CASE HISTORY

# THROUGH-CARBURIZED TACKS

*Tackmaker, commercial heat treater, and metallurgical consultant collaborate on developing an innovative process that negates the need to buy new machine tools and hire additional operators.*

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About two years ago, Hayes Heat Treating (HHT) was given an opportunity to work on a project with one of furnace builder C.I. Hayes' customers. The East Providence, R.I., manufacturer makes very small metal tacks that are used to attach signs and labels to machines (Fig. 1). Tacks are driven into steel plate as hard as 100 HRB using special pneumatic hammers.

Tacks were turned from wire coil of AISI 41L40, a leaded low-alloy steel, and heat treated in a shaker-type furnace with muffle (a C.I. Hayes Model CST). Parts were run in nitrogen atmosphere and oil quenched, and then oven-tempered in air. The CST furnace gave very good results with minimal lot variation in hardness. Properly hardened and tempered 41L40 tacks have the hardness and toughness required for this high-impact application.

**Substitute sought:** Faced with increased demand for its tacks, the manufacturer was considering the purchase of additional turning machines and the hiring of more machine operators. The alternative would be to find a different tack material that could be machined at a higher rate than 41L40, thereby improving productivity enough to meet the increased demand. The substitute material would also have to perform as well as 41L40 in the application, and have a similar price per pound and availability.

With the help of a metallurgical consultant (ASM member Gregory W. Dexter, Metallurgical Solutions Inc., Providence, R.I.), the company elected to investigate replacing 41L40 material with AISI 11L17. The leaded, resulfurized carbon steel machines approximately 50% faster than 41L40, has a slightly lower price per pound, and is more readily available. However, the mechanical properties of hardened and tempered 11L17 cannot match those of 41L40 in the same condition.

*Fig. 1 — Tacks are machined from steel wire and heat treated. Vacuum carburized, hardened, and tempered AISI 11L17 has replaced hardened and tempered 41L40.*

**Through-carburized:** To overcome the mechanical property drawback, it was decided to modify the chemical composition of 11L17 by carburizing the tacks to a uniform carbon content of 0.77% throughout — not a carbon gradient, which is the usual objective. This "new" eutectoid steel would then be austempered to form bainite. Unlike tempered martensite, bainite would impart the toughness required for performance equal to that of hardened and tempered 41L40.

Tack carburizing is done by Hayes

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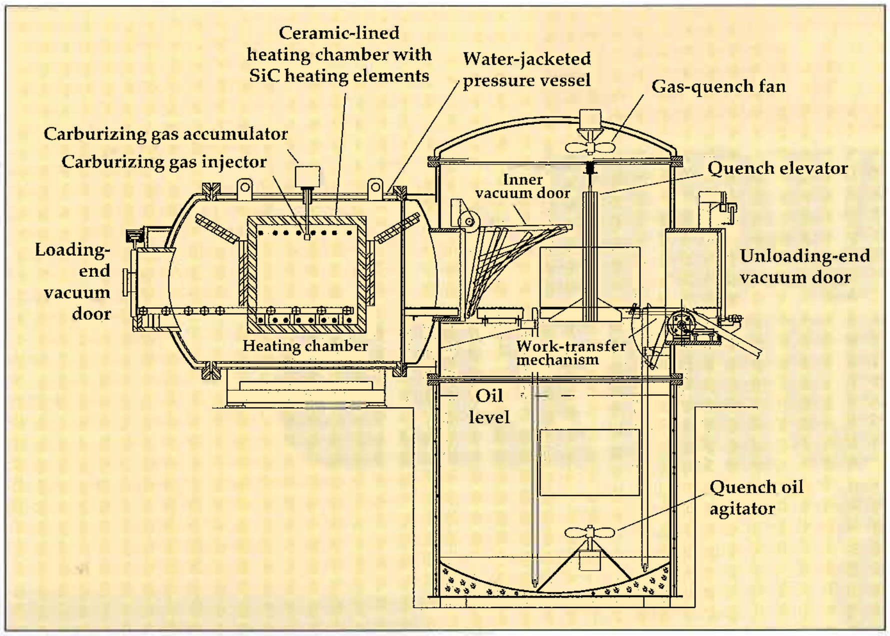


*Fig. 2 — A C.I. Hayes Model VBQ furnace equipped with pulse-pump vacuum carburizing technology. The furnace is used by Hayes Heat Treating to through-carburize tacks.*

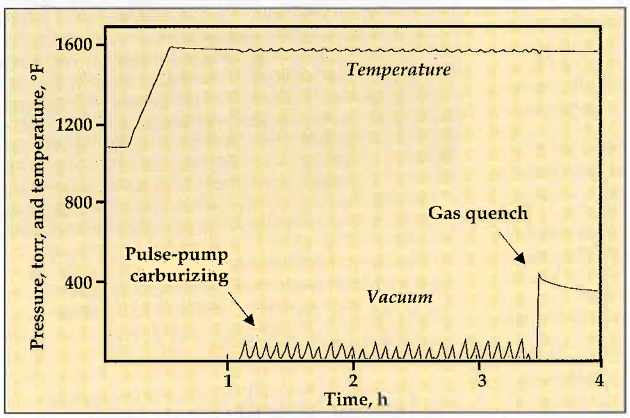


*Fig. 3 — How temperature and pressure vary during pulse-pump vacuum carburizing of tacks. The objective is a uniform carbon level of 0.77%, rather than a carbon gradient*

Heat Treating (HHT) using a C.I. Hayes Model VBQ furnace and pulse-pump vacuum carburizing technology (Fig. 2). The boost/diffuse process introduces carbon-bearing gases at relatively low furnace pressures (10 to 100 torr, 1.3 to 13 kPa) in short, controlled bursts through an injection nozzle (Fig. 3). Carburizing parameters were tailored to provide the required uniform carbon level.

The process development stage of the project lasted for more than two years. Hundreds of thousands of tacks were processed and tested before any were released to end-users. To determine the actual carbon content, entire tacks were combustion analyzed for total carbon. In addition, metallographic cross sections were examined to assess uniformity of carbon penetration.

*Additional process development eliminated the need to austemper carburized tacks.*

A major problem that had to be solved during process development was carbide formation during carburizing. Carbides were forming at the very tip of the tacks, causing brittle fracture when driven into steel test plates. The problem was solved by increasing the dwell time between the pulses of carbon-bearing gas. This allowed intermediate diffusion to occur, reducing the carbon content at the tack tips.

The tack manufacturer began ramping to full production using carburized 11L17 material last fall. HHT processes 100,000 to 200,000 tacks per week.

**No austempering:** Additional cost savings and process enhancements have also occurred. For example, while the carburizing method was being developed at HHT, the tack manufacturer was investigating converting its shaker-type furnace from oil quenching to fluidized-bed quenching. The modified Hayes CST could then be used for in-house austempering, eliminating the need to outsource this step in the tack-making process.

However, because the tacks delivered by HHT have such a consistent, uniform microstructure, the customer was prompted to check out whether hardening and tempering the carburized 11L17 could be substituted for austempering. Performance of hardened and tempered, carburized 11L17 turned out to be equivalent to that of hardened and tempered 41L40. As a result, austempering of carburized tacks will not be required, which eliminates the need for outsourcing or for converting the shaker-type furnace.

HHT was the source of yet another cost savings. The commercial shop now uses a separate, single-chamber vacuum furnace for the lengthy diffusion step that's needed to obtain the required uniform carbon level. This unit is less expensive to operate than the vacuum carburizing furnace. **HTP**

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