Is there a quality difference between seamless and welded tube for clean and ultra-clean applications?

By Cor Tiele – www.bpe-technology.com

Introduction
In the Semiconductor, Biotech and Pharmaceutical industry, tube and fittings with a low surface roughness and high purity are used for transporting pure and high-purity gases and fluids. For this purpose seamless and welded tube in AISI 316 is used. Connections with other components like valves and fittings are made with orbital TIG welding systems.

How do they manufacture seamless and welded tube with a length of 6 meters and is there more risk if you install a welded tube? In this article you'll find all relevant information.

Bio and Pharma – most frequent used diameter 1 ½ ”

Semiconductor – most frequent used diameter ¼”

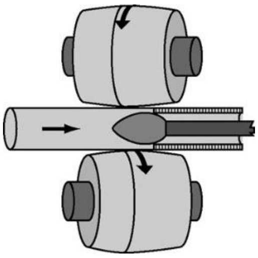
Background
Until 1970 a welded tube was oval and the longitudinal weld-seam was an uncertain factor. Pessimistic stories went around of experiences with over - and under thickness of the weld-seam, leakage, corrosion of the weld and in the HAZ while differences in the material structure caused challenges in weldability. Stories partly based on truth and partly supported by the manufacturers of seamless tube.
In this period there were increasing demands of the Semiconductor industry to improve the internal surface quality. The high purity gases, used to vaporize the "wafers" became purer and so more expensive – making the surface roughness and purity of the material as the most polluting factor. Stainless steel manufacturers responded by developing processes to remove material "impurities" when the material was almost finished, using VIM/VAR techniques (Vacuum Induction Melting and Vacuum Arc Re-melting). With these processes, the quality of the stainless steel could be improved each time it was re-melted as impurities moved to the upper liquid surface and could be removed. The idea was that with a reduced amount of impurities in the stainless steel, the material surface of a product would have fewer impurities too. Creating a more defined surface after electro polishing, having a better Cr/Ni ratio, getting a better Rt/Rz (Ra)… so a surface with a reduced risk. Having fewer impurities was an excellent idea, but at the end the positive effects were not big enough for the market to justify the increase in price per kilo/Ton.

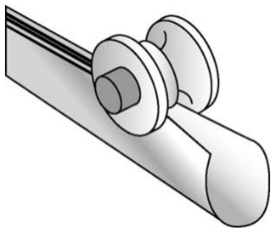
New stainless steel made from scrap

Plates rolled to a specific thickness

Production of an “Hollow”

At the same time seamless tube manufacturers fine-tuned their processes and some traders/stockholders started to cooperate with companies specialized in electro polishing. These developments - like the positive effects with regards to an increased quality of a gas at the point of use- meant that the Pharmaceutical industry wanted to implement those qualities in their production process too. However, there was a big difference between the semiconductor and the pharmaceutical industry with regard to applied diameters. In the semiconductor industry the bulk of the diameter is 6,35x0,89mm, while in the pharmaceutical industry 38,10x1,65mm is the most used. To cover the demands from the pharmaceutical industry, seamless tube in sizes from 38,10mm up to 76,20mm OD were manufactured, but with a price 10-fold from what the used to be, subsequently this did not result in orders. So manufacturers of welded tubes looked at the requirements and opened the doors to optimize their processes. This took place in the late 70s.



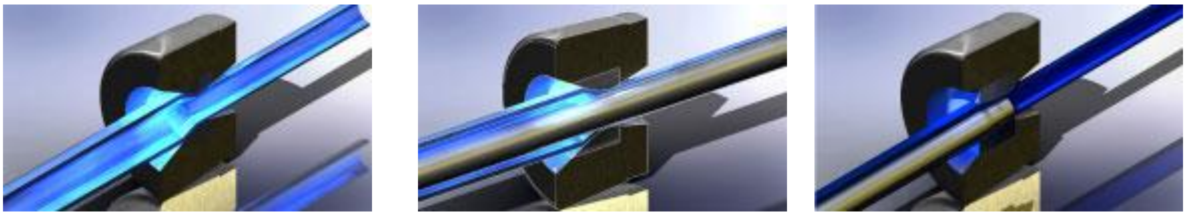


How it's made: Stainless Steel – YouTube

Manufacturing of seamless tube

Once there is roughly 70 tons of stainless steel scrap melted in the correct composition (the absolute minimum of demanded weight percentage), it is used to produce plates or "hollows".
To make a "hollow" the liquid stainless steel is being poured into a round shape and during the solidification a plug is pushed into the material – resulting in the first seamless tube.
"Hollows" are commonly used in combination with manufacturing methods using a "hardened rod" or a "plug".

