# Design of Pulsed Magnet for Adjusting the Residual Stress Field in Large-size Aluminum Alloy Rings

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## Introduction

Residual stress will be generated in the metal ring during machining processing. The electromagnetic force generated by the pulsed magnetic field is superimposed with the original residual stress of the workpiece to cause plastic deformation, which can relax and release the residual stress. In order to achieve the control of residual stress in large-size aluminum alloy rings, this paper uses the multiphysics finite element simulation software COMSOL to design and analyze a set of electromagnetic bulging system.

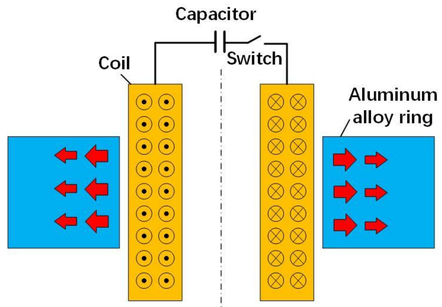


Fig. 1

## Finite element simulation

Fig.2 is the simulation schematic diagram.The research object is a large-size aluminum alloy ring with an outer diameter of 720mm, a wall thickness of 60mm, and a height of 60mm. The coil skeleton is made of epoxy material, and the inner side is a steel support ring.

**The goal of simulation design:**

- To improve the forming efficiency of the system;
- To increase the strength of the skeleton of magnet;
- To reduce the energy during a single discharge.

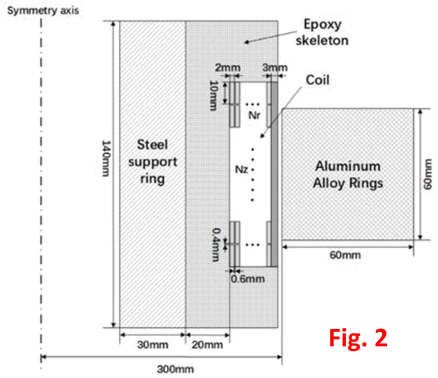


Fig. 2

## Results and discussion

### 1) Coil structure design

With the increase of the number of radial layers Nr and axial turns Nz of the coil, the plastic deformation of the aluminum ring increases significantly at first, and then begins to slowly decrease. The influence of Nr and Nz on the ring's plastic deformation are shown in Fig.4 and Fig.5. The electromagnetic force under different number of turns is shown in Fig.3.

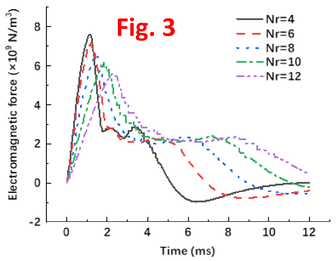


Fig. 3

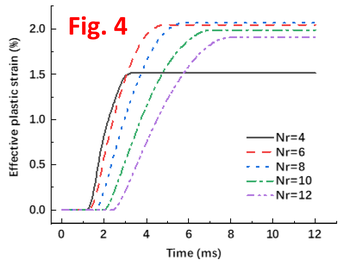


Fig. 4

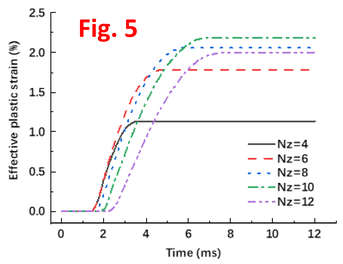


Fig. 5

When Nr=Nz=8, the deformation of the aluminum ring is the largest, and the forming efficiency of the system is the highest at this time.

### 2) Analysis of steel support ring

In order to increase the strength of the magnet, a steel support ring is added inside the epoxy skeleton of the coil, and we compare the simulation results of three cases——without steel ring, with complete steel ring, with truncated steel ring：

- Fig.6 shows the deformation of epoxy skeleton in three cases. After adding the steel support ring, the deformation of the skeleton was reduced by 80%, indicating that the steel support ring improves the strength of the skeleton significantly.
- Fig.7 shows the Plastic strain of the ring in three cases. The deformation of the aluminum ring is reduced with complete steel ring, and is almost the same in the other two cases. It shows that the eddy current effect of the steel ring itself has an impact on the forming efficiency of the system, which can be avoided by the truncated steel ring.

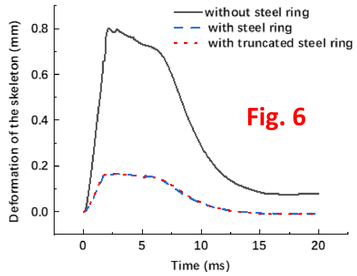


Fig. 6

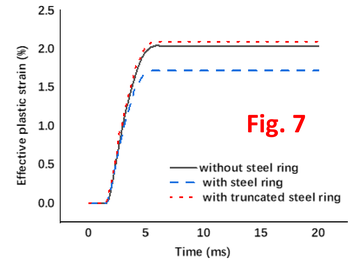


Fig. 7

### 3) Multiple discharge

In order to reduce the discharge energy, the simulation of multiple discharges on the aluminum ring is studied. Fig.8 and Fig.9 respectively show the current waveform and the deformation of the ring during multiple discharges. The deformation of the aluminum ring has increased significantly during the first three discharges, and basically no longer increase after five consecutive discharges. In the case of single discharge, to make the plastic deformation of the aluminum ring reach 2%, the discharge voltage is required 18kV, which is only required 16kV in the case of multiple discharges. The energy of each discharge process is reduced by 21%, which can effectively improve the service life and safety of the magnet.

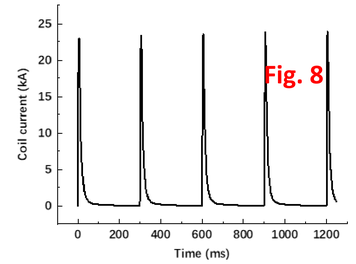


Fig. 8

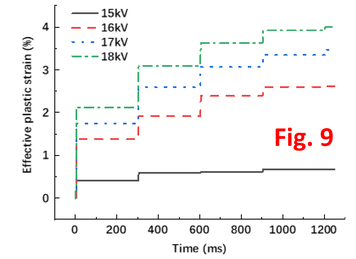


Fig. 9

## Conclusion

- The forming efficiency of the system is the highest when coil is 8 layers and 8 turns.
- Adding a truncated steel ring inside the epoxy skeleton can improve the strength of the skeleton significantly.
- Compared with the case of single discharge the energy of each discharge process is reduced by 21% in multiple discharges.