DEFECTS EVALUATION ON HADFIELD STEEL SHEETS

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Abstract

The key characteristic of austenitic Hadfield´s steel is its toughening (hardening) under mechanical loading (during operation). By the influence of mechanical loading austenite transformed to martensite, resulting in surface hardening (curing) with a good toughness. High abrasion resistance is the result.

Due to very difficult machinability and weldability are the final products made generally of either as casting or as simple parts made of rolled sheets.

This paper describes the most common faults on rolled sheets and their influence on abrasion resistance. As base for samples selection sheets of normal production were chosen on which were identified following defects: decarburized layer on surface, carbides on the grain boundaries, and martensitic structure in delivered condition before any mechanical loading. For the comparison of abrasive resistance was used test in shot blasting machine. Weight difference was evaluated on each sample.

Achieved results confirmed that the samples which were grinded of (surface defects removing) have about 25 to 40 % less weight loss than the samples which were left in common delivery conditions.

Keywords: Hadfield steel, X120Mn12, carbides, decarburized layer, wear resistance

1. INTRODUCTION

Mangalloy, also called manganese steel or Hadfield steel, after its discoverer Sir Robert Abott Hadfield, is a steel alloy containing an average of around 13% manganese. This steel is known for its high impact strength and resistance to abrasion once in its work-hardened state. Hadfield steel contains 0.8 to 1.25 % carbon, with 11 to 15 % manganese, roughly in ratio 1:10. Hadfield`s steel was unique in that it combined high toughness and ductility with high work-hardening capacity and, usually, good resistance to wear [1].

Usually, a fully austenitic structure, essentially free of carbides and reasonably homogeneous with respect to carbon and manganese, is desired in the as-quenched condition. If carbides exist in the as-quenched structure, it is desirable for them to be present as relatively innocuous particles or nodules within the austenite grains rather than as continuous envelopes at grain boundaries.

Table 1 The chemical composition of the steel according to DIN X120Mn12 (1.3410)

Element	C	Si	Mn	Cr	P	S
Range [%]	1.1-1.3	0.3-0.5	12-13	max. 1.5	max. 0.1	max. 0.04

The most frequent applications are in Mines, Coal mines, Cement plants, Iron industry, Foundry, Automotive industries, etc. The further additional information about a wide variety of engineering applications and Hadfield steel modifications can be find in following references [1-6]. Chemical composition shows **Table 1.**

2. EXPERIMENTAL PROCEDURES

2.1. Samples

Due to its specific characteristics is not Hadfield´s steel suitable for machining.

The most frequent processing method is therefore desired shape burning by plasma or laser (simple shapes with holes) of the plate, followed by bending and welding.

Production practice shows high variance of the quality of the available raw material (rolled sheets). The aim of this paper is to describe the most common deviations and defects on the Hadfield steel rolled sheets and their effect on the further usage as well as on the achieved characteristics of the final products. There were selected several samples from the common available steel sheets in as-quenched condition, thickness 6 - 12mm, for the further metallographic comparison.

Defects found on samples:

- Decarburized layer on the surface
- Carbides on the grain bondaries
- Martensitic structure in delivery condition
- Inclusions, segregation strip, microcracks

Listed defects have significant affection on the further production processing (e.g. cracks after bending) and also on the desired properties of the finished product (e.g. reduced durability - abrasion resistance).

2.2. Testing methods

2.2.1. Chemistry and decarburized layer

The samples were evaluated using GDOES chemical composition analysis. This analysis was performed on the surface of individual samples and other depths below the surface because of the detection of possible differences in the chemical composition and the depth of decarburization.

2.2.2. Metallography

Metallographic samples were prepared using automatic polisher. Photographic documentation was taken by light microscope CARL ZEISS Z1M using software Axiovision. Due to high reaction activity on the surface of samples, caused by oxidization and decarburization, cannot be used for etching commonly used Nital. Finally, to the visibility of the structure material was used a chemical compound having the following chemical composition: 50 ml CH_4, 50 ml HCl, 1 ml H_2SO_2.

2.2.3. Abrasion resistance test

There is no standardized test of abrasion resistance, although this is key characteristic for Hadfield´s steel. Different applications mean various types of abrasion stress, from the blasting to shear (wear) stress at various temperatures. We chose a test in a shot blasting machine. Even through that time for testing on shot blasting machine was provided by private company Disa / Wheelabrator Switzerland, just due to time and financial demands test cycle has to be limited to 20 h. Test samples (30 x 30 mm) were inserted into the fixture, which has been placed in the cabin of blasting machine. The fixture was rotated clockwise regularly. As the blasting medium chopped wire of 640HV 0.8 mm was used. The samples were wear surface to a depth of 0.8 - 1 mm. The weight loss of individual samples was evaluated.

