Design and Fabrication, and Test of a Dual-coil Electromagnetic Sheet Forming System

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Introduction

Electromagnetic forming (EMF) is a high-speed forming process, where the workpiece is deformed by pulsed Lorentz force generated by magnetic and eddy current on the sheet workpiece. Over the past few decades, EMF has been discussed both in theory and practice. Research shows that the structure of driving coil dominates the distribution of Lorentz force acting on the sheet metal, and thus determines the deformation behavior of the sheet metal workpiece. However, most of the researches are base on a conventional single-coil system, where the controllability of the spatial distribution of Lorentz force is relatively limited.

To solve the problem, a dual-coil system that can flexibly alter the distribution of axial Lorentz force acting on the sheet metal workpiece was presented. The principle of the system was introduced and a prototype of the dual-coil EMF was fabricated. Based on the prototype, a series of experiments were carried to validate the feasibility of the proposed system.

Principle

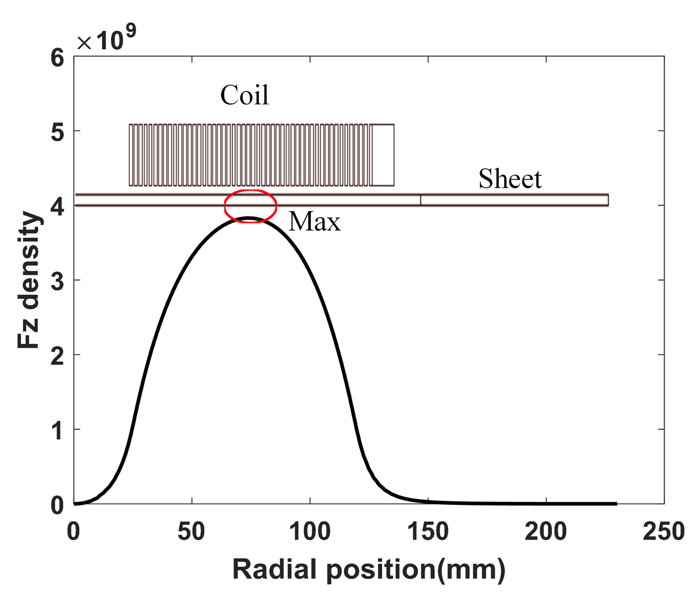

Fig. 1. The density of axial Lorentz force on the sheet generated by the conventional single-coil

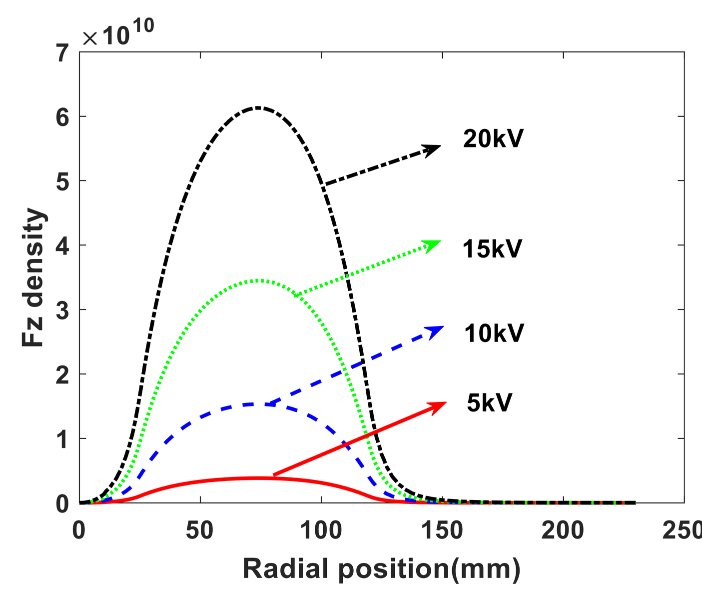

Fig. 2. The density of axial Lorentz force on the sheet at different discharge energies generated by the conventional single-coil

