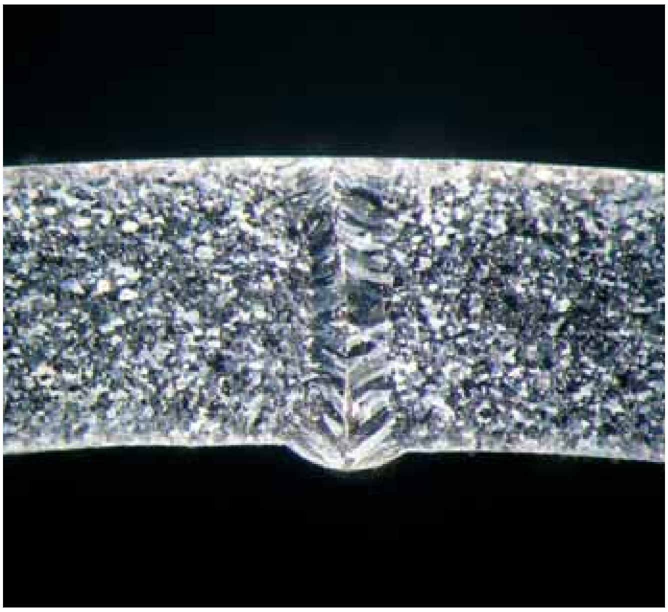
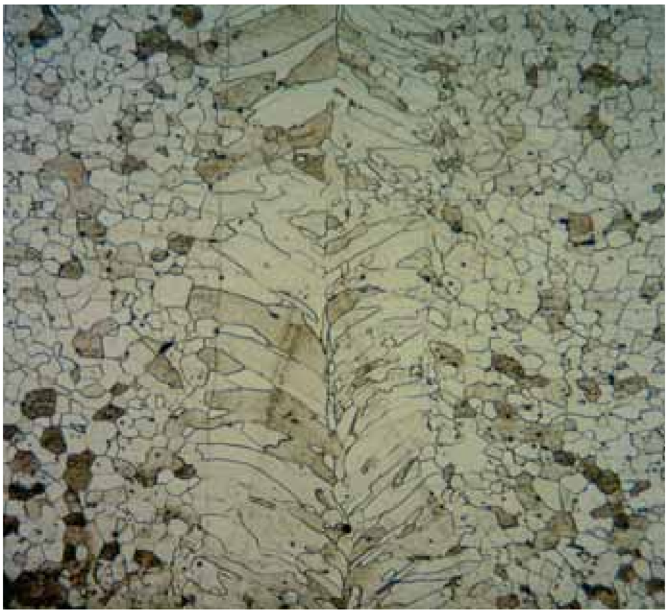
Ferritic chrome steel, 1.4521 – new material for stainless steel pipes in drinking water installations

Nickel-free ferrite offers the same corrosion resistance as the nickel-alloy material 1.4401 – with more stable prices

Sven Pitzer, Technical Manager



Text to Fig. 1: Macro image, overview of narrow laser weld seam 1.4521



Text to Fig. 2: Microstructure image, cross-section of narrow laser weld seam 1.4521

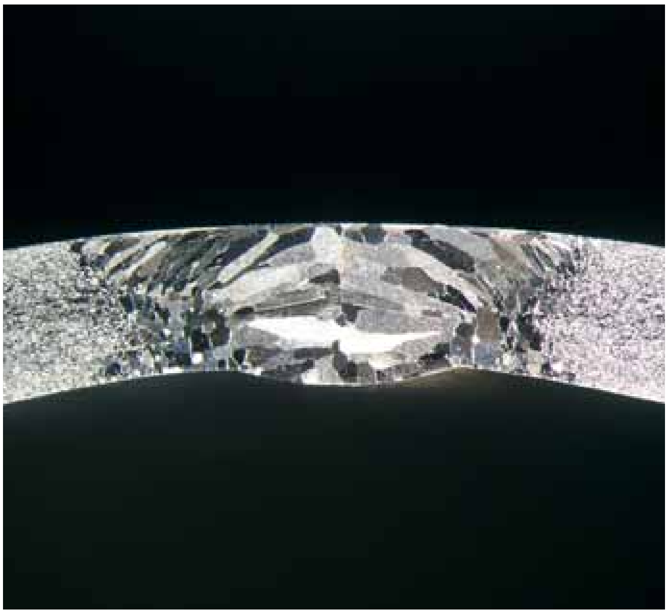
The extension of the austenitic range of materials to manufacture stainless steel pipes for domestic drinking water installations by a ferritic chrome steel is a genuine innovation in the field of "stainless steel" on account of the good cost-effectiveness with continued use in the drinking water segment. As with every innovation, there are critics who systematically discredit the new material. We thus want to try and provide initial answers to the questions circulating on the sanitary market and explain the properties of ferritic chrome steel in more detail.

