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Dynamic analysis of sheet metal forming process by uniform pressure electromagnetic actuator using the finite element method

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I. Introduction

Due to its high efficiency and uniform deformation force, the uniform pressure actuator (UPA) is a potential electromagnetic forming (EMF) technology for shaping of mesoscale dimensional metals, such as metal bipolar plates.

However, because of its complex structure, the current simplified two-dimensional model cannot fully reveal the law and characteristics of UPA, such as the role of conductive outer channel. A three-dimensional (3D) finite element model with the equations of the electrical equivalent circuit, electromagnetic field, and mechanical field has been developed for calculating the discharge currents through the forming coil, the magnetic forces acting on the workpiece, and the plastic deformation of the workpiece by COMSOL software.

II. Finite element model

Fig. 1

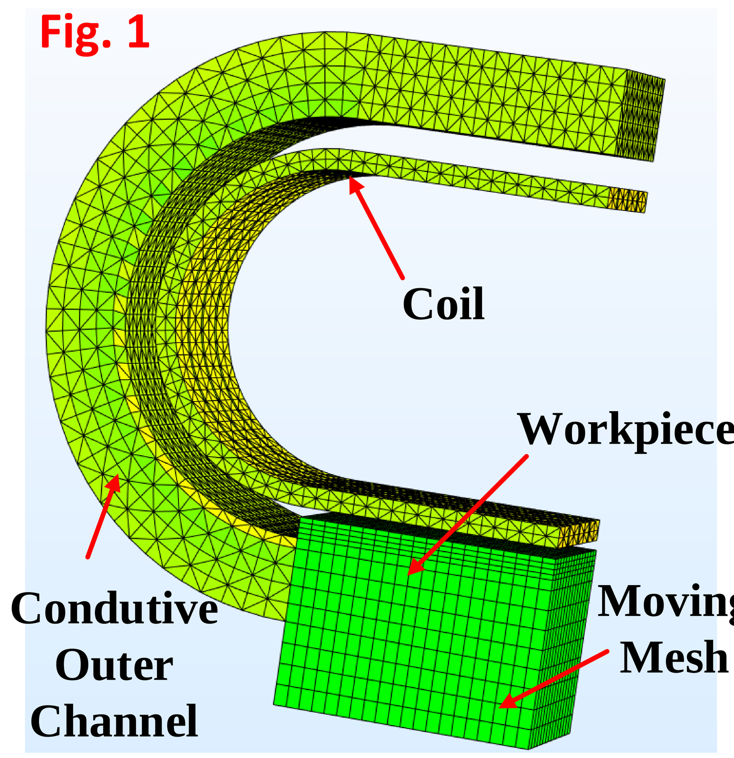


Fig. 2

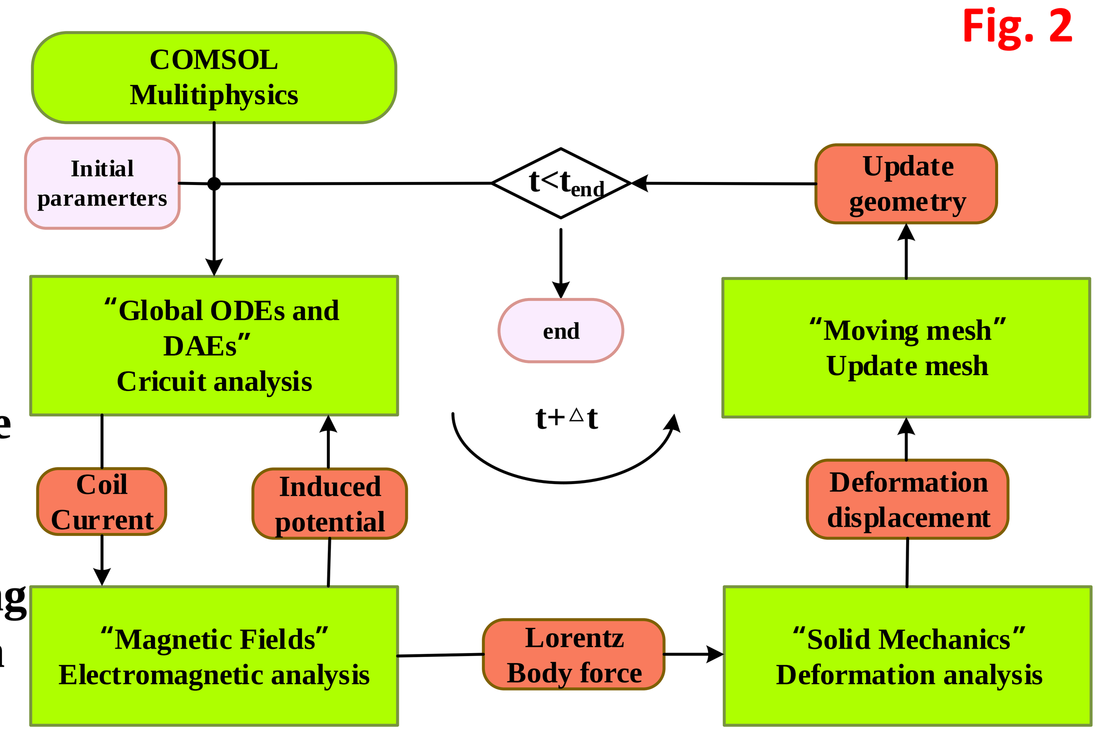


Fig. 1 shows the one-quarter finite element model of the uniform pressure actuator, including the coil, the conductive channel and the workpiece as well as the moving mesh area.

Fig. 2 is a simulation flow chart. Firstly, the coil current is calculated by "global ODEs and DAEs" model, and then the electromagnetic force and current distribution of the workpiece are obtained by the " magnetic Fields" model under the excitation of coil current. Driven by electromagnetic