

## **MODIFICATION OF NON-METALLIC INCLUSIONS BY TELLURIUM IN AUSTENITIC STAINLESS STEEL**

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### **ABSTRACT**

*Stainless steel plays an important role in all emerging technologies. In order to produce steels with better machinability, such as AISI 303 grades, an inclusion modification is presented. The machinability of steel depends mostly on the chemical composition of non-metallic inclusions as well on their shape and size. This work presents detailed metallographic analysis of manganese sulphide modified with tellurium. Machinability varies with the ratio of inclusion shape, so that it is desirable that the inclusions in steel have to be as spherical as possible.*

**Keywords:** *stainless steel, machinability, non-metallic inclusions*

### **1. INTRODUCTION**

Stainless steel type EN 1.4305 is popularly known as grade AISI 303 stainless steel. Grade AISI 303 is the most readily machineable of all stainless steel. The machineable nature of grade AISI 303 is due to the presence of sulphur in the steel composition. The AISI 303 stainless steel referred to as "free-machining" stainless steel has nominal chemical composition in accordance with the Table 1.

*Table 1: Chemical composition of standard AISI 303 austenitic stainless steels [%]*

C	Mn	Si	Cr	Ni	P	S
0.15	2.00	1.00	17.0-19.0	8.0-10.0	0.2	0.15 min

The MnS stringers help to promote the easy break up of metal shavings during machining [1, 2]. Whilst the sulphur improves machining, it also causes a decrease in the corrosion resistance and a slight lowering of the toughness and general decrease of the mechanical properties. Tellurium is considered to have a less deleterious effect than sulphur on mechanical properties and increased the machinability of steel. The machinability varies with the inclusion shape, which means that it is desirable that the manganese sulphide inclusions in steel must be as spherical as possible.

Tellurium addition improves machinability but is not available in standard grades of steel. The aim of the research is to investigate into the effect of Te on the modification of non-metallic inclusions of AISI 303 stainless steel, which are mostly in the form of typical manganese sulphides.

Besides improved chemistry control of non-metallic inclusions and as well a relation between solidification structure, precipitations and microsegregation [3-4] it is also necessary to find out the behavior of the inclusions in the work material for the improvement of the machining performance of steel.

## 2. EXPERIMENTAL WORK

### 2.1 Material and method

The aim of the research was to examine the possibility of increasing the effect of machinability of AISI 303 stainless steel alloying with tellurium.

Production of AISI 303 stainless steel was performed in a vacuum induction furnace with capacity of 20 kg at the Metallurgical Institute "Kemal Kapetanović" in Zenica. The ingots of mainly 20 kg were processed by forging, hot rolling and heat treatment. Two types of steel based on AISI 303 were used, this one as standard AISI 303 steel, and the other as modified AISI 303 steel with 0.04% Te.

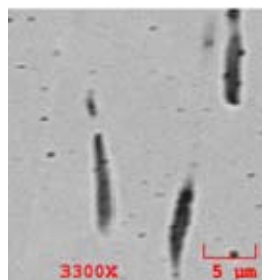
Using optical and electron probe microanalyzer type of inclusions were confirmed, whereas chemical composition and formed non-metallic inclusions were determined. SEM Elemental Mapping and EDS scan methods were used to examine the exact chemical composition of sulphides in atomic and mass percents.

## 3. DISCUSSION

### 3.1 Results without Te

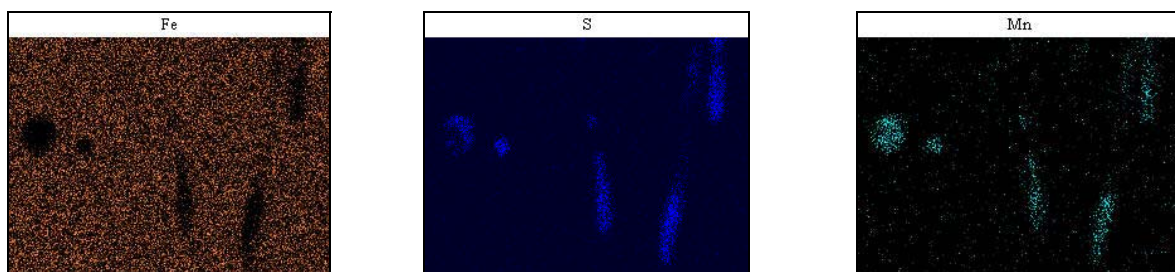
The non-metallic inclusions in the standard AISI 303 are typical MnS stringers.

