ABBOTT
Furnace Company

Steam Treating;
Enhancing the Surface Properties of Metal Components.

By

Stephen L. Feldbauer, Ph.D.

Figure 1. Ferrous steam treated components

Steam treating is the controlled oxidation of metals to produce a thin layer of oxide on the surface of a component. This process can be used to provide a component with increased corrosion resistance, better wear resistance, increased surface hardness, an attractive surface finish and, in the case of porous materials such as powder metal, seal the part porosity and increase the density.

Process Fundamentals

Like any thermal process, the time, temperature and atmosphere relationship is critical to the success of the process.

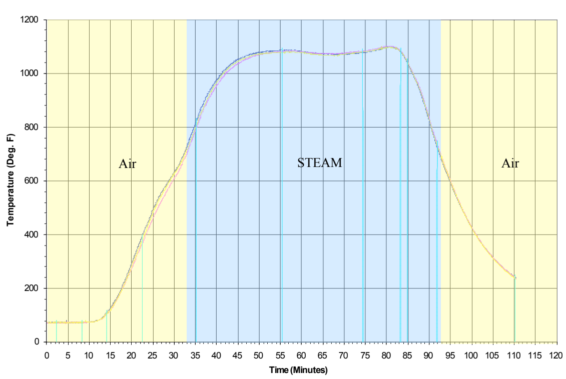

Figure 2. Thermal history of a steam treated part

When processing a ferrous component, the first step is to heat the component in air to a temperature above 600°F. A typical "rule of thumb" is to heat the part above 700°F before exposing it to steam to be sure that the entire load of parts is above 600°F.

Once at 700°F, the component is brought into contact with dry steam; meaning 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.

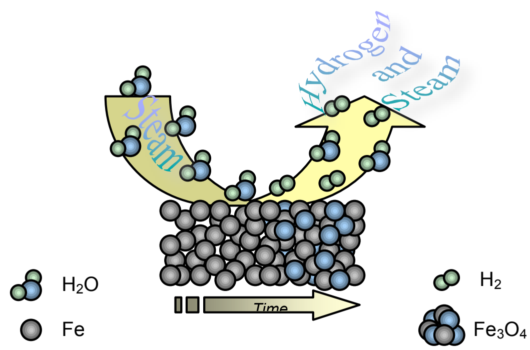

Figure 3. Schematic of the desired oxide formation

The water vapor in the steam will begin to react with the iron in the part to form magnetite (Fe_3O_4).

(1) $4\ H_2O_{\ (gas)} + 3\ Fe \leftrightarrow Fe_3O_4 + 4\ H_{2\ (gas)}$

Fe_3O_4 is an oxide of iron that is blue to black in color and has a micro-hardness of ~50 on the Rockwell C scale.

The ferrous parts continue to be heated to a temperature of ~ 1000°F at which temperature the reaction and the reaction rate for the formation of Fe_3O_4 by water vapor are optimized.

The time that 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 in the dry steam at ~1000°F for ~ 60 minutes; while

1068 Trout Run Road - St. Marys, PA 15857
Phone: (814) 781-6355 Fax: (814) 781-7334

other applications, like corrosion resistance or hardness, may only require a retention time of ~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 may indicate a potential reduction in the performance of the oxide layer of the component.

Contamination of the component surface prior to steam treating is a common cause of black spots on the steam treated components. The contamination may be from things such as machining fluids and oils or other foreign matter. 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 the quality of the components. If a ferrous component is exposed to steam before reaching 600°F, the water vapor will oxidize the iron to form hematite (Fe_2O_3) on the surface of the part through the following hydroxyl reaction.

(2) $6\ H_2O_{(gas)} + 2\ Fe \leftrightarrow 2\ Fe(OH)_3 + 3\ H_{2\,(gas)}$

(3) $2\ Fe(OH)_3 \leftrightarrow Fe_2O_3 + 3\ H_2O_{(gas)}$

The Fe_2O_3 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 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 Fe_2O_3. The resulting Fe_2O_3 appears as a red discoloration on the surface of the part.

Another form of contamination can be 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 a need for the boiler to be blown down more often to remove 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 will react with the iron and steam to form Fe_2O_3.

Steam treating components at a temperature above 1150°F is detrimental to quality as well. Above 1150°F, the oxide that will form through the reaction of the steam with the iron is wustite (FeO). FeO is not stable below 1150°F. The FeO will revert to Fe_3O_4 below 1150°F.

