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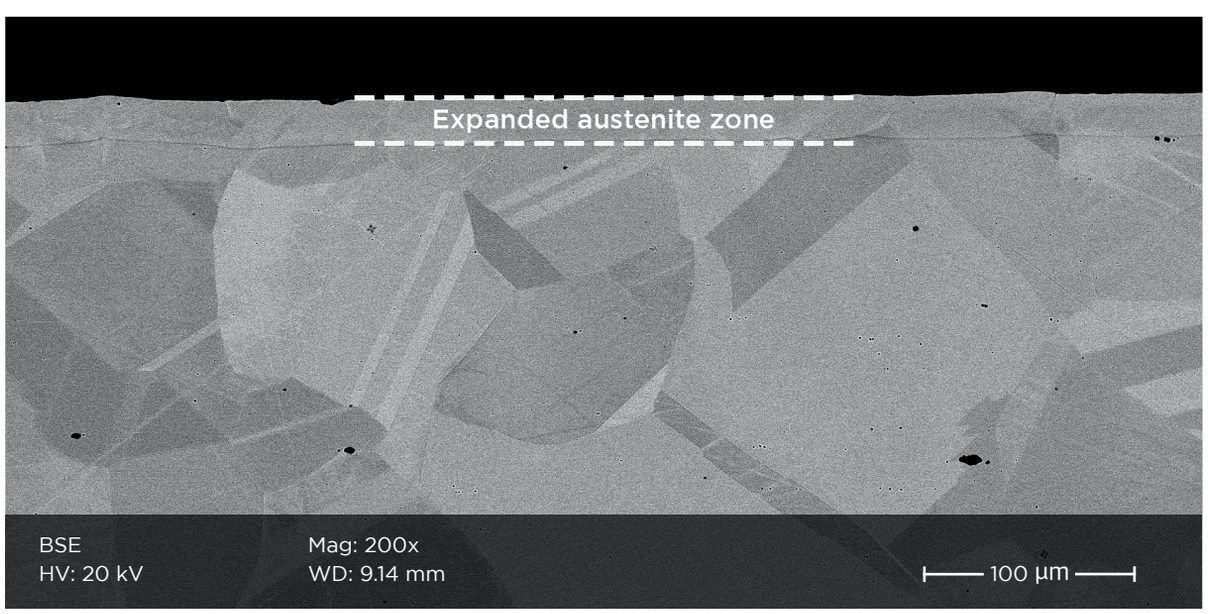
Stainihard® NC

whitepaper

STAINIHARD® MAKES STAINLESS STEEL HARDENING POSSIBLE

Stainihard® NC is a process for hardening the surface of (austenitic and duplex) stainless steel. By enriching the surface, using nitrogen and carbon, the hardness will rapidly increase (1200-1400 HV0.05), while tribological and fatigue characteristics will be enhanced. The unique thing about the Stainihard® process is that the corrosion resistance will not be adversely affected and will even improve in some cases!

Illustration below shows the shaping of the so-called *Expanded austenite zone* (s-phase), which is the result of the Stainihard® process in the surface of the product.



Caption: Stainihard®NC: 1200-1500HV0.01

This whitepaper discusses the technical aspects and advantages of the hardening of stainless steel by means of the Stainihard® process, compared with the application of a more conventional, but also more vulnerable, coating. This document finally discusses a great diversity of markets and applications, while the Aalberts Surface Technologies engineers involve the reader in the unique process.

HARDENING OF STAINLESS STEEL

Hardening of stainless steel is a relatively new process. From the 1970's and '80's, there has been a strong increase in the application of stainless steel. The application of stainless steel is ideal for example for the automotive and food producing industries, because of the resistance of the material against corrosion and the feature that it can be cleaned more easily than, for example, item's made from aluminum or copper alloy's.

