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A Method To Improve Forming Accuracy in Electromagnetic Forming of Sheet Metal by A Field Shaper

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I Introduction

Electromagnetic forming (EMF) is a high-velocity forming technology, which can improve the formability of metal materials effectively. It is one of the most effective techniques to solve forming for low density alloys. EMF technology is completely different from conventional quasi-static stamping technology. The action time of Lorentz force is only microsecond. The effective distance between the coil and the workpiece is increased with the movement of the workpiece, which leads to Lorentz force decay very quickly. Then the deformation of the work-piece depends on the inertia force.

Recently, most of the existing studies focus on pulsing power supply, forming coil and deformation limit of the workpiece. However, there is less study about the precision of the workpiece. In EMF processing, once forming coil wound, its basic structure has been fixed. At the same time, forming coil will be subjected to a large inner stress according to Newton's third law in forming process. So the structure of forming coil is mainly symmetrical structure. On the other hand, shape of the workpiece is constrained by die. Then forming coil and workpiece cannot match completely. There will be the shortage of insufficient Lorentz force in some regions.

In this work, Field shaper was applied in EMF system to solve the shortage of insufficient Lorentz force in some regions. In the following sections, the limitation of the conventional system was analyzed. Then the advantage of the improved system with field shaper was studied through analyzing the distribution of magnetic field and Lorentz force in EMF processing. Meanwhile, the outer surface structure of field shaper was improved. And the influence of the structure on the magnetic field and Lorentz force was analyzed.

II Methodology

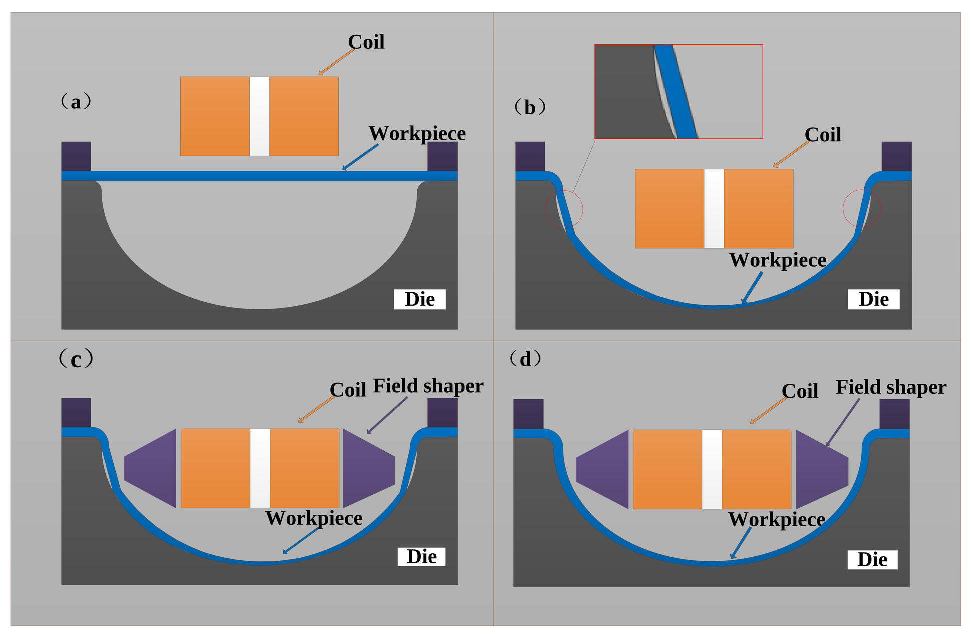

Fig. 1. The schematic diagram of the conventional EMF system and the improved EMF system;

Fig. 1 shows the principle of improving forming accuracy in EMF to sheet metal by a field shaper. The system adopted axially moveable to reduce the axial distance between forming coil and workpiece.To make the coil can be moved down into the cavity, the size of coil is designed relatively small. In Fig. 1(b), it shows a fact that the deformation of the workpiece at the side wall of the die is not enough. That means that there will be a deviation in the side wall regions.

