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New plug-and-play installation technology for surface hardening of stainless steel

by **Thomas Kreuzaler, Thomas Strabo**

For the last 12 years the founders of Expanite have been dedicated to the field of surface hardening of stainless steel and have received widespread recognition in the scientific community due to many important publications in the field. Their recognition has been reinforced by several patents that have been sold or licensed as a result of their work.

The founder's research has to a large extent contributed to the understanding of the mechanisms and reasons why stainless steels obtain their favorable properties by dissolution of carbon and or nitrogen. Consequently, tremendous knowledge is concentrated in the organization. This knowledge is valuable to the company and most importantly to our customers.

Expanite has, in cooperation with selected customers, been developing the process from scientific scale to industrial scale during the last three years.

EXPANITE PROCESS – PRINCIPLES AND APPLICATIONS

Few interstitial hardening processes (IHP) are available on the market. Generally, the principle that goes behind the IHP processes is the dissolution of carbon or nitrogen atoms in the surface region. Dissolution of carbon and nitrogen atoms is possible due to their smaller size as compared to the alloy metal atoms and they are able to reside on the interstices of the lattice as illustrated in **Fig. 1**.

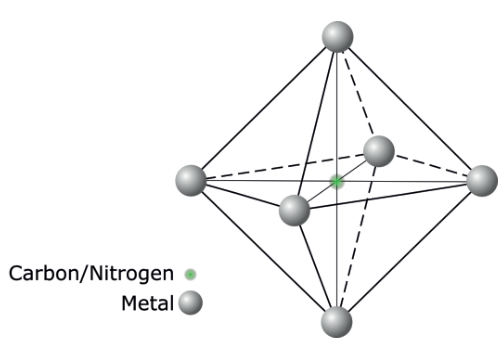

Fig. 1: Nitrogen and Carbon atoms in solid solution reside on the octahedral sides of the host lattice

As opposed to pvd or similar coating processes the IHP processes do not result in a coating, but a surface zone concentrated in carbon or nitrogen. The dissolution of carbon or nitrogen results in an expansion of the host lattice. This zone we call expanded austenite, expanded martensite or just Expanite.

HARDNESS PROFILE

The hard zone consists of carbon and nitrogen. The dissolution of carbon and nitrogen is a key feature of the process. Nitrogen adds increased peak surface hardness while carbon bridges the gap to the relatively soft base material. The consequence is a smooth transition in compressive stresses from the hardened zone to the soft base material as depicted in **Fig. 2**.

The smooth composition profile is crucial for the enhancement of the load bearing capacity and fatigue strength.

CORROSION RESISTANCE

An additional benefit of nitrogen in the hard zone is the significantly improved electrochemical properties, resulting in an improved pitting corrosion resistance. For applications operating in environments containing chloride, such as offshore, Expanite treated are well-suited. Expanite treated components have withstood more than 400 h in a salt spray chamber.

A GAS PROCESS

The procedure is a gas process. Because of this, faults and small cavities are easily reached by the gas molecules. **Fig. 3** shows a default in a screw. It shows that gas molecules penetrate the cavity and surface hardening is accomplished.

Combined with the fact that the process is performed at relatively low temperatures, causing the dissociation of gas molecules to slow down significantly, the obvious benefit is that parts can be treated as bulk ware, still obtaining an even and homogeneous surface hardening.

Gaseous surface hardening allows thermodynamically controlled formation of Expanite "layers" contrary to hitherto applied plasma and salt bath based methods. Consequently, tailoring of a combination of individual carburizing and nitriding potentials is indeed possible, which implies large flexibility in tailoring the materials properties whether scratch resistance or durability is required.

SUPEREXPANITE

The process for stainless steels can be combined with high temperature solution nitriding processes that can supply a recrystalized substrate with improved hardness. This Superexpanite-called combination of high temperature solution nitriding and Expanite provides superior material properties and an improved hardness profile curve. For the high temperature solution nitriding (HTSN) process an additional adapted high temperature vacuum furnace with high pressure quench (**Fig. 4**) is needed and is part of Seco/Warwick's standard products.

PRODUCTION LINE INTEGRATED CENTER

The guidelines for the development of the installation design were the process requirements and the strict request to implement a "production unit" like a turning, milling or other machining center into an existing production line.

The process properties, thermochemical reactions and exhaust products require knowledge in the selection of components, materials and design. All these items were selected thoroughly on the basis of experience, calculations and, if necessary, testing.

The integration into a production line asks for more consideration than just the process technology setup. The items encountered were:

- The infrastructure requirements (energy supply, number of media & supplies, media disposal, exhaust gases, space demand e.g.) should be as low as possible:
- The unit should be easy to operate by production line operators
- The unit should be maintenance-friendly and malfunction-free
- The unit should be in compliance with the design and properties of modern production plants.

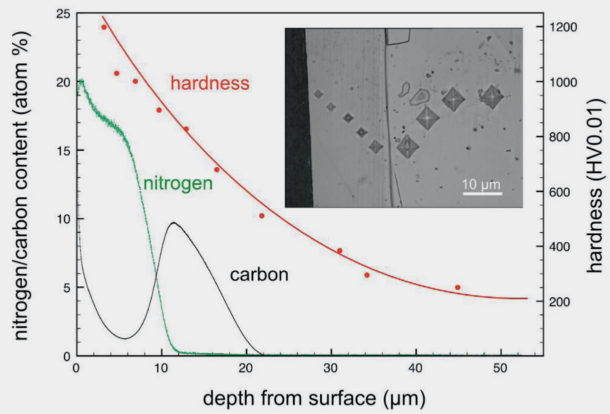

Fig. 2: A key feature of the process is the dissolution of nitrogen and carbon atoms in solid solution. The consequence is a smooth hardness profile

Fig. 3: Even small cavities are reached by the gas and surface hardening is accomplished

In accordance with the process Seco/Warwick developed a modern manufacturing unit with a one-button operation with all installations built in a specially designed enclosure. Installation time is reduced to a minimum, the unit is ready for operation after connection of electric power supply and four process gases only. The outer shape, measures and transportability of the installation were chosen to best-fit into line operations (**Fig. 5**).

