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Design and Simulation of a Three-Phase Electromagnetic Wiping Device

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I. Introduction

- Hot-Dip galvanizing is usually galvanizing process in the industry.
- The most common wiping method is the gas wiping. There are some disadvantages, such as splashing of zinc on the surface, oxidation and atomization of the zinc liquid, and environmental pollution [1-2].
- A three-phase electromagnetic wiping (TPEW) method is proposed. Theoretical and simulation analysis shows that the TPEW can produce greater axial electromagnetic force and has better wiping effect on the zinc liquid than the single-phase electromagnetic wiping [3].

II. Design and Simulation

- The TPEW device is to form a traveling magnetic field by longitudinally arranging a three coils to generate an electromagnetic force F . As shown in Fig. 1, three-phase alternating current is correspondingly introduced into the three coils A, B, and C. The direction of the traveling magnetic field is vertically downward, which is opposite to the movement direction of the galvanized workpiece.
- When the galvanized workpiece with zinc liquid attached to the surface passes through the TPEW device, each coil induces alternating current in the galvanized layer, thereby generating an oblique downward electromagnetic force. Under the action of the combined electromagnetic force F of the three coils, the upward movement of the liquid galvanized layer is suppressed, and when the adhesion is exceeded, the excess zinc liquid is wiped off to achieve the wiping effect.
- The F_r is related to B_z, and F_z is related to B_r. The magnetic flux in the single-phase coil is axial, so that B_z is much larger than B_r. Thus, the electromagnetic force is radially compressive, and the axial wiping force is small, and the efficiency is lower. For the TPEW device, the main magnetic flux of each coil is still axial, but due to the action of the traveling magnetic field, the axial electromagnetic force F_z will be significantly enhanced.
- The structure of the entire device is as shown in Fig. 2 and Fig. 3.

