INVESTIGATION OF THE EFFECT OF PULSE ELECTRIC CURRENT ON DUCTILITY IN LOW AND MEDIUM CARBON STEELS

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DECLARATION OF THE CANDIDATE AND SUPERVISOR

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Name of the supervisors	Signature of the supervisors	Date:
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Prof. G.I.P. De Silva		2025-04-07

ABSTRACT

The motivation to do the research is to investigates the impact of the electroplasticity phenomenon on the mechanical behavior of two plain carbon steel samples with different carbon contents (0.09 wt.% and 0.39 wt.%) under uniaxial tensile loading combined with low-frequency high amplitude electrical pulses. Prior to the tensile tests, all samples underwent normalization heat treatment. The experimental results demonstrate a progressive decrease in yield stress accompanied by an improvement in ductility as the pulse frequency increases, up to a frequency of 0.83 Hz. These findings suggest a positive influence of the electroplasticity effect on the tensile properties of plain carbon steels. However, beyond 0.83 Hz, despite further reduction in yield stress, a gradual decline in ductility is observed until a frequency of 1.64 Hz, primarily attributed to enhanced strain localization and induced defects resulting in premature fracture.

Microstructural analysis reveals that the fracture surfaces of samples tested under electrical current exhibit intermediate grain sizes between non-deformed samples and deformed samples tested without current. Additionally, the presence of characteristic dimples on the fractographs further supports the observed variation in ductility with pulse frequency. Notably, the combination of a pulse frequency of 0.83 Hz and an effective current of 777.8 A yields a significant enhancement in formability.

Furthermore, the tensile tests under electric current resulted in increased toughness and fracture strain for both steels compared to normal tests. Simulation results indicate that the maximum temperature accumulation within the material is insufficient to induce phase transformation, and the electroplasticity effect is responsible for reducing the lateral contraction of grains. These findings demonstrate that significant formability enhancement can be achieved by employing this specific combination of pulse frequency and effective current, significantly contributing to understanding the interplay between pulse current and material response, providing valuable insights for optimizing manufacturing techniques and design considerations for plain carbon steel components.

KEY WORDS: Electroplasticity effect, electrically assisted forming, plain carbon steel, uniaxial tensile test, pulsed current

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LIST OF ABBREVIATIONS

AISI	American Iron and Steel Institute
ASTM	American Society for Testing and Materials
CNC	Computer numerical control
EA	Electricity Assisted
EP	Electroplasticity
EAPW	Electrically-Assisted Pressure Welding Process
FCC	Face-Centered Cubic
FEA	Finite Element Analysis
SEM	Scanning Electron Microscope
TEM	Transmission Electron Microscope
UTS	Ultimate Tensile Strength