The manganese content of this steel must be high enough to ensure that all sulphur is in the form of manganese sulphide. Figure 1 shows typical inclusions in stainless steel AISI 303.



*Figure 1: Typical non-metallic inclusion in standard AISI 303 Steel in form of MnS*

SEM-Mapping-figures of non metallic inclusions in this standard AISI-303 steel are presented in Figure 2. Lighter colours in the figure indicate increased concentration of chemical elements. By means of additional research of sulphides it has been established that those are pure manganese sulphides with atomic share Mn : S 1 : 1.



*Figure 2: SEM-Elemental Mapping-figures of non metallic inclusions in standard AISI-303 steel (see Fig. 1)*

These elongated manganese sulphide inclusions promote shaving formation and breakup during subsequent machining. As the MnS is harder than steel, the MnS acts as an internal stress concentration source when the work steel material reforms into a shaving at the cutting edge.

### 3.2 Results with Te

Tellurium has been added to AISI 303 steel as a replacement for sulphur, and to improve machinability. Figure 3 shows the modified, spherical shaped inclusions in stainless steel AISI 303 containing approximately 0.04% Te.

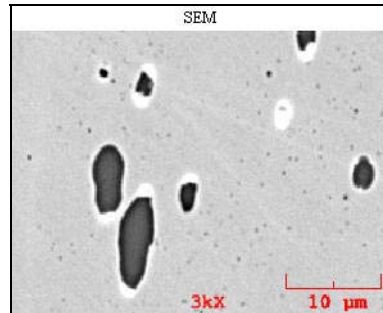


Figure 3: Modified spherical shaped MnS with outer Te-layers in modified AISI 303.

Figure 4 - mapping-measuring shows an increase of concentration of Mn, S as well Te (lighter colours) but Fe (dark colours) was poured at the same place. The outer Te layers mean that these are manganese sulphides enriched around with Te.

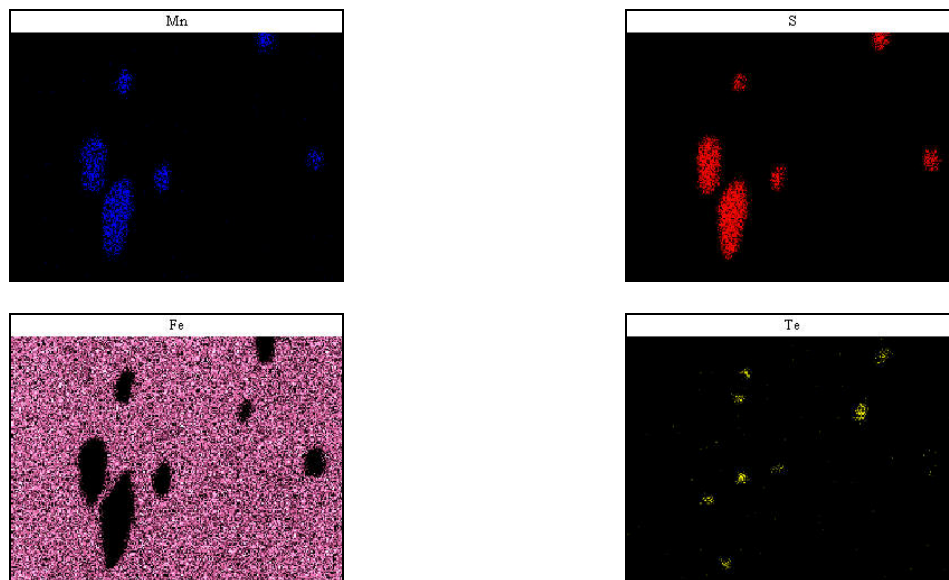


Figure 4: SEM-Mapping-figures of non metallic inclusions in modified AISI-303 as well as enrichment with elements Mn, S and Te