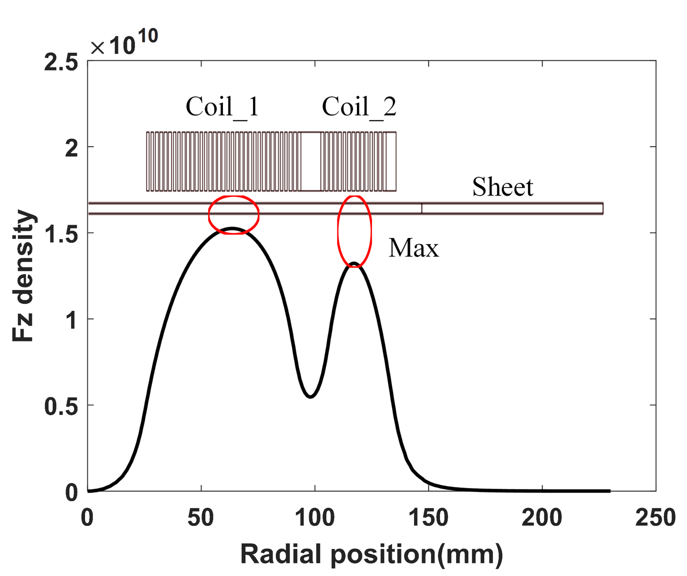

Fig. 3. The density of axial Lorentz force on the sheet generated by the dual-coil.

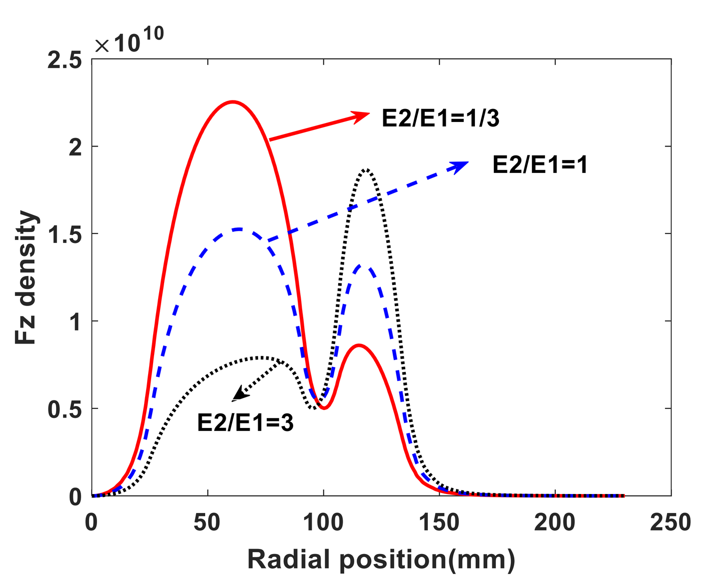

Fig. 4. The density of axial Lorentz force on the sheet at different discharge energy ratios generated by the dual-coil

A. Limitation of conventional EMF system

The Lorentz force consists of two components–an axial Lorentz force (Fz) and a radial Lorentz force(Fr). Commonly, Fz plays a leading role on shaping the sheet metal. Fig. 1 shows the distribution of Fz generated by the conventional single-coil. It reaches the peak value at the central area along the coil width. The magnitude of Fz increases with increase of discharge voltage, but the radial distribution of Fz is approximately the same, as shown in Fig. 2. For the conventional single-coil, the controllability of the distribution of Fz is relatively poor.

B. Solution for overcoming the limitation

A dual-coil system is proposed to improve the controllability of the spatial distribution of Lorentz force. Fig. 3. shows the axial Lorentz force generated by the dual-coil. The Fz has two peaks which are generated by coil_1 and coil_2, respectively. Furtherly, the two peak values can be adjusted by changing discharge energy ratios, as shown in Fig. 4. It should be noted E1,E2 are defined as the discharge energy of coli_1 and coil_2, respectively. E2/E1 is defined as the discharge energy ratio of the dual-coil system.

