AN ANALYSIS OF STAINLESS STEEL SERIES 200 VS. SERIES 300

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ABSTRACT: Stainless steels are iron-carbon alloys, which contain at least 10.5% chromium as the main alloying element. It is well known that ordinary steels exposed to unsuitable conditions of rusty environment, on their surface appears a layer of rust formed of oxides that do not protect the material, but develop in depth, over time leading to compromise of the part. But if there is more than 10.5% chromium in the composition of the steel, the surface oxide layer has special properties, is extremely thin, protects the part in extremely varied and hostile environments and is very easy to self-repair when removed. This layer is what gives steels the character of "stainless" and its self-repair gives superiority over ordinary steels which in order to protect them are coated with galvanized layers of zinc or cadmium or are painted, and these coatings once damaged can only be restored by human reintervention, involving new costs. The paper proposes a particular analysis related to stainless steels 1.4301 (the best-selling brand internationally) and J4 (company brand not covered by internationally recognized standards and specifications). The purpose of this analysis is to clarify a marketing aspect, because lately J4 seems to be promoted under the slogan "Same as 1.4301, but cheaper!". Let's see if this is true or not ....

KEYWORDS: stainless steel, chrome, nickel, carbon, corrosion

1. INTRODUCTION

The first observations on the chemical properties conferred on steels by chromium alloy were made by BERTHIER in 1821. The first batches of stainless steels, dating from the early nineteenth century, were reported simultaneously by Guillet, Chevanard and Portevin in France and Goldschmidt, Giesen and Monartz in Germany. Their results have been closely linked to the discovery of the properties conferred on steels by the addition of a sufficient amount of chromium, which makes the alloy very well resistant in many aggressive environments, which is normally called passivity.[1]

According to the European standard EN10020, stainless steel is an alloy of iron, chromium and carbon, with more than 10.5% Cr and less than 1.2% C. Other elements such as nickel, molybdenum, titanium, etc., can be added to give the alloy particular properties.

The name "stainless steels" is very restrictive, as are those used in English (stainless: stainless steel) or in German (nicht rostende Stahl: non-rust steel), names that were imposed at the beginning of their discovery due to obvious resistance of these steels to atmospheric corrosion.

Nowadays when we say about a steel that it is stainless we have to specify: in relation to which media, liquid or gaseous, in what temperature limit and corrosion resistance, in comparison with ordinary or weakly alloyed steels.

The corrosion resistance of stainless steel comes from the formation on the surface of a thin protective film (fig. 1). It is made up of chromium-containing oxides and is formed spontaneously in the presence of oxygen. Even if it is physically or chemically damaged, this protective film has the property of recovering as soon as the cause that caused the damage is removed and the surface is again exposed to the action of oxygen in the air or water.[1]

