

## **DETERMINATION OF THE CONTENT AND COMPOSITION OF INCLUSIONS IN GUN BARREL STEEL**

Report No.: M410

Date: 06/03/2023

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Order date: 05/12/2022

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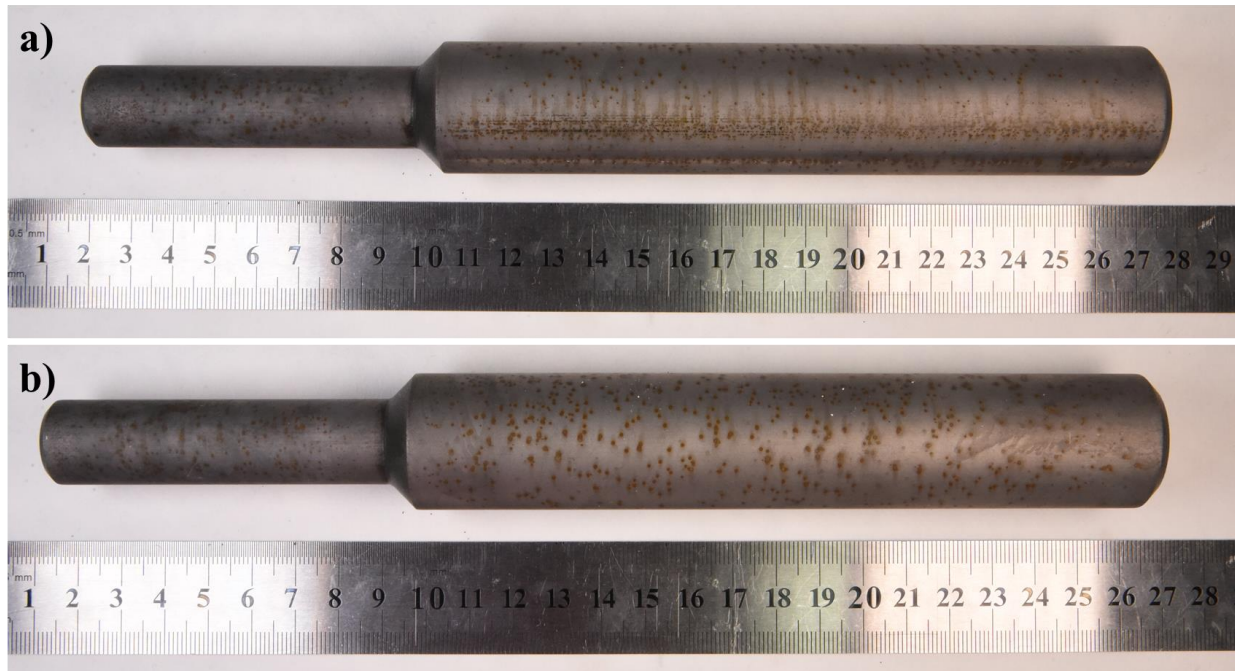
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## 1. Introduction

A piece of gun barrel steel from IMPAX material (Figure 1) was delivered by the customer. Spots of red rust formed during pickling in dilute sulphuric acid were unevenly distributed over the surface. The aim of the work was to determine the morphology and origin of the spots.



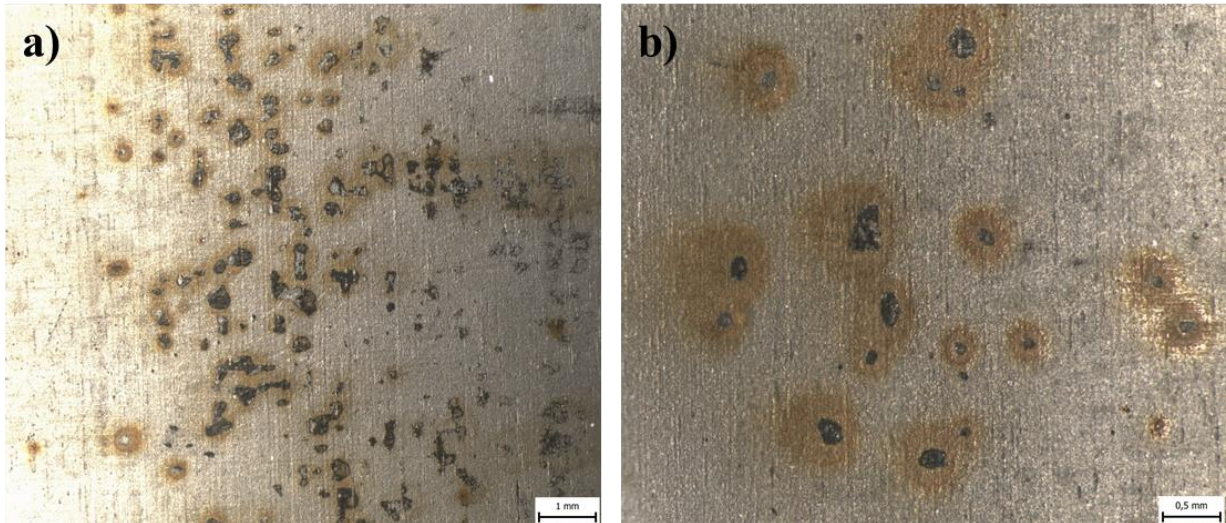
**Figure 1.** Delivered rod of gun barrel steel