Before dealing with the opinions and delegations from the market, we would just like to mention that the German Association of the Gas and Water Industry (DVGW) has tested the new alternative ferritic material and has declared this to be worthy of approval as a supplement to their rules on the basis of a resolution. Consequently, some manufacturers have already successfully completed their first tests. Products approved by the DVGW are rightly regarded as being safe and harmless for use in the designated field of application. For this reason alone, consumers can trust in the high quality of the new ferritic chrome steel 1.4521 on the sanitary market, allowing its risk-free use as a drinking water pipe.

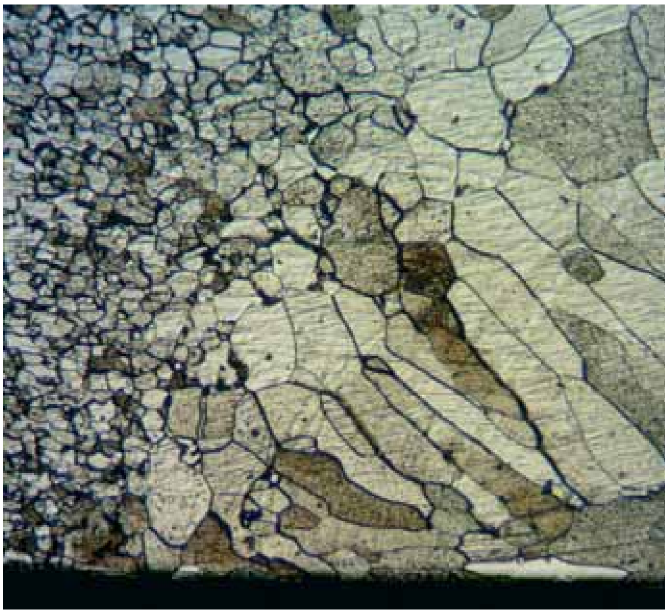
The following information relates to the materials 1.4401/1.4404 and 1.4521 in the segment of thin-walled stainless steel pipe for domestic drinking water installations which has been welded automatically with no admixing of fillers according to the Tungsten-Inert-Gas (TIG) or laser method. The focus lies on the practical consideration of common features and differences.

HOW NEW IS 1.4521?

The ferritic stainless chrome steels are generally younger than the austenitic qualities with respect to their widespread distribution, through the technical knowledge has been around just as long and are founded on an equally good technical basis. Their further use, however, has not been pushed as strongly since in the past, nickel did not have such a dramatic effect on the price as an alloying element for the austenitic materials. Furthermore, the manufacture of stainless chrome steels placed other demands in terms of plant and process engineering on the manufacturing and processing industries. The austenitic qualities are often easier to handle, the tolerance window for various processes (e.g. welding) are larger. Ferritic qualities only became interesting for further fields of application following the dramatic rise in the price of nickel in conjunction with the further improved melting and manufacturing technology. Apart from the traditional fields of applicant such as panelling for so-called "white goods", façade elements, roofs or automobile exhaust systems, operators of heat exchangers in power plants also rely on the properties of ferritic steel. Domestic drinking water installations are now a justified field of application for the "new" material 1.4521 too.



Text to Fig. 3: Macro image, overview of relatively wide TIG weld seam 1.4521



Text Abb. 4: Micro image, transition molten material/parent metal TIG weld seam with grain coarsening

CAN A MAGNETISABLE MATERIAL BE A "GENUINE STAINLESS STEEL"?

