# PROPERTIES OF AUSTENITE STAINLESS STEEL X8CrNiS18-9 MICROALLOYED WITH TELLURIUM

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**ABSTRACT**
*More recently modified stainless steels have been used to produce various structural elements that work in complex operating conditions. Stainless steel X8CrNiS18-9 (standard EN 10088-3: 2005) is the most commonly used austenitic stainless steel due to its good machinability. This steel has high mechanical and working properties thanks to complex alloying, primarily with the elements such as chromium and nickel. The content of sulphur present in the steel from 0.15 to 0.35% improves machinability. However, sulphur at the same time decreases the mechanical properties, particularly toughness. The addition of sulphur, which is the cheapest available additive for free machining, will impair not only the transverse strength and toughness but also the corrosion resistance.*
*The aim of this work is to determine the influence of tellurium on the machinability, corrosion resistance and mechanical properties of the mentioned steel.*

## 1. INTRODUCTION

Tellurium in the periodic table of elements belongs to the group consisting of oxygen and sulphur [1].
It appears in the form of telluride in steel. Due to the extremely low melting point of iron telluride, Figure 1, (1187 K – 914 °C), which is precipitated in the form of a film at the boundaries of the primary grains, tellurium must be bound to manganese [2, 3].
The presence of tellurium in steel leads to the formation of globular sulphide inclusions, which at the same time favorably affect the machinability of steel since its presence in steel reduces the energy required to separate the material in the shear zone during cutting. This is due to the low melting point of manganese telluride (1428 K – 1155 °C) [3], which is lower than the melting point of manganese sulphide in Figure 2 [2], and the very high chemical surface activity of tellurium.
The addition of tellurium to improve the cut surface is due to the lubrication ability of manganese telluride. In sulphur alloy steels, tellurium always occurs as telluride because it is minimally soluble in manganese sulphide (0.01%). Tellurium occurs in steels in inclusions in the form of manganese (sulpho) telluride ($MnTe_xS_{(1-x)}$), as a white envelope of manganese sulphide (Figure 3), or in the form of globular inclusions, which are at the base of manganese sulphide or manganese silicate. The formation pattern depends on the tellurium content of the steel. It is necessary to consider the ratio Mn:S = 4 and Mn:Te = 20. Otherwise, during hot processing, characteristic cracks occur along the edges of the intermediate products [1].

Tellurium forms manganese telluride (MnTe) inclusions and is apparently more effective than sulphur for machinability of austenitic stainless steels. As well as selenium, it also promotes globularization and expansion of sulphide inclusions. However, tellurium causes problems with hot processing of austenitic stainless steels and has not been used for commercial purposes [4].

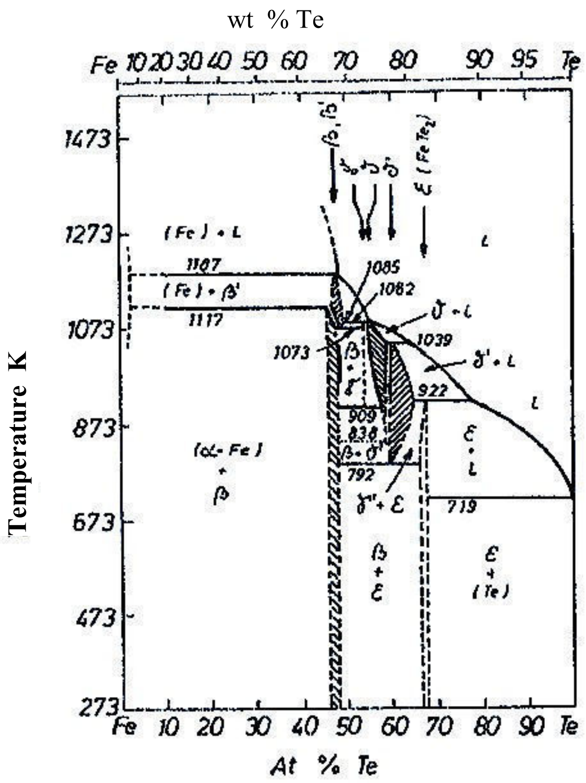


Figure 1. Fe – Te binary phase diagram [2,3]