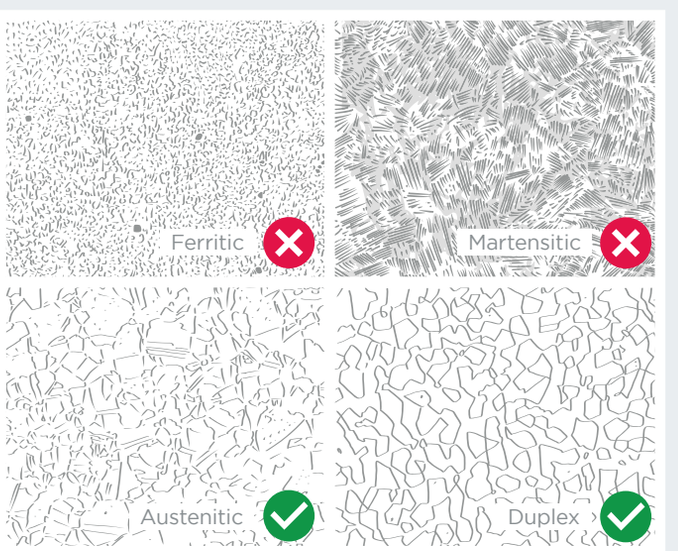
The austenitic metal structure of this type of stainless steel is unsuitable for hardening in a traditional way. It meant that stainless steel parts were subject to too much wear.

In the 1980's, a first process for hardening austenitic stainless steel was introduced, which ensured that this stainless steel could be used even more widely.

In metallurgy, Stainless Steel is defined as an Iron-Carbon alloy with a minimum or 11.5 wt% chromium content. A passive oxide layer is formed spontaneously on the surface, consisting of chromium oxide (Cr2O3). This layer is chemically passive in most environments. Steels with a minimum or 11.5 wt% chromium content are therefore considered as corrosion resistant.

The Stainihard® NC treatment is suitable for:
- Austenitic Stainless Steel
- Duplex and super duplex SS
- Specials such as 17 4 PH and NI-base alloys

Different types of stainless steel



Application on an industrial scale

At Aalberts Surface Technologies Eindhoven, not only the possibilities, but also the limitations of the available techniques were noticed. That is why the team went looking for an own process for the hardening of stainless steel. During the quest, the company found the Technical University of Denmark (DTU), where also a process was developed to harden the surface of austenitic stainless steel. Aalberts took out a license and together they unavailingly attempted to make this process suitable for industrial applications. Eventually, Aalberts autonomously developed a process that can be applied widely and has made its mark.

Meanwhile, Stainihard® has become a proven technique to harden stainless steel in a premium way and it is applied in a wide variety of markets

Industries as:
- Food & beverage machinery
- Medical and pharmaceutical
- Energy
- Automotive
- Oil and gas
- Process technology
- E-mobility
- Luxury goods

CHALLENGES IN THE HARDENING OF STAINLESS STEEL

But what makes the hardening of austenitic stainless steel so difficult? Corrosion resistant steel, also known as stainless steel, is an umbrella term for a number of alloys consisting mainly of iron, chrome, nickel and carbon, but also molybdenum, titanium, manganese, nitrogen and silicon. We speak of stainless steel if there is a minimum of 11.5% chromium and a maximum of 1.2% carbon in the material. The presence of the chrome ensures that in case of exposure to oxygen, a passive (chromium oxide) layer is created on the material that protects the material against external influences.

And although there are various possibilities for the hardening of stainless steel, in the event of austenitic and duplex stainless steel it is only possible to harden the surface. The most widely applied form of hardening is by means of diffusion of, for example, nitrogen and/or carbon in the surface. The difficulty here is that the chromium oxide surface counteracts this diffusion, just like corrosion or other external influences.

Hardening stainless steel with Stainihard®

Stainless steel hardening by diffusion requires a process during which the chromium oxide layer is temporarily removed. This can be done in various ways, however this involves the risk that the metal loses its corrosion resistance, which is common during the more conventional processes applied to ferro metals.

“ The corrosion resistance of stainless steel is dependent on free chromium for the formation of the chromium oxide film. It is important to retain this free chromium, even after the diffusion process. Above certain temperatures, under influence of Nitrogen and Carbon, Chromium will be bound as Chromium nitride and Chromium carbide. Then the metal loses its corrosion resistance properties.”

