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Non-destructive investigation of microstructural transformations and mechanical hardening by electromagnetic techniques in cold-rolled ferritic-pearlitic steel wire of flexible pipelines

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Thermomechanical manufacturing processes or use in service of mechanical and structural steel components in marine pipelines cause microstructural changes and generate complex stress fields. Due to the challenges faced in oil and gas exploration in deeper areas, there is a need to develop measurement techniques and continuous monitoring of equipment, in order to detect possible defects, prevent catastrophic failures and maximize system availability. Electromagnetic techniques work as a suitable method for the non-destructive monitoring of microstructural, morphological, and mechanical properties transformations in deformed steels. This work seeks understand and analyze the influence of different strain hardening levels on a medium carbon steel wire used in the manufacture of flexible pipelines through non-destructive testing (NDT) techniques based on the behavior of Magnetic Barkhausen Noise (MBN), Magnetic Hysteresis and Electrical Resistivity signals. The samples were analyzed as received and plastically deformed by cold rolling with thickness reductions of 5, 10, 20 and 35%. The detected signals were related to microstructural transformations, crystalline lattice distortions, dislocation density, and changes in mechanical properties through Scanning Electron Microscopy (SEM), X-Ray Diffraction (XRD), and hardness tests. The results show that the higher the strain degree, the lower the MBN peak amplitude and the higher the energy required to reach magnetic saturation. There is an increase in coercivity and the area of the hysteresis curve in the sample with a 5% reduction compared to the as-received condition. The electrical resistivity grows with the evolution of strain, indicating greater impediment to the flow of free electrons. The variation of these signs indicates an increase in structural heterogeneities, such as the elongation of cementite lamellae, increase in dislocation density, presence of discontinuities and cracks, dissolution of carbides in the ferritic matrix, and non-homogeneous stress field distribution, which increase the area of sites fixation of magnetic domains, making the movement of the domain walls difficult. Therefore, it is emphasized that the techniques in question can be used efficiently in the inspection of flexible ducts installed in areas of difficult access.