200 SERIES STAINLESS STEEL
CrMn GRADES

OVERVIEW

Nickel prices have been relatively high over the last couple of years. As a result, there has been increased interest in low-nickel or no-nickel grades of stainless steel. One such family of stainless steels is the 200-series and use of these has doubled this decade. They have become popular in China and South East Asia, particularly. However, this has not been without problems. Because the 200-series grades are austenitic, they are not magnetic and therefore very difficult to distinguish from the widely used 300-series grades, such as Grade 304, which are also non-magnetic. This has led to confusion in the marketplace, including cases of incorrect labeling, etc, with 200-series material being sold as Type 304.

Most growth in 200-series use over recent years has been in low-nickel and therefore low-chromium versions which have less corrosion resistance than Grade 304. The end result has been corrosion failures in some applications and dissatisfied customers. In addition, there are concerns that this 200-series material may contaminate the existing stainless steel recycling circuit which is based on Grade 304.

The 200-series are a technically valid family of stainless steels but, like all stainless steel grades, they have their limitations. If you are considering the use of a 200-series material then you should ensure that you have all the necessary information that you require to make a rational judgment – mechanical and physical properties, corrosion performance in your environment etc. And it is strongly recommended that you deal only with reputable and knowledgeable suppliers who can provide high quality material of known origin.

BACKGROUND

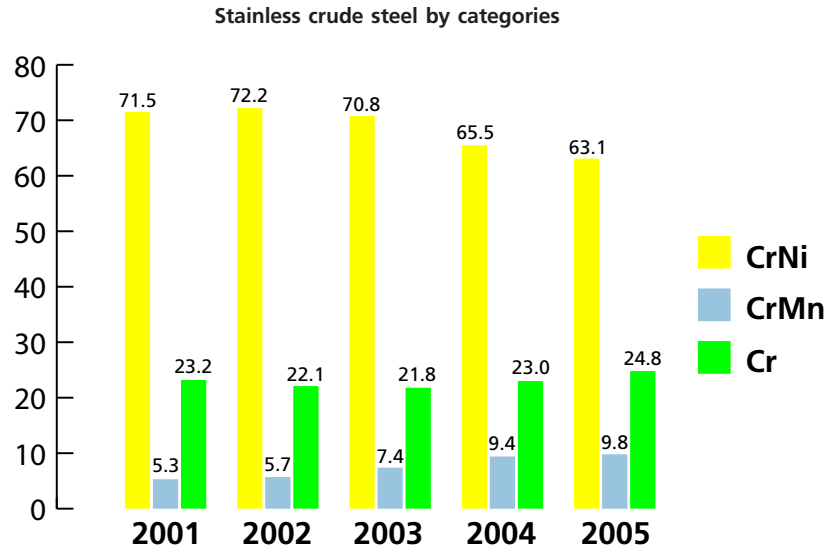
There are five families of stainless steels. Three of these have specialized properties and relatively low market shares:

- Martensitic 2%
- Precipitation hardening 1%
- Duplex 0.6%

The other two families are used in large volumes:

- Austenitic 72%
- Ferritic 24%

There are two types of austenitic stainless steel: 300-series and 200-series. Most stainless steel used around the world is of the 300-series type but 200-series use has increased significantly over the last couple of years during which nickel prices have been high. The International Stainless Steel Forum (ISSF) estimates usage by weight according to the following graph:



HIGH VOLUME STAINLESS STEELS

The nature, characteristics and uses of the ferritic and austenitic grades may be summarized as follows:

Ferritic stainless steels

The term "ferritic" describes the crystal structure of this family of stainless steels. In a carbon steel, the atoms of iron (Fe) are arranged in a pattern called "body centred cubic". There is an atom of Fe at each corner of a cube and one in the centre of the body. Metallurgists call this structure "ferrite".

Stainless steel is made by adding chromium (Cr) to steel, since a very thin chromium oxide layer then forms on the steel surface and it is this which gives the metal its "stainless" appearance and corrosion resistance. When Cr is added to steel in this way, the crystal structure does not change since Cr is a ferrite former. All that happens is that some of the Fe atoms are replaced by Cr atoms in proportion to the composition of the stainless steel. That is why this material is called "ferritic stainless steel".

These cubes of atoms are very small – there are a billion billion of them in each cubic millimeter of steel. But they are very important since they are the basic building blocks of the metal and they give the metal its mechanical properties (such as strength) and physical properties (such as magnetism).

