FRAGMENT OF THE SUPPORT STRUCTURE OF AN ENGINE VHS-404 - GREY CAST IRON - MODERN TIMES

Artefact name Fragment of the support structure of an engine VHS-404

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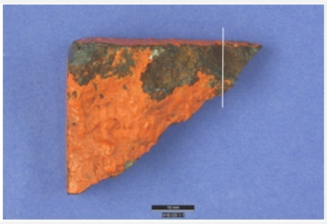
Url /artefacts/330/

The object



Credit HE-Arc CR.

Fig. 1: left: Flush-deck side-wheel paddle steamer, The SS Rigi. Right: grey cast iron section from the supporting structure of the engine (after www.verkehrshaus.ch, consulted on December 5, 2011),

Description and visual observation

Description of the artefact	Fragment of the support structure of the engine from the SS Rigi (oldest surviving flush-deck side-wheel paddle steamer in the world, Fig. 1), painted (Fig. 2).
Type of artefact	Supporting structure
Origin	Flush-desk side-wheel paddle steamer SS Rigi
Recovering date	Removed in 1952 during the last renovation
Chronology category	Modern Times
chronology tpq	1860 A.D.
chronology taq	1896 A.D.
Chronology comment	1860 _ 1896
Burial conditions / environment	Outdoor to indoor atmosphere
Artefact location	Swiss Museum of Transport, Luzern, Lucerne
Owner	Swiss Museum of Transport, Luzern, Lucerne
Inv. number	VHS-404
Recorded conservation data	Renovated in 1860 and 1880. The engine was replaced in 1894 and in 1952.

Complementary information

Nothing to report.

Study area(s)

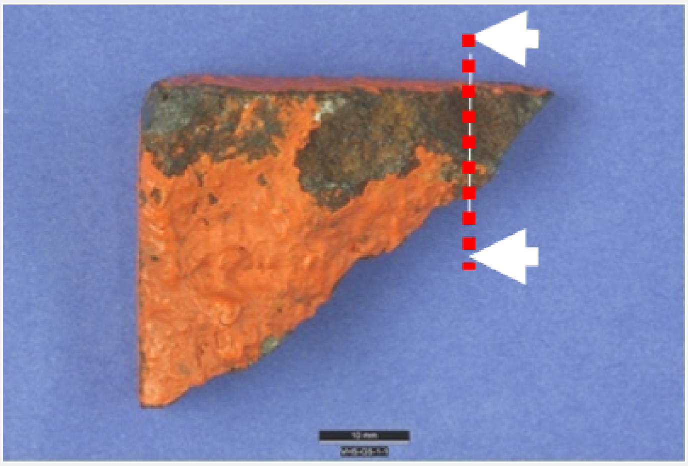


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Fig. 2: Location of sampling area,

Binocular observation and representation of the corrosion structure

Stratigraphic representation: none.

MiCorr stratigraphy(ies) – Bi

Sample(s)

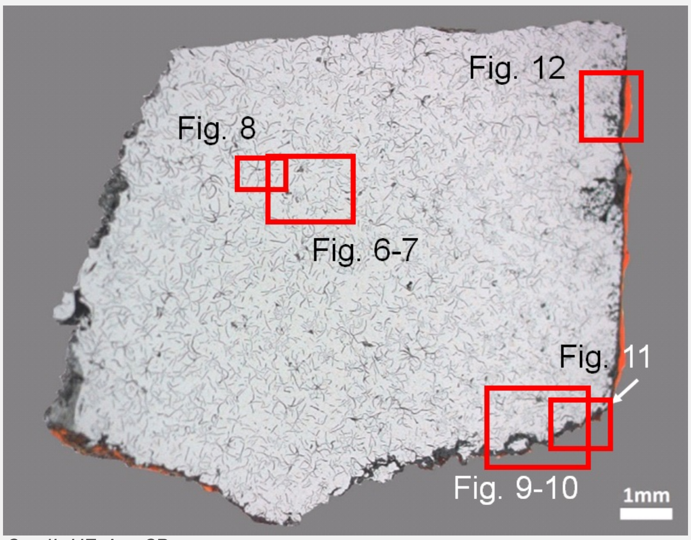

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Fig. 3: Micrograph of the cross-section showing the location of Figs. 5 to 12,

Description of sample	The sample is a cross-section through the fragment of the machine support (Fig, 3). Dimensions: Lmax = 10mm; Wmax = 10mm.
Alloy	Grey cast iron
Technology	As-cast
Lab number of sample	VHS-G-1
Sample location	Empa (Marianne Senn)
Responsible institution	Swiss Museum of Transport, Luzern, Lucerne
Date and aim of sampling	07/09/2009 metallography

Complementary information

Nothing to report.