– Steffen Schneiders, Managing Director of Aalberts Surface Technologies Eindhoven

Figure for Aisi 304

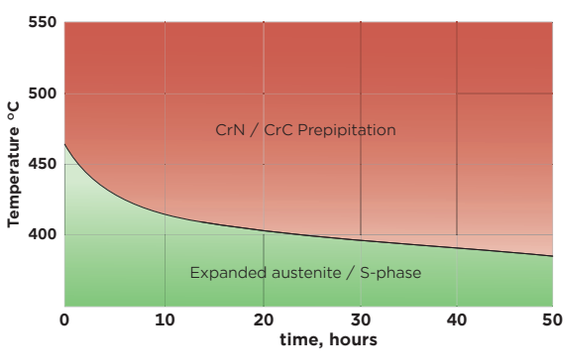
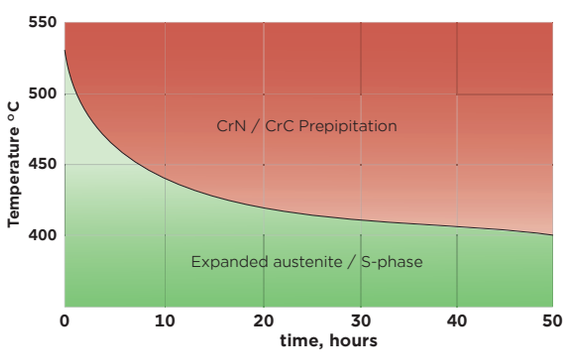


Figure for Aisi 316



Caption: The low treatment temperature is important to prevent the formation of CrN and CrC. Temperature against time for two austenitic types of stainless steel. Chromium nitride and carbide formation will emerge above the curve (red zone).

Stainihard® is Aalberts surface technologies process to harden stainless steel and maintain its corrosion resistance. Diffusion of N and C atoms at low temperature gives an expanded austenite hardened zone with the result that stainless steel does not lose its corrosion resistance. The result is a 5 to 8 times harder corrosion resistant surface, which can be used in a wide variety of industries.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“Stainihard® is a relatively new process, still unknown to many people. We are keen to discuss the different process options, to subsequently find the best, most cost-effective solution.”
– Jeroen Jansen, Area Sales Development Manager Aalberts Surface Technologies Eindhoven

A coating or actually the hardening of stainless steel?

If stainless steel is used in demanding environments, wear or fatigue can be limited to a minimum by coating the stainless steel or hardening it. But when and why would you opt for hardening instead of a coating? Jeroen Jansen, Area Sales Development Manager at Aalberts Surface Technologies Eindhoven mentions the two main reasons:

" You should go for the hardening of stainless steel if a coating cannot comply with the application's requirements, or when these unique properties of the stainless steel, like corrosion resistance, are adversely affected. In terms of costs, the hardening of stainless steel is also usually interesting."

Coating

A coating is a substance that does not belong with the material, yet functions as a layer on top of the surface: the coating is a hard, protective layer of a few microns, on top of the softer substrate. Often, stress emerges between the softer basic material and the hard coating. It also involves several risks; a coating could 'break-out'/detach and end up elsewhere in the process. In the pharmaceutical or food industry, for example, this is an unacceptable risk. The coating could also break as the result of a fall, point-load or wear during use, which is also known as the egg-shell effect. In these instances, the stainless steel is no longer protected and wear may arise, as a result of which the part could, for example, fail or accelerated corrosion could appear.

In addition, stainless steel limits the choice for a coating, because the chromium oxide film offers limited adhesion. In practice, it is not always easy to find a suitable coating that meets all requirements.

Stainihard®: diligent hardening of stainless steel

Compared to the application of a coating, Stainihard® has a number of substantial advantages:

- No risk of break(out) of the hardened zone
- Dimensional stability
- Predictability of shape change
- Retention of corrosion resistance
- No elements are added that do not belong with the material

From the basic material until the Stainihard® hardened zone, the hardness gradually increases to a much higher level (>1200HV0.05) at the surface. This is also the reason for the high ductility of the zone and the reason why it keeps functioning, for example when pressed: the zone will also move along with the material in case of a high point-load, where a coating, for example, would break(-out).