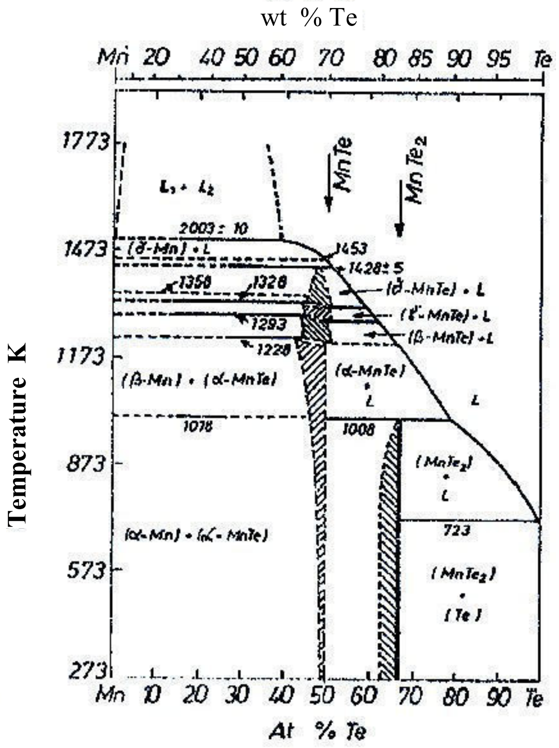


Figure 2. Mn – Te binary phase diagram [2,3]

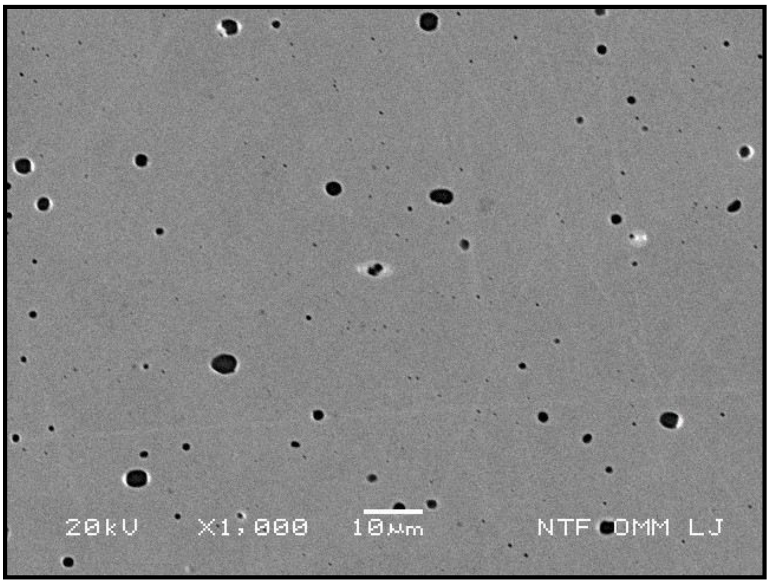


*Figure 3. Tellurium, as a white envelope around manganese sulphide inclusions [5]*

## 2. EXPERIMENTAL RESEARCH AND TEST RESULTS

The aim of the research was to examine the influence of the tellurium on machinability, corrosion resistance and mechanical properties of austenitic stainless steel X8CrNiS18-9 with and without alloying with tellurium. Production of austenitic stainless steel X8CrNiS18-9 was performed in a vacuum induction furnace at the Institute "Kemal Kapetanović" in Zenica. The ingots (Figure 4), were processed by forging, hot rolling and heat treatment.

*Figure 4. Ingot after the solidification process [5]*

The chemical analysis of the two melt variants is given in Table 1.

*Table 1. Chemical analysis of melt variants [5]*

| Melt variants | Chemical composition (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | C | Si | Mn | P | S | Cr | Ni | Te |
| Without alloying elements | 0,03 | 0,42 | 0,61 | 0,021 | 0,18 | 18,3 | 9,4 | – |
| Alloyed with Te | 0,05 | 0,40 | 0,80 | 0,010 | 0,16 | 18,9 | 9,3 | 0,033 |

In preliminary research is planned that after primary processing (approx $\phi$ 50 mm) samples will be tested by cutting forces, in order to determine to what extent the modification of the chemical composition affects the machinability of this material, and corrosion resistance. Of particular importance is to determine the behavior of nonmetallic inclusions in the process of developing structural parts and in a later exploitation. For this reason it is planned to simulation processing of austenitic stainless steel by plastic processing and by forging and rolling with two different degrees of processing. After that, the samples will be taken and laboratory testing of mechanical properties will be performed on them.