Analyses and results

Analyses performed:
Metallography (nital etched), Vickers hardness testing, LA-ICP-MS, SEM/EDS.

Non invasive analysis

Metal

The remaining metal is a high P and Si grey cast iron with elevated Mn and V contents (Tables 1 and 2). The structure contains black graphite flakes and graphite nodules (Fig. 5) as well as angular grey manganese sulphide inclusions which can contain a dark alumina-rich centre (Fig. 5 and Table 1). The graphite flakes are irregular and vary in size. At low magnification the flakes are evenly spread over the entire surface with a tendency to form clusters. Some porosity is noticeable. Under SEM, in the BSD-mode, an additional eutectic phase is visible (Fig. 6). After etching one can see how the graphite is surrounded by alpha-iron in a pearlite matrix (Figs. 7 and 8). The lamellar pearlite includes steadite (Fe_3P) and manganese sulphide (MnS) inclusions. According to the cast iron diagram after Maurer (Bargel and Schulze 2008, 257), the structure is typical for a hypoeutectic pearlitic grey cast iron (C content <4.3 mass%, Si content ca. 2.0 mass%) including pearlite, steadite and graphite. The slow cooling rate and the higher Si level have favoured the formation of graphite. The high P content favours the growth of interconnected networks of steadite. The average hardness of the metal is HV1 160. This hardness is only approximate. Normally cast iron hardness is determined with a Brinell test, but due to the small size of the sample this could not be carried out. The calculated HB is about 150.

Elements	Ni/Co	Al	P	Ti	V	Cr	Mn	Co	Ni	Cu	As	Mo	Ag	Sn	Sb	W	C* mass%
Median mg/kg	2.9	<	20000	1200	2000	700	4500	160	460	110	610	20	<	10	20	<	<4.3
Detection limit mg/kg	-	4	73	8	1	11	2	1	3	1	2	3	1	0.4	1	2	-
RSD %	2	-	47	26	38	19	18	3	2	10	14	30	-	17	13	-	-

*visually estimated

Table 1: Chemical composition of the metal. Method of analysis: LA-ICP-MS, Lab Inorganic Chemistry, ETH.

Elements	O	Al	Si	P	S	Ti	Mn	Fe	Total

MnS inclusions (centre)	23	21	20	<	<	5.7	30	2.3	102
MnS (global)	<	<	<	<	35	<	60	2.0	98
Metal (average of 5 similar analyses)	<	<	2.0	2.4	<	<	0.8	95	101
Steadite (Fe_3P) (average of 3 similar analyses)	<	<	<	16	<	<	1.1	88	105

Table 2: Chemical composition (mass %) of the metal. Method of analysis: SEM/EDS, Laboratory of Analytical Chemistry, Empa.

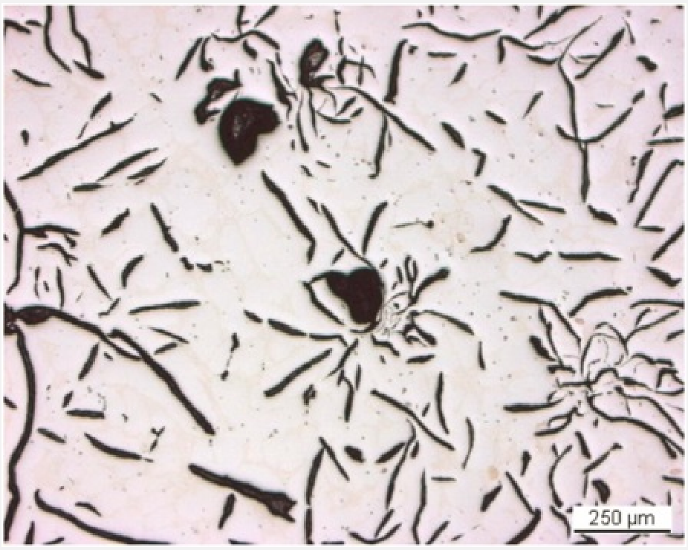

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Fig. 5: Micrograph of the metal sample from Fig. 3 (inverted picture, detail), unetched, bright field. We observe graphite flakes and irregular nodules in black and the metal in white. The small grey spots are manganese sulphide inclusions,

Credit HE-Arc CR.