The question of corrosion resistance has nothing to do with the magnetisability. The difference lies in the crystallites of both alloys: austenite, with its cubic, face-centred lattice (cfc) (such as can be found for example in aluminium, copper, silver and gold) is hardly magnetisable. We are all familiar with the differences as regards the corrosion properties, e.g. between aluminium and gold, both non-magnetisable materials. Pure nickel also has a cubic, face-centred lattice, but is ferromagnetic like iron. Nevertheless, the excellent corrosion resistance of pure nickel is undisputed. The corrosion resistance thus has to be due to something other than the magnetisability, which briefly speaking is caused by the alignment of magnetic fields in the crystallites of ferromagnetic materials through the influence of an external field. The lattice structure of stainless chrome steels is cubic body-centred (cbc). The lattice differences cfc / cbc lead to differences in the deformation characteristics through a different arrangement and number of gliding planes in the main axis. Of course, magnetisable steels can thus be "genuine stainless steels", they simply belong to a different group.

IS THE CORROSION RESISTANCE EQUAL?

The corrosion resistance of 1.4521 and 1.4401 can be seen as identical. In fact, 1.4521 is in some aspects (e.g. insensitive to stress corrosion cracking) is slightly more resistant than the familiar 1.4401. This has been demonstrated by both our own comparative electrochemical tests as well as in publicly accessible reports. This is not surprising considering that the elements chrome (Cr) and molybdenum (Mo) are the decisive elements in certain alloys with respect to the corrosion resistance. In order to assess the material behaviour under a corrosion load a formula has been developed to calculate the "Wirksumme" (W). This corresponds to the "PRE" (pitting resistance equivalence) mentioned in some publications and is a measure of the theoretical pitting resistance of a material. The PRE is based on the realisation that there is a linear correlation between the level of the chrome and molybdenum content and the pitting resistance. There are various ways to calculate the PRE due to the different integration of the nitrogen content with very high alloy austenites or duplex materials. The following calculation, however, is normally accepted for 1.4521 and 1.4401: PRE = %Cr + 3.3 x %Mo. Assuming the minimum content for Cr and Mo pursuant to the product standard, in the case of 1.4521 DVGW has increased the minimum value compared to the product standard through a resolution on the set of rules – this results in a value of 23.1 for 1.4401 (Cr min. 16.5 / Mo min. 2.0) and 24.1 for 1.4521 (Cr min. 17.5% / Mo min. 2.0%). Modifications of 1.4401 are also available that have increased the molybdenum content to at least 2.3%. The PRE is then on the same level as modified 1.4521.

CAN FITTINGS OF AUSTENITIC MATERIALS BE CONNECTED TO PIPES OF 1.4521?

Allegations have been made on the market that the differences in the electrochemical series leads to corrosion problems. This risk does not exist. The materials are of a similar order and may be connected directly to each other, just like the pairing gunmetal/stainless steel. Austenitic filler metals are even approved and harmless in welding technology to weld together ferritic steels.

CAN THE FORMER DISINFECTION METHODS STILL BE USED IN FUTURE?

The methods for basic and permanent disinfection previously used for 1.4401 remain valid with no change provided on observes the correct procedure (manufacturer's documents, DVGW Worksheets).

DOES 1.4521 HAVE A SUFFICIENT SPALLING RESISTANCE?

The spalling resistance of ferritic steels is more than sufficient for the sanitary sector. It is true that austenitic materials are superior in the temperature range of around 500°C and above, but the materials are identical up to this figure.

"1.4521 IS NOT VERY DUCTILE AND HAS A LOWER ELONATION AFTER FRACTURE"

The statements made on ductility are generally based on the higher permanent limit of elongation ($Rp_{0,2\%}$) compared to 1.4401, with is at least 205 N/mm² for 1.4401 according to standards (welded pipes EN10296-2) and at least 280 N/mm² for 1.4521. It should be noted that pipes of 1.4401 which have been available up to now on the market, for example of the size 15 x 1 mm, had a 0.2% proof stress of between 270 and 450 N/mm² for the different manufacturers. Nevertheless, theses pipes could be processed with no problems. The practical value for 1.4521 is between around 350 and 400 N/mm², and thus well within the normal range for processors. The theoretical force that has to be exerted to start a deformation is thus only higher compared to very well solution annealed pipes of 1.4401, though in exchange the hardening does not increase during deformation as much as with 1.4401. In any case, the common cold bending of the pipes is still possible with no restrictions, Fig. 5. The elongation after fracture according to the aforementioned standard is at least 40% for 1.4401 and at least 20% for 1.4521. Practical values for the product are between around 50 to 60% for 1.4401 and 30 to 35% for 1.4521. Thus although chrome steel falls noticeably shot of the figures for 1.4401, in absolute terms the elongation reserves are fully adequate for all processing steps for domestic drinking water installations.

