NO HYDROGEN EMBRITTLEMENT WITH LOW PRESSURE GAS CARBURIZING

Results of study of steel carburized at low pressure using a vacuum furnace show no evidence of hydrogen embrittlement, which should relieve any concern of the possibility of such an occurrence in low pressure gas carburizing.

Donald Jordan*
Trevor Jones
Solar Atmospheres Inc.
Souderton, Pa.

Harry Antes
Metallurgical Consultant

Member of ASM International and member, ASM Heat Treating Society

Low pressure gas carburizing using acetylene or some other hydrocarbon facilitates the penetration of small blind holes and channels. A preheat in hydrogen reduces surface oxides and provides an active surface for the dissociation of the hydrocarbon for carburization [1]. During the dissociation of the hydrocarbon, nascent hydrogen is produced at the surface of the part being carburized.

Owing to the high temperature and the carburizing cycle, there should be no problem with hydrogen embrittlement[2]. However, there is concern by some about the possibility of hydrogen embrittlement. This study was conducted to determine whether there is evidence of any problems that might exist in carburizing an AISI 4330 steel.

Experimental Procedure

The study was conducted in accordance with ASTM F 519-05: Standard Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating Processes and Service Environments,

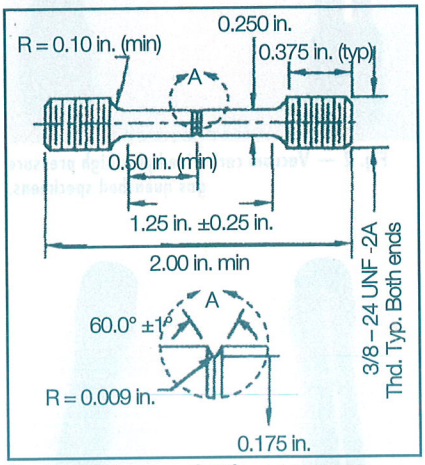
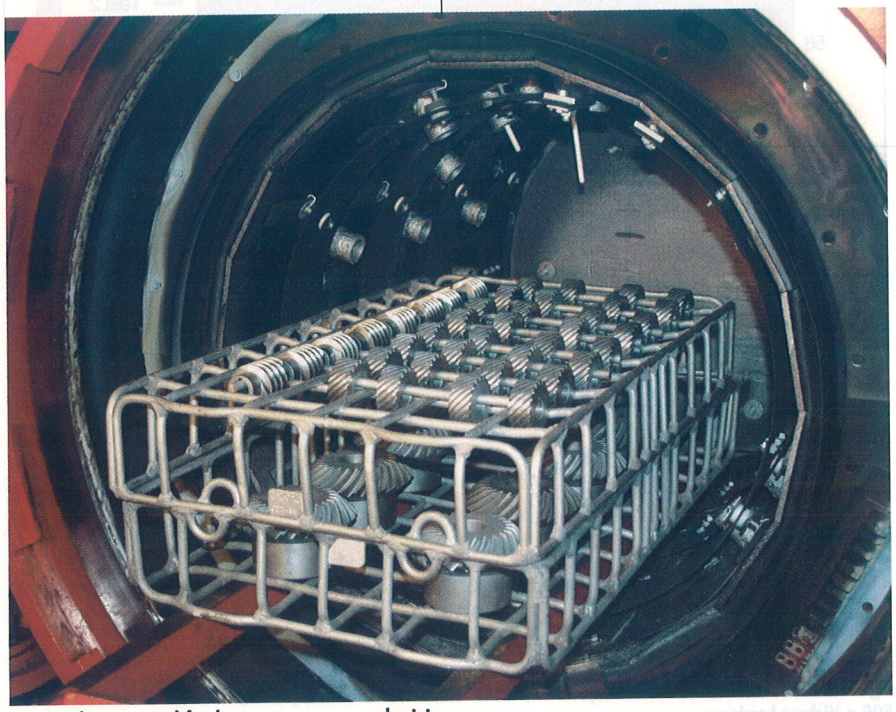