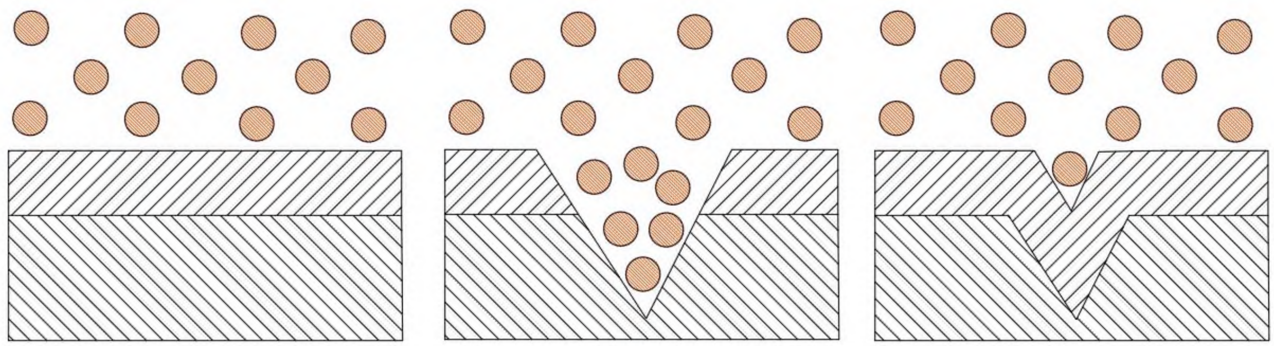


Fig. 1. Formation of the thin protective film on the surface of stainless steel

Stainless steel is resistant to the extremely varied temperatures encountered in the food industry. It is not altered by heating, boiling, baking, cooling, freezing. It is very important that the physical properties of stainless steel give it good workability. Depending on the composition, stainless steels are well processed by deformation, cutting, welding well, which makes the equipment in the food industry can be made in economical conditions and with excellent functionality. There is a guarantee, given the material, that they will withstand impact, fatigue, wear, abrasion and corrosion.[2]

It is interesting to note that when the equipment made of stainless steel has ended its life cycle and needs to be replaced, the stainless steel still does not exhaust its life, it can be reused. Today, new equipment contains, on average, 60% recycled stainless steel.

2. TYPES OF STAINLESS STEEL. INDICATIONS REGARDING THE USES AND SELECTION OF STAINLESS STEEL

Stainless steels are iron-carbon alloys, which contain at least 10.5% chromium as the main alloying element. It is well known that ordinary steels exposed to unsuitable conditions of rusty environment, on their surface appears a layer of rust formed of oxides that do not protect the material, but develop in depth, over time leading to compromise of the part. But if there is more than 10.5% chromium in the composition of the steel, the surface oxide layer has special properties, is extremely thin, protects the part in extremely varied and hostile environments and is very easy to self-repair when removed. This layer is what gives steels the character of "stainless" and its self-repair gives superiority over ordinary steels which in order to protect them are coated with galvanized layers of zinc or cadmium or are painted, and these coatings once damaged can only be restored by human reintervention, involving new costs. Along with iron, carbon and chromium, other elements are added to the composition of stainless steels that improve their properties or give them new ones.

The high carbon content gives hardness and mechanical strength. The addition of nickel stabilizes the austenitic structure, the material is non-magnetic and less brittle at low temperatures. Manganese acts in the same way as nickel, giving the material the same properties, but at a lower cost. Molybdenum increases corrosion resistance and high temperature.[3]

From the point of view of their crystalline structure, determined by the chemical composition, stainless steels are classified into five types (fig. 2):

- austenitic and superaustenitic: contain maximum 0.15% carbon, minimum 16% chromium and sufficient nickel and manganese to stabilize the austenitic structure; the addition of nickel in stainless steels improves their deformability and weldability; an addition of 8 ... 12% nickel allows stainless steels to be rolled, pressed, stamped and increases corrosion resistance;
- ferritic: contain 10.5 .... 18% chromium and approximately 0.05% carbon;
- martensitic: contain approx. 13% chromium and high percentages of carbon (even over 1%); they are the cheapest stainless steels, but they are difficult to deform and weld;
- duplex: they have an extremely high chromium content (over 22%) and approx. 3% molybdenum; withstands the most corrosive environments;
- Durable by precipitation: contain as an alloying element copper (which improves acid resistance) and niobium (which reduces corrosion in the weld area); they are expensive stainless steels, have high machining costs, but combine the remarkable corrosion resistance of austenitic steels with the excellent mechanical properties of martensitic steels.[3]