Fig. 6: SEM image from Fig. 3 (detail), BSE-mode, unetched. We observe the graphite flakes in black, the manganese sulphide inclusions in grey and the eutectic mixture in light-grey,

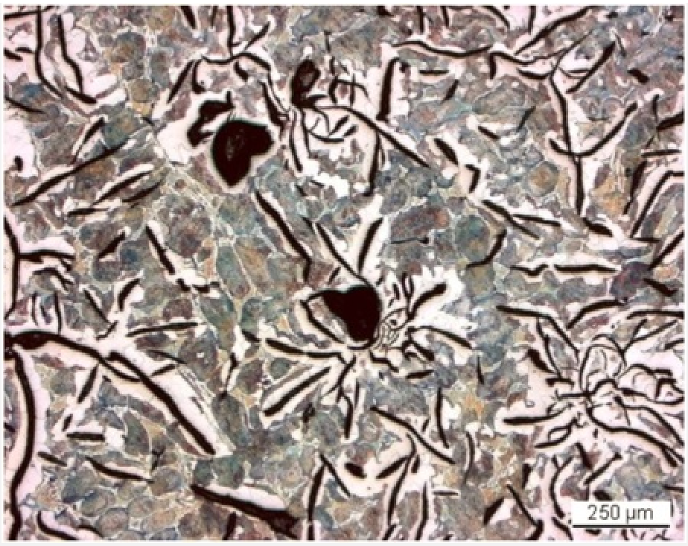

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Fig. 7: Micrograph (same as Fig. 5), etched, bright field. In between the black graphite flakes we observe alpha-iron in white and pearlite / steadite in grey,

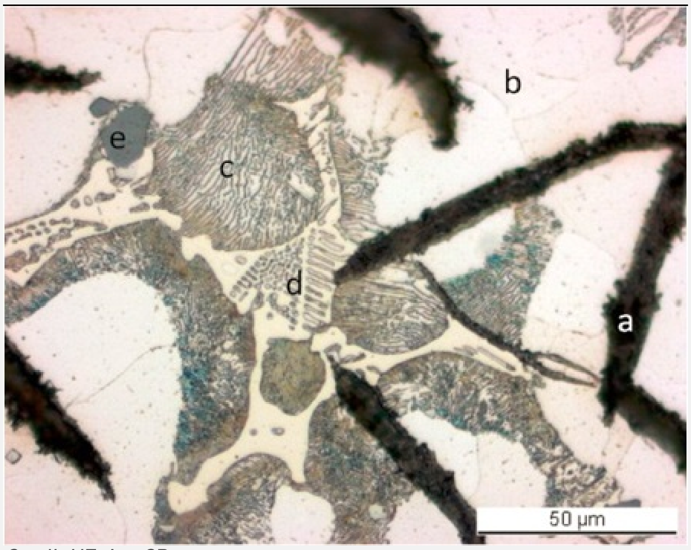

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Fig. 8: Micrograph of the metal sample from Fig. 3 (detail), etched, bright field. The structure is composed of graphite (a), ferrite (b), pearlite (c), steadite (d) and MnS inclusions (e),

Microstructure	Graphite lamellars + pearlite + ferrite + steadite (Fe3P)
First metal element	Fe
Other metal elements	C, Si, P, Mn

Complementary information

Nothing to report.

