Surface Combustion

Case Hardening Solutions

Furnace Options for

Treating Steel

Case Hardening is a surface modification process that is utilized for steels to achieve a hardened surface area by diffusing an element such as carbon and/or nitrogen into the surface of the steel.

Case hardening processes, such as carburizing, carbonitriding, and nitriding are by no means new. They have evolved over the years through continual research and development. Whether your processing requires atmosphere, vacuum, or ion (plasma) furnace designs, Surface Combustion offers one of the most diverse product offerings in the industry. Along with this wide array of furnace designs and configurations, we can provide any required atmosphere gas generator and process/cycle controls that assists in maintaining consistent processing results. As with any heat treating process, selecting the proper style of furnace to meet metallurgical and production requirements many times is dependent upon the parts that are being processed.

Surface Combustion single chamber vacuum carburizing furnace located in the Maumee, Ohio R&D facility.

This article is intended to provide a brief overview of the various types of popular equipment that Surface manufactures, and the advantages/disadvantages of these designs that are used for case hardening processes.

Vacuum and Ion (Plasma) Carburizing

Recently, there has been many developments in the heat treating industry associated with low pressure vacuum carburizing. Along this line, Surface has developed the VringCARB® line of vacuum carburizing furnace designs. The advantages of vacuum carburizing include:

- Higher carburizing temperature capabilities
- Faster carburizing cycles
- Reduced energy/utility consumption
- Cleaner part surface appearance
- Improved case uniformity in some cases
- Lack of intergranular oxides
- Ability to process difficult geometries

These advantages are similar when using ion (plasma) based carburizing, since the carburizing process is also performed under a vacuum environment.

The main processing disadvantage of vacuum and/or ion (plasma) carburizing is parts cannot be bulk loaded or as tightly placed in baskets as they might be in typical atmosphere gas carburizing. All vacuum carburizing furnaces are best suited for uniformly loaded baskets/trays. This is a result of the actual vacuum carburizing process where the hydrocarbon medium is presented to the parts being processed by a vapor dispersion around the parts. Since no fan is utilized to recirculate the vapor (gas) throughout the entire workload, spacing must be provided to give a clear path to all surfaces of the part to be carburized. This same “patterned” loading provides for uniformity in carburizing, as well as the cooling of the parts after processing. Therefore, vacuum carburizing is best suited for parts such as gears, shafts, pinions, drive train components, and other parts that can be uniformly loaded.

Surface produces a wide range of vacuum furnace designs which includes: single chamber furnaces, multi-chamber furnaces, cloverleaf furnaces, and other specialized configurations such as pusher type furnaces.

Atmosphere Carburizing/Carbonitriding

Two chamber vacuum carburizing furnace with oil quench capabilities.

Atmosphere carburizing and/or carbonitriding are undoubtedly the most commonly used case hardening processes in the United States, if not the world. Both processes are adaptable to most all types and configurations of parts on either a batch or continuous basis. In almost all cases, the same equipment can be used for either atmosphere carburizing or carbonitriding.

One of the most important requirements for processing dense loads in either batch or continuous furnaces is the use of an efficient fan to "force" circulate the prepared atmosphere being used through the entire workload. In shallow or open loads, the fan also is desirable to assist with temperature uniformity within the furnace, increase heat transfer coefficients by convection, and to provide a uniform flow of constant potential atmosphere past all surfaces of the parts being processed.

Since gas carburizing was invented, many new developments in furnace construction, furnace components (such as radiant tubes), atmosphere generators, and process controls have evolved. One furnace design that has utilized all of these developments and probably is the most popular style of batch processing is the batch integral quench furnace. Surface's Allcase® furnace has been the leader of the industry throughout the years for this style of furnace. The Allcase furnace is used for the widest variety of parts, can be used for heavy and bulk loaded processing, and allows for liquid quenching the loads immediately after the case hardening process is performed.