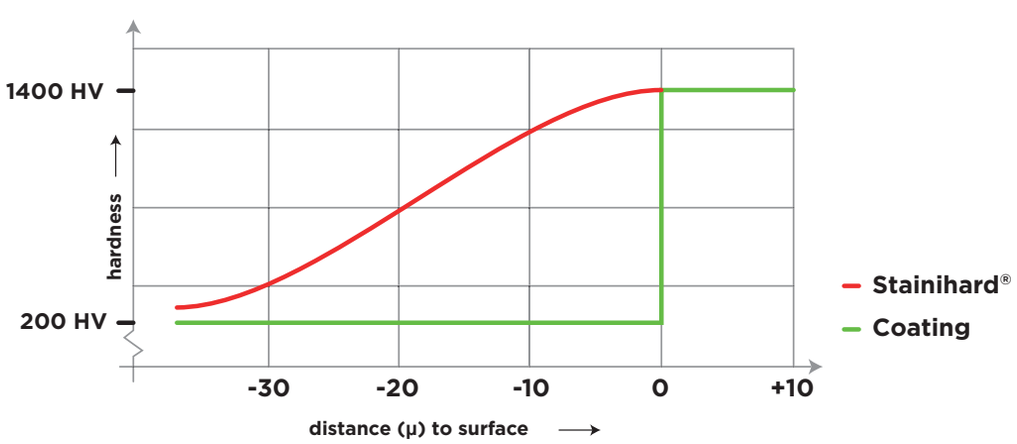
Picture below illustrates the above and compares the hardness development of Stainihard® with a coating:

Post-processing Stainihard®

Basically, Stainihard® is the last process when manufacturing a product and post processing is no longer necessary after the Stainihard process. Yet there are applications that require post-processing, for example, when very high purity or surface condition requirements are set. After Stainihard, it is possible to improve the surface quality, for example, by polishing, without notable detriment to the high hardness obtained.

Stainihard® process is accepted by the FDA and EFSA

The Stainihard® process was tested by independent laboratories and was accepted for use, in accordance with the directives of the U.S. Food and Drug Administration (FDA) and the European Food Safety Authority (EFSA). A test piece treated with the Stainihard® process was tested in conformity with the European EU CM/ReS 2013/9 Directive for materials that come in contact with food. For application in the United States, the test pieces were investigated and approved for use in the food industry, in accordance with the FDA BGBl. I S. 2618.



STAINIHARD® CASE STUDIES

In many markets, Stainihard® can make the difference and, for example, substantially enhance the life cycle or even the application.
For illustration purposes, we would like to share a number of examples or applications from various markets in which Stainihard® is successfully being used.

“ Stainihard® is a relatively new process that is still unknown to many. Many processes have been established for years and were accepted, despite, for example, the deterioration of the corrosion resistance of the stainless steel. We will happily discuss this to find the best, most cost-effective solution.”
– Jeroen Jansen, Area Sales Development Manager Aalberts Surface Technologies Eindhoven

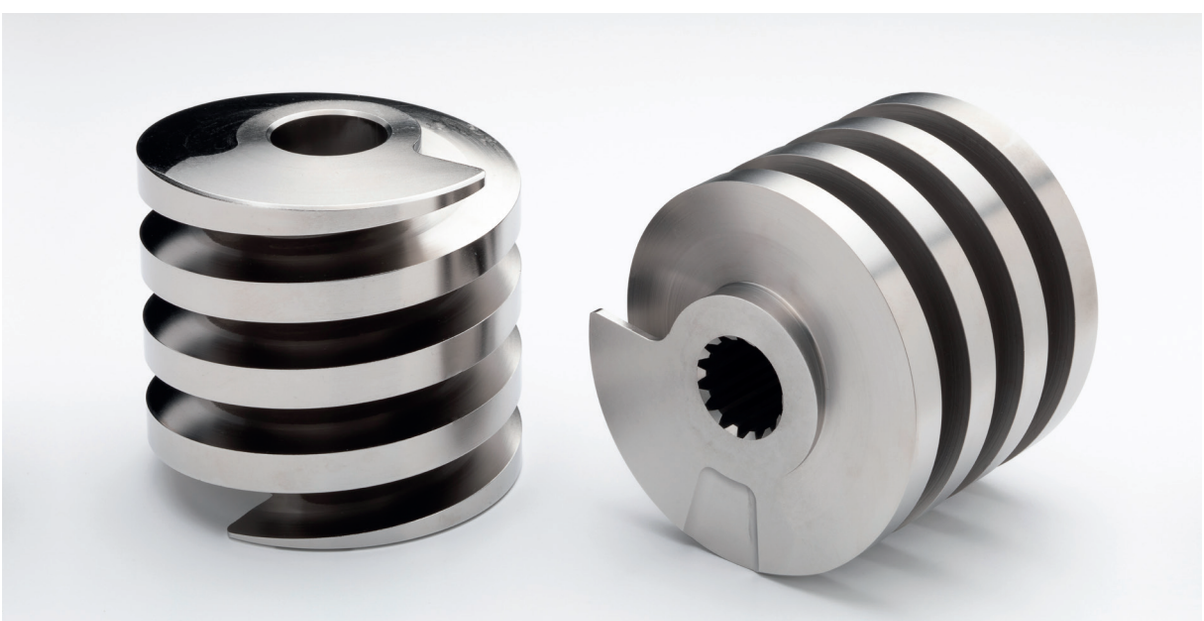
Screw spindle for pump in the food industry