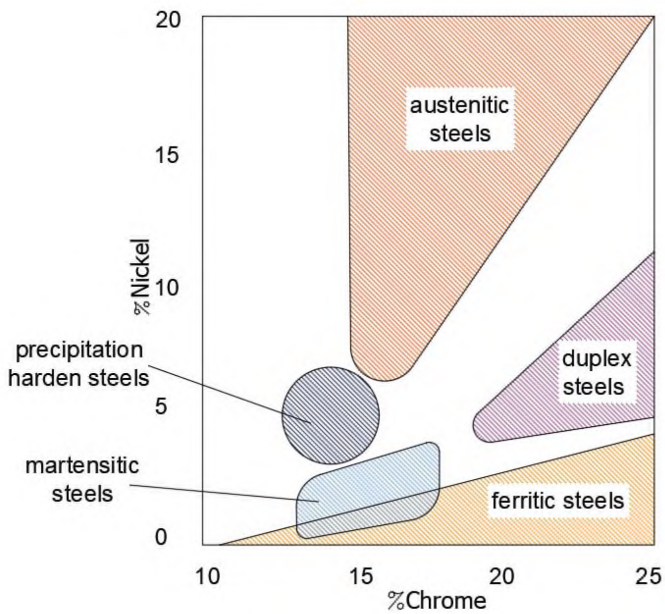


Fig. 2. Types of stainless steels according to chromium and nickel content

When choosing the type of stainless steel to be used in a particular application, the following must be taken into account: corrosion resistance, physical and mechanical properties, processing possibilities and costs.[3]

The main selection criterion must be the corrosion resistance in the environment in which the element made of stainless steel will work, and then the fulfillment of the other criteria will be pursued, at a low cost. It should be noted that the criterion of the minimum cost of the material is not essential here, but that of the minimum total cost involved in the lifetime operation. Stainless steel elements, even if they are more expensive in terms of material and processing costs, will avoid a whole range of costs related to repair, overcoating, repainting, decommissioning and the need for replacement, involved in other materials that do not resists corrosion.

Table 1 presents comparative general specifications on the properties of the main types of stainless steels.[3]

Table 1. Comparison of the properties of different types of stainless steels

Type of stainless steels	Corrosion resistance	Ductility	Resistance to high temperatures	Resistance to low temperatures	Weldability
Austenitic	high	very high	very high	very high	very good
Ferritic	middle	middle	low	low	low
Martensitic	middle	low	low	low	low
Duplex	very high	middle	low	middle	good
Precipitation harden steel	middle	middle	low	low	good

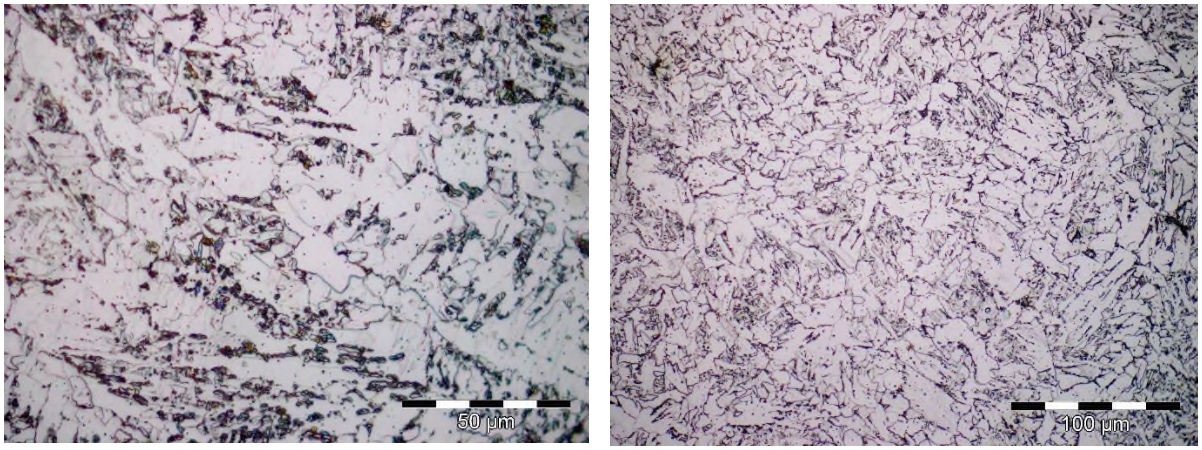
3. CASE STUDY

The case study proposes a particular analysis related to stainless steels 1.4301 (the best-selling brand internationally) and J4 (company brand not covered by internationally recognized standards and specifications). We propose this because lately J4 seems to be promoted under the slogan "Same as 1.4301, but cheaper!". Let's see if this is true or not ....

