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Effect of Pulsed Currents on the Springback Reduction of Ultra-High Strength Steels

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Abstract

In this paper, the effect of a single pulsed electric current on the springback reduction of UHSS is investigated by experiments. To do this, a current pulse generator and a bending setup were designed and manufactured. V-bending tests of the 1180 grade steel sheet under a pulsed electric current were then carried out for evaluating springback reduction. The electric pulse was applied to the specimen with constant amplitude of electric current and duration time after the specimen was deformed. The influence of the two adjustable electrical parameters pulse duration and current density on springback was analyzed. The experimental results showed that springback angles are sharply decreased with increasing current densities and pulse durations.

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Keywords: Electric pulse; V-bending; Springback reduction; Ultra high strength steel; Stress relaxation

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1. Introduction

Ultra high strength steel (UHSS) is currently considered a lightweight ferrous alloy and may be able to reduce the weight of structures while at the same time enhancing the crashworthiness. However, the high strength of UHSS may induce a considerable amount of springback after forming and make the design of the forming process very difficult. Many studies on springback control have been conducted in the past decades. Recently, it has been reported that the application of the electric pulses on metals during plastic deformation can greatly reduce their flow stress and improve the plasticity potential, such phenomenon is known as electro-plastic effect [1]. Despite numerous studies on electrical assisted forming, the explicit role of the electric current in the plastic deformation of metallic alloys is still unclear. Researchers accept the role of electricity in the plastic deformation, and they implicitly agree that electro-plasticity and Joule heating have coupled effects [2-4]. However, many researchers still ignore the so-called electro-plasticity effect, while the thermal effect induced by Joule heating is regarded as the major characteristic of electrically assisted deformation [5-6]. Magargee *et al.* [5] observed that the stress reduction during an electrically assisted tensile test was not pronounced when air cooling was enforced to keep the temperature of the specimen near room temperature.

In this paper, the effect of a single pulse of electric current on the springback of UHSS is investigated by experiments. In advance, a current pulse generator and a bending setup were designed and manufactured. V-bending tests under a pulsed electric current were then carried out for evaluating springback reduction. The electric pulse was applied to the specimen with constant amplitude of electric current and duration time after the specimen was deformed. The influence of the two adjustable electrical parameters pulse duration and peak current density on springback was analyzed. The effect of the electric pulse parameters on the microstructure of pulsed V-bending specimen was also briefly discussed.

2. Experimental procedure

In order to conduct V-bending tests under a pulsed electric current, a special experimental setup considering the flow of electrical pulses and insulation unit was designed and manufactured as shown in Fig. 1(a). V-shape die with an angle of 90° and a 20 mm inner bending radius was used in the bending process. Machinable glass ceramics (MACOR®, USA) was adopted as the punch and part of the die material for its good insulation performance. Electrically assisted V-bending tests was performed by a MTS810 universal testing machine. The direct electrical current was generated by a power source with a programmable pulse controller (Hyundai SPU-1000, South Korea) and was directly subjected to the specimen as shown in Fig. 1(b).

Testing materials is the ultra high strength steel (UHSS) sheet with the thickness of 1.4 mm and the ultimate tensile strength of 1210 MPa. The samples were cut into rectangular shape with 180 mm in length (L) along the rolling direction (RD) and 10 mm in width (W). All the specimen were polished by the abrasive paper to remove the oil and cooling liquid contamination produced during cutting to prevent sparkle during pulse duration.

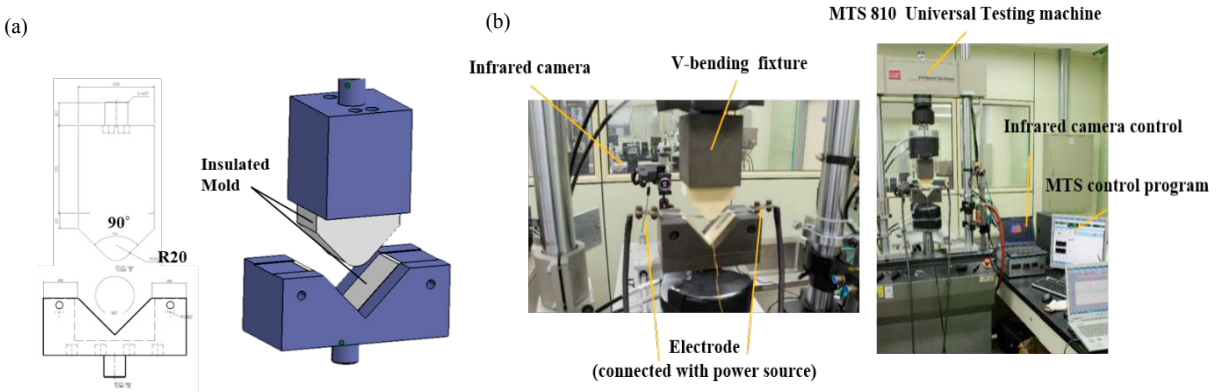

Fig. 1. Electrically assisted V-bending tests: (a) test fixture; (b) experimental set-up