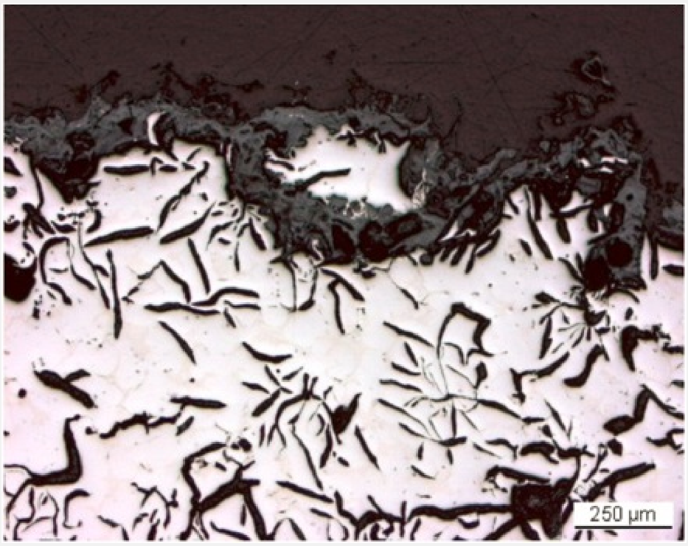
Corrosion layers

The thin corrosion crust (CP1) is limited to three sides of the sample and some remains of a paint coating (orange) are visible (Fig. 3). In bright field, the corrosion crust appears light-grey (Fig. 9), under polarised light-orange (Fig. 10). It is mainly composed of iron oxides (Table 3 and Fig. 11). The Pb and Ba-rich paint system has been applied directly onto the oxidized Fe, Si and Mn-rich casting skin (Fig. 11). The paint layer is probably an anodic inhibitor made from minium (red lead) with a barium sulphate filler. Because of the interference of Pb with S in the EDS spectra S is difficult to detect.

Elements	O	Mg	Si	P	S	Mn	Fe	Ba	Pb	Total
Inner light-grey corrosion layer (Fig. 12)	20	<	<	<	<	1.3	76	<	<	98

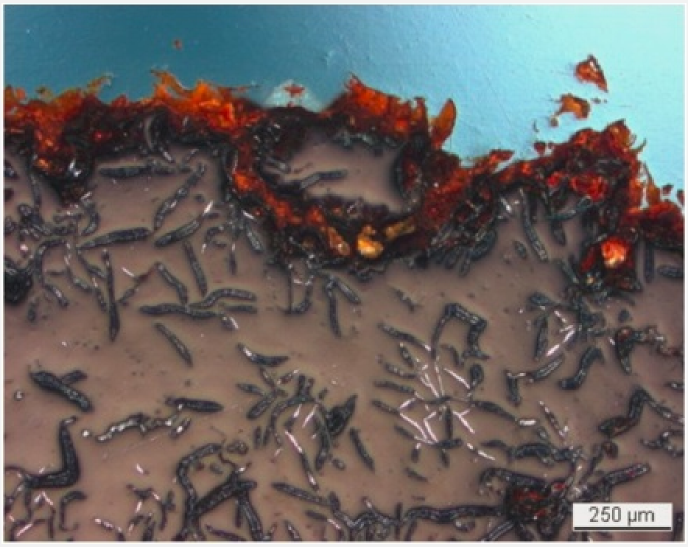
Dark-grey casting skin (Fig. 12)	27	<	14	<	<	21	33	<	<	95
Paint system (Fig. 12)	20	<	<	<	<	<	<	18	55	93
Grey corrosion layer (Fig. 11)	35	<	1.1	<	0.6	<	59	<	<	97

Table 3: Chemical composition (mass %) of the corrosion layer (from Figs. 11 and 12). Method of analysis: SEM/EDS, Laboratory of Analytical Chemistry, Empa.



Credit HE-Arc CR.

Fig. 9: Micrograph showing the metal - corrosion layer interface from Fig. 3 (inverted picture, detail), unetched, bright field. We observe in white the metal, in light-grey the corrosion layer, in black the graphite flakes,



Credit HE-Arc CR.

Fig. 10: Micrograph (same as Fig. 9) corresponding to the stratigraphy of Fig. 4, unetched, polarised light. We observe in violet the metal, in orange the corrosion, in blue the resin,

