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Performance Evaluation of Induction Heating Coils at Various Design Variables for Preheating In the Hot Stamping Process

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Extended Abstract
The hot stamping process, which is a manufacturing technology for ultra-high-strength steel with high-strength and lightweight components, has been widely used in the automobile industry [1]. Especially, patchwork blanks, which are composed of welding a patch of different thicknesses to the main blank, producing tailored blanks with different properties, and maximizing vehicle weight reduction and fuel efficiency [2]. However, the blanks with local thickening can lead to non-uniform temperature distribution compared to the main blank and prolong the reaching austenitization time in conventional furnace heating [3]. To address these challenges, rapid local preheating methods such as induction, resistance, and infrared heating have been proposed for the preheating of patches before the blank is loaded into the furnace. This preheating ensures that the patches and main blank reach the austenitization temperature simultaneously [4]. Induction heating offers the advantages of high energy efficiency and adaptability for complex geometries compared to other methods. Generally, longitudinal flux solenoid coils have been widely used due to their simplicity and stability [5]. However, it has limitations in thin and complex-shaped metal plates. On the other hand, transverse flux coils can achieve high heat concentration even for thin and complex geometries. The heating performance of transverse flux coils is highly dependent on coil designs such as the distance between the coil and the blank, coil height, coil width, and coil total radius. However, previous studies on coil designs in transverse flux coils are still limited due to their structural complexity, higher technical requirements, and difficulties in temperature control [6].

In this study, the heating performance of transverse flux coils is evaluated at various design variables for preheating of patchwork blanks through electromagnetic-thermal coupled simulations using Ansys Maxwell and Fluent. The design variables included the distance between the coil and blank, coil height, coil width, and coil total radius. The effects of each design parameter were analyzed at a frequency of 5500 Hz and a current of 1560 A. The sensitivity analysis for design variables was conducted using the response surface methodology. As the distance between the coil and blank, and the coil height decreased from 10 to 5 mm, the average temperature of the patchwork blank increased by 30% and 16%, respectively. As the coil width decreased from 10.15 to 7 mm, the average blank temperature increased by 25%. A reduction in coil total radius from 41.0 to 32.5 mm resulted in an 18% increase in temperature. In the same case as before, the standard deviation changed by 44%, 24%, 48%, and 37% for the distance between the coil and blank, coil height, coil width, and coil total radius, respectively. The sensitivity of the distance between the coil and blank showed the highest, followed by the coil's total radius. Finally, this study provides the design guidelines for transverse flux coils to enhance the heating performance of patchwork preheating in the hot stamping process.

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