Text to Fig. 5: Pipe with the dimension 22x1,2, bent with r = 2.5 x d, result: 1.4521 no difference to 1.4401

DOES THE WELD SEAM CONCEAL THE RISK OF INTER-CRYSTALLINE CORROSION (IC) AND A DROP IN TENACITY DUE TO THE COARSE GRAIN?

There are no objections to the use of the material 1.4521 in terms of inter-crystalline corrosion. It is true that diffusion processes leading to precipitations take place much faster in ferritic chrome steels than in austenitic materials thus the basic risk of IC is higher. However, 1.4521 is stabilised by the elements titanium and niobium in the DVGW modification. This means that the elements carbon and nitrogen, which cause the precipitations through the effect of heat (welding), are bonded into stable and harmless compounds. Double stabilisation with titanium and niobium also has the advantage over simple stabilisation with only titanium or niobium that coarse titanium carbonitride precipitations are avoided and at simultaneously this counteracts the tendency of clinking with simple niobium stabilisation. In addition, the amount of stabilising elements added is determined by the formula of at least 4x(C+N)+0.15% up to a maximum of 0.80% in the ratio of carbon to nitrogen so as to ensure adequate stabilisation. Furthermore, the amount of carbon + nitrogen (C+N) is limited to a maximum of 0.040%. This alloying measure produces a safe material that clearly and undisputedly refutes the concerns expressed with respect to IC.

The question of the formation of coarse grains through the effect of heat in the transition area of the weld seam requires a more detailed answer. This is where the pipe manufacturers come in, who have to select appropriate welding methods and limit the energy input per unit length so as to avoid disadvantageous coarse grains. One very safe method that can be named here is laser welding, which has only a very low energy input per unit length and coarse grains need not be feared in the transition area, Fig. 1 and 2. This helps retain the mechanical properties of the parent metal and the formability in the weld seam area too. Classic Tungsten-Inert-Gas (TIG) welding has some inherent disadvantages. A relatively large molten bath is produced which can lead to the formation of coarser grains in the adjacent material through a higher thermal input, Fig. 3 and 4. Useful results can also be achieved here by modifying the TIG process (e.g. TIG plasma, pulsed welding current, etc.). Manufacturers have a particular responsibility here to offer customers a in controlled and professionally processed product. Fig. 6 shows the differences that appear during the classic flaring test on the two materials with the chosen test set-up and the laser / TIG welding method. 1.4401 (laser welded) achieves a flaring of 31.5% before the pipe bulges and no longer flows over the flaring cone. 1.4521 (laser welded) achieves a flaring of 42.5% before the pipe bulges on account of the lower hardening tendency, making it superior to the austenite. 1.4521 (TIG welded with coarse grain share, cf. Fig.. 4) tears at approx. 37% flaring in the weld seam transition area without deformation since the coarse grain structure produced by the excessive energy input per unit length during welding makes the forming properties worse.

Text to Fig. 6: Comparative flaring tests, laser welding for 1.4401 and 1.4521 ideal, the TIG weld of 1.4521 with crack through grain coarsening

SUMMARY AND ADVANTAGES OF 1.4521

The new alternative material thus has no disadvantages compared to former materials for applications in the field of domestic drinking water installations. Nevertheless, it should be pointed out that ferritic chrome steels have a lower thermal expansion, thus reducing stresses during installation. 1.4521 has a high creep resistance and is easier to cut and process, an important aspect when cutting pipes. During bending 1.4521 has a much lower tendency to spring back than 1.4401. Material producers have thus developed an truly interesting alternative whose technical and economic advantages have to be tested by each user for themselves.

Author: Sven Pitzer
Authorised Representative (Prokurist) and Technical Manager Esta Rohr, Siegen
Pictures: Esta Rohr