Electrodeposition simulation with edge-based smoothed finite element method using 4-node tetrahedral elements for complex car body shapes

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Abstract

An accurate method to simulate the electrodeposition (ED) process of automotive manufacturing lines is presented. ED process is an important process to coat car bodies with thin paint film so as to prevent corrosion. A car body is dipped in the paint pool and a high voltage is applied between the body and electrodes, then the car body is covered with paint film based on the principle of electrophoresis. One of the difficulties in ED simulation [1, 2] is the complexity of the car body shapes. The analysis domain is usually discretized with tetrahedral meshes due to the infeasibility of hexahedral mesh generation. As the 2nd-order 10-node tetrahedral (T10) meshes increase the degrees of freedom (DOF) drastically, the 1st-order 4-node tetrahedral (T4) meshes are generally preferred to achieve a good balance between smaller DOF and better shape representation. Therefore, it is important to solve Laplace equations accurately with 4-node tetrahedral meshes for ED simulation. In this study, we propose an edge-based smoothed finite element method [3] using 4-node tetrahedral elements (ES-FEM-T4) [4] for ED simulation. ES-FEM-T4 is known as a novel finite element formulation that gives more accurate solution compared to the standard T4 element. In conjunction with the film growth model and film resistance model, our ED simulator gives the time-varying distributions of film thickness, current density, surface potential and so on for the practical ED process of automotive manufacturing lines.

Keywords: Smoothed finite element method, Tetrahedral element, Electrodeposition, Laplace equation, Film growth model, Film resistance model.

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