Austenitic steels, or the 300 series (by American standards), account for about 65% of stainless steel production. They contain a maximum of 0.15% carbon, between 16% ... 28% chromium and enough nickel (3.5% ... 32%) or manganese to stabilize the austenitic structure. Austenite is a crystalline structure in which atoms are arranged according to the CFC system - cube with centered faces, which leads to the existence of a large number of sliding planes in the network and increased deformation possibilities for the material in which this structure is present. In ordinary steels this structure appears only at high temperatures, at ambient temperature not being present. By alloying with nickel or manganese, it can be maintained at the cooling of steels during solidification and remains present at ambient temperature.

Nickel is not the only element that stabilizes austenite (gamagen element). Nitrogen behaves the same way. But being a gas, it can be added only in limited quantities, otherwise leading to the appearance of hard chromium nitrides and even porosity. Manganese is also an element that promotes the formation of austenite and allows the incorporation of a larger amount of nitrogen in steel.

In conclusion, manganese and nitrogen (and sometimes copper) can be used to replace nickel in the composition of stainless steels, thus resulting in the 200 series. They are also referred to as CrMn stainless steels. The combination of Mn and N is not sufficient to ensure a completely austenitic structure, so that a (rather low) percentage of nickel is preserved in the composition of the 200 series stainless steels.[4]



a) b)

Fig.3. Stainless steel 1.4301 (a) and J4 (b) microstructure

Figure 3 shows the microstructures of stainless steels 1.4301 and J4 and Table 2 shows the chemical composition of the main brands of stainless steels in the 200 series compared to stainless steel 1.4301 (AISI 304) in the 300 series.[3]

Table 2. 200 series stainless steels vs AISI 304

Type of steel		Chemical composition [%]			
AISI	UNS	Cr	Ni	Mn	N
304	S30400	18,0 - 20,0	8,0 - 10,5	2,0 max	0,10 max
201	S20100	16,0 - 18,0	3,5 - 5,5	5,5 - 7,5	0,25 max
202	S20200	17,0 - 19,0	4,0 - 6,0	7,5 - 10,0	0,25 max
205	S20500	16,5 - 18,0	1,0 - 1,7	14,0 - 15,5	0,32 - 0,40

Starting from the observation that the evolution of the price of stainless steels from series 300 follows the evolution of nickel price, series 200 was developed for economic reasons, aiming to reduce the production cost by decreasing the percentage of nickel used in processing and replacing it with manganese (fig. 2).

It can be seen from Table 2 that reducing the percentage of nickel to 1% involves introducing about 15% manganese into the stainless steel. However, the increase in manganese content raises a number of problems. In order to preserve the austenitic structure in steel, in the conditions of increasing the percentage of manganese, it is necessary to decrease the chromium content. This is shown in Figure 4 from which it can be understood that for a chromium - manganese steel with 1% nickel, in order to have an austenitic structure the percentage of chromium must be lowered below 15%. But chromium is the essential element in stainless steels, it gives resistance to corrosion and the decrease of chromium content is problematic.[5]

