What is the difference between EN 1.4404 and EN 1.4571?

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Introduction

The two steels EN 1.4404 and EN 1.4571 are two variants of a standard "acid-proof" steel (EN 1.4401).

The objective of these variants are primarily to fulfil the purpose of being able to manufacture the steels without loosing corrosion resistance as a consequence of structural changes in the heat-affected zone, and the two variants are the expression of two methods to obtain the same result. One method is related to older and less advanced steelwork technology compared to the other.

The aim of both types is to avoid precipitation of chromium carbides, for instance by welding.

How the chromium carbides result in a reduction of the corrosion resistance is described in the section: "Detailed review on the background for selecting either EN 1.4404 or EN 1.4571" at the end of this report.

How important the problem with loss of corrosion resistance is in practice depends on how much carbon is present to react with chromium, and how long time it has for the reaction.

The relation is this: The less carbon present to react with chromium, the more liberty is obtained with regard to process time i.e. welding, hot forming and heat treatment.

The chemical compositions of the two variants are shown in Table 1.

Steel	C	Si	Mn	P	S	Cr	Mo	Ni	N	Others
EN 1.4404	≤0.03	≤1.00	≤2.00	≤0.045	≤0.015	16.50-18.50	2.00-2.50	10.00-13.00	≤0.11	
EN 1.4571	≤0.08	≤1.00	≤2.00	≤0.045	≤0.015	16.50-18.50	2.00-2.50	10.50-13.50		Ti: 5 x C-0.70

Table 1. Chemical compositions of the two steels.

The basic difference between the two steels are, except for the marginal differences in the nickel content, the following:

EN 1.4404 is a low-carbon steel with a carbon content of maximum 0.03% C.

EN 1.4571 is a titanium-stabilised steel with a carbon content of maximum 0.08% C, but with a titanium content of 5 times the actual carbon content – that is enough to bind most of the carbon as titanium carbides. In practice the stabilised steel can be considered an alloy with maximum 0.02% C.

There exist diagrams,[1] which show that, in practice, work can be executed in the temperature range 600 – 900°C for a total of approx. 8 hours at 0.03% C and more than 10 – 20 hours at 0.02% C.

This difference has no influence on the welding, which does not require so long heating time.

In connection with unusually long heat treatments there may, as it can be seen, be a difference between the two types of steel.

Welding properties, here is a very small difference
The two types of steel have the same welding properties. In general the same type of filler metal/deposited metal can be used, typically this is low carbon-containing. Yet, as described below, critical corrosion conditions may arise where the risk of intercrystalline corrosion makes it necessary to use a niob-stabilised filler metal/deposited metal for EN 1.4571.

In connection with gas protection of the root side, the socalled root gas, special conditions may be present in the case of EN 1.4571. If you use nitrogenous protective gas, as e.g. Formier gas, a golden surface will appear at the root side of the weld seam. This is caused by the occurrence of titanium nitride, which gives the yellow colour. In connection with corrosion no negative consequences of the presence of titanium nitride have been observed.

In the introduction it was mentioned that EN 1.4571 is related to a less advanced technology. Therefore a generally higher content of impurities may be present in stabilised steels from certain works, which may entail a few more small slag particles on the weld seams.

EN 1.4404 is slightly superior with regard to machining
The hard titanium carbides entail more wear on the tools and require lower processing velocities during mechanical processing than the case for EN 1.4404.

Mechanical shaping is more limited for EN 1.4571
The content of carbides affects the material's ductility so that the titanium-stabilised EN 1.4571 is less suited for cold shaping, i.e. deep drawing and bending. Firstly the elongation properties are inferior, and secondly big carbides, if any, may lead to microfractures at the surface.

The physical and mechanical properties are almost the same
In general the physical properties of the two steels are the same. In one point there is a noticeable difference, namely in the coefficient of thermal expansion. The expansion is up to 5% larger for EN 1.4571 than for EN 1.4404.

The carbon content of stainless steel has a positive influence on the strength, especially at elevated temperatures. The carbon content in EN 1.4404 is kept low, while it is allowed to remain high in EN 1.4571. As a result the strength in the annealed condition is higher for EN 1.4571. Table 2 shows as example $R_{p0,2}$ at different temperatures for the two steels as well as for the corresponding standard steel EN 1.4401.

Steel	**Max. carbon content %**	**$R_{p0,2}$ at 20°C N/mm²**	**$R_{p0,2}$ at 200°C N/mm²**	**$R_{p0,2}$ at 500°C N/mm²**
EN 1.4404	0.03	190	137	100
EN 1.4401	0.07 (0.05)	205	147	110
EN 1.4571	0.08	210	167	129

Table 2. Relative strength for acid-proof steels.

The table shows that the difference between the two steels becomes bigger, the higher the temperature. The figure for carbon content in parenthesis is the normal level for EN 1.4401. It can thus be seen that the relative strength follows the carbon content.