A field shaper is an axis-symmetric component made of an electrically high conductive material, which features one axial slot as shown in Fig. 2. In EMF process, the sudden discharge of the capacitor causes a damped sinusoidal current flowing through forming coil which induces a related eddy current. Due to the skin effect and Lenz' law this induced eddy current flows to outer surface of the field shaper form the axial slot. Therefore the current direction is the same as in the forming coil. So the energy of forming coil is transferred from forming coil to workpiece. Based on this, the improved system with field shaper was applied to improve the radial deformation in the last step as shown in Fig. 1(c). Fig. 1(d) shows the expected effect of the workpiece finally.

Fig. 3 shows the 3D geometry of an EMF system with field shaper. In this paper, three kind of models was analyzed: conventional system without field shaper, improved system with normal field shaper and improved system with P1 field shaper. And the other parameters remain constant.

The most fundamental aim of simulation is to improve forming accuracy in electromagnetic forming of sheet metal. So the simulation only need to analysis the final shape of the workpiece.

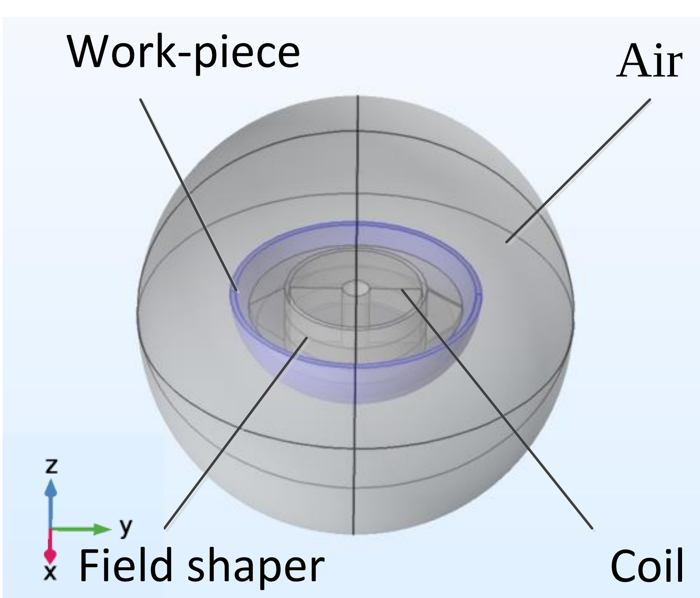

Fig.3. 3D geometry of finite element model

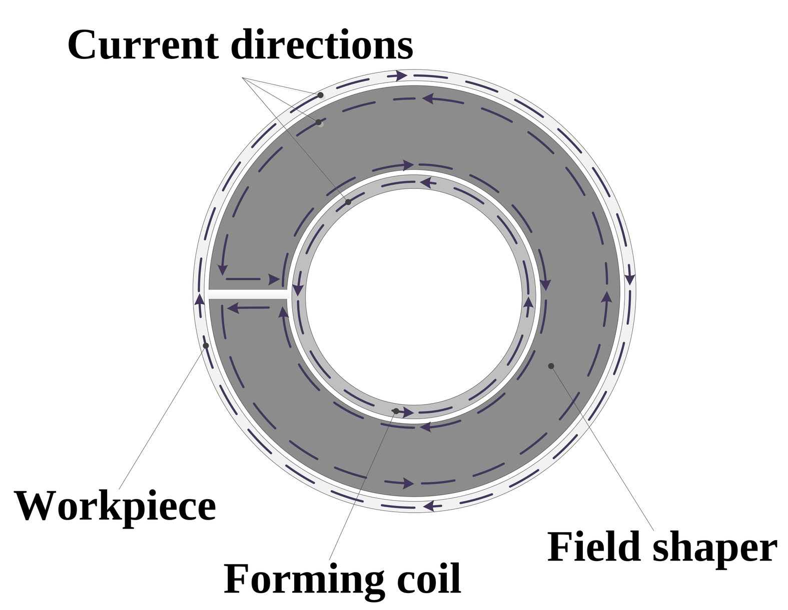

Fig. 2 Current directions in forming coil field shaper and workpiece.

