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RESEARCH ARTICLE

NONMETALLIC INCLUSIONS IN AUSTENITIC STAINLESS STEEL AISI 303 MICROALLOYED WITH ZIRCONIUM AND TELLURIUM

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Abstract

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The control of formation of nonmetallic inclusion and the characterization present the basis of improvement of steel product properties and lead to sustainable development in design of new steel grades. In order to produce steels with better machinability, such as AISI 303 grades, a modification of inclusions with carefully designed chemical composition is presented. Sulphur by creating sulphide inclusions reduces friction and cutting resistance, and increases the brittleness of the chip.Considering its harmful effect in steel, as well as the fact that non-metallic inclusions have been insufficiently tested for this type of high-alloyed steel, the aim of this research is to determine effects of microalloying on the possibility of modification of non-metallic inclusions. Modification with zirconium favorably affects the ductile properties of steel, and a step forward in this study is a modification of inclusions with tellurium.It is of particular importance to determine the behavior of non-metallic inclusions in the process of production of the structural part and in subsequent exploitation. Therefore, plastic processing of austenitic stainless steel was also carried out, forging and rolling with two different level of processing.

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Introduction:-

Stainless steel is an ideal material to create lasting solutions in demanding applications. Its uses are endless. Thanks to its unique properties such as durability, low-maintenance and resistance to corrosion, stainless steel is not only the strongest, but also the most economically sustainable choice.

Since 1950, stainless steels have seen the greatest increase in consumption, with the most frequent, austenitic [2].
In addition to alloying with at least 10.5% chromium, for stainless steel to be corrosion-resistant (passive), another condition must be fulfilled, namely the existence of a homogeneous single-phase ferrite, austenitic or martensitic microstructure

The use of stainless steels is small compared to carbon steels, but shows steady growth, Figure 1. [4]. In Figure 2. [4], which shows the annual growth rate of major metals from 1980 to 2018, it is easy to see that the growth rate of stainless steels is by far the highest.

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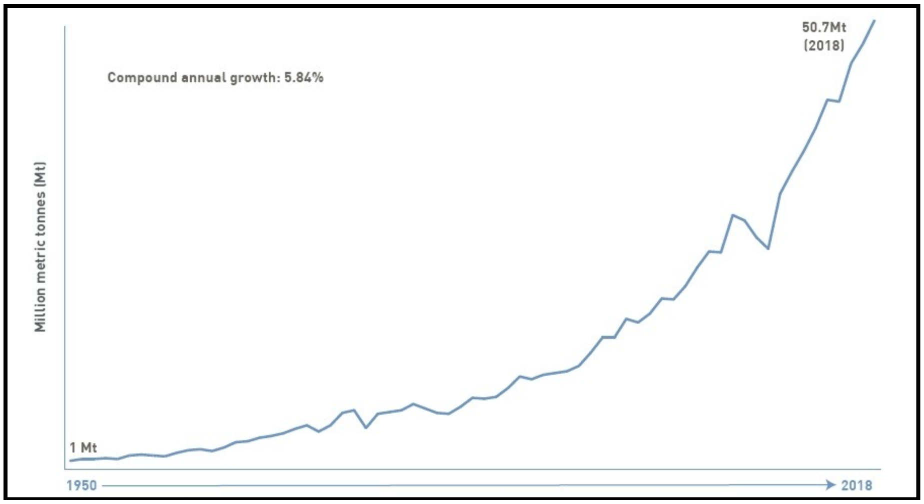


Figure 1:- Compound annual growth rate of world stainless melt shop production 1950-2018 [4].