Experiment and Results

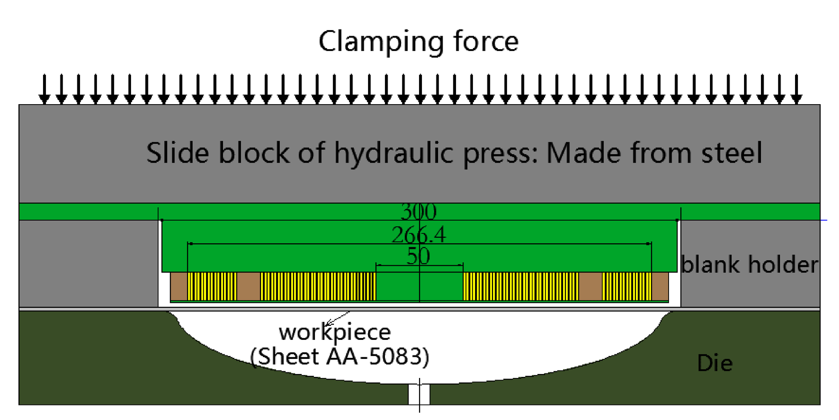

Fig. 5. Experimental setup schematic.

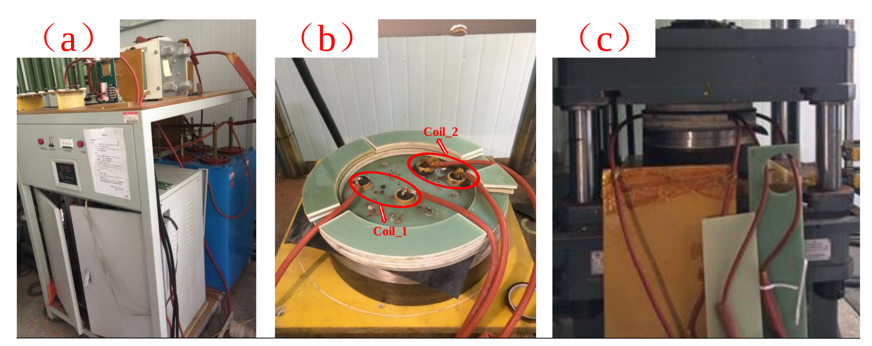

Fig. 6. Experimental setup.

The driving coil was placed atop the sheet workpiece, and the upper part of the driving coil is clamped by pressure machine to fix it during the forming process, as show in Fig.5. Fig. 6 (a) shows the capacitor bank system which was used to energized the coils in forming process, and the photos of experimental setup were shown in Fig. 6 (b) and (c), respectively.

Table I
Discharge Parameters of the Dual-coil

Symbol	High ratio	Moderate ratio	Low ratio
V1	5	7.1	8.66
V2	8.66	7.1	5
E2/E1	3/1	1/1	1/3

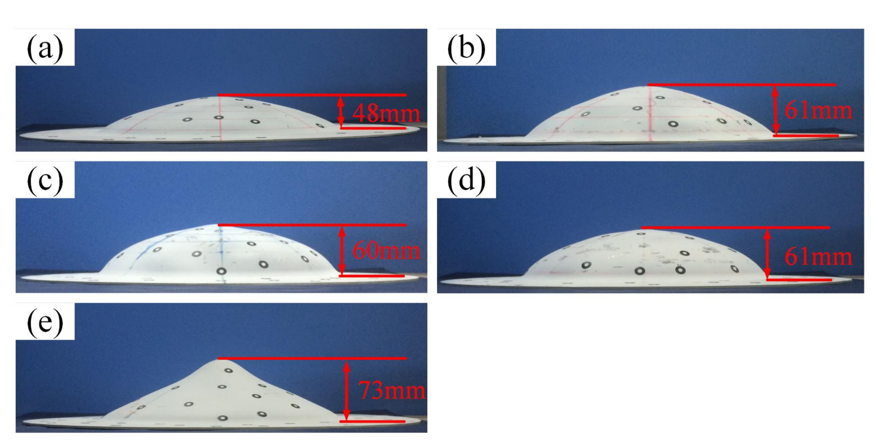

Fig. 7 Deformed sheets.

