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Intensive Quenching of Carburized Steel Parts

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Absract: - It was discovered that an intensive quenching process creates high and dipper penetrated compressive stresses at the surface layer of steel parts and can reduce significantly carburizing time. The presence of residual surface compressive stresses increases a service life of steel parts. The paper describes an application of the intensive quenching process to a variety of carburized products. It also presents comparison data on the hardness distribution for steel parts. A fully automated environmentally friendly intensive quenching system was designed for processing of carburized products. The system was installed at the Akron Steel Treating Co. of Akron, Ohio, USA.

Key words: -**I**ntensive quenching, Carburized steel parts, Equipment, Automated system

1 Introduction

In this paper, we discuss different applications of intensive quenching (IQ) techniques to actual steel products as well as to steel samples provided by part manufacturers. We applied two IQ methods: an IQ-3 technique or "direct convection cooling," and an IQ-2 technique, a two-step quenching that uses a water nucleate boiling (self-regulated thermal process) following by a convection heat transfer mode of cooling. These two methods were used for quenching carburized steel parts with a goal to reduce significantly duration of the carburization procedure. We conducted experiments for a variety of steel products. For intensive quenching carburized steel parts, we used our two IQ units: an experimental high-velocity IQ system and a production 6000-gallon IQ system installed at Akron Steel Treating Co, of Akron, Ohio, USA.

2 IQ Equipment

The experimental high-velocity IQ system was specifically designed for the implementation of the IQ-3 quenching process. It differs by the ability to provide very high water flow velocity along the part being quenched (up to 20 m/sec). The system is able to provide optimum IQ-3 quenching conditions to a variety of steel products. The system is capable to quench steel parts up to 15 cm in diameter and up to 40 cm in length.

Figure 1 presents a schematic of the system. The high-velocity IQ system includes a 3.0 m^3 (800-gallon) water tank, 1; a 600-gpm high-pressure pump, 2; a three-way solenoid valve, 3; piping, 4; shut-off valves, 5; flow meters, 6; a loading table, 7, that is moved up and down by means of four air cylinders, 8, and four linear bearings, 9; interchangeable different fixtures for holding parts being quenched; and proper controls.

The high-velocity IQ system works as follows. Initially, the IQ system is at an idle condition: the pump is "ON" and it pushes the water from the tank through the 3-way valve and a bypass pipe, 10, back to

