact and abrasion involved in the crushing process are responsible for short wear life of crushers structural components. Therefore, for both technical and economic aspects of the process, it is important to choose proper hammers materials.

Hadfield cast steel has become popular because of the fact that a relatively unsophisticated manufacturing technology produces a material of particular properties. An important characteristics of Hadfield cast steel is its hardening as a result of strong pressures and impacts [1–3].

The most commonly found chemical composition of the alloy is as follows: 1,1–1,3% C, 12–13% Mn and 0,3–0,5% Si.

The cast steel has a stable austenitic structure above 900°C, below this temperature, under the equilibrium conditions or those close to equilibrium, manganese cementite precipitates from the matrix, whereas below 600°C ferrite is formed. According to the vertical section of Fe-Mn-C system shown in Fig. 1, below approx. 400°C the structure is composed of ferrite and manganese cementite.

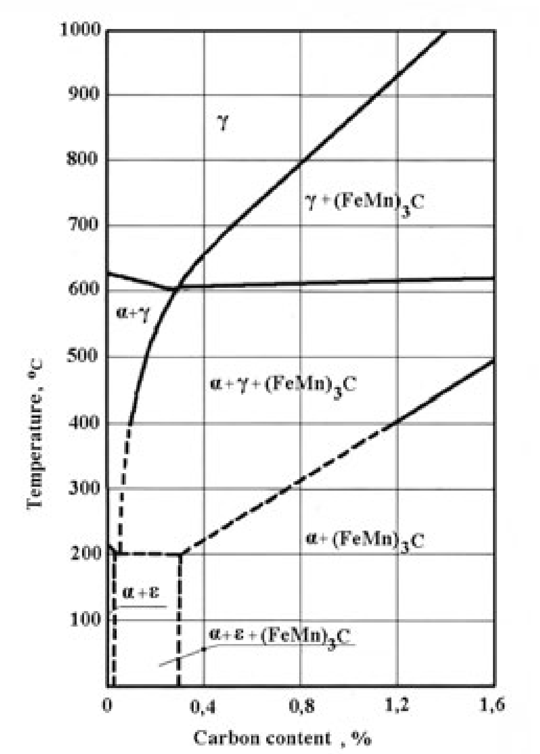

Fig. 1. Vertical section of Fe-Mn-C diagram state for Mn content 13% [4]

Fast cooling in the range of the austenite formation ensures obtaining stable austenitic microstructure at room temperature and lower temperatures [4].

The main advantage of Hadfield cast steel is strong hardening due to cold work. Hadfield cast steel hardness increases over 500 HB as a result of cold work, making it highly resistant to abrasion and, at the same time, difficult to machine.

Without the effect of cold work, cast steel does not demonstrate high abrasion resistance.

1. Methodology of experimental work

Investigations were conducted using hammers made of Hadfield cast steel that were available on the market. The first stage of investigations involved the metallographic examination with Epityp 2 microscope, which aimed at the rough evaluation of grain size distribution in the cross-section of randomly selected hammer.

In the second stage, a batch of hammers was fixed in the crusher. They operated under real service conditions.

After disassembly, the hammers were inspected and examined macroscopically with OLYMPUS SZX 9 stereo microscope.

2. Experimental results

Metallographic investigations were conducted using a few samples collected from randomly selected hammer following the delivery. Microstructure observations were made on microsections surfaces that included both external layers of the material and the zone which was the last to crystallize in liquid metal in the casting process.

The results of investigations are shown in Figs 2-5. They indicate that, as expected, the surface layers of the casts demonstrate compact, fine-grained structure. In zones located farther from the surface, much larger grains and grain boundary precipitation (in interdendritic spaces) that accompanies large grain sizes are found.

The wear of the hammers operating under real service conditions was observed to proceed in two phases. The first phase involves uniform, relatively slow loss of the material. Then after approx. 3-5 mm layer of the material is ground off, a catastrophic degradation occurs. It is particularly clearly seen in the zones corresponding to the geometric parting plane. The effects of wear are shown in the photographs, Figs 5 and 6.