The manufacturing starts by deforming one end of the Hollow in such a way that it fits into a holding-clamp. The clamp is connected to a chain/motor, with which the hollow can be pulled through a reducing collet/die. In this way large differences can be realized in the OD and Wth and as the length of the tube increases -for which automatic saw-equipment is implemented – they cut the tube into 'manageable' lengths. As it's a cold forming process, the material gets hard and brittle. In order to eliminate this, the tube is annealed at a temperature of 1050-1150^{0}C in an inert environment to normalize the structure of the material.
Having achieved the largest deformations, a different production method is chosen for which the ultimately desired quality (internal roughness and damage) is determined.

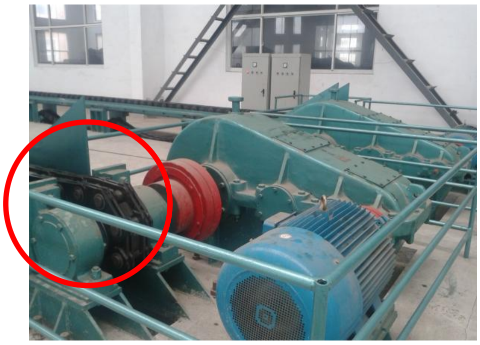


Sink drawing – rod drawing and plug drawing. Images of Fine-Tubes/Ametec.

The largest diameter reductions can be achieved by positioning a hardened stainless steel rod in the tube, but the disadvantage of this "Rod-drawing" method is that the rod must be removed out of the reduced tube, causing damages. Smaller OD-reductions are made with a "Plug-drawing" method.

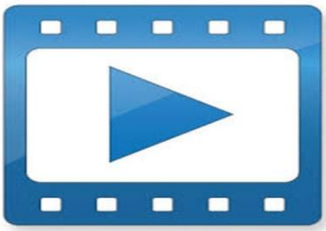
Here a plug (made of tungsten or vapour-deposited with diamond waste) is positioned under the collets into the tube. With this method the inner surface is controlled, as well as the OD and wall thickness.

Coiled tube



Size of the chain used for pulling tube through a collet/die

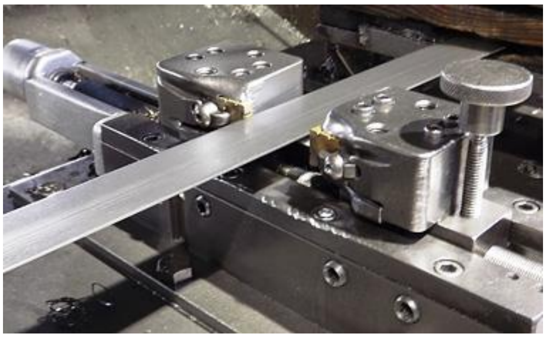
The inner surface quality of the tube depends to a large extent on the quality of the plug and a Ra≤0,2µm/8 µin is no exception. Both of these methods can then be followed by a number of steps to reduce the tube without using a rod or plug. The tube is just stretched, reducing the OD and wall thickness – and instead of cutting the tube at a manageable length – it is now rolled up creating coiled tube. Depending on the OD these coils may have a length up to 380 meters.
All tube undergoes a final heat treatment, is cleaned in a bath, is stretched (with straight tube), the OD is grinded, marked with relevant information and packed for shipment to the customer.



Forming, welding and trimming of steel tube

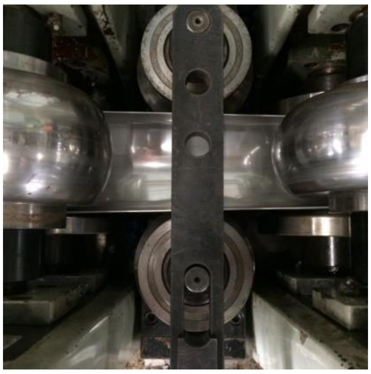
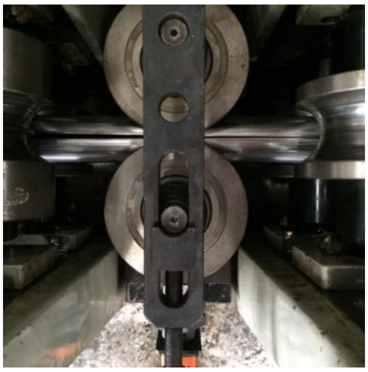
Manufacturing of welded tube
Everything starts with rolled plates after melting the stainless steel. The sheets are placed on equipment which deforms and rolls the plates to the required thickness and surface roughness and after every process step, the sheet is coiled and de-coiled. This is then delivered to a "strip-cutter", specialized in cutting the sheets to strips with a specific width and sometimes even a specific angle, called edging. Finally the coiled strips are supplied to a manufacturer of welded tube. Depending on the required diameter to produce, a strip with a specific width will be added into the equipment, where a series of rollers form the flat strip into a tube.