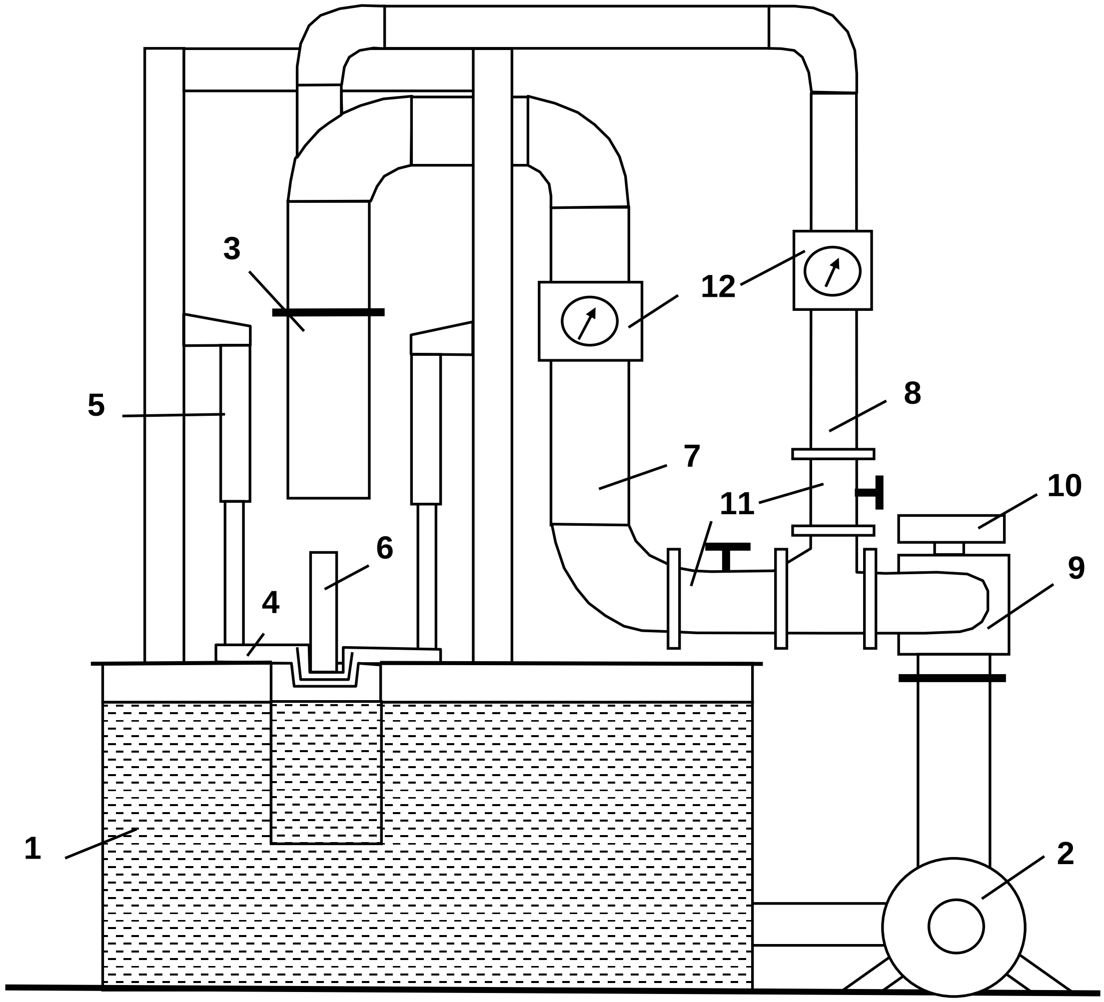

Fig. 1 High-Velocity IQ System schematic

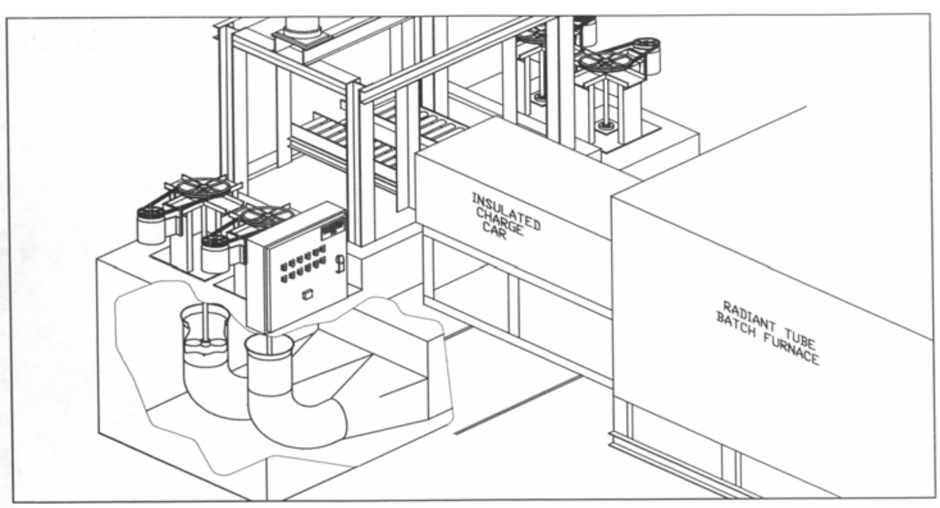

Fig. 2 Production 6,000-gallon IQ System Installed at Akron Steel Treating Co., USA

the tank. The loading table, 7, with an attached fixture is in the lower position. A hot part to be quenched is put into the lower section of the fixture that is attached to the loading table. The lower section of the fixture holds the part in a vertical orientation. The air cylinders, 8, move the loading table, 7, with the part up towards a stationary upper section of the fixture. The upper section of the fixture (not shown) is a pipe that is attached to the tube, 11, by means of a quick connector (a pipe clamp). The lower end of the upper fixture has a flange with an attached rubber ring. When the loading table is at the upper position, the rubber ring is held against it providing sealing of the system. As soon as the part is in position within the upper section of the fixture, the three-way valve, 3, switches the water flow from the idle direction into the piping, 4, leading to the fixture with the part. After the quench is completed, the 3-way valve, 3, switches the water flow back to the bypass pipe, 10, and the air cylinders push the loading table with the part down. Note that when the system is in quenching mode, the water flow may be split in two flows after passing the 3-way valve. A shut-off valve, 5, and a flow meter, 6 control each water flow path. The reason for this is that when quenching bearing rings it is necessary to control both water flows: along the ring ID surface and along the ring OD surface

Figure 2 presents a schematic of the full-scale production IQ system. The system includes a Surface Combustion atmosphere furnace having a work-zone of 91cm×91cm×122cm (36”×36”×48”) and the IQ quench tank of 22.7 m^3 (6,000 gallons). The mild steel IQ tank is equipped with four 46 cm (18”) propellers that are rotated by four motors. The tank uses a water/ sodium nitrite solution of low concentration (8-10%) as the quenchant. The quenchant flow velocity in the tank is about 1.5 m/sec (5 ft/sec) as it passes over the parts. An air-cooling system maintains the quenchant temperature within the required limit. The production IQ system is designed for quenching loads of up to 1,135 kg (2,500 lb).

3 Intensive Quenching of Carburized Steel Parts

We evaluated a potential use of the IQ process with carburized AISI 8617 steel automotive bearing cages used for CV joints [1]. Figure 3 shows the part picture. The objective of the study was to determine if an acceptable distortion and a desired hardness profile could be achieved by intensively quenching of the bearing cages after a reduced carburizing cycle. We evaluated the carburizing cycle reduced by 50% (compared to the standard cycle) followed by intensive quenching.