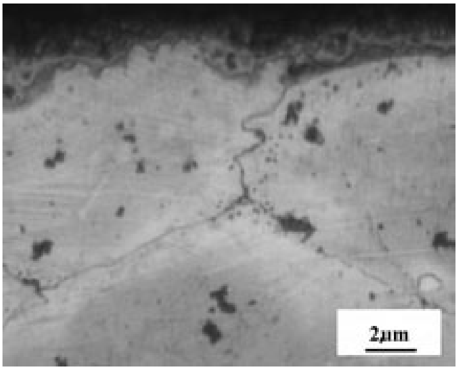

Fig. 2. Microstructure of the hammer material in the cast near-surface layer. Nital

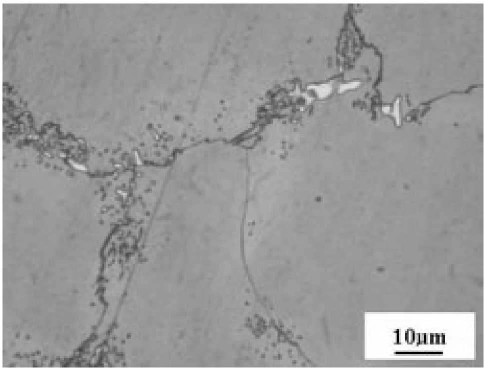

Fig. 3. Microstructure of the hammer material. Distance from the surface approx. 8 mm. Nital

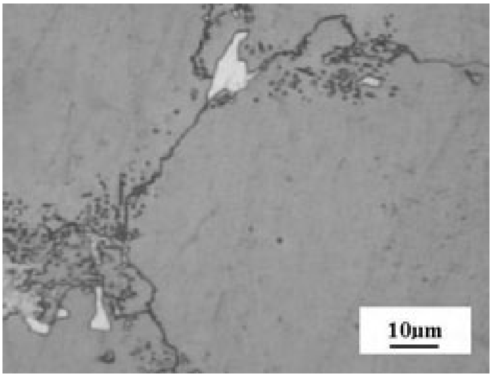

Fig. 4. Microstructure of the hammer material. Distance from the surface approx. 20 mm. Nital

Fig. 5. A view of crusher hammers after service tests (1- at the delivery state, 2-4 after service)

Fig. 6. A view of crusher hammers after service tests (the first hammer on the left – the delivery state, the other - after two months' in service)

Microscope inspection of the hammers confirms that during the first phase, the hammer material is intensely abraded by the mineral load of the crusher, which is shown in Fig. 7. The total wear of the external, i.e. fine-grained, compact layer of the hammer material leads to high material loss mainly due to the spalling of weakly bound grains, which is caused by the mechanical action of the quarried minerals (Fig. 8).

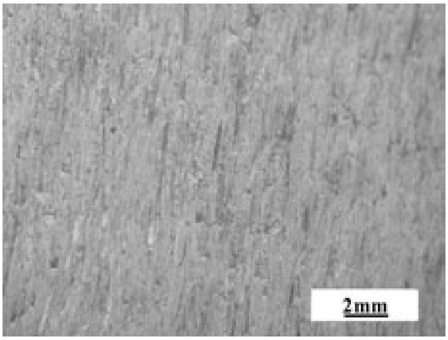

Fig. 7. A view of the crusher hammer surface after a few days' in service

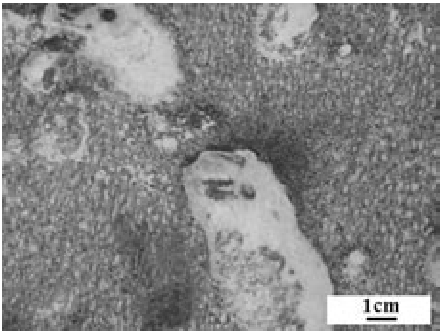

Fig. 8. A view of the crusher hammer surface after two months' in service

3. Discussion of the results

The observations documented with photographs indicate that at the initial stage of the service, the wear caused by the abrasive action is dominant in the hammers (Fig. 7).