## 2. Experimental

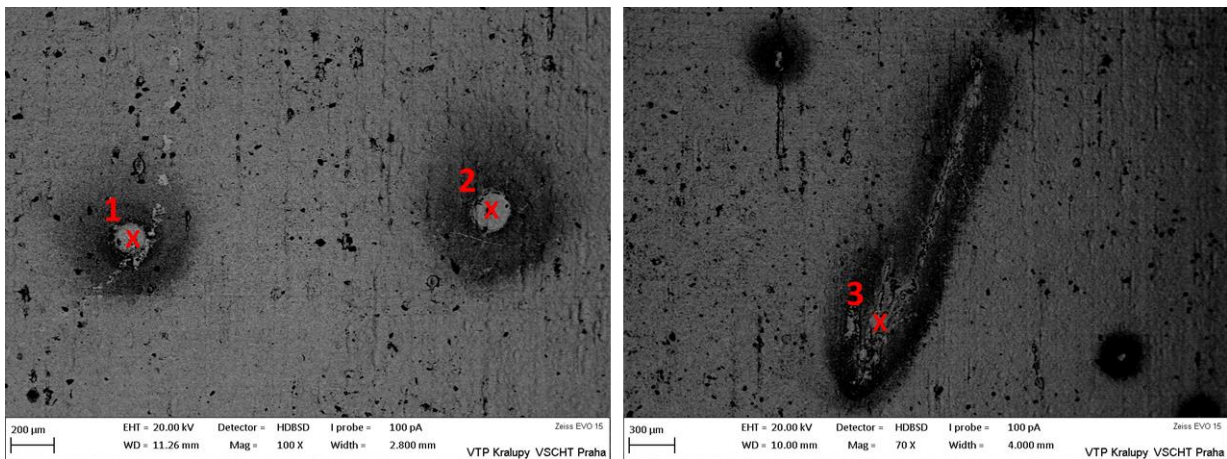
To assess the surface defects, samples were cut for observation on a stereomicroscope Olympus SZX. Metallographic cross-cuts were prepared to determine the distribution, size and composition of the inclusions. Samples were ground down to grit P2500 SiC paper and polished using D2 diamond paste. Then, an analysis of the defects using scanning electron microscope (SEM) ZEISS EVO 15 with energy dispersive spectroscopy (EDS) detector was performed. Size of the defects was determined by ImageJ software.

## 3. Results

First, an analysis of the pickled surface was carried out. It was found out that the defects were corrosion pits, see Figure 2. Surrounding of the pits was discoloured with corrosion products. The pits were present over the entire surface with uneven distribution. The diameter of the pits was determined to vary over a wide range from 80 to 450  $\mu\text{m}$  with an average value  $230 \pm 91 \mu\text{m}$ . The pits were also analysed using SEM-EDS analysis (Figure 3). Results of chemical composition in wt. % are showed in Table 1. The high content for C, Mn and Cr suggests that there were mixed carbides of Fe, Cr and Mn present there.



**Figure 2.** Pits on surface of the delivered steel rod



**Figure 3.** SEM-EDS analysis of corrosion pits on surface

**Table 1.** Chemical composition in wt. % of pits determined by EDS analysis

| Spot | Fe   | C    | O   | Si  | Mo  | Cr  | Mn  | Ni  | Cu  |
|------|------|------|-----|-----|-----|-----|-----|-----|-----|
| 1    | 74.4 | 10.3 | 3.4 | 0.9 | 0.7 | 6.6 | 2.6 | 0.8 | 0.3 |
| 2    | 89.4 | 3.9  | -   | 0.7 | -   | 3.4 | 1.6 | 1.0 | -   |
| 3    | 83.6 | 5.5  | 2.6 | 0.8 | 0.8 | 4.1 | 1.8 | 0.8 | -   |

Subsequently, metallographic cross-section analysis was performed. A high number of inclusions was present in the material. Examples are shown in Figure 4. It can be observed that the inclusions have different size and morphology. The average size of the inclusions is in the order of units of  $\mu\text{m}$ . The chemical composition of the inclusions was analysed. In addition to carbides mentioned above, aluminium oxide particles (Figure 5) were also identified.