Ferritic stainless steels have the general characteristics:

- Usually cheaper (because they have no or low nickel content)
- Less formable and weldable than the austenitic grades
- Lower thermal expansion coefficient than the austenitic grades
- Excellent resistance to a type of corrosion known as chloride stress corrosion cracking
- Magnetic

The largest single application for ferritic stainless steel is for automotive exhaust systems where Grade 409 is the most common grade. But they are also used for many other items such as washing machine drums, bright trim on automobiles, roofing, siding and railway wagons for coal and iron ore. They represent about 25% of all the stainless steel used worldwide.

Austenitic stainless steels

The term austenitic describes another type of crystal structure. Some elements have the ability to change ferrite to austenite when they are added into stainless steel. They are called austenite formers and the best known and most widely used of these is nickel (Ni). If sufficient Ni is added, the crystal structure changes from ferrite to a structure where there is one atom at each corner of the cube and one in the middle of each face – this "face

centred cubic" structure is called "austenite":

When Ni is used to create the austenite structure, the resulting stainless steels are known as the 300-series. The most common of these is Grade 304 which contains approximately 18% Cr and 8% Ni. This 8% Ni is the minimum amount of Ni which can be added into an 18% Cr stainless steel in order to change all the ferrite to austenite. Another common 300-series grade is Type 316 which is essentially Type 304 with 2% molybdenum (Mo) added to improve corrosion resistance.

Ni is not the only element which can change ferrite into austenite. Nitrogen (N) is also very powerful at doing this. But it is a gas and can only be added in limited amounts before problems arise, such as the formation of chromium nitrides and even gas porosity. However, manganese (Mn) is also an austenite former and has the additional characteristic that it allows more N to be added. So Mn and N, sometimes with copper (Cu), may be used to replace some of the Ni and the resulting stainless steels are known as the 200-series. They are commonly referred to as the CrMn stainless steels, although it is the N which has the greatest effect in forming austenite. A combination of Mn and N is normally not sufficient to change all the ferrite to austenite so some Ni is still added, although in a smaller amount compared to what would be used in a 300-series grade.

The austenitic stainless steels have the general characteristics:

- Usually more expensive than the ferritic grades (the 200-series are usually cheaper than the 300-series)
- Good formability and weldability – generally much better than the ferritic grades
- Excellent toughness (impact resistance) even to very low, cryogenic temperatures – ferritic grades have poor low temperature toughness
- Not magnetic (although some small degree of magnetism can develop when cold worked, such as in a bolt or at a bent edge)

The combination of good formability and weldability mean that the austenitic grades have good fabricability – they can easily be used to manufacture all manner of items. It is for this reason that the 300-series dominate stainless steel use worldwide.

TYPES OF 200-SERIES STAINLESS STEELS

Because of the increased use of CrMn grades over the last couple of years, there is a tendency to think of them as a new development. However, they have been around since the 1930s and a lot of development work was done in the 1940s and 1950s, particularly in USA, because of a shortage of nickel at the time. Useful alloys which came out of that work were registered with the American Iron and Steel Institute (AISI) and given AISI numbers (such as 201) and Unified Numbering System (UNS) numbers (such as S20100). Some of the most common of these registered 200-series grades are set out in table 1 (below), compared with the composition of Grade 304

Another interesting development occurred in India in the 1980s. India has no indigenous supply of nickel and imported nickel was very expensive. So, to develop the market for stainless steel, local producers turned to the 200-series. Grades such as J1 and J4, developed by Jindal Stainless Limited, became widely used (table 2 below).

These grades were mainly used in India for cookware, and very successfully. Ferritic grades such as Grade 430 could also have been used to avoid the cost of nickel but CrMn grades were chosen because they are not magnetic. Indian consumers who were buying cookware had already associated quality with non-magnetic stainless steel, since high quality products had been mainly made from Grade 304. Lower quality, cheaper items had been made from Grade 430, which is magnetic, so the belief arose among consumers that high quality stainless steel was non-magnetic. CrMn grades, which are austenitic and therefore non-magnetic, fit that requirement. However, it should be noted that magnetism has absolutely nothing to do with corrosion resistance – this was a consumer perception only.