For cold worked material the strength is, by and large, the same, as it depends more on the degree of deformation than on the composition of so closely related steels.

Only a slight difference in the corrosion properties

The corrosion properties of a stainless steel are primarily determined by the content and the distribution of the alloy elements chromium and molybden. The content of impurities and intermetallic phases are also crucial for the corrosion resistance of the steel. In this connection EN 1.4404 is considered a slightly purer and more homogeneous steel grade than EN 1.4571, which, altogether, means that EN 1.4404 is slightly more corrosion resistant than EN 1.4571. However, this difference is only important in few applications.

Titanium is regarded as having a negativ effect on the steel's corrosion resistance against the localised corrosion forms such as pitting and stress corrosion cracking. On the contrary titanium has no effect on the crevice corrosion resistance. Yet it should be added that the mentioned effects of titanium are considered marginal, and, according to experience, are without importance in practice regarding localised corrosion. One single exception is intercrystalline corrosion, where the risk is generally larger for the EN 1.4571 grade. In special cases, where this steel has been through an unfortunate heat treatment in connection with welding and subsequently is exposed to an acidic, strongly oxidizing environment (i.e. strong nitric acid), a special form of intercrystalline corrosion ("knife-line attack") may occur. For this reason EN 1.4404 is regarded better suited for corrosive environment with strongly oxidizing conditions.

EN 1.4571 is not suited for high mirror finish

In contrast to EN 1.4404 the titanium-stabilised EN 1.4571 grade is not suited for high mirror finish. This is due to the presence of hard titanium carbide particles that lead to scratches by mechanical polishing or buffing.

As titanium carbide is more difficult to dissolve than the basic material itself, electropolishing is also an improper process for EN 1.4571. Electropolishing of EN 1.4571 will typically lead to a "mottled" surface, whereas a perfect mirror-like surface can be obtained with EN 1.4404.

The problems with mechanical as well as electropolishing of stabilised steel can vary a lot, depending on the actual carbon content and the course of temperature during steel processing and heat treatment.

Items for polishing should therefore be produced mainly in EN 1.4404. Alternatively you should specify the requirements for carbide content, either by stating the maximum carbon content and size of carbide, or by taking a sample in the actual finish.

Detailed review on the background for choosing either EN 1.4404 or EN 1.4571

The objective is to avoid precipitation of chromium carbides by welding

By heating of a stainless steel to 600-900°C the alloy elements chromium and carbon begin to interact. The reaction products, chromium carbides, contain first and foremost chromium and carbon, and are characterised by the fact that the chromium content is very high compared with the carbon content. Chromium bound in carbides are not available for corrosion resistance, and can thus be considered removed from the steel. As the carbides, as mentioned, need much chromium, precipitation of chromium carbides means that the chromium is taken from the adjacent areas. This means that narrow material zones along the grain boundaries may contain so little chromium that they are no longer corrosion resistant. Precipitation of chromium carbides is thus equal to loss of corrosion resistance. Especially the temperature range 600-900°C is critical as a consequence of insufficient diffusion, that is supply of chromium from inside the grains to the grain boundaries where it is lost due to the formation of carbides.

When welding a stainless steel the temperature in the melting bath rises to approx. 2000°C. At some distance from the melting limit the steel does not get hot. Therefore there is an area where the temperature goes from room temperature and up to the high temperatures in the melt. This area is known as the heat-affected zone. In this heat-affected zone, the temperature can stay for the longest time in the critical area, and thus it is also here that the loss of corrosion resistance may occur.

The higher carbon content in the steel, the faster, and to a larger degree, the chromium carbides are precipitated. A steel with 0.08% carbon can only endure heating to 800°C for approx. ½ minute before carbide precipitation is started. It is thus obvious that it will be an advantage to reduce the carbon content to avoid carbide precipitation in connection with welding of the steels.

Modern steel work technology makes it possible to remove carbon from the stainless steel – for instance by the AOD and VOD methods. Therefore the limit of carbon content in standard steels is approx. 0.045%, though the standard tolerates up to 0.07%. The 0.045% gives enough margin to weld in reasonable material thicknesses with well-executed procedures without getting problems with carbide precipitations. If the work is to be done in large material thicknesses, a larger heat input or room for repairs of the welding are needed, the carbon content must be reduced further.

Here the two special variants come into the picture.

By the modern methods the carbon content can be further reduced, i.e. so that a socalled low-carbon version with a maximum content of 0.03% carbon is achieved. Here the tolerance is several hours in the dangerous temperature range before precipitation of carbides takes place. Previously it was difficult to obtain the low-carbon content by removing carbon. Therefore another method was used where, instead of removing the carbon, it was veiled by reaction with titanium. When the carbon is first bound to titanium, it cannot react with chromium – the steel is ”titanium-stabilised”. By welding a titanium-stabilised steel acts as if the carbon content was around 0.02% - that is very low.

[1] Reference for instance: Corrosion resistant stainless steel - How? E. Rislund, Industriens Forlag, 1996.

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