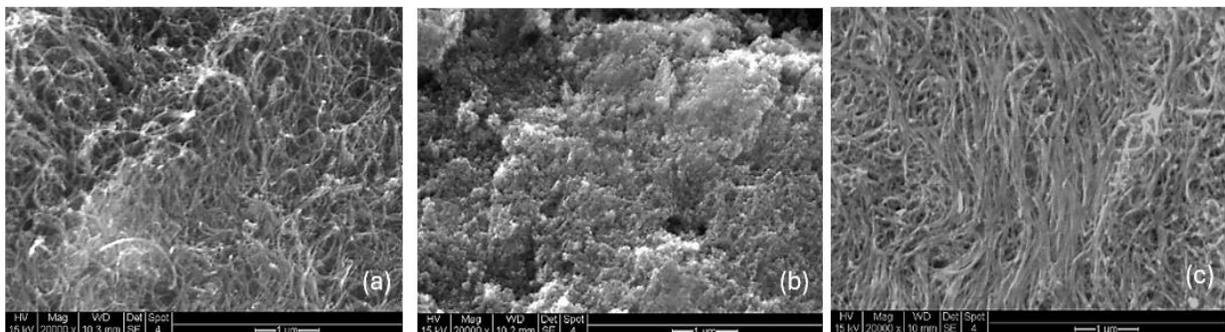


## The addition of Carbon Nanotubes (CNTs) in DTM coatings for enhanced corrosion protection performance

Carbon Nanotubes (CNTs) are advanced carbon nanomaterials with unique properties such as high conductivity and superior mechanical strength. As such, CNTs have drawn much attention from researchers who focus on improving the properties of materials by using CNTs as additives. In this research, we tried adding different types of CNTs into industrial Direct-to-Metal (DTM) coatings for improved anticorrosion performance. DTM coatings are known to provide robust protection against corrosion, rust, and weathering for metal surfaces, acting as both a primer and topcoat in one, reducing application steps and costs. In this work, we evaluated various CNTs in two types of DTM coatings on metal surfaces. one was A waterborne polyurethane (PU) DTM coating from Valspar and the other one is a waterborne epoxy coating formulated by Ecosil.

Tested CNTs were 1) multi-wall (MWCNTs) and 2) single-wall (SWCNTs) with varied lengths and surface functionalities. These CNTs were pre-dispersed in de-ionized water by sonication before adding them into the coatings.

Figure 1 presents SEM images of two types of MWCNTs tested in this work. Figure 1(a) shows a commercial MWCNT tangled together, which breaks into small fragments after sonication (Figure 1(b)). Figure 1(c) shows an experimental MWCNT that remains as long, noodle-like bundles even after sonication. The experimental MWCNT are at least ten times longer than the commercial one.

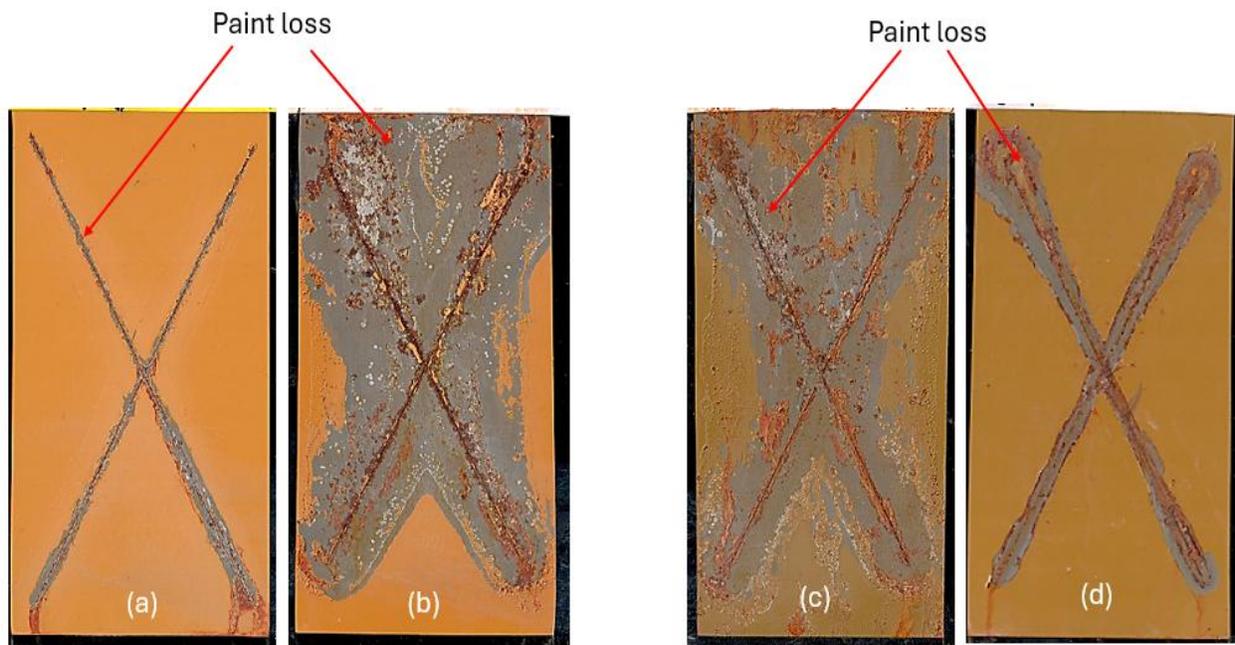


**Figure 1.** SEM images of the two CNTs tested in this work; (a) as received, commercial MWCNTs without surface functionalities, (b) the MWCNTs shown in (a) after sonication dispersion and (c) experimental MWCNTs made by the University of Cincinnati after sonication dispersion