3. RESULTS AND DISCUSION

3.1. Depth of decarburization

Summarized results of decarburized layer of each studied sample are seen in **Figure 1.**

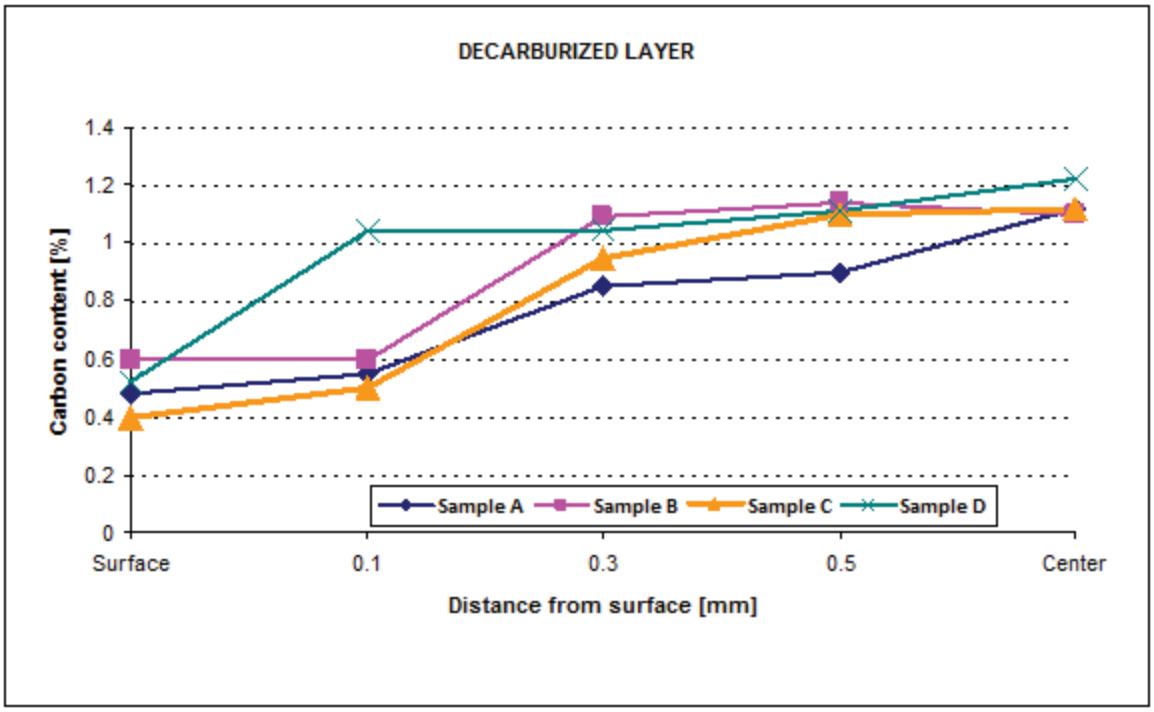

Figure 1 Decarburized layer

3.2. Metallography

Metallographic results of all investigated samples are summarized in **Figures 2 - 9.**

Sample A

Metallographic analysis showed the presence of carbides along austenite grain boundaries, decarburization surface, oxidic diaper and inclusions size up to 360 μm.

Figure 2 Sample A - 300 μm under surface, carbides on the grain boundaries

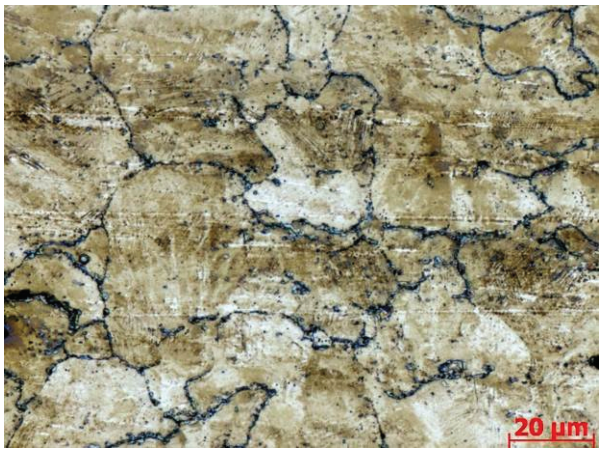

Figure 3 Sample A (in central area), carbides on the grain boundaries

Sample B

Numerous inclusions throughout the sample thickness, size up to 90 μm (longitudinal section), globular inclusions in strips line length up to 220 μm, carbides on the grain boundaries, changes on the surface during etching (up to 180 /220 mm) - decarburization.

