

Raw Material Processing:

Advances in Spheroidize Annealing of Wire Rod Using 100% Hydrogen

by:

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Over the past decade, advances made in the area of hydrogen bell-type furnace convection design and atmosphere control have been merged into a spheroidize annealing system for cold-heading quality wire that is delivering new levels of quality consistency and productivity, while reducing running costs.

Less Equipment (a Lot Less) & Higher Quality

One hydrogen bell-type annealing base can do the spheroidizing of three conventional/nitrogen multi-stack (20 ton) bases, or eight single-stack (7 ton) bases—and produce consistently at a higher quality level and a lower per-ton running cost.

Bells Have Been a Mainstay

For decades, the bell-type furnace (seen in **Figure 1**) has been a standard for the heat treatment process of spheroidize annealing medium-carbon alloy steels for cold-heading quality (CHQ), which is a key step in preparing wire rod for the fastener manufacturing process. The advantages include a well controlled convection system leading to product uniformity—of critical importance to the spheroidize annealing cycle. A sealed inner cover along with a protective atmosphere of nitrogen inhibits decarburization. The nature of the bell furnace concept results in efficient use of the furnace chamber space, resulting in lower atmosphere and fuel consumption. The furnace can be configured for a single-stack of coils, or for multiple-stacks under one inner cover.

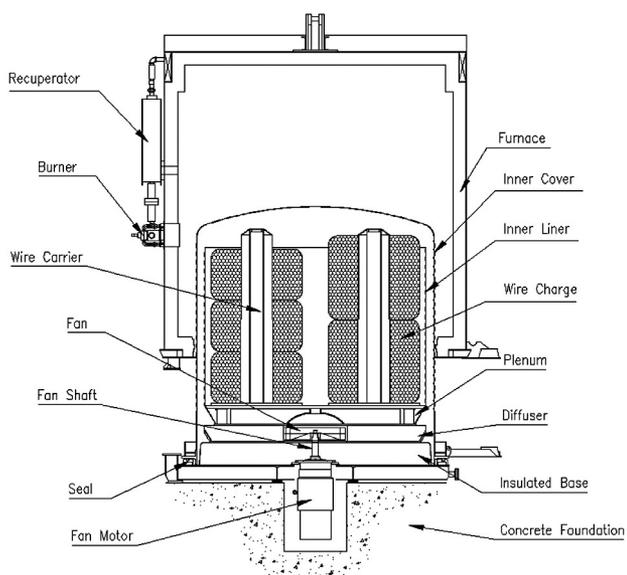


Fig. 1 — Bell-type batch annealing furnace.

Early bell furnace designs, and conventional ones today, use nitrogen as the protective atmosphere for annealing wire rod. The inert nitrogen gas displaces and dilutes O₂, CO₂, and H₂O to levels that minimize the decarburization of the wire rod surface—the bane of fastener manufacturing. Depending

on the nature of the sealing system, and other process factors, sometimes an additive gas is employed.

Hydrogen—An Established Standard in Bell Annealing

For the bell annealing of cold-rolled strip steel, hydrogen has become the standard protective atmosphere, starting back in the 1980s. The benefits of hydrogen to this process are well-documented including shorter cycle times, improved surface properties, larger charges—all resulting in lower overall operating costs and a smaller facility footprint. The safety systems from established manufacturers have been well-developed and have stood the test of time. Today, virtually all new bell furnaces for steel strip worldwide are hydrogen type.

Using Hydrogen to Spheroidize Anneal Wire Rod

Very Short Cycle Times. The modern bell-type hydrogen annealing system shortens the cycle in every segment including oxide reduction, soaking, spheroidizing and cooling. Closed-loop atmosphere control (e.g., patented **RAD-CON AC/APEX™**) uses the hydrogen to minimize the oxide reduction step, in contrast to long dew point holds in conventional equipment. The soaking is shortened as the convection system drives heat into the charge much faster. Spheroidizing is shortened due to the tight temperature uniformity throughout the charge. And removal of the heat from the charge is also accelerated (see **Table 1**).

Table 1. Typical Performance Difference.

	Conventional/Nitrogen	Hydrogen
Wire Rod	JIS SCM435 (AISI 4140), 13 mm (½")	
Charge Weight	20 t (22 USt)	30 t (33 USt)
Cycle Time (load to unload)	30h-40h	19 h
Spheroidization	≥ 90%	

Unprecedented Convection. The convection flow of today's hydrogen annealing equipment is more than five times the flow of the advanced systems of the 1980s, and 10 times some of the conventional nitrogen annealers in use today throughout the world (see **Figure 2**). The higher convection flow along with the properties of hydrogen itself, substantially increases the rate at which heat is delivered to the charge.

This convection also maintains tight uniformity through the critical spheroidizing segment. With the temperature differential throughout the charge stabilized at ±5°C (9°F) or better, the time the furnace must spend in the spheroidizing segment is vastly reduced. When the uniformity is not so tight as in the case of a less sophisticated furnace, additional furnace time must be expended as each part of the disparate charge passes through the spheroidizing window at differ-

FTI EMPHASIS: Heat Treating

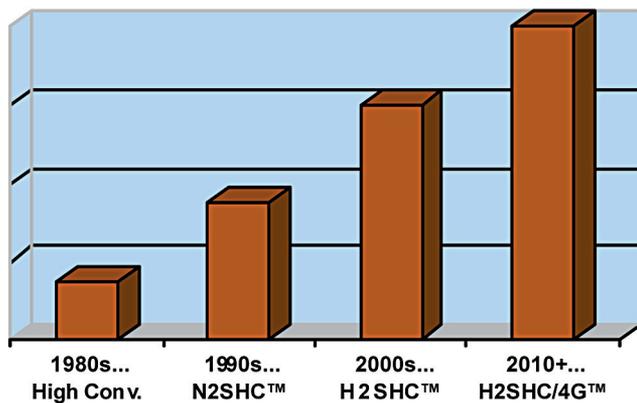


Fig. 2 — Convection flows: 1980s to the present.

ent times. Any attempts to shorten this segment beyond the capabilities of the equipment risks spoiled spheroidization in some parts of the charge.