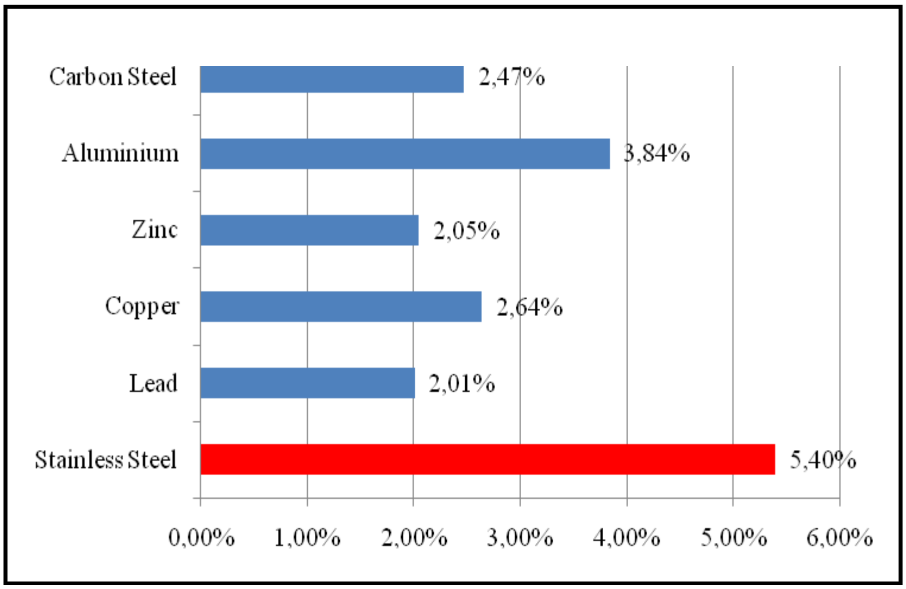


Figure 2:- Compound annual growth rate of major metals (% / year): 1980 - 2018 [4].

Stainless steel is the most recycled material in the world and it is estimated that 82% of stainless steel used is recycled into new steel. When recycled, melted recycled steel has as good qualities and properties as the original steel.

Today, approximately 60% of the raw materials used for the production stainless steels are recycled steels [5].

Influence Of Alloying Elements In Steel:
Manganese is most commonly used as a deoxidizer and desulphuriser during steel production. Due to its high affinity for sulphur, manganese produces MnSsulphide, thus preventing the negative effect of FeSsulphide [3].

High sulphur content has a positive effect on machinability characteristics. Tool wear is reduced, and chip separation is more favorable [6].

Zirconium addition causes sulphide inclusions to be spherical (globular) rather than elongated, which improves the strength and ductility of microalloyed cast steel [7].

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 [8].

Tellurium forms manganese telluride (MnTe) inclusions and is apparently more effective than the sulphur for machinability of austenitic stainless steels. It also promotes globularization and expansion of sulphide inclusions [6, 7].

Experimental Research And Test Results:-

The melting and casting of austenitic stainless steel X8CrNiS18-9 was carried out in a vacuum induction furnace, and is located at the Department for melting and metal casting of the Institute "Kemal Kapetanović".

Four meltings were done. The first melt is austenitic stainless steel X8CrNiS18-9 without alloying elements. Subsequently, in the following three melt, the composition with the corresponding contents of zirconium and tellurium was modified so that each of the above elements was added independently, and then in combinations with both alloying elements. Chemical analyzes of all melt variants are given in Table 1.

Figure 3:- Casted samples for metallographic tests [9].

Table 1:- Chemical analyzes of all melt variants [9].

Melt variants	*Chemical composition (%)*								
	C	*Si*	*Mn*	*P*	*S*	*Cr*	*Ni*	*Zr*	*Te*
without alloying elements	0,03	0,42	0,61	0,021	0,18	18,3	9,4	–	–
alloyed with Zr	0,04	0,35	0,75	0,021	0,17	18,8	9,4	0,016	–
alloyed with Te	0,05	0,40	0,80	0,010	0,16	18,9	9,3	–	0,033
alloyed with Zr i Te	0,03	0,47	0,72	0,012	0,18	18,5	8,9	0,007	0,040

Metallographic Testing Of Casted Samples:

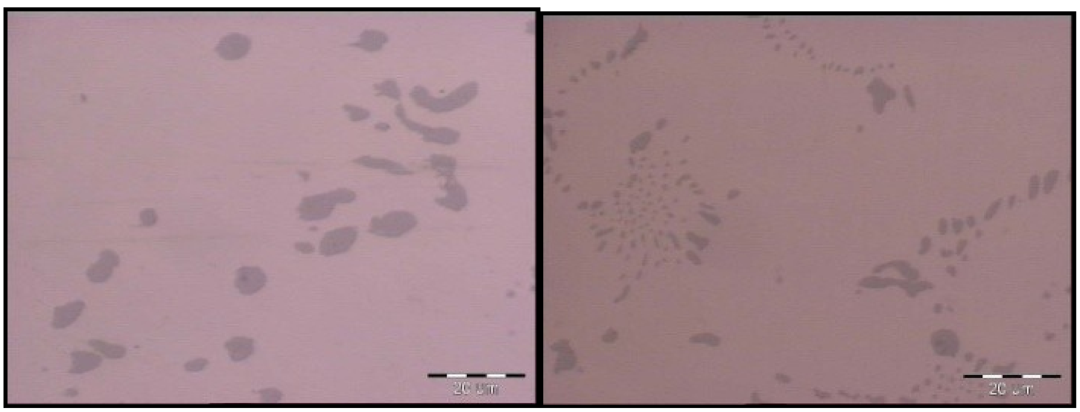
All ingots are subjected to heat treatment: solution annealing – heating to 1050 °C, followed by rapid cooling in water. After the heat treatment, samples were taken next to the ingot head for metallographic testing of the cast state (Figure 3 - after grinding and polishing).