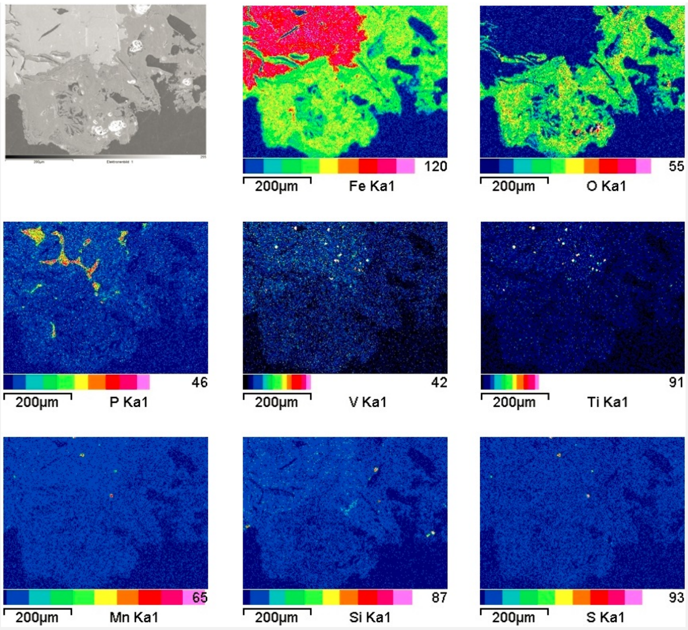


Fig. 11: SEM image, SE-mode, and elemental chemical distribution of the selected area from Fig. 3 (detail). Method of examination: SEM/EDS, Laboratory of Analytical Chemistry, Empa,

Credit Empa.

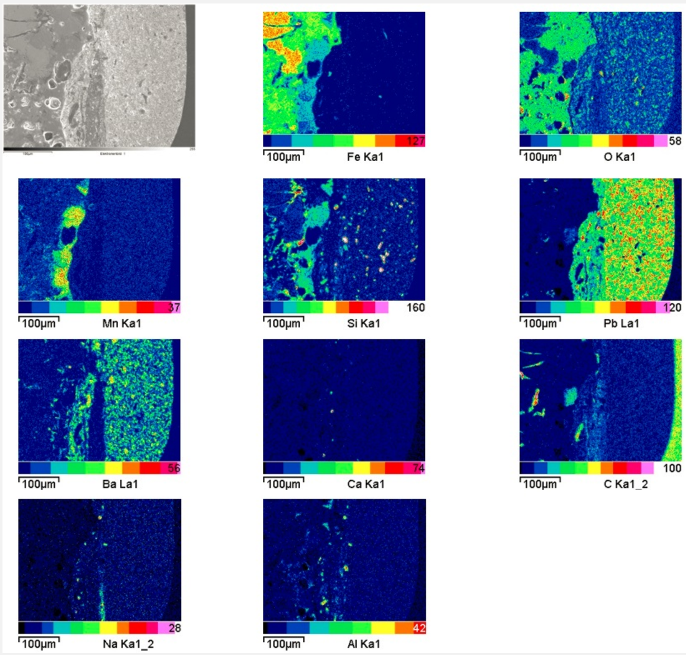


Fig. 12: SEM image, SE-mode, and elemental chemical distribution of the selected area from Fig. 3 (detail). Method of examination: SEM/EDS, Laboratory of Analytical Chemistry, Empa,

Credit Empa.

Corrosion form Uniform - transgranular

Corrosion type ?

Complementary information

Nothing to report.

MiCorr stratigraphy(ies) – CS

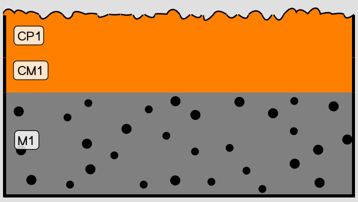


Fig. 4: Stratigraphic representation of the object in cross-section using the MiCorr application. This representation can be compared to Fig. 10.

Synthesis of the binocular / cross-section examination of the corrosion structure

Corrected stratigraphic representation: none.

Conclusion

The metal is a hypoeutectic pearlitic grey cast iron with significant amounts of Si and P. A P-content in excess of 0.4 mass % causes a decrease in the tensile and impact strength. P is concentrated in the hard, brittle steadite phase. Supporting elements for machines are often manufactured from such metal because it can absorb a high degree of vibration. The metal is still covered by the casting skin which was left as a natural protection against corrosion. An applied Pb-based anodic paint system formed a further protection layer. The corrosion is minimal.

References

References on object and sample

References sample

1. Auskunftsblatt der Sammlung des Verkehrshauses der Schweiz Luzern (Wasserverkehr) zu VHS-404.

References sample

2. Senn, M. Prüfbericht 205'340-2, 2011.

References on analytic methods and interpretation

3. Bargel, H-J., Schulze, G. (ed.) (2008) Werkstoffkunde, Springer, 249-270.