Steam treating offers an efficient method to enhance corrosion resistance and other properties of ferrous parts, as well as providing an aesthetically pleasing appearance. For higher production volumes, a continuous straight through furnace design provides throughput and cost of ownership benefits compared with other designs.

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Steam treating is a controlled oxidation treatment of metals to produce a thin layer of oxide on the surface of the component. The process is used to impart increased corrosion and wear resistance, to increase surface hardness, and to provide an aesthetically pleasing surface finish. In the case of porous materials, such as powder metallurgy parts, the process seals porosity and increases the density.

Process Fundamentals

Similar to other thermal processes, the time, temperature, and atmosphere relationship is critical to the success of the process (Fig. 1). In processing a ferrous component, the first step is to heat the component in air to a temperature above 600°F (315°C); a rule of thumb is to heat the part above 700°F (370°C) before exposing it to steam to ensure that the entire furnace charge is above 600°F. After the load is at temperature, it is brought into contact with dry steam, which means that any condensate as a result of the steam cooling while going between the boiler and steam treating unit is allowed to flow to a drain and not into the steam treating unit.

The water vapor in the steam begins to react with the iron in the part (Fig. 2) to form magnetite (Fe₃O₄) in the reaction:

\[
4 \text{H}_2\text{O}(\text{gas}) + 3 \text{Fe} \leftrightarrow \text{Fe}_3\text{O}_4 + 4 \text{H}_2(\text{gas})
\]

Fe₃O₄ is an oxide of iron that is blue.
to black in color and has a microhardness of ~50 HRC.

Heating continues to a temperature of about 1000°F (540°C), at which temperature the reaction and the reaction rate for the formation of Fe₃O₄ by water vapor are optimized. The time the components are held at 1000°F in the steam is a function of the application. Applications such as sealing require that the part be held in dry steam for about 60 minutes; while other applications, such as increasing corrosion resistance or hardness, may only require a retention time of about 30 minutes to achieve the desired result.

The final step in the process is to allow the component to exit the steam treating unit. Even though the component is still very hot, exposure to open air is generally not a problem. Many producers collect the part in a container and allow them to cool naturally.

**Process Troubleshooting**

Inconsistencies in the surface color of a component and part-to-part variation in component weight gain after processing can potentially lead to a reduction in the performance of the oxide layer. Contamination of the component surface prior to steam treating is a common cause of black spots or oxide flaking on steam-treated components.

The contamination may result from foreign materials such as machining fluids, oils, etc. Components should be clean prior to entering the steam treating process. The control of the temperature and atmosphere at each stage of the process is very important to achieve the required quality of treated parts. For example, if a ferrous part is exposed to steam before reaching 600°F, the water vapor will oxidize the iron to form hematite (Fe₂O₃) on the part surface through the following hydroxyl reaction:

\[
6 \text{H}_2\text{O} \text{(gas)} + 2 \text{Fe} \leftrightarrow 2 \text{Fe(OH)}_3 + 3 \text{H}_2 \text{(gas)}
\]

2 Fe(OH)₃ \leftrightarrow Fe₂O₃ + 3 H₂O (gas)

The Fe₂O₃ that results from this reaction shows up as pink inconsistencies in the color of the part surface.

The purity of the steam prior to entering the process and during processing also is very important to maintaining product quality. If the steam that contacts the components is not dry, the liquid water will react with the iron on the surface of the part to form a very dense form of Fe₂O₃. The resulting oxide appears as a red discoloration on the surface of the part.

Another form of contamination is seen as white spots on the surface of the steam-treated components. These spots are a result of contaminants in the water used to produce the steam, which are deposited on the components. The water contaminants are typically due to water-treatment chemicals, or to particulates from the boiler, which reflects a need for the boiler to be blown down more often to remove the particulates.

A brown discoloration of the component surface is usually a result of air contaminating the steam. Upon contacting the part, the oxygen in the air reacts with the iron and steam to form Fe₂O₃.

Steamp treating components at a temperature above 1150°F (620°C) is detrimental to quality as well. Above this temperature, the oxide that forms through the reaction of steam with the iron is FeO (wustite), which is not stable below 1150°F, thus reverting back to Fe₃O₄.

\[
4 \text{FeO} \leftrightarrow \text{Fe}_2\text{O}_4 + \text{Fe}
\]

The result is a layer of Fe₂O₃ that is not the same as that formed in the temperature range of 700 and 1150°F. Because the oxide layer contains free iron, the total oxide weight gain is lower, and the performance of the component may not meet the desired specifications.

Continued
Steam Treating Equipment

Steam treating equipment used to achieve the time, temperature, and atmosphere relationship needed to successfully treat components continues to evolve. Steam treating initially was carried out in a batch type device (Fig. 3). In batch steam treating, parts are loaded into a basket that is placed inside the unit, and are heated up to a temperature of 700°F in air, and temperature is allowed to equalize throughout the load. Steam is added as the load is heated up to a temperature around 1000°F. Another soak is performed to allow the time for the oxide layer to form on the parts. The system is then cooled to 600°F, at which point the parts are unloaded and cooled in air to room temperature.

Batch steam treating is best suited for lower volume production requirements. The need to heat and cool the entire system for each cycle results in a loss of energy and time. The loading style of this type of system also adds to the inefficiencies due to the need to soak to achieve temperature uniformity throughout the load.

As cost-competitive production requirements increase, steam treating has moved toward continuous processing. These systems allow a component to be loaded onto a belt and passed through heating zones of a furnace that contain either air or steam. This technology produces an excellent steam-treated product. The first continuous belt steam treating units were hump-back designs (Figs. 4 and 5). The belt path consists of a slope on which parts are loaded that leads to an elevated horizontal section and finally to another slope returning the parts back down to be unloaded. This design takes advantage of the fact that warm steam rises, which prevents air from mixing with the steam. However, the force required to pull the belt through this shape increases stresses in the belt, which, in turn, reduces belt life. This technology is best suited for products that require a tall furnace opening.

More recent technology for steam treating uses a straight-through belt furnace that eliminates the need to pull the belt up and down inclines (Fig. 6). The quality of steam-treated components is equal to that of parts treated in hump-back and batch style units. However, straight-through belt-furnace technology optimizes production capacity and reduces the need for maintenance.

Bibliography

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