III Results and discussion

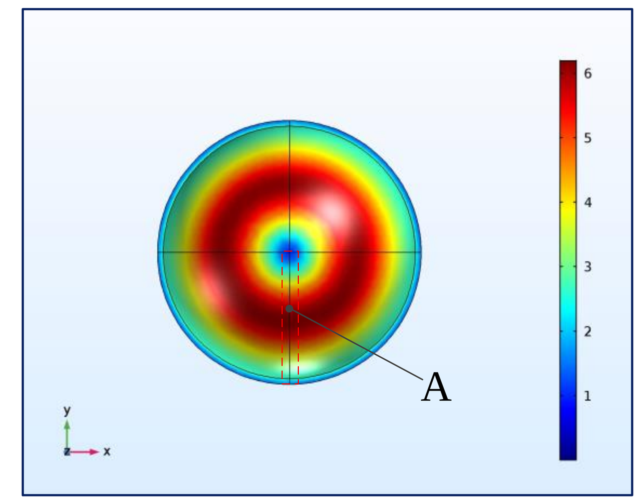

Fig. 4. Distribution of the magnetic flux density around the workpiece in conventional system.

Fig. 4 shows the magnetic flux density distribution in the whole region in conventional system. It can be seen that the magnetic flux density mainly distributes in the bottom of the die and the magnetic flux density in the side wall is relatively small.

Fig. 5 shows the distribution of magnetic flux density on A line in conventional system, the improved system with normal field shaper and the improved system with P1field shaper respectively. Compared with the magnetic flux density distribution, it can be seen that field shaper can change the magnetic flux density effectively. Fig. 5(b) shows the maximum value reached 7.01T, and the region in the side wall. Therefore, the normal field shaper improved the axial magnetic flux density effectively.

Pi field shaper was applied in Fig. 5(c). The outer surface of the field shaper was changed into angular surface (the angle is 21.8。), match the final workpiece. It can be seen that the magnetic flux density distribution on A line. From the trend of the curve can be seen that the magnetic flux density is not only large but also more uniform.