Surface Quality Control. Uncontrolled, hydrogen can cause decarburization, which is precisely why a proper atmosphere system (e.g., patented RAD-CON AC/APEX™) must be used to assure repeatable surface quality results when annealing wire rod. Hydrogen is a reactive gas, so unlike nitrogen, it does not displace contaminants, it reduces them.

The advantage of hydrogen is that it can quickly reduce the oxides inherent at the surface of the wire and entrained in the coatings. It is vital that the reduction process be complete below the temperatures at which decarburization can occur. Of practical importance are the variable conditions of the incoming wire rod due to differences in sources, processing, and storage. A closed-loop atmosphere control system accurately and repeatedly senses and adjusts cycle after cycle to compensate, which is the essence of the AC/APEX™ patent.

The other huge advantage of hydrogen is complete avoidance of soot deposition—a problem encountered by those systems using hydrocarbon additives, including endothermic atmospheres used by pusher-type box furnaces. Not only the wire, but the annealing base itself finishes each cycle clean, making quality results repeatable. The ability to start fresh is in contrast to some conventional annealing processors use of air to burnoff soot, which then results in oxides in the annealing charge chamber starting the next cycle.

Lower Running Costs. Fuel, electricity, hydrogen, and nitrogen are all optimized by the modern hydrogen system. See the cost comparison in **Figure 3**. The shorter cycle saves fuel. Less furnace time, means lower thermal losses.

Also, today's direct-fired burners with recuperation are more efficient than traditional radiant tubes. The higher flow hydrogen convection system effectively distributes the heat concentrated from these direct-fired burners.

The hydrogen gas is 1/14th the mass of nitrogen, leading to substantially reduced electrical consumption by the convection motor.

Atmosphere gases are carefully applied. The tight seals, space-efficient atmosphere chamber, and atmosphere control, lead to a minimal usage of hydrogen. With the AC/APEX™ control system, the hydrogen consumption can be matched to the conditions inside the bell. Today's clamped annealing bases and seals allow the atmosphere gas to be turned completely off and to pressurize the inner cover. Purging monitors

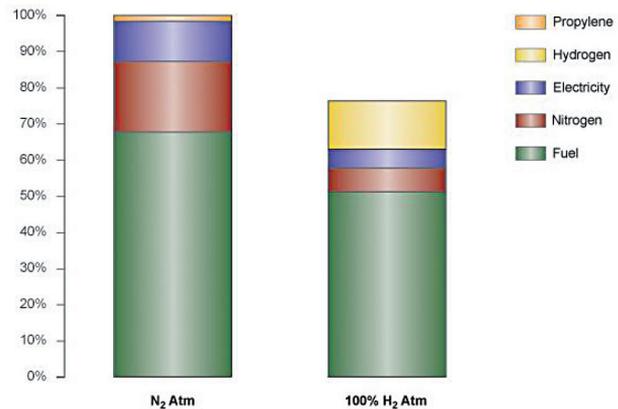


Fig. 3 — Utility cost comparison.

minimize the nitrogen consumption as well.

Hydrogen Not Available?

Some of the same advances have been applied to nitrogen annealing as well. For markets where hydrogen is not readily available, nitrogen can be used. However, there are drawbacks.

Electrical power consumption of the convection motor is two and half times higher than with 100% H₂ to achieve similar flow rates. Also, since oxide reduction cannot be effected with nitrogen, controlling the heating rate to avoid decarburization can lead to longer dwell times—sometimes a factor overlooked when comparing the two approaches.

Think Outside the Box

Short cycles are not the only reason for using hydrogen bell-type annealing. Shorter cycles have been the boast of certain pusher-type box furnaces. And it is true that these furnaces, married with a CO/CO₂ control system, have been able to provide closed-loop atmosphere control with decent quality results. However, the hydrocarbon gas feedstock for the endothermic atmosphere generator makes the atmosphere used in these furnaces expensive (and this atmosphere is also combustible).

Considering generator heating and feedstock, it requires one part natural gas to make only two parts of endothermic gas. The empty space in the box-type work chamber leads to high atmosphere consumption, further exacerbating the high atmosphere and purging costs. A survey of installations in Asia has shown running costs to be one and half to two times that achieved by today's hydrogen bell-type annealers.

And since the quality differences are not there, the justification for this type of furnace is confined to saving a few crane lifts, against higher capital costs and significantly higher utility bills. www.rad-con.com

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Company Profile:

RAD-CON Inc. supplies capital equipment and software along with related services to manufacturers in need of high-quality batch annealing process that is part of their manufacturing of hot and cold reduced strip and wire metal coils. RAD-CON specializes in bell-type batch annealing furnaces that use a protective atmosphere of 100% hydrogen. The company also increases efficiencies of existing anneal facilities through software models. www.RAD-CON.com