For conventional single-coil EMF, two experiments with discharge voltage of 7 kV and 10 kV were conducted. For dual-coil EMF three experiments with different discharge energy ratios were conducted. Fig. 7 shows the deformed sheet workpieces under the condition of different discharge voltages and forming coils. The forming height increased 27% from 48 mm to 61 mm, when the discharge voltage was raised from 7 kV to 10 kV, as shown in Fig. 8. To intuitively evaluate the morphology changes of the deformed sheet workpieces, the axial displacement were normalized by their maximum height, as show in Fig. 9 and 10. Compared with the forming height described above, it can be concluded that, for single-coil, the control of the discharge energy can only change the forming height, while cannot alter the deformation profile. Fig. 10 presented that the profile (red line in Fig. 10) obtained by single-coil EMF is located between two profiles (black and green lines) obtained by dual-coil EMF under different energy ratios, which indicates that the dual-coil offers much greater flexibility than single-coil on altering the deformation of the sheet

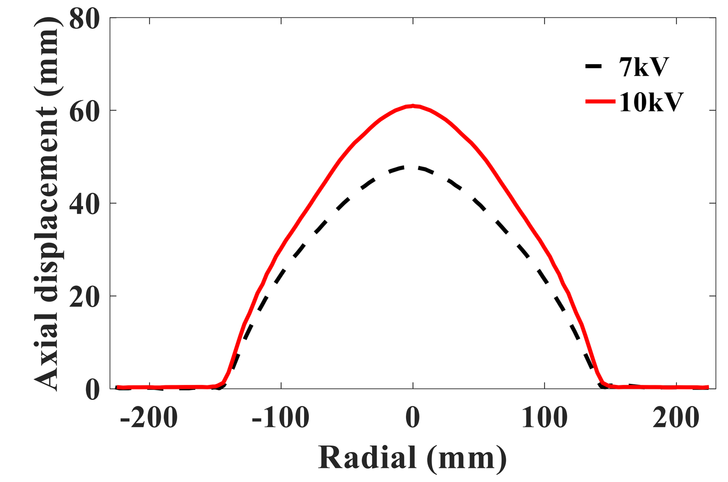

Fig. 8. Axial displacement of the workpieces deformed by the conventional single-coil

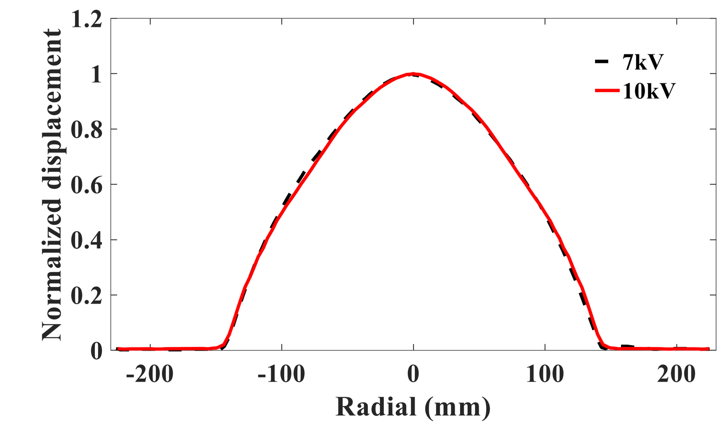

Fig. 9. Normalized axial displacement of the workpieces deformed by the conventional single-coil

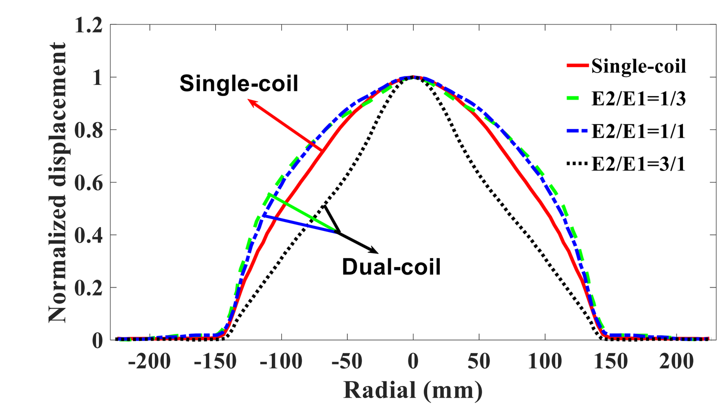

Fig. 10. Normalized axial displacement of workpieces deformed by dual-coil with different discharge energy ratios.

Conclusion

A prototype of the dual-coil EMF system of sheet metal forming was fabricated and has been verified to be effective by experiments. The results show:

1. The dual-coil offers much greater flexibility than conventional single-coil on adjusting the distribution of Lorentz force.
2. The dual-coil EMF can effectively alter the forming shape, when compared with the conventional single-coil EMF.

Reference

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