The resulting micro hardness distribution of two standard production bearing cages and a 50% reduced-time/intensively quenched cage are summarized in Figure 4 [1]. The surface hardness of the intensively quenched bearing cage was 2-5 HRC greater than that obtained for the standard production cages. At the HRC = 50 point, the intensively quenched part exhibited a significantly better hardness profile while still having an acceptable distortion [1,2].

Fig. 3 AISI 8617 steel bearing cage used for automotive CV joints.

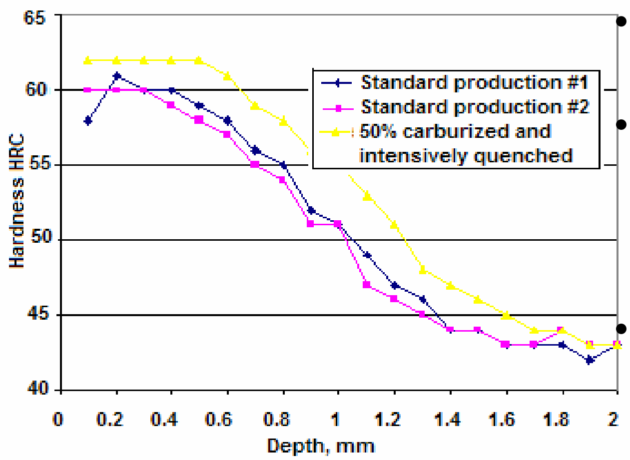

Fig. 4 Hardness distribution throughout AISI 8617 bearing cage with wall thickness of 4 mm and case depth of 1.2-1.5 mm

In another study, we evaluated the IQ process for universal crosses made of carburized AISI 8620 steel [3]. The results of a thorough metallurgical evaluation showed the following [3]:

- No unacceptable distortion or cracks were observed.
- The case microstructure for both standard carburized and oil-quenched and reduced carburization cycle/intensively quenched crosses consisted of a fine tempered martensite with approximately 5% retained austenite with no non-martensitic products and no network carbides observed. The core microstructure was a low-carbon martensite for the intensively quenched crosses while the standard oil-quench core structure was a mixture of a low-carbon martensiteand bainite. The intensively quenched crosses exhibited a finer core martensitic structure than standard oil quenched crosses.
- The case depth was uniform throughout the intensively quenched surface of the cross.
- Both the 50% carburized and 60% carburized crosses exhibited a R_C =50 at a greater case depth compared to standard carburized and oil quenched crosses by 10% and 32% respectively.
- The specified mean case depth of 1.5 mm was achieved with the intensively quenched 60% carburized crosses.
- The core hardness exceeded the required minimum.
- No intergranular oxidation was observed in intensively quenched crosses.

In some cases, intensive quenching provides a hardness profile that is sufficient to permit the complete elimination of a carburizing cycle. This was shown for a forged railroad part made of AISI 4137 steel, which was intensively quenched. Figure 5 shows that after intensive quenching, the hardness distribution in the part (below the carburized case) shows that there is no need to carburize this part. Intensive quenching without carburization yields sufficient hardness depth with the same alloy.

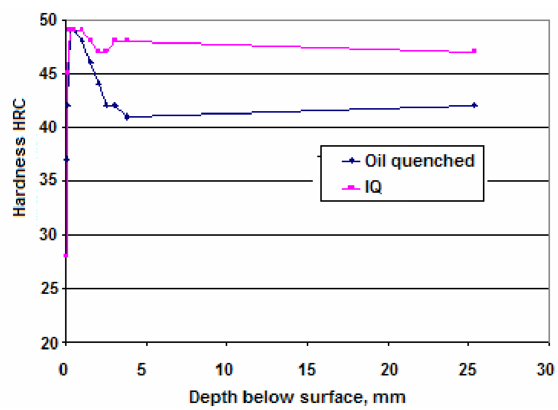

Fig. 5 Hardness distribution throughout 4137 forged railroad part. Cross section of 110x116 mm and case depth of 1.5-2.0 mm

Table 1 provides a summary of the results of intensive quenching of various carburized steel parts obtained to date. These results have shown that typically carburization cycles can be reduced by 40-50% relative to standard carburization cycles with conventional oil quenching.

Table 1 – Carburization cycle reduction for different parts

Part	Steel	Case Depth (mm)	Cycle Time Reduction (%)
Universal joint cross	8620	1.5	40
Bearing cage	8617	1.8	50
Crankshaft	8620	1.5	40
Railroad part	4130	2.0	50
Railroad part	4138	2.0	Complete elimination

Summary

1. An intensive quenching process allows reducing the duration of the carburization cycle by 40-50%. In some cases, it is possible to fully eliminate the carburization cycle by using the IQ process. This, in turn, will result in the significant improvement of a heat-treating equipment production rate and in tremendous savings of energy.
2. Computer modeling of the heat treating processes considered as well as the self-regulated thermal process requires a development of the proper database including optimum critical heat fluxes, heat transfer coefficients, etc.

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