Non destructive inspection of precipitate evolution in 17-4PH martensitic stainless steel using magnetic Barkhausen noise

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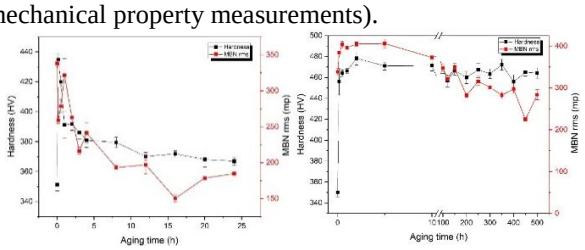
17-4PH is a precipitation hardenable martensitic stainless steel used extensively in safety critical components in the chemical, oil and gas and nuclear industry due to combination of good mechanical properties, high corrosion resistance and ferromagnetic behaviour. The use of 17-4PH and related materials in these high integrity components has driven concerns over the long term stability of the precipitate population. Several studies have characterised these precipitates, most notably using transition electron microscopy (TEM) and atom probe tomography [2,3] and small angle neutron scattering (SANS). However, these studies require samples to be extracted from material, which is destructive in nature. Devoloping a non-destructive examination technique for components which can provide a statistically representative estimate of the precipitate distribution or their evolution over time would be very useful for the industry.

Samples of 17-4PH (SA630 grade) have been solution heat treated at 1050°C for 1 hour, quenched in water and subsequently precipitation hardened by thermally aging at a range of temperatures and time that includes the industrially important H900, H1050 and H1100 heat treatment conditions and 400ºC and 450ºC. The magnetic Barkhausen noise (MBN) measurement were undertaken using a BN analyser (Rollscan 350) and a flat sensor supplied by Stresstech. A magnetising frequency of 100 Hz and voltage of 8V was used in all samples, the signal processing and analysis was undertaken using Microscan software provided by Stresstech. Nanoscale precipitates of the range 1 - 50 nm are formed inside the material due to thermal aging [2,3]. One of the samples aged for 24 hours at 560ºC was observed using TEM where fine and evenly distributed Copper rich precipitates was observed as shown in Figure 3. During aging of the material, the precipitate evolves and grow with aging time.

The root mean square (rms) MBN parameter initially increases with aging time and then reduces after reaching a peak value. This trend of MBN rms has been found to be consistent with the hardness, as shown in Figure 1 (a) and (b). The increase in MBN could be attributed to the evolution of nanoscale precipitates, which acts as pinning points to the magnetic domain wall movement [1]. The quick evolution of precipitates in the material also affects the hardness, by hindering the dislocation motion thereby increasing the hardness of the material. The MBN behavior of sample aged at 400ºC was also found to be in correlation with precipitate evolution as observed by H. Mirzade et al. [4]. The peak position of MBN rms value shifts to higher aging time as the temperature was reduced from 560ºC to 482ºC to 400ºC. This behavior of MBN with aging time and temperature is in correlation with precipitate evolution. Further in-depth study is required to understand the effect of precipitates on pinning of domain walls and increase in MBN rms value. Future work will characterize the precipitates formed in the material using SANS. The knowledge of the precipitate features gained from the SANS data will also enable a direct and novel comparison between the interaction of precipitates with magnetic domain walls (from the MBN measurements) and the interaction of precipitates with dislocations (from mechanical property measurements).



(a) (b)

Figure 1. Variation of MBN and hardness with aging at (a) 560ºC and (b) 482ºC

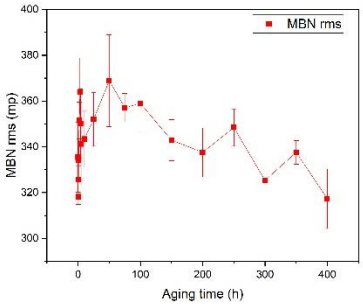


Figure 2. Variation of MBN in sample aged at 400ºC (Correlate with precipitate evolution as per [4])

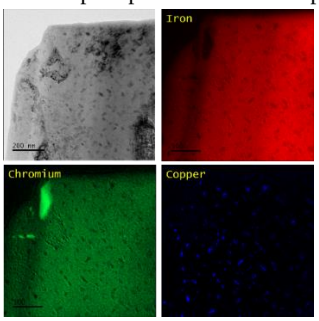


Figure 3. Characterisation data from 17-4PH aged for 24 hours at 560°C from TEM plus EDS (U. Huddersfield)

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