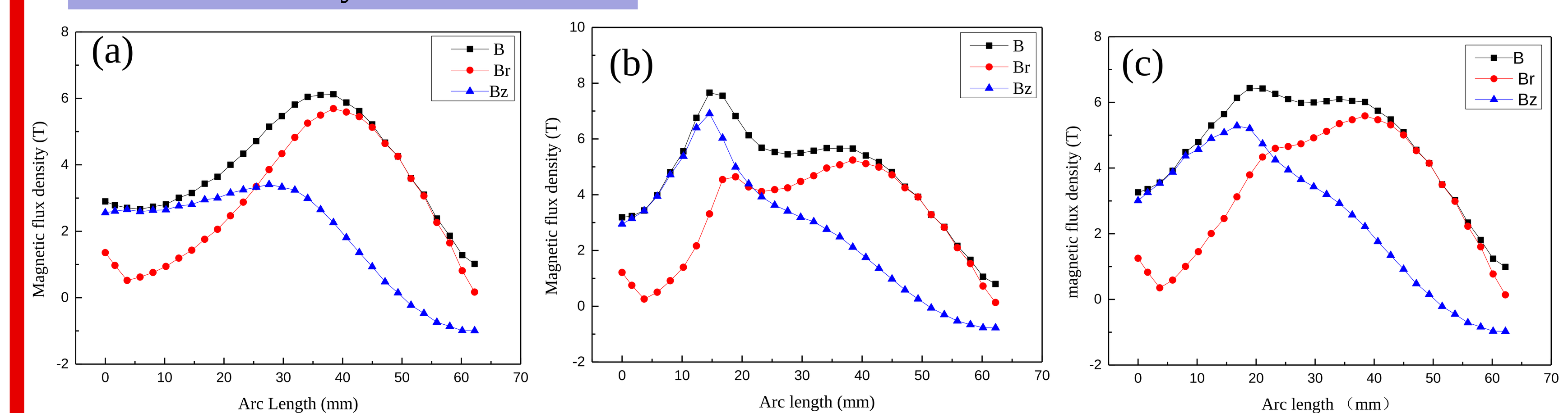

Fig. 5. (a) Distribution of the magnetic flux density in A region of the conventional system. (b) Distribution of the magnetic flux density in A region of the improved system. (c) Distribution of the magnetic flux density in A region of the improved system with P1 field shaper.

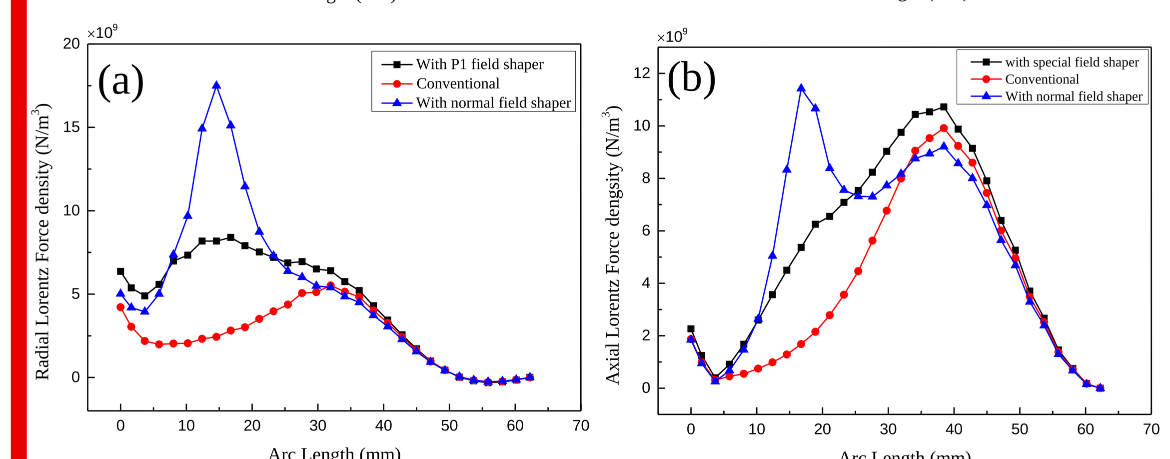

Fig. 6. (a) The radial Lorentz force density varies with distance of the die. (b) The axial Lorentz force density varies with distance of the die.

Fig. 6 shows the radial Lorentz force density and the axial Lorentz force density varies with distance of the die in different way. The radial Lorentz force density with normal field shaper increased significantly in the side wall of the die, relative to the conventional, especially in the desired region (10mm~20mm). The comparison between the values of the radial Lorentz force density with field shaper, while increasing the Lorentz force in the desired region, the radial Lorentz force acting on the workpiece is more uniform.

IV Conclusion

Lorentz force descend quickly with the distance between coil and work-piece increases. In this paper, subject to the structure limitation of the forming coil and the die, the Lorentz force is not enough in the side wall of the die. To solve this shortage, a field shaper was proposed, and applied to an axially movable electromagnetic forming system for shaping of the workpiece. Compared with conventional system, an additional field shaper can increase the magnetic flux density and Lorentz force in the side wall of the die. Meanwhile, the structure of field shaper was improved, mainly aimed at the outer surface of filed shaper. The result show that not only magnetic field and Lorentz force increased, but also became more uniform. All these simulation results have shown that field shaper can solve the local correction effectively in the mold forming. When some region appeared Lorentz force is not enough, selected appropriate structure of field shaper is a good way.

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