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Design and analysis of a pulsed electromagnetic blankholder system for electromagnetic forming

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Abstract

A pulsed electromagnetic blankholder system consisting of a pulsed magnet driven by a capacitor bank and a conductive ring as a blank holder has been proposed, designed, and analyzed for electromagnetic forming. The blank holder force (BHF) supplied by the system is a huge repulsive electromagnetic force generated in the blank holder by the interaction between the pulsed magnetic field and the induced eddy current. The electromagnetic performance of the system has been investigated in detail based on finite element method, and simulation results show that the system can generate a pulsed BHF ranging from 0 to 1000 kN at different discharge voltages with a rise time of more than 5 ms, which fulfills the common requirements for electromagnetic forming process.

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Keywords: Pulsed electromagnetic blankholder; Electromagnetic force; Sheet metal forming

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1. Introduction

In the sheet metal forming process, a blank is usually drawn into a die cavity to form the desired shape. The blank holder force (BHF) is often applied to the blank to reduce the occurrence of forming defects such as wrinkling, tearing and springback. An excessive BHF will cause insufficient material flow which results in tearing, while wrinkling will appear when the BHF is too small due to an excessive material flow. Therefore, the BHF plays an important role in the sheet metal forming process.

For decades, there are numerous research works and published papers dealing with the various applications of BHF. Conventionally, BHF can be exerted by hydraulic machines [1, 2], which require complex control modules and occupy a large area. To increase the flexibility and accuracy for controlling the BHF, Seo [3] proposed a method using the electromagnetic force as the BHF, which is essentially the magnetic attraction generated on the ferrous blank by an electromagnet. This method is suitable for deep drawing and stamping, however, the generated BHF is limited since ferromagnetic materials will be saturated when the generated magnetic field further increases. Lai [4] designed a system using pulsed electromagnetic attractive force between two coils to supply BHF for electromagnetic forming, which can provide much higher BHF with the aid of reinforcement technology of high-strength coil than the system presented by Seo [3].

Different to the above methods, a novel pulsed electromagnetic blankholder (PEB) system using electromagnetic repulsive force is proposed and analyzed for electromagnetic forming in this work. This method has inherited the advantages of the method proposed by Lai [4]. Moreover, the discharge energy and installation dimensions required in this method can be greatly reduced. In this paper, the basic principle of the PEB system was introduced. Two methods for generating electromagnetic repulsive force were compared and one of them consisting of a discharge coil and a conductive ring was adopted. Then, simulation results based on finite element method were presented to validate the effectiveness of the PEB system.

2. Principle and Requirement

2.1. Principle of PEB system

The concept of the proposed PEB system is to provide a sufficient BHF with enough pulse width for electromagnetic forming. Generally, there are two methods for producing an electromagnetic repulsive force. When a high-density current flows through two parallel coils in opposite directions, there would be a repulsion between them according to Ampere's force law. Each coil generates a magnetic field and as a consequence the other coil would experience a magnetic force, as represented in Fig. 1(a). Similarly, when one coil is replaced by a conductive ring, the interaction between the pulsed magnetic field and the eddy current induced on the ring would produce a Lorentz force on the ring, as shown in Fig. 1(b).

Comparing the two methods, it can be seen that there is only one coil used in the latter, which not only saves the cost but also makes this method easy to implement. Therefore, the latter structure is adopted to supply BHF in our proposed PEB system.

The schematic diagram of the PEB system is shown in Fig. 2. The system is mainly consisted of a fixed blankholder coil driven by a capacitor bank and a conductive ring as a blank holder, while the Lorentz force generated in the blank holder can directly transmit to the flange of the workpiece. The forming coil here is designed for generating forming force to reshape the workpieces. The magnitude of the BHF is determined by the discharge energy of the capacitor bank, which is flexible and accurate to control.

2.2. Design object of PEB system

The PEB system is designed to control material flow in the electromagnetic forming process. Since the forming of sheet metal parts is limited by two types of failure: wrinkling and tearing, there would be an acceptable blank holder force range for the entire forming process [5]. Thus, the two following points are required for the pulsed BHF:

- the magnitude of the BHF should be high enough to supply appropriate holding force, and