Figure 5 presents change in composition at the interface of the MnS inclusion, with evidence of a Te-enriched zone (white colour) around the MnS inclusions. When tellurium is present in free machining steel, all the tellurium is in inclusion form. In the case of modified AISI 303 there are telluride based on Mn, Cr and Fe. Figure 5a shows the results of an EDS made at the point labelled 1 in Fig 4., traversing the telluride. The energy-dispersive spectroscopy (EDS) profile shows the enrichment with Te, Cr and Fe. Tellurium forms a manganese telluride (MnTe) inclusion and is more effective than sulphur in free-machining austenitic stainless steels. It also promotes globularization and enlargement of sulfide inclusions.

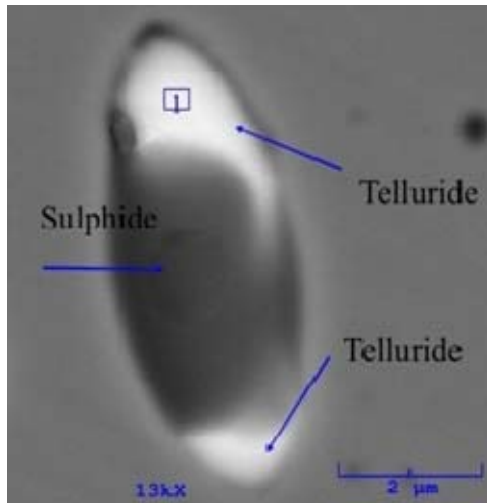


Figure 5: Modified spherical shaped MnS with telluride in modified AISI 303

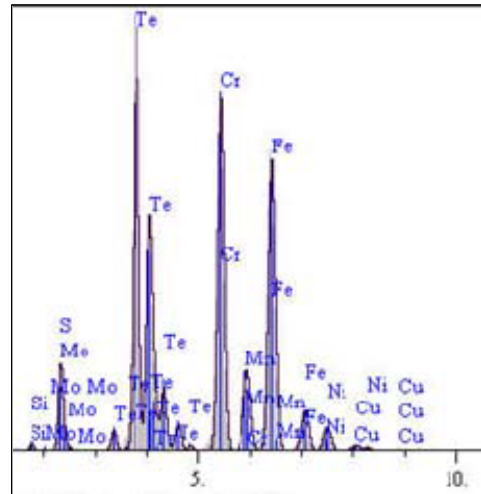


Figure 5a: EDS profile at the point labelled 1 in Fig 5, traversing the telluride

The very hard constituents, such as the complex inclusions that contain tellurium, chromium or manganese effectively act as shaving breakers. The cutting forces were measured. On the whole, the cutting force in the standard AISI 303 steel was bigger than that in the modified AISI 303 steel. This fact led smooth surface roughness that of the modified AISI 303 steel. The Te inclusions act as lubricant and reduce cutting resistance.

The modified steel grade has up to better machinability compared to standard AISI 303 grade and with the mechanical properties in the limits prescribed for standard AISI 303 steel.

#### 4. CONCLUSIONS

The nature of sulphides can be changed by chemical effects on the formation of complex non-metallic inclusions. In order to produce steels with better machinability, such as AISI 303 grade, the effects of Te on modification of inclusions are investigated. Typical inclusion is related to AISI 303 are the precipitates of manganese sulphides.

The results show that after alloying with tellurium the modification of manganese sulphide of AISI 303 stainless steel can be significantly changed. The manganese sulphides during the machinability act as an internal stress concentration source, but by the alloying with Te there is a formation of complex inclusions whose shape are 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.

#### 5. REFERENCES

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