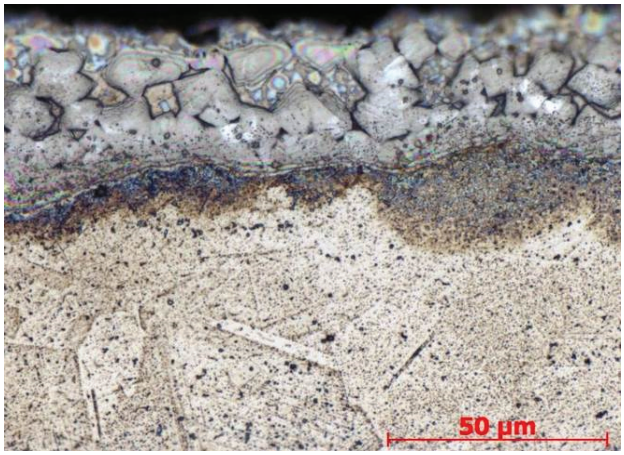

Figure 4 Sample B - surface, decarburization

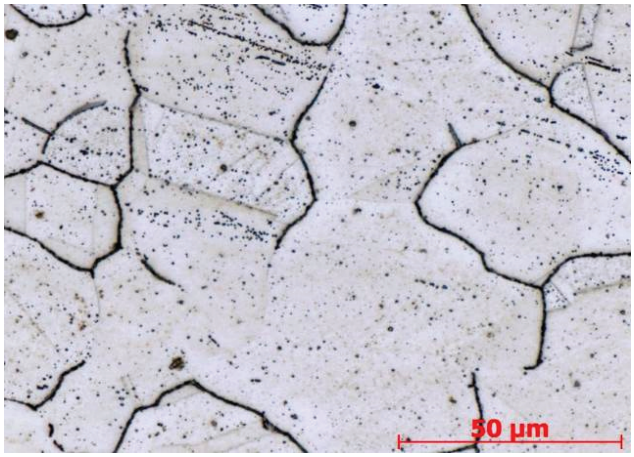

Figure 5 Sample B - central area, carbides on grain boundaries

Sample C

On the surface were analyzed martensitic structure - indicated loss of carbon. As confirmed by the chemical composition determined at various depths, we have indeed revealed loss of carbon. Neither carbides nor inclusions were observed.

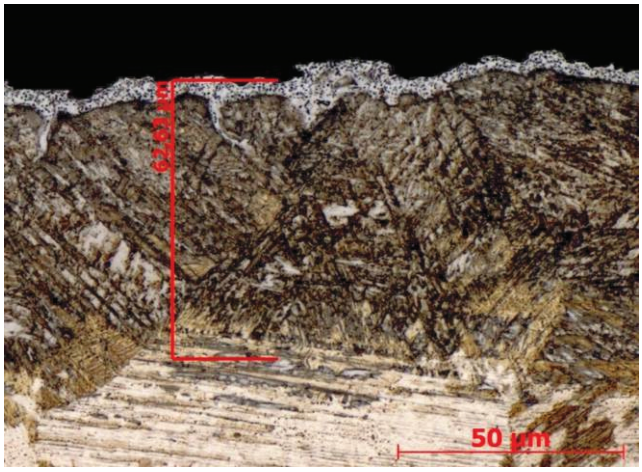

Figure 6 Sample C - surface, martensitic needles

Figure 7 Sample C - central area

Sample D

Martensitic structure on the surface, but surface decarburization was not observed. There were identified carbides along the grain boundaries (continuous envelopes).

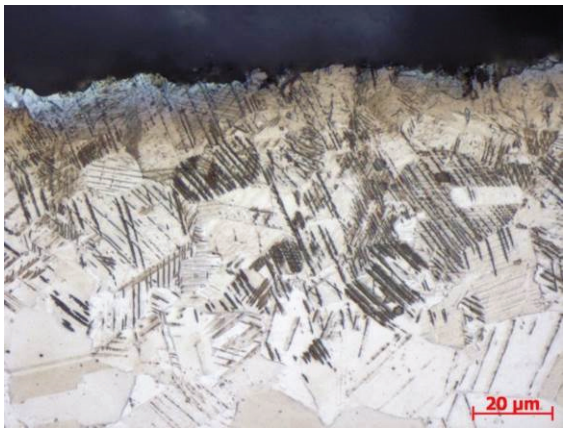

Figure 8 Sample D - surface, martensitic structure

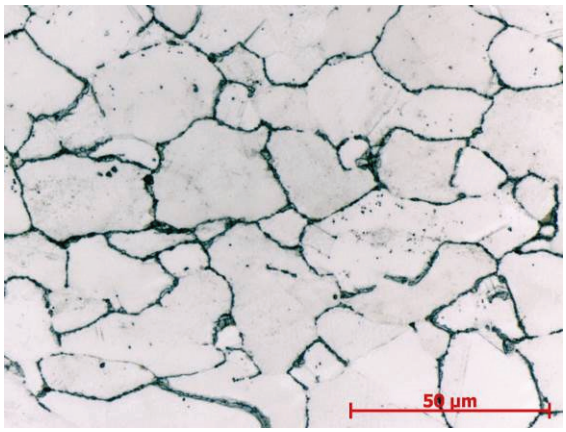

Figure 9 Sample D - central area, carbides on the grain boundaries

3.3. Abrasion resistance test (wear test)

Results of abrasion resistance test expressed in form of weight loss **Figure 10** demonstrates.