The purity and corrosion resistance of stainless steel are indispensable in the food industry when it comes to food safety. Bacteria and pollution can hardly attach to the stainless steel substrate and, for example, machines for food production are better protected against the usually aggressive cleaning agents that are commonly used in these markets. Stainless steel is indispensable regarding food safety at an industrial scale.

A excellent example is the ‘twin screw’ depicted below. This is part of a pump that is widely used in food production and moves the product through the process. The installation becomes self-cleaning when also cleaning agents are pumped through the system.

The pump sometimes moves thick liquids. These often contain hard particles like pips, seeds and stones that end up in the blade clearance and cause wear in the form of scratches and dents. Wear is inevitable, but due to the use of Stainihard® hardened stainless steel, it is reduced to a minimum. The alternative for hardening, a coating, is not possible for this application, because a coating could ‘break-out’ and end up in the food. Not only will this damage the machine, but it is also hazardous to people, when it ends up in food.

Aalberts Surface Technologies treats the spindle with Stainihard® where, in addition to the hardening and retention of the stainless steel corrosion resistance, mainly the high precision and predictability of the process is important. The gap space between the casing and the screw is essential, more space means more loss of capacity during the pumping. The predictable and extremely constant influence of the Stainihard® causes the blade clearance to be reduced to a minimum. In this case, the gap space is only 0.05 millimeters.



“The different techniques for hardening stainless steel have been tested extensively and Stainihard® manages to best reduce the wear. The additional challenge in this product is purity. The client wants a beautiful, metallic blank product. So we did invest a lot of time in the optimization of the process to realize this in a consistent manner. We succeeded, partly due to special cleaning beforehand and afterwards, but also by adjusting the process such that the product keeps as clean as possible during the treatment.” – Jeroen Jansen, Area Sales Development Manager Aalberts Surface Technologies Eindhoven

Pallet for lenses in the pharmaceutical industry

Another example of an application where a (nickel) coating does not comply with the strict requirements, is this pallet for producing contactlenses. The pallet goes through the entire production cycle, from the injection molding of the lenses to the packaging. The different pallets are next to each other on a belt conveyor and on the transport lines, they more often collide, as a result of which a coating could slowly break off and end up in the lenses fluid.

“The client has decided to cease the use of coatings. Stainihard® is the solution to give the pallet similar properties; galling- and wear resistance without the risk of “coating-flakes” being able to end up in the product. The production of lenses is a very meticulous process of which the pallets are a critical element. The tolerances for this pallet go to 20 micron.” – Jeroen Jansen, Area Sales Development Manager Aalberts Surface Technologies Eindhoven

Stainihard® and the automotive industry

The automotive industry uses more and more austenitic stainless steel. This is due to the required corrosion and acid-resistance, but also the non-magnetic properties of stainless steel. Meanwhile, a lot of applications are used in the car-industry, where Stainihard® has proved itself. This doesn’t merely concern the wear-resistance, but also, for example, the enhancement of the fatigue strength.

Substantial improvement of fatigue strength and wear-resistance of a pawl

This pawl, a springy section of the coupling, is the first validated automotive part widely processed by Aalberts Surface Technologies, by use of the Stainihard® process. This part is under tension and when applying the clutch, it is subject to bending stress, causing a cyclic load which leads to fatique and wear. This will eventually lead to ruptures in the component. Elsewhere, the client could not get the desired performance from the hardened component, for which reason they turned to Aalberts, asking to harden the component and to secure the critical requirements to the component.