Subsequently, an analysis of the content, size and distribution of the nonmetallic inclusions in the unetched state was performed, and the results of the tests are given in Table 2. The imaging of samples under a specific magnification (x50) was performed on an Olympus PMG3 type optical microscope, and one image was given for each sample (Figure 4). The figures show inclusions of average size, while Table 2 also lists individual inclusions that are significantly larger than average.

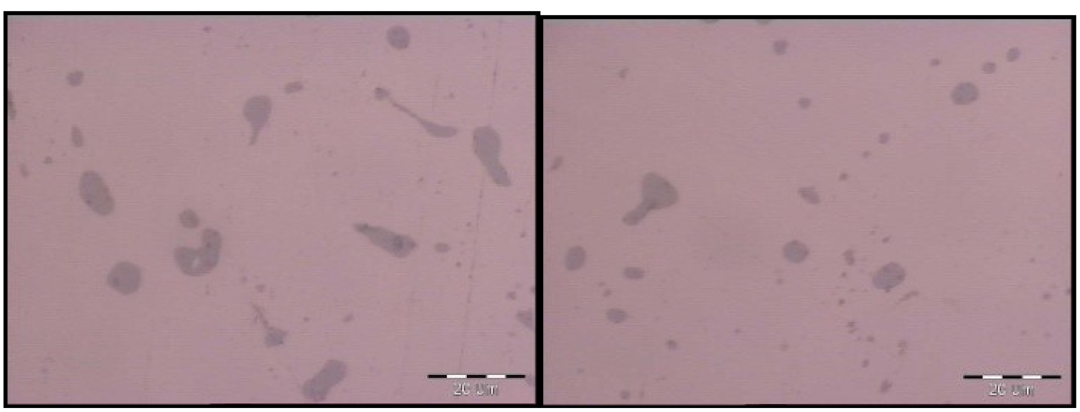
Table 2:- Results of metallographic testing of casted samples [9].

Melt variants	*Size of sulphide inclusions (µm)*		*The total number of inclusions by zones **			*Note*
			I	*II*	*III*	
without alloying elements	200,1 150,0 90,0 85,0	60,1 55,5 40,8	7	8	4	Lots of small sulphide inclusions; Size porosities 264 i 140µm
alloyed with Zr	115,3 193,1	69,2	3	3	6	Lots of small sulphide inclusions
alloyed with Te	162,1 110,8	63,1	1	5	7	Lots of small sulphide inclusions
alloyed with Zr i Te	54,0 75,0 102,0	168,0 184,0	4	8	8	Lots of small sulphide inclusions

* Zones I, II and III represent sample areas, so that zones I and III represent the edges of the sample, while zone II represents the central part of the sample.



a) without alloying elements b) alloyed with Zr



c) alloyed with Te d) alloyed with Zr and Te

Figure 4:- Microstructure of all melt variants for the casted state [9].

Metallographic testing of forged samples:

After solution annealing, the specimens were hot deformed, namely forging on a hydraulic press and a hammer, which are located at the Department for Plastic Processing of Metals of the Institute "Kemal Kapetanović", up to a dimension of ϕ 50 mm. The samples, after the completion of forging process and rough machining, are shown in

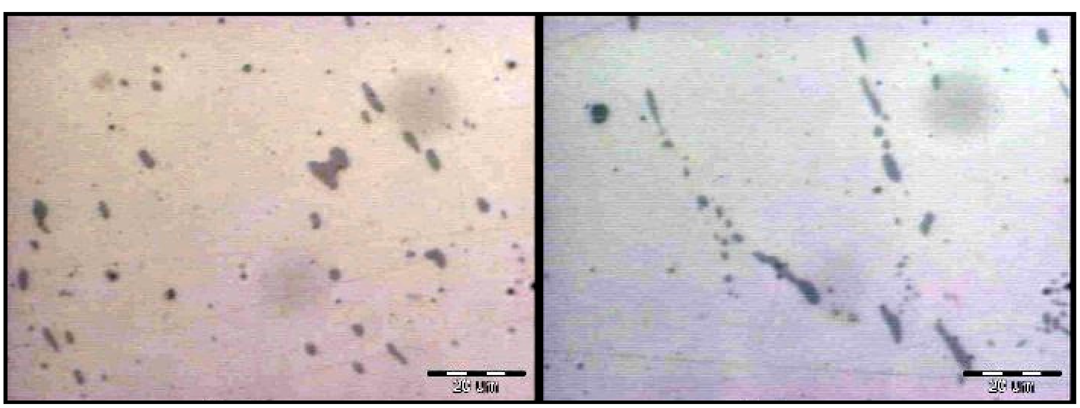
Figure 5. Upon completion of the forging process, samples were taken to perform metallographic testing for the forging condition.