Sheet cut in strips



Edging a strip with a specific angle

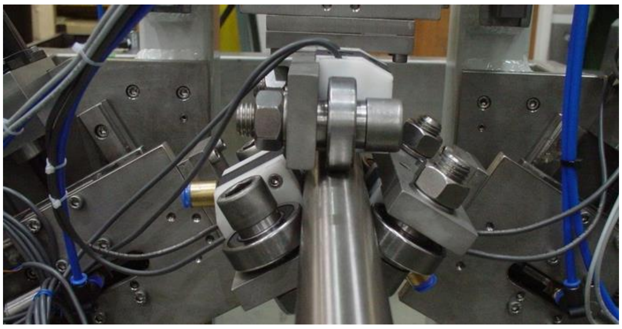
When the tube is formed and the two ends of the strip touch each other, the seam is welded in an inert atmosphere using a TIG or Plasma welding process – in general depending on the OD -. Directly after the welding process the over-thickness of the seam (OD and ID) is removed with a chisel and rolled away. The tube will be passed through a number of Collets to bring the OD within the specified tolerances and will be automatically cut-off into the desired length and collected. The tube will be annealed, cleaned, stretched, and grinded on the OD, marked and packed for shipment to the customer.


Images ofmanufacturing stages of welded tube at CSE Thailand

All seamless and welded tubes are inline checked for wall thickness and material density with Eddy Current testers and/or an Ultrasound test, when a wall thickness difference, a crack, or porosity is detected, this specific length will be automatically removed from the manufacturing process.
At the end of the manufacturing stages, seamless and welded tubes are annealed in an inert environment to bring the stainless steel to its original structure. As the furnace where the tubes are passed through has to maintain an inert atmosphere, rice (yes, indeed rice) is used to close the end of the furnace from oxygen. Some call this "soft annealed" as otherwise the material is hard and therefore brittle. Comparable to the car antenna we used previously: thin material, strong and especially hard. Hard means brittle, because when you accidentally bump against it, it breaks off. Usually all tubes and fittings are annealed, unless you specifically ask for a “hard” condition.

Inline Eddy-Current test



Inline Ultrasound test

Tubes passed into an annealing oven

After the heat treatment the tubes are not straight anymore, which is not important during the manufacturing steps – that’s why straightening of the tube is only done at the end.

Seamless tube is mainly used up till an OD of 1/2″ with a wall of .048″ (12,70x1,22mm) in the semiconductor industry. Larger sizes are normally manufactured in a welded condition, as production-wise it's easier to manufacture a seamless tube with an OD of 1/4″, 3/8″ or 1/2″ (6,35, 9,53 or 12,70mm) than in a welded variant with a smooth inner surface.

The available capacity among manufacturers of seamless and welded tube is almost incomprehensible, especially because the required space needed for production has diminished in recent years. CSE for example - which mainly manufactures tube to produce fittings- manufactures monthly 60,000 meters tube with 4 production-lines and still buying large quantities at specialized tube manufacturers.

Conclusion

There is a visual difference between a seamless and a welded tube - after all, the weld seam is recognizable in a welded version. This weld, however, has the same surface roughness (it is even obliged to have 1 of the 4 roughness measurements on the weld seam) and corrosion resistance as the rest of the material. In addition, there is an important difference in the tolerance of the wall thickness.

In a seamless tube, the standard tolerance is specified according to ISO 1127-T2 which allows a variation in wall thickness of +/- 12.5% (and at least 0.4mm). This can cause easily problems using Orbital welding equipment. When for example a tube has a nominal size of 19.05x1,65mm, the wall thickness can vary between 1,25 and 2,05mm without leading to rejection. The same standard is applied to welded tubes, but because these are produced from strip, there's actually not a risk for variations in the wall thickness.

Currently there's no difference in quality between seamless and welded tube. Both variants can be used in the Biotechnology, Pharmaceutical and Semiconductor industry - and are available from stock in the internationally desired surface conditions.

A choice for a specific use – or customer – can therefore best be based on the price per meter.

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