Automotive e-coat paint process simulation using fea

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By applying an electrical current, a thin paint film forms veer all the surfaces in contact with the liquid, including those surfaces in recessed portions of the body. The E-coat paint process deposits a thin paint film on the automotive body under the influence of a voltage gradient of about 200 to 300 volts. The water-based E-coat paint bath is conductive with an array of anodes that extends into the bath delivering a DC current. The paint film that forms has physical properties that resist corrosion (these appear only after the automotive body has been cured in an oven).

However, as the paint film forms, its electrical resistance increases. In the past several years, two-dimensional (2-D) FEE models of the E-coat paint process have been developed for specific or limited applications. In this paper, we discuss a general three-dimensional (3-D) FEE method using ALGER software. This method can simulate the formation of the E-coat film and can thus predict its thickness at any point on the surface of the automotive body.

Operational variables, such as voltages and process duration, are used to simulate the time-dependent interaction among the automotive body, the increasing paint layer and the liquid thin the E-coat bath. The method is based on a quasi-static technique that accounts for the changing material properties of the paint layer. A quasi-static approach is appropriate because the time required for the electric field to be established is much smaller than the duration of the paint deposition process.

The actual time is simulated by considering a series of time steps, each of which requires an electrostatic solution. The E-coat film thickness is updated during each time step. A primary concern is how to model the changing FEE geometry due to the growth of the E-coat film. Technologyhas been developed that is capable of generating a film of specified thickness (as a function of position) on the automotive body. Because of symmetry along the longitudinal axis of the automotive body, only half the body was modeled.

In addition, an enclosing box was constructed around the automotive body and features were created for the possible anode locations. Generally, there is little electrical interaction between two adjacent automotive bodies. Any net electrical current that flows into the leading and trailing surfaces of the enclosing box is considered negligible. The space between the outside of this box and the automotive body will be considered as the E-coat paint bath. Furthermore, the growth of the E- coat film is assumed to be perpendicular to the surface of the automotive body at all times.

Laboratory experiments can establish an accurate estimate of the deposition coefficient of the E-coat film that forms in response to the flow of electrical current. The result of interest is the flow of DC electrical current that causes the E-coat film to form. The growth of the E-coat film is dependent on the number of Coulombs that are levered. In each iteration, the FEE model is solved for electrical current flow from which the E-coat film thickness can then be calculated. The material properties for each of the elements where the E-coat film develops are also changed in response to the growth in the E-coat film thickness.

Another feature of a typical automotive E-coat paint system is the use of multiple voltage zones and differing locations where the anodes are placed in the E-coat bath. These factors affect the application of voltages in the FEE model. The appropriate voltage values must be added or updated for each new iteration as required. The primary use of the method is to predict how, as the paint layer forms, the effective electrical resistance increases, which prompts the current to seek out less resistive paths.

Even though the paint film that forms has drastically reduced conductivity compared to the surrounding E-coat paint bath, it is not enough to stop its continued growth past the optimum thickness which is generally about 25 p. A 3-D FEE model of the E-coat paint process would not only help he designers of a new automotive body obtain a more uniform paint distribution, but could be advantageous to existing assembly plants, as they explore means to reduce costs as well as make improvements to existing designs.

It is well known that the layout of the anodes and the automotive body have a significant impact on the overall electrical resistance of the system, and thus the amount of current that must be delivered. In some circumstances, assembly plants are faced with the challenge of obtaining an adequate E-coat paint thickness on exposed parts of the automotive odd, while avoiding an insufficient thickness in recessed regions.

The standard solution is to increase the overall voltage, which results in greater energy and material costs. The resulting E-coat paint thickness achieved on the exposed parts of the body is particularly costly because it provides for no additional corrosion protection. Using the method discussed in this paper, engineers can perform a variety of optimization exercises without incurring the high costs or risks of making operational modifications to the existing E-coat paint process at an assembly plant.