## 1) The addition of CNTs in industrial DTM coatings for anticorrosive performance enhancement

A Valspar waterborne polyurethane (PU) coating was used as a vehicle for CNT loading. Figure 2 shows the PU-coated steel panels after 240-hr salt spray test (SST) according to ASTM B117. The thickness of these coatings was controlled at 1 mil (25 micron). The painted steel panel surfaces were “X” scribed before SST.

Figure 2(a) presents a PU coating with zinc phosphate as anticorrosive pigment; Figure 2(b), a PU coating with no anticorrosive pigment; Figure 2(c), a PU coating with 0.5% MWCNT; and Figure 2(d), a PU coating with 0.5% commercial SWCNT. After 240 hours of SST, the zinc phosphate-loaded PU (Figure 2(a)) shows the least paint loss, while the SWCNT-loaded PU (Figure 2(d)) offers some corrosion protection but is less effective. The PU coatings without pigment (Figure 2(b)) or with broken MWCNT (Figure 2(c)) perform similarly, showing the most significant paint loss.



**Figure 2.** 240-hr SST results for waterborne polyurethane coated steel panels; (a) PU with zinc phosphate anticorrosive pigment, (b) PU without anticorrosive pigment, (c) PU with sonicated MWCNT (in Figure 1(b)) and (d) PU with SWCNT. (\* both CNTs tested in PU were commercial products) (Before the PU coating application, the steel panels were iron phosphated)

## 2) The addition of CNTs in DTM epoxy coating for anticorrosive performance enhancement

The experiment MWCNT (shown in Figure 1(c)) was added into an epoxy DTM coating formulated by Ecosil. Two metal substrates used here were Al 2024-T3 alloy and hot-dip galvanized steel (HDG). Figure 3 shows the coated metal panels after 500-hr SST. Compared to the epoxy coating without CNT, the epoxy-CNT coatings on both substrates show significantly less or no paint loss after SST, indicating this type of CNT (long length) can dramatically improve the anticorrosive performance of the epoxy DTM coating.

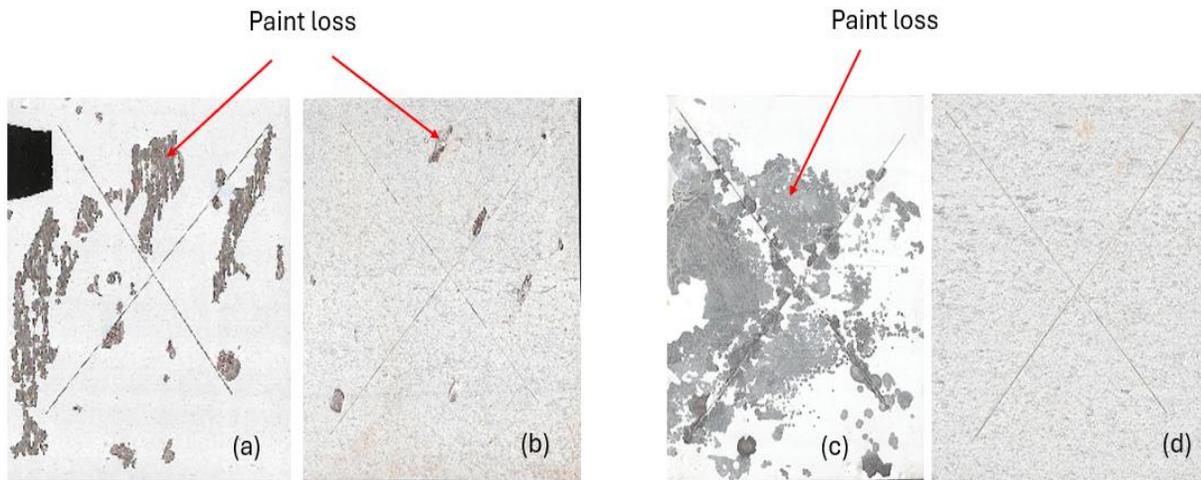


Figure 3. 500-hr SST results for the Epoxy DTM coated metals; (a) Epoxy-only coated Al 2024-T3, (b) epoxy-CNT coated Al 2024-T3, (c) epoxy-only coated HDG, (d) epoxy-CNT coated HDG

### Remarks:

- 1) Only certain CNTs enhance the anticorrosive performance of DTM coatings on metals.
- 2) Sonication is an effective method for dispersing CNTs, but it must be used carefully; improper use can break CNTs into small fragments, rendering them unusable.
- 3) Long CNTs seem to be very effective in significantly improving coatings' anticorrosive performance.