Multiple furnaces, placed in-line, can be used to increase production rates and/or add flexibility in varying process parameters. The furnaces are loaded with a charge car assembly, which is also used to load/unload other line installed companion equipment such as Uni-DRAW ® temper furnaces and washers. This arrangement offers the widest range of available automation options to suit the level of automatic processing desired.

The Allcase® batch integral quench furnace was named for the ability to perform almost "all case" hardening processes.

Another popular batch furnace design for case hardening processes is the pit furnace. Pit furnaces are typically used for parts that require vertical orientation during processing and heavy loads that are mounted in fixtures and trays. Since parts processed are removed from the furnace atmosphere for quenching, a certain amount of part surface contamination results. In most cases, this planned contamination (scaling) is removed by machining or some other process such as pickling after the heat treating is complete. In some cases, the parts are reheated and press quenched in place of removing the parts for liquid quenching.

Other batch furnace designs can be used, but are somewhat less common and are specialized to meet specific processing requirements. An example would be a batch revolving retort design which is used to process smaller parts such as pins, bushings, and rollers that require a "tumbling" action for greater exposure of part surfaces, allowing for uniform light case carburizing/carbonitriding. These furnaces are not good for fragile parts and parts that cannot have nicking. Radiant tube box (RTB) furnaces can also be used for case hardening processes where the parts are removed from the furnace for quenching or press quenching such as previously described for the pit furnace designs.

Continuous furnaces are generally preferred for processing large quantities of the same part, or parts which require similar case hardening cycles. Continuous furnaces are typically ideal for non-stop, high production with a minimum amount of attention. On the basis of tonnage, pusher type furnaces are undoubtedly the most widely used continuous case hardening furnace design.

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Charge end of a two row pusher skid tray furnace, which is used for high production of similar parts.

Parts processed in pusher type furnaces range from small parts that are bulk loaded into baskets to large gears, both of which are supported on trays. These trays are then indexed, tray-on-tray, through the furnace by a mechanical pusher device. Pusher furnaces can range from Surface's latest pre-engineered and innovative OneRow® pusher tray furnaces to multiple row designs. Normally, multiple row furnaces are 2, 3, or 4 rows wide, but special units have been manufactured up to 8 rows wide. Multiple row furnaces allow for processing different case depth requirements per row by using different push rates on each row. The parts processed can be either liquid quenched or press quenched depending on the final properties and acceptable distortion allowed.

The main disadvantage to any pusher type furnace - they are not self emptying. To remove all parts being processed, additional trays (in most all cases, empty) must be used to push the remaining parts loaded on trays through the furnace. To alleviate the self emptying disadvantage for tray conveyed parts, a roller hearth type furnace can be utilized. The furnace is not only self-emptying, but lighter weight trays can be used since a tray-on-tray motion throughout the furnace is not required, as associated with pusher type furnaces. Roller hearth furnaces used for case hardening processes typically are provided for tray widths up to 36" wide, but wider widths can be provided to meet specific requirements.

Other types of continuous furnaces include; mesh and cast belt furnaces, revolving retort furnaces, and shaker hearth furnaces. All of these types of furnaces are used for lighter loading and lighter case depth requirements. Rotary hearth furnaces can be used for heavier loads and where parts are normally reheated and press quenched.

Atmosphere (Gas) Nitriding

Gas nitriding is basically a batch furnace process where nitrogen is introduced into the surface of the parts by heating to temperatures below the austenite transition temperature, while the parts are still in the ferrite form, in a nitrogenous medium such as ammonia (NH3) with its dissociation products (N2 and H2). The ammonia breaks down at the metal surface, creating activated nitrogen which combines with the metal. One of the major controlling factors in the nitriding of steel is the presence of various alloying elements such as chromium, aluminum, vanadium, and molybdenum. These elements are used because of their tendency to form nitrides. The material grain size and surface finish also have an effect on the rate of nitriding.

Since nitriding is done in the ferritic temperature range, there is less distortion to the parts because the parts do not go through phase changes such as with carburizing. But, nitriding is also different from carburizing in that a produced layer literally grows on the surface of the part which slightly changes the part dimension.

