WEAR OF HADFIELD CAST STEEL MACHINE PARTS DUE TO IMPACT AND ABRASION IN SERVICE ENVIRONMENT

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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.

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 (L.2–4).

The most commonly found chemically 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 equilibrium shown in Fig. 1, below approx. 400°C the structure is composed of ferrite and manganese cementite.

Fast cooling of the range of the austenite formation ensures obtaining stable austenitic structure at room temperature and lower temperatures (L.1).
The main advantage of Hadfield cast steel is strong hardening due to cold work. Hadfield cast steel hardness increases to over 500HB 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.

![Fig. 1. Vertical section of Fe-Mn-C system equilibrium state for Mn content 13% (L.1)](image)

**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 material metallographic examination with Epityp 2 microscope, which aimed at the rough evaluation of grain size distribution in the hammer cross-section at the time of delivery.

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. Results of observations are presented below.
**Experimental results and discussion.** Metallographic investigations were conducted using a few samples collected from randomly selected Hadfield cast steel hammers 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 the photographs (Fig. 2–5). They indicate that surface layers of the casts demonstrate compact, fine-grained structure. In zones located farther from the surface, larger grains, grain boundary impurities that accompany large grain sizes, and also porosities are found, (Fig. 3–4).

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. 3–5mm layer of the material is ground off, an accelerated degradation occurs, which is often catastrophic in character. It is particularly clearly seen in the zones located close to the geometric parting plane (Fig. 5, hammers no. 2 and 4, also Fig. 6, the hammer on the right). The effects of wear are shown in the photographs, Fig. 5 and 6.

The first hammer on the left – the delivery state, the other hammer - after two months’ service. A considerable material loss in the hammer central part can be seen.

Stereo microscope inspection of the hammers indicates that during the first phase, the hammer material is intensely abraded and polished. The effect of wear is shown in the photograph, Fig. 7.

The second phase involves an intensive material loss, mainly due to casting defects that reveal themselves. Spalling of grains of Hadfield cast steel material probably occurs in the same phase as a result of mutual action of hammer material and mineral material being crushed, Fig. 8.

![Fig. 2. Microstructure of the hammer material in the cast surface-adjacent layer Nital](image-url)
Fig. 3. Microstructure of the hammer material. Distance from the cast surface approx. 8 mm Nital

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

Fig. 5. View of Hadfield cast steel crusher hammers after service tests. 1— at the initial state – first on the right (delivery state), 2–4 following service

Fig. 6. View of crusher hammers after service tests. The first hammer on the left – the delivery state, the other hammer - after two months’ service. A considerable material loss in the hammer central part can be seen

Fig. 7. The view of the crusher hammer surface after a few days’ service

Fig. 8. The view of the crusher hammer surface after two months’ service
**Summing up and conclusions.** The observations indicate that at the initial stage of the service, the wear caused by the abrasive action is dominant in hammer crashers (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 porosities, which additionally shorten 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 on Hadfield cast steel.

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

Undoubtedly, 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 together with diversified hammer structure cause their non-uniform wear as the function of service time. Impact hardened 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.

Hammer wear results in many problems related to lower efficiency of the mineral material sizing, stoppages and necessary replacements of working elements. That leads to high use-related costs of hammer crushers.

The steps that can be taken to significantly prolong the hammer material life and for which no additional outlays will be necessary can be divided into two groups:

1) improvement in the quality of the casts;
2) attempts at the cast structure modification in the process of hammer production.
With other options [5; 6; 7] like:
3) modification of the external layer of hammer material, e.g. with thermochemical treatment methods;
4) modification of the structure and composition of Hadfield cast steel in such a way so that austenitic matrix with the properties of Hadfield cast steel could be obtained;
5) replacement of hammer material with a different one, highly resistant to abrasion it is necessary to make financial outlays on research and implementation investigations.

Observations made so far have helped to set the direction of further investigations, which are presently carried out into post-service hammer material.

**Literature**