Figure 5:- The samples after the completion of forging process and rough machining [9].

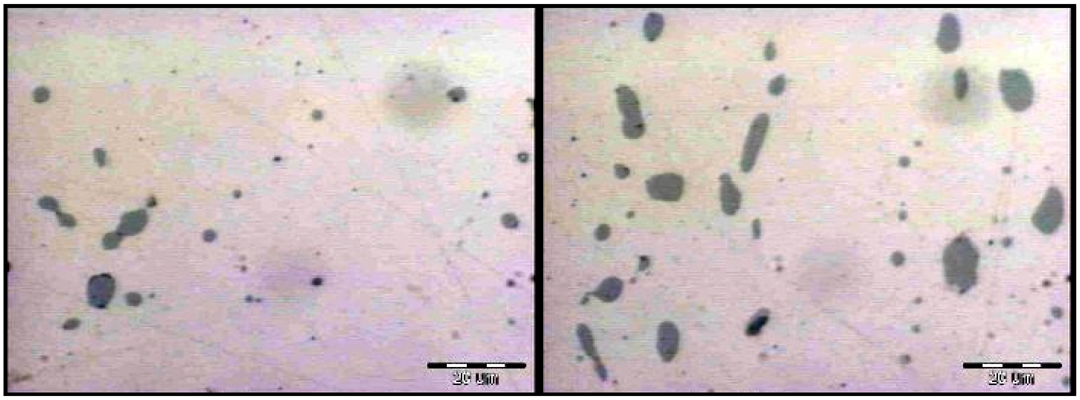
As with the cast samples, an analysis of the content, size and distribution of the nonmetallic inclusions in the unetched state was performed, and the test results are given in Table 3. Samples were also imaging on an OLYMPUS PMG3 type optical microscope (x50), and one image was taken for each sample (Figure 6).

Table 3:- Results of metallographic testing of forged samples [9].

Melt variants	*Size of inclusions (□ m)*			Note
without alloying elements	Complex globular inclusions:			Lots of small sulphide inclusions
	50,0	90,0		
alloyed with Zr	Complex inclusions:			Lots of small sulphide inclusions
	50,0 x 20,0	25,0 x 20,0	48,0 x 18,0	
alloyed with Te	Globular inclusion: ~ 20,0 Complex inclusion: 139,0 x 30,0			Lots of small sulphide inclusions
alloyed with Zr i Te	Complex inclusions:			Lots of small sulphide inclusions
	70,0 x 30,0	150,0 x 30,0		



a) without alloying elements *b) alloyed with Zr*



c) alloyed with Te *d) alloyed with Zr and Te*

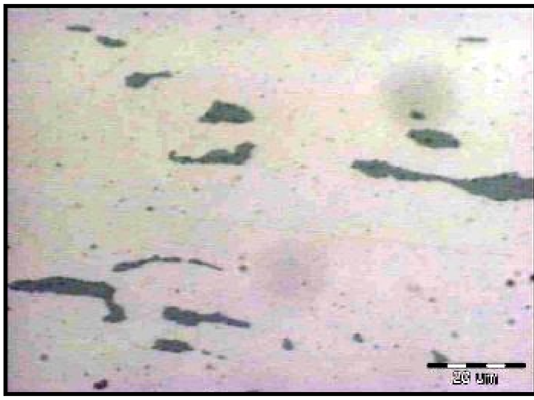
Figure 6:- Microstructure of all melt variants for forged state [9].

Metallographic testing of rolled samples:

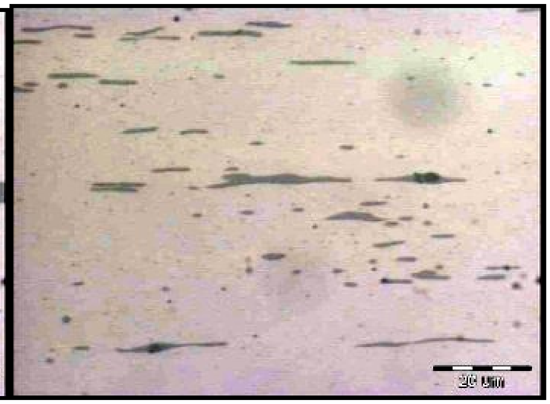
The rolling was performed on the SKET rolling mill, with the first section being reduced to 18 mm, while the second one reached a final sample size of 14 x 50 mm. The rolling speed was 400 rpm. After completion of rolling, all samples were quenched in water in order to avoid the effect of sensitisation. All samples are of different lengths depending on the amount of material in each variant. Figure 7 shows all the samples after the rolling process has been carried out. Upon completion of the second stage of deformation (rolling to dimensions 14 x 50 mm), samples were taken to perform metallographic testing for the rolling condition.

