Paint System Performance

A 'paint system' comprises of chemically compatible materials (etch primer when required), primer and topcoat applied to a suitably pre-treated substrate. Paint coatings must exhibit good adhesion in order to be effective. The durability and performance of paint coatings depend on two basic properties: cohesion and adhesion.

Cohesion is the inner strength of a material, and it is determined by the strength of molecular forces in the paint. Cohesive failure examples are chipping (brittle coating), cracking (stressed coating) and abrasion (soft coating) etc.

Adhesion is the strength of the bonds forming between one material and another. Adhesive failure can be blister forming at the interface, lifting of the paint film.

Both cohesion and adhesion are required for a long-lasting, protective coating. Example of the failure of both cohesion and adhesion simultaneously is flaking paint from the substrate.

Critical Adhesion Mechanisms - Absorption, Chemical and Mechanical Interlocking

With paint systems, adhesion is provided by three mechanisms known as: adsorption, chemical, and mechanical interlocking. Not all three mechanisms are required depending on substrate and paint system.

- **Absorption -** The molecules in the paint film wet or flow freely over the substrate and make intimate contact with the substrate, forming interfacial bonds.
  Further Reading: A bond develops from the adsorption of paint molecules on the substrate and the resulting attractive forces, usually designated as secondary or van der Waals forces. The paint film must make intimate, molecular contact with the substrate surface. The process of establishing continuous contact between a liquid paint film and the substrate surface is known as "wetting." Good wetting results when the adhesive flows into the valleys and crevices on the substrate surface; poor wetting results when the adhesive bridges over the surface irregularities. If the substrate is contaminated then adequate wetting will be prevented. Also, if the substrate is contaminated with loose particulate matter, the contaminant becomes a weak boundary layer.

- **Chemical** bonds are formed at the interface between the paint and the substrate.
  Further Reading: Certain paint systems are formulated with binders that have a functional group that can chemically bond to a compatible substrate (etch primers). In these applications the formation of covalent chemical bonds occurs across the interface. These strong and durable bonds are generally the result of close contact or adsorption of the adhesive on the surface followed by a chemical reaction.

- **Mechanical Interlocking** - The paint film penetrates the roughness on the substrate surface, resulting in mechanical interlocking once the paint dries.
  Further Reading: The surface of a solid material is never truly smooth; it consists of a maze of peaks and valleys. In order to function properly the paint film must penetrate the irregularities on the surface, displace the trapped air at the interface, and lock-on mechanically to the substrate. One way that surface roughness aids in adhesion is by increasing the total contact area between the paint and the adherend.

The above critical mechanisms of adhesion are controlled by; qualified paint materials, validated (established and repeatable) processes, verification activities and periodic testing. Failure modes can include; cleaning, pre-treatment, humidity and temperature, paint mixing, curing times and temperatures, equipment and maintenance, skills and training, paint system compatibility (substrate, etch primer, primer and top coat etc)

Adhesion Testing

At the very minimum it is expected, as good practise, paint process suppliers perform batch adhesion testing to validate the paint process.

Adhesion test methods are destructive testing using test coupons for each batch of paint application. Reliable paint systems, applied correctly against an application of paint process specification will be able to meet the following criteria when tested by one of the following methods: -
ASTM 3359 Test Method A X-Cut: 5A No Peeling or removal
ASTM 3359 Test Method B Cross Cut: 5B 0% Removed