(4) $4\ FeO \leftrightarrow Fe_3O_4 + Fe$

The result is a layer of Fe_3O_4 that is not the same as that formed between 700°F and 1150°F. The total oxide weight gain is lower and the performance of the component may not meet the desired specifications.

Steam Treating Equipment

The equipment that is used to achieve the time, temperature and atmosphere relationship needed to successfully steam treat components continues to evolve.

The first steam treating was done in a batch type device. In batch steam treating, the parts are loaded into a basket that is placed inside of the steam treating unit. Once loaded, the basket and parts are heated to 700°F in air. The temperature is then held at 700°F to allow the parts to all equalize in temperature. Steam is then added as the load is heated to ~1000°F. Another soak is then performed to allow the time for the oxide layer to form on the parts. The system is finally left to cool until it reaches ~ 600°F. At that point the parts are unloaded and exposed to air to finally cool to room temperature.

1068 Trout Run Road - St. Marys, PA 15857
Phone: (814) 781-6355 Fax: (814) 781-7334

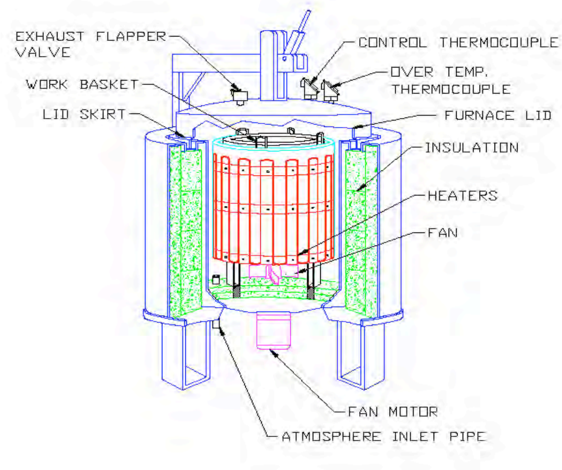

Figure 4. Schematic of a batch steam treater

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

As cost competitive production requirements increase, steam treating has moved toward continuous processing. The first continuous belt steam treating units were hump-back designs.

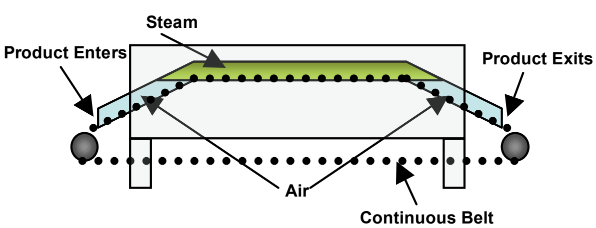

Figure 5. Schematic of a hump-back steam treater

These systems allow a component to be loaded onto a belt and pass through heat zones of a furnace that contain either air or steam. This technology produces excellent steam treated product. The belt path consists of a slope on which parts are loaded which 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 desire for the warm steam to raise and keep air out of the steam. However, the tension required to pull the belt through this shape increases the stresses in the belt which in turn reduces belt life. This technology is best suited for products that require a tall opening.

Figure 6. Hump-back continuous stream treater

More recent technology for steam treating uses a straight through belt furnace that eliminates the need to pull the belt up and down inclines. The quality of the steam treated components is equal to those of the hump-back and batch styles. However, the straight through technology optimizes the production capacities and reduces the need for maintenance.

Figure 7. Straight through continuous steam treater

ABBOTT
Furnace Company

Summary

Steam treating of metal components is a valuable tool for enhancing the properties of metal components both physically and esthetically. The lower temperature required and the environmental benefits of steam treating over conventional heat treating make steam treating a technology that is growing in application and technology. For higher production volumes, a continuous straight through furnace design provides throughput and cost of ownership benefits compared to other designs.

The next time that a designer needs to increase wear, hardness, corrosion or the appearance of a component, they should first consider steam treating.

References

1. A. Gallo, S. A. Gallo and A. Vitiello: "Steam oxidation of ferrous sintered parts, Contribution to study", Powder Metallurgy, Vol. 46, No. 3, 2003.

2. General Signal Corporation Literature: "Corrosion – Resistant, Blue – Black Finish on Steel Parts, 1982.

3. Dr. W. Feilbach: "Steam Treatment of Ferrous P/M Parts", Draft to Committee B-9 of ASTM, 10/25/90.

1068 Trout Run Road - St. Marys, PA 15857
Phone: (814) 781-6355 Fax: (814) 781-7334