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Influence of plastic compression on the magnetic behaviour of a pipeline steel

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Sensitivity of magnetic behaviour to plastic deformations is only documented in literature for uniaxial tensile testing and few models claim to take into account the plastic deformation sign. We present in this paper some new results showing the influence of a plastic compression on the magnetic behaviour of a pipeline steel and highlighting strong differences between tension and compression for a same deformation amplitude. Results are interpreted in term of kinematic hardening and magneto-elastic effect.

Keywords: Pipeline steel, plastic deformations, hysteresis cycle

1. Introduction

The study and modelling of the influence of mechanical state on magnetic properties of materials is still a relevant challenge, remaining for example a crucial issue in many industrial applications. The magnetic behaviour sensitivity to stress is on the contrary useful as a non-destructive testing principle, especially in the oil and gas industry, where the preventive location of defaults along pipelines can avoid dramatic accidents. In situations like accidental sinking, mechanical loadings reach so high values than plastic (permanent) deformation occurs. It is consequently required to have a good knowledge of how plastic deformations can influence an hysteresis cycle.

2. Former works and new experiments

Many works have shown that macroscopic magnetic behaviour is sensitive to any mechanical loading depending on the loading level (elastic, plastic). Plastic strain leads to strong non-linear changes in the magnetic behaviour [1–4]. Such changes are usually qualified as a “degradation” since magnetic losses are increased and permeability decreased. The sign of the plastic deformation (i.e. deformation obtained in tension vs. compression) is often completely omitted, mainly because performing a sufficiently homogeneous plastic compression to allow a subsequent magnetic measurement is a difficult task. In this paper, a two-phase ferrite-pearlitic pipeline steel is considered. Specimen used for tension and compression tests have been designed by non-linear finite element method in order to avoid plastic buckling and to ensure an homogenous area for magnetic measurements. Local deformation is measured using the digital image correlation method. Quasi-static magnetic measurements are performed using a dedicated permeameter [5]. The magnetic behaviour is carried out at the unloaded state and for different plastic

strain levels obtained by tension and/or compression.

3. Experimental results and modelling

Fig. 1 shows a preliminary result of magnetic hysteresis obtained before or after tension and compression plastic straining (0%,3%,-3%). The magnetization decreases with tension plastic straining and coercive field increases. Under compression plastic strain of same amplitude, the magnetic behaviour seems to be improved leading to a higher magnetization and a lower coercive field. These results, unexpected at first, can be interpreted in term of kinematic hardening and magneto-elastic effect [6].

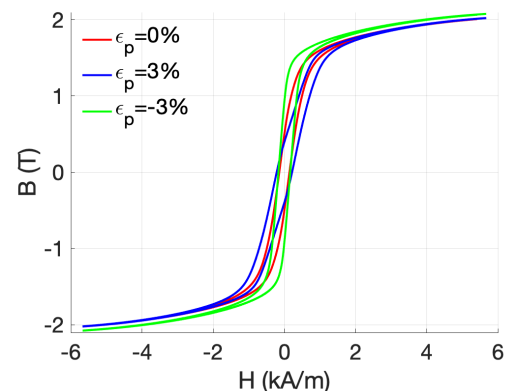


Fig. 1: Modification of the hysteresis cycle with plastic deformation

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