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Wed-Mo-Po.05-10: Improved Array Welding Magnet Structure Design and Optimization for Enhancing Magnetic Pulse Welding Quality of Dissimilar Metal Tubular Components

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Welding of dissimilar metals can significantly enhance the performance of metal components by utilizing the distinct physical and chemical properties of different materials, offering substantial potential in lightweight and multifunctional manufacturing. Magnetic Pulse Welding (MPW), a solid-state process, employs pulsed electromagnetic fields to accelerate dissimilar metals to supersonic speeds within microseconds. This results in high-speed collisions, facilitating atomic diffusion and metallurgical bonding at the weld interface. However, traditional MPW for tubular components uses a single-coil coaxial structure to deliver magnetic energy, which may be inefficient for large-diameter tubes. As the coil radius increases with component size, the total discharge circuit inductance and discharge current rate rise, limiting effective deformation velocity within the short acceleration period. Additionally, conventional MPW systems are constrained by coil structure limitations. During discharge, the welding magnet undergoes significant radially outward expansion forces. Under the combined mechanical-electrical-thermal loading conditions and geometric constraints, existing MPW magnets suffer from low energy conversion efficiency, poor interfacial bonding, and limited adaptability of coil topologies.

To address these challenges, this study introduces a novel array-based welding magnet structure for tubular components. The proposed topology features two key components: circumferentially distributed modular array coils and an encircling conductive channel. The modular coils are arranged in equidistant multi-stage configurations along the component's periphery, with multiple independent power supplies to enhance discharge current rates. The conductive channel, made from high-strength chromium-zirconium copper alloy with superior conductivity, forms a closed circuit and utilizes leakage flux from the coil array to improve energy efficiency. Together, these components optimize the uniformity of collision interface pressure, enhancing weld quality while reducing equipment complexity.

A three-dimensional FEM-BEM collision model of the welding process was developed using LS-DYNA software to simulate energy transfer and collision dynamics. Key parameters, such as coil spacing, cross-sectional geometry, and axial coil stages, were optimized. The results show that the array-based magnet structure, in conjunction with multi-stage coordinated power discharge, effectively increases material acceleration in large-diameter component welding. Additionally, the conductive channel transforms the outward-expanding electromagnetic forces into inward compressive forces, greatly improving the magnet's load-bearing capacity. These findings provide crucial insights for enhancing MPW joint quality and broadening the industrial applications of this technology.

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