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Research Progress on Coil system and Force Distribution in Electromagnetic Forming Process

Speaker: Li Qiu College of Electrical Engineering and New Energy China Three Gorges University, Yichang, China

Netherlands





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Basic Principle



Introduction

Lightweight

- ♦ Increase carrying capacity
- ◆Enhance emission efficiency
- ◆ cost reduction



Electromagnetic Forming(EMF) can improve the material (light alloy) plastic deformation and increase its forming limit by 5-10 times.

EMF is one of the effective ways to solve the difficult problems in





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Introduction





Basic Principle



(c)

Diagram of EMF equipment. (a) Basic principle. (b) electromagnetic tube forming. (c) electromagnetic sheet forming. Firstly, the capacitor is charged by the charging system. Secondly, the stored energy is loaded into the coil system through the discharge switch to generate a pulse large current and a pulse strong magnetic field around the coil system. Thirdly, the changing magnetic field produces inductive eddy current in the workpiece. Finally, the electromagnetic force between the pulse current in the coil system and the induced eddy current in the workpiece drives the workpiece instantly accelerated and deformed. Usually, EMF is divided into electromagnetic tube forming and electromagnetic sheet forming, according to the different workpiece geometric structure.

The electric field intensity in the workpiece and the electromagnetic force acting on the workpiece is calculated:

$$\nabla \times \boldsymbol{E}_{\phi} = -\frac{\partial \boldsymbol{B}_{z}}{\partial t} + \nabla \times \left(\boldsymbol{v}_{z} \times \boldsymbol{B}_{r}\right) \quad (a) \qquad \boldsymbol{F}_{z} = \boldsymbol{J}_{\phi} \times \boldsymbol{B}_{r} \quad (a)$$

$$\nabla \times \boldsymbol{E}_{\phi} = -\frac{\partial \boldsymbol{B}_{z}}{\partial t} + \nabla \times (\boldsymbol{v}_{r} \times \boldsymbol{B}_{z}) \quad (b) \quad \boldsymbol{F}_{r} = \boldsymbol{J}_{\phi} \times \boldsymbol{B}_{z} \quad (b)$$





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EMF technologies

Electromagnetic Incremental Forming



Electromagnetic incremental forming

Firstly, a small coil is used to generate local electromagnetic force and form part of large-scale sheet, and then the large-scale sheet is completely deformed by moving the coil system with computer control.



sheet profile using Electromagnetic incremental forming

It is verified that Electromagnetic incremental forming is feasibly to produce a large part with small coil and small discharge energy. However, the workpiece is mainly bulged but slightly flowed in Electromagnetic incremental forming process.

Reference: X.H. Cui, et al. Electromagnetic Incremental Forming (EMIF): A Novel Aluminum Alloy Sheet and Tube Forming Technology, Journal of Materials Processing Technology, vol. 214, pp. 409-427, 2014.

EMF technologies

Space-Time-Controlled Multi-Stage Pulsed Magnetic Field Forming



Principle of axial-radial force bi-directionally loaded in double coil electromagnetic forming

Coil 1 mainly provides the axial electromagnetic force, while coil 2 mainly provides the radial electromagnetic force. Because of the radial electromagnetic force in the flange of the sheet, the material flow property is increased effectively.

Space-Time-Controlled Multi-Stage Pulsed Magnetic Field Forming can enhance the material plastic flow by applying multiple sets of coils. But the price is also increased due to the large investment of equipments.



double coils for deep drawing

Reference: Zhipeng Lai, et al. Radial Lorentz Force Augmented Deep Drawing for Large Drawing Ratio Using a Novel Dual-coil Electromagnetic Forming System, JMPT, vol. 222, pp. 13-20, 2015.

EMF technologies

Electromagnetic Tube Expansion with Axial Compression



Coil system. (a) conventional electromagnetic tube expansion;(b) electromagnetic tube expansion with axial compression.

Firstly, the axial and radial magnetic flux density are generated in the workpiece region by the coil system. Secondly, the radial electromagnetic force is generated by the interaction the eddy current and the axial magnetic flux density, and the axial electromagnetic force is simultaneously generated by the interaction the eddy current and the radial magnetic flux density. Finally, the radial electromagnetic force drives the workpiece radial expanding, and meanwhile the axial electromagnetic force makes the workpiece axial compressing. ---- electromagnetic tube expansion



Axial electromagnetic force and thickness of the deformed tube





Introduction

Basic Principle





Electromagnetic incremental forming, Space-Time-Controlled Multi-Stage Pulsed Magnetic Field Forming, and electromagnetic tube expansion with axial compression have been discussed in this paper. In general, each new method can solve some problems in conventional EMF process, and promote EMF for development. However, some key technical issues in EMF should be solved for achieving industrialized application.

➢ How to design the corresponding coil system according to the specific forming requirements.

➢ How to solve the temperature problem in the coil system caused by the large current.

EMF should been widely used in light alloy forming in the future.