force, the workpiece began to deform, which was solved by "Structural Mechanics". In this process,the coil impedance changes during the forming process are coupled to the circuit equation through the coil voltage. The effect of air deformation caused by workpiece deformation in the structure field is coupled to the electromagnetic field through the " Moving Mesh".

III. Experiments

Fig. 3 is the size diagram of the workpiece, in which the conductive channel and the workpiece are cut into a whole to avoid the influence of contact resistance between them, which is difficult to accurately measure from the experiment.

Fig. 4 is the forming depth of the workpiece, the discharge voltage is 2kv, 3kv and 4kv respectively, and the corresponding forming depth is 2.96mm,5.55mm and 6.9mm respectively.

Fig. 5 is the schematic diagram of induced current measurement of workpiece. The workpiece are cut entirely by the same piece of H62 brass, and a round hole is reserved in the middle so that the Rogowski coil can pass through to measure the induced current. In order to avoid the influence of workpiece deformation, the induction currents of two kinds of uniform pressure coils are measured at low voltage 1kV.

Fig. 6 is the schematic diagram of magnetic field measurement of workpiece. The magnetic field measurement probe is designed independently. The suitable size and turns of the spiral coil are designed first, and then calibrated by the standard magnetic field generator. The magnetic field near the workpiece is obtained by integrating the induced voltage of the probe measured by the Oscilloscope