Figure 7:- The samples after the rolling process was performed [9].

As with the previous samples, the content, size and distribution of nonmetallic inclusions in the unetched state were analyzed, and the test results are given in Table 4. The test for the rolling condition was performed in accordance with ASTM E45-11 – Standard Test Methods for Determining the Contents of Inclusions in Steel. BAS EN 10088-1 does not specify limit values for the content of nonmetallic inclusions. Sample imaging under a certain magnification (x50) was performed on an OLYMPUS PMG3 type optical microscope, and one image was given for each sample (Figure 8).

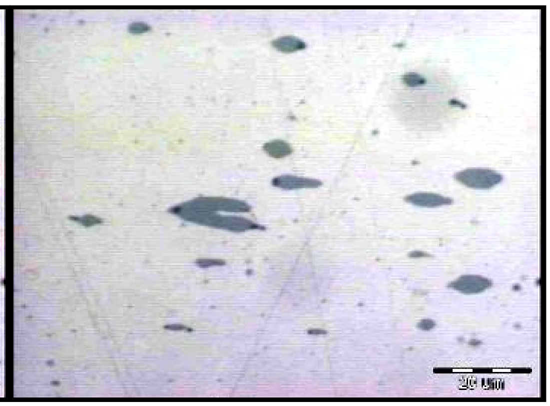


a) without alloying elements



b) alloyed with Zr

c) alloyed with Te



d) alloyed with Zr and Te

Figure 8:- Microstructure of all melt variants for rolled state [9].

Table 4:- Results of metallographic testing of rolled samples [9].

Melt variants	*Sulphides*		*Note*
	Thin	*Thick*	
without alloying elements	3	1,5	Many small sulphide inclusions with thickness less than 2µm have been observed. A complex inclusion of 250 *µm* size was also observed.
alloyed with Zr	3	3	Many small sulphide inclusions with thickness less than 2µm have been observed. A complex oxysulfide inclusion of 500 µm size was also observed.
alloyed with Te	3	3	Many small sulphide inclusions with thickness less than 2µm have been observed. Complex inclusions of size 600, 500, 300, 200 µm were also observed.
alloyed with Zr i Te	1,5	3	Many small sulphide inclusions with thickness less than 2µm have been observed. Complex inclusions of size 600, 150, 60 µm were also observed.

Conclusions:-

Based on experimental research, it is possible to make the following conclusions:

1. In experimental melts after rolling and after heat treatment, the presence of type A inclusions (sulphides) according to ASTM E45-11 was detected. The largest number of inclusions and the biggest inclusions were determined for tellurium alloyed melt.
2. Addition of tellurium with zirconium improves the globularization of austenitic stainless steel X8CrNiS18-9, in this respect tellurium is particularly dominant;
3. Elements of zirconium and tellurium are added for the purpose of modifying sulphide inclusions, in particular their globularization and thickness increase. This work confirmed this, especially in the case of tellurium.

References:-

1. http://www.outokumpu.com/sitecollectiondocuments/outokumpu-stainless-steel-handbook.pdf (december 2019)
2. M. Oruč, R. Sunulahpašić - "Contemporary metal materials" – University of Zenica, Faculty of Metallurgy and Technology, Zenica, 2005
3. StjepanKožuh: "Special steels - script", University of Zagreb, Faculty of Metallurgy, Sisak, 2010
4. http://www.worldstainless.org (december 2019)
5. www.sustainablestainless.org (december 2019)
6. J.R. Davis: Alloying Understanding The Basics, ASM International, Materials Park, Ohio, USA, 2001
7. D. Senk: Steel metallurgy - challenged by materials, Stahl und Eisen 134 (2014) No. 11, p. 110-121
8. K. Hribar: ″ Influence of metal and non-metallic additives on the shape of inclusions and technological properties of steels ″, Master's thesis, Jesenice, 1981
9. D. Mujagić – "Contribution to research of influence microalloying with boron, zirconium and tellurium on properties of austenitic stainless steel with sulphur addition X8CrNiS18-9", PhD thesis, University of Zenica, Faculty of Metallurgy and Technology, Zenica, January 2017.