Fig. 1 — Hydrogen-embrittlement test coupon.

with some modification. F 519-05 is designed to evaluate the occurrence of hydrogen embrittlement in plating processes and service environments, and specifies using AISI-4340 steel in the tests. However, because this steel is not typically carburized; tests were conducted using AISI 4330, which is more representative of a carburizing alloy. Furthermore, following carburization, a region of the case will exist that contains ~0.40% carbon as in 4340. The 4330 material used in these tests was vacuum melted, 0.5 in. diameter bar stock. Specimens were made in accordance with ASTM F 519-05, Type 1a.1, standard size, as shown in Fig. 1 [1].

Four different carburizing treatments were used (Table 1). Seven specimens were processed for each carburizing condition; three specimens were used to determine the notched fracture strength (NFS) and four were used for sustained-load embrittlement testing where the stress was 75% of the NFS. Carburizing treatments were performed to achieve an effective case depth to about 0.012 in. Tests 1, 2, and 3 were quenched and tempered to a surface hardness of 51 to 53 HRC, as specified by ASTM F 519-05 for 4140. Test 4 was quenched and tempered at 325°F to avoid approaching a commonly stated industry standard hydrogen embrittlement-relief tempera-



Vacuum furnace used for low pressure gas carburizing.

Fig. 2 — Vacuum carburized plus high pressure gas quenched specimens.

Fig. 3 — Atmosphere carburized plus oil quenched specimens.

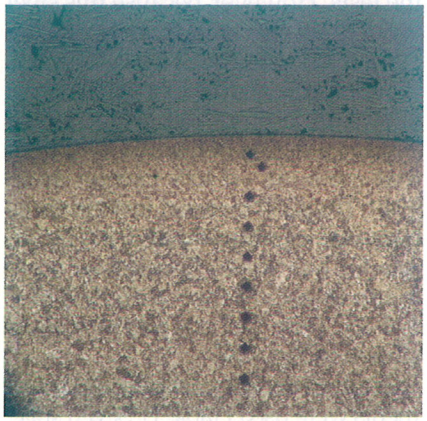


Fig. 4 — Micrograph of microindentation hardness traverse of carburized specimen. 50×

Table 1 — Carburizing treatments

Test	Heat Treatment
1	Atmospheric – Endogas carburizing
2	Vacuum, N_2 heat up, acetylene (C_2H_2) carburizing
3	Vacuum, H_2 heat up, C_2H_2-H_2 mixture carburizing
4	Same as Test 3, but tempered to higher hardness

Table 2 — Results of mechanical testing for hydrogen embrittlement

Test	NFS, ksi	Prestress, ksi	Failures in 200 h @ 75% NFS
1	286.6	215.2 to 217.5	No failures
1	289.1		
1	291.9		
1 average	289		
2	287.4	222.9 to 225.2	No failures
2	306.9		
2	309.3		
2 average	301		
3	293.6	224.3 to 226.5	No failures
3	304.5		
3	308.5		
3 average	302		
4	204.0	145.0 to 147.3	No failures
4	206.0		
4	172.3		
4 average	194		