Fig. 3

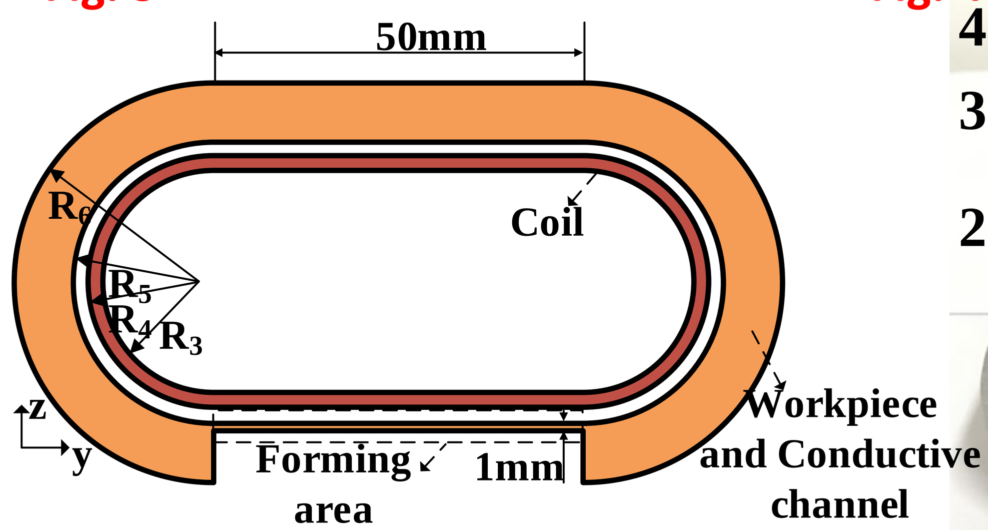


Fig. 4

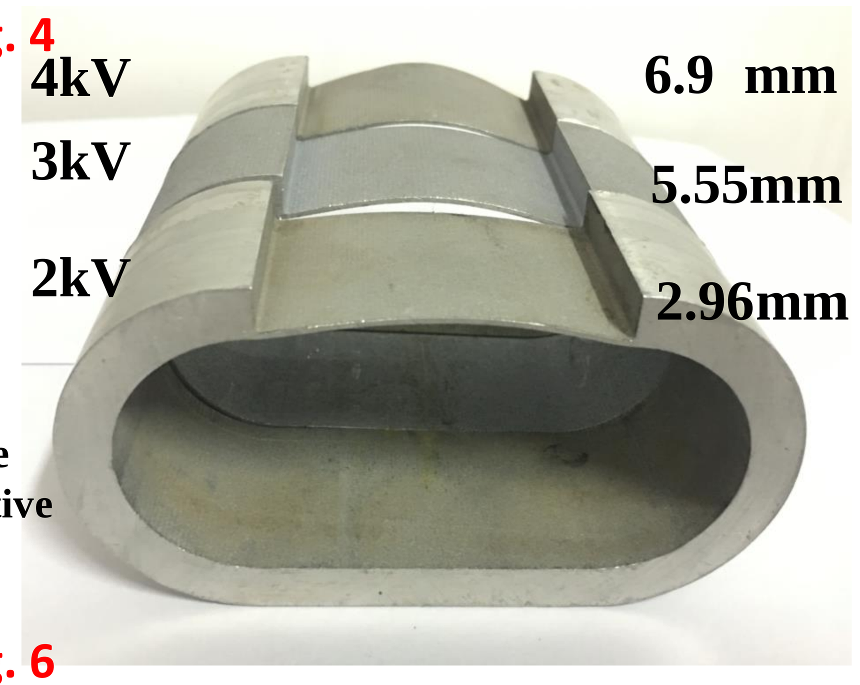


Fig. 5

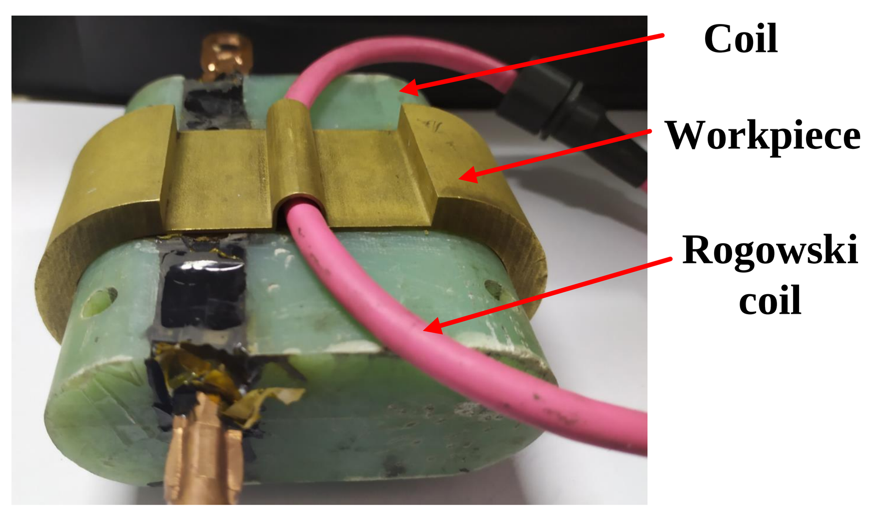
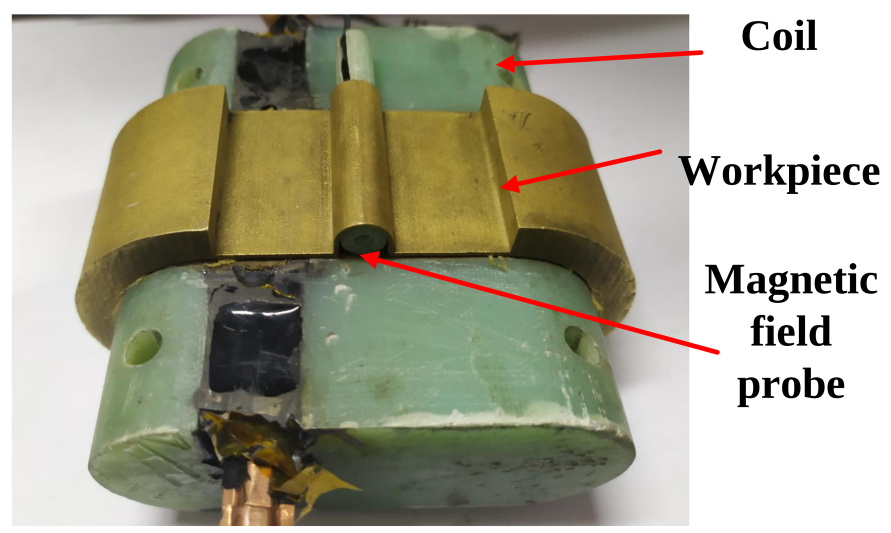