The process – like other thermochemical processes – produces a small amount of combustible gases during the process. Normally, these are burnt off with an open flame and a certain amount of natural gas. This natural gas consumption has been recognized as a major point of energy waste. Our new solution for this is a temperature and air controlled electrical catalytic incinerator, which allows compliance with emission regulations (**Fig. 6**).

Air supply for burn-off and dilution can be adjusted to meet the optimum exhaust mixture regarding emission and efficiency. Depending on the factory circumstances the customer can use heat recovery, direct exhaust or a chimney.

Like other heat treatment equipment the unit requires a small amount of cooling water. This is supplied by an integrated chiller and reduces the infrastructure cost of the customer even further. This operates in closed circuit and does not require an additional water supply.

Fig. 4: High temperature vacuum furnace with high pressure quench

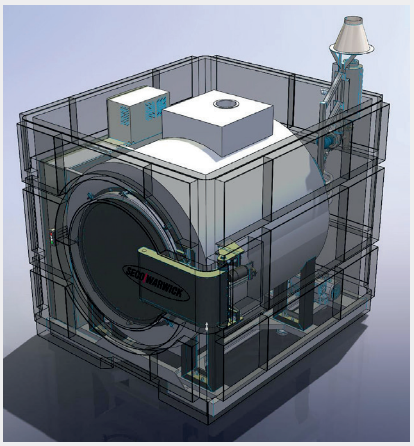

Fig. 5: Design study of Expanite production center

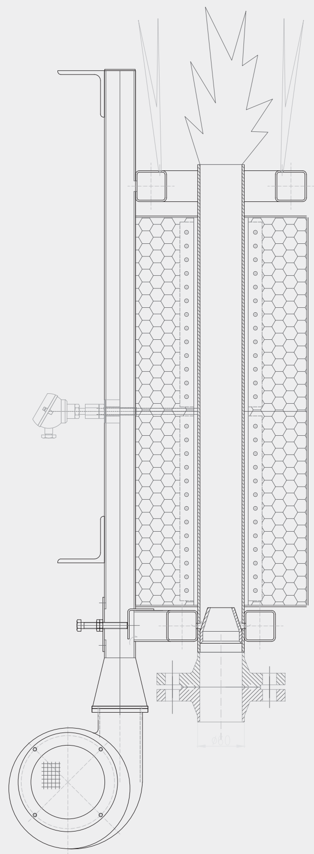

Fig. 6: Exhaust catalyst burn-off and diffusor

The unit control system features the protection of the IP of Expanite. The superior process is protected by "per-process" supply of operation data. This explains the absence of temperature and media flow indicators on the unit itself.

The user operates a touchscreen with the choice of the previously licensed processes (one button control), while data access and remote process supervision is done at Expanite's process control center. Remote maintenance of the installation technology can be carried out at Seco/Warwick, too. The operator has four indicator lights to that show the unit is ready to be loaded, unloaded, in operation or that a malfunction has occurred.

The unit is equipped with an advanced alarm system that constantly monitors the progress and compares it with the recipe. If deviations above a threshold occur the system will react immediately following the principle: safety-first, batch-second. All imaginable scenarios are handled; empty gas bottles, furnace disconnection from power source, earthquake, loss of Internet connection and unexpected interference by the end user. The mentioned alerts are only a few, and are all a part of the hard-wire security system.

For the Superexpanite process SECO/WARWICK can supply a range of high pressure gas furnaces in different sizes customized to the customer's and process's individual needs. These furnaces can run high temperature solution nitriding processes and other vacuum processes and are contrary to the gas process center multipurpose process furnaces.

The Expanite unit can be equipped additionally for Seco/Warwicks Zeroflow-nitriding and nitrocarburising on customer demand. The control of the unit will be operating then either in nitriding/nitrocarburizing - or Expanite mode.

A CASE STUDY

In two particular customer cases high surface hardness combined with high load bearing capacity and extreme corrosion resistance was required. In both applications the components needed to "bite" into the surface of a softer counterpart, which calls for a high peak surface hardness. The nitrogen in the outermost hard zone provided this with surface hardness values above 1,500 HV. However, the mechanical properties were still not acceptable, in particular the ability to withstand high loads was challenged. To avoid this egg shell effect normally associated with high hardness layers on a relatively softer base material, the duplex case with nitrogen and carbon, and thereby a smooth transition from the hardened zone to the base material, imparted the load bearing capacity of the material and solved the problem. The final value proposition, extreme corrosion

Fig. 7: Actual expanite unit

resistance, was achieved by in-detail metallurgical knowledge and accurate control of the gas process. Components last more than 400 h in a salt spray chamber, which is outstanding and outperforms untreated material, in this case from the 300 series.

CONCLUSION

The flexibility of the Expanite process allows for tailoring the materials properties to an extent hitherto unseen. Other properties like tribological can be optimized for as well. These features make the treatment suitable to prevent wear in applications where e.g. interacting metal surfaces are in direct contact; gearboxes, ball bearings, fasteners and valves. The first industrial application is realized at SSP, Twinsburg, Ohio, where the Expanite process is carried out on day-to-day basis in a predecessor installation of Seco/Warwick's actual Expanite unit (**Fig. 7**).

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