Nitriding-Quenching of Low-Alloy Steel Using Atmospheric-Pressure Plasma Jet

Takashi Inoue, Ryuta Ichiki, Hirokazu Nagamatsu, Masashi Yoshida, Shuichi Akamine, and Seiji Kanazawa

1Oita Univ, Japan
2Shizuoka Institute of Science and Technology, Japan

Up to now, we have developed a new plasma nitriding using the pulsed-arc (PA) plasma jet and realized the steel surface hardening with plasma nitriding under atmospheric pressure [1,2]. By taking advance of the experience of plasma-jet nitriding, we have newly started to develop nitriding-quenching (NQ) treatment using atmospheric-pressure plasma jet. NQ treatment is composed of the following three phases: 1.[Heating phase] Heat steel up to the austenite range. 2.[Nitriding phase] Supply nitrogen atoms into the austenite phase. 3.[Quenching phase] Cool the steel down rapidly enough to invoke martensite transformation. In this treatment, low alloy steels can be hardened in contrast to nitriding treatment [3].

N2/H2 mixture gas is introduced from the upper part of the nozzle (the coaxial cylinder electrode) shown in Fig.1. Pulsed arc discharge is generated with a high-frequency power source (4.5 kV in voltage, 1 A in discharge current, and 20 kHz) between the internal and the external electrode. The afterglow is injected through the orifice onto sample surface. The distance between nozzle tip and sample is kept at 4 mm for rising the temperature to 900°C. After the nitriding phase, the sample was dropped into distilled water for water quenching. The tip of plasma jet is fitted with a cover made of quartz to purge oxygen from treatment atmosphere as shown in Fig.1. As a sample, we used SPCC which is low alloy steel containing almost no alloy elements. The hardness of SPCC base material is approximately 150 Hv.

Fig.2 shows the hardness profile of sample cross-section. We can see that, SPCC was partially hardened up to 800 Hv by NQ treatment. However, the hardness profile is considerably non-uniform. The hardest part was formed into ring shape with a center of jet splaying point. Fig.3 shows metallographic structure of cross-section of the hardest part. The metallographic structure indicates that the hardest part is likely the iron-nitrogen martensite. The iron-nitrogen martensite formation requires optimum nitrogen density and treatment temperature. We consider that these conditions were optimum at the radius of hardest ring.