“ This product comprises two critical requirements with challenges: the angle magnitude is decisive in the function of the component and must be able to bounce, during which no fatigue should occur, while the surface must be wear-resistant due to the movement of another component against the surface of the pawl. The Stainihard® treatment applies a hard wear-free layer in the surface that also improves the fatigue strength of the component. The treatment however causes the angle, applied to the product in advance, as well as the surface roughness, to change slightly. Together with the client, we tested how and when the product’s angle had best be corrected, to realize the desired angle and also achieve the desired roughness of the surface, by polishing it after the Stainihard® treatment.”
- Jeroen Jansen, Area Sales Development Manager Aalberts Surface Technologies Eindhoven

The Stainihard® layer has a very high compressive stress. The fatigue strength has significantly improved, while wear of the head is prevented, as a result of which the component can no longer rupture and has a longer life cycle.

STAINIHARD® PROCESS

A well designed process is crucial for a successful, consistent processing. For each product, not only is the optimal Stainihard® recipe decided, but the team will also make sure that the entire process contributes to an optimal result.

In this chapter we discuss both the process gone through by our own engineers and the main focus points and considerations in the ultimate production process.

The Stainihard® process largely consists of the following steps:

- Process definition
- Reception
- Cleaning
- Activation
- Diffusion
- Testing and checking
- Cleaning
- Post-treatment and packaging

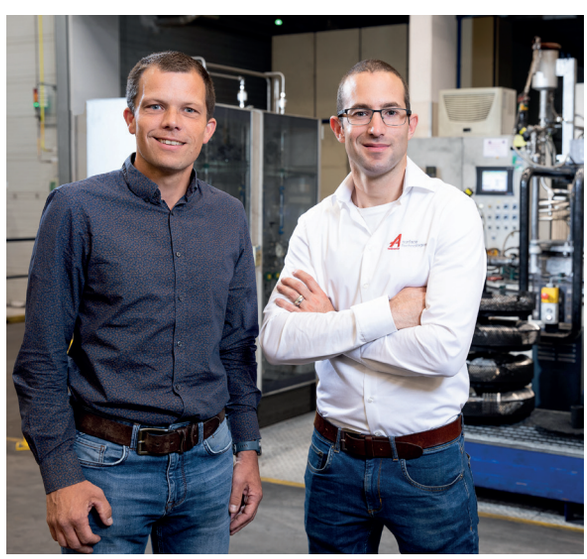
Process definition: robust process necessary for success

Clients visit Aalberts Surface Technologies, bringing a product drawing. While the drawing and all processes used to be established in the past, nowadays the Aalberts engineers are asked more and more often to think along during an earlier stage of the process. This offers engineers the opportunity to think along from A to Z about the production process, the techniques applied and the prerequisites.

“More and more often, we are around the table before the drawing and the process are ‘frozen’, allowing us much more influence and to get the maximum out of our technology, as well as the product.” – Eric Maas, Lead Process Engineer

In short, the Stainihard® process consists of two phases; activation and diffusion. Yet the effect and success of these phases are determined by multiple factors, the most important of which are: material type (chemical compound and quality), how was a product processed and how will it be delivered, but also the temperature, term and the chemical compound of the process. Based on the drawing and technical requirements, we can determine the most optimal Stainihard® process, in consultation with the client, and also start the initial testing in the event of a project.

“ We aim for an as robust as possible process, to be able to treat as many different types of components as possible. Since we are at the end of the chain, also other factors are important. A variation during an earlier phase in the process chain may only be revealed during our process. That is what makes excellent client contact from the beginning very important.” – Jeroen Knippenberg, Process Engineer



Reception of the product is the starting signal

In process definition

The process definition phase consists of testing and documenting of the delivery specifications. Material is investigated on manufacturing methods and processing, stress and purity. The delivery specifications include prerequisites on the material and the packaging. The manufacturing method and packaging, for example, play a major role in the purity of the material, purity in turn is crucial because the diffusion may already get affected by the smallest quantity of pollution, like oil.

OVERVIEW OF THE PROCESS:

In production
As soon as the process is defined, the reception of the product to be treated is the starting signal of the production process. Upon delivery, the dispatch will accurately document the way in which the material was delivered and assess where it concerns a new or known product. A new product will always undergo the production process while supervised by the engineer, even if this concerns a familiar recipe and/or client. Familiar/recurring products can be processed by the production as quickly as possible, without the intervention of an engineer.

