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A Review of Industrial Heat Treatment Processes and Opportunities of Waste Heat Recovery from Process Furnace

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***Abstract*—The fatigue strength of steel based materials are increased by carburizing and nitriding processes. There are lots of energy saving opportunities in the furnaces where these processes take place. If the wasted energy in furnaces is effectively recovered and utilized, it improves the process dynamics and economical operation.**

***Index Terms*—carburizing, nitriding, furnace, energy, waste heat recovery**

I. Introduction

Carburizing and nitriding are two industrially important heat treatment operations. These processes are carried out in furnaces at very high temperatures. Carburizing and nitriding are similar to operations like hardening, annealing etc. which are used for the manufacture of auto parts, gears, precision turned components and construction machinery parts. The processes are carried out generally in pit-pot type furnace that is equipped with automatic temperature control, hydraulic lifting and drip feed of carburising fluid. It can be electrically heated, oil fired or gas fired. Nitriding specifically increases the wear resistance, surface hardness and fatigue life of the stock by dissolution of nitrogen and hard nitride precipitations. Since these operations include large amount of heat transfer, there occurs a lot of energy wastage as heat. This loss is not at all financially viable and is non-feasible for the efficient operation. Energy conservation can be done by recovering the above mentioned waste heat and using it for preheating and other purposes.

II. Description Of Processes

A. Carburizing Process

In general, carburizing is the addition of carbon to the surface of low carbon steels at temperatures generally between 850 and 950°C (1560 and 1740°F) at austenite region that had high solubility for carbon and the stable crystal structure. Hardening is accomplished when the high-carbon surface layer is quenched to form marten site so that a high-carbon martensitic case will have good wear and fatigue resistance. Carburizing steels for case hardening usually have base-carbon contents of about 0.2%, with the carbon content of the carburized layer generally being controlled at between 0.8 and 1% C. However, surface carbon is often limited to 0.9% because too high a carbon content can result in retained austenite and brittle marten site. Carburizing process increases the grains size due to permanence for a long time in the austenitic region of the phase diagram, and makes necessary a posterior heat treatment to refine the grains. Parts are packed in a high carbon medium such as carbon powders are heated in a furnace for 8 to 12 hours at 850°C, 900°C and 950 ºC. At this temperature CO gas is produced which is a strong reducing agent. The reduction reaction occurs on the surface of the steel releasing carbon, which is then diffused into the surface due to the high temperature. When enough carbon is absorbed inside the part (based on experience and theoretical calculations based on diffusion theory), the parts are removed and can be subject to the normal hardening methods.

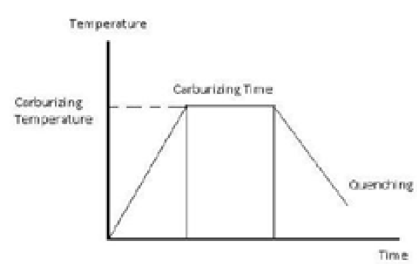

Fig. 1. Carburizing process

B. Quenching

Usually when hot steel is quenched, most of the cooling happens at the surface, as does the hardening. Different quenching media provide a variety of cooling rates. Quenching can be done by plunging the hot steel in water. The water adjacent to the hot steel vaporizes, and there is no direct contact of the water with the steel. This slows down cooling until the bubbles break and allow water contact with the hot steel. As the water contacts and boils, a great amount of heat is removed from the steel. With good agitation, bubbles can be prevented from sticking to the steel, and thereby prevent soft spots. Water is a good rapid quenching medium, provided good agitation is done. Water is used when fastest cooling rate is required.

C. Carbonitriding

Carbonitriding is a form of case-hardening where both carbon and nitrogen are added to the steel. This is achieved by performing the case hardening in an atmosphere containing ammonia. The presence of nitrogen increases the hardenability of the steel, and makes it possible to case-harden also low-alloy steel.

D. Nitriding

Gas nitriding is a thermo chemical surface treatment in which nitrogen is transferred from an ammonia atmosphere into the surface of steels at temperatures within the ferrite and carbide phase region. After nitriding, a compound layer and an underlying diffusion zone are formed near the surface of the steel. The compound layer, also known as the white layer, consists predominantly of ε - Fe2-3(C, N) and/or Fe4N phases and can greatly improve the wear and corrosion resistances. The hardened diffusion zone, which is composed of interstitial solid solution of nitrogen dissolved in the ferrite lattice and nitride precipitation for the alloy steels containing the nitrides forming elements, is responsible for a considerable enhancement of the fatigue endurance. Furthermore, being a low temperature process, nitriding minimizes the distortion and deformation of the heat treated parts. Therefore, nitriding is an important surface treatment for ferritic steels.