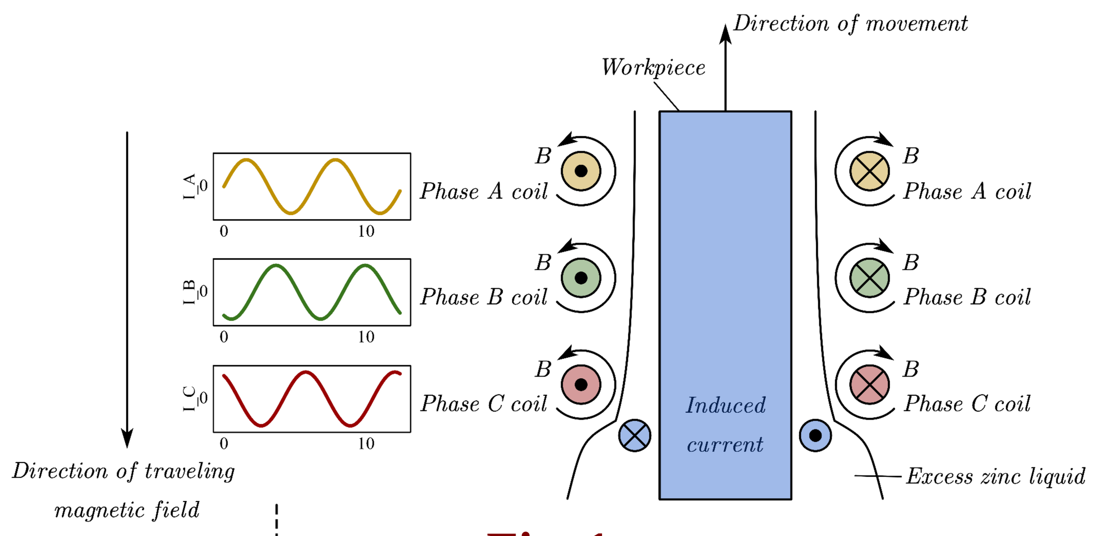

Fig. 1

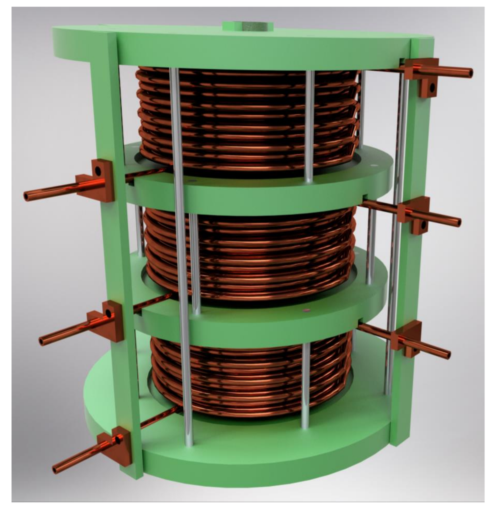

Fig. 2

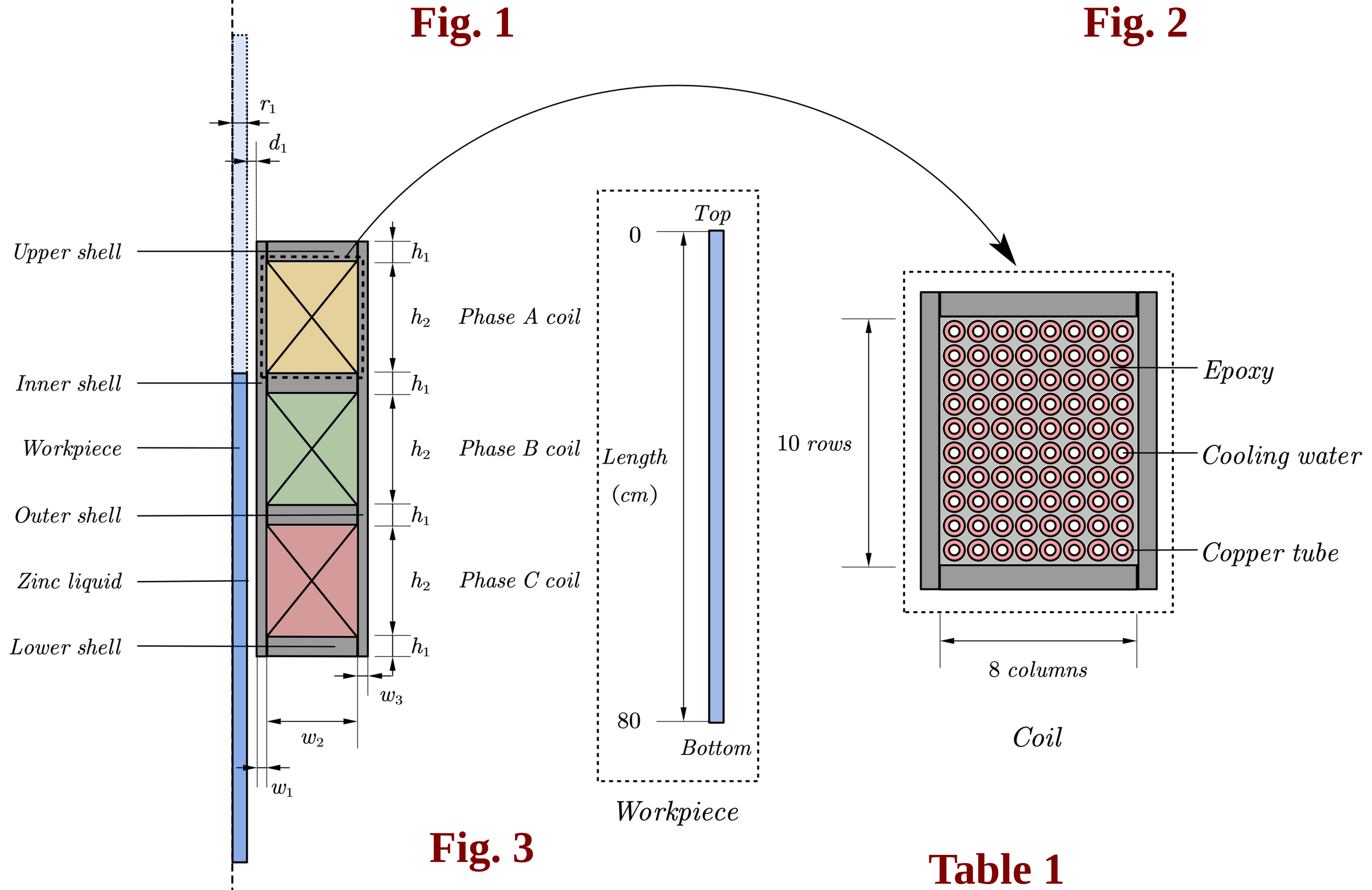

Fig. 3

$$F = F_A + F_B + F_C$$
$$= F_{Ar} + F_{Az} + F_{Br} + F_{Bz} + F_{Cr} + F_{Cz}$$
$$= F_r + F_z$$
$$= J \times B_z + J \times B_r$$

Table 1

Name	Size(mm)
Radius of workpiece/r_1	20
Gap between workpiece and TPEW/d_1	3
Width of inner shell/w_1	10
Width of coil/w_2	91
Width of outer shell/w_3	20
Gap of coils/h_1	20
Height of coil/h_2	113
Outer diameter of copper tube	10
Inner diameter of copper tube	6