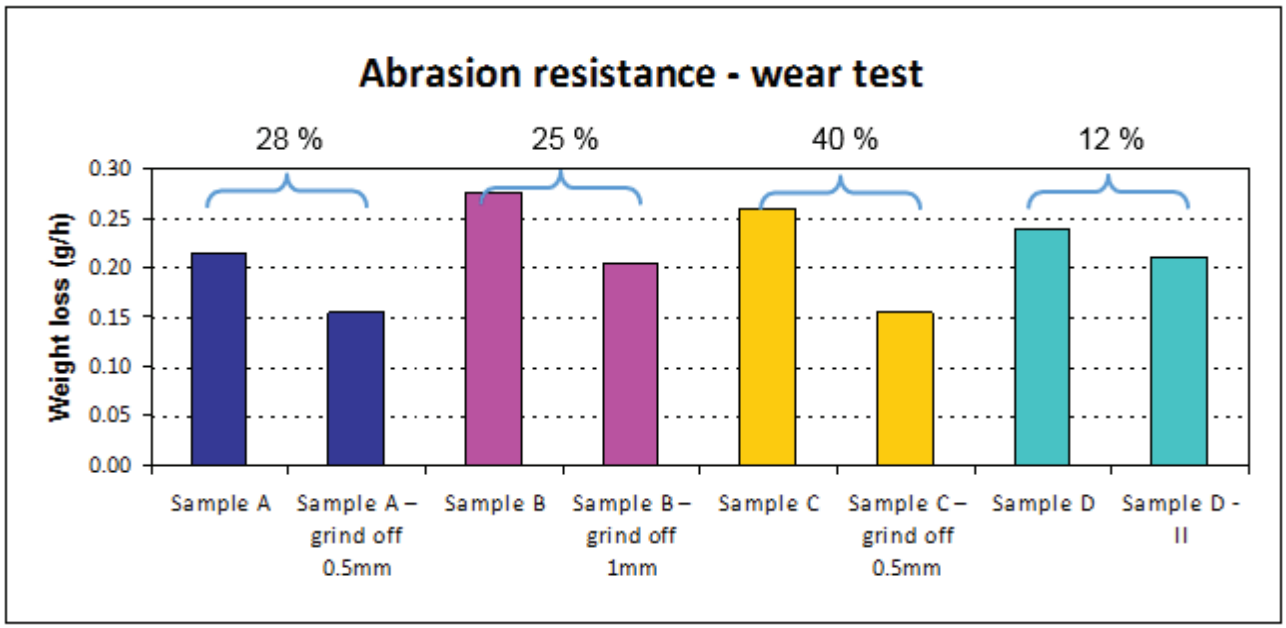

Figure 10 Abrasion resistance test - weight loss (g / h)

4. CONCLUSION

Pure austenitic structure was not observed on any sample. Each of the samples showed defects both on the surface and in the middle of the thickness of the sample. Most commonly it were carbides on the grain

boundaries (on three samples), inclusions, and especially decarburized layer (the most decarburization was on sample A, where it was only 0.9 % C even at a depth of 0.5 mm below the surface). The test of abrasion resistance showed a significant effect of the individual defects - mainly decarburization surface - on the wear rate (measured weight loss in g / h). On the each sample was the surface layer worse than the center of the sheet thickness, so the samples A, B, C, were grinded of the surface layer, which contained most of defects to a depth of 0.5 to 1 mm. Sample D was grinded of in order to ascertain recoverability (repeatability) of this wear test. The difference between sample D and D-II was 12 %, therefore it is necessary to take into consideration the 10% as a possible measurement error. Still wear test confirmed the higher abrasion resistance for samples, where the surface layers were grinded of. When comparing the same sample, once with the surface in the delivery condition as-quenched and secondly with grinded of surface layer, then grinded sample has always better performance, this difference was always at least 25 %, in the martensitic structure it was even 40 %. This test was relatively short (20h) and in particular shows the influence of the surface layer (1 mm), for the evaluation of durability would require longer test.

ACKNOWLEDGEMENTS

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