Prevention of hydrogen permeation by surface-layer microstructure control in type 304 stainless steel

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Metastable austenitic stainless steel, such as type 304, is characterized by a high strength obtained by cold working. This is due to the deformation-induced martensite formed during the cold working. However, the hydrogen permeation into the steel is significantly enhanced by cold working because the deformation induced martensite acts as a fast diffusion path of hydrogen, and this causes hydrogen embrittlement of the steel. Therefore, in a hydrogen environment, stable austenitic stainless steel with a moderate strength must be used as structural materials. In this study, type 304 stainless steel sheet was solution-nitrided to stabilize austenite in the surface layer and then cold-rolled to increase the strength of the material. Through this process, we can obtain 'microstructure-gradient stainless steel', where stable austenitic structure is remained in the surface layer to prevent the hydrogen permeation from the environment, while a large amount of deformation-induced martensite is dispersed in the center of the steel sheet for increasing strength. The behavior of hydrogen permeation was compared between the microstructure-gradient stainless steel and conventional cold-rolled type 304 stainless steel. It was found that the amount of cathodically charged hydrogen was significantly increased with increasing the reduction by cold rolling in type 304 stainless steel, which corresponds to the increase in the amount of deformation-induced martensitic structure. On the other hand, the microstructure-gradient stainless steel exhibits a very low level of hydrogen absorption. The diffusible hydrogen content was reduced to less than one sixth. As a result of tensile testing, it was confirmed that the deterioration of ductility due to hydrogen charge is effectively suppressed in the microstructure-gradient stainless steel.