**2.1. Machinability**

In the Laboratory for metal cutting and machine tools of the Faculty of Mechanical Engineering in Zenica, the machinability test of the ingots was done, based on the estimation of parameters of the cutting force. Testing on both samples was performed under the same treatment regime. The results of the cutting force tests (individual forces $F_x$, $F_y$, and $F_z$ as well as the resultant force $F_R$) are given in Table 2.

*Table 2. The results of the cutting force tests [5]*

| Melt variants | Cutting force (N) | | | The resultant force $F_R$ (N) |
|---|---|---|---|---|
| | Component $F_x$ | Component $F_y$ | Component $F_z$ | |
| Without alloying elements | 180 | 218 | 361 | 458,52 |
| Alloyed with Te | 154 | 200 | 317 | 405,22 |

The melt micro-alloyed with tellurium has significantly lower resultant cutting force and accordingly significantly better machinability compared to melt without alloying elements.

## 2.2. Corrosion resistance

General corrosion tests for X8CrNiS18-9 stainless steel samples were performed on a potentiostat/galvanostat PAR 263A-2 device in an electrochemical cell prescribed by ASTM G5-94. The samples were tested in a solution of 1% HCl at room temperature. The solution was previously deaerated with argon for 30 minutes as provided by ASTM G5-94. To test the general corrosion of the X8CrNiS18-9 stainless steel samples, the Tafel Directional Extrapolation Method described by ASTM G3-89 was used.
The results of testing the general corrosion rate of these samples are given in Table 3.

*Table 3. Test results for general corrosion rate [5]*

| Melt variants | Corrosion current, $I_{Corr}$ (μA) | Corrosion rate, $v_{Corr}$ (mm/godinu) | Open Circuit Potential, $E_{(I=0)}$ (mV) |
|---|---|---|---|
| Without alloying elements | 4,266 | 4,955 | -475,320 |
| Alloyed with Te | 8,949 | 10,390 | -504,517 |

The melt micro-alloyed with tellurium has a significantly worse corrosion rate compared to melt without alloying elements.

## 2.3. Mechanical properties

After the rolling process was completed, specimens were prepared for mechanical testing (tensile properties and impact toughness testing). The tests were performed at the Mechanical Laboratory of the Institute "Kemal Kapetanović" in Zenica.
The results of the tensile properties and impact toughness testing are given in Table 4.

*Table 4. Test results of tensile properties and impact toughness in rolled condition [5]*

| Melt variants | Conventional yield strength $R_{p0,2}$ (N/mm$^2$) | Tensile strength $R_m$ (N/mm$^2$) | Elongation A (%) | Reduction Z (%) | Impact toughness ( J ) KV 300 J | |
|---|---|---|---|---|---|---|
| | | | | | Individually (J) | Average (J) |
| Without alloying elements | 349 | 670 | 50,0 | 70 | 60 | 57 |
| | | | | | 56 | |
| | | | | | 56 | |
| Alloyed with Te | 314 | 635 | 46,5 | 59 | 58 | 62 |
| | | | | | 69 | |
| | | | | | 60 | |

The melt micro-alloyed with tellurium has slightly worse tensile strength, but also slightly better impact toughness value compared to melt without alloying elements.

## 3. CONCLUSIONS

The aim of the research was to determine the effects of tellurium in austenitic stainless steel with the addition of sulphur X8CrNiS18-9 on the machinability, corrosion resistance and mechanical properties of the mentioned steel.

After all the tests performed, it is possible to draw the following conclusions:

- Nonmetallic inclusions of manganese sulphide types, in combination with tellurium, can be translated into a suitable form, whose shape is more spherical. These inclusions are more effective than pure sulphide in free-machining austenitic stainless steels, while effectively acting as shaving breakers and thus they improve machinability.
- With regard to the effect of tellurium microalloying on the corrosion rate of austenitic stainless steel X8CrNiS18-9, it can be concluded that melt alloyed with tellurium shows a marked increase in corrosion rate compared to the melt without alloying additives.
- But, on the other hand, all values of tensile properties (tensile strength, conventional yield strength, elongation and reduction), as well as impact toughness, are within the limits prescribed by the relevant standard for the material specified.

## 4. REFERENCES


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