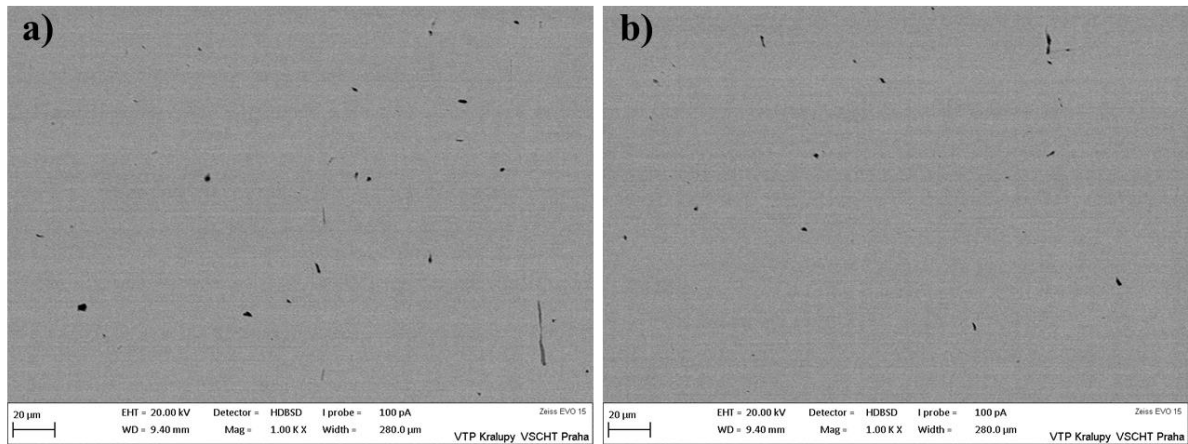


Figure 4. Distribution of inclusions present in sample

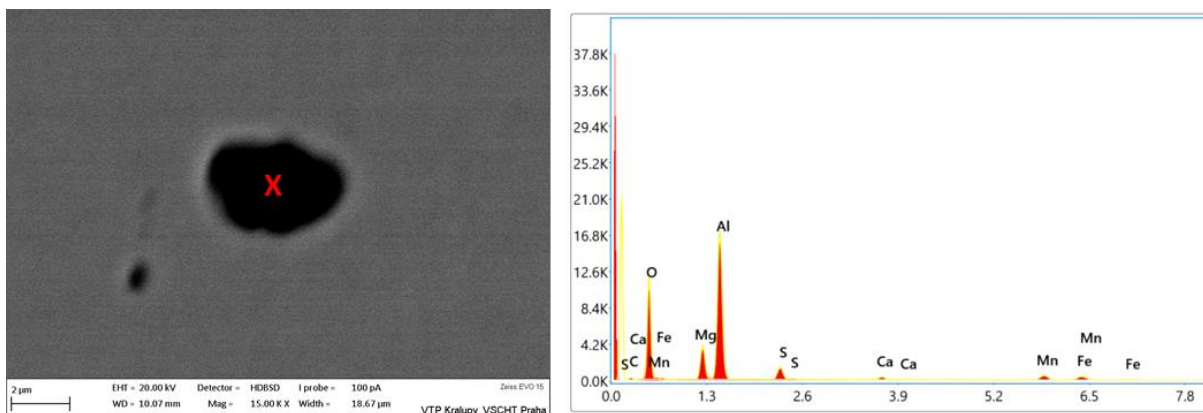


Figure 5. Aluminium oxide particle

## 4. Conclusions

An analysis of the delivered gun barrel steel rod was carried out. Corrosion pits were observed over the entire surface of the sample. A large number of inclusions was present in the material. Their size was typically of several micrometres in diameter. The analysis of the chemical composition showed that the inclusions were mainly mixed carbides of iron, chromium and manganese as well as aluminium oxide particles. Most probably, the inclusions were responsible for the pitting during acid pickling.