TABLE 1: REGISTERED 200-SERIES GRADES

Grade		WChemical composition (wt%)			
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 – 1.75	14.0 – 15.5	0.32 – 0.40

TABLE 2: GRADES J1 AND J4

Grade	Chemical composition (wt%)				
	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	0.2 max	1.5 - 2.0

This decade has seen a significant rise in stainless steel use, particularly in Asia. This has been accompanied by high nickel prices. As a consequence, the market share enjoyed by 200-series grades has doubled from about 5% to about 10%. And this growth has occurred in grades such as J1 and J4, which are 4% and 1% Ni grades respectively. Because of the desire for cost saving, the 1% Ni grade became particularly popular.

It should be noted that these grades, such as J1 and J4, are proprietary alloys – they are company specific and not covered by international codes and specifications, unlike the traditional 200-series grades such as Grade 201. So their composition is at the discretion of the manufacturer and there are now many small producers of grades such as these in China.

DIFFERENCES BETWEEN 200-SERIES AND 300-SERIES STAINLESS STEELS

The differences between these two series of stainless steels may be summarized as follows:

Corrosion resistance

In all of these stainless steels, Cr is trying to form ferrite while the austenitising elements, Ni, N, Mn and Cu, are trying to form austenite. The higher the Cr content, the more austenitising elements are needed to change all the ferrite to austenite. J4 is a good example – in order to get the Ni level down to 1% Ni, and so minimize the price, it has been necessary to reduce the Cr content to 15-16%. This is much lower than the 18.0 – 20.0% Cr specified for Grade 304 and it is Cr which makes the greatest contribution towards corrosion resistance. This means that such 200-series grades have lower corrosion resistance and are suitable for a much narrower range of applications than Grade 304. This has not been well understood and there are many instances where 200-series grades have failed due to corrosion, such as when they have been used for components like handrails in exterior applications.

Another issue can be high levels of impurities such as sulphur (S) in some 200 series grades. Sulphur significantly reduces resistance to corrosion such as pitting. High S is not a problem which is inherent in 200-series grades; it is a problem caused by poor steelmaking practices, and has been observed in some 200-series material made by small producers with inferior equipment and practices.

A similar situation applies to carbon (C) which is normally controlled to very low levels during steelmaking in order to avoid welding problems. High C has been measured in some 200-series material manufactured by small Asian producers and this can result in intergranular corrosion when welded structures are put into corrosion service.

Strength and hardness

Nitrogen is a very effective strengthening addition. As a result, the 200-series grades are generally stronger and harder than the 300-series. This can be quite significant and useful

in some applications. Grade 201, for instance, has a yield strength about 30% higher than Grade 304. And some very specific high strength 200-series grades have been developed for applications such as propeller shafts on motor boats and for resistance to galling.

Formability

The downside to this higher strength is that the 200-series grades are generally more difficult to form. Formability can be improved by the addition of copper which also has the benefit that it is an austenite former.

RECYCLING

The positive image which stainless steel enjoys is enhanced by its very high level of recycling. Little stainless steel is lost to landfill because it is an inherently valuable material, and it is the nickel content which represents most of the scrap value. But because both 200-series and 300-series grades are non-magnetic, it is not possible to separate them except by sophisticated analysis. As the amount of 200-series material in the community increases, so too does the likelihood of this material getting into the established 300-series scrap circuit and causing contamination with manganese, copper and possibly other impurities. This is an issue of concern to the entire stainless steel industry since anything which disrupts the efficient recycling of stainless steel has the potential to damage the whole industry.

CONCLUSION

CrMn grades of stainless steel have been in existence for many decades and have been successfully used in numbers of applications. But there have also been many failures and unsatisfied customers. This has particularly been the case over recent years with the rapid growth of these materials in China and South East Asia. Because they are non-magnetic, they cannot be easily distinguished from Grade 304 and this has led to their misuse in some cases.

Even when 200-series material is identified as such, it must be recognized that it may not have the same level of corrosion resistance, formability and weldability as a 300-series grade. Consequently, it is most important that anyone considering using these grades should have all relevant mechanical, physical and corrosion data in order to be satisfied that the material will be suitable for the intended purpose. Ideally, case histories should be available to verify the satisfactory performance of the material in applications similar to that being considered.

It is strongly recommended that 200-series material should only be sourced from reputable and knowledgeable suppliers.

ADDITIONAL INFORMATION

If you are seriously considering the use of a 200-series grade, it is recommended that you also visit the ISSF website www.worldstainless.org and read their article: "New 200-series" steels: An opportunity or a threat to the image of stainless steel?

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