Fig. 6



III. Result and Discussion

Fig. 7

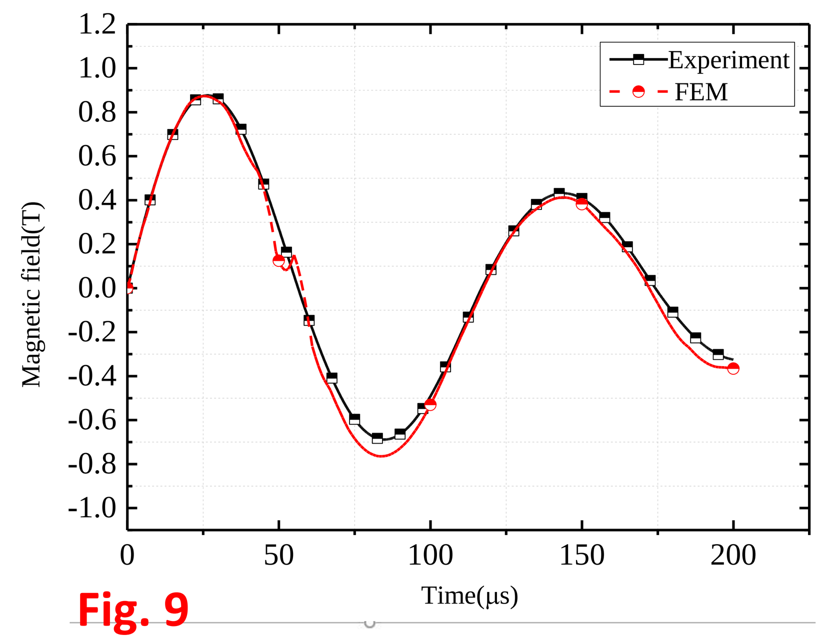


Fig. 8

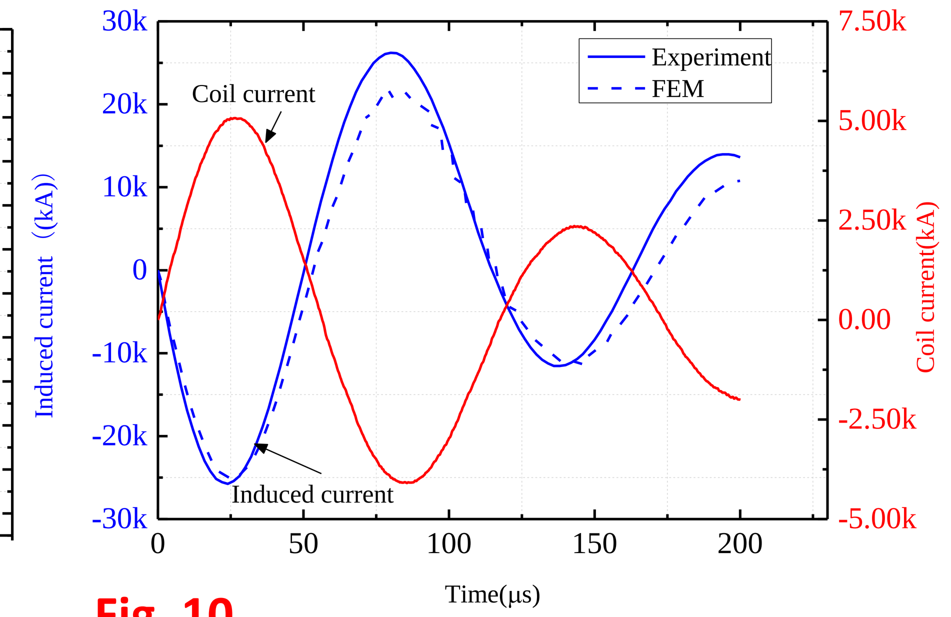


Fig. 9

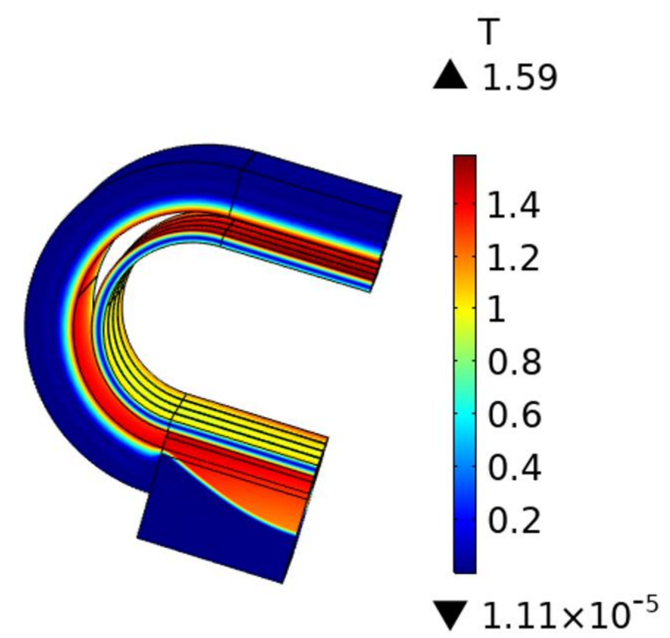


Fig. 10

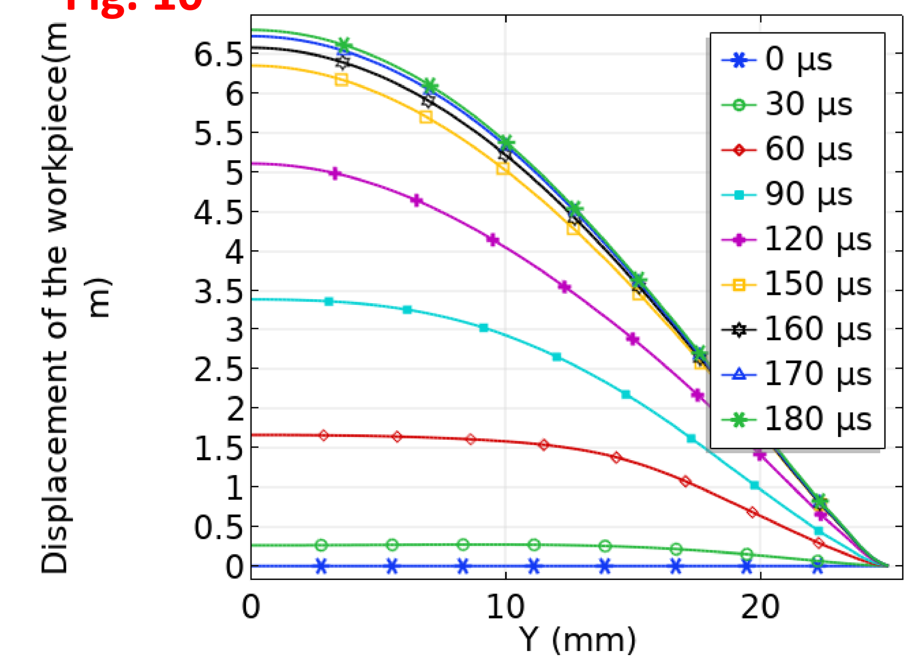


Fig.7 is the comparison diagram between the simulation and experiment of the induced magnetic field of workpiece. It can be seen that the simulation and experiment basically match.

Fig.8 shows the comparison diagram between the simulation and experiment of the induced current of workpiece, and it can be seen that the simulation and experiment basically match.

Fig.9 shows the magnetic field cloud in 180us. It can be seen that the distribution of magnetic field changes with the deformation of workpiece .

Fig.10 shows the displacement of the workpiece under the discharge voltage of 4kV,and the final forming depth is also agree with the experiment

IV. Conclusion

A three-dimensional fully coupled FEM model of uniform pressure actuator is established, and the influence of workpiece deformation on magnetic field distribution is taken into account. The results are in good agreement with the measured induced current, magnetic field and forming depth.