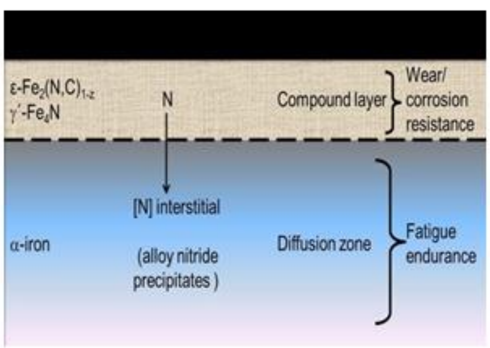

Fig. 2. Nitriding

E. Applications of Nitriding

Typical applications include gears, crankshafts, camshafts, cam followers, valve parts, springs, extrusion screws, die-cast tooling, forging dies, aluminium-extrusion dies, injectors and plastic-moulds. Nitriding is most effective when applied to the range of steels containing nitride-forming elements such as chromium, molybdenum, vanadium and aluminium. The process is also applicable to tool steels such as hot-work, cold-work and mould steels.

F. Types of nitriding

- Gas nitriding
- Plasma nitriding
- Salt bath nitriding
- Pack nitriding

The successful gas nitriding process control depends on the process parameters selection to meet the specification and accurate process parameters control during the process. The gas nitriding process parameters include temperature, time and nitriding atmosphere.

G. Lehrer diagram

The Lehrer diagram, which describes the phase stabilities in pure iron under different nitriding potentials and temperatures, is inherently designed to provide the gas nitriding process parameters.Lehrer diagram has been widely used to provide the process control parameters for the gas nitriding process of steels in industry.However, applying the pure iron Lehrer diagram for the steels can lead to erroneous results because of the different phase stabilities in the steels

III. Mass Transfer Mechanism

The mass transfer mechanism involves three steps:

1. The ammonia transfer from the atmosphere to the substrate surface.
2. Surface chemical reactions including ammonia adsorption and dissociation and nitrogen absorption and desorption
3. Diffusion of the absorbed nitrogen atoms and growth of nitrides layers.

A. Case Depth

After the thermo chemical surface treatment, the ferrous substrate surface layer which becomes substantially harder than the remaining material is called the case. Effective case depth is the perpendicular distance from the surface of a hardened case to the deepest point at which a specified level of hardness is reached. Total case depth may be defined as the perpendicular distance from the surface of a hardened or unhardened case to the point at which differences in chemical or physical properties of the case and core can no longer be distinguished.

IV. Characteristics of an Efficient Furnace

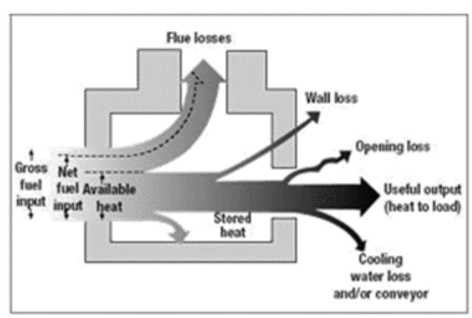

Fig. 3. Efficient furnace

1. Determination of quantity of heat that should be supplied to the furnace.
2. Minimization of losses

3. Uniform distribution of temperature

Factors affecting efficiency of the furnace are poor maintenance, selection of wrong lining material, low supply voltage, absence of insulator, poor quality scrap and low molding efficiency.

Energy saving opportunities include

1. Complete combustion with minimum excess air
2. Correct heat distribution
3. Operating at desired temperature
4. Reducing the heat loss from furnace openings
5. Maintaining correct amount of furnace draught
6. Optimum capacity utilization
7. Waste heat recovery from flue gases
8. Minimum refractory losses
9. Use of ceramic coating

A. Utilizing the waste heat for other process

When a large amount of steam or hot water is needed in a plant, installing a waste heat boiler would be effective. If the waste heat is suitable in terms of quality, temperature etc. the fuel consumption can be reduced greatly. In one case, the recovered waste heat from a quenching furnace was used as the heat source of a tempering furnace.

V. Conclusion

Carburizing and nitriding are essential processes in manufacturing of steel products. Treating the materials in a carburised or nitride environment enhances its fatigue strength. But there occurs huge energy loss during the process as heat. This heat, can be effectively used through suitable methods of waste heat recovery. Such utilization of conserved heat enhances the process, utility life and also the economy of industry.

References

[1] Olga Karabelchtchikova, Fundamentals of mass transfer in gas carburising.
[2] Mei Yang, Nitriding- fundamentals, modelling and process optimization.
[3] Malin Kellan, Energy efficient opportunities with in heat treatment industry.
[4] Mohd Marhan Bin Ansari, A study on heat treatment of carburising carbon steel.