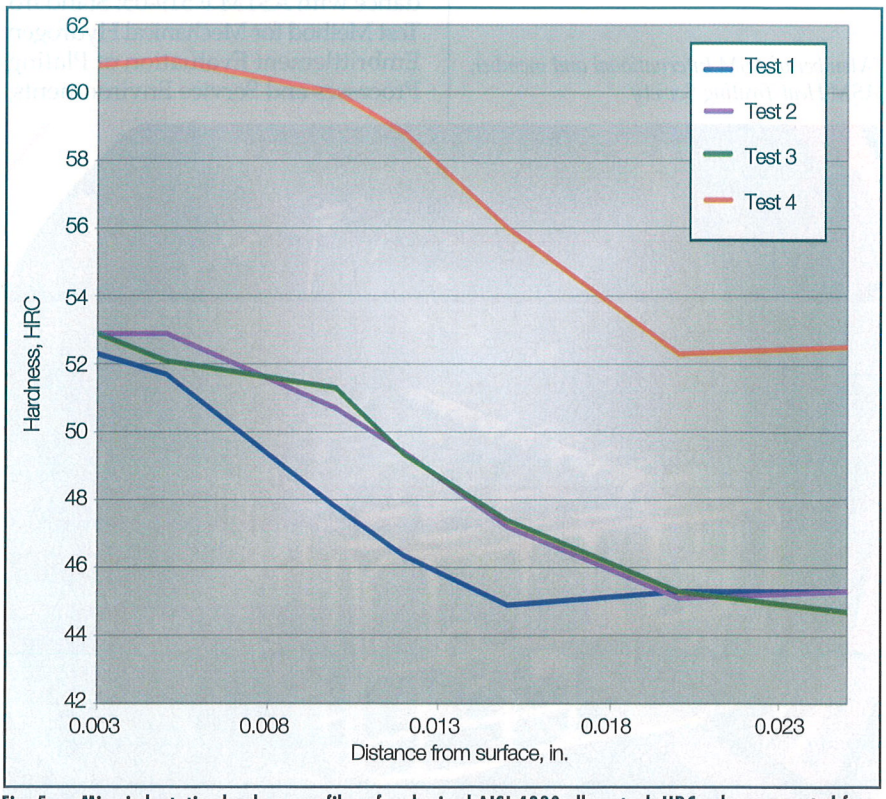


Fig. 5 — Microindentation hardness profiles of carburized AISI 4330 alloy steel; HRC values converted from 500 g Vickers hardness.

ture of 375°F. Atmospheric carburizing in Endogas (Test 1) was carried out by an independent heat treater. Vacuum carburizing was carried out at Solar Atmospheres. All mechanical testing was performed by a NADCAP accredited independent testing laboratory in accordance with ASTM F 519-05 and MIL-STD-1312-5 [4]. Test results are shown in Table 2. Vacuum carburized plus high pressure gas quenched specimens and atmosphere carburized plus oil quenched specimens are shown in Figs. 2 and 3, respectively.

Analysis of Test Results

Microindentation hardness traverses were made on cross sections of specimens (Fig. 4) in each heat treated condition. Results are shown in Fig. 5. Essentially identical hardness profiles were obtained for Tests 2 and 3. The material for Test 2 was vacuum carburized with a nitrogen atmosphere heat up, and the material for Test 3 was vacuum carburized with a hydrogen atmosphere heat up and hydrogen use during carburization. The hardness profile for the Test 1 material (carburized at atmospheric conditions with Endogas) has a somewhat lower hardness for a given depth in the carburized zone. Test 4 has a purposely higher hardness; the higher hardness was used to determine whether the carburized material became hydrogen embrittled at higher strength levels, which it did not. However, Table 2 shows that the higher hardness material (Test 4, 60+ HRC) has a lower NFS than the lower hardness material (51-53 HRC). This indicates that the material is more notch sensitive.

Summary

None of the carburized material of this study became hydrogen embrittled. Thus, it is considered safe to say that carburizing steel in a vacuum furnace at low pressure using acetylene gas plus the use of either nitrogen or hydrogen during heat up and/or during carburization will not cause hydrogen embrittlement of the material. Also, conventionally carburized steel using atmospheric Endogas does not cause embrittlement. **HTP**

For more information: Don Jordon is vice president, Solar Atmospheres Inc., 1969 Clearview Rd., Souderton, PA 18964; e-mail: dfj@solaratm.com; Web site: www.solaratm.com.

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2. Private communication with Dr. John DeLuccia, international expert on hydrogen embrittlement.
3. ASTM F 519-05: Standard Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating Processes and Service Environments.
4. NASM1312-5, Fastener Test Methods, Method 5, Stress Durability.

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