Gas nitriding is normally done in batch furnaces that use a sealed retort assembly. The most popular style of furnace is a pit type furnace where a sealed retort assembly, with parts internally fixtured or placed in baskets, is lowered into the furnace for the heat portion of the cycle. Cooling of the load can be accomplished in the furnace setting or the retort assembly can be removed and relocated to a cooling stand which allows an additional retort assembly to be placed into the furnace. A cover and base furnace configuration operates in a similar manner except the furnace and the associated heating source is moved and the retort assembly remains for the cooling portion of the cycle. Horizontal retort furnaces can also be used, but typically this type of furnace doesn't have the production capabilities of the vertical pit furnace or cover and base designs.

The biggest advantage to the gas nitriding process is the cost of the capital equipment that is involved. When compared to the other nitriding processes, such as ion nitriding, the equipment cost is substantially lower. Another advantage to gas nitriding is the use of an internal retort fan for uniform atmosphere distribution through heavy or tightly loaded parts. The fan also improves temperature uniformity throughout the effective workload area.

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The main disadvantage to gas nitriding is the use of ammonia and the hazards associated with the gas. Additional safety equipment and inert gas purge systems are required to insure for the safe usage of ammonia and its potentially explosive nature when used as an atmosphere for heat treating.

Variations In The Gas Nitriding Process

There are many different variations in the nitriding process. An example is when a carbon source is added to the nitriding atmosphere it becomes Ferritic Nitrocarburizing (FNC). This process produces wear resistant parts and can be further combined with a blackening process to make the parts corrosion resistant, thus greatly expanding their applications.

Many times, the Allcase® batch integral quench furnace design is supplied with the capability of triniding™ or the ferritic nitrocarburizing process.

Another variation is Surface's patented Triniding™ process where a lower percentage of ammonia is combined with either NX® exothermic generator gas or nitrogen and methane (CH4) to process parts that require a very thin, but hard surface. Since the triniding process is shorter in duration than typical gas nitriding, and the amount of ammonia is reduced, other types of furnaces can be used. The most popular batch furnace design is the Allcase batch integral quench furnace. For continuous furnace processing, most any type of atmosphere furnace can be used, but the more popular types include pusher type furnaces and roller hearth furnace designs.

Ion (Plasma) Nitriding

Glow discharge processes have been around for quite some time, but the actual use in production situations has been limited due to the additional costs typically associated with equipment that use a vacuum environment. This includes ion nitriding, which uses a batch single chamber configuration. The furnace designs can be horizontal or vertical in orientation and are typically sized to meet specific end-user's load sizes, although standard sizes do exist. High production furnace styles include horizontal front load, carbottom, vertical pit, vertical bottom load and cover/base designs. Laboratory size units are also available for low production and testing requirements.

When compared to conventional atmosphere gas nitriding, the main advantage of ion nitriding is in the controllability of the nitrogen supply to the surface of the parts being processed, resulting in the control of the case thickness, hardness and homogeneity of the compound and diffusion zones that allow for optimum properties of the parts. Other advantages of ion nitriding are the ability to process at lower temperatures than gas nitriding, lower part distortion, typically faster cycle times, no environmental hazard (freedom from handling ammonia), reduced energy consumption, and the ability to shield areas where nitriding is not desired by simple mechanical masking.

Multiple (4) vertical bottom load type ion nitriding furnaces used for high production demands.

The main disadvantage of the ion nitriding process is the need to load parts in such a manner to allow for the plasma "glow" around the parts to not overlap, avoiding localized over heating of the parts during processing. Proper spacing also allows for uniform nitriding of the surface of the parts.

Conclusion

As you can see, there is a wide variety of furnace designs available for a wide range of case hardening applications. Surface Combustion has been providing rugged equipment for case hardening processes for 100 years and continues to research/develop new technology associated with these processes to meet our customer 's needs. If you have a case hardening requirement, give Surface a call and see what's new.

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