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Plasma Nitriding of Vanadium-Alloyed Air-Hardening Ductile Steels

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Steel components exposed to dynamic loads are prone to wear and oxidation. Nitriding is a thermomechanical treatment employed to overcome these issues. The significant enhancement in the properties of steel components following nitriding is mainly attributed to increased surface hardness, the development of internal stresses, and chemical modifications within the treated zone. Vanadium as an alloying element in steels can significantly influence the plasma nitriding process and its outcomes. The presence of vanadium can enhance the overall nitriding performance of the material.

A recent innovation introduces a new class of martensitic steels that achieve their final properties through air cooling directly from the forging heat. These air-hardening ductile (AHD) forging steels, alloyed with approximately 4 wt.% manganese, develop a uniform martensitic microstructure without quenching and tempering, significantly lowering CO_2 emissions. With the first commercial melts of these steels now available, interest in their performance across various applications is increasing.

This study focuses on the role of vanadium in the plasma nitriding behavior of AHD steels, particularly its influence on hardness and phase formation. Vanadium-alloyed AHD steels were subjected to plasma nitriding at various temperatures, and their microstructural evolution and mechanical properties were systematically analyzed. Hardness measurements using micro-Vickers indentation revealed that vanadium-containing compositions exhibited higher hardness compared to vanadium-free counterparts. Phase analysis conducted via X-ray Diffraction (XRD) indicated variations in nitride formation, while microstructural characterization using Scanning Electron Microscopy (SEM) and Light Optical Microscopy (LOM) provided insights into surface morphology and diffusion depth. The findings highlight the potential of vanadium as an important alloying element in the nitriding performance of AHD steels.

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