III. Result and Discussion

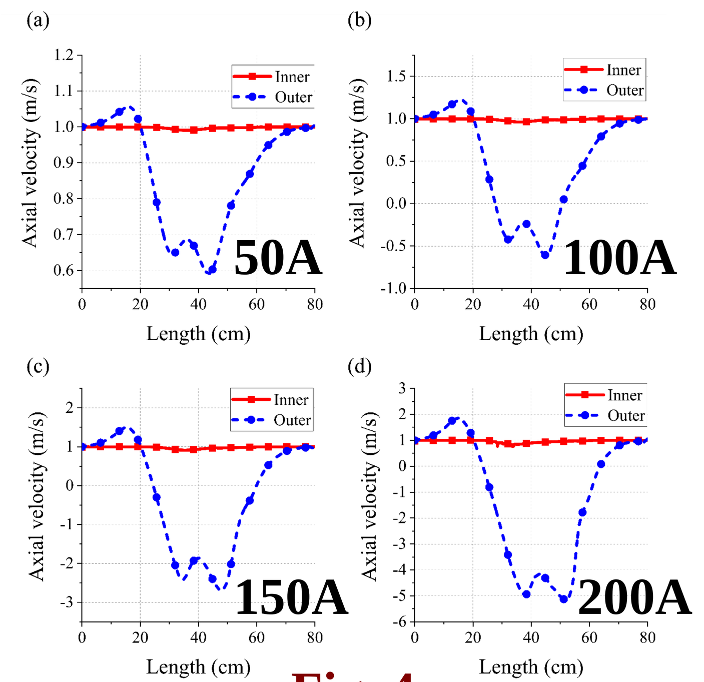

Fig. 4

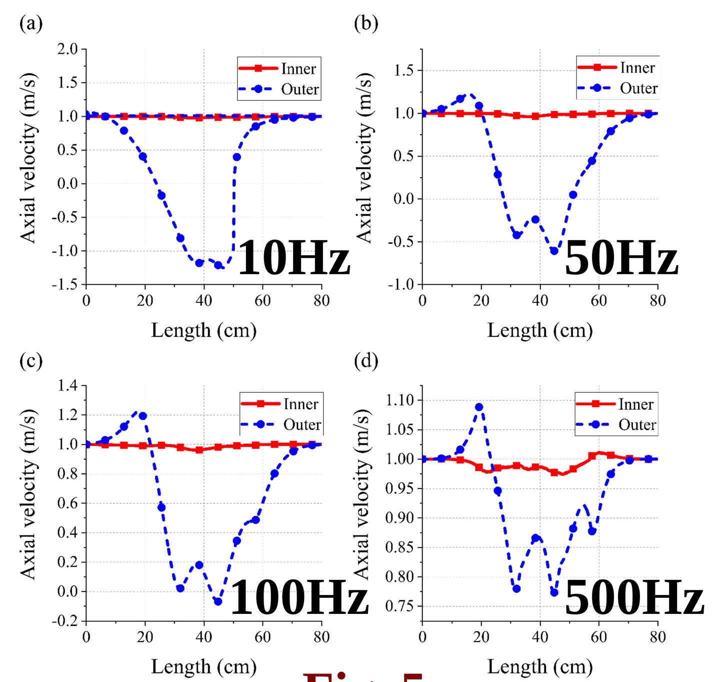

Fig. 5

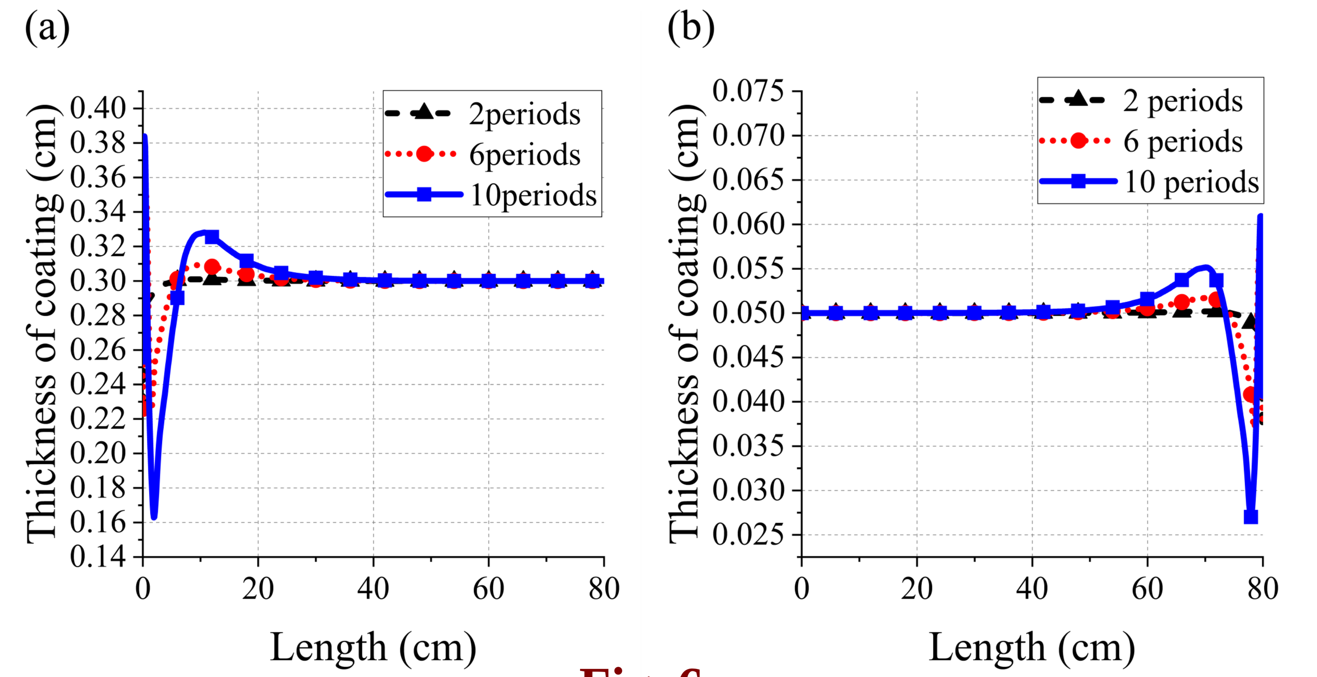

Fig. 6

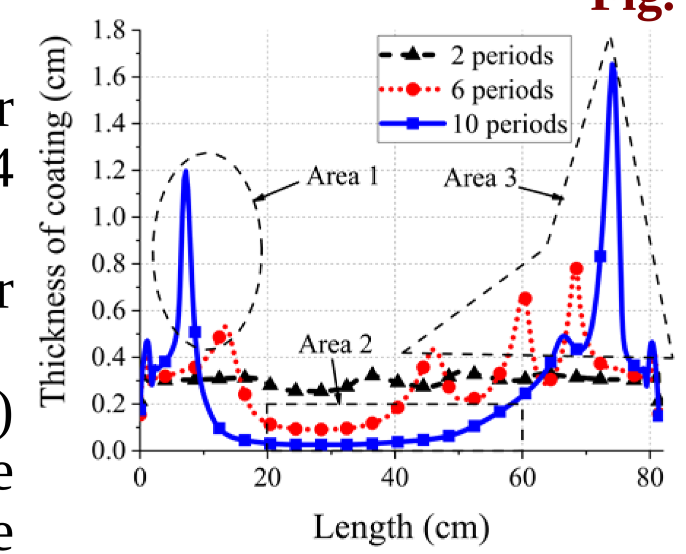

Fig. 7

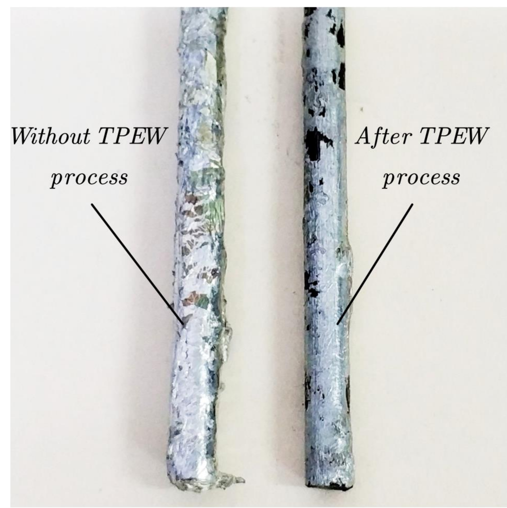

Fig. 8

- Zinc liquid axial velocity distributions of the inner and outer layer at different current and frequency are shown in Fig. 4 and Fig. 5.
- The larger the current and the lower frequency, the greater the effect on the reduction of the zinc liquid velocity.
- Thickness variation as the workpiece enters (a) and exits (b) the TPEW device are shown in Fig. 6. The zinc liquid of the workpiece top is compressed when entering the device while the zinc liquid of the bottom is compressed when leaving.
- The thickness distributions of the coating from top to bottom at different time are as shown in Fig. 7. Finally, the thickness of the coating gradually decreases from 0.3 cm to 0.05 cm.
- A preliminary experiment of electromagnetic wiping is carried out. Fig. 8 shows the result for a small sample without TPEW process (Left) and after TPEW wiping process (Right).

IV. Conclusion

- The device is capable of generating a wiping force to achieve an electromagnetic wiping. Without direct contact between the device and the workpiece, the coating is not damaged.
- Compared with the single-phase electromagnetic wiping device, this device can generate a more significant axial electromagnetic force, thereby improving the wiping efficiency.
- The flow velocity of the zinc liquid can be controlled by changing the amplitude and frequency of the current, then the thickness of the galvanized layer can be effectively controlled, and the zinc layer is thinner and more uniform.

References

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