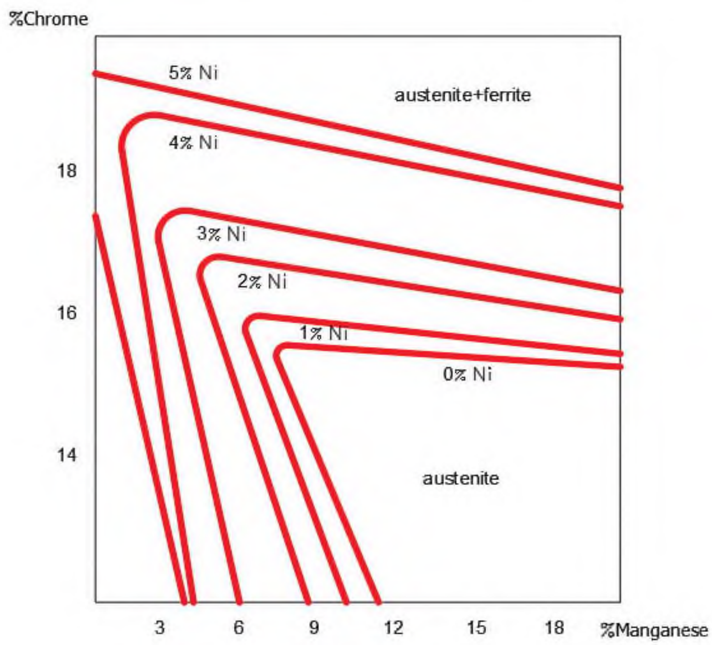


Fig.4. The relationship between the content of chromium, manganese and nickel and the structure of stainless steels

In conclusion, the development of the 200 series as an economic alternative to 1.4301 involves a basic chemical composition with 15 ... 19% chromium, 1 ... 6% nickel and the addition of manganese, nitrogen and copper.[5]

The advantages offered by the steels in this series are:

- lower cost, due to the fact that the percentage of nickel decreases from 6 ... 20% (series 300) to 1 ... 5% (series 200);
- increased mechanical strength by approx. 30% compared to 1.4301, which allows more economical sizing of stainless steel components and reducing their mass;
- the plastic deformation properties are kept good, these steels can be processed to obtain semi-finished products (sheets, bars, pipes) on the same equipment on which 1.4301 is processed.

However, there are a number of disadvantages of the 200 series related mainly to the decrease of chromium content, which leads to decreased corrosion resistance and thus to the restriction of the range of applications to components that will operate in low corrosive environments.

The chemical composition of marks J1 and J4 is presented in table 3. These are steels with 4% Ni (J1) and 1% Ni (J4), in which the chromium content is lowered around 15%, but manganese appears in the composition. in a percentage of approx. 8% and copper 1.5 ... 2%. It is necessary to emphasize that these brands are company brands and are not covered by internationally recognized standards and specifications. Thus, their composition is at the discretion of the producers, and at present, there are numerous producers of J steels, especially in China. More than 2,000,000 tons of J steels are produced per year in Southeast Asia, and it is extremely important, if such steel is imported from that area, to be made from a recognized producer! Small manufacturers, due to the technology they use, do not have the opportunity to properly control the carbon and sulfur content, which is usually higher than in the company's brand specifications.

Table 3. Chemical composition of marks J1 and J4

Type of steel	Chemical composition				
	Cr	Ni	Mn	N	Cu
J1	14,5 - 15,5	4,0 - 4,2	7,0 - 8,0	0,1 max	1,5 - 2,0
J4	15,0 - 16,0	0,8 - 1,2	8,5 - 10,0	0,2 max	1,5 - 2,0

The disadvantage is that these producers lower the chromium content extremely much. Some analyzes, carried out by independent research institutes, on J steels from China showed a chromium content of only 11%, extremely problematic, thus compromising the main property of stainless steels, corrosion resistance.

Tables 4 and 5 present excerpts from the company's offer (in which we have kept the terms used in English, as in the original), from which a series of conclusions can be drawn regarding the comparison between brands 1.4301 (AISI 304) and J4.[6]

Table 4. Extract from the company's offer (1)

Grade	C	Mn	P	S	Si	Cr	Ni	Mo	N	Cu
304	0,08	2,0	0,045	0,03	0,75	18,0-20,0	8,0-10,5	-	0,10	-
316	0,08	2,0	0,045	0,03	0,75	16,0-18,0	10,0-14,0	2-3	0,10	-
316L	0,08	2,0	0,045	0,03	0,75	16,0-18,0	10,0-14,0	2-3	0,10	-
J4	0,10	8,5-10,0	0,090	0,03	0,75	15,0-16,0	0,8-1,2	-	0,20	1,5-2,0

Table 5. Extract from the company's offer (2)

