Affect of Temper Embrittlement on Magnetic Barkhausen Noise of Q1N and HY-80 Steels

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Temper embrittlement reduces fracture toughness in high-strength low-alloy steels exposed to high temperatures for an extended period. Embrittlement progresses due to migration of impurity elements, such as sulphur, phosphorus, tin, arsenic and antimony to prior austenitic grain boundaries, and can also alter the fraction of carbides within steel grains. Migration of impurity elements can modify pinning sites that interact with magnetic domain walls within steel grains during magnetization (see Figure 1). In this study, effect of pinning site density within grains of Q1N and HY80 steel, on magnetic Barkhausen noise (MBN) generation was investigated. Samples of Q1N and HY-80 steel were heat treated to produce temper embrittlement. The steels, which are used in submarine applications, can be exposed to temperatures in the embrittling range of 371 to 599 ºC. Evaluation of the state of temper embrittlement in the steels can contribute to risk assessments that provide assurance that in-service components will not undergo failure. The present work evaluated response of MBN to changes in temper embrittlement in HY-80 cast and Q1N rolled steels. Steel samples were subjected to a constant temperature (525° C) at different holding times, to produce different amounts of embrittlement in each sample. The MBN measurement system used a flux controlled waveform, facilitating reproducibility of MBN measurements and permitting extraction of variations in permeability between samples. MBN signal response decreased as a function of time held at temperature. Microstructural characterization of the samples, using scanning electron microscopy, showed migration of carbides toward grain boundaries. Decreased MBN signal response was therefore, attributed to reduction of pinning sites for the movement of domain walls within grains. Stress dependence of MBN for Q1N samples was also investigated. An increase in MBN energy with stress was observed for all the temper embrittled samples, however, the rate of increase varied between samples. These results have implications for the assessment of temper embrittled Q1N and HY-80 steel when residual stress is also present.

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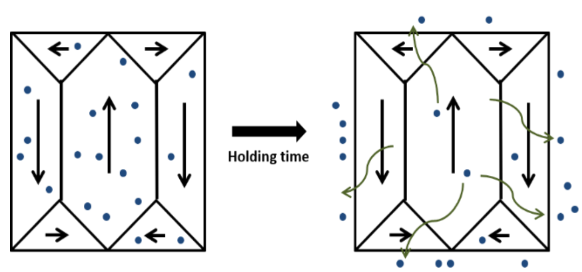

Figure 1. Schematic of a single grain (or magnetic object) indicating presence of magnetic domains and impurities within grains. Impurity migration towards grain boundaries, during temper embrittlement, can reduce interaction with magnetic domain structures.