Pre-cleaning: crucial in Stainihard® process

The first step in the Stainihard® process is the cleaning of the base material. The surface must be as clean as possible, which is why it is documented in the process design how clean the material was upon delivery, how clean it should be and in which way it is cleaned. By default, at this point, Aalberts has incorporated a quality check, by means of a test. A test piece will be joining in the production process, on the one hand to guarantee the process and on the other hand, as proof that the process is followed correctly.

“ Supplied material does not always have the same quality or is supplied according to the same standards. With the test piece, we add one piece of our own to the treatment, checking that the process is followed correctly. If the test piece is okay, we can establish that the treatment was done properly and that any deviation is the result of a (hidden) property of the product.” - Eric Maas, Lead Process Engineer

Activation of the surface

During the activation phase, we make the surface of the stainless steel accessible for the nitrogen and carbon atoms. Activation can be done in different ways, depending on the material and the starting situation is chosen for the most optimal activation. In the process definition, we establish at which temperature and with which chemical compound the activation will be executed, on the basis of different tests. The activation phase is the most critical phase of the process. The oven atmosphere is crucial here, it prevents that the free chromium on the surface comes in contact with oxygen and forms an impermeable Chromium oxide layer. The activation phase makes diffusion possible.

Diffusion of stainless steel

The activation of the surface allows the carbon and nitrogen atoms to penetrate the stainless steel surface. That is why directly after the activation, the diffusion takes place, at low temperature. Diffusion at low temperatures prevents that the chromium atoms bind with the carbon or nitrogen that diffuses in the surface and thus remains present as a free atom. During this phase of the production process, the oven atmosphere is crucial for the prevention of discoloration by undesired substances. After diffusion of the surface layer, products in the oven are cooled down to room temperature, in a protected nitrogen atmosphere.

Testing and checking

Products are measured on hardness to determine the hardness of the layer and the depth of the hardened zone. In the process design, we document whether this is a 100% check or representative sample. This is partly dependent on the series quantity supplied. We test the hardness by use of a micro Vickers hardness measurement. The depth of the hardened zone is measured by means of destructive testing. To do this, a test piece and/or product is cut, polished and etched. The Stainihard® layer that becomes visible after this, is investigated on hardness.

“ Quality is an absolute priority for us. A well-equipped laboratory does not only ensure that we secure the quality, but also allows us to make optimal choices, even during the process design.” - Eric Maas, Lead Process Engineer

Cleaning and passivation

The test phase shows whether the process went correctly, after which it is released for cleaning. The cleaning removes the carbon residue present and ensures return of the metallic bright color. Subsequently, the natural reaction of chromium and oxygen will occur, retaining the natural properties like corrosion resistance. In case of any deviations during the test phase, subsequent steps will be decided in consultation with the client.

Post-treatment

The last phase in the process before the products are packed, is a possible post-treatment. There are different post-treatments possible for the enhancement of the corrosion resistance, reduction of the roughness and optical improvement of the product, such as electrolytical polishing, honing or tumbling (gleitschleiffen). Possible post-treatments are documented in the work instructions, just like the packaging requirements, where, in general it applies that after the post-treatment the products are packed for return transport.

“We are usually the last step in the process chain. We handle the products extremely carefully to prevent dirt and damage, but also packaging material plays a major role, which we make agreements about with the customer.” - Jeroen Knippenberg, Process Engineer

DISCLAIMER

All values/properties mentioned in the brochure/website are dependent on the type of stainless steel and its condition.

Besides the chemical composition of the material, the results also depend on pre- heat treatment and/or machining.
The passive layer has the best properties if the microstructure of the base material is uniform. Non-uniformities such as sulfides, deformation martensite and delta ferrite also contribute to reduced corrosion resistance.
The look of a product after treatment depends on the delivery conditions of the part.

The treatment and specification of end products must be determined in advance in agreement with Aalberts Surface Technologies Eindhoven B.V.

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Aalberts Surface Technologies Eindhoven B.V.
Achtseweg Noord 3 / 5651 GG Eindhoven / The Netherlands
+31 40 2663000 / info.eindhoven-heat@aalberts-st.com

www.aalberts.com/st
www.stainihard.com