Magnetoelastic effect for 316LN-IG stainless steel at low temperatures

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Background

316LN-IG stainless steel is austenitic and used widely in devices operating at liquid helium temperatures, in particular, in TF-coils of the ITER magnet system. Non-magnetic under normal conditions, it becomes magnetic under low-temperature plastic strain as a result of the γ → austenite martensitic transformation. As is known, appearance of magnetic austenite is a sign of embrittlement of austenitic stainless steels, which results in development of cracks and is highly undesirable in exploiting apparatus under extreme conditions, such as nuclear reactors. This is a problem also for devices operating at liquid helium temperatures, the more that a strain at these temperatures is uneven and can result in dynamic forces.

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Objectives

- Uniaxial tensile testing the steel 316LN-IG (0.013% C; 11.5% Ni; 16.5 Cr; 2.0% Mn) in liquid and gaseous helium below 7 K.
- Measuring time dependences of strain, strain induced magnetization and temperature of stressed samples.
- Interrelating elastic, magnetic and thermal effects arising in the steel strained at the helium temperatures.

Preparation and appearance

Samples were made from tubes as received as well as after complete simulation of the production cycle in manufacturing of conductors for ITER magnet system in accordance with the requirements of ASME E1450-2000. The tubes were cut out from tubes along their axis by wet wet cutting.

X-ray phase analysis

In the elastic and plastic ranges the magnetoelastic effect indicating a negative longitudinal magnetostriction for the initial γ phase and the strain-induced a phase is found.

Taking into account the magnetoelastic effect, a lack of local heating at strain jumps found in the previous work (Krivykh AV, Anashkin OD, Keilin VE, Ester DN, Pukhov AV, Shcherbakov VS. Proc. Int. Sci.-Tech. Conf. Nanotechnologies of Functional Materials (NFM'12), St. Petersburg, Russia, 2012, pp. 235-240 (in Russian)) can be explained by the magnetoelastic effect in regions unloaded at the jumps. Such situation is possible if energy needed for adiabatic reorientation of magnetic moments when stress drops is comparable with heat release in slip bands.

Conclusion

- In the range of the jumping plastic strain a complicated behavior of local deformation near slip bands is observed. Regions adjacent to slip bands are unloaded and shrink at the moment of strain jump.
- In the elastic and plastic ranges the magnetoelastic effect indicating a negative longitudinal magnetostriction for the initial γ phase and the strain-induced a phase is found.

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