Grade	Tensile strenght		Yield strenght		% Elongation	Hardness	
	Kai	MPa	Kai	MPa		HRB	HB
304	75	515	30	205	40	92	201
316	75	515	30	205	40	95	217
316L	70	485	25	170	40	95	217
J4	100	700	50	350	40	97	222

Thus, from the elements summarized in table 6, the following conclusions can be drawn regarding the similarities and differences between 1.4301 and J4:

Table 6. Comparison between 1.4301 and J4

	C max%	Si max%	Mn	P max%	S max%	N max%	Cr	Cu	Ni	R_m [Mpa]
J4	0,1	0,75	8,5-10,0	0,08	0,03	0,2	15,0-17,0	1,5-2,0	1,0-1,5	650-900
1.4301	0,07	1,0	1,5-2,0	0,045	0,015	0,11	17,5-19,5	-	8,0-10,5	540-750

In terms of chemical composition:

- both steels have an austenitic, non-magnetic structure, with good machinability by plastic deformation;
- the essential alloying element, namely chromium, is in a lower percentage in J4, but the percentage is still appreciable, which favors the corrosion resistance;
- the percentage of nickel is much lower in the case of J4, which can give, when the price of nickel is high, a competitive advantage related to the price;
- in J4 nickel is replaced by manganese, and to preserve the austenitic structure the nitrogen content increases;
- the increase of the hardness of the steel, caused by the increase of the nitrogen and carbon content, is compensated by the addition of copper, which "softens" the structure and makes the J4 steel easily workable by plastic deformation;

In terms of corrosion resistance:

- the lower chromium content of J4 also implies the decrease of the corrosion resistance;
- the increased sulfur content in J4 compared to 1.4301 leads to the faster appearance of corrosion by pitting in the case of components made in J4;
- the higher percentage of carbon in the composition of J4 is unfavorable in terms of increasing the tendency to intergranular corrosion in welded areas;
- special attention will have to be paid to the good reputation of the supplier; If there are questions about the origin of J4 steel, it is good to analyze the chemical composition, especially the percentage of chromium;
- it should be emphasized that the use of J4 is not indicated in outdoor applications (corrosion can occur even in mild, slightly aggressive environments) and is totally forbidden for industrial applications in corrosive environments; in these cases 1.4301 cannot be replaced by J4;

In terms of mechanical strength and hardness: J4 has higher mechanical strength and hardness than 1.4301, which leads to reduced weight of components and material savings, in applications where it is allowed to replace 1.4301 with J4 (especially applications interior, in the field of construction and architectural elements, including stairs and railings, in the field of catering and food preparation equipment);

In terms of plastic deformation processing capacity: in the case of J4 it is lower than for 1.4301; the addition of copper aims precisely at recovering the deformability; in the case of J4 there is a dangerous phenomenon of embrittlement due to cold deformation, which leads to the appearance of cracks and fissures, being necessary a post-deformation heat treatment, which reduces the tendency of embrittlement;

In terms of the possibility of recycling: as is well known, stainless steels are materials with a very high degree of recycling; J4 and 1.4301 being non-magnetic, they cannot be easily separated for recycling, requiring sophisticated chemical analyzes; this leads to contamination with manganese, copper and other impurities of 300 series stainless steels, as the percentage of 200 series stainless steels used worldwide increases (currently about 10%); this contamination thus becomes a major problem, with the very opinion that the use of "cheaper" steels with a little nickel turns from a beautiful dream into a real nightmare, destroying the efficiency of recycling and having the potential to harm the entire stainless steel industry.

4. CONCLUSION

The detailed analysis shows us that J4 is not the same as 1.4301, is part of different classes of stainless steels, poses problems related to corrosion resistance in outdoor environments and is totally contraindicated in corrosive environments. There is also the issue that J4 is not standardized internationally, being in fact a company brand. A very important aspect is that J4 stainless steel imposes many restrictive conditions on the waste recycling industry.

The only advantage of J4 is that it has a lower nickel content and thus a lower price .... but in the current conditions, when the price of nickel is extremely low (approx. $ 10,000 / ton) and this advantage is put in question.

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