During this period the wear rate is relatively low because of the presence of a fine-grained layer formed in casting. (Fig. 2). As the external layer disappears, the wear rate increases until it becomes a catastrophic failure when a layer approx. 3-5 mm in thickness has been abraded.

Apart from the above-mentioned wear, casting defects were observed such as blisters and shrink holes, which additionally shortens hammers life.

The corrosion of the hammer material under pre-set service conditions (the mineral load is mainly composed of limestones) either does not occur or only slightly contributes to the hammers degradation, which might be attributed to passivating action of the environment in austenitic cast steel.

Owing to observations it was possible to draw conclusions on the causes of catastrophic wear of hammers used to reduce mineral material to a smaller size.

Undoubtedly, rapid hammers wear is, to a great extent, related to the quality of the casts. Coarse-grained structure, impurities and casting defects quicken hammer degradation.

Percussive, abrasive and polishing action of the mineral load on hammers together with diversified structure cause their non-uniform wear as the function of service time. Hardened hammers areas have a long life, which can be seen in the photographs. The effect of hardening of centrally located areas decreases over time due to the deepening of furrows. Then the main wear mechanism includes abrasion, polishing and the material spalling. Weak pressures and impacts do not produce the hardening effect in the cast steel and the material wear proceeds as in materials that have poor abrasive wear resistance.

Excessive hammer wear results a lot of problems related to lower efficiency of the mineral material sizing, stoppages and frequent replacements of working elements. That leads to high use-related costs of hammer crushers.

Conclusions

The steps that can be taken to significantly prolong the hammer material life and which do not increase running expenses can be divided into two groups:

- improvements in the quality of the casts,
- attempts at the cast structure modification in the process of hammer production to obtain, among others, fine-grained structure extending over the whole of hammer section.

With other options like:

- modification of the external layer of hammer material, e.g. with thermochemical treatment methods,

- modification of the structure and composition of Hadfield cast steel in such a way so that the structure containing carbides, e.g. Cr-carbides, and Hadfield cast steel austenitic matrix [5] could be obtained,
- replacement of hammer material with a different one, highly resistant to abrasion [6].

It is necessary to make financial outlays on research and implementation investigations.

Options concerning modifications of the external layer and the structure of the steel seem the most interesting ones, as the data available in the literature on the subject suggest that new materials [5, 7, 8] can increase many times the wear resistance in service where impacts, high pressures and abrasion occur either separately or concurrently.

Observations made so far have helped to set the direction of further investigations, which are presently carried out into post-service hammer material. The initial stage of investigations aims at testing the thesis that external zones become strongly hardened by impacts produced by mineral load, which contributes to the formation of a proper service surface layer. In the areas where furrows are formed, the material cannot produce a proper surface layer, i.e. conditions necessary for hardening do not occur or the hardening is not sufficient to resist the wear caused by abrasion with shattered mineral load. In the author's opinion, investigation results can contribute to obtaining hammers that are improved as regards their structure, material and thus performing better in service.

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Reviewer:
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Zużycie elementów ze staliwa Hadfielda pracujących w warunkach przemysłowych

Słowa kluczowe

Staliwo Hadfielda, młotki kruszarek, struktura, zużycie eksploatacyjne.

Streszczenie

Młotki kruszarek jako elementy pracujące w zmiennych warunkach eksploatacyjnych narażone są na zużycie. Zachowują się one rozmaicie, zależnie od dostawy i dostawcy młotków, ale generalnie zaobserwowano, że niezależnie od źródła pochodzenia, przyśpieszona degradacja materiału młotków następuje po zużyciu zewnętrznej warstwy, która charakteryzuje się drobną i zwartą strukturą. Szczególnie szybka degradacja materiału młotków następuje, jeżeli odlewy mają wady wewnętrzne.